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GEOLOGY OF THE ROWLAND QUADRANGLE, ELKO COUNTY, NEVADA

BUSHNELL

NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

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MACKAY SCHOOL OF MINES
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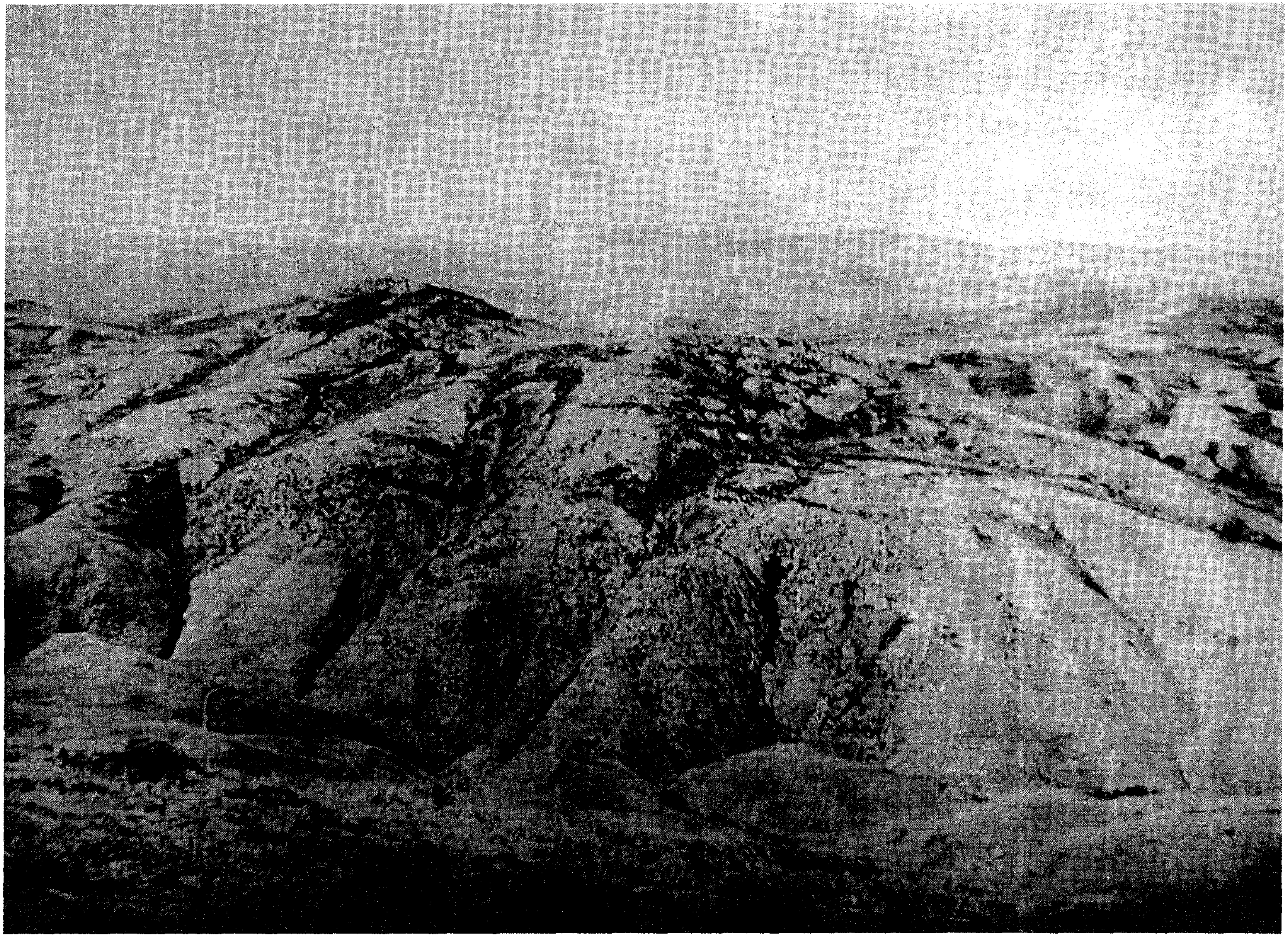
FOREWORD

Mr. Kent Bushnell made brief preliminary studies of the Rowland quadrangle in the summer of 1952. He completed the mapping of the quadrangle in the summers of 1953 and 1954 and later submitted this work as a doctoral thesis to Yale University. Toward the end of his investigations, the Nevada Bureau of Mines furnished Mr. Bushnell some financial aid.

The Bureau was very interested in Mr. Bushnell's work in a geologically unmapped part of the State and invited him to submit his report for publication. Dr. Bushnell, who is presently employed as a geologist with the Chevron Oil Co., Denver, Colorado, has revised the stratigraphic nomenclature and structural concepts contained in his first manuscript. These revisions were necessary because of geological investigations of adjacent areas that have been made since Dr. Bushnell did his field studies. The revised report is here published as Nevada Bureau of Mines Bulletin 67, "Geology of the Rowland Quadrangle, Elko County, Nevada."

VERNON E. SCHEID, *Director*
Nevada Bureau of Mines

April 1967
Mackay School of Mines
University of Nevada



Frontispiece: Pine Mountain from the northeast.

The Bruneau River Valley is in the foreground, Tennessee Mountain on the far right, and the Independence Mountains in the background.

GEOLOGY OF THE ROWLAND QUADRANGLE, ELKO COUNTY, NEVADA

By Kent Bushnell

ABSTRACT

The Rowland quadrangle is situated in northern Nevada, along the boundary between the Great Basin and the Snake River Plain. It lies at the intersection of the northeast-trending Paleozoic Antler orogenic belt and the east-west belt of Late Cretaceous granitic stocks and batholiths in northern Elko County.

The pre-Cenozoic stratigraphy is typical of that along the Antler orogenic belt. Undated and unnamed argillaceous formations of the western facies are in thrust fault contact with the following argillaceous, calcareous, and quartzitic formations of the eastern facies: Tennessee Mountain Formation (€–O), Prospect Mountain(?) Quartzite, and some unnamed formations. An overlap assemblage of conglomerates and limestones, the Sunflower Formation and its tentatively correlative Diamond A Formation, of Upper Pennsylvanian-Lower Permian Age, lies unconformably on the older rocks. No Mesozoic or early Cenozoic sedimentary formations are recognized in the area.

Two granitic stocks were forcibly emplaced during the Late Cretaceous, possibly along earlier major east-west-trending folds.

The Bieroth Andesite, Jarbidge Rhyolite, and Idavada Volcanics, dominantly rhyolitic, were deposited during the middle and late Tertiary. Coarse alluvial and colluvial gravels were deposited on an old erosion surface that was formed after the extrusion of the Jarbidge Rhyolite. The drainage became entrenched during the Pleistocene, and unstable slopes resulted in slumping and landsliding. Pleistocene glaciation was minor and cirque floors were formed only above an altitude of about 9,000 feet.

Three periods of deformation are recognized. (1) A Carboniferous orogeny which consisted of thrust faulting followed by regional uplift in the south and east, and by deposition of the Sunflower Formation. (2) A late Mesozoic to early Cenozoic orogeny that included thrust faulting, large-scale folding, normal faulting, and emplacement of granitoid stocks. This deformation is noted for the development of east-west trends at right angles to the regional Mesozoic trends. (3) A mid-Cenozoic orogeny consisting of block faulting and northward tilting of the older rhyolites. The Trail Gulch fault, a major fault with possibly 5 miles of right lateral strike-slip movement, originated during the second period of deformation.

The most important mineral deposits are hydrothermal fissure and shear zone deposits which have yielded silver and lead ores. Contact metasomatic tungsten deposits peripheral to the granitic stocks may be important in the future.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Rowland quadrangle, bounded by the parallels 41°45′ and 42°00′ N., and the meridians 115°30′ and 115°45′ W., lies mostly in northern Elko County, Nev. The northernmost portion, a strip less than a quarter of a mile in width, lies in Owyhee County, Idaho. The nearest principal settlement, Mountain City, Nev., lies about 11 miles to the west of the quadrangle. The location of the Rowland quadrangle and nearby areas is shown in figure 1.

A paved road, State Route 43, extends 60 miles northward from Elko, Nev., to Wild Horse at the southern tip of the Wild Horse Reservoir southwest of the quadrangle. State Route 11A continues northwestward 18 miles to Mountain City, Nev., and northward to the Idaho border, where it meets Idaho State Route 51. The map area can be reached from Mountain City or Wild Horse by dirt roads. The area can also be reached from Rogerson, Idaho, which is 25 miles south of Twin Falls, Idaho, on U. S. Highway 93, by 70 miles of gravel road which passes through Three Creek and Murphy Hot Springs, Idaho.

Travel within the quadrangle by passenger car is limited to the few miles of gravel road along the west and north sides. Trucks and jeeps, however, can travel the various ranch and prospect trails which give access to nearly all of the quadrangle. The Copper Mountains area in the southeastern part of the quadrangle is the only area that is inaccessible to motor vehicles.

PREVIOUS WORK

Early geologic work in Nevada was concentrated around areas of economic importance. Although the Rowland quadrangle contains some gold, silver, lead, and tungsten prospects, it has been relatively unproductive, and no serious geologic work was done in the quadrangle prior to the present project. The Rowland quadrangle, however, is situated between mining districts of some note—the Jarbidge district on the east and the Mountain City (Rio Tinto) district on the west. Early geologic work in these districts included some of the Rowland quadrangle.

The earliest work near the Rowland area is that of the Fortieth Parallel Survey of 1875 (see Emmons, 1877). The northern limit of the maps presented in this work is the southern border of the Mount Velma quadrangle some 15 miles to the south. Emmons was in charge of the geological work north of the Humboldt River in this area; he assigned the quartzites, shales, and limestones in the northern limits of his map area to the Carboniferous Weber Quartzite and "Upper Coal-Measures," on lithologic evidence only. Vertebrate

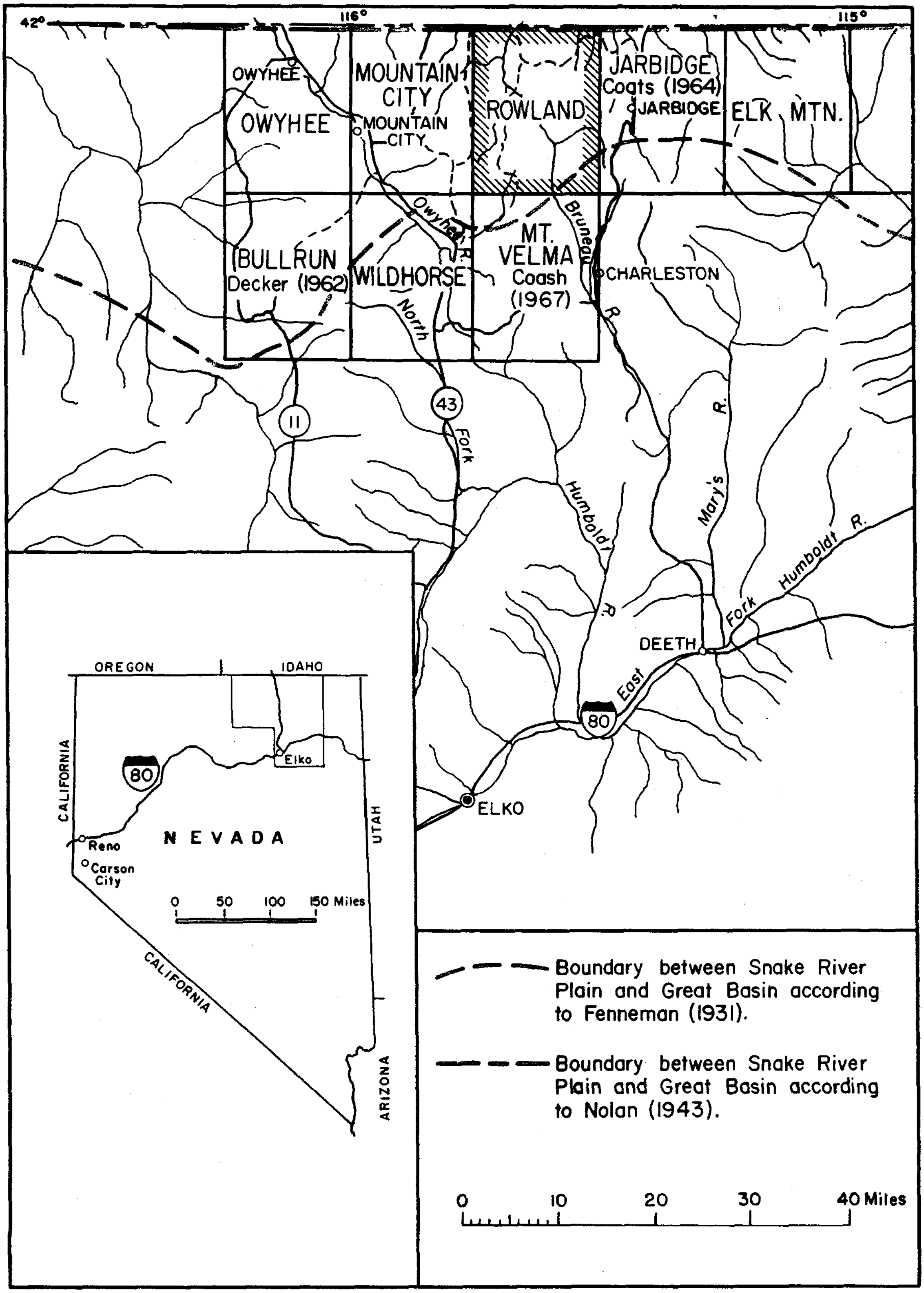


Figure 1. Map showing the location of the Rowland quadrangle in relation to geographic features.

remains, which Leidy (*in* Emmons, 1877) believed dated the wide-spread continental Humboldt Formation as Pliocene, were found in Bone Valley, north and east of the North Fork of the Humboldt River.

W. H. Emmons (1910) made a reconnaissance of some of the mining camps in north-central Nevada, including Mountain City and the Centennial Range (now the Independence Mountains) southwest of Mountain City. He assigned the greater part of the thick sequence of sedimentary rocks in the Mountain City and Centennial Range areas to the Carboniferous on the basis of the work of the Fortieth Parallel Survey and Hague's (1892) classic work at Eureka. This sequence included the great thickness of quartzite beds of the Centennial Range.

In 1912 and again in 1923, the U. S. Geological Survey published reports by F. C. Schrader on the Jarbidge mining district. In the later report Schrader included a reconnaissance map of the Charleston district on the northeast border of the Mount Velma quadrangle. This map indicates the presence of quartzites, limestones, and shales in the eastern part of the Rowland quadrangle.

In 1932, S. F. Hunt discovered the Rio Tinto copper deposit south of Mountain City. The Anaconda Copper Mining Co. obtained control of this deposit and their geologists mapped the area. Shortly before the Anaconda work, T. B. Nolan of the U. S. Geological Survey had made a brief study of the Mountain City region and wrote a short report (1937) on the Rio Tinto mine and its geological setting. D. C. Gilbert (private report, 1943) and E. C. Stephens (private report, 1946) of the Anaconda Co. later extended Nolan's work to include all of the Mountain City quadrangle and the northern end of the Centennial Range. These authors also assigned the formations of the area to the Carboniferous.

R. W. Decker (1962), who mapped the Bull Run quadrangle (see fig. 1) southwest of Mountain City, added Cambrian, Ordovician, Silurian(?), and Devonian(?) formations to the Carboniferous formations around the Rio Tinto mine.

J. R. Coash (1967) mapped the Mount Velma quadrangle just south of the Rowland quadrangle. He found only a few formations which he could correlate with formations in the Mountain City area, although his formations also are mostly Paleozoic. Among his new formations is one of possible Triassic Age. Several of Coash's units, including the Tennessee Mountain Formation and the Sunflower Formation, also crop out in the Rowland quadrangle.

PRESENT WORK AND ACKNOWLEDGMENTS

At the suggestion of Prof. C. R. Longwell, the geological investigation of the Rowland quadrangle was undertaken as a dissertation problem for Yale University. Field work was carried on for three weeks during the summer of 1952, from June to mid-September in 1953, and from June to mid-October in 1954. During that time and during the writing of this report, Ralph Roberts and Robert Coats of the U. S. Geological Survey, and the staff of the Geology Department of Yale University freely offered their counsel and encouragement. For this the writer is greatly indebted.

Among the many others who contributed in some way to this report, the writer would like to acknowledge and thank the following: J. R. Coash, who mapped the neighboring Mount Velma quadrangle; Helen Duncan of the U. S. Geological Survey, who identified fossils from the quadrangle; William Prinz and Andre Deland of Yale University, who aided the study of the intrusive rocks; Gerald Horton of the U. S. Forest Service; and the Anaconda Company, which permitted reference to the unpublished work of Stephens and Gilbert. The cooperation of James Trisoliere, manager of the Diamond Jim Mining Co.; Charles Gribble, owner of the Gribble Quartz mine; and Joseph Riff, who furnished mine and prospect data is much appreciated.

The Donnel Foster Hewett Fellowship Fund, Yale University, and the Nevada Bureau of Mines, University of Nevada, furnished financial aid for field expenses, thin sections, and equipment.

This present report, based on the Yale dissertation, has been revised as a result of subsequent geological work in adjacent areas.

GEOGRAPHY

PHYSICAL FEATURES

The Rowland quadrangle is located along the boundary between two physiographic provinces, the Snake River Plain to the north and the Great Basin to the south, and incorporates features of each (see fig. 1, also Fenneman, 1931, and Nolan, 1943). The southern part of the quadrangle has the greatest relief (4,500 feet) and the highest altitude (9,911 feet), and is typical of basin-and-range topography. The Copper Mountains in the southeast part, and Pine and Rosebud Mountains in the south-central part of the quadrangle, are northeast-trending blocks which rise above the regions to the north and south. Mount Velma, to the south in the Mount Velma quadrangle is part of another northward-trending block. Relief and altitudes gradually decrease northward, and as the volcanic cover thickens, the scenery changes to the flat tablelands, plains, and deep stream canyons typical of the Snake River Plain. Only a few knobs, such as Bearpaw Mountain, which represent prevolcanic hills, rise above the general level of the lava plain.

The Bruneau River, the major stream of the area, flows north-northwest, then north-northeast through the center of the map area, and ultimately northward into the Snake River. Its main tributary, Meadow Creek, heads in the southwest corner of the quadrangle and flows northward, joining the Bruneau about 2 miles south of Rowland. Their courses are controlled, at least in part, by the structure and lithology of the Paleozoic rocks. Although presently the Bruneau River and

Meadow Creek flow in steep-sided valleys cut in volcanic and Paleozoic rocks, some suggestion of a mid-volcanic broad-valley stage is present; and the main drainage pattern of the quadrangle may date from the middle Cenozoic. Coash (1967), Decker (1962), and Stephens (private report, 1946) have discussed the possibility that the Owyhee River and other northward-flowing streams in the Mount Velma, Mountain City, and Bull Run quadrangles formerly had a connection with the Humboldt River and flowed southward. However, no evidence for this was observed in the Rowland area.

There are many other small streams in the district, and, surprisingly, a large number of them flow continuously throughout the year, even during dry years such as 1954, when drought conditions prevailed over much of the West.

CLIMATE, VEGETATION, AND CULTURE

In spite of the large number of streams, the area is considered semiarid. The annual precipitation is about 13 inches and most of this falls as snow during the winter. Summers are dry, but there are occasional short, violent thunderstorms and hailstorms. Summer days are warm, although the nights are cool and frost is always a possibility. Winter temperatures are seldom extreme. Schrader (1923) writes of work continuing throughout the year in the mines and mills of Jarbidge, with temperatures rarely below 20° F. Steep-sided valleys such as Rattlesnake Canyon and the Bruneau River Valley, though quite hot in the summer, are generally mild and pleasant during the winter.

Most of the map area is included within the Humboldt National Forest, and here, where grazing has been controlled, wild grasses dominate, but scattered clumps of sage and other common brushes such as buckbrush, service berry, and snowbrush also are present. Outside the Forest boundary, the range has been overgrazed, and sagebrush dominates the vegetation. Willows and alders grow along the streams. Mountain mahogany grows everywhere, but it is most common on the andesite and rhyolite outcrops along the western side of the quadrangle, where the area has been named "The Mahoganies." It is also present on the limestone slopes of Rattlesnake Canyon.

Forest growth is sparse but includes quaking aspen, a few cedars and junipers, and large stands of alpine fir and limber pine on the Copper Mountains and east and southeast of Rattlesnake Canyon.

The only plants that show invariable rock associations are bright, orange-red lichens which grow only on limestones, and bright yellow-green lichens which grow only on rocks with a high silica content such as rhyolites, chert, and quartzites.

During the late 19th century, many homesteads were located along the Bruneau River, Meadow Creek, and their tributaries, but the abundance of excellent grazing soon gave rise to feuds between the homesteaders and the owners of large sheep ranches. In 1907, after the shooting of a sheepherder by a homesteader, petitions were circulated and the contested land was incorporated into the Humboldt National Forest. A few small ranches within the National Forest are still privately owned. They are located along the major streams where the meadows are irrigated and the wild grasses cut for hay.

The area has been prospected since 1870, but mining has been sporadic and never very profitable. At present, only a few mining claims are being maintained.

This region along the northern border of Nevada with its relatively large, perennial streams; open, accessible country; and abundant wild game is becoming increasingly favored by sportsmen. Consequently, the tourist trade may become a major part of the region's economy.

PALEOZOIC STRATIGRAPHY

REGIONAL SETTING

During the last two decades, geologists of the U. S. Geological Survey and the geology departments of several universities have shown in increasing detail the stratigraphic and structural complexities of the Antler orogenic belt, the dominating geologic feature of north-central Nevada. The Antler orogenic belt consists of an eastern avolcanic facies, a western volcanic facies, a central transitional facies, and a postorogenic overlap assemblage that lies unconformably on the deformed beds of the first three facies. During the Mississippian and Pennsylvanian periods, the western and transitional facies were moved eastward along a regional discontinuity, the Roberts Mountains thrust, into the area of eastern facies (Roberts and others, 1958; 1967). The postorogenic overlap assemblage was deposited during the Middle Pennsylvanian to Permian (Dott, 1955).

During the early 1950's when mapping in the Rowland quadrangle was started, the Antler orogenic belt and the trace of the Roberts Mountains thrust was thought to extend in only a general way north and northeastward from central Nevada. Mapping in the quadrangle revealed rocks similar to those in the western, eastern, and overlap assemblages farther south, and established the area as one of the most northerly outcrops of the Antler orogenic belt; any northward extension of the belt lies beneath the Tertiary volcanics of the Snake River Plain. However, fossils were nearly nonexistent and the correlations were mainly by lithologic similarities. Since the mapping in the Rowland quadrangle, workers have traced a major structural break, with western facies thrust over eastern facies, northeastward from central Nevada to the Lone Mountain area north of Elko (Lovejoy, 1959), through the Independence Range (Kerr, 1962; Fagan, 1962), and into the Bull Run quadrangle (Decker, 1962) just southwest of the Rowland quadrangle.

LOCAL SETTING

Within the Rowland quadrangle, erosion of a Cenozoic volcanic cover has revealed five areas of Paleozoic sediments and two Mesozoic granitic intrusions. The largest area of sedimentary rocks covers the southern third of the Rowland quadrangle and extends southward into the Mount Velma quadrangle (Coash, 1967), and eastward into the Jarbidge quadrangle (Coats, 1964). The stratigraphic section here is the downward continuation of that described by Coash (1967) for the Mount Velma quadrangle (see table 1). The four other areas are in the northern part of the quadrangle and are separated from the southern area by the larger of the granitic intrusions mentioned above. The stratigraphy of the northern part of the quadrangle is different from that of the southern part, and the two areas are treated separately.

The youngest Paleozoic formation of both areas is a limestone unit with a basal quartz-chert pebble conglomerate and these two units are tentatively correlated. In each section the formations below this limestone are slightly to highly metamorphosed and have structurally complex relationships. For this reason, each section is described in reverse order, from youngest to oldest, or, from the best known to the most obscurely known.

In the following descriptions, the color terms used are from the Rock Color Chart (National Research Council, 1948). A number designation is used only when two colors have the same name. The stratification terms used are those proposed by McKee and Weir (1953). The rock classifications and descriptions are based on those presented by Williams and others (1954).

STRATIGRAPHY OF THE SOUTHERN PART OF THE QUADRANGLE

Sunflower Formation

The name Sunflower Formation was first used by Coash (unpublished Ph.D. thesis, 1954) in reference to a sequence of conglomerate, limestone, and sandstone which crops out along the common boundary of the Rowland and Mount Velma quadrangles. The following description of the type section is condensed from that of Coash (1967).

The name Sunflower Formation is from Sunflower Reservoir which is located in sec. 6, T. 45 N., R. 55 E., in the southwestern part of the Rowland quadrangle. Sections were measured across hill 7260 in sec. 35, and across the hill in sec. 36, southeast of the reservoir, and three members were distinguished as shown in table 1.

Occurrence and thickness

In the Rowland quadrangle, the Sunflower Formation crops out principally in an east-west belt paralleling the southern boundary of the quadrangle south of Sunflower Flat and Sunflower Reservoir. Along the outcrop the dip of the formation changes from steeply southward west of the reservoir to steeply northward and overturned east of the reservoir.

Westward, the formation extends to the Jenkins Peaks in the southeast portion of the Mountain City quadrangle, where it strikes northwestward and is buried under lavas and pyroclastic rocks west of Chicken Creek. Eastward, it can be traced across Big Bend and Martin Creeks, to Rosebud Mountain. East of Rosebud Mountain, the formation is found as a small block, downfaulted between Rosebud and Pine Mountains and Cornwall Basin. In this block, the Sunflower strikes approximately north-south, and dips west. The conglomerate overlies the limestones, hence the formation is overturned at this place. Other small downfaulted blocks of highly deformed, crystalline, light-gray limestone located along the southeast flank of Pine Mountain and on the northeast side of the Copper Mountains are tentatively included in the Sunflower Formation.

The basal conglomerate member forms a row of hills just south of the reservoir. Although the contact with the underlying Tennessee Mountain Formation on the north side of these hills is covered with mantle and vegetation, it can be located within a zone 50 feet wide. Along the contact the diverging dips and strikes of the two formations indicate that the conglomerate lies discordantly against the Tennessee Mountain Formation. Regionally, the contact of the Sunflower and the underlying formation is probably an angular unconformity. Wherever observed, the basal conglomerate member grades into the middle limestone member through a transition zone of about 10 feet. The thickness of the conglomerate is variable but it is about 325 feet thick on the westernmost hill in the row of hills south of the reservoir. Southeast of the reservoir, where faulting may have repeated the section, the conglomerate appears to be 500 to 800 feet thick. The distinction between the middle limestone member and the upper sandstone member is not clear, and no attempt was made to separate the two. In the Rowland quadrangle, up to 1,100 feet of limestone is present above the basal conglomerate member.

Description

The formation is broken, shattered, and brecciated throughout its outcrop area, and shot through with calcite and quartz veinlets. It is, however, the least altered pre-Cenozoic formation exposed in the Rowland quadrangle.

Basal conglomerate member. The conglomerate member is composed of angular to rounded fragments of quartz, quartzite, and chert, ranging in size from fine sand to cobbles. Texture varies throughout the member, although any one layer is fairly uniform. The sand-size grains occur as lenses or thin beds of quartzite. Granules and small pebbles, commonly rounded but locally angular, lie in a matrix of medium to coarse sand and are aligned parallel to bedding. Large pebbles and cobbles apparently have no preferred orientation and form massive beds. No cross-bedding or graded bedding was observed and the only observed top and bottom evidence is one channel filling that shows that the bottom of the formation is toward the north (Coash, 1967).

From a distance, and especially near faults, the outcrops are reddish brown. Close-by, and in hand specimens, the rock is lighter colored and appears to consist of light-gray and yellowish-orange quartz fragments with a few scattered fragments of gray and black chert.

East of the reservoir (NE¼ sec. 31, T. 45 N., R. 56 E.) is a small exposure of a very fine-grained, pale-red to light brownish-gray, argillaceous limestone surrounded by conglomerate. No contacts are exposed and this limestone may be either a small lens in the conglomerate or a small fault-block. Some brachiopods and bryozoans are present, but they are so poorly preserved that detailed identifications are impossible.

Limestone member. The basal conglomerate member grades through a thin zone of conglomeratic and sandy limestone into thick-bedded, cherty, medium-gray limestone. The limestone is composed of fine clastic calcite grains, fragmental fossil material, and a large amount of very fine sand and silt. Locally it has recrystallized to a coarsely crystalline rock. Coash (1967) reports that a normal sample has 30 to 50 percent insoluble material, mostly finely divided silica, and that some of the crystalline limestone beds contain as much as 20 percent detrital quartz. Fresh surfaces are medium to dark gray with a smooth, subconchoidal fracture. The weathered surfaces are lighter colored and gritty. Outcrops commonly appear massive and light gray.

Chert is found throughout the limestone member. South of Sunflower Reservoir, black chert is present as lenses and thin beds about 1 foot thick. On the east side of Rosebud Mountain, it occurs as thin beds and nodules 3 to 4 inches in diameter. A bed of thin-bedded, grayish olive-green chert occurs about 800 feet above the base of the middle limestone member. It can be traced from Jenkins Peaks eastward for 3 miles to where it is cut off by a fault southeast of the reservoir. It is also present in the fault-block of the Sunflower Formation between Rosebud Mountain and Cornwall Basin. This bed is only 10 to 20 feet thick, but it is quite conspicuous. It dips steeply to form a wall-like outcrop

Table 1. Stratigraphic section for the Mount Velma quadrangle and vicinity including the southern part of the Rowland quadrangle. After Coash (1967).

Age	Formation		Thickness (feet)	Description	
Cenozoic	Alluvium		0–135	Unconsolidated stream gravels	
	Terrace gravels		0–60+	Partially consolidated stream gravels	
	Volcanic rocks		3,500±	Rhyolitic tuffs and flows	light upper member
					dark lower member
	Prevolcanic gravels		0–75	Irregular gravels, with chert, quartzite, and granite pebbles to boulders	
Tr.(?)	Triassic(?) Formation		1,000–4,000±	Thin-bedded, yellow volcanic(?) ash, with chert and limestone	
Permian	Poorman Peak Formation		3,100±	Black mudstones and dark cherts, with crinoidal limestones and fine conglomerates	
	Hammond Canyon Formation		1,960–2,500±	Thin-bedded limestones, with interbedded chert laminae	
	Sunflower Formation	Upper sandstone member	1,460–2,000±	Fine-grained, micaceous sandstone and siltstone, with thin silty limestones; basal ash bed	
		Middle limestone member	296–530	Clastic limestone, gray, locally very fossiliferous (crinoidal)	
		Lower conglomerate member	100–1,910	Quartzite- and chert-pebble conglomerate, with beds of quartzitic and friable sandstone	
Lower(?) Paleozoic	Tennessee Mountain Formation			Interbedded limestone and shale, partially metamorphosed	
	Copper Mountains Quartzite		960–3,000	Light-brown to gray, bedded quartzite with schistose partings	

standing in places 5 to 10 feet higher than the surrounding limestone and has a growth of bright yellow-green lichen which adds to its distinctiveness.

A lens or wedge of thin-bedded, yellowish-gray to yellowish-brown, very fine-grained argillaceous sandstone is found in the southwesternmost corner of the quadrangle. It lies about 500 feet above the base of the limestone member and is itself about 100 feet thick. It may be part of the upper sandstone member described by Coash (1967), but the relationships between this sandstone and the surrounding limestone units are not clear. The upper sandstone member described by Coash (1967) was not recognized in the Rowland quadrangle.

The formation is fossiliferous. Corals, brachiopods, bryozoans, fusulinids, and crinoid columnals are present in thin beds and lenses separated by layers of barren rock. The fossils are fragmented and abraded and were probably carried by wave and current action into small channels or pockets in the sea floor. Later deformation has crushed and broken many of the fossils. Even the microfossils were affected; fusulinids commonly are cut by minor faults which offset their axes. The fossils are slightly silicified and stand out with slight relief on the outcrops.

Age

The Sunflower Formation is the only formation in which fossils were observed in the Rowland quadrangle. The following collections were made by Coash and the author from the limestone member and submitted to the U. S. Geological Survey for identification. Mackenzie Gordon, Jr., with help from Helen Duncan, made a preliminary study of the corals and bryozoans; G. A. Cooper studied several brachiopods; and James Steele Williams worked on general faunas (Coash, 1954, personal communication). Helen Duncan later restudied the corals and bryozoans in more detail and found fusulinids that were previously overlooked. The following collections provide evidence on the age of the formation, and were assigned permanent numbers in the U. S. Geological Survey Upper Paleozoic locality catalog and placed in the Survey's stratigraphic collections.

USGS 16379. Rowland quadrangle, Nevada; hill (altitude 7,260 feet) in southwest corner of quadrangle, sec. 35, T. 45 N., R. 55 E.
- fusulinids
- *Caninia* sp.

USGS 16380. Mount Velma quadrangle; Hay Meadow Creek south of Island Mountain; NE corner sec. 25, T. 44 N., R. 55 E.
- Crinoid columnals
- *Rhombotrypella* sp.
- *Fenestella,* coarse-meshed species
- Rhomboporoid bryozoans, genera indet.

USGS 16381. Locality same as USGS 16380.
- Crinoid columnals
- *Rhombotrypella* sp.

USGS 16382. Mount Velma quadrangle; north slope of center peak of Cornwall Mountain, NW¼ sec. 3, T. 44 N., R. 56 E.
- Horn corals, indet.
- *Polypora* sp.
- *Productus (Dictyoclostus?)* sp. indet.
- *Productus (Linoproductus?)* sp. indet.
- *Neospirifer* sp.
- *Phricodothyris?* sp.

USGS 16383. Mount Velma quadrangle; Cornwall Mountain.
- *Bradyphyllum?* sp.

USGS 16384. Mount Velma quadrangle; Cornwall Mountain.

> "There are abundant indications of *Fenestella* and *Polypora.* Possibly other fenestrate types (Fenestellidae and Acanthocladiiac) are present, but I am not sure. *Penniretepora* is represented, though some of the specimens I tentatively considered to be this genus might, on further investigation, turn out to be *Ptylopora* or related genera. I found some encrusting stenoporoid bryozoans. What appear to be fragments of rhomboporoids are abundant, but with the exception of two examples that I think are *Rhabdomeson,* I could not place them. . . . Laminar fistuliporoid bryozoans were found in several of the pieces, and I think that examples of a primitive *Hexagonella* are present." (Helen Duncan, written communication, 1954.)

Uncatalogued lot (Field number 53–13–2). Rowland quadrangle; south side of the southwesternmost hill, about 300 feet above the conglomerate-limestone contact to the north; at about 6,959 feet elevation. Enclosing formation is the same as that at locality of USGS 16379.
- Thin but extensive zone of caninoid corals.

Miss Duncan writes as follows about the dating of the collections:

> "USGS 16379, in which only *Caninia* was originally identified, was found to contain fusulinids that suggest a late Pennsylvanian or early Permian (Wolfcamp) Age.
>
> "USGS 16380 and 16381 contain bryozoans that are believed to be indicative of Pennsylvanian (fusulinid phase) or Permian Age.
>
> "USGS 16382, 16383, and 16384 contain either corals or bryozoa, or both, that I think are much more likely to occur well up in the Pennsylvanian or in the Permian than in early Pennsylvanian or Mississippian rocks.
>
> "In brief, I think that all the collections reviewed here came from rocks that are not older than the fusulinid phase of the Pennsylvanian. The same types of fossils, however, persist into the Permian."

Professor Dunbar and the author studied the fusulinids from USGS 16379 and some collected during the summer of 1954 from a nearby locality. The 1954 locality is on the east side of hill 7260, at 7,200 feet altitude, 350 feet stratigraphically above the basal conglomerate. Two species of *Triticites, T.* cf. *T. cuchilloensis* Needham and *T.* cf. *T. ventricosus* (Meek and Hayden) were found. *T. ventricosus* is a rather common, widely distributed form present in the Upper Pennsylvanian (Virgil and Cisco) and the Lower Permian (Wolfcamp) (Thompson, 1954). Needham (1937), who collected and named *T. cuchilloensis* stated: "*T. cuchilloensis* is found somewhat below the middle of the *Triticites* zone" (p. 15), and, "This form is rare near the middle of the Magdalena Formation in the Cuchillo Mountains [New Mexico]" (p. 37). However, his table 2 (p. 61) is drawn so that the middle Magdalena correlates with the lower Gaptank, Canyon, and Missouri series, although he placed the middle of the *Triticites* zone opposite the Virgil, upper Canyon, Cisco, and upper Gaptank series. Thus the age of *T. cuchilloensis* is doubtful. Needham did not find it with *T. ventricosus,* but their association in the Rowland quadrangle suggests that it ranged into the Upper Pennsylvanian (Virgil and Cisco series).

The lack of such definitely Permian forms as *Schwagerina* and *Pseudoschwagerina* implies that the Sunflower Formation, at least the middle part, is limited to the Upper Pennsylvanian.

The limestone member of the Sunflower Formation that crops out in the Rowland quadrangle is Late Pennsylvanian or Early Permian. It is, at least in part, equivalent to the Antler Peak Formation in the Golconda quadrangle, and to the Strathearn Formation of Dott (1955). Although the basal conglomerate member of the Sunflower Formation lies below Antler Peak equivalents, it cannot definitely be stated that it is correlative with the Battle Formation (conglomerate with limestone lenses), which underlies the Antler Peak and is of Early Pennsylvanian (Des Moines) Age.

Tennessee Mountain Formation

Occurrence and age

The Tennessee Mountain Formation was tentatively defined by Coash (unpublished Ph.D. thesis, 1954) in reference to a thick sequence of highly deformed, interbedded, thinly bedded limestone and argillaceous rocks which crop out on the southern and western flanks of Tennessee Mountain in the southwest quarter of the Rowland quadrangle. Coash estimated this unit to have a thickness of several thousand feet. As the unit referred to is valid, the name is retained and the formation is further defined in this report.

The type section of the Tennessee Mountain Formation is on Tennessee Mountain where a typical sequence can be observed northeastward from Sunflower Reservoir, across Waterlog Summit, east of Slate Creek, to Tennessee Mountain. Similar outcrops can be traced eastward and westward in an area bordered on the east by Pine and Rosebud Mountains, on the south by the row of hills south of Sunflower Reservoir, on the west by Sunflower Flat and The Mahoganies, and on the north by the shoulders and peak of Tennessee Mountain.

Two small fault blocks of deformed limestone, one lying east of Rosebud Mountain, the other on the north end of Pine Mountain between Badger Creek and a bend in the Bruneau River, are tentatively included in the Tennessee Mountain Formation. No other outcrops of the Tennessee Mountain Formation are known in the quadrangle.

The formation has been more intensely deformed than any other in the southern part of the quadrangle. It is tightly folded, faulted, cut by cleavage, and slightly to highly metamorphosed. It is discordant with all of the surrounding units: normal faults separate it from the Prospect Mountain(?) Quartzite to the east; the Sunflower Formation and Cenozoic volcanic rocks and alluvium unconformably overlie it to the south and west, respectively; and it is cut off on the north by a granitic stock. The main structural trends of the formation range from about N. 60° E., in the southern exposures, to north-south in the northern exposures. Superimposed on these trends, and mostly paralleling them, are cleavage, small faults, and small complex folds.

No fossils have been found in the Tennessee Mountain Formation within the Rowland quadrangle, but outcrops in the adjacent Mountain City quadrangle have yielded two collections of brachiopods that are considered to be of Cambrian or Ordovician Age by A. R. Palmer (R. R. Coats, written communication, 1964). Elsewhere in Nevada, interbedded limestones and light-colored shales are typical of the Upper Cambrian and Lower Ordovician rocks of the eastern facies. Consequently the Tennessee Mountain Formation which lies below the Sunflower Formation is tentatively assigned a Cambrian or Ordovician Age.

Description

Argillaceous rocks are dominant along the southern exposures of the Tennessee Mountain Formation; thinly bedded limestones are dominant along the northern exposures. As the Sunflower Formation lies unconformably on the Tennessee Mountain Formation to the south, the argillaceous rocks are considered the younger or upper unit, the limestones, the older or lower unit.

Typically, the limestone consists of thin beds (0.5–1.5 cm thick) of medium-gray, aphanitic limestone and silty limestone separated by very thin phyllite laminae. On the weathered surfaces the limestones are light gray, the silty limestones yellowish gray or light brown, and the phyllite light gray to greenish gray. Locally, the phyllite laminae are torn and broken into more or less rectangular-shaped pieces. Long straight cracks paralleling the long sides of the rectangles separate the pieces. A lineation present on the broken laminae is perpendicular to the cracks.

There are several minor variations of the typical limestone. Just east of Bieroth Spring the fresh limestone is light brown rather than light gray. Between Meadow Creek and Bieroth Spring, the color is dark brown to dark gray and the laminae are more equal in size, both the phyllite and limestone layers being about 0.2–5.0 mm thick. The argillaceous laminae are darker, more resistant, and stand out as thin ridges on weathered surfaces.

Thin phyllite beds, 10 to 50 feet thick, are occasionally interbedded with the limestones. Southward along Meadow Creek, and from Slate Creek, the phyllite beds become thicker and more numerous, and south of Waterlog Summit they are dominant, with the laminated or thinly bedded limestone occurring only as thin lenses or beds. The phyllite is not a resistant rock; hence it does not form prominent outcrops. The best exposures are in road cuts such as the one along the Meadow Creek road north of Waterlog Summit and prospect cuts such as at the Gribble claims (see pl. 1). The phyllite ranges in color from yellowish gray to grayish green. Cleavage has obliterated bedding in the phyllite and only the presence of the limestone layers gives an indication of the attitude of the formation.

Where the formation is in contact with the large granitic stock, reaction between the argillaceous limestone and the granitic magma has resulted in the formation of tactite, a garnet-pyroxene rock. Scheelite, a tungsten mineral, is present in the tactite, and the Tennessee Mountain Formation is of some importance as a host rock for tungsten ore deposits. The tactite aureole around the intrusive is irregular, virtually absent in some places, but well developed in others. Outward from the tactite, both the calcareous and argillaceous rocks are hornfelsic, dark, hard, and heavy. Beyond the hornfels but within a mile of the intrusive, the limestone is coarsely crystalline and contains crystals of tremolite. Elsewhere throughout the formation, spotted slates are present. Pyrite occurs throughout the limestones and phyllites and is probably the result of igneous activity rather than sedimentary environmental conditions. The metamorphism of the shales to phyllites may be partially due to the intrusion of the granitic rocks; but more likely, considering the wide extent of the phyllite, the change was due to preintrusive regional metamorphism.

No attempt was made to measure the thickness of the formation. The width of the outcrop area perpendicular to the general strike is about 3 to 4 miles. Allowing for the locally, extremely varied attitude of the bedding, and the possibility of repetition by folding and faulting, a conservative estimate of the thickness of the formation would be about 5,000 feet of phyllite and 5,000 to 7,000 feet of limestone, with a total thickness of about 10,000 feet.

Paleozoic(?) Phyllite (Pzp)

A distinctively weathering phyllite crops out along the Bruneau River in the southeast quarter of the quadrangle. Similar rocks are present in small isolated blocks on the north end of the Copper Mountains. Wherever observed, the formation is in fault contact with surrounding formations, which in nearly every case is the Prospect Mountain(?) Quartzite. The unit is of undetermined age, and could be assigned to any of several horizons. It may be: (1) a metamorphosed equivalent of one of the argillaceous members of the Tennessee Mountain Formation, (2) a thick interbed of phyllite in the lower part of the Prospect Mountain(?) Quartzite or in the Precambrian metasediments described by Coats (1964, p. M3), or (3) an isolated part of the northern sequence of Paleozoic rocks. Its red weathering suggests a possible correlation with the argillites (Pza), a western facies formation. It is considered a Paleozoic formation in this report.

The phyllite is medium to dark gray on the fresh surface. In large outcrops, the mass effect is of a very dark-red to blackish-red surface, but the color of the weathered surfaces actually ranges from grayish red to light olive gray. In most places the formation is a phyllite with schistosity intersecting the bedding at angles of about 30°. In the exposures along the north side of the Copper Mountains the phyllite has been changed to a hornfels with large chiastolite porphyroblasts. This change may be related to the granitic intrusion which is present to the north.

Prospect Mountain(?) Quartzite

Occurrence

Prominent outcrops of light-colored, bedded to massive quartzites are present on the flanks and crest of the Copper Mountains in the southeastern part of the Rowland quadrangle; these outcrops are tentatively correlated with the Lower Cambrian Prospect Mountain Quartzite, the basal Paleozoic formation of other eastern Nevada sections. The quartzites are of two general types; thin- to thick-bedded quartzites with interbeds of schists, and massive, yellowish-gray quartzite. The two types are apparently gradational and the massive quartzite appears to be the younger. Typical sections of the bedded quartzites and schists are exposed on the cirque wall on the northern and eastern sides of the main crestline, on the slopes at the head of Deer Creek on the southwest flank of the range, and along the north fork of Cottonwood Creek west of the central part of the crest. Quartzites of this type are also exposed on the east side of Cornwall Mountain in the Mount Velma quadrangle. The massive quartzite crops out on the north end of the Copper Mountains, north and south of Miller Creek, and forms both Pine and Rosebud Mountains.

The Prospect Mountain(?) Quartzite underlies most of the southeastern quarter of the map area. The quartzite's resistance to weathering, and its structural elevation along Late Cretaceous and Cenozoic faults, account for the mountainous terrain of this part of the quadrangle.

Description

The lower part of the Prospect Mountain(?) Quartzite consists of alternating layers, 50 to 200 feet thick, of: (1) thin- to thick-bedded, light-colored quartzite with schist interbeds; and (2) interbedded, laminated to thin-bedded, dark-colored quartzites and schists.

The first-named type is light gray to light brown on fresh surfaces, pale brown to grayish orange pink on the weathered surface. It is a "clean" rock, composed almost entirely of poorly size-sorted, rounded quartz grains. Only a few dark grains were noted. In its premetamorphic state, this quartzite would be classified as a quartz arenite. The thin schist interbeds are grayish brown to grayish olive with obvious chlorite, but with mud cracks still preserved.

The lithology of the second type in the lower part of the formation is that of a slightly metamorphosed quartz wacke. In the hand specimen, laminae and small lenses of fine- to medium-grained, light olive-gray to grayish-brown quartzite are interbedded with schistose layers. Small flakes of biotite are scattered throughout the quartzites. Thin sections show that the rock is composed of angular to subrounded quartz grains and more than 10 percent matrix of muscovite and sericite. Zircon is a common accessory mineral. The quartz grains range in size from 0.03 mm to 0.35 mm; the thin quartzite layers consist of a high percentage of large quartz grains, the schist layers consist of an argillaceous matrix with a low percentage of small quartz grains. The development of secondary magnetite, embayment of some of the quartz grains, and reaction between the matrix and the quartz grains may have occurred during the metamorphism of the quartz wacke and shale to quartzite and schist; it may be due to hydrothermal action caused by the intrusion of a nearby granitic stock; or may have been caused by both the metamorphism and the intrusion.

Locally, as at the head of Deer Creek, the schist layers dominate and form beds up to 50 feet thick. Crossbedding is present but not prevalent. Ripple marks, mud cracks, and rill marks(?) are present on the schist layers, indicating shallow water, near shore deposition. A small outcrop of dark-gray quartzite on Copper Mountain, the highest peak in the Copper Mountains, is a quartz wacke with a high percentage of argillaceous matrix.

The massive quartzite in the upper part of the formation is very similar to the bedded, light-colored quartzite of the lower part of the formation. It is massive, light gray to light brownish gray, and weathers to a pale brown and pale yellowish brown. Thin sections show that the rock is composed of subangular to rounded but predominately subrounded quartz grains that range in size from 0.3 mm to 1.7 mm. The quartz grains, like those in the lower units, show undulatory extinction and have dustlike opaque inclusions. There is very little matrix, accessory minerals, or cementing material. Some secondary pyrite and hematite are present.

Although no exposures show a definite transition from the bedded quartzites to the massive quartzites, a transition is suggested by exposures along the north end of the crestline of the Copper Mountains. On the west flank of the Copper Mountains, the massive quartzite lies west of west-dipping, bedded quartzites. On Rosebud Mountain, the massive quartzite lies higher than the bedded quartzite on Cornwall Mountain in the Mount Velma quadrangle to the south. In this report, both the massive quartzite and bedded quartzite are placed in one formation, with the massive quartzite above the bedded quartzite. Future workers may separate the quartzites into two formations.

A thin conglomerate layer is present on the north end of the main crestline of the Copper Mountains and on knob 8562 on the ridge north of Miller Creek. It consists of coarse, rounded quartz grains, angular fragments of light-colored, aphanitic quartzite, and light-green, rounded masses of actinolite. The conglomerate and several thin beds of dark phyllite and schist are the only indication of bedding throughout the whole outcrop area of the massive quartzite.

The joints and faults in the quartzite, especially the upper massive unit, served as channelways for hydrothermal solutions and the quartzite is a host rock for minor lead, silver, and gold deposits.

Neither the lower nor upper contacts of the Prospect Mountain(?) Quartzite is exposed in the Rowland or Mount Velma quadrangles. No sections were measured in the Copper Mountains because of the numerous faults with unknown displacement. However, outcrops on the southwest side of Copper Mountain, where no faults were observed, give some indication of a minimum thickness for the formation. Quartzites are exposed from an altitude of 7,250 feet at the head of Fawn Gulch to an altitude of 9,911 feet at the top of Copper Mountain. Dips in this area are about 10° eastward. Thus a minimum thickness of the formation is estimated at 3,500 feet. Coash (1967) measured a partial section of 623 feet on Cornwall Mountain in the Mount Velma quadrangle.

Age and correlation

Although no fossils were found in the Prospect Mountain(?) Quartzite, it is tentatively dated as Lower Cambrian and correlated with the type Prospect Mountain Quartzite on the basis of lithology. The possibility exists, however, that some if not all of the Prospect Mountain(?) Quartzite is Precambrian in age. The following quotations are descriptions of the Prospect Mountain Quartzite at Eureka, Nev.; southern Ruby Mountains, Nev.; and Gold Hill, Utah.

Eureka, Nevada (Wheeler and Lemmon, 1939, p. 17).

> ". . . (Prospect Mountain) consists typically of a reddish brown, highly broken, fractured quartzite, occasionally interbedded with conglomerate and with thin beds of micaceous shale. . . ."

Southern Ruby Mountains, Nevada (Sharp, 1942, p. 651–652).

"This formation is a massive vitreous quartzite (Pl. 2, fig. 1) that contains some schistose beds or partings and sparsely conglomeratic layers. It is normally white, light gray, or light tan and weathers dark brown with associated streaks, spots, and diffusion rings of iron oxide. The quartzite is completely crystalline, is medium grained (0.1 to 2 mm), and contains minor amounts of orthoclase, zircon, apatite, ilmenite, muscovite, pyrite, and hematite or limonite, the first four of which appear to be detrital. Thin beds of mica schist scattered sparsely through the formation contain quartz, biotite, muscovite, sericite, sillimanite, zircon, and pyrite. This latter assemblage suggests high-grade metamorphism of shaly beds. The thin conglomerates contain small (½ to 1 inch) pebbles of whitish quartzite that have been secondarily flattened and elongated.

"The Prospect Mountain is fairly well-bedded on a 6-inch to 2-foot scale and near the top contains much thinner layers of mica schist. Some beds of quartzite are faintly laminated; others are crudely cross-bedded. The mica schist and parts of the quartzite show foliation parallel to bedding."

Gold Hill, Utah (Nolan, 1935, p. 6).

Section of Prospect Mountain quartzite on Basin Creek.

Cabin shale	Feet
Massive, dominantly light-colored quartzite	2,500
Slate and quartzite (shale member)	300
Light colored quartzite	500
Slate and quartzite (shale member)	600
Light colored quartzite	200
Slate and quartzite (shale member)	100
Light colored quartzite	500
Shale	50
Base not exposed	
	4,750

The only other thick quartzite unit in the region with which the Prospect Mountain(?) Quartzite could be correlated is the Ordovician Kinnikinic Quartzite of central Idaho. However, the Kinnikinic has calcareous beds in the upper part, which the Prospect Mountain(?) Quartzite lacks. In general, the Prospect Mountain(?) Quartzite seems most similar to the Prospect Mountain at the type locality and at other Nevada areas. The similarity of the Prospect Mountain(?) Quartzite in the Rowland quadrangle to that at Gold Hill is striking, especially the presence at both locations of a massive light-colored quartzite in the upper part of the formation. Coats (1964) places a schist and quartzite sequence that crops out on the eastern flank of the Rowland quadrangle in the Precambrian. The outcrops correspond with those mapped as Prospect Mountain(?) Quartzite, lower bedded member, in this report. Bick (1959) also has separated the massive member from an underlying bedded series. He dated the upper unit as Cambrian, the lower as Precambrian. For the present, all of the quartzite on Copper Mountain is considered as Prospect Mountain equivalent.

STRATIGRAPHY OF THE NORTHERN PART OF THE QUADRANGLE

The stratigraphy of the northern part of the Rowland quadrangle is more disjointed and vague than that of the southern part. A small granitic stock lies north of the large stock that divides the quadrangle into two parts, and this small stock and a partial cover of Cenozoic volcanic rocks separate the Paleozoic rocks of the northern part into four main areas of exposure: (1) along the Bruneau River from Hot Springs northwestward to McDonald Creek, including Rattlesnake Canyon; (2) along Taylor Creek; (3) on Bearpaw Mountain; and (4) in Long Canyon. Furthermore, both sedimentary and possibly the igneous pre-Cenozoic rocks are divided structurally by the Trail Gulch fault. To the east of the fault, structural trends are dominately N. 60° E. to east-west; to the west of the fault, N. 45° E. (see pl. 1).

The youngest formation in the northern part of the quadrangle is the Diamond A Formation (Ꞓda) which is found east and west of the Trail Gulch fault. In both areas it unconformably overlies an argillaceous formation (Pza_1) that contains a dark quartzite member. Below these two formations the stratigraphy is uncertain; six other formations are exposed, but only in small blocks separated by fault contacts. One formation, a laminated dark limestone (Pzd), crops out only east of the Trail Gulch fault, the other five, only west of the fault. Neither the total thickness, the age, nor the local stratigraphic position of the formations beneath the Diamond A Formation is known. To add to the confusion, all of the rocks are somewhat metamorphosed.

Hopeful that future workers in this region will be able to trace these formations to areas where they are better exposed and have clearer relationships, the formations in the northern part of the Rowland quadrangle, with the exception of the uppermost limestone, the Diamond A Limestone, are not given formal names but are merely designated by letter-number combinations. The letter represents a general rock type, the number, a variation of that rock type. The formations are based only on lithology, and division of a rock type does not imply that the units so divided are correlatives. They may be correlatives; they may be either lateral or vertical variations of a formation; or they may be entirely separate formations. The lack of key beds and fossil evidence leaves the matter open to question.

Nolan (1937), and later Stephens (private report, 1946), described the following sections near the Rio Tinto mine (table 2). The dominant structural trends in the Mountain City quadrangle are east-west and are, in general, a continuation of the trends in the northern part of the Rowland quadrangle. Despite the similarity of structural trends, only a few formations in the Mountain City quadrangle can be correlated with formations in the Rowland quadrangle. The Diamond A Formation is similar to the Banner Formation of the Mountain City quadrangle. The upper part of the Diamond A includes some black slates and schists which in the Mountain City quadrangle may be included in the lower part of the Mountain City Formation. The black quartzite member of the Paleozoic unit Pza_1 is similar to the Black Rock quartzite. Paleozoic unit Pza_3 is similar to the Copper King and Rio Tinto Formations. Any other correlations would be extremely tenuous.

Diamond A Formation

Occurrence

The Diamond A Formation is herein named and defined for exposures of bedded limestones with shale members and a basal chert-quartz pebble conglomerate found along the north side of Bearpaw Mountain (sec. 17 and N½ sec. 19, T. 47 N., R. 57 E.; SE½ sec. 24, T. 47 N., R. 56 E.) and along the Bruneau River from Rowland, west of hill 5767, northward to McDonald Creek. The name is from the Diamond A Desert which lies just northwest of Bearpaw Mountain.

The lower contact of the Diamond A Formation varies from place to place. At Rowland, it rests on the black quartzite member of unit Pza_1. The formations are generally concordant but, locally, the dips diverge and slight drag folds are developed in the limestone. In some places on the north side of Bearpaw Mountain (SW¼ sec. 17, and NW¼ sec. 20), black hornfelses of the unit Pza_1, present above the black quartzite member, seem to grade conformably into the lower part of the Diamond A Formation. In other places, (for example in N½ sec. 19), the two are in fault contact and the basal conglomerate member of the Diamond A Formation is strongly metamorphosed and has a gneissic texture. Along the east side of Deep Creek (SE¼ sec. 24), the conglomerate rests on the unit Pza_1 with a slight angular unconformity. In the Mountain City area, Nolan thought the Banner Formation (Diamond A Formation correlative) rested conformably on, and was

Table 2. Stratigraphic section of the Mountain City quadrangle. After E. C. Stephens (unpublished report, 1946).[1]

Age		Formation	Thickness (feet)	Lithologic description
Paleozoic		Mountain City Formation	4,000±	Dark, argillaceous schists, partly calcareous, with some interbedded quartzites; calcareous schists more abundant near base, quartzites near top.
	Carboniferous	Banner Formation	1,100±	Arenaceous, massive, blue-gray limestones; brownish sandstones; conglomerate member near base; minor schists. Poorly preserved fossil control.
		Jenkins Peak Formation		Conglomerate, quartzite, sandstone, limestone, schists, and slates. May correlate with Banner Formation.
		Angular unconformity		
		Rio Tinto Formation	2,085 max.	Alternating light and dark shales, grading into schists and slates; argillites, cherts, conglomerates, quartzite lenses. Basal unit of dark-gray, thin-bedded chert 145 to 300 feet thick.
		Black Rock Quartzite	1,000	Medium- to coarse-grained, massive, dark-gray quartzite compcsed of subrounded quartz grains.
		Copper King Shale	540	Black and gray shale; weathers to lighter shades.
		Copper Mountain Quartzite	2,500 max.	Massive, light-colored quartzite with some crossbedding. Varies greatly in thickness.
		Crosby Formation	5,000–7,000	Bluish-gray, well-bedded cherts with varying amounts of shale, shist, sandstone.
		Van Duzer Formation		Mostly well-bedded bluish-gray limestone; contains argillite members, narrow quartz lenses.

[1]The section proposed by Nolan (1937) differed from that of Stephens in the following ways:
(a) The Nelson amphibolite, an altered andesite, was included between the Banner and Mountain City Formations.
(b) The Banner Formation was conformable above, and possibly gradational from, the Rio Tinto Formation.
(c) The Rio Tinto Formation, the Black Rock Quartzite, and the Copper King Shale were grouped together as the Rio Tinto Formation.
(d) The Copper Mountain Quartzite was believed to have been thrust over the Copper King Shale.

possibly gradational into, the Rio Tinto Formation (correlatives of unit Pza_1) (see table 2), whereas Stephens believed the Banner was unconformable on the Rio Tinto. An explanation accounting for all these variations would be that slight folding and erosion of unit Pza_1 and the Rio Tinto Formations preceded deposition of the Diamond A and Banner Formations. Thus the Diamond A Formation and unit Pza_1 would seem unconformable in some areas and conformable in others, with the Banner resting on Rio Tinto shales in the Mountain City area and the Diamond A Formation on either the quartzite or hornfelses of unit Pza_1 in the Rowland area. The drag folds observed at Rowland may be the result of later deformation.

Description

Two sections on Bearpaw Mountain were measured by pacing. They do not match in detail, but they do show a similar sequence of basal conglomerate with overlying limestones and interbedded shales. This is the same general sequence found along the Bruneau River and in the Banner Limestone in the Mountain City quadrangle.

Stratigraphic section of the Diamond A Formation on the north side of Bearpaw Mountain; SE¼ sec. 17, T. 47 N., R. 57 E.; north of the saddle between knobs 7,400+ feet and 7,450+ feet; on the long gentle slope east of cabin and road; elevation — 6,650 to 7,000 feet:

North to south	Estimated thickness in feet
Cenozoic volcanics	.....
Covered; fragments of limestone and dark siliceous rocks	300
Limestone, very thin-bedded, light-gray, aphanitic; weathering grayish orange with smooth cherty texture	30
Limestone, medium-gray, crystalline; weathers to an olive-gray, sandy surface	20
Limestone, light- to medium-gray, medium-grained; interbedded and grading into black, laminated hornfels; dip is almost vertical and the rocks form upright slabs or "tombstones"	50
Hornfels, black, laminated	450
Limestone, crudely laminated, medium dark-gray, rust-spotted, crystalline; interbedded with light to medium light-gray, crystalline limestone	530
Limestone, medium-gray, crystalline, with small lenses (less than 10 feet thick) of quartzite-chert pebble conglomerate. Pebbles are of light-colored, fine-grained quartzite and chert; well-rounded but secondarily broken; largest pebbles range in size from 2 by 4 mm to 3 by 3 mm. Limestone and interbedded conglomerate change along strike to black hornfels	20
Limestone, gray, crystalline	100
Hornfels, black; structure and relationships to units above uncertain; may be conformable	.....
	1,500

North and east of this section, outcrops are poor and the ground is covered with small fragments of dark siliceous rock.

Stratigraphic section of the Diamond A Formation on the northwest side of Bearpaw Mountain; NW¼ sec. 19, T. 47 N., R. 57 E.; along northwest ridge north of spring on the west boundary of sec. 19; south-southeast of sec. corner 6512:

North to south	Estimated thickness in feet
Cenozoic volcanics	.....
Quartzite, light-gray, aphanitic	10
Limestone, medium- and dark-gray, thin-bedded, crystalline. White calcite fragments indicate former fossils, especially crinoid columnals	280
Spotted schists, black, and light-olive to dusky-yellow, chloritic schist. A dark-green altered porphyry sill or flow lies about 30 feet from northern contact	120
Limestone, similar to above. Near base, lenses of chert-quartzite pebble conglomerate; some with limestone matrix, others wholly siliceous, consisting of medium-gray phyllite with sheared and stretched pebbles; lenses vary in thickness, 3 to 30 feet; pebbles are predominately white or light-brown quartzite or chert, angular or platy to subrounded, ranging in size from ¼ to 4 inches, averaging about ½ inch. The limestone around the lenses is light gray to olive, crystalline; weathering light brown with a sandy surface; forms slabby fragments, but some crude lamination is observable	200
Hornfels, black, and dark quartzite; structure uncertain, probably a normal-fault contact with unit Pza_1	.....
	610

Except for some minor differences, the limestone sequence north of Rowland is like that on Bearpaw Mountain. Small arenaceous lenses along the southeastern contact are exposed east of the highest shaft of the Bruneau mine on hill 5861. The lenses consist of pale-yellowish-brown chert-quartz pebble conglomerate in a limestone matrix and thin sandstone layers. Chert is locally present as nodules and veinlets in the limestone. Locally the limestone has been recrystallized and its bedding is obscured or represented by thin white subparallel streaks. No recognizable fossils were found, but white, irregularly shaped, large calcite grains may indicate their former presence. Toward the upper part of the formation, thin layers of greenish-gray (5GY 6/1), light olive-gray, or olive-gray shale are sparsely interbedded with the limestone. These shales may be a less metamorphosed equivalent of the hornfels in the upper part of the sections measured on Bearpaw Mountain.

About 2,500 feet of steeply dipping sediments are exposed from Rowland to McDonald Creek, but this section may be repeated by faulting and folding. The stratigraphic thickness is probably no more than that on Bearpaw Mountain, or about 1,500 feet.

Age and correlation

Because of lithologic similarity, the Diamond A Formation is tentatively correlated with the Banner Formation of the Mountain City quadrangle. The Banner Formation was determined as "probably upper Mississippian" (Nolan, 1937; Stephens, private report, 1946) on the evidence furnished by a few corals collected in 1932. Helen Duncan (1955, written communication) restudied this collection (USGS 15384) and reports:

> "The occurrence of a lithostrotionoid coral in this collection must have weighted the 'circumstantial evidence' in favor of a tentative Mississippian assignment. As we now have more extensive information on the geographic and stratigraphic distribution of the lithostrotionoid corals in the West, an age assignment more specific than Carboniferous or Permian(?) cannot safely be made on such fossils. Another collection obtained subsequently by James Steele Williams near Mountain City in rocks believed to be Banner consists of poorly preserved corals, bryozoans, and brachiopods. None of the brachiopods can be identified with confidence, but Mr. Williams and I have the general impression that the assemblage is of Pennsylvanian or Permian age. We are not sure, however, that this collection came from the same unit that yielded the original coral collection."

Stephens (private report, 1946) tentatively correlated the Banner with the Jenkins Peaks Formation, which crops out in the southwest portion of the Mountain City quadrangle. The Jenkins Peaks Formation can be definitely traced into the southern part of the Rowland quadrangle where the name Sunflower Formation is used for the unit. As the age of the Banner is uncertain, the Sunflower cannot be positively correlated with it. If the Banner, Jenkins Peaks, Sunflower, and Diamond A Formations are temporal equivalents, the conglomerate facies of the Sunflower Formation thins out northward and westward from the southern part of the Rowland quadrangle and from the northern part of the Mount Velma quadrangle. The source of the conglomerates would therefore be southeast of the Sunflower outcrops. Much of the material in the conglomerate is light-colored quartzite and may have been derived from the Prospect Mountain(?) Quartzite which crops out east of the Sunflower exposures.

On the other hand, if the age of the Banner is eventually established as Mississippian, the possibility that the formation is correlative with the Jenkins Peaks Formation would be eliminated, and the Diamond A, which is correlated with the Banner, would be a Mississippian formation. Near Elko and southward, upper Mississippian limestones with chert-quartz pebble conglomerates and associated black shales are overlain by Pennsylvanian limestones with chert-quartz pebble conglomerates (see Spencer, 1917; Dott, 1955). Conceivably this sequence might be represented in the Rowland quadrangle by the Diamond A Formation and the Sunflower Formation.

As fossils have not been found in the Diamond A, and as evidence on the age of the Banner is uncertain, the Diamond A Formation is dated only as undifferentiated Carboniferous.

Paleozoic Argillite and Phyllite (Pza)

Dark argillaceous rocks occur in isolated blocks throughout the northern Rowland quadrangle. Although the rocks in these outcrops generally show similar lithologies, in detail they appear different enough to justify dividing them into three different units. One unit, Pza_1, characterized by a dark quartzite, consistently lies unconformably under the Diamond A Formation. The other two, Pza_2 and Pza_3, occur as fault-bounded blocks on the west side of the Trail Gulch fault. These three units may be lateral equivalents, vertical parts of the same formation, or they may be completely unrelated.

Pza_1

The dark quartzite is the key lithologic unit in this formation and it can be recognized in several places: along the Bruneau River east of Rowland; in the northern part of the Taylor Creek and Long Canyon area; and on the northeast end of Bearpaw Mountain. Dark shales are associated with the quartzite in all these areas, but dark shales without quartzites are found along the lower end of Trail Gulch and around the head of Taylor Creek. These are also included in the unit Pza_1, as they lie on strike from Pza_1 outcrops on Bearpaw Mountain.

The shale has been slightly metamorphosed and although the weathered surface is medium to dark gray and dull, the fresh surface is black and glittery due to the presence of small flakes of mica. The few outcrops weather slabby to blocky, with a blackish-red to dusky-red, chertlike surface. Many of the outcrops are along faults and are brecciated with a medium blue-gray chalcedony filling the interstices of the breccia. Mostly the shale weathers to small black chips and forms smooth slopes. The smaller chips are even and smooth, but the larger ones, 3 to 6 inches long show a faint irregular lamination.

Coarsely crystalline, gray limestones are present in the Trail Gulch area and also along the granite contact to the north. They may be lenses in the shale or beds which have been broken and repeated by faulting.

A dark quartzite member occurs near the top of unit Pza_1. It is best exposed along the Bruneau River by B. M. 4922, and southward through hills 5861 and 5727 in sec. 29 and NE¼ sec. 31, T. 47 N., R. 56 E. It forms prominent outcrops of dark, massive, well-jointed rocks. The color is typically dark gray to grayish black although some light-gray and tan beds are present. A few thin to thick beds of dark slates and schists and very thin-bedded dark cherts are the only indication of bedding. On Bearpaw Mountain, the quartzite grades into shales. Thin sections show that the quartzite, despite its dark color, has no argillaceous matrix and no accessory minerals. The quartz grains range in size from 0.05 to 0.70 mm, with an average of about 0.30 mm, and are subangular to subrounded.

A light-gray, highly sheared quartzite which is light brown to light gray on the weathered surface, crops out in Trail Gulch north and south of the Jarbidge road east and northeast of B. M. 5569. In places, it forms a light-brown to dark yellowish-orange clayey soil with scattered granules and pebbles of quartz. Some layers, formerly conglomeratic, now consist of large stretched quartz pebbles set in a matrix of dark, purplish hornfels. The quartzite is very close to an intrusive body, and is cut by small, white, fine-grained, quartz and feldspar veins.

A similar quartzite is found in the northern Taylor Creek area in the SW¼ sec. 15, T. 47 N., R. 56 E. It is pale brown to grayish-orange pink, medium grained, with wavy, thin beds. Some layers were apparently once conglomeratic. The weathered surface is pale light brown. The relationship of these two quartzite units to the surrounding rocks is uncertain, but they are tentatively included in unit Pza_1. An alternate possibility is that these conglomerates are metamorphosed conglomerates of the basal Diamond A Formation. This correlation would not greatly change the structural picture east of the Trail Gulch fault, but it would extend the outcrops of the Diamond A Formation along the Bruneau River at Rowland northeastward under the Tertiary rhyolites to the Taylor Creek area. This would simplify the interpretation shown in figure 2.

Pza_2

The unit Pza_2 is similar to unit Pza_1 except that the black quartzite member is not present and some units not in unit Pza_1 are present. The formation crops out along Taylor Creek in SW¼ sec. 22, and NW¼ sec. 27, T. 47 E., R. 56 E. A west-trending gully on the east side of Taylor Creek in sec. 22 exposes several of the minor units interbedded in the argillaceous sequence. Southwestward from Taylor Creek are two faults, one along Meadow Creek, the other about 2,000 feet west of the first. The zone between the two faults is mostly covered by Cenozoic volcanics and alluvium, but there is a suggestion that this zone is underlain by argillaceous rocks. These argillaceous rocks are tentatively included in unit Pza_2.

Along Taylor Creek, unit Pza_2 lies between two blocks of limestone. It is faulted against the limestone to the northwest but may be either faulted or conformable on limestone to the southeast. The only evidence, however, suggesting conformity is the parallelism of strike of the two formations and an apparently gradational contact. The evidence suggesting a fault contact is stronger. The bedding in the underlying limestone has been obscured within a few feet of the contact and the limestone itself has been recrystallized with the formation of tremolite. Minor fault zones in unit Pza_2 lie close to and parallel the contact. Southward, the argillaceous rocks along Meadow Creek, tentatively included in unit Pza_2, definitely are bordered by a fault on their eastern boundary. Hence, a fault contact along both sides of unit Pza_2 along Taylor Creek is favored in the interpretation in figure 2.

Unit Pza_2 is predominately a black argillite or slightly metamorphosed silty shale of crystalline or silt-size grains with little or no size stratification. Some crude color banding is present. The lighter bands, about 1 cm wide, are of light-colored quartz grains and are broken and cut by bands of black cryptocrystalline material. Other rock types interbedded with the argillite are dark-gray to black metamorphosed chert(?), greenschists, calc-schists, and altered flows.

The greenschists and calc-schists are fine-grained, dark-green, poorly schistose rocks that react slightly to hydrochloric acid. Thin sections show that the greenschist is composed of a granoblastic matrix of xenoblastic albite, with secondary, large calcite grains, and clusters of radiating to fibrous actinolite. The calc-schists consist of a matrix of fine-grained, hornblende, feldspar, calcite, and argillaceous material with larger crystals of orthoclase, calcite, hornblende, and minor plagioclase. The schists are concordant with the surrounding layers and probably represent metamorphosed basic sills and argillaceous limestones or dolomites.

The altered flows are vuggy, light-colored, fine-grained rocks. Thin sections show that they consist in one specimen of a matrix of fine-grained argillaceous material with nonoriented strings or needles of opaque matter and small, scattered grains of quartz and feldspar; and in another specimen, a matrix of fine-grained, much altered quartz and orthoclase crystals with an iron stain extending from crystals of secondary pyrite. The vugs, perhaps vesicles, are in places filled with quartz and calcite. The vuggy, fine-grained texture and high quartz and orthoclase content suggest acidic flows.

Pza_3

Light and dark phyllites, schists, and cherts are exposed about a mile south of Rowland along the ridge east of Hill 5757 in sec. 32, T. 47 N., R. 56 E. The weathered surface of the phyllites and schists is typically pinkish gray to bluish white or a darker reddish purple. The fresh surface is usually dark. Dark, slightly crumpled and brecciated, very thin-bedded, microcrystalline to cryptocrystalline quartzites and cherts are minor units within the phyllites and schists. A few thin layers of brownish, arenaceous limestone are also present. On the west end of the ridge, the phyllites are in fault contact with the black quartzite of unit Pza_1; on the east end they are covered with volcanics.

Paleozoic Schist and Limestone (Pzb)

The schist and limestone unit is exposed on the south side of the ridge east of hill 5767, down slope and along strike from the phyllite and chert sequence of unit Pza_3. At the eastern contact, which is the water gap 2,000 feet northwest of B. M. 5062, the outcrops are composed of massive, recrystallized, partly silicified, light-gray limestones. Bedding in this limestone is represented only by light-gray, subparallel streaks within a darker gray rock. West of this, the dominant lithology is a low-grade calc-schist. Minor lithologies are low-grade mica schists, altered argillaceous sandstones, and thick-bedded, recrystallized limestones. Apparently, limey, argillaceous sediments were metamorphosed slightly to form a pale-olive or grayish-yellow-green calc-schist. Thin sections of these units show that for the most part the rock consists of a fine-grained matrix of muscovite, sericite, and chlorite, with varying amounts of large calcite crystals and quartz grains. Some of the calc-schists have been tightly folded and the large calcite crystals show distorted cleavages.

The question remains as to whether these calc-schists on the south side of the ridge east of hill 5767 are a separate formation or whether they are equivalent to the phyllites of the unit Pza_3 along the ridge top. The phyllites in the critical area on the ridge, though not well exposed, do not appear to grade down slope into the calc-schists. Many minor faults and small folds are also present. On the side of the ridge, the phyllites definitely extend all the way from ridge top to river level. The evidence seems to indicate that a northwest-dipping fault lies between the phyllites and the calc-schists. Consequently, in figure 2, the calc-schists and the phyllites are shown as two formations with a fault between them.

Paleozoic Limestone (Pzc)

Pzc_1

Limestone forms prominent outcrops on the steep valley walls of the Bruneau River and Meadow Creek near the junction of the two streams in secs. 4 and 5, T. 46 N., R. 56 E. The formation is bounded on the east by the Trail Gulch fault, on the west by another fault and covered by volcanic rocks to the north and south. Small blocks of faulted and sheared, yellowish limestone also lying just west of the Trail Gulch fault, one along Coffee Pot Creek in SE¼ sec. 17, T. 46 N., R. 56 E., the other along Taylor Creek in the SE¼ sec. 27, T. 47 N., R. 56 E., are also tentatively included in the unit Pzc_1.

This formation, Pzc_1, is a thin-bedded to very thin-bedded, aphanitic limestone with silty or cherty partings. The fresh surfaces of the limestone are typically pale yellowish brown to grayish orange pink or less commonly light to medium gray. The weathered surfaces, in either case, are light brown to yellowish orange, and silty. The formation weathers to a light-brown silty soil or to angular blocks which form long, light olive-gray talus slopes. A distinctive feature is the large amount of bright orange to brown jasperoid within the formation. Silicification is quite abrupt, with little or no transition from limestone to jasperoid, and it is apparently controlled by faults. The presence of some light-gray limestone indicates that the typical yellowish color of the formation may be due more to secondary silicification than original deposition. If so, the formation is probably a southward extension of the unit Pzc_2.

Movement along the Trail Gulch fault may have displaced the block west of the fault upward and northward. If so, Pzc_1 may be an offset part of the Tennessee Mountain Formation which is lithologically similar in places.

Pzc_2

Outcrops of limestone strike northeastward across Taylor Creek in sec. 27, T. 47 E., R. 56 E., and are repeated to the north in sec. 22 by a fault. They are in line with outcrops of Pcz_1, but are separated from them by faulting and a thick volcanic cover.

Outcrops of Pzc_1 and Pzc_2 are similar except for the different color and the lack of widespread silicification in Pzc_2. Pzc_2 is light to medium gray, and contains small white calcite fragments which may represent fossils, especially the circular ones which may be crinoid columnals. Along some faults, the limestone weathers pale, yellowish orange and varying shades of yellowish gray. East of hill 6010 in sec. 22, where the outcrops show much faulting and folding, grayish-brown chert has developed along the bedding planes and replaces some thin limestone beds.

Paleozoic Limestone and Argillite (Pzd)

This unit crops out east of the Trail Gulch fault in a band 2 or 3 miles wide across the center of the quadrangle. Rattlesnake Canyon is a strike valley carved in the formation; typical exposures of the rocks can be observed in any of the side draws and washes leading into the canyon. The northern boundary of the formation is an intrusive granite contact, which generally follows the north rim of Rattlesnake Canyon eastward to the quadrangle border where the formation is covered by volcanic rocks. The southern boundary is another intrusive granite contact, located about one-third of the way up the south side of the southern rim of Rattlesnake Canyon. The formation extends westward across the Bruneau River to about a mile west of Hot Springs Butte, where it is bounded by the Trail Gulch fault and buried under volcanic rocks.

Although the formation has been mapped as a single unit, it can be divided into two members, a lower(?) argillaceous member and an upper(?) laminated limestone member. These are the equivalents of Coats (1964) units Pzl and Pzph. The lower argillaceous member is best exposed north and south of Buck Creek, along the south rim of Rattlesnake Canyon, and in the Bruneau River by Hot Springs. It consists of very thick beds of argillaceous rocks with minor amounts of interbedded limestones. At some distance from intrusive rocks, the argillaceous member is composed of dense, dark, slabby weathering argillites. Lamination is inconspicuous on the fresh surfaces but is accentuated by weathering. The fresh surfaces are dark gray to grayish black; the weathered surfaces are light olive gray, olive gray, or greenish gray.

Adjacent to the southern intrusive the argillaceous member is definitely laminated or foliated and has been converted to hornfels, slates, and spotted schists with rare augen of quartz and clusters of mica and amphiboles. Cleavage is common but lineation was observed in only two outcrops.

The argillaceous beds are interbedded with crystalline, micaceous, light to dark-colored, laminated limestones. Along the igneous contacts, the limestones have been converted to marbles and light-green tactites. The exposures along the south rim illustrate the control of lichen growth by lithology. The siliceous beds are covered with bright yellow-green lichens and adjacent limy beds support bright, orange-red lichens.

Cleavage has obscured original bedding in almost all exposures, but in a few favorable spots where thin-bedded limestones with shaly partings are present, considerable small-scale tight folding is obvious.

The division between this member and the overlying laminated limestone member is obscure. It is arbitrarily placed on the south side of Rattlesnake Canyon which is essentially a dip slope with few exposures. The limestones in the argillaceous member are like the higher limestones and the change from argillaceous deposition to continual lime deposition was gradational. Numerous faults are present in the formation and some of these undoubtedly offset the boundary between the lower and upper members.

The upper limestone member is well exposed on both sides of Rattlesnake Canyon and is especially well exposed on the north wall, and along the sides of the Bruneau River. It consists of a thinly laminated to laminated, medium-light to medium dark-gray, aphanitic limestone. Individual laminae alternate, light and dark, and this alternation is repeated on the larger scale of alternating thick or very thick beds of light and dark limestone. Thin sections show that the darker layers are composed of calcite grains mixed with platy particles of clay, silt, or carbonaceous material, whereas the lighter layers are of calcite with only a few grains of accessory minerals such as quartz and zircon. The diameter of the accessory minerals is 0.02 to 0.70 mm; the calcite grains are about the same size, but they have been recrystallized and tiny calcite veins cut the laminations. Larger white calcite and quartz veins both cut and parallel the bedding. Within a few feet of the granite of the north rim, the distinct lamination has been obscured and reduced to subparallel, interwoven streaks of light and dark crystalline limestone, the outcrops are massive rather than flaggy, and the weathered surfaces are pitted and rough. Silica content increases with both topographic and stratigraphic height along the north side of the canyon. Low in the stratigraphic section, near the canyon floor, silica occurs as a porous rind less than a millimeter thick composed of grayish-orange, pink quartz on the weathered surfaces of some limestone layers. Midway up the slope beds occur which seem composed mostly of chert or fine-grained quartzite but which have a definite lime content. At the canyon rim, silica occurs as beds of light-gray and black-streaked chert up to several inches thick, all alternating with layers of crystalline limestone. These changes in silica content although coinciding with the presence of a granitic intrusive are believed to be original sedimentary features.

Contortions like those near the southern intrusion also occur near the northern intrusion, and these are probably related to the emplacement of the granite. In the exposures near the canyon bottom, distant from the intrusions, tightly crumpled laminae lie between even, undisturbed laminae. This interlaminar corrugation has two possible origins: as depositional features due to penecontemporaneous deformation, or, more probably, as tectonic features due to the movement of the beds caused by squeezing of the rocks between the two intrusive bodies.

The dominance of aphanitic, laminated limestone together with the slaty habit of the argillaceous members is responsible for the similarity of weathering throughout the area. The outcrops are platy, flaggy, or slabby. The mantle covering the slopes of the canyon is a light- to dark-gray, powdery lime soil. Most of the outcrops are dark gray, but near the top of the north slope, perhaps associated with increased silica, the outcrops support lichens, whose white, gray, light-green and red colors merge at a short distance from the outcrop to give a drab, pale yellowish-brown or pale reddish-brown appearance to the rock.

Age and Correlation of the Formations Below the Diamond A Formation

The formations below the Diamond A Formation cannot be placed in any continuous or conformable stratigraphic sequence. They have yielded no fossils and are bounded by either faults or igneous rocks. Any correlation of these formations with named and dated formations elsewhere is merely tentative.

The location of the Rowland quadrangle along the Antler orogenic belt, and the similarities of the lithologies, indicate that the units can be assigned either to the eastern, western, or transitional facies. The limestone units Pzc_1, Pzc_2, and Pzd are thought to belong to the eastern, avolcanic facies, and are possibly mid-Paleozoic in age; the dark, argillaceous units Pza_1, Pza_2, and Pza_3 are believed to belong to the western volcanic facies and are probably of lower Paleozoic Age. Unit Pzb may be a transitional unit.

In the Bull Run quadrangle, 30 to 40 miles to the southwest of the northern Rowland quadrangle, Decker (1962) mapped a continuous section of eastern facies lower and mid-Paleozoic rocks. The upper four units consist of alternating phyllites and laminated to massive limestones. The unit Pzd in the Rowland quadrangle consists of phyllite at the base, grading upwards into laminated-to-massive limestone; it could represent either the Aura-Chellis combination (Ordovician and Silurian) or the Storff-Van Duzer sequence (Silurian(?)-Devonian(?)) in the Bull Run quadrangle. Present U. S.

Geological Survey mapping in the Mountain City quadrangle, lying between the Bull Run and Rowland quadrangles, may establish firm correlation between the two areas. At present, the Pzd unit seems most like the Storff and Van Duzer formations.

Other correlations are best made by comparing the Rowland area with sections even further away. Thick calcareous formations are typical of the mid-Paleozoic rocks in central and eastern Nevada. Merriam and Anderson (1942) described an Upper Ordovician to Devonian section in the Roberts Mountains consisting of the Hansen Creek Formation (Ordovician), the Roberts Mountains and the Lone Mountain Formations (Silurian), and the Nevada and Devils Gate Formations (Devonian). The Hansen Creek and the Lone Mountain are widespread dolomitic formations. The Roberts Mountains, the Nevada, and the Devils Gate are thin-bedded, light- to dark-gray limestones. These formations or their equivalents have been described east and northeastward in the Eureka district (Hague, 1892; Merriam, 1940) and the southern Ruby Mountains (Sharp, 1942). In the Rowland quadrangle, the units Pzc and Pzd are lithologically similar to the Roberts Mountains, Nevada, and the Devils Gate Formations. The unit Pzd is most like the Roberts Mountains (Silurian) or the Devils Gate (Devonian); Pzc_1 and Pzc_2 are most like the Nevada (Devonian). However, R. J. Roberts who visited the quadrangle during the 1954 field season, reports (personal communication):

> ". . . fossiliferous limestone of Silurian age at the north boundary of Eureka County along Boulder Creek. The limestone is medium bedded, and has characteristic yellowish to brown sandy interbeds very similar to the limestone [Pzc_1] along the Bruneau River southeast of the Mink Ranch. It is about 75 miles from the Bruneau River to Boulder Creek—a rather long distance for correlation on the basis of lithology—but the resemblance of the two units is most striking."

The eastern assemblage rocks of the northern Rowland quadrangle are almost impossible to date with assurance. Tentatively, however, units Pzc_1 and Pzc_2 are considered to be of Silurian Age and unit Pzd to be Devonian.

The dark argillaceous rocks Pza_1, Pza_2, and Pza_3 are lithologically similar to the Valmy and Comus Formations of the Golconda quadrangle (Roberts, 1951; Ferguson and others, 1952) and the Vinini Formation of the Roberts Mountains (Merriam and Anderson, 1942). The presence of igneous rocks in unit Pza_2 favors this correlation with the western facies.

Unit Pzb, with limestones and volcanic rocks, is considered to be a part of the transitional facies, and of undetermined age.

Another possible correlation of the argillaceous rocks is with Mississippian black shales found in the Eureka and Ely districts. In the Mountain City quadrangle, black argillaceous rocks underlying the Banner Limestone are included in the Carboniferous by Nolan (1937), and Stephens (private report). Similarly, if the Diamond A Formation is correlated with the Banner and the Banner is Mississippian, which is doubtful, the dark argillaceous rocks under the Diamond A may also be Mississippian and belong to the eastern facies. Objections to this correlation are the greater thickness of the argillaceous formations in the Rowland quadrangle compared to those in the Eureka and Ely districts, and the presence of igneous rocks, typical of the western facies, in the argillaceous formations of the Rowland quadrangle.

INTRUSIVE ROCKS

GRANITIC STOCKS

Two large granitic stocks and part of a possible third are exposed in the quadrangle. The largest, herein referred to as the Coffeepot stock because of its typical exposures in the vicinity of Coffeepot Creek and Big Coffeepot Spring, crops out in an east-west belt through the center of the quadrangle. To the east and west it disappears beneath Cenozoic volcanic rocks. The configuration of the western part of the stock suggests that it does not extend much farther west than the observable outcrops.

The second stock, referred to as the Deep Creek stock, also has an east-west trend and crops out 2 or 3 miles north of the Coffeepot stock. Its western boundary is exposed in Trail Gulch, where it is locally in fault contact with Paleozoic rocks. Its eastward extension is concealed under Cenozoic volcanic rocks. The northern and southern boundaries of both stocks are the Paleozoic rocks into which the stocks were intruded.

Granitic rock also is exposed at the head of Long Canyon, although it is impossible to say how far it might extend eastward under the volcanic rocks. Moreover, in some areas where no granitic rocks crop out, steeply dipping hydrothermal mineral veins and metamorphosed Paleozoic rocks suggest the presence of granitic rock at a relatively shallow depth.

The Deep Creek and Coffeepot stocks are petrographically similar. Both consist of light-colored, generally coarse-grained, porphyritic rocks ranging in composition from adamellite to granite. Potash feldspar and, less commonly, quartz form large grains up to 1½ inches across. The border zones of the stocks are usually finer grained and have less dark minerals than the interior, but in some places a coarse porphyry is present at the contact. There is some interfingering of the intruded and intrusive rocks in narrow zones along the contacts and, where argillaceous limestones have been intruded, reaction between the granitic rocks and the limestones has formed tactite. Alaskite and aplite veins cut both the stocks and the host rocks. Altered veins of quartz and feldspar are present in the host rocks distant from the stocks, and these parallel the intrusive contacts.

The dips of the contacts between the stocks and the host rocks are nowhere obvious. Around the Coffeepot stock northwest of Tennessee Mountain and at the head of Wickiup and Young America Creeks, and around the Deep Creek stock north and northwest of the Alvarea ranch in Rattlesnake Canyon, the intrusive-host rock relationships suggest a contact that is either vertical or that dips steeply away from the centers of the stocks. Around the Deep Creek stock at the heads of Columbet and Dorsea Creeks, and along Deep Creek, the contacts seem to dip steeply towards the center of the stock.

Lineation and foliation, if present in the stocks, are not megascopically discernible; jointing is the only structure observed. The rock is deeply weathered and friable and erosion, controlled by the jointing, has formed large rounded monoliths. The border zones of the stocks and the surrounding sedimentary rocks are commonly more resistant to erosion than the main bodies of the intrusions, hence the stocks underlie large basins which are rimmed by hornfels and tactites.

Coffeepot Stock

Four thin sections were made from rocks collected from the border and in the interior of the Coffeepot stock. On the basis of the ratio of the alkali feldspar to the total feldspar, the rocks are classified as adamellite (quartz monzonite).

The plagioclase consists of albite (An_{10-15}) in all four thin sections. It forms between 20 to 30 percent of the rock and occurs as euhedral to subhedral crystals. Some of the crystals show normal zoning.

The potash feldspar comprises 20 to 40 percent of the rock and occurs both as anhedral to subhedral interstitial grains of microline, and as porphyroblasts of microcline.

Quartz constitutes 30 to 35 percent of the rock and shows undulatory extinction. It occurs as large anhedral grains, some of which enclose biotite and plagioclase crystals, and as smaller, anhedral, interstitial grains.

The dark minerals are biotite and, less commonly, hornblende. The biotite occurs as euhedral to subhedral crystals making up from 5 to 10 percent of the rock. Some grains are moderately pleochroic, yellowish brown to olive brown, but other grains are reddish brown. Accessory minerals include epidote, clinozoisite, magnetite, euhedral wedge-shaped crystals and subhedral grains of sphene, and zircon.

Sections made from rocks in the border phase of the stock are exceptions to the above generalizations. In one section from the border west of Hot Springs, the plagioclase (An_{10-15}) forms 40 percent, potash feldspar, 25 percent, and quartz, only 15 percent of the rock. Hornblende and minor biotite form as much as 20 percent of the rock. The hornblende occurs as pleochroic, dark-green, stubby, porphyroblasts which are locally zoned, with dark centers. The minerals show little alteration, although some of the plagioclase crystals have been partly altered to sericite. A section from granite in the border zone on the south side of Tennessee Mountain, shows that the granite is medium grained and leucocratic and consists of 5 percent microcline and plagioclase, 70 percent orthoclase, 25 percent quartz, and less than 1 percent dark minerals.

Deep Creek Stock

Two thin sections from the Deep Creek stock were examined; one from near the northern contact, the other from the central part. The rock has a high percentage of alkali feldspar and is transitional between a granite and an adamellite. The thin section from the contact zone contains 20 percent plagioclase (An_{10-15}), 40 percent microcline, 30 to 40 percent quartz, and less than 1 percent biotite. All the minerals are fine-grained, subhedral to anhedral crystals, and there is a slight suggestion of a cataclastic fabric.

The thin section from the center of the intrusive consists of 60 percent orthoclase and plagioclase (An_{10-15}), 30 percent quartz, and 10 percent biotite and hornblende. Magnetite and clinozoisite are minor accessory minerals. No microcline is present. The plagioclase occurs as euhedral to anhedral grains, which commonly have somewhat altered centers composed partly of muscovite and sericite. Some of the larger grains have bent twin-lamellae and strain shadows. The orthoclase occurs both in the groundmass as subhedral grains with some minor zoning and strain shadows, and as phenocrysts, some of which enclose stubby euhedral grains of plagioclase. Locally, myrmekite is present between grains of orthoclase and plagioclase. Quartz forms both large euhedral grains and small anhedral to subhedral grains with undulatory extinction and minor dusty inclusions. In a few places the quartz seems partially to replace plagioclase grains.

Contact Metamorphism and Metasomatism

Prior to the emplacement of the stocks, and probably prior to the deposition of the Sunflower Formation, the shale, sandstone, limestone, and argillaceous limestone formations had undergone low-grade regional metamorphism which changed them to slates, phyllites, quartzites, calc-schists, and crystalline limestones. The contact metamorphism associated with the emplacement of the granitic stocks is of a higher grade than the region of metamorphism. Moreover, the contact metamorphism around the Coffeepot stock is of a higher grade than that around the Deep Creek stock, suggesting that the Coffeepot stock was emplaced at a higher temperature and was possibly more fluid when emplaced.

Along the northern contact of the Deep Creek stock, the shales and sandstones of the Paleozoic argillite and phyllite (Pza_1) have been metamorphosed to quartzites and hornfelses. A thin section of a hard, dark siliceous rock seamed with small, white, quartz veins shows that the rock consists of colorless amphibole, possibly actinolite, epidote, and minor calcite and sphene. Bedding is suggested by a strong alignment of the minerals.

Contact effects in the Paleozoic limestone (Pzd) along the southern edge of the Deep Creek stock include recrystallization of the limestones to marble, epidotization, and possible contact metasomatism with the addition of silica to the limestones. In some places along the contact, a light-green to white, aphanitic, siliceous rock is present. A thin section of this rock shows that it consists of granoblastic crystals of epidote and quartz, minor chlorite and calcite.

Along the north side of the Coffeepot stock, the argillaceous member of the limestone (Pzd) has recrystallized to dark hornfelses and spotted slates; some of the limestone has recrystallized to marble; and in some places limestone and the granitic magma have reacted to form tactite containing scheelite.

Along the south side of the Coffeepot stock the intruded rock is the Tennessee Mountain Formation, an argillaceous limestone, and the effects of the intrusion of the granitic magma are strikingly demonstrated. About half a mile to a mile from the intrusion, the limestone has recrystallized with the formation of large tremolite crystals. Nearer the contact, especially at the heads of Mill and Martin Creeks, the limestone has changed to a dense, purplish, streaked, aphanitic, siliceous rock. Tactite is present as lenses along the contact, but is especially well developed at the head of Tennell Creek and on the west side of Tennessee Mountain. A thin section of this tactite shows that garnet comprises 60 percent of the rock; the remainder is pyroxene, hornblende, and minor chlorite, actinolite, epidote, and plagioclase (An_{30}). Ore minerals that are locally present in the tactite include scheelite, molybdenite, chalcopyrite, and pyrite. The granite near this tactite is leucrocratic, suggesting that iron and magnesium may have been transferred from the magma to the limestones.

The Prospect Mountain(?) Quartzite along the southeast side of the Coffeepot stock seems to have been least affected by contact metamorphism. The addition of pyrite, the embayment of quartz grains, and slight sericitization are probably due to later hydrothermal activity rather than to any reactions between the quartzites and the magma. The metamorphism of shales to hornfelses, some with chiastolite crystals, may be due to contact metamorphism.

Associated Veins and Dikes

Small quartz-feldspar veins are present in the limestones (Pzd) in Rattlesnake Canyon, and aplitic dikes occur in the limestones and phyllites south of Tennessee Mountain. They are commonly discordant with the surrounding rocks and may have been emplaced along minor faults associated with the stocks. Similar dikes and veins occur in the border zones of the stocks with crosscutting relationships. No direct connection was found between the two groups of dikes and veins, but it is assumed that they are related and that both groups were formed during the last stages of magmatic activity.

Thin sections from the veins in Rattlesnake Canyon show that the veins are fine-grained and consist of orthoclase and quartz, highly altered to muscovite and sericite.

The dikes around Tennessee Mountain are larger, up to 15 feet thick; medium to coarse grained; and composed of subhedral to euhedral plagioclase and orthoclase, anhedral quartz, and secondary magnetite, sericite, muscovite, and chlorite. The orthoclase crystals are more altered than the plagioclase, and some are completely replaced by sericite and muscovite.

Origin of the Stocks

Most of the available evidence indicates that the stocks of the Rowland quadrangle were emplaced as forcible intrusions of mobile magma at shallow depths and at a higher temperature than the country rocks.

The stocks have an east-west elongation in concordance with the regional structural trends, although locally and in detail they are discordant with the country rock. The northern dip of the Diamond A Formation and the southward dip of the Sunflower Formation suggest doming over the intruding stocks. Structural trends in the Tennessee Mountain Formation suggest that the formation splits and bends around the end of an intrusive body. Normal faults dipping away from the stocks, and reverse faults toward the stocks, imply an upward movement of the stocks. Considerable crumpling and small-scale folding in the metamorphic rocks adjacent to the stocks further suggest the stocks moved upward, displacing the overlying country rock.

Other features of the stocks are temperature indicators. Their massive internal structure with no foliation or lineation, their tendency towards an "ideal" granite composition, the strong contact metamorphism and metasomatism around them and the aureoles indicating decreasing temperatures outward from the stocks, all indicate an emplacement temperature higher than the country rock.

Age of the Granites

Coats and others (1965) report the ages of samples from several plutons in Elko County. One of his samples, 63NC20, is from the Deep Creek stock on Bearpaw Mountain, SE¼ NE¼ SE¼ sec. 20, T. 47 N., R. 57 E., in the Rowland quadrangle. Other samples are from localities in the Mountain City quadrangle. Coats (written communication, 1966) later collected a sample (65NC80) from the Coffeepot stock in the SW¼ NE¼ sec. 7, T. 45 N., R. 57 E.

The sample from Bearpaw Mountain has a lead-alpha age of 100± 20 m.y. and an Ar/K age of 73 m.y. The sample from the Coffeepot stock has a lead-alpha age of 120± 10 m.y.[1] These dates indicate a Late Cretaceous Age for the plutons.

The granites in the Rowland quadrangle are part of a belt of granitic plutons that extend from the southern

[1]Coats has kindly allowed quoting of the date from this sample which appears in Report No. WA195.

> "Lead determination was by Harold Westley. All values are averages of duplicate determinations. The lead-alpha ages were calculated from the following equation: $t=CPb/\alpha$, where t is the calculated age in millions of years, C is a constant based upon the Th/U ratio, Pb is the lead content in parts per million and α is the alpha counts per milligram per hour. The following constants were used. Assumed Th/U ratio 1.0, C 2485. Age is rounded off to nearest 10 m.y. The error quoted here is that due only to uncertainties in analytical techniques."

Independence Mountains eastward to eastern Cassia County in south-central Idaho (see Decker, 1962; Nolan, 1937; Schrader, 1935; Anderson, 1931) a distance of some 150 miles. This east-west belt of granites coincides with a major east-west structural trend, and the intrusions appear to belong to a late, but not necessarily final, stage of deformation. The Late Cretaceous Age of the granites in the Rowland quadrangle helps to date this major structural belt. The pluton in the Contact quadrangle to the east, located near the center of this east-west structural element, is outwardly larger than the plutons in the Mountain City and Rowland quadrangles. Coats has dated the Contact pluton as Jurassic; it may represent a central intrusion, and the Mountain City and Rowland stocks may be younger satellitic intrusions on its western flank.

DIKES

Five dikes, up to 10 feet thick and composed of dark-greenish altered rocks, crop out in the quadrangle. Three of them are amphibolite, probably derived from basic igneous rocks, or possibly lamprophyres associated with the granitic stocks. The other two are less altered, contain little or no hornblende, and are of intermediate to acid composition.

One of the amphibolite dikes is located on the east side of peak 9146 on the south end of the Copper Mountains where it cuts a schist member of the Prospect Mountain(?) Quartzite. Another cuts Paleozoic limestone (Pzd) on the east side of Trail Gulch; the third is located on the north side of Bearpaw Mountain, southeast of section corner 6940. In general, the dikes are fine grained and in thin sections they appear to consist of highly corroded indeterminate plagioclase, amphibole, and minor quartz and epidote. The amphibole is commonly dark green, probably hornblende, but in the dike in Trail Gulch, it occurs as colorless crystals forming radiating clusters and is probably tremolite.

The other dikes are present on the north side of Bearpaw Mountain. One that cuts both the Deep Creek stock and Paleozoic phyllite (Pza_1) has a very fine-grained matrix of altered feldspar and secondary muscovite, chlorite, and hornblende, and phenocrysts of plagioclase (An_{35-40}), quartz, and orthoclase. Some cataclastic texture is present. Although it is altered, the plagioclase and quartz content suggest that the original rock was a dacite porphyry.

The fifth dike is not exposed on the surface, but is only present in a small prospect tunnel in S½ sec. 17 on the north side of Bearpaw Mountain. It is a porphyry with a fine-grained, medium dark-gray groundmass and phenocrysts of feldspar and biotite up to 3 mm across. A thin section shows that it is not as greatly altered as the other rocks. The groundmass consists of a large amount of anhedral to subhedral quartz, euhedral to subhedral orthoclase and minor plagioclase, with minor quantities of sphene, calcite, and epidote. Most of the phenocrysts are euhedral to subhedral crystals of slightly altered plagioclase (An_{35-40}), in some places normally zoned. Reddish-brown biotite forms large phenocrysts and is also present in the groundmass as small fragments and stringers. The rock is classified as a quartz latite porphyry.

The age of the dikes is not known. They may belong to one or several periods of intrusive activity. One cuts across a stock, the others cut only Paleozoic rocks. Probably they are related to the extrusion of the mid-Cenozoic volcanic rocks, especially the rhyolites.

CENOZOIC ROCKS AND GEOMORPHOLOGY

MIDDLE CENOZOIC

Beginning in the middle Cenozoic, and locally continuing until the late Pleistocene, southern Idaho and northern Nevada were the sites of the extrusion of vast amounts of volcanic rocks. The Owyhee quadrangle is almost entirely covered by volcanic rocks, the Mountain City, Mount Velma, and Rowland quadrangles are at least half covered, and in the Jarbidge quadrangle, 7,000–8,000 feet of rhyolite flows and pyroclastics accumulated to form a large east-west-trending dome with a north flank that dips gently toward the Snake River Plain. Southward, volcanic rocks, lithologically similar to those in the Jarbidge Mountains, extend nearly to Elko. Because of this, Fenneman (1931) drew the boundary between the Snake River Plain and the Great Basin well inside the Nevada boundary. Nolan (1943) believed that structure was a more definitive criterion, and drew the division to coincide with the Nevada-Idaho line, thus including block-faulted volcanic areas in the Great Basin (see fig. 1).

Schrader (1912, 1923) divided the extrusive rocks of the Jarbidge mining district into the "older" and "younger" rhyolites of Miocene and Pliocene(?) Ages respectively. Malde and Powers (1962), introduced the name Idavada Volcanics for rocks that include Schrader's "younger rhyolite." Later, Coats (1964) defined the Jarbidge Rhyolite as synonymous with Schrader's "older rhyolite" and the Cougar Point Welded Tuff as corresponding closely to Schrader's "younger rhyolite." Correlatives of the "older" and "younger" rhyolites are present in the Rowland quadrangle and have been mapped as the Jarbidge Rhyolite and the Idavada Volcanics. Other Cenozoic units present in the Rowland quadrangle include the Bieroth Andesite of Eocene(?) Age, and the Young America Gravel, which was deposited in the interval between extrusion of the Jarbidge Rhyolite and the Idavada Volcanics.

Throughout the Snake River Plain, the volcanic rocks are believed to have been quietly extruded along fissures, with minor eruptions forming small cinder cones. The extrusion of the volcanics in the Rowland quadrangle is believed to have taken place in a similar fashion. The welded tuffs present throughout the series were probably violently erupted along the same fissures as the flows (Gilbert, 1938; Fenner, 1948). The large amount of pyroclastics, especially in the youngest series, implies rather explosive eruptions and perhaps the formation of cinder cones. No such features were observed in the quadrangle, and probably, if any were present, they were destroyed by erosion or concealed by later flows.

Bieroth Andesite

The Bieroth Andesite is named for volcanic rocks which crop out around Bieroth Spring in sec. 14, T. 45 N., R. 55 E. They dip gently westward beneath the Jarbidge Rhyolite, and have a low, subdued topography. Similar rocks crop out along Big Bend Creek southeast of Sunflower Reservoir, along the Bruneau River north of McDonald Creek, between Taylor Creek and Long Canyon, and on the north side of Bearpaw Mountain. Their location along the western boundary of the quadrangle suggests that they belong to an extrusive province centered west of the quadrangle.

The Bieroth Andesite consists of tuffs, welded tuffs, and flows, in places grading conformably upwards into the Jarbidge Rhyolite. The rocks are light brownish gray, yellowish gray (5Y8/1 and 5Y7/2), and pinkish gray on the fresh surface, darker on the weathered surface. Small euhedral biotite crystals are abundantly scattered throughout the rock. Thin sections show a glassy to microcrystalline matrix with larger crystals of reddish-brown biotite, hornblende, and plagioclase. The plagioclase has an average composition of An_{40-50}, although some as calcic as An_{58-60} was recorded. The index of refraction of the glassy matrix is about $1.522 \pm .004$, which indicates that approximately 60 to 65 percent silica is present (George, 1924; Williams and others, 1954, p. 27, 28, 93). On this basis, the rock is classified as an andesite. Most of the rocks are flows, but a thin section made from rock north of B. M. 4900, SE¼ sec. 17, T. 47 N., R. 56 E. shows a matrix in which glass shards are squeezed and bent around larger fragments, good evidence that the rock is a welded tuff (Gilbert, 1938; Barksdale, 1951). Drab-colored tuffs, ash, and tuffaceous sediments are intercalated with and overlie the flows and welded tuffs.

On Sunflower Flat the Bieroth Andesite is nearly horizontal and grades conformably upward into the Jarbidge Rhyolite; in the northern part of the quadrangle, it dips about 20° north and is overlain unconformably by the Idavada Volcanics. The total thickness of flows and pyroclastics is about 200 to 400 feet.

Jarbidge Rhyolite

In the Jarbidge quadrangle, the Jarbidge Rhyolite (Coats, 1964) forms the core of the Jarbidge Mountains, probably the major source area of the volcanic rocks in this district. Similar rocks are also present in the Rowland, Mount Velma, and Mountain City quadrangles, however, and this wide distribution implies that other, perhaps relatively minor, sources were present. In the Rowland quadrangle, the Jarbidge Rhyolite crops out west of the Coffeepot stock and Meadow Creek; underlying the area designated as The Mahoganies; and also along the upper part of the Bruneau River. It does not crop out north of Rattlesnake Canyon where the Idavada Volcanics rest directly on the Bieroth Andesite.

Although the Jarbidge Rhyolite covered the Jarbidge area, forming a dome whose present eroded crest is over 10,000 feet high, it did not blanket the whole Rowland quadrangle. Here the topography on which it was extruded was more or less similar to that of the present, at least in the southern part of the quadrangle, where Pine Mountain and the Copper Mountains stood high with a valley between. The Copper Mountains were a barrier, and diverted the volcanics around the ends and into the valley, where they may have joined. The Jarbidge Rhyolite, which crops out opposite the southwest end of the Copper Mountains, is part of a series of outcrops extending southward and eastward around the Copper Mountains and adjoining the volcanics of the Jarbidge quadrangle. Northeast of the Copper Mountains, just east of the quadrangle border, Jarbidge Rhyolite rests on granitic rocks at an elevation of 8,000 feet, and may have extended southward up the Bruneau Valley and westward across the Coffeepot stock, joining similar rocks underlying The Mahoganies. Tennessee Mountain was probably not covered but may have formed the east side of a large, northeast-trending basin into which the older volcanics were extruded.

In The Mahoganies the Jarbidge Rhyolite is nearly horizontal, but northwest of Tennessee Mountain it dips 10°–15° east. In the Bruneau Valley, it dips 10°–15° east on the west side of the river, but the dip lessens and becomes horizontal on the east side. East of Rattlesnake Canyon, the Jarbidge Rhyolite rises gently toward the east rim of the canyon and it seems likely that the Rattlesnake Canyon area was a topographic high not covered by this formation. Possibly Bearpaw Mountain also rose above the Jarbidge Rhyolite, although it later was partially covered by the Idavada Volcanic series.

The Jarbidge Rhyolite consists mostly of flows with some minor intercalated beds of ash, tuff, tuffaceous sediment, and agglomerate. The flows are characterized by an aphanitic groundmass and abundant phenocrysts, mostly quartz but some feldspar, up to 3 mm across. A thin section shows that the groundmass is microcrystalline and felsitic and the phenocrysts are rounded quartz, euhedral sanidine, and minor plagioclase, with a quartz-feldspar ratio of about 2 to 1.

The fresh surfaces of the lavas are light gray; in some places they have a reddish or pinkish tinge; the weathered surfaces are commonly grayish orange or moderate reddish orange, or locally, dark reddish brown. Sheeting or flow structure is prevalent, and the flows weather to flaggy or slabby outcrops. The abundance of large quartz phenocrysts causes the rock to weather to a coarse, granular soil similar to that formed on the coarse-grained granitic rocks. The terrane underlain by the Jarbidge Rhyolite has a rough, broken, irregular topography, such as that in The Mahoganies and in the Rough Hills in the Mount Velma quadrangle.

Minor beds of slightly consolidated pyroclastics and sediments are interbedded with the lava flows. A lens of tuffaceous sediment about 75 feet thick and several hundred feet long crops out between the lavas just east of the Hall Ranch (W½ sec. 7, T. 46 N., R. 56 E.). It is composed of grayish-orange to pale yellowish-orange, fine to coarse ash, with scattered angular to rounded fragments up to 1½ inches in diameter of dark shales, hornfels, granitic rock, older lavas, and quartzite. A rather thick section of coarse conglomerates is exposed along Meadow Creek where it is interbedded between thick flows. In the Twin Buttes area, thin beds of gravel composed of rounded cobbles of Jarbidge Rhyolite occur throughout the section.

At Twin Buttes, the flows are nearly horizontal and here the Jarbidge Rhyolite is at least 1,000 feet and possibly 1,500 feet thick. Exposures are not as good in The Mahoganies, but the thickness there is probably about the same.

Young America Gravel

After the extrusion and subsequent deformation of the Jarbidge Rhyolite, an erosion surface was formed that is still preserved in the southern part of the quadrangle. This surface is best exhibited between Tennessee Mountain and Pine Mountain, where a high flat divide, developed on granitic rock, metamorphosed limestone, and quartzite, separates the southern and northern drainage. Northward from this divide, the old erosion surface is present on the Coffeepot stock and dips gently north and eastward to form a broad valley in which the present Bruneau River is entrenched. Southward it dips gently southwestward towards Sunflower Reservoir and to the Jarbidge Rhyolite on Sunflower Flat, and forms the tops of the ridges between Mill and Meadow Creeks. Pine, Rosebud, and the Copper Mountains were still high areas, although flat areas on the north end of Pine Mountain may be part of the old erosion surface. The Idavada Volcanics now cover much of the northern part of the quadrangle, but the land surface apparently rose from the Bruneau River northeastward to Bearpaw Mountain and dipped northwestward, in a general way parallel to the present Bruneau Valley. Cross sections of Rattlesnake Canyon offer some evidence for a broad valley stage which preceded a later cycle of stream entrenchment. It is assumed that the formation of this broad valley correlated with that of the old erosion surface elsewhere in the quadrangle. The present altitude of the bottom of the projected profile of the broad valley would be about 6,700 feet.

Following the formation of this old erosion surface, movement was renewed in the quartzite block, erosion there was increased, and gravels composed mostly of quartzite cobbles and boulders were spread over the old surface. In the southwestern part of the quadrangle, large, light-colored boulders of Prospect Mountain(?) Quartzite, almost certainly derived from Pine and Rosebud Mountains, cap the ridges between Mill and Martin Creeks and between Mill and Big Bend Creeks; the hill south of Waterlog Summit, and low ridges south of Sunflower Reservoir in the Mount Velma quadrangle. On the east side of Sunflower Flat, on hill 7050, a small patch of these gravels overlies pyroclastics of the Jarbidge Rhyolite.

These gravels are composed of angular to subrounded fragments, ranging in size from less than 1 inch to 3 feet across. Reddish quartzite is the most abundant component, but white, tan, and black fragments are also present. Other minor components are fragments of black argillaceous rock, of white vein quartz, and of the basal conglomerate of the Sunflower Formation. In places, the fragments are packed together forming a pavement several square feet in area. The size of the cobbles and boulders increases eastward, and the gravels are probably the remnants of alluvial fans, talus, landslides, and slope wash, debris from the uplift of Pine and Rosebud Mountain. During a later cycle of erosion, this debris was reworked and most of the finer material removed, leaving only the coarse, heavier material.

Contemporaneous with the deposition of the gravels on the old erosion surface, alluvial gravels were deposited along a course parallel to the present Bruneau River from the southern border of the quadrangle to Trail Gulch where the Idavada Volcanics cover any northwestward extension. In general, the gravels consist of poorly sorted sands and subrounded to rounded quartzite, Jarbidge Rhyolite, and granitic pebbles and cobbles. The quartzite cobbles were derived from the Prospect Mountain(?) Quartzite, and decrease in size and increase in roundness northwestward, showing that the gravels were deposited by a river flowing northwestward.

Between Pine Mountain and the Copper Mountains near their source, the gravels consist of poorly size-sorted, subrounded to rounded fragments of quartzite and Jarbidge Rhyolite up to 12 inches across.

At Twin Buttes, the Jarbidge Rhyolite crops out athwart the trend of the gravel outcrops. The stream depositing the gravels could not have passed east of Twin Buttes, but it may have passed through the narrow valley west of Twin Buttes by B. M. 5385, closely paralleling the present course of the river. Although gravels were not observed there, they may have been flushed out by the later downcutting of the Bruneau River. Alternatively, the block of Jarbidge Rhyolite may have been emplaced by post-gravel faulting or warping, but no evidence for this was noted. The northeast trend of the gravels between Miller and Coon Creeks suggests that a former Coon Creek may have flowed around the north end of the Copper Mountains.

Northwest of Twin Buttes, the gravels rest on granitic terrane and include cobbles of granitic rock and pieces of petrified wood. The gravels fill a trough that has a steep east side which is probably a fault scarp. Large granitic boulders, mixed with many smaller pieces of weathered granitic rock, occur near the old valley floor and along its steep eastern margin, indicating that here the river gravels interfinger laterally with mass-wasting debris from the steep east side of the valley.

Warping and possible faulting along a northeast-striking axis and erosion of the gravels from the raised areas along the Bruneau River in the Hot Springs area before the extrusion of the Idavada Volcanics may be responsible for the absence of the gravels there.

Farther downstream, northwest of Hot Springs, tributaries on the northeastern side of the Bruneau River, cut through an old gravel-filled channel, 200 to 300 feet deep, lying several hundred feet northeast of and paralleling the present Bruneau River channel (pl. 1, cross-section C–C′). In this channel, large dark hornfels blocks and granitic boulders exhibit the same interfingering of river gravels and mass-wasting debris that is present to the southeast.

Idavada Volcanics

Schrader (1923, p. 20–21) states that in the Jarbidge quadrangle, "After a considerable interval of volcanic quiescence and vigorous subaerial erosion, the younger rhyolitic lavas were poured out from essentially the same vents as the old lavas and covered their deeply eroded surfaces. . . . They were poured out at greater elevations than the old lavas; they were also more liquid, and, being erupted in successive flows conformably one upon another, they spread widely and reflooded the entire district more extensively than the old lavas, though not so deeply, and gave to the Jarbidge Mountains roughly the form of a huge east-west dome."

In the Rowland quadrangle, the Copper Mountains, Pine Mountain, and Tennessee Mountain probably continued to form a barrier that prevented the spread of the younger or Idavada Volcanics (Malde and Powers, 1962) westward and southward across the southern part of the quadrangle. The Idavada Volcanics are restricted to the northern part, where their upper surface forms a ragged sheet which dips gently northward, and gradually levels out near the Idaho-Nevada boundary. Formerly they extended up the Bruneau River Valley as far as Twin Buttes, across Trail Gulch, and over the western end, at least, of Bearpaw Mountain, as indicated by small outcrops or scattered fragments.

Since the extrusion of the Idavada Volcanics, their former surface has been lowered somewhat, they have been stripped from the higher parts of the prevolcanic topography, and the Bruneau River and its tributaries have entrenched themselves in canyons up to 200 feet deep. The Idavada Volcanics appear to have been deformed only in gentle synclines which can be attributed to the compaction of underlying tuff, sand, and gravel beds, and in monoclines on the north side of Bearpaw Mountain. Thus, the topography of the Idavada Volcanics—broad flat tables cut by deep canyons —is in decided contrast to the rough topography of the Jarbidge Rhyolite.

South of Hot Springs Butte and Rattlesnake Canyon the surface on which the Idavada Volcanics were deposited was probably similar to that of the present, a mature topography with the Bruneau River, upper Meadow Creek, and the creek in Rattlesnake Canyon flowing in broad valleys. The topography of the northern part of the quadrangle, as revealed by small inliers in the Idavada Volcanics, probably consisted of northeast trending ridges and valleys, the unit Pzc and the black quartzite of unit Pza_1 forming the ridges, with the valley between possibly an extension of the pre-Jarbidge Rhyolite basin west of the Trail Gulch fault (fig. 3). During the extrusion of the volcanics, the Bruneau may have been dammed by flows, as lacustrine deposits overlie the gravel deposits south of Hot Springs. At the close of the extrusion period, the Bruneau, fixed in its upper course between the high areas of the Copper Mountains and the south rim of Rattlesnake Canyon to the east, and Pine Mountain and Hot Springs Butte to the west probably followed a random course over the newly constructed plain to the north, governed only by the regional dip and the irregular topography of the latest extrusives. From that time to the present, it has been cutting downward, entrenching itself into its present valley.

The Idavada Volcanics consist of lower pyroclastic beds and upper rhyolite flows with minor intercalated ash beds. The pyroclastics, up to 300 feet thick, consist of ash, tuff, tuffaceous sediments, and welded and vitric tuffs. A section exposed on the north side of Wickiup Creek north of Twin Buttes, consists of a lower layer, possibly a lake deposit, about 4 feet thick, of white to light-gray, crumbly, clayey sediment with scattered granitic and quartzite pebbles, followed by a laminated to thin-bedded, light-gray ash, about 10 feet thick, which grades upward into grayish-red to grayish-red-purple tuffs. Overlying the tuffs are some compact pale reddish-brown to medium-gray vitric and welded tuffs. Elsewhere, along Meadow Creek and at the head of Taylor Creek, similar pyroclastics range in color from light gray to grayish orange.

The flows range in thickness from 10 to 50 feet and in many places overlap the pyroclastics and rest directly on the older rocks. Layers of light-gray to black obsidian, as much as 3 feet thick, are present at the base of some flows. Many of the flows are coarsely vesicular, and in places the vesicles are filled or lined with chalcedony and jasper. Crude columnar jointing and sheeting are common, and the flows weather to platy or flaggy, castellate outcrops.

The flows consist of pale-red or minutely mottled red and gray aphanitic rock with tiny vesicles drawn out parallel to the direction of flow, imparting a streaked or grained appearance to the weathered surface. Small phenocrysts of quartz and feldspar are present but not abundant. The matrix is glassy to microcrystalline. The index of refraction of the glassy part is 1.505 ± 0.003, indicating that silica forms about 65–70 percent of the matrix.

Age and Correlation

The Jarbidge Rhyolite is dated as late Miocene. This is based on a dating by Axelrod, quoted by Coats (1964), from ". . . sanidine from the Jarbidge Rhyolite, collected on Meadow Creek, in the Rowland quadrangle. The sanidine gave an age of 16.8 (±0.5) m.y. . . ."

The age of the Bieroth Andesite is not known, but as it grades conformably upward into the Jarbidge Rhyolite it is also considered to be of Miocene Age.

The Idavada Volcanics are dated as early Pliocene. (Malde and Powers, 1962, p. 1201).

The Young American Gravels lie between the late Miocene Jarbidge Rhyolite and the early Pliocene Idavada Volcanics, so although no direct fossil dating is known, the age of the gravels is fairly well defined.

PLEISTOCENE

Glaciation

The Pleistocene glaciation of northeastern Nevada has not been studied in detail. Blackwelder (1934) made a brief reconnaissance through the region. He noted that two glacial stages were present in the Independence Mountains and that probably the Copper and Jarbidge Mountains were glaciated, but he did not give any altitudes for the cirque levels.

The nearest detailed work was that of Sharp (1938) in the Ruby-East Humboldt Mountains. He dated the glaciation there as Wisconsinian and separated it into two substages. The cirque floors are at an altitude of about 9,300 feet on the west side of the Ruby-East Humboldt Mountains, and about 8,900 feet on the east side. Evidence for glaciation is not present wherever the crestline is presently below 9,800 feet, and Sharp believes that 9,800 feet was the altitude of the snowline during the Wisconsin.

The Jarbidge Mountains have peaks as high as 10,839 feet, and much of the crestline is over 10,000 feet. R. R. Coats (1955, written communication) found evidence for two stages of glaciation in the Jarbidge quadrangle. The older cirque levels vary from 8,500 to 9,200 feet and some may be as low as 8,000 feet. More recent cirques form small shelves at about 10,000 feet within the larger and older cirques. Apparently the Jarbidge Mountains extended high above the earlier Pleistocene snowline and were able to support large, active glaciers.

Maximum altitudes of the Copper Mountains, the highest in the Rowland quadrangle, are not much above 9,800 feet, the critical elevation in the Ruby-East Humboldt Mountains; and most of the crestline is below 9,600 feet. Except for Pine Mountain, 8,647 feet, the rest of the quadrangle lies below 8,500 feet. Thus, even allowing for a drop of the Wisconsin snowline northward from the Ruby Mountains, not much of the Rowland quadrangle would have supported glaciers.

Cirques and glacial moraines are present only on the north and east side of the Copper Mountains. Altitudes of the cirque floors are fairly consistent at 9,000 feet on the east side, but are somewhat lower and more variable on the north side. The moraines extend from one-half to three-quarters of a mile beyond the cirques. Dating of the glaciation as Wisconsinian rests only on the good preservation of the morainal topography. No evidence for two glacial stages was observed. Since glaciation, protalus ramparts have developed in the cirques on the east slopes.

On Pine Mountain, which is well below the level of the cirque floors, there are several large boulder fields or felsenmeers, consisting of quartzite fragments and blocks up to 10 feet across. Probably these were formed at the same time as the cirques and moraines on the Copper Mountains.

Drainage, Alluvium, and Mass Wasting

The drainage from the Rowland quadrangle is northward along three main rivers, the Jarbidge to the east, the Bruneau, and the Owyhee to the west. These three ultimately flow into the Snake River which serves as base level for the quadrangle. Hence, the later Cenozoic history of the quadrangle is directly related to that of the Snake River which is summarized by Wheeler and Cook (1954, p. 535–536) as follows:

> "Following the accumulation of these silicic volcanics, the Snake River syncline was further downwarped, and a corresponding east-west structural high was developed immediately to the south, its axis lying in northernmost Utah and Nevada. . . . This combined downwarping of bordering areas, appears to have defeated the Snake, thus impounding its waters to create Idaho Lake in western Idaho and easternmost Oregon. . . .
>
> "Finally, and presumably at the highest stage of Idaho Lake and presumably during the early part of the Pleistocene epoch, the lake appears to have found a new outlet, . . . From that time to the present the rapid cutting of Hell's Canyon, entrenchment of the Snake's larger tributaries, gradual retreat and lowering of the Idaho Lake outlet, culminating in the eventual drainage of the lake and commencement of downcutting with the former lake basin, are not only the predictable results, but the actual ones as well."

Controlled by the downcutting of the Snake River during the Pleistocene, the rejuvenated Bruneau River produced canyons as deep as 1,000 feet below the level of the newly constructed volcanic plain, and youthful valleys 100–500 feet deep in the prevolcanic broad valley of its upper reaches. Contemporaneous with the activity of the main river, the tributaries also carved deeper, forming Rattlesnake Canyon in a prevolcanic, broad valley, and Meadow Creek Canyon. South of the divide between Tennessee and Pine Mountain, Big Bend, Mill, and Martin Creeks have cut into the old erosion surface, carrying away the finer debris that once covered it and leaving patches of large quartzite boulders.

The small amount of alluvium in the quadrangle is mostly derived from the valley sides adjacent to the streams. It consists of finer, reworked material mixed with much coarser slump, landslide, and slope-wash material. At present the tributaries are bringing debris into Bruneau Valley faster than it can be carried away, and in several places the course of the river within the valley has been shifted by the deposition of alluvial fans across its path. In Rattlesnake Canyon, rapid erosion and the formation of alluvial fans on the north side have forced the main creek to flow along the south side of the canyon. Much of the water in the upper part of the canyon flows underground through the porous fan gravels and reappears as a large spring near the Alvarea Ranch.

Another consequence of the rapid downcutting is slumping and landsliding along the steepened valley slopes. North of the intersection of Meadow Creek and the Bruneau River, and northeast of the intersection of Coffeepot and Meadow Creeks, large blocks of the younger rhyolites that have slipped and rotated inward now lie at the base of a scarp toward which they are inclined 30°–45°. Typical hummocky landslide topography is present on the north side of Bearpaw Mountain, the north end of Pine Mountain, and on the slopes of the Copper Mountains.

STRUCTURAL GEOLOGY

The Rowland quadrangle lies at the intersection of two regional structural trends. An east-west group of Late Cretaceous plutons and related folds cuts across the older, north-northwest-trending Antler orogenic belt. As might be expected, the local structures are a composite of both trends. The interpretation of the structural history is both complicated and helped by igneous rocks. They cover three quarters of the area, obscuring or destroying many of the structural features. On the other hand, they are well dated, and their crosscutting or unconformable relationships aid in deciphering the tectonic history.

Four well-dated reference horizons define three periods of deformation, each with its own distinctive tectonic style. The first period of deformation, a pre-Sunflower orogeny, is correlated with the Antler orogeny of central Nevada and has major overthrusting as its characteristic structural feature. The second, a late Mesozoic to early Cenozoic orogeny, is characterized by high-angle folding, normal faulting, and intrusive activity. The third, of mid-Cenozoic Age, was less intense and is dominated by extrusive activity with some gentle folding and normal faulting.

ANTLER OROGENY

In its type area, the Antler orogeny occurred prior to the deposition of the Antler Peak Formation, which correlates with the Sunflower and Diamond A Formations. Obviously, structures that are overlapped by the Sunflower or Diamond A could be dated as part of the Antler orogeny. Unfortunately, in the Rowland quadrangle, many structures do not involve the Sunflower or Diamond A, and their time of origin is doubtful. The Antler orogeny, however, elsewhere along its trend, offers another clue that suggests a dating for these structures; the orogeny has a distinctive tectonic style; western and transitional facies are thrust over eastern facies. By analogy, structures in the Rowland quadrangle that separate eastern and western facies are conditionally assigned to the Antler orogeny.

One such feature is the fault exposed along the east side of Trail Gulch, near its junction with the Bruneau River. Here, Paleozoic argillite (Pza_1) rests on limestone (Pzd). The two formations are generally concordant, but show some local discordance, and the limestone has recrystallized to a more massive form. The fault surface dips 45°–60° northwestward, more or less parallel to the dip and strike of the underlying beds. No indication of the direction of movement was observed, but on the assumption that the argillite is Ordovician of the western facies and the limestone is Silurian or Devonian of the eastern facies, the fault is interpreted as a bedding plane thrust fault. To the west the thrust is cut off by the later Trail Gulch fault. A small outcrop of quartzite, surrounded by faults but tentatively included with the argillite (Pza_1), lies south of the Trail Gulch outcrops and the Bruneau River (SE¼ sec. 9, T. 46 N., R. 56 E.), and may be part of the thrust sheet.

Eastern, western, and transitional facies rocks form vertically dipping outcrops along the Bruneau River, northwest of the Mink Ranch. Northwestward along the strike, western and eastern facies rocks form similar outcrops in the Taylor Creek drainage. The two areas are separated by 2 to 3 miles of volcanic cover. In both areas, the different facies are separated by faults which also dip steeply, subparallel to bedding. Breccia is not present along the faults, but adjacent limestones are thoroughly recrystallized and streaked. Figure 2 and cross-sections A–A′ and B–B′ of plate 1 show an interpretation of the relationship within and between the two areas. The faults are interpreted as imbricates from a main sole thrust, which stacked up a series of thrust plates of various facies. The whole sequence, including the postorogenic Diamond A Formation, was originally fairly flat-lying, but later, during the last Mesozoic orogeny, was tilted to its present verticle attitude.

The main sole thrust, mentioned above, would have outcropped in pre-Diamond A time in the area now underlain by granite intrusions. The thrust sheet lay in the northern part of the quadrangle, where the Diamond A Formation rests only on Pza_1 along the length of its outcrop. The subthrust formation was exposed in the southern part of the quadrangle, where the Sunflower Formation rests only on the Tennessee Mountain Formation. The lack of angular unconformity between the faulted formations and the postorogenic formations, and the few exposures of faults in the northern part of the

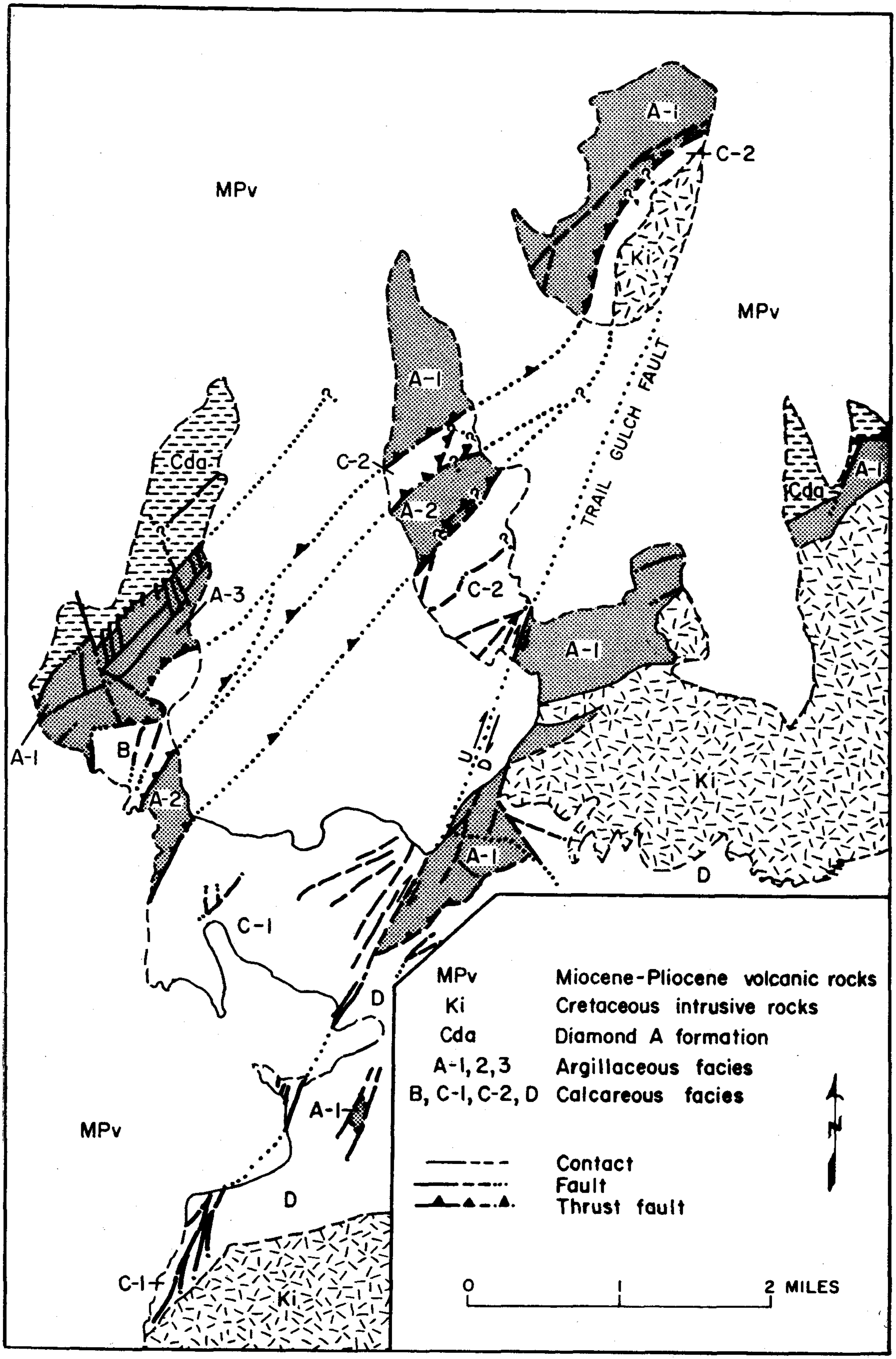


Figure 2. An interpretation of the structural geology of the northern part of the Rowland quadrangle. Compare with plate 1.

quadrangle, suggest that the main fault was flat-lying, essentially a bedding plane feature that became imbricated where it rose to the ground surface at a steeper angle.

The conglomerates at the base of the postorogenic formations represent another feature characteristic of the Antler structures. The conglomerates contain a high percentage of quartzite and are coarser grained and more massive to the south, finer grained and lenticular to the north and northwest. This distribution points to a source in the southern or southeastern part of the quadrangle, where the Prospect Mountain(?) Quartzite now forms high-standing outcrops. If the conglomerate was derived from outcrops of the Prospect Mountain(?) Quartzite in this area, then it is possible that some of the normal faults, now bounding the quartzite mass (see pl. 1), originated during a late stage of the Antler orogeny.

LATE MESOZOIC TO EARLY CENOZOIC OROGENY

In the interval between the deposition of the Sunflower Formation and the extrusion of the Late Miocene Jarbidge Rhyolite, the Rowland quadrangle was subjected to deformation resulting in thrust faults, large-scale folding and normal faulting, the emplacement of the Deep Creek and Coffeepot stocks, and continued faulting with the development of the Trail Gulch fault. The stocks are dated as Late Cretaceous, and as their emplacement was one of the last phases of deformation, the deformation is believed to be mainly Cretaceous or Laramide. This may be an oversimplification and deformation may have occurred throughout the Late Paleozoic and Mesozoic.

Thrust Faulting

The block of Sunflower Formation in secs. 34 and 35, T. 45 N., R. 56 E., between Rosebud and Pine Mountains and Cornwall Basin, is overturned and dips westward on Prospect Mountain(?) Quartzite. It seems to be a small remnant of a thrust sheet, preserved by being dropped into the overthrust rocks along normal faults. Other blocks of limestone on the eastern flank of Pine Mountain, tentatively called Sunflower Formation, have been considerably faulted and contorted and lie on gently west-dipping beds of the Prospect Mountain(?) Quartzite. Their relationships are well exposed on the west side of the Bruneau River northwest of B. M. 5703 and northwest of Humphries Cabin. These blocks also are interpreted as remnants of a thrust sheet which was dropped into the overthrust Prospect Mountain(?) Quartzite (pl. 1, cross section H–H′). The same explanation may apply to the limestone on the north end of Pine Mountain.

An argillaceous formation (Pzph), crops out on the south end of Rosebud Mountain. It is in contact with the underlying quartzite along faults that strike about east-west and dip southward 45° or less. No direction of displacement along the faults was observed and they may be normal faults; their low angle, however, suggests that they are thrust faults, which are perhaps related to those on the southeast flank of Pine Mountain.

The opposite situation is found on the east flank of the Copper Mountains, where Coats (1964) mapped the Copper Mountains thrust, which brings the Prospect Mountain(?) Quartzite over undated Paleozoic limestone (Pzl). His cross sections indicate that the thrust extends eastward under the Copper Mountains. On the northeast flank of the mountains, the Paleozoic limestones of the lower plate are mapped in the Rowland quadrangle as Sunflower Formation. This dates the Copper Mountains thrust as part of the Late Mesozoic orogeny. The relationship of the Copper Mountains thrust to the thrust on Pine and Rosebud Mountains is uncertain. Possibly, the blocks of Sunflower Formation are not truly thrust, but are gravity-slide blocks, and have no connection with the Copper Mountains thrust. Certainly it is hoped that a synthesis of this work with that of Coats (1964) and Coash (1967) can provide a more complete structural explanation of this complex area.

Large-scale Folding

A more obvious result of the Mesozoic orogeny is the number of steeply dipping to overturned Paleozoic formations common throughout the quadrangle. Some of the dips may reflect Cenozoic deformation because the Cenozoic Jarbidge Rhyolite has dips of 15°–20° and, locally, dips as high as 45°. However, where intrusive rocks cut sedimentary rocks that are dipping 45°–90°, as in Rattlesnake Canyon and on Tennessee Mountain, most of the dip must indicate movement before or during the igneous action.

South of the Coffeepot stock, the structural trends are like those in the Mount Velma quadrangle. The Prospect Mountain(?) Quartzite forms a block in which the formation strikes northeast to north and dips gently to steeply southeast and northwest, although some minor broad, gentle folds with east-west axes are present. The Sunflower Formation strikes east-west in the southwestern part of the quadrangle, but in the south-central part and in the neighboring parts of the Mount Velma quadrangle it strikes north-south. The Tennessee Mountain Formation, which has a trend like that of the formations to the north of the Coffeepot stock, or about N. 60° E., assumes a north-south strike around the western end of the Coffeepot stock.

North of the Coffeepot stock, the Trail Gulch fault separates the pre-Cenozoic rocks into two structural blocks. West of the Trail Gulch fault the formations strike northeast and dip vertically to steeply northwest, whereas east of the fault and north of the Deep Creek stock the strike is about N. 70° E. and the dip north. Between the Deep Creek and the Coffeepot stocks, Paleozoic limestone (Pzd) strikes about N. 60° E. and dips north on the north side of Rattlesnake Canyon; along the south rim of the canyon the strike is about N. 60°–70° W.

Regionally the large-scale folding has an east-west trend. Decker (1962, p. 53) reports preintrusive steep folds which form two anticlinoria with east-west trends in the southern Centennial Range. Nolan (1937) and Stephens (private report, 1946) indicated that the Paleozoic formations in the Mountain City quadrangle form a homoclinal structure trending east-west and dipping north. In the Rowland quadrangle, large deviations from this regional trend, such as that on the west side of the Trail Gulch fault and in parts of the Sunflower Formation, may have resulted from movement along the Trail Gulch fault and along faults bordering the block of Prospect Mountain(?) Quartzite. Other anomalous trends, especially the north-south trend in the Tennessee Mountain Formation, may have been caused by the intrusion of the stocks.

Structures Associated With the Granitic Stocks

The granitic stocks cut across major structures but are themselves only slightly deformed, an indication that their emplacement was one of the last phases of the Mesozoic orogeny. Although the emplacement probably involved a combination of processes, the possible doming of formations over the stocks, faulting around the sides of the stocks, and folding and development of cleavage in some of the formations near the granitic contact suggest that forcible intrusion of magma into the country rock was largely responsible. These three kinds of structural evidence are outlined below.

(1) North of the stocks the Diamond A Formation dips steeply north and northwest, whereas south of the stocks the Sunflower Formation dips steeply south or is overturned steeply to the north. Thus, if the Sunflower Formation is correlative with the Diamond A Formation, the area was possibly domed by the rising magma.

(2) Some faults which cut only Paleozoic rocks also seem related to the emplacement of adjoining stocks. On the north side of Bearpaw Mountain a series of normal faults, one set striking about east-west, another set about N. 70° W., may have resulted from upward movement of the granitic magma, as the faults are cut by the stock, dip steeply north, and seem to be downthrown on the side away from the intrusion. Where the conglomerate of the Diamond A Formation is located near these faults, it has a gneissic texture and the individual pebbles are flattened and elongated, possibly as a result of high temperature and upward movement of the magma. In many places, white vein quartz has been deposited along the faults and brecciated by later movement. The sequence of events may have been: (a) faulting, when the magma was at a lower level pushing its way through the overlying rock; (b) filling of the fractures with quartz-rich solutions from the magma; and (c) continued faulting as the magma rose to its present structural level.

(3) Near the granitic contacts, the thin-bedded limestones are considerably deformed. Limestone (Pzd) lies between the two stocks and dips northward. Much of its deformation apparently resulted from upward movement of the two granitic masses which squeezed the formation between them and exerted compressive stress nearly parallel to the bedding planes of the formation. The results are drag folding and brecciation along the bedding planes, contortion of the beds, and development of a cleavage which cuts the bedding but is approximately parallel to the surface of the intrusion.

Similar features, but on a larger scale, are developed on the south side of Tennessee Mountain, in the Tennessee Mountain Formation. They may have directly resulted from intrusion of the magma, but possibly they are related to movement along larger folds and faults formed during a preintrusion orogeny. At any rate the change in the strike of the bedding and cleavage from N. 60 ° E. on the south side of the Coffeepot stock to north-south on the west side of the stock may represent the "shouldering-aside" of the country rocks by the rising intrusion.

Faults With Apparent Vertical Movement

Movement along steeply dipping faults began before the stocks were emplaced, and along some it continued after the intrusive activity. In general these faults strike northeast or northwest, and from the little evidence available—slickensides, offsetting of formations, and mullion structure—the movement along the faults was vertical or steeply oblique.

The block of Prospect Mountain(?) Quartzite may have been a positive block since late in the Paleozoic Era, and movement along faults within and bordering the block probably occurred intermittently throughout the late Mesozoic and the Cenozoic. The observed faults are of several ages. Some, probably the oldest, are indicated by long zones of white vein quartz and faint remnants of breccia but show no topographic expression; others, seemingly younger, are bordered by coarsely brecciated rock, have little or no vein quartz, and form small scarps. Both older and younger faults strike northeast to northwest.

The best evidence for a preintrusive age for this faulting is the shape of the Coffeepot stock. The southern contact between the stock and the country rock swings northward around the block of Prospect Mountain(?) Quartzite so that the intrusion is club shaped in plan, with the head of the club surrounded by limestone and the handle bordered on the south by quartzite. This deflection could be explained if the quartzite and the Tennessee Mountain Formation had about the same level before the emplacement of the granitic rocks. An intruding magma would rise along the lines of least resistance, supplied in this case, by the thin-bedded limestones rather than the massive, chemically inert quartzite. It would thus be spatially restricted by the quartzite.

The fault shown bordering the quartzite block west of Pine Mountain is suggested by the presence of known later faults west of Rosebud Mountain, and by a northeastern linearity observable on aerial photographs. The fault has no topographic expression, and its assumed location is covered by scree and vegetation.

The Jarbidge Rhyolite on the north end of Pine Mountain is not disturbed along the trend of the fault, and neither, apparently, are the granitic rocks; it is a preintrusive fault.

Quartzite beds along the south fork of Cottonwood Creek on the west side of Copper Mountain are vertical, but a few feet east of these exposures they dip gently eastward. This abrupt change in structure may represent drag along a major northeast fault which strikes across the Copper Mountains and possibly is exposed in a cirque on the east side of the crest (pl. 1, cross section G–G′). Other faults are present in the Copper Mountains, but cannot be traced very far. Exposures are somewhat better on Pine and Rosebud Mountains and there the faults are mapped more accurately.

The Sunflower Formation also is cut by vertical faults which offset the basal conglomerate. They extend into the Tennessee Mountain Formation but cannot be traced northward to the Coffeepot stock. These faults could be either pre- or postintrusion. The pattern of dips and strikes in the Tennessee Mountain Formation suggests large faults, which are possibly extensions of those that cut the Sunflower Formation or the Prospect Mountain(?) Quartzite. Any extension, however, of a fault locally exposed in the Tennessee Mountain beds is obscured by the tight folding and monotonous lithology.

In Rattlesnake Canyon the faults seem to be preintrusive, although a lack of key beds, together with contact metamorphism, obscures much of the evidence of faulting. The contact between the limestone and the argillaceous members (Pzd) is offset by faults with strikes ranging from northeast to northwest. One fault is definitely located just west of knob 8341 on the southeast rim of the canyon. Other faults not exposed but strongly suggested may be present on the east side of the east rim of the canyon, where argillaceous rocks striking about N. 70° W. are replaced westward along the strike by limestones. In the small canyon leading into Rattlesnake Canyon by the Alvarea Ranch, the dip and strike of the limestones vary from one side of the canyon to the other, and an argillaceous unit present on the west side is not present on the east. The contact of the Deep Creek stock is not offset along the strike of the fault. Other faults may coincide with the numerous tributary valleys on the sides of the main canyon, but exposures are poor, vegetation is concentrated in the valleys, and no actual outcrops of faults were observed. In general many faults are suggested but few have been proven, and none seem to extend into the granitic rocks.

Trail Gulch Fault

The Trail Gulch fault is named for exposures in the lower end of Trail Gulch in secs. 3 and 4, T. 46 N., R. 56 E. It is one of the major structural features of the quadrangle and can be traced southwestward from Taylor Creek across the Bruneau River to Coffeepot Creek. Extensions of this fault to the north and south are concealed under the Cenozoic volcanic rocks. The fault divides the northern part of the quadrangle into two structural blocks; an eastern block with N. 60° E. trends, and a western block with northeast trends. It is a fault zone and consists of several subparallel faults. It is marked by outcrops of massive, light- to moderate-brown jasperoid in Trail Gulch and northwest of Hot Springs Butte, and by outcrops of pale-red to moderate reddish-brown fault gouge along Coffeepot Creek.

The age of the Trail Gulch fault and its relationship to other structures are somewhat uncertain. Relatively undeformed Bieroth Andesite and Jarbidge Rhyolite cover the inferred southwest extension of the fault, indicating that it is no younger than Miocene. Its relationship to the Late Cretaceous Coffeepot and Deep Creek stocks is uncertain. It appears to cut the Coffeepot stock west of Coffeepot Creek, but outcrops are scarce, and the area is covered with volcanic rocks and alluvium that obscure the actual relation of the fault to the stock. Granite is exposed in the Long Canyon area northward along an extension of the fault, but whether it extends eastward under the volcanics across the fault or is cut off by the fault is unknown. The general trend of the fault coincides with the northwestern ends of the Deep Creek and Coffeepot stocks. This perhaps indicates that the fault was controlled by the stocks and originated after they were emplaced.

As discussed below, the Trail Gulch fault may be a right lateral strike slip fault. It strikes N. 30° E., which would suggest compressive stresses along a N. 60° E. line. This direction does not agree with either the east-west stresses responsible for the Antler orogenic belt, or the north-south ones creating the Late Cretaceous east-west line of folds. If the Trail Gulch fault is postintrusive, its distinct orientation may be a local component caused by the influence of the massive plutons.

No direct evidence, such as slickensides, of the direction or amount of displacement was observed, although the regional trends of the Paleozoic phyllite (Pza_1), the Diamond A Formation, and the Sunflower Formation offer some basis for an estimate of both. (See figure 2).

A distinctive light-gray and brown, sheared, conglomeratic quartzite is present in unit Pza_1 on both sides of the Trail Gulch fault (p. 14, 15). Projection of the two outcrops along their strike into the Trail Gulch fault suggests a right lateral separation of 5 to 7 miles. If the Diamond A Formation outcrops are projected along their strike, under the volcanic cover, a right lateral separation of about 5 miles is again indicated. Another separation index could be the thrust faults on both sides of the Trail Gulch Fault. If the vertical faults separating eastern and western facies along the Bruneau River, Trail Gulch, and the head of Long Canyon are tilted imbricates off of the main thrust now lying east of the Trail Gulch fault, their strike projection also indicates a right lateral separation of 5 to 7 miles. If the Trail Gulch fault is postintrusive, then the granite at the head of Long Canyon west of the fault could be part of the Deep Creek or even Coffeepot stocks. Right lateral movement of about 4 miles is suggested by this interpretation. The Sunflower Formation which strikes east-west in the Rowland quadrangle, strikes northwest in the southeastern corner of the Mountain City quadrangle. It is possible that the Trail Gulch fault extends through Sunflower Flat along the eastern edge of a volcanic basin (figure 3). By this interpretation, the change in strike of the Sunflower is attributed to drag along the Trail Gulch fault. Restoring the Sunflower to its regional east-west strike gives a minimum apparent right lateral movement of 2 to 3 miles.

Although other alternatives are possible, the interpretation favored here is that the Trail Gulch fault is a right lateral strike slip fault with an apparent displacement of about 5 miles.

Regional Relationships

The belt of east-west folds and elongated stocks lying across northern Nevada and Utah are in striking contrast to the Mesozoic structures elsewhere in the Great Basin and central Idaho. In those regions, north-south folds and apparent west-to-east thrusting imply stresses differing in orientation from those that affected northern Nevada.

Nolan (1943, p. 176–177), in his summary of the Basin and Range province, mentions only four major areas of east-west trends:

> "The most southerly of these east-west belts is thought to lie along the northern border of the Mojave Desert region in southern California. . . . A second belt is suggested by the work of Ferguson and Muller (1949) in west-central Nevada. They found a pronounced offset in the outcrops of sedimentary beds deposited along the eastern border of the early Mesozoic seaway north and south of a zone in which east-west structural trends were dominant. A possible third belt lies along the line of the Western Pacific Railroad in western Utah. This belt roughly coincides with the westerly projection of the Uinta axis and is marked by a zone of east-west strikes. A few observations near Wendover, Utah, close to the Nevada boundary, suggest that major transverse faults may also occur in this belt. The most northerly belt lies along the northern boundary of the province and extends from northwestern Utah in northern Nevada."

In addition, Eardley (1951, p. 225) and the Tectonic Map of the United States (Longwell, 1944) show northeast to east-west structural trends in central Oregon. There, and in west-central Nevada, the east-west structural trends correspond with east-west basins or embayments in which the Paleozoic and Mesozoic sediments were deposited. A similar east-west basin could conceivably have been present in northern Nevada, and could have controlled the subsequent deformation and intrusion, but its existence is far from proved, and the evidence may be buried under the Snake River Plain.

MIDDLE CENOZOIC OROGENY

The Rowland quadrangle lies in a transition zone between two provinces characterized by different structural histories, the Great Basin and the Snake River Plain. In the Great Basin, block faulting and the formation of basins and ranges are believed to have begun as early as the Oligocene epoch and to have continued intermittently to the present. Block faulting near Elko was dated by Sharp (1939) as beginning in the late Miocene and continuing into the Pliocene. The Snake River Plain, on the other hand is essentially a broad downwarp. The work of Malde and Powers (1962, p. 1202) dates the inception of this feature as early Pliocene.

In the Rowland quadrangle, block faulting was subordinate to the extrusion of lavas and pyroclastics, and the subsequent development of the Snake River Plain. Both block faulting and downwarping occurred after the extrusion of the Jarbidge Rhyolite and before the deposition of the Young America Gravel (in the northern part of the quadrangle, before the extrusion of the Idavada Volcanics).

Basin and range structure is most obvious in the block of Prospect Mountain(?) Quartzite, where movement, either along Mesozoic faults or parallel to them, has tilted the Jarbidge Rhyolite at Twin Buttes to the southeast and down-dropped it into the granitic rock of the Coffeepot stock. Two faults are largely responsible for this; one strikes northwestward between Twin Buttes and the granitic rocks to the east, the other cuts the Prospect Mountain(?) Quartzite at the north end of Pine Mountain, crosses the Bruneau River by the Palacio Ranch and strikes northeast toward the Palacio cabins south of Coon Creek. Other faults in this region were probably active at this time, but no direct evidence is available.

Northwest of Tennessee Mountain, where Meadow Creek enters the volcanic terrane, the Jarbidge Rhyolite is tilted 10°–15° eastward on the west side of Meadow Creek, although it is horizontal on the east side of Meadow Creek and westward in The Mahoganies. In this area the rocks consist of flows, tuffs, agglomerates, and volcanic breccia. Possibly a fault is obscured by the agglomerate and volcanic breccia, but the only apparent structure is an east-dipping monocline.

In the northern part of the quadrangle, along the north side of Bearpaw Mountain and along the Bruneau River north of McDonald Creek, the Bieroth Andesite series is tilted about 15°–20° northward and is unconformably overlain by the Idavada Volcanics.

Following the extrusion and deformation of the Jarbide Rhyolite, coarse river and fan gravels were deposited along the Bruneau River and on an old erosion surface south of Tennessee Mountain. Some warping, and possibly faulting, is indicated by removal of the gravels and deposition of the Idavada Volcanics directly on granitic rocks in the Hot Springs area. The estimated

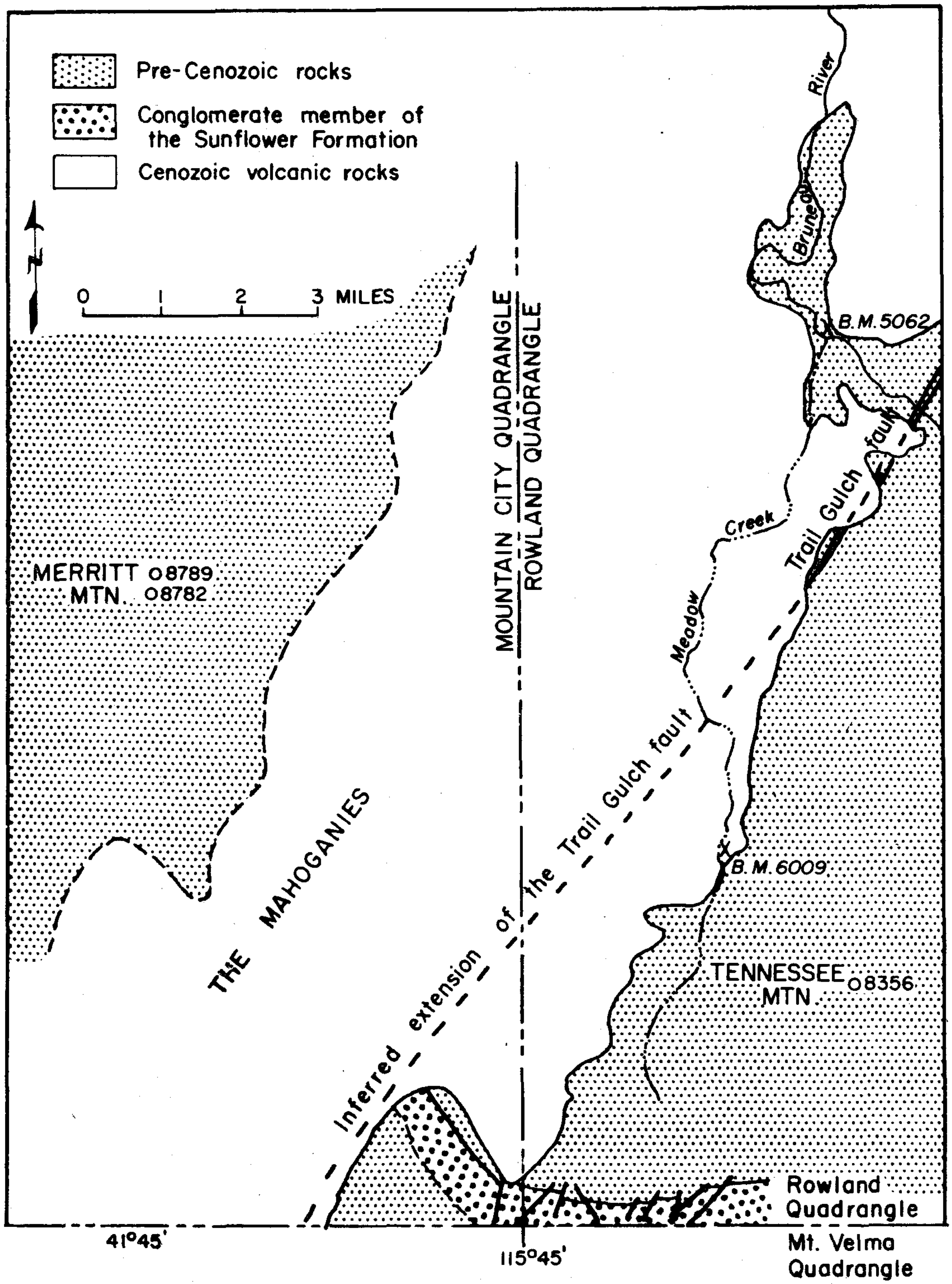


Figure 3. Map showing the volcanic-filled trough along the Trail Gulch fault.

200 to 300 feet of uplift which has occurred, can be accounted for by the development of a low, broad anticline striking approximately northeast and with limbs dipping less than 10°.

The Idavada Volcanics, derived mostly from the Jarbidge area, form a long constructional slope, dipping 1°–5° northward and merging with the Snake River Plain. In the Rowland quadrangle the flows are almost undeformed. They have been folded into low north-dipping monoclines north of Bearpaw Mountain, and into shallow synclines along the Bruneau River between Hot Springs and Twin Buttes. The synclines overlie thick gravel and tuff beds, their limbs dip 5° or less, and the formation of the synclines probably is due to the compaction of the underlying sediments.

ECONOMIC GEOLOGY

The field-mapping schedule did not permit a detailed study of the economic mineral deposits in the Rowland quadrangle, hence most of the material in this report is based only on cursory observations and discussions with local prospectors and miners.[1]

ORE DEPOSITS

The economic mineral deposits are of three types: (1) contact metasomatic deposits in the aureoles of the granitic stocks, especially the Coffeepot stock; (2) fissure and shear zone deposits of hydrothermal origin which are present throughout the quadrangle; and (3) placer deposits.

The first claims in the quadrangle were located along Young America Creek in 1869 (White, 1871) and were on fissure veins in the Coffeepot stock. From that time to about World War II, most of the prospecting and mining in the quadrangle were concentrated on the fissure or shear zone deposits. In the quadrangle, these characteristically consist of a gangue of white quartz that forms a massive outcrop, and carries varying amounts of pyrite, chalcopyrite, sphalerite, galena, silver, and gold. They commonly fill the minor or secondary fractures along major fault zones, and are present in all the pre-Cenozoic rocks.

On Rosebud Mountain, many of the numerous joints and faults in the Prospect Mountain(?) Quartzite have been mineralized. The veins are characterized by a high silver and lead content, with minor gold and, in some places, copper-iron sulphides.

In the Gribble claims on Big Bend Creek, stibnite is present in quartz veins and in an argillaceous fault gouge. Veins of scheelite in a calcite gangue are also present in the claims, but their relationship to the stibnite deposits is unknown.

In 1910, gold was discovered in the Jarbidge Mountains, and within a short time, fairly successful mines were operated. The deposits are tabular gold-bearing quartz fissure veins or lodes in the Jarbidge Rhyolite, the "older rhyolite" of Schrader (1912). No such deposits were found in the older rhyolites in the Rowland quadrangle, although the Rowland area was probably thoroughly searched after the Jarbidge discoveries. Some of the quartz veins in the pre-Cenozoic rocks, however, may have extended upwards into older rhyolites which have since been eroded away.

In 1932 near Mountain City, a zone of supergene-enriched sulphides was discovered 228 feet beneath barren gossans by Frank Hunt (York, 1944, p. 71). The deposit was rich in copper and was the main ore body of the Rio Tinto mine. It is located along the contact between the Black Rock Quartzite and the Rio Tinto Formation, formations tentatively correlated with the argillaceous rocks (Pza) in the Rowland quadrangle. Although similar dark quartzites and argillaceous rocks in the region were carefully prospected, no other discoveries were made. In the Rowland quadrangle, much of the Paleozoic unit Pza_1 is now concealed beneath the Idavada Volcanics, and moreover, gossans are not common.

Although the recent emphasis has been on contact metasomatic deposits, the only producing mine in the quadrangle at the time of the author's visits, the Diamond Jim mine on Rosebud Mountain, produced ore from a hydrothermal fissure vein and shear zone deposit.

In the Rowland quadrangle, strong zones of tactite are present along the contact between the Coffeepot stock and the Tennessee Mountain Formation on the south, and with other Paleozoic limestone (Pzd) to the north. Consequently, much of the mining and prospecting has been along these contacts. On Tennessee Mountain the tungsten occurs as scheelite which is finely disseminated through the tactite. It is associated with pyrite, molybdenite, and minor chalcopyrite.

The area has a long history of placer mining, which started as early as the 1860's. The two most important districts were the Gold Basin district, located around the town of Rowland, and the Alder or Tennessee Gulch district (Smith and Vanderburg, 1932). The total gold produced has been negligible, and these districts did not attain the prominence of the Island Mountain or Gold Creek district to the south, and the Charleston district to the southeast.

PRODUCTION

Although many claims were located, most of them never amounted to much and have been abandoned. Mills were installed at the Bruneau mine in Rowland and in Tennessee Gulch. Gold ore was supposedly produced in both places, but in the Bruneau mine at least, the result was "more promotion than production." Other mills that were installed have since been removed. In spite of the great interest in tungsten deposits, no quantity of tungsten ore has been produced, although some is produced along Coon Creek and in Copper Basin in the Jarbidge quadrangle. In 1955 the only

[1]Editor's note: Additional descriptions of the mineral deposits of the Rowland quadrangle can be found in the report by Granger and others (1957), issued subsequent to field work on which the present descriptions are based.

producing mine in the quadrangle was the Diamond Jim mine, which shipped 115 tons of silver and lead ore averaging $70.00 per ton between October 1954, and February 1955.

MINES AND PROSPECTS

The numbers enclosed in parentheses correspond with numbers on plate 1, and show the location of the mines and prospects listed below.

Diamond Jim Mine (1)

The Diamond Jim mine is located on the west side of Rosebud Mountain at about 7,800 feet elevation. Work on claims held by Joseph Riff of Rowland was started by the Diamond Jim Mining Co. of Salt Lake City during the summer of 1954. An open cut was made along a fault which trends about N. 60° W. and dips 45° S. Ore was intersected after about 75 feet excavation. Production figures for 1954 were: lead, 45,900 lbs.; copper, 89 lbs.; silver, 3,386 ozs.; gold, 5 ozs.

The ore consists of silver and lead sulphides in a quartz gangue which occurs as cavity fillings and minor replacements in small pockets, veins, stringers, and lenses, in a zone about 9 feet thick, in the Paleozoic phyllite (Pzp). The vein more or less parallels a fault between the phyllite, which forms the hanging wall, and the Prospect Mountain(?) Quartzite.

Gribble Claims (2)

These consist of claims, held separately by two brothers, located on Big Bend Creek in NW¼ sec. 29 and NE¼ sec. 30, T. 45 N., R. 56 E. The Star Metal mine is owned by Percy Gribble, the Gribble Quartz mine by Charles Gribble. Both mines are along a shear zone that strikes about N. 60° E. and dips steeply northward. The footwall is phyllite, the hanging wall limestone, and both are members of the Tennessee Mountain Formation. The Star Metal mine has produced some antimony and tungsten, the Gribble Quartz mine some tungsten. In the Star Metal mine, stibnite is present in a quartz gangue along the fault. Some scheelite is present. This ore yields 0.9 to 1.5 percent tungsten, as much as 27 percent antimony, and small quantities of lead and zinc. In the Gribble Quartz mine, tungsten is present in a calcite gangue.

Tennessee Mountain (3)

This area includes a group of claims on the peak and north shoulder of Tennessee Mountain (secs. 16 and 17, T. 45 N., R. 56 E.). The claims are held by Messrs. Knowles and Montrose of Mountain City. Active prospecting and development work were carried out during the summer of 1953; tunnels were excavated and some exploration holes were drilled. The claims were not worked during the summer of 1954, and no production or assay records are available. The ore is scheelite, which is disseminated in tactite, and is associated with pyrite, molybdenite, and minor chalcopyrite.

Tennessee Mountain (4ab)

Several claims on the west and southeast slopes of Tennessee Mountain are held by Jack Mink of Elko. These claims are along tactite zones and fissure deposits. There has been no known production, although active development work was being done during 1953 and 1954.

Ridge Between Buck and Wickiup Creeks (5)

Several claims held by various people from Jarbidge and Rowland are located along the contact between the unit Pzd and the Coffeepot stock. Active development work was going on during the summer and fall, 1954, but no ore was produced.

Bruneau River (6)

These claims are held by Mr. Mendive of Gold Creek, and are located in NE¼ sec. 31, T. 47 N., R. 56 E. A minor amount of gold ore was produced from hydrothermal fissure fillings in unit Pza_1.

Tennessee Gulch (7)

This mining district was once active but is now abandoned. It lies north of Tennessee Mountain and includes several mines and prospects. Some gold was produced from fissure veins in the Coffeepot stock and placer deposits. A mill was constructed and is still present near Parks Cabin.

Bruneau Mine (8)

This mine is located near Rowland, in NW¼ sec. 29, T. 27 N., R. 56 E. Two tunnels were excavated along fissure veins in the Diamond A Formation, and a mill and barracks were constructed. A small amount of gold was produced.

Deep Creek (9)

Several tunnels were driven in the Diamond A Formation on the east side of Deep Creek (SE¼ sec. 24, T. 47 N., R. 56 E.). The claims are now abandoned and the tunnels have caved. Perhaps a minor amount of gold was produced.

Bearpaw Mountain (10)

Several tunnels were driven along quartz fissure veins in the Diamond A Formation and unit Pza_1 (SW¼ sec. 17, T. 47 N., R. 57 E.). The claims have been abandoned after a minor amount of gold was produced.

Copper Mountains (11)

Several tunnels were excavated in the Prospect Mountain(?) Quartzite on the west side of peak 9146. A mill was constructed so presumably some ore was produced, although the kind and amount are unknown.

Rosebud and Pine Mountains (12)

The massive Prospect Mountain(?) Quartzite has been mineralized along joints and fractures. Minor amounts of lead, silver, and gold ore have been mined from several claims on these mountains. Most of the claims have been abandoned. The latest activity is that of the Diamond Jim mine discussed above.

Hot Springs (13)

Several claims are located along the granite-limestone contact in the Hot Springs area (sec. 14, T. 46 N., R. 56 E.) on tactite and fissure deposits. Some minor development work was done during 1954.

Taylor Creek (14)

Minor prospects are located along fissure veins and faults in unit Pza_2 (S½ sec. 22, T. 47 N., R. 56 E.). No ore is known to have been produced.

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