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NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN 77

GEOLOGY AND MINERAL DEPOSITS OF SOUTHERN NYE COUNTY, NEVADA

(Prepared cooperatively by the United States Geological Survey)

HENRY R. CORNWALL

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA • RENO
1972

GEOLOGY AND MINERAL DEPOSITS OF SOUTHERN NYE COUNTY

H.R. CORNWALL

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FOREWORD

"Geology and Mineral Deposits of Southern Nye County, Nevada" is one of a series of county studies being conducted under a cooperative program of the U.S. Geological Survey and the Nevada Bureau of Mines and Geology to provide information on the geology and mineral resources of Nevada.

Nye County is the largest county in Nevada and the third largest in the United States. It contains some 17,376 square miles. Because of its size, the county was divided into two studies under the cooperative program to deal separately with the northern and southern sections. The present report concerns only that area south of the 38th parallel.

Nye County has played a major role in the history of the State since before Territorial days. It has been of interest to prospectors and geologists since the early 1860's. Within the southern section of the county described in this bulletin are a number of well-known mining districts, including the historically famous Bullfrog-Rhyolite gold and silver area; the Bare Mountain district, which has produced much fluorspar; and the Ash Meadows district with its important deposits of the industrial mineral, bentonite. The geologic map shows the existence of several volcanic centers, some of which are calderas and may be of future interest as possible sites of deep-seated ore deposits. Other basic geologic information will be valuable in the development of mineral and water resources of the area.

The report is the work of Henry R. Cornwall of the U.S. Geological Survey.

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

April, 1972
Mackay School of Mines
University of Nevada

GEOLOGY AND MINERAL DEPOSITS OF SOUTHERN NYE COUNTY, NEVADA

By HENRY R. CORNWALL

ABSTRACT

Southern Nye County, along the southwestern boundary of Nevada, is underlain by a wide variety of rocks that range in age from Precambrian to Quaternary. Older Precambrian rocks, cropping out in small areas west of Beatty and east of Mount Helen, consist of gneissic granite and quartz monzonite and quartz-biotite schist. Younger Precambrian rocks, widespread in the southern part of the county and locally exposed elsewhere, are composed of quartzite, siltstone, micaceous shale or schist, and lesser amounts of marble, dolomite, and limestone.

Paleozoic rocks have a distribution similar to that of the younger Precambrian rocks and range in age from Early Cambrian to Pennsylvanian. Limestone and dolomite predominate in most of the Paleozoic section, but sandstone, siltstone, shale, and argillite are abundant in the Lower and Middle Cambrian and Mississippian units.

Mesozoic intrusions of granodiorite and quartz monzonite crop out in two areas near the north end of Yucca Flat. Mesozoic or Tertiary megabreccias composed of limestone and dolomite of Cambrian Age occur in several areas in the southern and western parts of the county. The megabreccias are believed to be landslides whose source was in ridges of similar rocks as much as 5 miles away.

Tertiary volcanic and associated tuffaceous clastic rocks cover a large part of the central and northern portions of southern Nye County. A conglomeratic unit commonly lies at the base of this section and unconformably overlies older rocks. Pyroclastic tuffs and welded tuffs (ash flows) ranging in composition from dacitic to quartz-latitic and rhyolitic are most abundant, but lava flows and intrusives of similar composition, and some andesites and basalts, also are common. A composite section of all the units exceeds 20,000 feet. The vast quantities of volcanic material were probably derived from 9 or 10 centers scattered around the area, at least some of which are calderas.

The intermontane basins in the county are covered by Tertiary and Quaternary alluvial fans and playa lake deposits. In some areas the fans are thin and overlie rock-pediment surfaces. Elsewhere the fans and playa lake deposits are 2,000 or more feet thick.

Quaternary basalt flows and cinder cones, some very young, are present in several lowland areas scattered around the county.

Several patterns of structural deformation are recognized in the county. The Precambrian and Paleozoic rocks have been moderately to intensely deformed by folding, thrust and related tear faulting, and strike-slip faulting, mainly in Cretaceous time. The Las Vegas Valley right-lateral shear zone, also of Cretaceous Age, enters the county at the southeastern boundary, probably passes northwestward into an oroflexural bend, and may terminate southwest of Mercury, Nev.

The development of the 9 or 10 calderas or grabens with associated domes, elevated blocks, and normal faults resulted from volcano-tectonic activity in the Miocene and Pliocene. Several of these may be underlain by a northwestward extension of the Las Vegas Valley shear zone.

Basin-range faults ranging in age from Miocene to Holocene are present throughout most of the county; mountain ranges are commonly bounded by such faults.

Twenty-three mining districts are scattered throughout the county. Most of the districts contain gold and silver deposits. The two largest are the Bullfrog and Johnnie districts, which have produced, respectively, gold and silver valued at approximately $2 million and $400,000. Most of the remaining gold-silver districts have had only minor production.

The Bare Mountain district has produced fluorspar valued at more than $2 million and a little mercury, volcanic cinder, ceramic silica, pumicite, and gold-silver. The only other mining district in southern Nye County to exceed $2 million in production is the Ash Meadows district, whose recorded bentonite production is valued at nearly $3 million.

INTRODUCTION

Nye County, as originally composed, was established in 1864 and was named after Governor J. W. Nye (Kral, 1951, p. 1). In 1866 the southeastern part was separated into Lincoln County, and in 1869 and 1875, parts along the east side were added to Lincoln and White Pine Counties. This report is concerned with the southern part of the county as now constituted, that is, with the part that lies south of 38° latitude.

PURPOSE

This bulletin is part of the series of county reports being prepared by the U.S. Geological Survey in cooperation with the Nevada Bureau of Mines and Geology. Purpose of the series is to aid in the exploration and development of each county's mineral and water resources, to facilitate further regional and local geologic studies, and to supply geologic data to be used in a projected compilation of a State geologic map.

LOCATION AND EXTENT OF AREA

Southern Nye County (fig. 1) lies along the southwestern boundary of Nevada and is bounded on the east by Clark and Lincoln Counties, on the north by the 38° parallel and northern Nye County, on the west by Esmeralda County, and on the southwest by Inyo County, Calif.

U.S. Highway 95, connecting Las Vegas with the northwestern part of the State, crosses the county from south to north. State Highway 58 extends southwestward from Beatty and connects with the southern California highway system. Numerous roads, some paved, but mostly graded, connect outlying areas with the major highways. Airports are near Beatty, Tonopah, and in several other areas in the county or near the county boundaries.

A large part of southern Nye County is now included in the Nellis Air Force Range, the Las Vegas Bombing and Gunnery Range, and the Nevada Test Site of the Atomic Energy Commission (see pl. 1). Public access to these areas is not permitted.

RELIEF, DRAINAGE, AND WATER RESOURCES

The topography and drainage of southern Nye County (fig. 1) are characteristic of the Basin and Range province, having closed basins separated by ranges, hills, and mesas, and internal drainage into enclosed basins. Elevations within the basins range from 2,500 feet at the south end of the county to 6,000 feet at the north end. The mountains rise 1,000 to 6,000 feet above the basins. Kawich Peak in the Kawich Range, with an elevation of 9,404 feet, is the highest peak. A number of mountains, including all of those in the northern half of southern Nye County, exceed 7,000 feet in elevation. The Pahute Mesa, a large, nearly flat mesa at the south end of Gold Flat and Kawich Valley, has an elevation of approximately 6,000 feet.

Drainage in southern Nye County appears to be mainly by subsurface flow of ground water. The water apparently flows both through the alluvium and along solution cavities and fractures in Paleozoic carbonate rocks that underlie the basins and intervening highlands. Thomas (1964, p. 308) concludes that Sarcobatus Flat and Amargosa Desert contain the discharge areas of ground water that has moved south and west from Ralston Valley, Mud Lake Valley, Stonewall Flat, Cactus Flat, Gold Flat, Reveille Valley, Kawich Valley, Oasis Valley, Yucca Flat, and Frenchman Flat.

Walker and Eakin (1963, p. 2) estimate that 1.4 million acre-feet of ground water is stored in the upper 100 feet of saturated alluvium in the southern Amargosa Desert, and the annual recharge to, and discharge from, the reservoir is estimated to be 24,000 acre-feet. Malmberg and Eakin (1962, p. 1) estimate the annual recharge to, and discharge from, the Sarcobatus Flat reservoir at 3,500 acre-feet.

CLIMATE AND VEGETATION

Southern Nye County has an arid to semiarid climate characterized by low precipitation and humidity and high summer temperatures (U.S. Weather Bureau, 1960, 1965). Mean annual precipitation (rain plus snow) ranges from less than 4 inches in the desert valleys to nearly 20 inches in the mountains. Beatty had a 44-year average annual rainfall of 4.60 inches, with a high of 0.71 inches in January and a low of 0.07 inches in June. Lathrop Wells, during a 14-year period, had an average annual precipitation of 2.94 inches, with a high of 0.38 inches (in January) and a low of 0.05 inches (in June). Sarcobatus Flat had a 17-year annual average of 3.34 inches, with a high of 0.47 inches (in November), a low of 0.11 inches (in June). Figures for each area are fairly close to the corresponding figures for the 10-year period 1951–1960.

Temperatures in southern Nye County range from a mean minimum in January of 18° F. in the northern part to a mean maximum in July of 104° F. in the southern part, based on the period 1931–1952 (U.S. Weather Bureau, 1960). Extremes of temperature in the county are illustrated by the data for Beatty, where the recorded extremes for a 39-year period (U.S. Weather Bureau, 1965) are 114° F. (in July) and 1° F. (in February).

The vegetation in southern Nye County is typical of the southwestern deserts and ranges and is zoned according to altitude. In the lower valleys, where the water table is close to the surface, the common plants are mesquite, salt grass, greasewood, and rabbit brush. Creosote brush is predominant on the alluvial fans and lower slopes, where the water table is relatively deep; bur-sage, saltbrush, Mormon tea brush, barrel cactus, and yucca also are found in these areas. Joshua trees are found between 3,800 and about 5,000 feet in elevation and extend nearly to the north end of southern Nye County. Grasses are quite abundant above about 5,000 feet, as are piñon pine and juniper.

PREVIOUS WORK AND ACKNOWLEDGMENTS

The chief sources of map data for compilation of map and report are shown on plate 1 by a number keyed to its reference list. Most of Nye County was first mapped geologically in reconnaissance by Ball (1907). The Bullfrog district was mapped and studied by Ransome and others (1910) and by Cornwall and Kleinhampl (1964; 38 on pl. 1). The Goldfield district was mapped and studied in detail by Ransome (1909); the northern Spring Mountains were mapped by Nolan (1929) and by Vincelette (1964; 44 on pl. 1); and the Specter Range quadrangle by Burchfiel (1965; 41 on

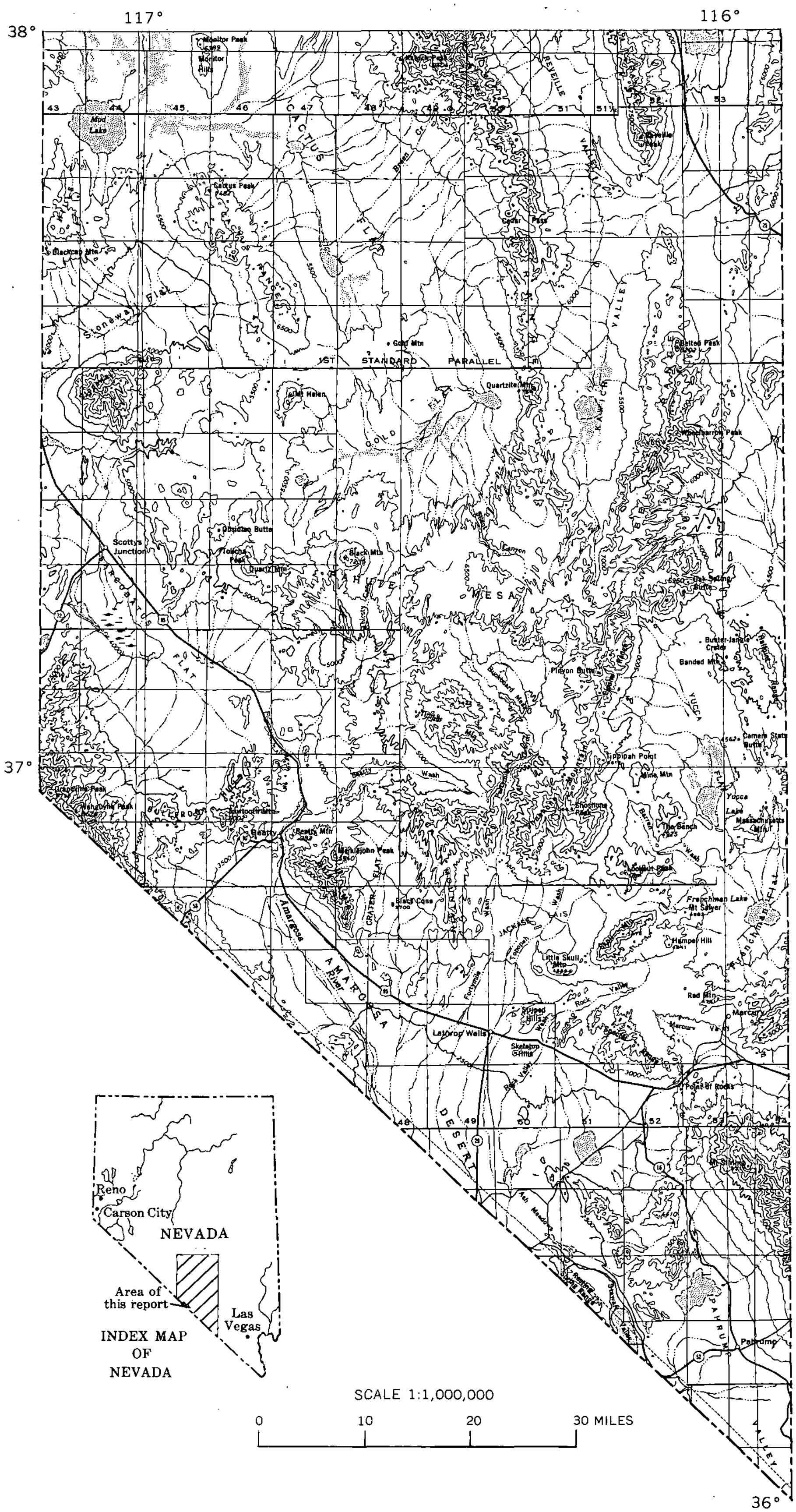

Figure 1. Index map of southern Nye County.

pl. 1). Much of southern Nye County (1–36 on pl. 1) has been mapped by the group of Geological Survey geologists who recently completed a detailed mapping program in the Nevada Test Site and adjoining areas. The writer especially wishes to acknowledge the assistance and thoughtful opinions given to him by F. M. Byers, Jr., R. L. Christiansen, and E. B. Ekren of this group. He appreciates the help and advice of J. P. Albers, R. P. Ashley, E. H. McKee, and Clark Blake, also of the U.S. Geological Survey, and of geologists of the Nevada Bureau of Mines and Geology.

The mineral resources of all the mining districts in southern Nye County have been described by Kral (1951).

It is unlikely that all the conclusions and concepts presented here are acceptable to all the geologists acknowledged above, and the writer accepts complete responsibility for what is written here.

PRECAMBRIAN ROCKS

GNEISS AND SCHIST

Rocks of older Precambrian Age crop out in a small area in the Bullfrog Hills, 6 miles west of Beatty (Cornwall and Kleinhampl, 1964, p. J1). Light-gray quartz-muscovite-feldspar gneiss and dark-gray quartz-muscovite-biotite schist have been intruded by irregular bodies of gneissic pegmatitic granite. The granite is nearly white and very coarse grained and consists mainly of quartz and feldspar with minor muscovite.

Gneissic quartz monzonite and biotite schist of probable early Precambrian Age also crop out in the Trappman Hills in an area 3 miles long by 1 mile wide between Mount Helen and Gold Flat (E. B. Ekren and others, written communication, 1966). The gneissic quartz monzonite is light to brownish gray, fine to medium grained, and locally pegmatitic; it contains 33 to 46 percent quartz, 26 to 30 percent orthoclase, 25 percent plagioclase, and 1 to 15 percent muscovite and biotite. The gneiss contains fragments of schist and in part has intruded the schist lit-par-lit. The schist has a variable composition: in places it contains quartz, orthoclase, plagioclase, biotite, and tremolite or actinolite; elsewhere it is calcareous with abundant clinozoisite. The gneiss and schist rocks are cut by a few thin aplite dikes and many quartz veins.

JOHNNIE FORMATION

The Johnnie Formation was named by Nolan (1929, p. 461–463) for outcrops bordering Johnnie Wash in the northwestern part of the Spring Mountains, Nye County. Exposures of the formation in that area total approximately 35 square miles. Smaller exposures occur 2 to 5 miles northeast of Yucca Flat and 5 miles west of Big Dune, Amargosa Desert, in eastern and southwestern Nye County, respectively.

The formation is composed of fine-grained quartzite, sandstone, siltstone, and shale with several thin interbeds of dolomite. Nolan (1929, p. 462–463) describes the formation as follows:

> "The lower part of the formation is composed chiefly of fine-grained quartzites, characteristically greenish or grayish green on freshly broken surfaces, in beds generally six inches to a foot in thickness. Locally, cross-bedding is found in these beds. Layers of greenish shale are abundant, but are, as a rule, comparatively thin. A few shale zones, however, are as much as 250 feet in thickness, but these contain a large amount of sand. The upper 1,000 feet is distinguished by a much larger proportion of shales and by the presence of two or three beds of dolomite, each about ten feet thick. Many of the shales are green in color, as are those lower in the section, but shades of brown and gray are also found. The gray shales in places show a fine banding. One thin bed of cream-colored dolomite, about 750 feet beneath the highest exposed beds, is notably persistent and its striking outcrop greatly assists in the mapping of the minor faults."

The upper part of the Johnnie Formation, consisting mostly of shale, siltstone, and silty limestone, has been named the Rainstorm Member by Barnes and others (1965) for exposures in the Halfpint Range, northeast of Yucca Flat, where it is 1,025 feet thick. This member is present at the top of the Johnnie Formation over an extensive area in the southern Great Basin.

The cream-colored dolomite described by Nolan is distinctively oolitic; the siltstones and shales are phyllitic. Nolan reported a thickness of 4,500 feet in the type section; this is a minimum figure, as the basal part is not exposed. Nolan (1929, p. 466) reported that a flat thrust fault forms the contact between the Johnnie Formation and the overlying Stirling Quartzite in the area of the northern Spring Mountains that he mapped. Burchfiel (1964, p. 42) found that the Stirling Quartzite conformably overlies the Johnnie Formation in most exposures in the Specter Range quadrangle, adjoining Nolan's area on the northwest. According to Longwell and others (1965, p. 13), a complete section of the Johnnie Formation in the Desert Range, 35 miles northeast of the northern Spring Mountains, is 4,200 feet thick. Hazzard (1937, p. 303–306) reports a thickness of 2,550 feet in the Nopah Range, 35 miles southwest of the type area, where the Noonday Dolomite is conformable below the Johnnie Formation and the Stirling Quartzite is conformable above it.

No fossils have been found in the Johnnie Formation. It has therefore been assigned to the late Precambrian.

WYMAN FORMATION

The Wyman Formation crops out in three small exposures, surrounded by Tertiary volcanic rocks, on the north flank of Stonewall Mountain near the west margin of southern Nye County. To the west, outcrops of the Wyman Formation are scattered across Esmeralda County (J. H. Stewart, written communication, 1966). The formation was first identified by Maxson (1935) at Wyman Canyon in the Inyo Range, southeastern California.

The outcrops of Wyman Formation on Stonewall Mountain are similar to exposures in Esmeralda County described by Stewart (written communication, 1966) as follows:

> "The Wyman Formation is composed of phyllitic siltstone and silty claystone and minor amounts of limestone, sandy limestone, limy siltstone, and limy very fine-grained sandstone. These strata are somewhat metamorphosed everywhere . . . The phyllitic siltstone is medium gray, olive gray, or dark greenish gray . . . The sandy limestone and limy sandstone light to medium gray, yellowish brown weathering, distinctly and evenly laminated . . . The very thin layers of sandy limestone and limy sandstone, as well as of more pure limestone, are intricately interlayered with the phyllitic siltstone and silty claystone."

Approximately 700 feet of the upper part of the Wyman are exposed in the northwest corner of Stonewall Mountain, where it is overlain, probably conformably, by the Reed Dolomite. Somewhat thinner sections crop out in the other two exposures of the formation on Stonewall Mountain.

No fossils have been found in the Wyman Formation. It has therefore been assigned to the Precambrian.

STIRLING QUARTZITE

The Stirling Quartzite was named by Nolan (1929, p. 463) for exposures on Mount Stirling near the north end of the Spring Mountains, where the formation is 3,200 to 3,400 feet thick and consists of gray to pink quartzite with minor conglomerate, siltstone, and shale beds. Exposures of Stirling Quartzite are widespread in the southern part of the county, both in the Spring Mountains and in hills to the west. Partial sections of the formation also crop out 3 to 10 miles west of Big Dune, on Bare Mountain, and on the northeast side of Yucca Flat. A nearly complete section, 5,300 feet thick, is exposed in several fault blocks at the south end of the Kawich Range, on and near Quartzite Mountain (E. B. Ekren and others, written communication, 1966).

The Stirling has recently been correlated over a wide area of the southern Great Basin by Stewart (1966, p. C70–C71), who has informally divided the formation into five members. The lowest, the A member, is yellowish-gray quartzite and conglomeratic quartzite in the lower part, and grayish-purple quartzite and minor siltstone in the upper part. The B member is relatively thin and consists of grayish-red-purple and grayish-purple coarse siltstone to fine-grained sandstone with minor coarse-grained quartzite. The C member consists of greenish-gray siltstone overlain by purplish siltstone and quartzite. The D member at Bare and Quartzite Mountains consists of 270 to 500 feet of pale-orange and gray dolomite and limestone; farther south, in the Spring Mountains area, the dolomite and limestone grade laterally into quartzite and dolomitic sandstone. The E member is a thick, homogeneous, pale-red quartzite and conglomeratic quartzite. On Bare Mountain it also contains considerable phyllite and fine-grained sandstone. According to Stewart (1966, p. C68–C69), the D and E members are correlative with the Reed Dolomite.

No fossils have been found in the Stirling Quartzite, but its stratigraphic position indicates a late Precambrian Age.

REED DOLOMITE

The Reed Dolomite crops out in the northwest corner of Stonewall Mountain, where it dips steeply south and appears to overlie conformably the Wyman Formation. In this area the Reed Dolomite consists of a homogeneous white to medium-gray or yellowish-gray dolomite, medium to coarsely crystalline. The formation here is similar to exposures in northern Esmeralda County (J. H. Stewart, written communication, 1966); in southern Esmeralda County and in the White and southern Inyo Mountains (Nelson, 1962, p. 141), upper and lower dolomite members are separated by the Hines Tongue, 100 to 800 feet thick, composed of yellowish-brown dolomite, sandy dolomite, and very fine-grained dolomitic sandstone and quartzite.

The section of Reed Dolomite on Stonewall Mountain has an apparent thickness of 1,800 feet, but there may be duplication due to faulting. The upper contact is not exposed.

No diagnostic fossils have been found in the Reed Dolomite. It has been assigned to the late Precambrian.

PRECAMBRIAN AND CAMBRIAN ROCKS

Most of the rocks of late Precambrian and Cambrian Age in southern Nye County belong to the eastern assemblage of Roberts and others (1958) and were deposited in a shallow-water miogeosynclinal environment with limestone and dolomite predominant over shale and quartzite. Exceptions to this are the Wyman Formation and Reed Dolomite of Precambrian Age, which crop out in a small area on the north flank of Stonewall Mountain, and the Emigrant Formation, of Cambrian Age, which crops out in the Monitor Hills in the northwest corner of the map area. These three formations are transitional between the eastern and western assemblages of Roberts and others (1958, p. 2817), containing both fine-grained clastic rocks and carbonate rocks.

The Wood Canyon Formation of Precambrian and Cambrian Age, described below, consists predominantly of fine- to medium-grained clastic material but is nevertheless considered to be part of the eastern assemblage (J. H. Stewart, oral communication, 1969).

WOOD CANYON FORMATION

The Wood Canyon Formation, named by Nolan (1929, p. 464) from exposures in Wood Canyon, northern Spring Mountains, conformably overlies the Stirling Quartzite. The formation is 2,100 feet thick in the type area and crops out along the west flank of the northern Spring Mountains and in hills to the west, northwest, and north. It also crops out in smaller areas in the southern Kawich Range, the Belted Range, and on the northeast margin of Yucca Flat. Stewart (1966, p. C71) recently correlated the Wood Canyon Formation with the type Daylight Formation on Bare Mountain, earlier defined by Cornwall and Kleinhampl (1964, p. J2–J3) as a separate formation because there was some uncertainty as to the correlation of the unit with the Wood Canyon Formation. Now that such equivalence has been clearly established (Stewart, 1970), the term Daylight Formation is considered abandoned and the name Wood Canyon Formation will be used herein for these rocks on Bare Mountain.

Stewart (1966, p. C71) has divided the Wood Canyon Formation into three members. The lower member consists of grayish-olive siltstone, a little yellowish-gray quartzite, and three prominent and persistent brown-weathering dolomite beds. The middle member consists of grayish-red quartzite, partly conglomeratic, and a little siltstone. On Bare Mountain this member contains less quartzite and conglomerate than elsewhere. The upper member consists of grayish-olive siltstone, shale, and yellowish-gray, fine-grained quartzite with trilobite scraps and *Scolithus* tubes in the upper part. The upper part also contains one to five beds of light-brown-weathering limestone or dolomite, partly oolitic, with pelmatozoan plates and archeocyathids. Shales in this zone contain the olenellid trilobites *Nevadia* and *Nevadella,* indicative of Early Cambrian Age. The lower and middle members and the basal part of the upper member of the Wood Canyon Formation contain only indeterminate worm trails and borings and are considered to be late Precambrian in age.

CAMBRIAN ROCKS

ZABRISKIE QUARTZITE

The Zabriskie Quartzite conformably overlies the Wood Canyon Formation as used here. It was originally described by Hazzard (1937, p. 309–310) and defined as a member of the Wood Canyon, but it has more recently been raised to the rank of a formation by Wheeler (1948, p. 26) and Barnes and others (1965). Cornwall and Kleinhampl (1964, p. J3–J4) applied the name Corkscrew Quartzite to similar rocks on Bare Mountain because of uncertainty of correlation with the Zabriskie, but Stewart (1966, p. C72) has now definitely established this correlation and the name Corkscrew Quartzite is considered abandoned.

The Zabriskie Quartzite ranges in thickness from 20 feet or less in the Spring Mountains and in the hills west of these mountains to about 1,150 feet on Bare Mountain and in the Bullfrog Hills, 6 miles north of Beatty. It also crops out in the southern Belted Range, where it is 150 feet thick. The Zabriskie Quartzite is mapped separately on the geologic map at Bare Mountain and the Bullfrog Hills; elsewhere it is mapped with the Wood Canyon Formation because it is too thin to show separately.

The Zabriskie Quartzite is a pure, homogeneous, pale-red, fine- to coarse-grained quartzite. Siltstone and micaceous quartzite transitional into the underlying Wood Canyon Formation are locally present. Vertical *Scolithus* tubes are locally present near the base of the quartzite. Diagnostic fossils have not been found in the formation, but its stratigraphic position clearly indicates an Early Cambrian Age.

CARRARA FORMATION

The Carrara Formation was named by Cornwall and Kleinhampl (1961 and 1964) for exposures on the west flank of Bare Mountain 10 miles southeast of Beatty. The Carrara Formation conformably overlies the Zabriskie Quartzite and correlates in faunal and general lithologic character with the sequence of Latham Shale, Chambless Limestone, and Cadiz Formation in the Providence Mountains, Calif., described by Hazzard (1954, p. 30–32), and with the Bright Angel Shale as used by Nolan (1929, p. 464) in the northern Spring Mountains. Recent work (Barnes and Palmer, 1961, p. C100–C102; Barnes and others, 1962, p. D27–D30) in southern Nevada and California has indicated the desirability of grouping these rocks as a single unit, and the name Carrara Formation is now commonly used for this unit.

The Carrara Formation is 1,785 feet thick at the type locality on Bare Mountain. It crops out with a thickness of about 1,500 feet in the Bullfrog Hills, 6 miles north of Beatty, and in the northern Spring Mountains and the hills west and north. The formation also crops out south and east of Yucca Flat; thickness of the eastern outcrop is 1,960 feet (Barnes and others, 1962). In the Belted Range a 1,580-foot section of rocks that resemble the lower part of the Carrara Formation at Bare Mountain and contain fossils indicative of an Early and Middle Cambrian Age is overlain by a sequence, about 1,400 feet thick, that contains fossils indicative of a Middle Cambrian Age and resembles the Emigrant Formation. The exposures, extending for 6 miles along the strike, have been shown as Carrara Formation on the map (pl. 1).

The Carrara Formation consists of interstratified shale and limestone with minor amounts of sandstone and siltstone. Shale predominates in the lower part, limestone in the upper. The base is a transition from the underlying Zabriskie Quartzite and consists of alternating beds of sandstone, siltstone, shale, and limestone. Above this are several hundred feet of greenish-, yellowish-, to brownish-gray shale and interbedded gray and orange limestone; at the top is a massive, cliff-forming, dark-gray, algal *(Girvanella)* limestone bed, commonly 100 feet or more thick. Above the algal limestone are several hundred feet of gray to brown shale and siltstone, overlain by 500 to 1,000 feet of brightly colored limestone, alternating white, pink, orange, and brown, which is somewhat clayey or silty.

On Bare Mountain, in the lower part of the formation, the trilobites *Bristolia* and *Paedümias* were found below the massive *Girvanella*-bearing limestone, *Fremontia, Olenellus,* and *Paedumias* above it; these genera are indicative of a late Early Cambrian Age. East of Yucca Flat, Early Cambrian fossils were found in the *Olenellus* zone in the lower part of the formation, and Middle Cambrian fossils were found in the *Albertella* and *Glossopleura* zones in the middle and upper parts of the formation (Barnes and others, 1962, p. D30).

EMIGRANT FORMATION

The Emigrant Formation was named by Turner (1902, p. 265) for exposures near Emigrant Pass, Esmeralda County, Nev. The formation crops out in many areas in Esmeralda County, but in southern Nye County it has been identified only in the Monitor Hills (northwest corner, pl. 1) and possibly also in the Belted Range (E. B. Ekren and others, written communication, 1966), where part of the area mapped as Cararra Formation resembles the Emigrant Formation in lithology.

According to J. H. Stewart (written communication, 1966):

> "The Emigrant Formation is divided into three members named informally, from bottom to top, the limestone and siltstone member, the shale member, and the limestone and chert member.
>
> "The limestone and siltstone member consists of closely interlayered beds of medium-gray aphanitic to very finely crystalline limestone, light-gray, pale-red, and pale red-purple papery-splitting fine siltstone, and minor amounts of medium-gray thinly laminated silicified limestone.
>
> * * * * *
>
> "The shale member is a monotonous sequence of olive-gray to greenish-gray very thinly laminated, papery-splitting claystone.
>
> * * * * *
>
> "The limestone and chert member consists dominantly of thinly interlayered beds of limestone and chert. Individual outcrops of this lithologic type locally cover several square miles. The limestone is medium gray, aphanitic, and occurs in beds from ½ to 3 inches thick interstratified with the chert. The chert is medium gray, although it commonly weathers with a dark yellowish-brown color, is evenly laminated, and occurs as ⅛- to 1-inch layers or lens-shaped masses interstratified with the limestone. The chert constitutes about 20 percent of the strata although locally the percent is higher."

Stewart states that in Esmeralda County the limestone and siltstone member is 300 to 500 feet thick; the claystone member averages 300 feet; thickness of the limestone and chert member is probably considerably greater than the maximum measured in incomplete sections, 610 feet. Fossils are not abundant in the Emigrant Formation, but diagnostic fossils, mostly trilobites and brachiopods, range in age from oldest Middle Cambrian to Late Cambrian.

In southern Nye County, the limestone and chert member that makes up the upper part of the Emigrant Formation crops out over an area of several square miles in the Monitor Hills. The formation there consists of interlayered thin beds of medium- to dark-gray aphanitic limestone and laminated dark-gray to black chert that weathers brown. The chert beds average about 1 inch in thickness; the limestone beds tend to be somewhat thicker.

In the Belted Range, limestone, silty limestone, and shale of Middle Cambrian Age, shown on plate 1 as Carrara Formation, resemble the lower two members of the Emigrant Formation (E. B. Ekren and others, written communication, 1966). This sequence comprises two units: The lower unit, 940 feet thick, consists of alternating zones of medium- to dark-gray aphanitic to fine-grained limestone and brownish-weathering silty limestone and siltstone with scattered thin lenses of black chert in the upper part. The upper unit, 640 feet thick, consists of gray to greenish-gray fissile shale that weathers brown. The following fossils, indicative of Middle Cambrian Age, were collected from the lower unit; then were identified by A. R. Palmer (E. B. Ekren and others, written communication, 1966):

Ogygopsis typicalis Resser
Pagetia sp.
Pagetia clytia Walcott
Pagetia maladensis Resser
Oryctocephalus sp.
Tonkinella? sp.
?Tonkinella idahoensis Resser
"Agnostus" lautus Resser
Alokistocare sp.
undetermined ptychoparioid trilobites
Hyolithes
Girvanella

No determinable fossils were collected from the upper unit in the Belted Range, but it also is of probable Middle Cambrian Age.

BONANZA KING FORMATION

The Bonanza King Formation was first described in the Providence Mountains, Calif., by Hazzard and Mason (1936, p. 234–238), and later revised by Palmer and Hazzard (1956, p. 2494–2499) as a result of findings in the Nopah Range, Calif. The formation crops out extensively on Bare Mountain, where Cornwall and Kleinhampl (1961) measured a thickness of 3,800 feet. The formation also crops out extensively in the Spring Mountains and in hills to the west, north, and northwest. Burchfiel (1964, p. 48) measured a thickness of 3,031 feet in the Specter Range, northwest of the Spring Mountains. The Bonanza King Formation crops out rather extensively south, north, and east of Yucca Flat; a thickness of 4,600 feet was measured east of Yucca Flat (Barnes and others, 1962, p. D30). A small exposure was found in the Kawich Valley west of the north end of the Belted Range (E. B. Ekren and others, written communication, 1966).

The Bonanza King Formation is mostly thin- to thick-bedded dolomite with some limestone; it includes a few bands as thick as 150 feet that contain intercalated silty and sandy layers and partings and, locally, thin cherty bands. A typical section at Tungsten Canyon in Bare Mountain has been described by Cornwall and Kleinhampl (1961) as follows:

> "[The section] contains roughly a dozen units that differ from one another chiefly in content of clastics, chert, and secondary dolomite and in the spacing of light- and dark-gray bands. In the bottom and top thirds of the formation the alternating gray bands are 20 to 200 feet thick, and rather indistinct except at the very top. The middle third of the formation, on the other hand, has very distinct light- and dark-gray bands that are only 1 to 20 feet thick. This predominantly striped middle unit probably corresponds to striped unit no. 7G in the Cornfield Springs formation (Hazzard, 1937, p. 277, 319) in the Nopah Range, which according to a revision of nomenclature (Palmer and Hazzard, 1956, p. 2498–2499) forms the upper part of the Bonanza King formation.
>
> "Three distinct bands, each about 200 feet thick, that are from bottom to top black, white, and gray, form the uppermost part of the Bonanza King formation at Bare Mountain."

No diagnostic fossils were found at Bare Mountain or in the Specter Range, but Barnes, Christiansen, and Byers (1962, p. D31), who studied a section on the east side of Yucca Flat, report that the Bonanza King Formation is of Middle and Late Cambrian Age. They found Late Cambrian fossils of the *Crepicephalus* and *Aphelaspis* zones in the upper 300 feet of the formation.

NOPAH FORMATION

The Nopah Formation was named by Hazzard (1937, p. 320–322) for exposures in the Nopah Range, Inyo County, Calif., where it consists of 1,640 feet of varicolored dolomite underlain by 100 feet of shale with minor limestone and sandstone. Christiansen and Barnes (1966, p. A51; also Barnes and Christiansen, 1967, p. G31) have correlated the upper 400 feet of the section measured by Hazzard with the overlying Goodwin Limestone and have estimated a thickness of 1,270 feet for the Nopah Formation in the Nopah Range. The formation also crops out on Bare Mountain, where it is 1,900 feet thick and very similar to the section in the Nopah Range (Cornwall and Kleinhampl, 1961). Burchfiel (1964, p. 49–50) identified the Nopah Formation in the Specter Range at the north end of the Spring Mountains. He restricted the name Nopah to the dolomite unit, 1,063 feet thick, and called the underlying 200 feet of shale and silty limestone the Dunderberg Shale.

The Nopah Formation also crops out on the south, north, and east margins of Yucca Flat; Johnson and Hibbard (1957, p. 342–343) identified the Dunderberg Shale at the east margin. Later Barnes and Byers (1961, p. C103–C106) correlated the carbonate sequence overlying the Dunderberg Shale with the Windfall Formation. Recently, however, Christiansen and Barnes (1966; Barnes and Christiansen, 1967) have correlated these rocks with the Nopah Formation and have locally included the Dunderberg as a basal member. The Nopah Formation also crops out in the Belted Range and in the southern part of the Quinn Canyon Range where Nevada Highway 25 crosses it at the east margin of the county.

The section of Nopah Formation on Bare Mountain is similar to exposures elsewhere in the county and consists of three members now called, in ascending order, the Dunderberg Shale, Halfpint, and Smoky Members (Christiansen and Barnes, 1966; Barnes and Christiansen, 1967). The Dunderberg Shale Member there is about 100 feet thick and consists of paper-thin brownish-gray to black shale with thin interbeds of gray, aphanitic to fine-grained limestone. The shale member overlies the Bonanza King Formation with a sharp contact and passes abruptly upward into the Halfpint Member. At Striped Hills in the Specter Range, the shale member is 100 feet thick (Harley Barnes, written communication, 1969); in the Yucca Flat area, it is 223 feet thick (Barnes and Palmer, 1961, p. C103).

The Halfpint Member, overlying the Dunderberg Shale Member, consists of conspicuously laminated, platy and flaggy, medium- to dark-gray limestone with intercalated laminae of silty limestone and dolomite and very thin beds of chert. On Bare Mountain this member ranges in thickness from 0 to 200 feet; east of Yucca Flat, it is 715 feet thick (Barnes and Byers, 1961, p. C104). In the Belted Range the estimated thickness is 1,900 feet (E. B. Ekren and others, written communication, 1966); in the Specter Range, about 150 feet (Harley Barnes, written communication, 1969); it is absent in the southern Quinn Canyon Range.

The dolomitic Smoky Member of the Nopah Formation is 1,600 to 1,800 feet thick on Bare Mountain and has thin and thick, faintly and sharply contrasting, parallel and subparallel gray-colored bands and one or two moderately thick, very pale-orange or gray bands. The dolomite is fetid when struck with a hammer, fine to coarse grained, obscurely to well stratified, and locally cross bedded. Brownish- to olive-gray silty layers are common in the lower half. This member contains some chert in zones of blebs, nodules, and thin lenses; also, the dolomite has partly recrystallized to coarse-grained, white to yellowish-gray flecks and stringers and irregular masses. In the Yucca Flat area, the Smoky Member is

1,070 feet thick and is similar to the section on Bare Mountain except that some limestone is present and stromatolites and *Girvanella* are locally prominent.

Most or all of the Nopah Formation mapped by Burchfiel (1964, p. 49–50) probably correlates with the Smoky Member. In the Belted Range the Smoky Member is typical and is 900 feet thick (E. B. Ekren and others, written communication, 1966).

In rocks shown here as Nopah Formation in the southern Quinn Canyon Range, A. R. Palmer (written communication, 1963) has identified the following trilobites: *Eurekia* sp., *Idiomesus* sp., *Tostonia*? sp., *Bienvillia* sp., and apatokephalid types. He states that this collection is indicative of the uppermost part of the Upper Cambrian in beds of the upper part of the Windfall Formation and correlative units. The rocks are lithologically similar to the Windfall Formation but because areas of exposure are small, they have been included in the upper member of the Nopah Formation on the geologic map. An exposed section about 500 feet thick consists of thin-bedded to laminated, medium- to dark-gray limestone with interbedded yellowish-brown to pale-red-weathering sandstone, siltstone, and minor chert.

In the Dunderberg Shale Member on Bare Mountain, *Pseudagnostus* have been identified by Palmer (A. R. Palmer, written communication, 1957). In the same unit east of Yucca Flat, Johnson and Hibbard (1957, p. 343) reported the trilobites *"Pterocephalina," Pseudagnostus, Geragnostus,* and *Dunderbergia.* These fossils indicate an early Late Cambrian Age.

The Halfpint Member, formerly called the Catlin Member of the Nopah Formation in the Yucca Flat area, contains fauna of the *Elvinia* and *Ptychaspis-Prosaukia* zones, both of Franconian Age (Barnes and Byers, 1961, p. C105–C106). Thus, this member is of Late Cambrian Age. A diagnostic fossil, *Matthevia,* has been found in the Smoky Member (Yochelson and others, 1965) in a number of places in the southern Great Basin, and this member also is considered to be of Late Cambrian Age.

ORDOVICIAN ROCKS

POGONIP GROUP

In southern Nevada, Ross (1964) has shown that the Pogonip Group includes the Goodwin, Ninemile, and Antelope Valley Formations as defined by Nolan and others (1956) for the area around Eureka, Nev. The individual formations are not shown on the geologic map but have been identified in most areas of the county where the Pogonip Group occurs. On Bare Mountain, Ross (1964, p. C24–C31) measured 358 feet of Goodwin Limestone, 232 feet of Ninemile Formation, and 908 feet of Antelope Valley Limestone, a total thickness of 1,498 feet. Sections measured north of Yucca Flat, east and southeast of Frenchman Flat, by Byers and others (1961, p. C106–C110) were: Goodwin Limestone, 990 feet; Ninemile Formation, 335 feet; Antelope Valley Limestone, 1,355 feet; total, 2,680 feet. In the Belted Range (E. B. Ekren and others, written communication, 1966) a complete section measures: Goodwin Limestone, 1,010 feet; Ninemile Formation, 300 feet; Antelope Valley Limestone, 1,700 feet; total, 3,010 feet. In the Specter Range, a complete section could not be measured because of faulting (Burchfiel, 1964, p. 50–52).

The Goodwin Limestone consists of medium-light-gray to olive- and yellowish-gray limestone, laminated to thick bedded, in part containing abundant silty and shaly partings and local chert nodules and lenses. The lower and upper parts are commonly ledge forming; intraformational conglomerate is common toward the top. Fossils are abundant in the Goodwin Limestone and indicate an Early Ordovician Age (Ross, 1964).

The Ninemile Formation consists of interbedded gray nodular thin-bedded limestone and olive to greenish-gray calcareous siltstone and shale. Limestone is more abundant toward the top. Fossils are abundant and indicate an Early Ordovician Age (Ross, 1964).

The Antelope Valley Limestone, at the top of the Pogonip Group, comprises three units. The lower, ledge-forming unit is composed of thin- to thick-bedded medium-gray, fine-grained limestone with laminae and irregular networks of orange-weathering, silty limestone. This unit is overlain by a middle unit of silty, olive-gray limestone containing yellow and red mottled silty layers. Lens-shaped bioherms have been found in several places in the lower half of the middle unit (Ross and Cornwall, 1961), all flat on the bottom and within the same horizon. The largest, on Bare Mountain, is half a mile in lateral extent and about 300 feet thick; the other two, one north and one southeast of Yucca Flat, are smaller. The bioherms consist of pale-gray, very pure aphanitic limestone with few internal depositional structures. At the top of the Antelope Valley Limestone is a third unit consisting of thin-bedded, commonly silty, olive- to yellowish-gray limestone top and bottom and a massive, thick-bedded, gray limestone in between that contains *Palliseria, Maclurites,* and *Receptaculites.* Brachiopods and other fossils are also abundant in this upper unit of the Antelope Valley Limestone. The age of the Antelope Valley Limestone, and, locally, of the Pogonip Group, is Early and Middle Ordovician.

Six miles south of Johnnie and 10 miles west of the Spring Mountains is a ridge of Pogonip Group that differs from those described above in that the entire section is dolomite rather than limestone. Other features of the lithology are similar to that of typical Pogonip sections.

EUREKA QUARTZITE

The Eureka Quartzite was named by Hague (1883 and 1892) for outcrops near Eureka, Nev. Its definition was later revised by Kirk (1933). In southern Nye County the Eureka Quartzite ranges in thickness from

100 to 450 feet (Ross and Longwell, 1964, p. C91; Burchfiel, 1964, p. 52); it is mapped with the overlying Ely Springs Dolomite on the geologic map. The Eureka Quartzite crops out in the following areas: Bare Mountain, 340 feet thick, and northwest of there in the Bullfrog Hills; Specter Range, about 450 feet; northern Spring Mountains, 290 feet (F. G. Poole, written communication, 1968); 8 to 12 miles northwest of Pahrump, 230 feet (F. G. Poole, written communication, 1968); south, east, and north of Yucca Flat, 315–380 feet; and the Belted Range. The Eureka Quartzite is white to grayish orange, vitreous, and fine grained; grains are well rounded and well sorted. The formation is indistinctly and distinctly very thin to thick bedded, with local faint crossbedding. The quartzite contains some sandstone, partly limy or dolomitic, particularly near the top and bottom. In southern Nye County in the Ranger Mountains, south of Frenchman Flat, diagnostic fossils have been found in a 35-foot silty limestone and dolomite unit 60 feet above the base of the quartzite. The Eureka Quartzite is considered to be Middle Ordovician in age.

ELY SPRINGS DOLOMITE

The Ely Springs Dolomite was named by Westgate and Knopf (1932) from exposures near Pioche, Nev. Its two members and upper contact were described by Poole and Christiansen (1966), whose definition of the Ely Springs Dolomite is used in this report. The formation, which is not differentiated from the Eureka Quartzite on the geologic map, crops out in the same areas in southern Nye County, namely, at: Bare Mountain, Bullfrog Hills, Specter Range, northern Spring Mountains, Spotted Range, northwest of Pahrump, Belted Range, and around Yucca Flat. Measured sections show the following thicknesses: Bare Mountain, about 300 feet (Cornwall and Kleinhampl, 1961); Specter Range, about 450 feet (F. G. Poole, written communication, 1968); northern Spring Mountains, about 500 feet (F. G. Poole, written communication, 1968); north of Yucca Flat at Oak Spring Butte, 340 feet (E. B. Ekren and others, written communication, 1966).

A typical section at Bare Mountain is largely of medium- to dark-gray, aphanitic to very fine-grained, laminated to thin-bedded blocky dolomite. Chert, as anastomosing irregular lenses, makes up about 10 percent of the rock. Toward the base the formation is sandy. Extensive patches of dark-gray limestone are locally present, and near the top of the formation limy dolomite beds are lighter gray, in contrast to the prevalent dark-gray beds. Lithologically, the sections described elsewhere in the county are similar to the exposures at Bare Mountain. Fossils are common in the Ely Springs Dolomite in some areas. The formation is Middle and Late Ordovician in age.

SILURIAN ROCKS

ROBERTS MOUNTAINS FORMATION

The Roberts Mountains Formation, which has its type section at Roberts Creek Mountain in central Nevada (Merriam, 1940, p. 11–12; Nolan and others, 1956, p. 36–37), has been recognized only on Bare Mountain and in the Bullfrog Hills, 6 miles northwest of Bare Mountain (Cornwall and Kleinhampl, 1961; 1964, p. J5). The formation ranges in thickness from 650 to 900 feet in these areas and consists of three units.

The lowest unit, 150 to 200 feet thick, consists of thin-bedded, dark-gray dolomite or interstratified light- and dark-gray limy dolomite with chert nodules and layers and sparse sand grains. A conspicuous black chert bed at the base, typical of the formation in the type area, is present in part of the exposures on Bare Mountain. The middle unit consists of 400 feet of medium- to dark-gray, platy, laminated to thin-bedded limestone and limy dolomite. The upper unit, 200 feet thick, consists of thin-bedded, dark- to medium-gray dolomite that grades upward into light-gray dolomite.

Fossils are most abundant in the upper part of the middle unit and the lower part of the upper unit, where collections yielded pentameroid brachiopods similar to the fauna from the type locality (Merriam and Anderson, 1942, p. 1687); this dates the formation as Middle Silurian. Graptolites have also been found in the lower unit of the formation at Chuckwalla Canyon on Bare Mountain.

Silurian rocks have been recognized in the Specter Range, northern Spring Mountains, northwest of Pahrump, in the hills north of Mercury, west and north of Yucca Flat. Because of facies changes, the Roberts Mountains Formation has not been recognized in these areas (Johnson and Hibbard, 1957; Burchfiel, 1964 and 1965; E. B. Ekren and others, written communication, 1966), but Burchfiel (1964, p. 53) tentatively considered a unit in the Specter Range correlative with the Roberts Mountains Formation.

LONE MOUNTAIN DOLOMITE

A homogeneous dolomite conformably overlying the Roberts Mountains Formation on Bare Mountain has been correlated (Cornwall and Kleinhampl, 1961) with the Lone Mountain Dolomite as restricted by Merriam (1940, p. 10, 13–14; Nolan and others, 1956, p. 37–40) at Lone Mountain in central Nevada. The Lone Mountain Dolomite at Bare Mountain is similar to that described in the type section; it consists of 1,600 feet of a very light-gray dolomite underlain by a roughly equal amount of slightly darker gray dolomite. A partial section of the Lone Mountain Dolomite crops out in the Bullfrog Hills 6 miles northwest of Bare Mountain.

The Lone Mountain Dolomite at Bare Mountain has three units. The lowest unit, 300 feet thick, consists of vuggy, light-gray dolomite that is fine- to medium-grained, coarser upward, and massive and contains crinoid stems. Above this is 500 feet of blotched light- and dark-gray, fine- to medium-grained, massive dolomite with scattered sandy layers in the upper part. The upper part of the formation consists of 800 feet of light-gray, medium-grained, massive dolomite, thin to thick bedded. Diagnostic fossils were not found in the Lone Mountain Dolomite at Bare Mountain, but the formation has been assigned to the Upper Silurian in other areas.

As mentioned above in the description of the Roberts Mountains Formation, undifferentiated Silurian rocks occur in the Specter Range, northern Spring Mountains, northwest of Pahrump, Spotted Range, near Mercury, Ranger Mountains, and west and north of Yucca Flat. Burchfiel (1964, p. 53) tentatively recognized strata equivalent to the Lone Mountain Dolomite in the Specter Range but did not map them separately.

SILURIAN AND DEVONIAN ROCKS

DOLOMITE OF SPOTTED RANGE

A thick dolomitic unit that overlies the Ely Springs Dolomite and is informally referred to as the dolomite of Spotted Range (Poole and others, 1967) is believed to range in age from Early Silurian to Early Devonian according to F. G. Poole (written communication, 1965). This dolomitic unit is largely limited to relatively small areas north and west of Yucca Flat and south of Frenchman Flat in the Spotted Range and Ranger Mountains.

The section in the Ranger Mountains, described by Poole (1965) is typical of the dolomite of Spotted Range. It is 1,710 feet thick and consists of light-, medium-, and dark-gray, cliff-forming dolomite, fine to coarse grained, partly cherty and partly vuggy. Poole has divided the dolomite into six units, largely on the basis of color or color banding, grain size, bedding characteristics, and presence or absence of vugs and chert blebs.

A 435-foot unit somewhat below the middle of the dolomite contains the following silicified fossils: *Halysites, Favosites, Alveolites, Spongophylloides* cf., *Pilophyllum* and cf. *Rhegmaphyllum* (W. A. Oliver, Jr., oral communication, 1972).

DEVONIAN ROCKS

NEVADA FORMATION

The Nevada Formation was defined by Hague (1883 and 1892) and later redefined and restricted by Merriam (1940, p. 10–17). A regional synthesis of the Nevada Formation was made by Poole and others (1967). In southern Nye County the formation crops out in the Specter Range, the northern Spring Mountains, about 10 miles northwest of Pahrump, east of Mercury, and southwest, northwest, and north of Yucca Flat. In part of the map it has been combined with the overlying Devils Gate Limestone (pl. 1). A sequence of Devonian rocks on northern Bare Mountain, earlier designated the Fluorspar Canyon Formation by Cornwall and Kleinhampl (1961), is correlative with the middle part of the Nevada Formation. The name Fluorspar Canyon Formation is herewith abandoned.

Burchfiel (1964, p. 54–55) describes a typical section in the Specter Range. There the formation is 1,605 feet thick and consists of a lower slope-forming dolomite and quartzite member and an upper cliff-forming, massive dolomite member. The lower member, 435 feet thick, contains gray, olive-weathering, medium-bedded dolomite overlain by light-brownish-gray, medium- to coarse-grained quartzite with interbeds of dolomite and sandy dolomite. The upper member, 1,170 feet thick, consists of light- to dark-gray, medium- to fine-grained dolomite and some limestone. The beds are grouped in units that are either gray or interbedded gray and dark-gray dolomite.

Around Yucca Flat the Nevada Formation locally has a more variable lithology, containing more limestone than in the Specter Range. Johnson and Hibbard (1957, p. 353–355) measured a thickness of 1,070 feet in that area. Burchfiel (1964, p. 55) states that in the Specter Range a fossil collection near the base of the formation containing *Favosites* and *Breviphyllum* sp. dates that part as Early Devonian, and another near the top containing *Stringocephalus* sp. indicates a Middle Devonian Age.

On Bare Mountain several partial sections of the Nevada Formation in separate fault blocks have a total thickness of about 1,700 feet. The basal part, 300 feet thick in Tarantula Canyon, conformably overlies the Lone Mountain Dolomite and consists of dark-gray, cherty dolomite with sandstone lenses and a little limestone. Fossils collected near the top of this unit were identified by C. W. Merriam as *Favosites* sp., *Cladopora* sp., *Alveolites* sp., *Schizophoria* sp., *Cyrtina* sp., and *Crurithyris* sp. This collection indicates a late Middle Devonian Age. A second section, exposed on Razorback Ridge, includes 550 feet of light- to dark-gray, fine- to medium-grained dolomite with sandstone units near the base; 75 feet of light- to dark-gray sandy and limy dolomite and gray to brown sandstone; and an upper unit, 215 feet thick, of aphanitic to fine-grained, medium-gray limestone and dolomite containing white to pink sandstone and quartzite beds as thick as 5 feet in the lower half. *Amphipora, Stringocephalus(?),* and *Orecopia(?)* were found in this unit. A third section, 580 feet thick, exposed northeast of Meiklejohn Peak, consists of medium- to dark-gray dolomite, partly fetid, with a fauna similar to that of the second section. Thus the age of the Nevada Formation is considered to be Early and Middle Devonian in the area of this report.

DEVILS GATE LIMESTONE

The Devils Gate Limestone, defined by Merriam (1940, p. 16–17) for exposures near Eureka, Nev., was included in a regional synthesis by Poole and others (1967). It crops out in southern Nye County southwest, northwest, and north of Yucca Flat, and east of Mercury; also in the eastern part of the Specter Range, northern Spring Mountains, and northwest of Pahrump Valley. For most of the area it is mapped (pl. 1) with the Nevada Formation, but separately in the Specter Range and Spring Mountains.

In southern Nye County, as in the type area, the Devils Gate Limestone consists mostly of cliff-forming, light- to dark-gray and blue-gray limestone with minor dolomite. Sandstone or quartzite and calcareous beds up to 100 feet thick occur in the upper part of the formation. The formation is more than 1,000 feet thick in the Specter Range (Burchfiel, 1964, p. 55), 1,335 feet thick southwest of Yucca Flat (P. P. Orkild and F. G. Poole, written communication, 1963), and slightly more than 1,670 feet thick northwest of Pahrump Valley (Hamill, 1966).

The Devils Gate Limestone is of Middle and Late Devonian Age (Nolan and others, 1956, p. 50; Poole and others, 1967). Merriam has recognized several diagnostic zones. No diagnostic fossils have been identified from the formation in southern Nye County, but the rodlike corals *Amphipora* or *Cladopora,* characteristic of Devonian rocks in the Great Basin, are locally abundant.

DEVONIAN AND MISSISSIPPIAN ROCKS

ELEANA FORMATION

The Eleana Formation was named by Johnson and Hibbard (1957, p. 357–360) for widespread exposures on the west side of Yucca Flat in southern Nye County. The formation was described in greater detail by Poole and others (1961, p. D104–D111). The Eleana Formation also crops out south of Shoshone Mountain, 15 miles southwest of Yucca Flat, on the west flank of the Cactus Range in the northwestern part of southern Nye County and 5 miles southeast of Belted Peak in the eastern part of the county. On the northern part of Bare Mountain, a sequence of rocks correlative with part of the Eleana Formation has been named the Meiklejohn Formation by Cornwall and Kleinhampl (1961). These rocks are here included in the Eleana Formation and the name Meiklejohn Formation is herewith abandoned.

The Eleana Formation has a minimum thickness of 7,700 feet, measured in several incomplete sections. The formation consists of shale, argillite, siliceous siltstone, quartzite, conglomerate, and minor limestone. The abundant argillite is yellowish brown to pale red and is laminated; the siltstone, quartzite, and conglomerate are brown. Gray and brown crystalline limestone occur at the base and in the upper part of the formation. The Eleana in the Cactus Range is partly conglomeratic (E. B. Ekren and others, written communication, 1966). Southward along the west side of Yucca Flat, the detrital strata of the formation become successively finer grained, and near the south end of the county in the Spring Mountains and bordering Pahrump Valley, correlative units are mostly limestone. On Bare Mountain a 3,200-foot section of the Eleana Formation is also much finer grained than the section in the Cactus Range. These facies changes probably represent an apron of clastic material that spread southward and eastward from the Antler orogenic belt postulated by Roberts and others (1958).

Poole and others (1961) first considered the Eleana Formation to be Late Devonian, Mississippian, and possibly Early Pennsylvanian on the basis of fossils collected in the Yucca Flat area. Fossils collected from near the base of the formation are indicative of Late Devonian Age, according to W. A. Oliver, Jr., and J. T. Dutro, Jr. (Poole and others, 1961): *Trapezophyllum* sp., *Favosites* sp. (common), *Alveolites* sp., *Thamnopora* sp., *Atrypa* (large).

A bed of uncertain stratigraphic position, fairly high in the formation (Poole and others, 1961, p. D107, bottom of page), yielded a small collection of 13 species of fossils, believed by Mackenzie Gordon, Jr. to be Early Mississippian in age. According to Gordon, Duncan, and Yochelson (written communication to Poole, 1964), the locality is actually of early Late Mississippian (Meramec) Age. The new collection, totaling 66 species, includes the coral genera *Amplexus, Amplexizaphrentis, Zaphrentites, "Menophyllum," Canadiphyllum?, Permia?, Cyathaxonia, Lophophyllidium,* new genus aff. *Lophophyllidium, Rhopalolasma, Sochkineophyllum,* plerophyllid genus indet., lithstrotionoid? fragment, and *Cladochonus;* bryozoan genera include *Tabulipora, Leioclema?, Fenestella, Polypora, Hemitrypa, Penniretepora?, Cystodictya, Coeloconus,* along with unidentified fistuliporoid, glyptoporoid?, trepostomatous, stenoporoid, and rhomboporoid genera; brachiopod genera include *Rhipidomella, Rugosochonetes, Semicostella,* new genus aff. *Avonia, Inflatia, Echinoconchus?, Auloprotonia?, Antiquatonia, Ovatia, Coledium?, Tylothyris, Spirifer, Imbrexia?, Dimegalasma, Torynifer?, Hustedia,* as well as compositoid and terebratuloid species. The gastropods *Platyceras* and *Straporollus* and a trilobite *Griffithides?* are also present. Most of the brachiopods occur also in the Diamond Peak Formation at Conical Hill near Eureka, Nev., according to Gordon (written communication, 1970). Some reworked corals of Late Devonian and Early Mississippian Age were also found in this assemblage. This locality appears to have been a shoal at approximately the same time the Conical Hill beds were laid down.

The earlier find at Quartzite Mountain, Nevada Test Site, of the coral *Lophophyllidium* in the Eleana Formation (Poole and others, 1961, p. D107, collection 6) near the base of informal unit I, was interpreted in accordance with then current thinking as indicating Pennsylvanian or Permian Age for the containing rock. A later collection from the same locality (Poole and others, 1965, p. A52) yielded *Siphonodendron (Cionodendron)* sp. and *Reticulariina* cf. *R. spinosa* (Meek and Worthen), which are characteristic Late Mississippian fossils. *Faberophyllum* was found in slightly higher beds (Gordon, Duncan, and Yochelson, written communication to Poole, 1964) nearby in Grouse Canyon. The *Faberophyllum* Zone is regarded by U.S. Geological Survey paleontologists as marking the top of the Meramec Series equivalents in the western United States. All of the occurrences of *Lophophyllidium* in the Eleana Formation are now regarded as Meramec in age.

The highest fossiliferous beds in the Eleana Formation are very Late Mississippian (late Chester) in age (Gordon and Poole, 1968). From a section in Red Canyon, Nevada Test Site, approximately 100 feet below the top of the formation, Gordon and Poole (1968, p. 157, 160, fig. 2) have listed the ammonoids *Cravenoceras hesperium* Miller and Furnish, *C. merriami* Youngquist, *Syngastrioceras* sp., and *Eumorphoceras* sp. These are characteristic of the upper part of the *Eumorphoceras bisulcatum* (E_2) Zone, the highest ammonoid zone known in Mississippian rocks in the central and western United States. From a limestone bed 14 feet below the top of the formation, the same writers have listed *Rhipidomella nevadensis* (Meek), *Schizophoria* cf. *S. resupinoides* (Cox), *Diaphragmus* sp., *Spirifer* cf. *S. brazerianus* Girty, and *Platycrinites* sp. The *Rhipidomella nevadensis* Zone, to which these fossils belong, is the highest Mississippian brachiopod zone in the Great Basin.

Fossils collected from the Eleana Formation on Bare Mountain indicate a Late Mississippian Age, according to W. H. Hass and L. G. Henbest. One collection contains the conodonts *Cavusgnathus* sp., *Gnathodus bilineatus,* and *Ligonodina* sp. Another collection contains the Foraminifera *Monotaxis* sp., *Endothyra* sp., and a fusulinid genus having affinities with *Pseudoendothyra* sp.

The Eleana Formation lithologically resembles the Chainman Shale and Diamond Peak Formation near Eureka, Nev., which are there considered to be Late Mississippian in age (Nolan and others, 1956, p. 56–61). The Narrow Canyon and Mercury Limestones, limestone of Timpi Canyon, and part of the Devils Gate Limestone are temporally equivalent to the Eleana Formation in southern Nye County. Except for the Devils Gate Limestone, exposures of these formations, occurring along the county line east of Mercury, are mapped with the Eleana Formation (pl. 1) and are not described separately in the text.

The Eleana Formation and equivalent strata are overlain disconformably by the Tippipah Limestone (Gordon and Poole, 1968).

MISSISSIPPIAN ROCKS

MONTE CRISTO LIMESTONE

The Monte Cristo Limestone was named by Hewett (1931, p. 17–21) for exposures near the Monte Cristo mine in the Goodsprings quadrangle, southern Spring Mountains, Clark County, Nev. Hewett subdivided it into five members, in ascending order, Dawn and Anchor Limestone, Bullion Dolomite, Arrowhead and Yellowpine Limestone Members. In southern Nye County the Monte Cristo Limestone has been mapped and described by Vincelette (1964) in the northern Spring Mountains at the east margin of the county. The formation also crops out in two areas northwest of Pahrump Valley, where it has been described by Hamill (1966).

In the northern Spring Mountains, Vincelette (1964) measured 1,000 feet of dark- to light-gray limestone that is medium to coarse grained, highly fossiliferous, and cherty. Lithologically, he correlates this limestone containing abundant chert nodules and lenses with the Anchor Limestone Member of the Goodsprings district (Hewett, 1931, p. 17). Northwest of Pahrump Valley, Hamill (1966) measured 1,172 feet of Monte Cristo Limestone that closely resembles the section in the northern Spring Mountains.

Hewett (1931) concluded that the Anchor Limestone Member and the overlying Bullion Member of the Monte Cristo Limestone are Early Mississippian in age and the overlying members are Late Mississippian. The present writer and E. H. McKee collected fossils from the Monte Cristo Limestone in the two areas northwest of Pahrump. The collection from the western of the two areas was identified by Mackenzie Gordon, Jr., and Helen Duncan as Early Mississippian in age on the basis of the following fossils: *Amplexus* sp., *Caninia* sp., zathrentoid coral, *Cladochonus* sp., *Fenestella* 2 spp. The other collection, from the eastern area, they concluded, appears to be a Mississippian fauna, but the collection is too limited and poorly preserved to ascertain whether it is Early or Late Mississippian.

PENNSYLVANIAN ROCKS

TIPPIPAH LIMESTONE

The Tippipah Limestone was named by Johnson and Hibbard (1957) for incomplete exposures on Syncline Ridge on the west side of Yucca Flat. The formation also crops out in a small area on the south margin of Yucca Flat. A small exposure on the southeast boundary of the county, 5 miles east of Pahrump, mapped by D. T. Secor, Jr. (written communication, 1962) as the Bird Spring Formation, is shown provisionally on the accompanying map as Tippipah Limestone. The two formations are lithologically similar and largely correlative. The Tippipah Limestone consists of 3,600 feet of limestone with interbeds of pebbly and silty limestones (Barnes and others, written communication, 1963). Gray to light-brown beds of resistant and nonresistant limestone, 5 to 50 feet thick, alternate with each other throughout most of the formation.

Abundant fossils collected throughout the formation—fusulinids, gastropods, bryozoans, corals, and brachiopods—are of Early Pennsylvanian Age (Barnes and others, written communication, 1963). Cephalopods from the base of the Tippipah Limestone are Early Pennsylvanian in age (Gordon and Poole, 1968).

MESOZOIC ROCKS

GRANODIORITE AND QUARTZ MONZONITE

Two granitic intrusives, the Climax and Gold Meadows stocks, crop out near the north end of Yucca Flat near the east margin of southern Nye County, where they intrude deformed Precambrian and Paleozoic rocks and are unconformably overlain in part by Tertiary volcanic rocks. A third quartz monzonitic intrusive, too small to be shown on the map, crops out on the northeast margin of Yucca Flat, several miles southeast of the Climax stock. This intrusive appears similar to the quartz monzonite of the Climax stock (Barnes and others, 1963, ref. 13, fig. 2). Two other Mesozoic(?) granitic intrusives, almost completely covered by alluvium and not shown on the accompanying map, crop out in the Cactus and southern Kawich Ranges, respectively (E. B. Ekren and others, written communication, 1966). These intrusives are similar to the quartz monzonite of the Gold Meadows stock.

Climax Stock

The Climax stock crops out at the north margin of Yucca Flat east of Quartzite Mountain. Houser and Poole (1961, p. B176 and B177) and Barnes and others (1963) have described the stock as a composite intrusion of older granodiorite and younger quartz monzonite, both cut by dikes and sills and hydrothermally altered. The granodiorite is medium grained, equigranular, light to greenish gray. The quartz monzonite is light to medium gray, fine grained in a peripheral zone commonly less than 100 feet thick and medium grained in the interior. K-feldspar phenocrysts as much as 1.5 inches long are prominent. The quartz monzonite has a more mafic phase near its contact with the granodiorite. Modes and chemical analyses of the two stocks given by Barnes and others (written communication, 1963) are tabulated in table 1 (nos. 1 and 2); norms, calculated by the author, are also shown.

Aplitic and pegmatitic dikes and sills as much as 50 feet thick, ranging in composition from alaskite to syenite, cut the composite stock and surrounding calcareous rocks of the Pogonip Group. The limestones and dolomites within a few thousand feet of the stock have been metamorphosed; relatively pure carbonate rocks have been changed to marble, whereas silty limestones have been altered to calc-silicate hornfels and tactite. Hydrothermal alteration of the stock itself has produced moderate argillic alteration of plagioclase and chloritic alteration of biotite. Quartz veins with accompanying orthoclase, albite, montmorillonite, sericite, and calcite are widely developed in the stock and host rocks and are most abundant in the quartz monzonite. Sparse amounts of pyrite, molybdenite, and chalcopyrite occur along joints.

The stock is younger than the Devonian and Mississippian Eleana Formation and older than overlying Tertiary tuffs. The average K-Ar date of six biotite samples from the quartz monzonite is 93 m.y. (S. S. Goldich, written communication, 1962), or Cretaceous. Lead-alpha ages of zircons from the quartz monzonite are 230±25 m.y. and 330±35 m.y. (T. W. Stern, written communication, 1960); these ages appear anomalously great.

Gold Meadows Stock

The Gold Meadows quartz monzonite stock described by Harley Barnes and others (written communication, 1963) is located northwest of Yucca Flat and 8 miles west of the Climax stock. It is elongate parallel to several northeast-trending faults and intrudes quartzites of the Wood Canyon Formation or Stirling Quartzite, which dip northwestward into the stock. Bedded tuffs of Tertiary Age partly overlie the stock unconformably.

Chemical analyses, a norm and a mode, are given in table 1 (no. 3). The stock is more siliceous than the quartz monzonite of the Climax stock. The quartz monzonite is medium to coarse grained and porphyritic in the northeastern part, containing phenocrysts of perthite as much as 35 mm long. Other minerals in the rock are quartz, plagioclase, and minor biotite, magnetite, and apatite. Dikes and irregular segregations of aplite and pegmatite make up about 5 percent of the stock; most strike northeast and extend into the quartzitic wall rocks. The dikes approximate the quartz monzonite in composition; major constituents are quartz, perthite, and plagioclase and accessory minerals are muscovite, biotite, magnetite, apatite, and epidote.

The stock is partly sericitized and contains quartz veins with small amounts of hematite pseudomorphic after pyrite. Metamorphism of xenoliths and wall rocks adjacent to the stock has produced a micaceous, feldspathized quartzite with small black knotty aggregates of mica. The age of the stock determined by lead-alpha analyses of zircon ranges from 140 to 80 m.y. (T. W. Stern, written communication, 1960), that is, Late Jurassic to Late Cretaceous. F. M. Byers, Jr. (written communication, 1968) has obtained a K-Ar date for the stock of 91.8±2.6 m.y.

TABLE 1—Chemical analyses, norms, and modes of Mesozoic intrusives, and Oligocene or Miocene tuffs and flows, southern Nye County, Nevada

	1	2	3	4	5	6	7	8	9	10	11
CHEMICAL ANALYSES (WEIGHT PERCENT)											
SiO_2	67.6	69.1	72.7	67.2	66.2	58.06	75.9	73.8	59.6	59.8	67.7
Al_2O_3	15.8	15.8	15.0	16.1	15.4	17.43	13.0	13.5	16.2	16.9	15.2
Fe_2O_3	1.8	1.5	1.3	2.8	2.0	3.83	1.1	1.0	4.3	4.5	1.9
FeO	1.6	1.3	0.26	0.64	1.1	1.91	0.16	0.24	1.2	1.2	0.97
MgO	0.82	0.6	0.22	0.73	1.6	2.60	0.43	0.48	3.1	2.4	1.0
CaO	3.7	3.2	1.5	2.9	3.1	6.33	0.59	0.86	5.6	6.4	3.1
Na_2O	3.1	3.0	3.8	2.6	2.8	3.34	3.0	2.9	3.1	3.1	3.0
K_2O	3.5	3.9	4.4	4.4	3.4	2.61	4.5	4.9	1.4	3.3	3.8
H_2O^+	1.0	0.89	0.61	0.72	1.2	1.88	0.85	1.1	2.8	0.87	2.5
H_2O^-				1.3	2.4	0.97	0.41	1.0	1.6	0.64	0.32
TiO_2	0.39	0.40	0.20	0.43	0.46	0.87	0.20	0.17	0.79	0.86	0.30
P_2O_5	0.18	0.21	0.06	0.15	0.14	0.27	0.05	0.09	0.27	0.36	0.18
MnO	0.07	0.04	0.05	0.03	0.07	0.09	0.04	0.03	0.05	0.06	0.04
CO_2	0.20	0.10	<0.05	<0.05	<0.05	0.00	<0.05	<0.05	0.06	<0.05	<0.05
Total	100	100	100	100	100	100.19	100	100	100	100	100
NORMS[1] (WEIGHT PERCENT)											
Quartz	27.5	29.6	30.5	29.0	29.4	13.6	39.9	36.6	21.3	14.6	28.9
Orthoclase	21.0	23.3	26.1	26.5	20.9	15.8	26.9	29.6	8.7	20.0	23.1
Albite	26.6	25.6	32.3	22.4	24.6	29.0	25.6	25.0	27.4	26.5	26.1
Anorthite	17.4	14.6	7.1	13.7	15.0	25.5	2.6	3.8	27.2	22.7	14.6
Corundum	0.6	1.3	1.4	2.2	1.9	....	2.3	2.1	0.1	....	1.0
Wollastonite	....	....	....	....	....	2.1	....	....	....	3.0	....
Enstatite	2.1	1.5	0.6	1.9	4.1	6.7	1.1	1.2	8.1	6.0	2.6
Ferrosilite	1.0	0.6	....	....	....	....	....	....	....	....	....
Magnetite	2.6	2.2	0.4	0.9	2.5	4.0	0.1	0.4	1.8	1.6	2.5
Hematite	....	....	1.0	2.2	0.3	1.2	1.1	0.8	3.2	3.5	0.3
Ilmenite	0.8	0.8	0.4	0.8	0.9	1.7	0.4	0.3	1.6	1.7	0.6
Apatite	0.4	0.5	0.1	0.4	0.3	0.7	0.1	0.2	0.7	0.9	0.4
Total	100	100	100	100	100	100	100	100	100	100	100
MODES (VOLUME PERCENT)											
Groundmass	....	....	....	48	....	....	60	65	....	68	72
Quartz	28	28	34	18	....	....	19	15	....	....	1
Plagioclase	45	40	33	28	....	....	5	7	....	22	17
K-feldspar	16	25	....	1	....	....	11	12	....	....	....
Perthite	....	....	28	....	....	....	....	....	....	....	....
Magnetite	....	....	2	....	....	....	....	....	....	2	....
Pyroxene	....	....	....	....	....	....	....	....	....	6	....
Biotite	9	6	3	4	....	....	5	1	....	2	5
Amphibole	....	....	....	....	....	....	....	....	....	....	5
Calcite	....	....	....	1	....	....	....	....	....	....	....
Total	98	99	100	100	....	....	100	100	....	100	100

1. Granodiorite, Climax stock, average of 24 samples (Harley Barnes and others, written communication, 1963).
2. Quartz monzonite, Climax stock, average of 24 samples (Harley Barnes and others, written communication, 1963).
3. Quartz monzonite, Gold Meadows stock, average of 4 samples (Harley Barnes and others, written communication, 1963).
4. Tuff of Monotony Valley, east flank of Kawich Range, 1 mile north of Cedar Pass (E. B. Ekren and others, written communication, 1966).
5. Tuff of Monotony Valley, southeastern quarter of Jangle Ridge quadrangle, northeast of Yucca Flat (E. B. Ekren and others, written communication, 1966).
6. Milltown Andesite, collected from northwest corner of area of the andesite shown in plate 1 by Ransome (1909, p. 50, sample no. 1).
7. Tuff of White Blotch Spring, east flank of Kawich Range at Sumner Spring, 3 miles north of Cedar Pass (E. B. Ekren and others, written communication, 1966).
8. Tuff of White Blotch Spring, collected at White Blotch Spring near east county line, east of the Belted Range (E. B. Ekren and others, written communication, 1966).
9. Dacite flow, 3.5 miles northwest of Gold Reed, southern Kawich Range (E. B. Ekren and others, written communication, 1966).
10. Rhyodacite flow, 2.5 miles southeast of Mellan (E. B. Ekren and others, written communication, 1966).
11. Rhyodacite flow, northwest corner of Belted Range (E. B. Ekren and others, written communication, 1966).

[1]Analyses recalculated to 100 percent minus H_2O and CO_2.

MESOZOIC OR TERTIARY MEGABRECCIA

Megabreccias that are virtually monolithologic, being composed almost entirely of dolomite and limestone from the Bonanza King Formation of Cambrian Age, occur in several parts of southern Nye County. At the south end of the county, west of Pahrump Valley, three megabreccia masses, the largest 2 miles long and .5 to 1 mile wide, overlie the Stirling Quartzite and are overlapped by recent alluvium. The masses consist of thoroughly brecciated, dark-gray, partly cherty limestone. Bedding, visible in part of the megabreccia, dips moderately north. Five miles to the north is a southeast-trending ridge of Bonanza King Formation from which rock of the megabreccia probably slid. A small hill of Bonanza King megabreccia, surrounded by alluvium, occurs 1 mile north of the ridge.

Several miles southeast of Bare Mountain, a flat-lying mass of Bonanza King dolomitic megabreccia, 2 miles long and 1 mile wide, overlies Tertiary basalt and the Timber Mountain Tuff of early Pliocene Age. The probable source of the landslide megabreccia is a ridge of Bonanza King Formation in a flat thrust plate 3 miles to the northwest; another small mass of dolomitic megabreccia crops out in the alluvium just east of the ridge.

Several small exposures of dolomitic megabreccia of the Bonanza King Formation, overlain by Tertiary basalt and tuff, crop out 11 to 13 miles southwest and 11 miles south of Beatty near the southwest boundary of the county; and 9 miles west of Beatty two small lenses of similar dolomitic megabreccia are interbedded in the Paintbrush and Timber Mountain Tuffs (megabreccias not shown on pl. 1). Cornwall and Kleinhampl (1964, p. J6–J7) described the monolithologic megabreccias in this area and postulate that they slid eastward as landslides off the front of a northeastward-moving thrust plate during the Cretaceous and Tertiary. The fact that some of the megabreccias overlie the Timber Mountain Tuff (age 10.8 to 11.4 m.y.) shows that they are at least as young as early Pliocene, and the oldest megabreccias must be contemporaneous or younger than the period of thrust faulting and folding, believed to have occurred mainly in the Cretaceous.

The conclusion that the megabreccias in southern Nye County are landslide masses rather than tectonic breccias along the soles of thrust faults agrees with the findings of Longwell (1951), Kupfer (1960), and other geologists on similar breccias elsewhere in the Great Basin.

TERTIARY ROCKS

Tertiary volcanic and associated tuffaceous clastic rocks cover a large part of the central and northern portion of southern Nye County. A conglomeratic unit commonly occurs at the base of the Tertiary sequence, which unconformably overlies Paleozoic and Precambrian rocks. Pyroclastic tuffs and welded tuffs (ash flows) are most abundant but lava flows and intrusives are also common. A composite section of all the units exceeds 20,000 feet in thickness, and in the Silent Canyon caldera in the northeastern part of the Pahute Mesa, a drill hole penetrated 14,000 feet of tuffs and lavas without reaching a basement of Paleozoic or other older rocks (P. P. Orkild and K. A. Sargent, written communication, 1967). These vast quantities of volcanic material were apparently derived from 9 or 10 centers, some of which, in part at least, are calderas. The locations of possible centers (see pl. 1 and fig. 2) are discussed under Structure.

The Tertiary volcanic rocks, in which underground nuclear experiments are carried out by the Atomic Energy Commission on the Nevada Test Site, have been mapped and studied in great detail as part of a special project by a group of geologists of the U.S. Geological Survey. A number of the units have been given formal or informal names. In this report the author has attempted to summarize the large volume of available data, both published and unpublished, and to combine units where feasible in order to limit cartographic units on the composite geologic map.

The Tertiary volcanic rocks in the eastern part of the Test Site were named the Oak Spring Formation by Johnson and Hibbard (1957, p. 367–369). In 1957 Hansen and others (1963, p. A7) divided the Oak Spring Formation at Rainier Mesa into eight numbered units. Hinrichs and Orkild (1961, p. D96) divided the formation in the Yucca Flat area into a lower unnamed member and seven members, named, from lower to upper: Tub Spring, Grouse Canyon, Survey Butte, Stockade Wash, Topopah Spring, Tiva Canyon, and Rainier Mesa. Poole and McKeown (1962, p. C60–C62) raised the rank of the formation to the Oak Spring Group, naming the lower three members of Hinrichs and Orkild the Indian Trail Formation and their upper five the Piapi Canyon Formation. Orkild (1965, p. A44–A45) further revised nomenclature of Tertiary rocks on the Test Site by abandoning the term Oak Spring Group, leaving the Indian Trail Formation unchanged, and raising the Piapi Canyon Formation to a group composed of the newly named Paintbrush and Timber Mountain Tuffs.

TITUS CANYON FORMATION

The basal Tertiary unit along the southwest edge of the county, southwest of Beatty, is the Titus Canyon Formation. It was first named and mapped by Stock and Bode (1935), who established its type locality as exposures in Titus Canyon, north of Leadfield, Amargosa Range, Inyo County, Calif. The formation crops out for 30 miles in a narrow, almost continuous belt along the State line. Patches of the Titus Canyon Formation, too small to be shown on the map, also crop out 6 miles north of Beatty, where it unconformably overlies the Carrara Formation. In the first-mentioned belt along the State line, the Titus Canyon Formation unconformably overlies the Wood Canyon, Zabriskie, and Carrara Formations and is overlain, partly unconformably, by Tertiary tuffs, welded tuffs, lava flows, and tuffaceous sedimentary rocks.

The Titus Canyon Formation (Cornwall and Kleinhampl, 1964, p. J7–J8) consists of terrestrial conglomerate and interbedded sandstone, siltstone, limestone, and tuff and increases over a short distance from a featheredge to 3,000 feet. Conglomerate predominates in the lower half, but tuffaceous, arkosic sandstone, siltstone, and air-fall tuff increase in abundance upward. The conglomerate, reddish brown in color, contains highly polished, well-rounded pebbles, cobbles, and boulders of black and gray chert, white and brown quartzite, and gray to black limestone and dolomite in arkosic matrix. Reddish-brown to gray, muddy limestone, as much as 100 feet thick, occurs near the base, middle, and top of the formation.

The Titus Canyon Formation has been dated as early Oligocene (Stock and Bode, 1935, p. 577–578) on the basis of mammalian fossils, including the horse *Mesohippus,* two titanotheres, hydracodont rhinoceros, artiodactyls, and a sciuromorph rodent, from mudstones in the lower part of the formation.

TUFF OF MONOTONY VALLEY

The oldest volcanic rock that is specifically distinguished on the southern Nye County geologic map is the tuff of Monotony Valley. This tuff, described by E. B. Ekren and others (written communication, 1966), is late Oligocene or early Miocene and yielded a K-Ar date on biotite of 26.1 ± 0.7 m.y. Although the tuff is probably the most widespread Tertiary volcanic unit, covering most of the county north and east of Pahute Mesa, it is not conspicuous on the map because it is extensively overlain by younger units. It crops out in the northern Belted Range, southern Kawich Range, and western Cactus Range, as well as at the south end of the Quinn Canyon Range, where it is not shown separately on the map. It consists of a sequence of ash flows and has an average thickness of somewhat more than 1,000 feet. The vent area of the tuff is not known but probably is northeastward of the map area.

The tuff of Monotony Valley weathers reddish or greenish brown and forms gentle slopes and valleys because of its soft-weathering characteristics. The tuff is densely welded, completely devitrified, and partly altered. It contains 45 to 60 percent phenocrysts consisting of about 20 percent quartz (2 to 7 mm), 15 percent biotite (2 to 5 mm), 10 percent K-feldspar, and 50 percent plagioclase, plus 5 percent pseudomorphs of pyroxene and hornblende. Where hydrothermally altered, the mafic minerals are partly replaced by chlorite, calcite, and iron oxide. In the northern Belted Range, altered tuff of Monotony Valley was extensively prospected for gold and silver around 1940. The two chemical analyses and norms of the tuff of Monotony Valley given in table 1 (nos. 4 and 5) show that it ranges in composition from rhyodacite to quartz latite.

TUFFS OF ANTELOPE SPRINGS

The tuffs of Antelope Springs are a rhyolitic to rhyodacitic sequence of moderately to intensely welded ash flows having a composite thickness of 5,600 feet that crop out in the Cactus Range, the Mount Helen area, and the northern Belted Range (E. B. Ekren and others, written communication, 1966). Most of the rocks have been hydrothermally altered and are generally drab with greenish casts due to secondary sericite, chlorite, and epidote in both phenocrysts and matrix. Phenocrysts make up 15 to 40 percent of the rock and consist of plagioclase, K-feldspar, quartz, and biotite, present more or less in that order of decreasing abundance but with reversals in some units.

TUFF OF WHITE BLOTCH SPRING

The tuff of White Blotch Spring crops out in most of the hills and ranges north of Pahute Mesa and covers a large part of the Kawich and Reveille Ranges. It is a rhyolitic ash-flow sequence that ranges in thickness from 800 to 3,000 feet. The sequence is commonly densely welded throughout, giving a cliff-forming, monolithic appearance with rude columnar jointing. The rocks range from light brown and gray to medium and reddish brown and commonly contain conspicuous light-gray to white, flattened pumice fragments which give the rock a prominent eutaxitic structure. Locally there is a black vitrophyre or glass zone at the base as much as 50 feet thick. Lithic fragments, locally abundant in the lower part, are of tuff of Monotony Valley, tuffs of Antelope Springs, dacite, granite, and Paleozoic rocks.

The tuff of White Blotch Spring consistently contains about 30 percent phenocrysts consisting of prominent quartz phenocrysts averaging 3 mm in diameter, sanidine, plagioclase, and biotite. The sanidine and biotite phenocrysts also tend to be large and prominent. Minor accessory minerals are magnetite, apatite, zircon, and allanite.

In most of the area the tuff of White Blotch Spring consists of one intensely welded cooling unit, but at White Blotch Spring two cooling units, each about 400 feet thick, have been recognized (E. B. Ekren and others, written communication, 1966). Slight mineralogic differences from range to range and marked differences in the type and abundance of lithic fragments suggest that the tuff was extruded from more than one volcanic center.

The two chemical analyses with norms of the tuff of White Blotch Spring given in table 1 (nos. 7 and 8) show it to be rhyolitic. K-Ar dates from samples collected by the author in the central Kawich Range are 21.1 m.y. for biotite and 21.9 m.y. for sanidine, as determined by R. W. Kistler; possible analytical error is 3.0 percent.

TUFF AND TUFFACEOUS SEDIMENTARY ROCKS

Ash-fall tuff, tuffaceous sedimentary rocks, and unnamed nonwelded ash flows are scattered widely throughout the county. Such units are found near the south, southeast, and southwest margins of the county, also in the Bullfrog Hills, south and east of Mount Helen, the southern Kawich and eastern Reveille Ranges, and northwest of Mud Lake. The ash-fall (also called air-fall) tuffs and tuffaceous sedimentary rocks are most abundant near the base of the Tertiary volcanic sequence in the Oligocene and Miocene units and near the top in the Pliocene rocks.

The rocks range in thickness from a few feet to more than 2,000 feet and consist of tuffaceous conglomerate, sandstone, and siltstone, and interbedded ash-fall and minor ash-flow tuffs. The tuffs are partly bedded, partly massive. All these rocks are commonly light colored, ranging from white or yellow to brown or green. Alteration by groundwater or hydrothermal solutions is widespread; zeolitization (clinoptilolite) is most common, but locally there is intense opalization, silicification, and argillization.

MILLTOWN ANDESITE

The Milltown Andesite crops out along the west margin of southern Nye County, 8 to 12 miles south of Mud Lake. It was named by Ransome (1909, p. 47) for exposures at Milltown, 1 mile east of Goldfield, and consists of a sequence of andesitic flows with associated andesitic tuffs. Ransome estimated the total thickness of the formation to be 600 to 800 feet. The andesites range in color from nearly black to light gray; they contain abundant phenocrysts of plagioclase (An_{45-65}) as much as 3 mm long, smaller crystals of hornblende, augite, magnetite, and sparse biotite and apatite. The groundmass is a fine-grained aggregate of the same minerals. The andesites commonly are moderately to intensely altered, mainly to chlorite and sericite.

A chemical analysis and norm of the Milltown Andesite presented by Ransome (1909, p. 50–51) is given in table 1 (no. 6). The sample analysed was collected in Nye County near the county line in the northwest corner of the area of Milltown Andesite shown on plate 1. A K-Ar age of 21.5±0.5 m.y. for hornblende from the Milltown Andesite (Silberman and McKee, 1972) makes the formation Miocene in age.

DACITE AND RHYODACITE

Dacite and rhyodacite flows and intrusives that are younger than the tuff of White Blotch Spring and older than the Fraction Tuff are widespread in the northern part of southern Nye County, north of Pahute, as illustrated on the geologic map (pl. 1). These rocks are particularly prominent in the northern Belted Range, Reveille Valley, southern Kawich Range, southern Cactus Flat, Cactus Range, and the Goldfield Hills, south of Mud Lake. The sequence includes minor, localized units of quartz latite, andesite, and basalt. The dacite at Goldfield, described below, has a K-Ar age on biotite of 21.6±0.5 m.y. (Silberman and McKee, 1972). The lavas are most widespread and range in thickness from less than 50 feet to 3,000 feet (E. B. Ekren and others, written communication, 1966).

These rocks of intermediate composition, whether extrusive or intrusive, are similar petrographically and chemically, and range in color from nearly black to light gray, weathering to shades of brown. The rocks are porphyritic, containing 30 to 40 percent phenocrysts. Plagioclase phenocrysts (andesine-labradorite) are most abundant; biotite, hornblende, augite, and hypersthene are present in variable amounts; quartz and K-feldspar are sparse. The groundmass, glassy to fine-grained crystalline, is composed of plagioclase, K-feldspar, iron oxides, and biotite. The mafic minerals are in part altered to chlorite, calcite, and iron oxides.

Chemical analyses, norms, and modes of representative units of this intermediate series, obtained by E. B. Ekren and others (written communication, 1966) are given in table 1 (nos. 9, 10, 11). Most of the rocks, including the so-called dacite at Goldfield, are rhyodacites by chemical composition.

Dacite at Goldfield

The dacite at Goldfield, in which most of the gold-silver deposits occur, extends eastward into southern Nye County approximately 10 miles south of Mud Lake. Part of the dacite at Goldfield is intrusive, but to the east in Nye County, it is mainly extrusive in flat-lying flows with a thickness of as much as 700 feet. The dacite is typically dark gray with conspicuous, 5- to 10-mm phenocrysts of plagioclase (An_{45-55}), less abundant hornblende, augite, and pigeonite, and biotite in varying proportions. Phenocrysts of quartz are sparse and inconspicuous but are diagnostic and are critical for distinguishing the dacite from the Milltown Andesite, especially where the rocks are altered. The groundmass is fine grained.

Chemical analyses and norms are shown in table 2 (nos. 1, 2). As indicated by these analyses, the dacite of Ransome (1909, p. 54–61) is actually a rhyodacite. A K-Ar determination gives an age of 21.6±0.5 m.y. on biotite from the dacite, and of 20.8±0.7 m.y. on hornblende (Silberman and McKee, 1972).

DACITE VITROPHYRE

A rhyodacite welded tuff that was termed the dacite vitrophyre by Ransome (1909, p. 61) crops out 10 miles south of Mud Lake in the southeastern part of the Goldfield district. The welded-tuff sequence of thin ash-flows is nearly flat-lying, overlies the Milltown Andesite, and appears to overlie the dacite. The tuff is light gray or white, partly with a tint of pink or green, and speckled with abundant 1- to 2-mm biotite phenocrysts. Other phenocrysts are plagioclase (An_{60}), sanidine, quartz, augite, pigeonite, iron oxides, and hornblende. Total phenocryst content is approximately 50 percent (see mode, table 2, no. 3).

A chemical analysis is given in table 2 (no. 3). The dacite vitrophyre welded tuff is very similar to the fluidal

TABLE 2—Chemical analyses, norms, and modes of Miocene and Pliocene tuffs, flows, and intrusives, southern Nye County, Nevada

	1	2	3	4	5	6	7	8	9	10
CHEMICAL ANALYSES (WEIGHT PERCENT)										
SiO_2	62.6	59.95	59.99	60.58	63.5	53.0	73.8	70.2	74.05	73.6
Al_2O_3	14.3	15.77	16.14	17.80	16.7	17.4	12.6	14.8	11.85	13.5
Fe_2O_3	3.8	3.34	4.42	3.35	4.8	5.7	0.51	1.8	0.44	1.6
FeO	1.1	2.34	0.13	1.08	0.32	2.6	0.18	0.49	0.27	0.21
MgO	2.0	2.73	1.51	1.08	0.33	4.5	0.27	0.55	0.21	0.49
CaO	4.4	5.84	4.17	4.10	2.1	8.2	0.66	2.1	0.74	1.8
Na_2O	2.7	3.07	3.04	4.27	3.4	3.1	3.0	3.2	3.19	3.0
K_2O	3.4	2.52	2.82	4.59	6.8	2.0	4.6	4.4	4.50	4.5
H_2O^+	2.8	2.0	4.06	0.53	0.68	1.2	3.3	1.1	3.59	0.91
H_2O^-	0.9	0.95	3.35	0.60	0.26	0.75	0.71	0.45	0.58	0.31
TiO_2	0.96	0.82	0.64	1.18	0.78	1.0	0.11	0.32	0.12	0.24
P_2O_5	0.32	0.26	0.24	0.33	0.26	0.45	0.00	0.08	0.00	0.08
MnO	0.07	0.09	0.05	0.09	0.02	0.14	0.06	0.02	0.05	0.04
CO_2	<0.05	....	....	0.05	0.11	<0.05	<0.05	<0.05	0.19	<0.05
Total	99	99.68	100.56	99.63	100	100	99.85	99.56	99.78	100.3
NORMS[1] (WEIGHT PERCENT)										
Quartz	24.1	18.2	22.6	9.4	15.4	6.6	38.6	30.3	38.1	34.9
Orthoclase	21.0	15.4	17.9	27.6	40.7	12.1	28.4	26.5	27.9	26.8
Albite	24.0	26.9	27.6	36.7	26.9	26.7	26.5	27.6	28.3	25.6
Anorthite	18.0	22.5	20.6	16.1	8.3	28.2	3.4	10.1	3.8	8.5
Corundum	....	....	1.2	....	1.2	....	1.6	1.2	0.4	0.6
Wollastonite	1.3	2.4	....	1.0	....	4.3	....	....	....	....
Enstatite	5.2	7.0	4.0	2.7	0.8	11.4	0.7	1.4	0.5	1.2
Ferrosilite	....	0.4	....	....	....	....	....	....	....	....
Magnetite	1.1	5.0	....	0.4	....	6.5	0.5	0.7	0.7	0.1
Hematite	3.2	....	4.7	3.2	4.9	1.6	0.2	1.3	....	1.5
Ilmenite	1.9	1.6	0.4	2.3	0.7	1.9	0.2	0.6	0.2	0.5
Apatite	0.8	0.6	0.6	0.8	0.6	1.1	....	0.2	....	0.2
Sphene	....	....	....	....	0.4	....	....	....	....	....
Rutile	....	....	0.5	....	....	....	....	....	....	....
Total	100	100	100	100	100	100	100	100	100	100
MODES (VOLUME PERCENT)										
Groundmass	72	....	51.9	81.0	....	72.0	....	....	87.1	67.0
Quartz	....	....	2.5	16.9	....	....	....	....	5.7	7.9
Plagioclase	20	....	26.7	....	....	17.6	....	....	0.9	15.2
K-feldspar	....	....	0.7	....	....	....	....	....	6.2	6.6
Magnetite	1	....	2.1	1.6	....	1.2	....	....	....	....
Pyroxene	3	....	2.8	0.5	....	5.6	....	....	....	....
Biotite	3	....	13.0	....	....	....	....	....	0.1	2.3
Amphibole	1	....	0.3	....	....	2.2	....	....	....	....
Other	....	....	....	....	....	1.4	....	....	....	1.0
Total	100	....	100	100	....	100	....	....	100	100

1. Rhyodacite flow, equivalent to the dactite of Ransome (1909), eastern Goldfield Hills, 9 miles south of Mud Lake (E. B. Ekren and others, written communication, 1966).
2. Dacite intrusive rock, Goldfield district (Ransome, 1909, p. 56, sample no. 1). The analysis shows that this is a rhyodacite.
3. Dacite vitrophyre ash flow, collected by Ransome near Nye County line, 11 miles south of Mud Lake (Ransome, 1909, p. 61–63). The tuff is actually a rhyodacite.
4. Quartz latite flow, 6 miles northwest of Beatty (Cornwall and Kleinhampl, 1964, table 2, no. 17).
5. Quartz latite flow, south flank of Mount Helen (E. B. Ekren and others, written communication, 1966).
6. Andesite dike, northwest flank of Cactus Range (E. B. Ekren and others, written communication, 1966).
7. Fraction Tuff, southern Kawich Range, 5 miles northwest of Gold Reed (E. B. Ekren and others, written communication, 1966).
8. Fraction Tuff, southern Kawich Range, 5 miles south of Cedar Pass (E. B. Ekren and others, written communication, 1966).
9. Rhyolite dome, 5 miles northeast of Beatty (Cornwall and Kleinhampl, 1964, table 2, no. 15).
10. Rhyolite intrusive rock, northwestern part of Cactus Range (E. B. Ekren and others, written communication, 1966).

[1]Analyses recalculated to 100 percent minus H_2O and CO_2.

dacite at Goldfield, and, like that dacite, is actually a rhyodacite. Ransome (1909, p. 61–64) noted the chemical similarity and suggested that the two units are of the same age. For this report R. W. Kistler obtained a K-Ar age of 21.1±0.6 m.y. from a biotite fraction of the dacite vitrophyre tuff. Biotite from the fluidal dacite yielded an age of 21.6±0.5 m.y., and hornblende from the dacite 20.8±0.7 m.y.; the two rocks are therefore indeed approximately contemporaneous.

QUARTZ LATITE

Quartz latite flows and intrusives are prominent on and around Mount Helen, at the north end of the Kawich Range, the south end of the Quinn Canyon Range, and northwest and west of Beatty. The larger bodies are mostly flows, but the quartz latite in the Kawich Range is intrusive, and in the other areas there are associated intrusive stocks of quartz latite.

The quartz latites range in color from black to reddish brown and various shades of gray. Phenocrysts are common to abundant, partly glomeroporphyritic, with clusters of feldspar crystals particularly prominent. The groundmass is fine grained to aphanitic; some flows have a vitrophyre zone at the base. Flow layering is common.

The feldspar phenocrysts range in size to 2 cm or more in diameter; the other phenocrysts are commonly less than 5 mm. Plagioclase, ranging from oligoclase to andesine, is abundant, as are biotite, anorthoclase and/or sanidine, and magnetite. The plagioclase commonly is partly replaced by anorthoclase or sanidine. Phenocrysts of quartz, hornblende, pigeonite, augite, and hematite are present in small to moderate amounts in many bodies. Zircon, rutile, zoisite, and sphene have been identified in the groundmass.

Chemical analyses, norms, and modes of a quartz latite flow approximately 6 miles northwest of Beatty and of another on the south flank of Mount Helen are given in table 2 (nos. 4, 5). The quartz latites at Mount Helen are very high in potash, which ranges from 6.8 to 9.2 percent. E. B. Ekren and others (written communication, 1966) state that the plagioclase has been largely replaced by K-feldspar and suggest that the high potash content is probably due to hydrothermal or deuteric alteration.

The quartz latites at Mount Helen are considered by E. B. Ekren and others (written communication, 1966) to be intermediate in age between the tuff of White Blotch Spring and the Fraction Tuff, whose ages are, respectively, 21.5 and 17.8 m.y. The quartz latite near Beatty overlies, and is probably only slightly younger in age than, the Timber Mountain Tuff, whose upper unit, the Ammonia Tanks Member, has an age of approximately 11 million years.

COARSE-GRAINED RHYOLITE PORPHYRY

Coarse-grained rhyolite porphyry crops out in two areas in the northern Cactus Range, as shown on plate 1. According to E. B. Ekren and others (written communication, 1966), the tuff of White Blotch Spring is the youngest rock intruded by this granite. East-west- and northwest-trending similar-appearing granitic dikes, as much as 6 miles long, crop out farther south in the Cactus Range. Enclosing tuffs are altered for several feet along the granite contacts.

The granite porphyry is light brown to orange brown. It is made up of 30 to 75 percent of phenocrysts, including alkali feldspar crysts as long as 2 cm, smaller crysts of plagioclase and quartz, and minor amounts of biotite and magnetite. The groundmass is aphanitic and consists mostly of equigranular quartz and alkali feldspar.

ANDESITE

Along the west edge of the county 23 to 25 miles northwest of Beatty are two areas of andesite flows interbedded in welded tuff. The rock contains phenocrysts up to 2 mm long of labradorite (An_{53}), partly glomeroporphyritic, and small phenocrysts of magnetite and pigeonite. There is a fine-grained trachytic groundmass plus a little calcite.

In the Goldfield Hills, 7 to 13 miles southwest of Mud Lake, are dikes and flows of andesite and trachyandesite. The bodies lying 10 to 13 miles south of Mud Lake were named the Chispa Andesite by Ransome (1909, p. 64–65); they are flows. The Chispa Andesite contains phenocrysts up to 2 mm long of labradorite (An_{65}), augite, pigeonite, magnetite, and a little olivine altered to antigorite, iddingsite, and bowlingite.

Trachyandesite dikes 7 to 9 miles southwest of Mud Lake contain phenocrysts up to 1 mm long of andesine (An_{40}) and labradorite (An_{53}) and crysts of pigeonite, augite, a little hypersthene, magnetite, and hematite. The groundmass is very fine grained, trachytic, and consists of abundant plagioclase plus pyroxene and magnetite.

E. B. Ekren and others (written communication, 1966) report that andesite or andesitic basalt (not shown on map) underlies Mount Helen and that dikes and plugs of andesite also surround the northern part of the Cactus Range. The rock is dark gray to black, is faintly flow layered, and contains about 30 percent phenocrysts consisting of sodic labradorite, augite, hornblende, iddingsite, and magnetite in a hyalopilitic groundmass. A chemical analysis of an andesite dike on the northwest flank of the Cactus Range is given in table 2 (no. 6).

FRACTION TUFF

The Fraction Tuff was first described by Spurr (1905), who named it the Fraction Dacite Breccia for exposures south of Tonopah. Nolan (1930) noted that the tuff is not dacitic and renamed it the Fraction Breccia. Ekren and others (1967) have renamed it the Fraction Tuff because it is a sequence of ash-flow tuffs with a large content of lithic fragments that give it the appearance of a volcanic breccia.

Ekren and others (1967) report that the Fraction Tuff extends across most of the map area north of Pahute Mesa; it is 1,000 feet thick in the Belted Range, 7,200 feet in the southern Kawich Range, and 745 feet

(Spurr, 1905) near Tonopah. They suggest that the great thickness of the tuff in the southern Kawich Range is due to subsidence of a caldera concomitant with extrusion of the tuff, and that this is the source area. They report that the sequence here is densely welded in what they interpret to be a compound cooling unit, whereas in the Belted Range two cooling units appear to be present, and in the northern Cactus Range three cooling units are present in a section that is tentatively correlated with the Fraction Tuff. The Fraction Tuff is pinkish gray, pale brown, and brown with black vitrophyre near the base of cooling units.

The abundance and types of lithic fragments are diagnostic of this tuff. Some units contain as much as 50 percent lithic fragments. In the southern Kawich Range, the lower part of the section contains only 5 to 15 percent lithic fragments, but above the middle of the section, lithic fragments constitute 20 to 30 percent of the rock. These fragments, in order of decreasing abundance, are: intermediate lavas, gneiss, schist, granite, and Paleozoic sedimentary rocks. It is thus evident that they were derived from the earth's crust during ascent of the Fraction magma. The fragments range in size from less than 2 inches to 10 inches, rarely to as much as 3 feet.

Phenocryst content of the tuff ranges from about 20 to 30 percent, rarely as much as 50 percent, and is variable, with plagioclase abundant, K-feldspar moderately abundant to abundant, and quartz and biotite slightly to moderately abundant. Chemical analyses and norms given in table 2 (nos. 7, 8) show a composition of rhyolite or quartz latite close to the rhyolite field. Biotite separated from the Fraction Tuff of the southern Kawich Range gives a K-Ar age of 17.8 ± 0.5 m.y. (middle Miocene) (E. B. Ekren and others, written communication, 1966).

RHYOLITE

Rhyolite flows and intrusions crop out in a number of areas in the middle and northern parts of southern Nye County, as shown on plate 1. These rocks range in age from younger than the Milltown Andesite and tuffs of Antelope Springs to slightly younger than the Timber Mountain Tuff.

The rhyolite bodies are commonly flow layered, partly vitrophyric (glassy), and partly felsitic. Colors commonly range from black to gray in the vitrophyre, and from gray to purple or reddish brown in the felsite. The vitrophyre is usually perlitic and the felsite is fine grained to aphanitic, partly spherulitic. Phenocrysts, commonly as much as 5 mm long, make up 5 to 45 percent of the rock; they consist of quartz, sanidine, oligoclase or andesine, biotite, and minor magnetite, hematite, hornblende, sphene, and allanite.

Two representative chemical analyses of these rocks are given in table 2 (nos. 9, 10). Some of the rocks shown as rhyolite on plate 1 are probably quartz latite. Analysis 9 is from a rhyolite flow or intrusion sampled by the author 5 miles northeast of Beatty. A K-Ar determination by R. W. Kistler (written communication, 1964) on biotite from this rock yielded an age of 11.3 m.y., or early Pliocene. The extensive rhyolite flows southeast of Timber Mountain are chemically similar and also early Pliocene in age.

The samples of rhyolite obtained by E. B. Ekren and others (written communication, 1966) represent a type called the rhyolite of O'Brien's Knob, widespread in the northern part of southern Nye County. These rocks commonly have abundant phenocrysts. Sample no. 10, typical of this group with 33 percent phenocrysts, is shown in table 2. E. B. Ekren and others (written communication, 1966) have suggested that the rhyolite of O'Brien's Knob is genetically related to the chemically and petrographically similar Fraction Tuff. If it is, then the age should be close to that of the Tuff, that is, about 18 m.y.

BELTED RANGE TUFF

A thick sequence of volcanic rocks that crops out in a large area north and west of the Nevada Test Site in southern Nye County has been named the Belted Range Tuff by Sargent and others (1965). The formation includes the Tub Spring and Grouse Canyon Members and local informal units. The Tub Spring and Grouse Canyon Members are also members of the Indian Trail Formation (Poole and McKeown, 1962), which has been restricted to the Test Site.

The Belted Range Tuff crops out in the southern Belted and Kawich Ranges and on the margins of Pahute Mesa. In the Silent Canyon caldera under Pahute Mesa, drill holes have penetrated the Belted Range Tuff 5,000 to 6,000 feet below outcrops of the same tuff on the rim of the caldera. At most places the Belted Range Tuff is unconformably underlain by local tuff and lava units and is unconformably overlain by tuff, lava, the Paintbrush Tuff, or the Thirsty Canyon Tuff.

The Belted Range Tuff as described by Sargent and others (1965) and E. B. Ekren and others (written communication, 1966) consists mostly of comenditic (peralkaline soda-rhyolite) ash flows, ash-fall tuffs, and reworked tuffs. Two chemical analyses are given in table 3 (nos. 1, 2). The Tub Spring and Grouse Canyon Members are compound cooling units of ash-flow tuff. Soda-rich sanidine is the most abundant phenocryst mineral; sodic iron-rich clinopyroxene, fayalite, zircon, and apatite are ubiquitous minor phenocryst minerals. Quartz phenocrysts are abundant in the Tub Spring Member but are very sparse in the Grouse Canyon Member. Deuteric vapor-phase sodic amphibole is common, particularly in the ash-flow tuffs. The rocks range in color from gray, bluish gray, and green to brown or red.

The Belted Range Tuff is partly correlative with the Indian Trail Formation and is thus of Miocene Age (Orkild, 1965, p. A51).

INDIAN TRAIL FORMATION

The Indian Trail Formation was named by Poole and McKeown (1962, p. C60–C61) for a sequence of ash-flow and ash-fall tuffs that crop out in the Nevada Test Site around Yucca Flat and north of Jackass Flats. As

TABLE 3—Chemical analyses, norms, and modes of Miocene and Pliocene ash-flow tuffs, southern Nye County, Nevada

	1	2	3	4	5	6	7	8	9	10
CHEMICAL ANALYSES (WEIGHT PERCENT)										
SiO_2	72.0	76.0	74.7	69.02	76.0	75.02	67.12	76.5	68.5	73.6
Al_2O_3	13.0	11.0	12.5	15.60	13.0	12.56	15.25	13.0	16.0	12.2
Fe_2O_3	2.6	2.1	0.80	1.03	0.81	0.99	1.94	0.5	1.5	0.48
FeO	0.5	0.4	0.16	0.18	0.17	0.00	0.00	0.2	0.7	0.28
MgO	0.4	0.35	0.17	0.25	0.20	0.13	0.41	0.15	0.8	0.16
CaO	1.0	0.5	1.1	0.94	0.12	0.78	2.02	0.6	1.7	0.57
Na_2O	4.4	4.3	3.8	4.36	4.3	4.34	4.27	3.6	4.5	3.0
K_2O	5.0	4.7	4.9	5.93	4.7	4.74	5.69	4.8	5.2	4.2
H_2O^+	0.9	0.5	0.51	0.31	0.68	0.36	0.51	0.5	0.5	3.9
H_2O^-	....	....	0.17	0.22		0.18		....	....	0.66
TiO_2	0.35	0.15	0.10	0.41	0.13	0.15	0.44	0.15	0.5	0.11
P_2O_5	0.10	0.02	0.00	0.07	0.02	0.02	0.07	0.05	0.2	0.00
MnO	0.15	0.07	0.09	0.08	0.12	0.10	0.11	0.06	0.08	0.07
CO_2	0.5	0.1	0.37	0.01	<0.05	0.43	0.94	0.1	0.1	0.05
Total	101	100	99	99.31	100.3	99.80	99.46	100	100	99
NORMS[1] (WEIGHT PERCENT)										
Quartz	25.7	33.3	33.08	19.30	32.6	30.8	17.1	36.0	18.2	40.8
Orthoclase	29.7	27.9	29.58	35.45	27.9	28.3	34.6	28.4	30.9	26.2
Albite	37.4	30.6	32.84	37.16	36.6	37.2	37.1	30.6	38.2	26.8
Anorthite	1.0	....	2.64	3.86	0.5	0.8	5.8	2.7	7.2	3.0
Corundum	....	....	....	0.65	0.7	....	....	1.0	0.4	1.8
Wollastonite	1.4	1.0	....	....	....	1.2	1.2	....	....	....
Enstatite	1.0	0.9	0.43	0.63	0.5	0.3	1.0	0.4	2.0	0.4
Ferrosilite	....	0.4	....	....	....	....	....	....	....	0.1
Acmite	....	5.3	....	....	....	....	....	....	....	....
Magnetite	1.1	0.4	0.53	....	0.6	....	....	0.4	1.1	0.7
Hematite	1.9	....	0.45	1.95	0.4	1.0	2.0	0.2	0.8	....
Ilmenite	0.7	0.3	0.19	0.56	0.2	0.2	0.2	0.3	1.0	0.2
Apatite	0.2	....	....	0.17	....	....	0.2	0.1	0.5	....
Sphene	....	....	....	....	....	0.1	0.8	....	....	....
Rutile	....	....	....	0.12	....	....	....	....	....	....
Total	100	100	100	100	100	100	100	100	100	100
MODES (VOLUME PERCENT)										
Groundmass	....	....	97.8	83.9	....	94.7	....	....	....	....
Quartz	....	....	....	trace	....	0.1	....	....	....	....
Plagioclase	....	....	1.2	5.1	....	....	....	....	....	....
K-feldspar	....	....	0.9	9.6	....	4.3	....	....	....	....
Perthite	....	....	....	....	....	....	....	....	....	....
Magnetite	....	....	trace	0.5	....	0.1	....	....	....	....
Pyroxene	....	....	....	0.2	....	....	....	....	....	....
Biotite	....	....	trace	0.7	....	....	....	....	....	....
Amphibole	....	....	....	trace	....	0.1	....	....	....	....
Xenoliths	....	....	....	....	....	0.7	....	....	....	....
Total	....	....	100	100	....	100	....	....	....	....

1. Grouse Canyon Member of the Belted Range Tuff, average of a number of analyses (E. B. Ekren and others, written communication, 1966).
2. Tub Spring Member of the Belted Range Tuff, average of a number of analyses (E. B. Ekren and others, 1966, written communications, 1966).
3. Rhyolitic lower part of Topopah Spring Member of the Paintbrush Tuff, 5 miles northwest of Lathrop Wells (Lipman and others, 1966, table 2).
4. Quartz latitic capping of Topopah Spring Member of the Paintbrush Tuff, Shoshone Mountain (Lipman and others, 1966, table 2).
5. Yucca Mountain Member of the Paintbrush Tuff, collected at the northeastern edge of Yucca Mountain (Lipman and Christiansen, 1964, table 1, no. 2).
6. Rhyolitic lower part of Tiva Canyon Member of the Paintbrush Tuff, north end of Bare Mountain (Cornwall and Kleinhampl, 1964, table 2, no. 6).
7. Quartz latitic upper part of Tiva Canyon Member of the Paintbrush Tuff, Spring Canyon, Yucca Flat area (Harley Barnes and others, written communication, 1963).
8. Rhyolitic lower part of Timber Mountain Tuff cooling unit, average of a number of analyses (E. B. Ekren and others, written communication, 1966).
9. Quartz latitic upper part of Timber Mountain Tuff cooling unit, average of a number of analyses (E. B. Ekren and others, written communication, 1966).
10. Tuff of Tolicha Peak, collected 6 miles south of Mount Helen (E. B. Ekren and others, written communication, 1966).

[1]Analyses recalculated to 100 percent minus H_2O and CO_2.

mentioned above, the Tub Spring and Grouse Canyon Members of the Belted Range Tuff are also members of the Indian Trail Formation, and in the latter formation are underlain by a lower member of related ash-flow and ash-fall tuffs that fill hollows in a deeply eroded surface of pre-Tertiary rocks. The formation averages about 1,000 feet thick, with a maximum thickness of 1,900 feet at the north end of Yucca Flat.

The Tub Spring and Grouse Canyon Members are similar to the same units in the Belted Range Tuff described above. The lower member consists of rhyolitic tuffs and lava, tuffaceous siltstone and sandstone, and a little olivine basalt. The tuffs consist mainly of glass shards and pumice, mostly zeolitized, with phenocrysts of feldspar, quartz, and accessory minerals.

Orkild (1965, p. A51) reports that K-Ar determinations by R. W. Kistler indicate an age of 16 m.y. for the base of the formation at the north end of Yucca Flat, and that the top of the formation is older than 13.5 m.y., indicating a Miocene Age.

SALYER AND WAHMONIE FORMATIONS

A Tertiary sequence of lava flows, volcanic breccia, tuff, and tuffaceous sandstone east of Jackass Flats has been named the Salyer and Wahmonie Formations by Poole and others (1965). They suggest that the volcanic rocks in these formations are comagmatic and were derived from two adjacent volcanic centers located near the middle of the outcrop area. The older Salyer Formation covers an area exceeding 300 square miles with a maximum thickness of 2,000 feet and a volume of at least 20 cubic miles. The younger Wahmonie Formation crops out in an area exceeding 500 square miles, with a maximum thickness of 3,500 feet and a volume of at least 25 cubic miles. The Salyer Formation is generally overlain by the Wahmonie, but a late thin breccia flow related to the Salyer is interlayered with tuffs of the Wahmonie near Cane Spring.

The two formations are mineralogically similar in that both are predominantly medium- to dark-gray, purple, and red in color and contain about 30 percent phenocrysts of intermediate plagioclase, hornblende, pyroxene, biotite, and magnetite. However, the Wahmonie contains primary hornblende, is less altered, and consists mainly of lava flows and related tuffs, whereas the Salyer contains primary pyroxene, secondary hornblende, is more altered, and consists of breccia flows, tuff, sandstone, and volcanic breccia. In chemical composition, the Salyer Formation ranges from latite to rhyodacite, whereas the Wahmonie Formation ranges from rhyodacite to dacite.

The Salyer and Wahmonie Formations are dated as late Miocene. R. W. Kistler (written communication, 1963) obtained K-Ar dates of 12.9 and 12.5±0.5 m.y. for lower and upper parts, respectively, of the Wahmonie; the Salyer is considered to be slightly older.

PAINTBRUSH TUFF

The Paintbrush Tuff, as defined by Orkild (1965), includes, in ascending order, the Stockade Wash, Topopah Spring, Pah Canyon, Yucca Mountain, and Tiva Canyon Members. The Paintbrush Tuff underlies the eastern part of Pahute Mesa and crops out over a wide area east, south, and west of Timber Mountain, including the Bullfrog Hills, west of Beatty.

The basal Stockade Wash Member, 0 to 300 feet thick, consists of white to light-brown, nonwelded to partly welded ash-flow tuff with orange and tan pumice fragments and less than 10 percent phenocrysts consisting of oligoclase and K-feldspar plus some quartz and biotite.

The Topopah Spring Member, 0 to 900 feet thick, is brown and reddish-purple, densely welded tuff with black vitrophyre (glass) in upper and lower parts. It is a multiple-flow compound cooling unit with internal lithophysal zones and compositional zonation from basal rhyolite with 1 percent phenocrysts to a quartz latite capping, as thick as 100 feet, that contains approximately 20 percent phenocrysts (Lipman and others, 1966). Principal phenocrysts are sanidine, oligoclase, biotite, clinopyroxene, and magnetite. The crystal-poor rhyolite has roughly equal amounts of sanidine and oligoclase and little pyroxene; in the crystal-rich quartz latite, sanidine predominates and pyroxene is conspicuous. Representative chemical analyses of the two units are given in table 3 (nos. 3, 4).

The Pah Canyon Member generally ranges in thickness from 40 to 180 feet; the maximum thickness, at Yucca Mountain, is 300 feet. It is light-gray to light-brown, partly to densely welded tuff with 5 to 15 percent phenocrysts of biotite, alkali feldspar, and plagioclase; quartz and clinopyroxene are very rare. It contains abundant small pumice and felsic lithic fragments.

The Yucca Mountain Member is a cooling unit that crops out over an area of more than 30 square miles at Yucca Mountain, ranges from 0 to 250 feet thick, has gray to brown basal, upper, and distal nonwelded to partly welded zones and a purple-brown, densely welded interior with a lithophysal core. This member is described by Lipman and Christiansen (1964, p. B75) as a uniform shard tuff with 1 percent phenocrysts, mainly K-feldspar plus some oligoclase and sparse quartz and mafic minerals. Aphanitic grayish-red lithic inclusions are present but sparse, and pumice makes up only 3 to 4 percent of the rock except toward the margins of the sheet, where it makes up 10 percent. Chemical analyses of the four main phases of the member show that it is a rhyolite with very little variation in composition from bottom to top. A chemical analysis is given in table 3 (no. 5).

The Tiva Canyon Member, the uppermost member of the Paintbrush Tuff, covers a large area east, south, and west of Timber Mountain and ranges in thickness from 0 to 550 feet. It is a gray, purple, and brown densely welded ash-flow cooling unit with lithophysal zones in the middle and upper parts. Phenocryst content ranges from less than 5 percent in the lower part to 10–25 percent in the middle and upper parts. K-feldspar is predominant, with some oligoclase, lesser biotite, clinopyroxene, and sparse quartz. Two chemical analyses of the member are given in table 3 (nos. 6, 7). The lower and middle parts are rhyolite, as illustrated by sample no. 6, but the upper part is quartz latite locally (sample no. 7).

In summary, all members of the Paintbrush Tuff are similar in mineralogy, chemistry, and areal distribution (Orkild, 1965, p. A49). They are mostly rhyolitic but the Topopah Spring and Tiva Canyon Members commonly have quartz latitic units at their tops. K-Ar dates determined by Kistler (1968, p. 255) indicate that the Paintbrush Tuff ranges in age from 12.4 to 13.2 m.y. (late Miocene).

Byers, Christiansen, and others (1968) postulate that the units of the Paintbrush Tuff were erupted from a caldera nearly concentric with the Timber Mountain caldera, which surrounds Timber Mountain. They report that all members younger than the Topopah Spring Member are substantially thicker inside the Paintbrush cauldron than outside owing to subsidence following explosive extrusion of the successive units.

TIMBER MOUNTAIN TUFF

The Timber Mountain Tuff was defined by Orkild (1965). At the base is the Rainier Mesa Member, overlain by two local informal units, the tuff of Cat Canyon and the tuff of Transvaal. Above these units is the Ammonia Tanks Member.[1] The informal units occur only in or adjacent to the Timber Mountain caldera. The Rainier Mesa and Ammonia Tanks Members crop out in the caldera and for a wide area around, as well as in, the Bullfrog Hills and along the west edge of the county south of Stonewall Mountain. The Rainier Mesa Member ranges in thickness from 0 to about 1,000 feet and the Ammonia Tanks Member from 0 to about 800 feet (Byers, Orkild, and others, 1968, p. 89–91).[2] Both are composite or compound cooling units of rhyolitic ash-flow tuffs.

The Rainier Mesa and Ammonia Tanks Members each have a rhyolitic lower part and quartz latitic upper part. Average chemical analyses of the rhyolitic and quartz latitic phases are given in table 3 (nos. 8, 9). Phenocrysts of quartz, sanidine (K-feldspar), sodic plagioclase, biotite, and clinopyroxene make up 15 to 25 percent of both members. The Ammonia Tanks Member has a higher ratio of sanidine to quartz plus plagioclase than does the Rainier Mesa Member (F. M. Byers, Jr., oral communication, 1964). The Ammonia Tanks Member is also distinguished from the Rainier Mesa Member by its persistent content of accessory sphene and scattered fragments of red, densely welded older tuff.

A number of K-Ar dates have been obtained for units in the Timber Mountain Tuff. The Rainier Mesa Member has been dated at 11.3 ± 0.3 m.y. (Marvin and others, 1970, p. 2661 and table 2), and seven age determinations on the Ammonia Tanks Member range from 10.8 to 11.4 m.y. (Kistler, 1968, p. 254). The Timber Mountain Tuff is thus considered to be early Pliocene.

Byers and others (1963; oral communication, 1968) believe that the Rainier Mesa Member and the two overlying informal tuff units were derived from vents within the Timber Mountain caldera and that the large explosive eruption of the Rainier Mesa caused collapse of the underlying chamber, resulting in the subsidence of the Timber Mountain caldera.[3] Also, Byers, Orkild, and others (1968, p. 95–97) now imply that the Ammonia Tanks Member has its source in the Timber Mountain caldera. There is little concrete evidence to support an older idea that its source was a caldera in Oasis Valley, because most of the area is overlain by younger alluvium. Furthermore, the size of the postulated center in the Oasis Valley is too small to account for the large volume of pyroclastic material in the Ammonia Tanks Member. A likelier source for these ash flows is the Bullfrog Hills area, 2 miles farther west, where structures suggestive of a resurgent caldera are present (Cornwall and Kleinhampl, 1964).[4]

WELDED TUFF

Welded ash flows that have not been correlated with other tuffs shown on the map crop out in several parts of southern Nye County. The principal occurrences of these rocks are discussed here.

Stonewall Mountain, near the west margin of the county at the north end of Sarcobatus Flat, is underlain mainly by rhyolitic welded tuffs. The eutaxitic structures and flow contacts dip steeply, mainly east or west, and

[1]Byers, Orkild, and others (1968, p. 89–91) originally described the tuff of Cat Canyon as an informal unit within the Timber Mountain Tuff, but more recently, Byers (oral communication, February, 1972) stated that the tuff of Cat Canyon has now been equated with the overlying Ammonia Tanks Member, and the Cat Canyon term abandoned.

[2]Because the thick tuff of Cat Canyon (Byers, Orkild, and others, 1968, p. 89–91) is now considered a part of the Ammonia Tanks Member (Byers, oral communication, February, 1972), the thickness of the latter is at least 3,000 feet in the center of the Timber Mountain caldera.

[3]See footnotes 1 and 2, above.

[4]Since the above was written, Byers and others (1969, p. 84–86) have written for the first time about another caldera, the Crater Flat center, from which originated the tuff of Redrock Valley and overlying tuff of Crater Flat, 15.7 and 14.0 m.y. old, respectively. This center evidently has been partly truncated by the Timber Mountain caldera or otherwise concealed, and only a small segment of the northwestern caldera wall is preserved in the vicinity of northern Oasis Valley. Byers (oral communication, February, 1972) states that the source is not known for the lower cooling unit of the tuff of Crater Flat, which is correlative with cooling unit 2 of Cornwall and Kleinhampl (1964, p. J10 and pl. 5). He further states that the available data does not preclude a source in the area of the Bullfrog Hills.

the tuffs are intruded by several plugs of quartz latite. The densely welded tuffs are gray to reddish brown and have common to very abundant sanidine and anorthoclase phenocrysts, 3 mm long. Sodic plagioclase phenocrysts, highly zoned or rimmed by sanidine, are common in some units. Biotite is generally present but sparse. The groundmass is a devitrified-glass aggregate of fine-grained K-feldspar, quartz, and magnetite. A few grains of the following accessory minerals were identified: zircon, rutile, zoisite, apatite, clinopyroxene, sphene, and bowlingite (probably replacing pyroxene). These welded tuffs have been identified only on Stonewall Mountain. They appear to be overlain by flat-lying air-fall tuff on the east and by Thirsty Canyon Tuff on the south. They are thus older than 7.5 m.y.

On and around Tolicha Peak and northward to the area around Mount Helen, the rocks shown as unnamed welded tuff on plate 1 have been called the tuff of Tolicha Peak by E. B. Ekren and others (written communication, 1966). Six miles southwest of Mount Helen, the tuff is a compound cooling unit, 300 feet thick, of several ash flows with a vitrophyre zone at the base, 30 to 50 feet thick. The tuff is densely welded, gray to light or reddish brown, and contains 1 percent or less 1-mm phenocrysts of sanidine, plagioclase, quartz, and rare biotite and hornblende. The rock consists mostly of shards and small (less than 15 mm) pumice fragments. The glass is mostly devitrified and partly spherulitic. Elsewhere the unit called the tuff of Tolicha Peak is a composite sheet of two or three cooling units separated by nonwelded tuff and local fluvial and lacustrine sedimentary rocks. A chemical analysis of the tuff of Tolicha Peak given in table 3 (no. 10) shows that it is a rhyolite with very low content of femic constituents. E. B. Ekren and others (written communication, 1966) believe that the tuff was erupted from a caldera that surrounds Mount Helen. The tuff of Tolicha Peak is overlain by the Belted Range and Paintbrush Tuffs and is believed by Ekren to be of late Miocene Age.

Unnamed welded tuffs 5 to 10 miles north of Beatty are known only in that area. These tuffs are rhyolitic with abundant feldspar phenocrysts, sparse to moderate quartz, and sparse to abundant biotite. A biotite separate from the tuff with abundant biotite yielded a K-Ar age of 12.5 m.y. with a possible analytical error of 3 percent (R. W. Kistler, written communication, 1964). This unit has the same age as the Tiva Canyon Member of the Paintbrush Formation and is thus probably correlative with it.

Unnamed welded tuffs cover a sizeable area at the south end of the Quinn Canyon Range and in the Belted Range in the northeastern part of the map. Much of the welded tuff in the Quinn Canyon Range is the tuff of Monotony Valley, as described above from E. B. Ekren and others (written communication, 1966), and most of the remaining unnamed welded tuff is correlated by them with the Shingle Pass Ignimbrite of Cook (1960).

The Shingle Pass Tuff in the Belted and Quinn Canyon Ranges has four to seven cooling units with a total thickness of 700 feet. Most of the units have conspicuous basal black vitrophyre (glass) zones as much as 20 feet thick, overlain by densely welded, devitrified rock that is red, orange, or grayish purple. Most units have a lithophysal (gas bubble) zone at the contact between vitrophyre and devitrified rock. The tuff contains 8 to 20 percent phenocrysts of plagioclase, K-feldspar, and biotite, minor quartz and rare hornblende, altered pyroxene, and altered olivine. A K-Ar age of 25.3 m.y. was determined by R. W. Kistler (written communication, 1964) on a biotite separate of one unit.

THIRSTY CANYON TUFF AND ASSOCIATED TRACHYTE AND RHYOLITE OF BLACK MOUNTAIN

The Thirsty Canyon Tuff consists of a sequence of rhyolitic to pantelleritic ash-flow and minor ash-fall tuffs that were erupted from the Black Mountain caldera area (Christiansen and Noble, 1965). The Thirsty Canyon Tuff, as designated by Noble and others (1964, 1968), contains six formal members, from bottom to top: the Rocket Wash, Spearhead, Trail Ridge, Dry Lake, Gold Flat, and Labyrinth Canyon. The Black Mountain caldera is postulated to have formed by several stages of collapse of a shallow magma chamber during eruption of the Thirsty Canyon Tuff. Two elliptical collapse structures associated with eruption of the Spearhead and Gold Flat Members have been mapped (Christiansen and Noble, 1965, 1968; Noble and Christiansen, 1968). Trachytic to soda-rhyolitic lavas, mapped separately (pl. 1), were erupted from central volcanoes in the Black Mountain area before, between, and after eruption of the members of the Thirsty Canyon Tuff (Christiansen and Noble, 1968; Noble and Christiansen, 1968).

The Thirsty Canyon Tuff extends from Timber Mountain northwest to the area around Goldfield (northwest of Stonewall Flat), as shown on plate 1. The Spearhead and overlying Trail Ridge Members are the most voluminous and widespread units; together they attain a maximum thickness of 600 feet in Thirsty Canyon between Black Mountain and Timber Mountain. The Spearhead Member was named the Spearhead Rhyolite by Ransome (1909, p. 71) for exposures west of Goldfield.

According to Noble and others (1964, p. D24), the members of the Thirsty Canyon Tuff have similar mineralogic and chemical compositions. The rocks are typically reddish yellow, ocher, green, maroon, or gray. Phenocrysts make up 5 to 30 percent of the rock and include soda-rich sanidine, pigeonite, green aegirene or hedenbergite, fayalite, amphibole, and zircon. Chemically the rocks are soda rhyolites and pantellerites. Chemical analyses for three members are given in table 4 (nos. 1, 2, 3). The Gold Flat Member, which is pantelleritic, has been described by Noble (1965). Analyses are also given in table 4 of the associated trachyte (no. 4) that makes up Black Mountain and of the rhyolite lavas (no. 5) that surround Black Mountain.

The Thirsty Canyon Tuff and associated lavas are

TABLE 4—Chemical analyses, norms, and modes of Pliocene and Holocene ash flows, lava flows, and intrusives, southern Nye County, Nevada

	1	2	3	4	5	6	7	8	9	10
CHEMICAL ANALYSES (WEIGHT PERCENT)										
SiO_2	73.5	72.5	69.5	60.5	68.5	48.59	48.0	47.70	43.62	50.50
Al_2O_3	12.5	14.0	11.5	17.0	15.0	17.80	16.5	16.86	12.73	17.36
Fe_2O_3	1.9	1.8	4.0	3.0	2.8	8.70	4.5	5.86	4.89	2.98
FeO	0.3	0.2	1.2	2.6	0.7	0.93	7.0	4.10	4.10	6.64
MgO	0.2	0.2	0.3	1.3	0.25	4.85	5.2	6.62	9.37	5.12
CaO	0.7	0.9	0.5	2.8	0.55	10.49	8.5	9.71	11.62	8.76
Na_2O	4.5	4.2	5.2	5.2	5.1	3.06	4.0	2.98	2.96	3.14
K_2O	4.8	5.2	4.8	4.8	5.5	1.70	1.8	1.67	1.30	1.65
H_2O^+	0.2	0.5	0.6	0.6	0.4	0.67	0.7	0.79	3.94	0.41
H_2O^-	....	....	0.3	....	....	0.76	....	0.45	1.91	0.20
TiO_2	0.15	0.15	0.3	0.9	0.35	1.54	2.2	1.79	1.46	1.47
P_2O_5	0.03	0.04	0.07	0.5	0.04	0.43	0.9	0.79	0.82	1.06
MnO	0.08	0.08	0.16	0.15	0.15	0.14	0.19	0.16	0.12	0.18
CO_2	0.1	0.2	0.05	0.05	<0.05	0.55	<0.05	0.27	0.63	0.07
Totals	98.96	99.97	98.48	99.40	99.34	100.21	99.49	99.75	99.47	99.54
NORMS[1] (WEIGHT PERCENT)										
Quartz	28.4	26.3	22.5	5.3	16.7	....	....	....	....	0.8
Orthoclase	28.7	31.0	29.1	28.7	32.8	10.2	10.8	10.0	8.3	9.9
Albite	38.1	35.8	33.3	44.6	43.6	26.4	31.0	25.7	15.9	26.9
Anorthite	....	4.0	....	9.0	1.8	30.4	22.0	28.2	18.9	28.7
Nephelite	....	....	....	....	....	....	1.8	....	6.0	....
Acmite	0.5	....	10.5	....	....	....	....	....	....	....
Wollastonite	1.4	0.1	0.9	0.7	0.3	7.7	6.1	6.5	15.6	3.4
Enstatite	0.5	0.5	0.8	3.3	0.6	12.2	4.0	12.8	12.9	12.9
Ferrosilite	....	....	1.7	1.1	....	....	1.8	....	0.7	7.7
Forsterite	....	....	....	....	....	....	6.4	2.8	8.5	....
Fayalite	....	....	....	....	....	....	3.2	....	0.5	....
Magnetite	0.8	0.5	0.7	4.4	1.8	....	6.6	8.6	7.6	4.4
Hematite	1.2	1.5	....	....	1.6	8.9	....	....	....	....
Ilmenite	0.3	0.3	0.6	1.7	0.7	2.3	4.2	3.5	3.0	2.8
Apatite	0.1	0.1	0.2	1.2	0.1	1.0	2.2	1.9	2.1	2.5
Sphene	....	....	....	....	....	0.9	....	....	....	....
Totals	100	100	100	100	100	100	100	100	100	100
MODES (VOLUME PERCENT)										
Groundmass	....	....	....	....	....	....	....	....	....	6.6
Plagioclase	....	....	....	....	....	....	....	58.4	....	61.1
Magnetite	....	....	....	....	....	....	....	7.3	....	6.6
Pyroxene	....	....	....	....	....	....	....	21.0	....	23.4
Olivine	....	....	....	....	....	....	....	11.6	....	2.3
Biotite	....	....	....	....	....	....	....	1.7	....	....
Totals	....	....	....	....	....	....	....	100	....	100

1. Spearhead Member of the Thirsty Canyon Tuff, average of several analyses (E. B. Ekren and others, written communication, 1966).
2. Trail Ridge Member of Thirsty Canyon Tuff, average of several analyses (E. B. Ekren and others, written communication, 1966).
3. Gold Flat Member of the Thirsty Canyon Tuff, average of 4 analyses (Noble, 1965, table 1, no. 6).
4. Trachyte of Hidden Cliff, Black Mountain, average of several analyses (E. B. Ekren and others, written communication, 1966).
5. Rhyolite of Pillar Spring, Black Mountain, average of several analyses (E. B. Ekren and others, written communication, 1966).
6. Malpais Basalt, small area of basalt near Nye County line 7 miles southwest of Mud Lake (Ransome, 1909, analysis no. 2).
7. Basalt flow, north margin of Pahute Mesa (E. B. Ekren and others, written communication, 1966).
8. Basalt flow, 2 miles northeast of Beatty (Cornwall and Kleinhampl, 1964, table 2, no. 20).
9. Analcime basanite, 3.5 miles west of Beatty in Bullfrog Hills (Ransome and others, 1910, p. 60).
10. Holocene basalt flow, Crater Flat, east of Bare Mountain (Cornwall and Kleinhampl, 1964, no. 21, table 2).

[1]Analyses recalculated to 100 percent minus H_2O and CO_2.

Pliocene in age (Noble and others, 1964, p. D25–D26). A K-Ar age of 7.5 m.y. (R. W. Kistler, written communication, 1963) was obtained on sanidine from the Rocket Wash Member.

BASALT

Tertiary basalt flows and plugs crop out in a number of areas in southern Nye County, as shown on plate 1. Southwest of Mud Lake is a fairly large area of basalt flows. The dark-brown to black basalt has trachytic texture with predominant labradorite (An_{60}) laths up to 1.5 mm long and smaller crystals of olivine, mostly altered to iddingsite, pigeonite, augite, magnetite, and a little calcite. For several miles farther south in Goldfield Hills are several small patches of basalt that probably are remnants of the Malpais Basalt, named by Ransome (1909, p. 72–74) for exposures west of Goldfield. These flat-lying flows are as much as 100 feet thick and contain abundant phenocrysts of labradorite (An_{65}) and olivine in a crystalline groundmass of the same minerals plus abundant augite and magnetite and a little apatite. Ransome (1909, p. 72) states that there is probably also K-feldspar in the groundmass. The olivine is partly altered to iddingsite. A little biotite is also present plus a little calcite after labradorite. A chemical analysis is given in table 4 (no. 6).

Basalt flows crop out in several areas, some quite large, along the north, west, and southwest margins of Pahute Mesa. The western exposures are on Sarcobatus Flat near Highway 95. The basalts are porphyritic. The flows south of Gold Flat and northeast of Black Mountain, which are probably typical for the area, contain phenocrysts as much as 3 cm long of sodic labradorite and augite. The groundmass, consisting of sodic labradorite, augite, olivine, and magnetite, is partly trachytic and partly intergranular to subophitic. A chemical analysis of basalt north of Pahute Mesa is given in table 4 (no. 7).

A basalt dome, approximately 5 miles in diameter, crops out 5 miles northwest of Timber Mountain. The dome consists of dark-brown to black flows of olivine basalt. Southeast of Timber Mountain, flows of Dome Mountain consist of 800 to 1,000 feet of trachybasalt and trachyandesite with phenocrysts of plagioclase, olivine, and augite (Luft, 1964).

North of Bare Mountain and westward across the Bullfrog Hills to the county line are scattered exposures of Tertiary basalt flows and dikes. These basalts are dark gray to black, fine grained, porphyritic, with phenocrysts as long as 1 mm of labradorite and olivine partly altered to bowlingite, iddingsite, and antigorite (Cornwall and Kleinhampl, 1964, p. J11). The sample of analysis no. 8, table 4, is from one of these flows. The groundmass is commonly trachytic, with an intergrowth of labradorite or andesine, augite, magnetite, hematite, and a little biotite. One flow has phenocrysts as much as 15 mm across of andesine and quartz in a fine-grained groundmass of labradorite or andesine, quartz, augite, pigeonite, magnetite, hematite, and a little biotite. Two of the basalt flows grade abruptly, either horizontally or vertically, into basanite. The basanite (analysis no. 9, table 4) has phenocrysts as much as 4 mm across, of olivine, pigeonite, and augite in an aphanitic groundmass of analcime, plagioclase (An_{45-60}), pyroxene, magnetite, and a little biotite (Cornwall and Kleinhampl, 1964, p. J11).

On and around Jackass Flats, west of Mercury, Tertiary basalt flows crop out in several areas, particularly on and west of Skull Mountain. These flows consist of bluish- to greenish-black olivine basalt containing plagioclase and olivine phenocrysts and xenocrysts of quartz. Maximum thickness is about 250 feet.

In the northeastern corner of southern Nye County, Tertiary basalt flows cover a small area at the very south end of the Quinn Canyon Range.

The Tertiary basalts range from late Miocene to late Pliocene in age. In the Bullfrog Hills area basalt flows are interlayered with the Paintbrush and Timber Mountain Tuffs, 10.8 to 13.5 million years old, and overlie the Timber Mountain Tuff. Around Jackass Flats the basalt flows overlie the Timber Mountain Tuff. East of Sarcobatus Flat and northwest of Black Mountain, basalt flows underlie the Thirsty Canyon Tuff, which has an age of 7.5 m.y. In the Goldfield area, the Malpais Basalt overlies the Thirsty Canyon Tuff. Elsewhere the exact age of the Tertiary basalts is uncertain. Some may be as old as Miocene.

TERTIARY AND QUATERNARY ALLUVIUM

Older gravels and locally finer-grained alluvium crop out in a sizable area north of Bare Mountain and in smaller patches south of Timber Mountain, around Mount Helen, and near the county line west of Bare Mountain. These gravels and other alluvium probably are mostly Quaternary in age, but near Mount Helen weakly lithified alluvium and gravel crop out beneath the Thirsty Canyon Tuff in several areas (E. B. Ekren and others, written communication, 1966). The age of 7.5 m.y. for the tuff means that the underlying gravel and alluvium are clearly Pliocene in age.

The gravels are characterized by variable sorting of the detritus and represent old dissected fans. The lower ends of the fans have relatively fine detritus and cobbles, whereas the higher parts are strewn with boulders, most less than 3 feet across but a few as much as 6 feet across. North of Bare Mountain the boulders are partly arranged in linear trains along ridge crests, probably representing channels of old streams that flowed north from Bare Mountain. These boulders are mainly Paleozoic dolomite, limestone, and quartzite of the formations that make up Bare Mountain.

Elsewhere in the county the compositions of the boulders and cobbles in the older dissected gravels also reflect the types of rocks found in the neighboring hills and mountains. East of Mount Helen, for example, an old fanglomerate contains abundant boulders and cobbles of Precambrian quartz monzonite and biotite schist that crop out in the nearby Trappman Hills. Fragments of Tertiary volcanic rocks also are abundant. Near the county line west of Bare Mountain, the old dissected fans contain boulders of quartzite, dolomite, and limestone representative of the Precambrian and Cambrian formations that crop out in the nearby Funeral Mountains (a part of the Amargosa Range) to the west, as well as Tertiary volcanic rocks, which also crop out in the area. Two of these old fanglomerates have been intruded by younger basalt (see pl. 1).

QUATERNARY BASALT AND DETRITAL DEPOSITS

Quaternary rocks in southern Nye County consist of basalt flows and cinder cones, alluvial fans, stream gravels, dune sands, spring deposits, and playa lake deposits. Alluvial fans cover most of the desert basins, but playa deposits and basalt flows and cones are locally prominent.

BASALT

Basalt flows and cinder cones, some very young, crop out in and around Crater Flat east of Bare Mountain, on Buckboard Mesa east of Timber Mountain, and in the Reveille, Railroad, and Kawich Valleys in the northeast part of the county. Small Quaternary flows and cones are also present in Sarcobatus Flat and the Amargosa Desert.

The flows are fine-grained, black, or dark-gray, partly pilotaxitic basalt with olivine and plagioclase phenocrysts, commonly 1 to 2 mm in diameter. The flows in the Kawich Valley have abundant plagioclase phenocrysts as much as 20 mm across. The tops of the flows and most of the bombs, lapilli, and cinders in the cinder cones are brown or red, owing to a high Fe_2O_3 content.

The Quaternary basalt in Crater Flat has recently been described (Cornwall and Kleinhampl, 1961). The basalt is trachytic with phenocrysts up to 2 mm long of labradorite, olivine, and a little hypersthene and augite. The groundmass consists of trachytic laths, 0.15 mm long, of labradorite, and anhedral to subhedral grains up to 0.1 mm of pigeonite, hypersthene, augite, magnetite, ilmenite, some interstitial glass, and, in a few units, biotite. A chemical analysis, norm, and mode of one flow are given in table 4 (no. 10).

ALLUVIUM

The alluvial fans consist of gravel and rubble near the highlands and grade downward into sand and silt in the valley bottoms. In some areas the fans are relatively thin and overlie rock-pediment surfaces that slope away from mountains. Elsewhere the fans and other alluvial and playa lake deposits are thick; drill-hole data in Yucca Flat indicate thicknesses of 0 to 2,200 feet (W. P. Williams and others, written communication, 1963). D. L. Healey and C. H. Miller (written communications, 1962) found that gravity data suggest a thickness of as much as 4,500 feet for alluvium and volcanic rocks in the Kawich Valley and Gold Flat.

The surfaces of most alluvial fans are a mosaic of modern pavement and abandoned shallow washes with intervening patches of desert pavement composed of closely packed angular rock fragments. The fan surfaces are also partly covered by braided stream channels and gravel bars.

Sand dunes are prominent in some basins, particularly the Amargosa Desert. The Big Dune, 5 miles south of Bare Mountain, is 2 miles long, 1 mile wide, and 200 feet high. Farther south in the Amargosa Desert at Ash Meadows, Denny and Drewes (1965) have mapped a number of small patches of sand dunes; the largest measure approximately 1 by 1.5 miles. These dunes are 5 to 30 feet high and appear to be relatively stable.

Denny and Drewes (1965, p. L30–L32) have also found sizable areas at Ash Meadows that are covered by spring and alluvial deposits consisting of firmly cemented, pale-gray or brown sand and silt with many casts and molds of plant stems. Individual deposits are as large as half a mile in diameter and 2 to 20 feet thick. Spring deposits mantle low ridges and extend down to intervening washes. The ridges and buttes capped by resistant spring deposits are, according to Denny and Drewes (1965, p. L30), erosional remnants left after dissection by intermittent streams.

PLAYA LAKE DEPOSITS

Playa lakes occupy low areas in all the basins, and playa deposits partly or wholly covered by alluvium probably extend beyond the limits of the present ephemeral lakes in many areas, as they do at Ash Meadows (see pl. 1; Denny and Drewes, 1965). The playa deposit consists of sand, silt, and clay strata, white or pale gray and brown, with a few lenses of fine gravel. Tuffaceous beds and evaporites also are present. At Ash Meadows the playa strata are well exposed in numerous clay pits as well as in natural exposures along washes. Elsewhere in the county only the flat, hard clay surfaces of the present playas are visible.

STRUCTURE

Structural deformation in southern Nye County can be divided into the following types: (1) folding and thrust and related tear faulting; (2) strike-slip (wrench) faulting; (3) cauldron subsidence, doming, and high-angle faulting related to volcanic activity; (4) Basin-Range high-angle normal faulting; (5) gravity sliding. The most prominent structural features are shown on a generalized sketch map (fig. 2).

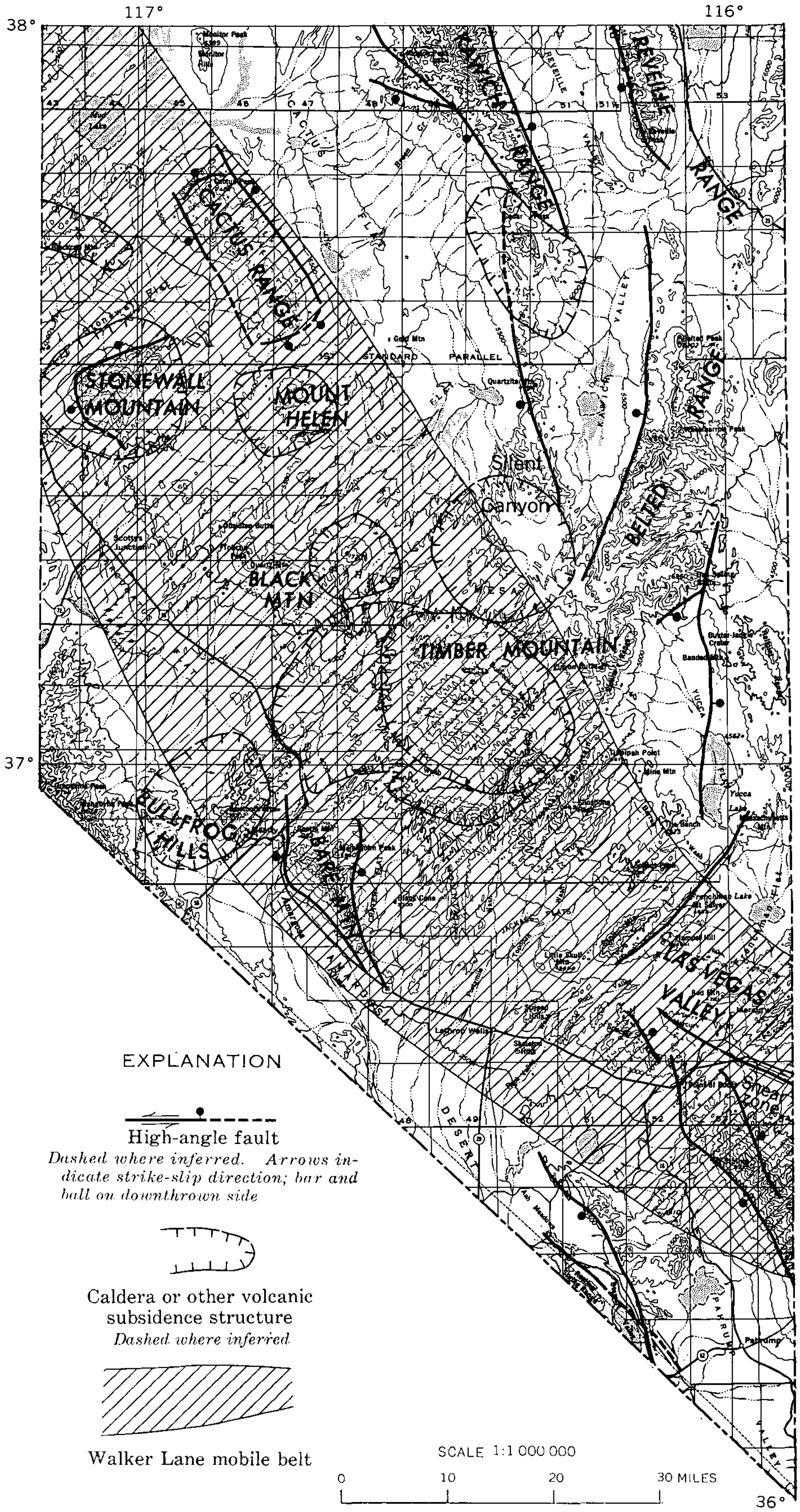

Figure 2. Most prominent structural features of southern Nye County.

Folding and thrust and tear faulting are most intense in the late Precambrian and Paleozoic rocks of Bare Mountain, the Spring Mountains, and elsewhere in the southern part of the county, but such deformation, where exposed elsewhere in the county, has similar patterns. It is probable that this deformation is related to the development of the Las Vegas Valley shear zone in Middle Cretaceous time as described by Longwell (1960) in Clark County. The shear zone, with an estimated right-lateral displacement of 25–40 miles (Stewart and others, 1968), enters southern Nye County in the valley north of the Spring Mountains, probably passes northwestward into an oroflexural bend, the Spotted Range oroflex (Albers, 1967; Stewart, 1967), and may terminate southwest of Mercury, Nev. Gianella and Callaghan (1934) and Locke and others (1940) postulated that the Las Vegas Valley shear zone connects northwestward with a similar right-lateral shear zone near Goldfield and at the Cedar Mountains, 200 miles northwest of Las Vegas. Locke and others (1940) named the northern lineament the Walker Lane and postulated that it passes south past Goldfield and down Sarcobatus Flat; if it does, it would pass very close to Bare Mountain before connecting with the Las Vegas Valley shear zone in the Mercury Valley area. This zone of folding and probable transcurrent faulting is shown as the Walker Lane mobile belt.

Shawe (1965) and E. B. Ekren and others (written communication, 1966) have suggested that a major lineament may extend northwestward from Las Vegas Valley through the line of volcanic centers at Timber Mountain, Black Mountain, Mount Helen, the Cactus Range, Tonopah, and on to Cedar Mountain.

Volcano-tectonic activity in the Miocene and Pliocene in southern Nye County resulted in the development of calderas or graben with some or all of the following associated features: domes, elevated blocks, and normal faults at the Bullfrog Hills, Timber Mountain, Black Mountain, Pahute Mesa (Silent Canyon caldera), Mount Helen, Cactus Range, Goldfield district, Stonewall Mountain, Kawich Range, and other places. Another pair of volcanic centers lies east of Jackass Flats and west of Frenchman Flat (Poole and others, 1965).

Basin-Range normal faults ranging in age from Miocene to Holocene are present throughout most of the county and bound the mountains and ranges. North-trending normal faults are most common but locally northeast and northwest trends are prevalent.

Gravity slides of lower Paleozoic rocks, mostly the Bonanza King Formation of Middle and Late Cambrian Age, occur in several widely scattered areas in the county, as described under Mesozoic or Tertiary megabreccia. The resultant megabreccias probably range in age from Cretaceous to Pliocene (Cornwall and Kleinhampl, 1964, p. J7). The two largest megabreccia bodies, shown on the geologic map (pl. 1), are located 7 miles west of Pahrump, near the county line, and 3 miles southeast of Bare Mountain; the indications are that these bodies, as much as 2 miles across, slid 5 and 4 miles, respectively. Smaller bodies of megabreccia, not shown on the map, occur in and southwest of the Bullfrog Hills.

In addition to these occurrences of landslide megabreccias, E. B. Ekren and others (written communication, 1966) have postulated that several equally large or larger blocks of partly brecciated Cambrian and Ordovician limestones slid by gravity a quarter of a mile to 4 miles west on the west flank of the Belted Range some time before late Oligocene time.

A more detailed description of the structural features of individual ranges and volcanic centers follows.

NORTHERN SPRING MOUNTAINS AND SURROUNDING AREAS

The northern Spring Mountains and surrounding areas described here consist of intensely deformed late Precambrian to Mississippian sedimentary rocks. Nolan (1929) postulated that the northern Spring Mountains are underlain by a flat décollement thrust at the base of the Stirling Quartzite, which rises across the entire Paleozoic section at Wheeler Pass, several miles northeast of Pahrump in Clark County. Vincelette (1964) also identified the fault at Wheeler Pass but concluded that it becomes flat northwestward at a lower level, either in or below the Johnnie Formation. Both agree that the upper plate moved southeastward. The rocks in the upper plate are also cut by northeast- and north-northwest-trending steep normal faults, and the range is bounded by normal faults with valley sides dropped down.

North of the Spring Mountains, the Specter Range consists of highly deformed Paleozoic rocks, mostly carbonate, ranging in age from Cambrian to Devonian. Burchfiel (1965, p. 175) states that:

> "The most characteristic structural features of the Specter Range quadrangle are the high-angle faults, many of which are topographically expressed. Folding is relatively unimportant and local. Three sets of high-angle faults are recognized on the basis of similar strike: (1) a northwest set, (2) a north-south set, and (3) a northeast set. The north-south set is interpreted as a regional set of normal faults, whereas the northwest and northeast sets are interpreted as right-lateral oblique-slip and left-lateral oblique-slip faults, respectively."

Recent work by Harley Barnes and others (written communication, 1969) indicates that the structure of the Specter Range is dominated by thrust and reverse faults complicated by later folding and extensive high-angle normal faulting.

The Las Vegas Valley shear zone, which passes northwestward across Clark County (Longwell, 1960; Longwell and others, 1965), enters southern Nye County in the alluvial valley north of the Spring Mountains (see pl. 1). Longwell (1960) estimates right-lateral displacement along the shear zone of about 25 miles, as indicated by displacement between the Keystone thrust on the southwest and its presumed counterpart, the Muddy Mountain thrust, in the Muddy Mountains to the northeast. Burchfiel (1965) estimates an offset of about 27 miles between the Wheeler Pass thrust in the Spring Mountains and a thrust involving similar rocks in the Las Vegas Range.

Burchfiel, in agreement with Longwell, considers that the Las Vegas Valley shear zone was active in the deep crust or basement below the sedimentary cover of Paleozoic rocks, which became uncoupled from the basement by décollement thrusting along incompetent layers. Thus in the Specter Range the deep-seated strike-slip movement is manifested in the cover of Paleozoic sedimentary rocks by horizontal slip along flat thrusts and by secondary left-lateral and right-lateral slip along conjugate sets of vertical fractures. He believes that the main shear zone passes westward beneath the Specter Range with some right-lateral movement in the sedimentary cover along a fault that separates the Bonanza King Formation of Cambrian Age on the north from Ordovician and younger rocks on the south (see pl. 1; also Burchfiel, 1965, pl. 3). This fault dips 50°–60° north, and the present writer prefers the interpretation of R. H. Moench and others (written communication, 1964) that it is a thrust fault with southeastward movement similar to other thrusts in the area. Recent mapping by K. A. Sargent (written communication, 1969) has verified that the fault is a thrust with southward movement of Cambrian rocks over an asymmetrical anticline of Ordovician rocks. He has also found that at least three, and possibly five or more, imbricate thrust plates of lower Paleozoic rocks are exposed in the Specter Range.

West of the Spring Mountains around Pahrump Valley is an area of late Precambrian and Paleozoic rocks, mapped by the author and by Hamill (1966), that have been tectonically deformed in a pattern similar to that of the Spring Mountains and Specter Range. The Stirling Quartzite and younger rocks have been thrust southeastward over Ordovician to Mississippian rocks along an arcuate thrust fault that enters Pahrump Valley 3 miles south of Johnnie. This thrust is called the Montgomery thrust by Hamill, who postulates that it correlates with, or is synchronous with, the Wheeler Pass fault described above, which projects westward into Pahrump Valley northeast of Pahrump. Such an interpretation necessitates an 8- or 9-mile offset on a postulated north-trending right-lateral fault in Pahrump Valley or along the west flank of the Spring Mountains.

Another thrust fault, roughly parallel to and 1 or 2 miles east of the Montgomery fault, has thrust Devonian and Mississippian rocks eastward over Ordovician rocks. In addition, the author has mapped a minor east-dipping thrust at the base of the Stirling Quartzite 1.5 to 5 miles northwest and north of Johnnie. A number of high-angle normal faults, mainly north-trending, have also been recognized. The longest of these flanks the ridges of Cambrian carbonate rocks on the east margin of Ash Meadows and extends southward to the county line with the west side dropped down. A right-lateral strike-slip fault has also been postulated 1.5 miles northeast of the county line and parallel to it.

The thrusting, lateral faulting, and related normal faulting in the Spring Mountains and surrounding areas are, as indicated above, probably genetically related to the deformation along the Las Vegas shear zone. Longwell (1960) considers that this deformation probably occurred near the middle of the Cretaceous with lesser deformation continuing into the Tertiary. As elsewhere in the county, the Basin-Range normal faulting was probably most active in the late Tertiary and Pleistocene but has continued to the present.

BARE MOUNTAIN

The late Precambrian to late Paleozoic sedimentary rocks of Bare Mountain have been intensely deformed by folding in the late Paleozoic or Mesozoic, intense thrust and right-lateral faulting, probably in the Mesozoic, and normal faulting in the late Tertiary to Holocene (Cornwall and Kleinhampl, 1961).

For the most part, the rocks dip northward in successive blocks separated by right-lateral tear faults and flat thrusts. The tilting occurred earlier than the faulting but may have been part of the same orogeny. The faulting consists of repeated thrusts locally to the point of imbrication and of related right-lateral tear faults. The thrust faults are low angle with undulating surfaces and occur in weak shaly units of the Wood Canyon and Carrara Formations, interbedded with more competent carbonate and quartzite units. Several have troughs that trend toward the southwest, which is the direction of movement as indicated by drag folds everywhere except in the northwest corner of Bare Mountain, where a south or southeast direction is indicated. The tear faults have right-lateral displacements, strike approximately north-south, and dip 50°–80° east.

The close genetic relationship between the tear faults and thrust faults is indicated by similar or compatible directions of displacement and also by the fact that to the northwest and west at least three of the north-trending steep tear faults change strike direction abruptly northward and themselves become north-dipping thrusts.

The deformation on Bare Mountain is similar to that in the northern Spring Mountains and Specter Range, and, like that of those areas, is probably related to the right-lateral shear in the Walker Lane tear faulting of the Las Vegas Valley shear zone described above, which is mainly of Cretaceous Age (Longwell, 1960).

Bare Mountain is bounded on the east and west flanks by Basin-Range normal faults of probable late Tertiary to Recent Age, with downward movement in the valleys. The presence of the faults has been corroborated by geophysical anomalies (D. R. Mabey, oral communication, 1965). The Paleozoic rocks on the east side of Bare Mountain are cut off abruptly along a sharp, nearly straight line, and the alluvial fans are small and relatively undissected, which indicates relatively recent movement. On the west side of the mountain at the north end, welded tuffs dated at 11 m.y. have been offset by the bounding normal fault, and farther south the gravels of the alluvial fan are offset (see pl. 1). The Paleozoic rocks at the north end of Bare Mountain are bounded by a moderate to steep north-dipping normal fault with the Paintbrush and Timber Mountain Tuffs (13.5 to 11 m.y. old) downdropped on the north side. It is believed that the downward displacement of the tuffs was caused by subsidence related to the Bullfrog Hills caldera (Cornwall and Kleinhampl, 1964, p. J18–J19).

YUCCA FLAT

Deformation of the late Precambrian and Paleozoic rocks around Yucca Flat has been complex and consists of broad folds, thrusts, and high-angle reverse and normal faults. The folds on the east side of Yucca Flat trend northwest, those on the west side northeast. Thrust faults, only a few of which are shown on plate 1 because of the small size of the blocks, are most prominent west of Yucca Flat but are also quite extensive on the east side. In a majority of cases, older rocks are thrust over younger, but sizable plates of younger rocks thrust over older are also present.

Prominent high-angle normal faults trending for the most part from northeast, north, and north-northwest have displaced the Precambrian and Paleozoic rocks and also the Miocene and Pliocene tuffs. A recently reactivated north-trending normal fault in Yucca Flat offsets alluvium and tuff as much as 1,200 feet, with east side down. Southwest of Yucca Flat, along the east flank of Skull Mountain, a prominent northeast-trending left-lateral strike-slip fault has ruptured the Salyer and Wahmonie Formations and younger rocks. In this area and to the northwest around Jackass Flats, the Miocene and Pliocene volcanic rocks are ruptured by numerous high-angle normal faults probably related to both tectonic and volcanic activity.

BELTED RANGE

Paleozoic rocks in the Belted Range, occurring mainly on the west side of the range, have been subjected to folding, thrusting, and gravity sliding prior to being overlapped by Oligocene and Miocene tuffs and flows (E. B. Ekren and others, written communication, 1966). Most of the Paleozoic rocks on the ridge along the west flank of the Belted Range are steeply overturned to the west and are believed to have slid west along a relatively flat gravity slide.

Two ages of normal faulting are recognized in the Belted Range (E. B. Ekren and others, written communication, 1966). The older set strikes northeast and northwest and cuts most of the Tertiary rocks older than the Belted Range Tuff, which is late Miocene in age. The younger set strikes north-south and ranges from Pliocene to Holocene in age. Such faults occur both within the range and flanking it. The Tertiary and older rocks have been tilted gently eastward. A prominent normal fault flanks the west side of the range and has a displacement of more than 2,000 feet (D. L. Healey, oral communication, 1964), valley side down.

REVEILLE RANGE

The Reveille Range in southern Nye County consists mainly of gently to moderately dipping tuff of White Blotch Spring (age, 21.5 m.y.). The range is bounded on the west side by a normal fault with the west side down, and the ash-flow tuffs in the range have been tilted approximately 20° eastward.

KAWICH RANGE

The Kawich Range is a horst with prominent straight, flanking normal faults on both the east and west sides. Stratigraphic throw of approximately 1,500 and 3,000 feet is recognized on the east and west sides, respectively (E. B. Ekren and others, written communication, 1966). Normal faults are abundant also within the range in the middle and southern parts, commonly striking northwest to west. At the south end is a belt of Precambrian rocks that dip moderately east and are disconformably overlain by Tertiary tuffs and flows.

At the north end of the area of Precambrian rocks, two northwest-trending normal faults have combined throws of 7,000 feet with the north sides down. This is believed to be the south boundary of a caldera that was filled with 7,000 feet of the Fraction Tuff (E. B. Ekren and others, written communication, 1966). The north rim of the caldera probably crosses the range near Cedar Pass (see pl. 1), and the remaining sides are covered by alluvium.

CACTUS RANGE

The Cactus Range is a northwest-trending horst that is bounded by an elliptical ring of mapped and inferred faults. Two major episodes of cauldron subsidence, more or less along the same ring-fracture zone, and associated with the eruptions of the tuffs of Antelope Springs and the tuff of White Blotch Spring, respectively, are indicated by relations within the range, according to E. B. Ekren and others (written communication, 1966). The complex structural evolution of the range is believed to have resulted mainly from volcano-tectonic deformation in the Miocene, but the northwest-southeast elongation of the range may be related to a major regional northwest-trending lineament, such as the Walker Lane (Locke and others, 1940), whose extension may pass near or along the Cactus Range.

The first major event in the Cactus Range was the eruption of the tuffs of Antelope Springs and subsequent collapse along the ring-fracture zone that deformed the tuffs near and inside the fracture zone but not outside or within the central part. In the same manner, eruption of the tuff of White Blotch Spring was followed by subsidence that formed a second caldera inside the ring-fracture zone. The tuff of White Blotch Spring is, in part, flat-lying over deformed tuffs of Antelope Springs, which shows that it postdates that deformation. The tuff of White Blotch Spring is highly tilted and locally overturned in the northern part of Cactus Range inside the ring-fracture zone and is gently dipping away from this zone, indicating a second period of cauldron subsidence in the deformed area.

The third major event, according to E. B. Ekren and others (written communication, 1966), was a prolonged period of intrusive activity throughout the range. Stocks, laccoliths, sills, and dikes of rhyodacite, granite porphyry, and rhyolite were forcibly intruded, causing uplift of the roof blocks along preexisting faults of the ring-fracture zone to give the range its present elevated position.

MOUNT HELEN

Mount Helen is made up of extrusive quartz latite in a structural dome inside a collapsed area 9 miles wide; another collapse zone, 4 miles across, lies within the larger structure (E. B. Ekren and others, written communication, 1966). It is possible that the larger collapse zone is a graben related to transcurrent faulting. Old Precambrian gneisses and schists flank the zone on the east and lower Paleozoic rocks on the west. Ekren and others (written communication, 1966) suggest that this structural discontinuity could be due to strike-slip faulting related to the Walker Lane, and that the lineament might also have controlled the location of the Timber Mountain, Black Mountain, and Cactus Range, as well as the Mount Helen calderas, for all of these structures lie along a nearly straight line extending northwest from northernmost known position of the Las Vegas Valley shear zone. The evidence for this is equivocal, however, as there are several other calderas or volcanic centers that are not along this postulated line.

Ekren and his colleagues seem to prefer the theory that the larger area of subsidence at Mount Helen resulted from the eruption of an ash-flow sheet whose identity is uncertain, with subsequent collapse of the underlying magma chamber. After this, quartz latite and basalt were erupted from a feeder vent at Mount Helen. Then ash flows known as the tuffs of Tolicha Peak were erupted, resulting in collapse of the smaller inner caldera. Following this, the Mount Helen dome was elevated by intrusion of resurgent magma into the underlying magma chamber.

BLACK MOUNTAIN

Black Mountain is a constructional volcano composed of trachytic lava flows. It formed within the smallest and youngest of a sequence of nested calderas related to eruption of the Thirsty Canyon Tuff (Christiansen and Noble, 1965). The first collapse for which map evidence is clear formed a caldera about 8 miles across and occurred after eruption of the Spearhead Member of the Thirsty Canyon Tuff. Evidence is also clear for a younger, smaller caldera, about 4 miles across, which formed in the western part of the post-Spearhead caldera after eruption of the Gold Flat Member (Christiansen and Noble, 1965, 1968; Noble and Christiansen, 1968). Other calderas may have formed following eruption of the Rocket Wash and Trail Ridge Members, but evidence for their existence has been partially obliterated by younger flows and tuffs.

Sanidines from units of the Thirsty Canyon Tuff have been dated as 6.2 to 7.5 m.y. (R. L. Christiansen and D. C. Noble, written communication, 1968); thus the Pliocene Black Mountain center formed the youngest major volcanic structures in southern Nye County.

SILENT CANYON CALDERA

Pahute Mesa is a broad, elevated, nearly flat plateau covered by flat-lying ash-flow tuffs of the Timber Mountain and Thirsty Canyon Tuffs, but deep drilling has revealed a concealed caldera approximately 13 miles wide that shows a collapse of about 5,000 feet (P. P. Orkild and K. A. Sargent, written communications, 1967). Drill holes to a maximum depth of 14,000 feet in the caldera are entirely in Tertiary volcanic strata consisting of rhyolitic and quartz-latitic air-fall tuffs and lavas. It is believed that the collapse followed extrusion of the distinctive Belted Range Tuff and related lavas and tuffs.

TIMBER MOUNTAIN

Timber Mountain is a resurgent dome in an oval caldera measuring about 15 by 20 miles that has a well-developed depressed or moat area surrounding the dome. Christiansen and others (1965) believe that the catastrophic collapse of the caldera followed eruption of ash flows of the Rainier Mesa Member (age, 11.3 m.y.) of the Timber Mountain Tuff. They state:

> "The Timber Mountain volcanic structure formed in three stages: early broad doming, caldera collapse, and resurgent doming of the caldera floor. As the early dome developed, its extended roof was downdropped along a zone of concentric faults, and subsequent caldera collapse occurred along roughly the same zone. Regional normal faults contemporaneous with the volcanic structure were adapted to it, and some of them were utilized in extension of the early dome and in caldera collapse."

Most of the faults of the central dome at Timber Mountain are linear graben faults that resulted from the resurgent doming (Carr, 1964). The marginal ring-fracture zone of the caldera is bounded by the eroded wall of the caldera on the south, east, and north sides and is also evidenced by a group of postcollapse rhyolite lava domes within the moat area encircling the central dome.

Recently F. M. Byers, Jr. and others (written communication, 1968) have postulated that two older calderas, truncated by the Timber Mountain caldera on the east, occupy a crescentic area west of that caldera (see pl. 1). The younger of these calderas may have collapsed twice following eruption of the Topopah Spring Member (age, 13.2 m.y.) and the Tiva Canyon Member (age, 12.4 m.y.) of the Paintbrush Tuff. The older caldera is believed to have collapsed following eruption of an ash-flow sheet in Crater Flat shortly before the Paintbrush Tuff eruption.

BULLFROG HILLS

The Bullfrog Hills have been described by Cornwall and Kleinhampl (1964) as a center of subsidence related to volcanic eruption. The resultant caldera is described (1964, p. J18–J19) as follows:

> "The caldera measured approximately 10 by 13 miles and is elongated in a northeasterly direction. The rocks in the caldera, mainly ash flow and air-fall tuffs, have the form of an intricately faulted dome, developed subsequent to initial collapse, with the ash flows and tuffs dipping outward toward the rim and normal faults commonly dipping inward.
>
> "The main fault on the rim of the caldera is exposed at the Montgomery-Shoshone mine on the southeast rim, where rocks in the caldera on the northwest side have been displaced downward about 3,500 feet with respect to those on the southeast. Additional subsidence of about 500 feet has occurred along several other faults parallel to this fault in a zone about 1 mile wide east of the Montgomery-Shoshone mine."

Northeastward from the southeast rim of the caldera, a series of normal faults have systematically dropped the volcanic rocks downward successively to the northwest; this further subsidence probably resulted from withdrawal of magma from an underlying chamber. Within the caldera a block of Precambrian and Paleozoic rocks bounded by a low-angle fault appears to have been pushed up into the volcanic rocks at a late stage by magma that reentered the underlying chamber. Reentry of magma also domed the volcanic sequence.

It was earlier believed that the tuffs and lava flows of the Bullfrog Hills are older than those related to Timber Mountain, but studies by P. P. Orkild and others (oral communication, 1966) have established that they are correlative and consist mainly of the Paintbrush and Timber Mountain Tuffs and the tuff of Crater Flat. The present writer now postulates that the caldera subsidence resulted from the violent eruption from an underlying chamber of rocks of the Ammonia Tanks Member of the Timber Mountain Tuff plus associated air-fall tuffs and lavas. These are the youngest highly deformed rocks in the caldera; they are unconformably overlain by slightly younger, gently dipping latite lava flows. This interpretation has been challenged by F. M. Byers, Jr. and others (written and oral communications, 1968), who have postulated that the caldera related to the eruption of the Ammonia Tanks Member is located directly east of the Bullfrog Hills beneath the alluvium of Oasis Valley. Whatever the true picture may be, it is clear that the locally intense deformation of the Paintbrush and Timber Mountain Tuffs in and southeast of the Bullfrog Hills must be related to volcano-tectonic deformation that took place shortly after the eruption of the Ammonia Tanks Member (age, 11 m.y.) of the Timber Mountain Tuff.

STONEWALL MOUNTAIN

Stonewall Mountain consists of steeply dipping rhyolitic and latitic welded tuffs intruded by quartz latite and bounded on the east by glassy rhyolite flows and plugs. Two blocks of Precambrian rocks border the intrusive quartz latite at the north end of the mountain. The welded tuffs have not been recognized outside of the mountain area. They may be concealed by younger rocks and alluvium that surround the mountain, or they may have been erupted into a volcano-tectonic graben and thus confined to that area.

The north end of Stonewall Mountain is bounded by a steep northward-dipping normal fault with recent downward movement on the north side.

GOLDFIELD DISTRICT

The Goldfield mining district, which extends eastward into southern Nye County, is a Tertiary volcanic center made up of air-fall and ash-flow tuffs, lava flows, and intrusives of andesite, dacite, rhyodacite, quartz latite, and rhyolite. A grabenlike subsidence area extends eastward from Goldfield. The west and northwest margins of the graben are bounded by a well-defined arcuate normal fault; elsewhere bounding faults are less obvious, or inferred (Albers and Cornwall, 1968).

Ransome (1909, p. 76) concluded that the volcanic and older rocks had been elevated in a gentle anticline, but recent mapping by Albers and Cornwall indicates that most of the units, especially those older than the Milltown Andesite, dip west. Several north-trending arcuate faults, concave to the east, cross the graben and successively drop units down on the east side. The flat-lying dacite vitrophyre ash flows (age, 21.1 m.y.) extend south from the south rim of the graben, and the graben subsidence may have resulted from their eruption.

Ordovician shale and Mesozoic alaskite and granite crop out locally on the west rim of the graben, north of Goldfield, and also in the graben 1 mile east of the west rim. R. P. Ashley (oral communication, 1968) has found evidence that the block in the graben with pre-Tertiary rocks exposed has been elevated, probably by intrusion of magma into a chamber beneath the block at a late stage in the volcanic activity of the area.

MINERAL DEPOSITS

The mining districts of southern Nye County and the minerals or metals produced in each district are shown on plate 2. Most of the districts have gold and silver deposits in quartz veins in Tertiary volcanic rocks; in a few districts, the veins are in Paleozoic or Precambrian sedimentary and metamorphic rocks. In several districts, gold is in part disseminated in dolomite beds in the Johnnie Formation or Stirling Quartzite.

None of the gold-silver districts have contained deposits comparable to those of the Comstock, Goldfield, or Tonopah districts. The largest gold-silver production has come from the Bullfrog district and amounted to $2 million to \$3 million. The second largest producer was the Johnnie district with production valued at from \$400,000 to \$1 million. All the remaining gold-silver districts, as shown on plate 2, produced ore valued at less than \$1 million, most of them considerably less.

The Bare Mountain district, comparable in output to the Bullfrog district, has produced fluorspar valued at more than \$2 million and a little mercury, volcanic cinder, ceramic silica, pumicite, and gold-silver.

The third and only other mining district in southern Nye County to exceed \$2 million in production is the Ash Meadows bentonite district, whose recorded production is nearly \$3 million.

The individual districts are discussed below in alphabetical order.

ANTELOPE SPRINGS DISTRICT

The Antelope Springs mining district is located 30 miles southeast of Goldfield on the east slope of the Cactus Range (Ts. 3 and 4 S., R. 47 E.) and has been described by Schrader (1913), Kral (1951, p. 11–13), and E. B. Ekren and others (written communication, 1966). The district was discovered in 1903. Several shafts were sunk along north-trending faults that dip about 30° W. The tuff of Antelope Springs has been displaced downward at least 1,000 feet on the west side along the fault zone. The tuffs are propylitically altered and, adjacent to ore-bearing veins, are intensely silicified and kaolinized. The veins average 8 feet in width and have been traced for as much as 2,000 feet along the strike.

The chief ore minerals are cerargyrite (AgCl) and argentite (Ag_2S) with some native silver-gold. The ore minerals are disseminated in a gangue of quartz, kaolinite, alunite, sericite, chlorite, calcite, iron oxides, and a little adularia. Bonham (1967a, b) estimates that the district produced 10,000 to 1,000,000 oz. of silver and 10 to 1,000 oz. of gold.

ASH MEADOWS DISTRICT

The Ash Meadows bentonite district has the largest production of any clay district in Nevada. The district has been described by Kral (1951, p. 13–16) and Olson (1964, p. 188). The district includes a number of calcium and magnesium montmorillonite deposits derived from the alteration of flat-lying tuffaceous lakebeds of Pleistocene Age. Olson (1964, p. 188) states:

> "Recorded past production has been almost \$3 million (Kral, 1951), but local residents who worked on these deposits over 30 years ago claim that the gross value of all production is many times this amount. The primary use of this clay was for filtering and clarifying mineral oils and as an absorbent. Some major oil companies still retain mineral rights in portions of the district, although production has been practically at a standstill since the 1930's."

Production in the district started about 1918.

BARE MOUNTAIN (FLUORINE) DISTRICT

The Bare Mountain or Fluorine mining district has produced a variety of minerals since the discovery of gold there in 1905 (Lincoln, 1923, p. 167). Lincoln restricted the district to the northern part of Bare Mountain, but Kral (1951, p. 60) expanded it to include all of Bare Mountain plus Crater Flat and part of Yucca Mountain to the east and the central Amargosa Desert to the southwest. Most of the mineral production, however, has come from the northern part of Bare Mountain. Large amounts of fluorspar have been mined since 1918, and a small production of mercury, ceramic silica, volcanic cinders, and pumicite has been recorded (Cornwall and Kleinhampl, 1961). Meager showings of gold, silver, and tungsten have been found in several prospects, but no production has been recorded. Unsuccessful attempts have been made to quarry marble at Carrara Canyon, 7 miles southeast of Beatty, and perlite, 3 miles east of Beatty.

The largest fluorspar deposit occurs 4 miles southeast of Beatty (sec. 23, T. 12 S., R. 47 E.). Since 1918 about 130,000 tons of fluorspar of metallurgical grade, averaging about 75 percent CaF_2 and less than 2 percent SiO_2, have been mined. Since 1927 J. Irving Crowell, Jr., and, in recent years, his son have been operating the mine, which has 2 shafts and 13 levels that extend down 550 feet. The annual production of recent years has been about 5,000 tons. At this rate, reserves are sufficient for many years' production.

The Daisy deposit occurs in dolomite of the Nopah Formation in a structurally complex area with prominent northeast-trending, steep-dipping, right-lateral tear faults and gently northwest-dipping thrust faults. The shape and extent of the ore bodies appear to be controlled in large part by these two sets of faults, which more or less bound the bodies both vertically and laterally. The ore shoots are almost everywhere bounded by gouge zones of faults, and these impermeable zones apparently restricted the ore solutions to definite channels where the fractured dolomite was almost completely replaced by fluorite.

The ore at the Daisy deposit consists of fine-grained purple fluorite (CaF_2) with seams and layers of yellow clayey gouge. In the lower levels the fluorite is partly to largely white or yellow and granular; calcite-filled fissures as much as 3 feet wide are common. Fine crystals of cinnabar are locally abundant, lining vugs in this calcite. The radioactivity of the deposit has been investigated and the equivalent uranium content was found to range from 0.002 to 0.015 percent (Cornwall and Kleinhampl, 1964, p. J21). The ore mineral was probably deposited by ascending hydrothermal solutions that moved along permeable channels in the fractured Paleozoic rocks. The ore solutions probably moved up from a nearby chamber of Tertiary rhyolite magma that also erupted voluminous ash flows, tuffs, and fluidal flows in the area just north of the Daisy mine.

Several other fluorspar deposits have been found on

Bare Mountain. A small deposit occurs along a shear zone in dolomite of the Nopah Formation at the Goldspar (formerly the Diamond Queen) mine on the east side of the Bare Mountain (sec. 5, T. 13 S., R. 48 E.). Ten thousand or more tons of fluorspar have been mined from this deposit since 1958 by the Monolith Cement Co. Another promising occurrence of fluorspar along a fault in the Lone Mountain Dolomite 2 miles north of the Goldspar mine was explored in 1958. Two other small deposits of fluorspar have been found in carbonate rocks near the Daisy mine, but there has been no production.

Several mercury deposits have been found in the Bare Mountain district. Cornwall and Kleinhampl (1961) have described these deposits as follows:

> "Mercury was discovered in 1908 at the north end of Meiklejohn Peak (7 miles east of Beatty, T. 12 S., R. 48 E.). Production from this property, which is known as the Harvey mine and also as the Telluride mine, was recorded as 72 flasks up to 1943 according to Bailey and Phoenix (1944, p. 142). The mine was active again in 1956, but the amount of production is unknown and probably small. The mercury occurs in cinnabar sparsely disseminated in a lens of chalcedony and opal along a steeply dipping fissure in dolomite of the Fluorspar Canyon Formation [Nevada Limestone] of Devonian age. Another small deposit known as the Tip Top mine is similar in occurrence to the Harvey mine and is located 600 feet north of it. Production here is reported as possibly about 100 flasks of mercury (Bailey and Phoenix, 1944, p. 144).
>
> "Small amounts of mercury have been found at the thoroughly explored Thompson mine in the northwest end of Yucca Mountain (sec. 29, T. 11 S., R. 48 E., unsurveyed). Cinnabar occurs locally as small seams and spheres in silicified and opalized rhyolitic tuff. Production has been very small (Bailey and Phoenix, 1944, p. 143)."

Volcanic cinders have been quarried from a Quaternary basaltic cinder cone 21 miles southeast of Beatty and 1 mile north of Highway 95. Kral (1951, p. 66) states that the cinders have been used to make building blocks and have also been sold to the Nevada State Highway Department, which uses them for building highways in that area.

An unknown but moderate amount of ceramic silica has been shipped from the Silicon mine at the northwest end of Yucca Mountain, 1.5 miles northwest of the Thompson mine described above. According to Kral (1951, p. 68), the silica runs about 99.7 percent SiO_2 and 0.04 percent iron. The silicification has resulted from the complete hydrothermal alteration of a rhyolitic tuff. A moderate amount of pumicite has been quarried from a pumiceous tuff located 3 miles north of Beatty for use in the manufacturing of light-weight aggregate building blocks (Kral, 1951, p. 68).

The discovery of gold at the Telluride (Harvey) mine (described above for its mercury production) at the northeast corner of Bare Mountain attracted prospectors to the area, but despite repeated attempts in several parts of the mountain to develop an ore body, there is no recorded production of gold. One of the greatest exploration efforts was made at the Gold Ace mine 6 miles southeast of Beatty (Kral, 1951, p. 63–64). Gold was discovered there in 1913, and between that time and 1936, several groups tried unsuccessfully to find an ore body. There apparently was a small but unknown production of gold, as indicated by a small mill tailings pile at the 75-ton mill. It is reported that the gold occurred in bedding-plane shears and veins a few inches to 4 feet wide in gently dipping strata here designated the Stirling Quartzite. Three other gold prospects, the Arista mine, Grand Junction claims, and Frank Oleniczak claims, 1 to 4 miles north of the Gold Ace mine on the west flank of Bare Mountain, are mentioned by Kral (1951, p. 64–65), as well as the Mexican claims 6 miles southeast of the Gold Ace mine in a dolomitic member of the Stirling Quartzite. The Mexican claims are reported to have shipped about 35 tons of ore assaying $16 per ton gold and silver.

BULLFROG (RHYOLITE) DISTRICT

The Bullfrog or Rhyolite mining district covers the Bullfrog Hills west of Beatty and is the largest gold producer in southern Nye County. Gold was discovered at the original Bullfrog mine at the south end of Bullfrog Mountain, 7 miles west of Beatty, in 1904 (Ransome and others, 1910, p. 12); total production of gold and silver through 1948 is valued at nearly $2 million (Kral, 1951, p. 29). Lincoln (1923, p. 162) gives a total production figure (including minor copper and lead) of $2,792,930 for the period 1905–1921. Most of the production came prior to 1910 from the Montgomery-Shoshone mine, 3 miles west of Beatty.

The gold deposits are in fissures and veins in rhyolitic welded tuffs and are for the most part related to steep normal faults. They have been described in detail by Ransome and others (1910, p. 90–125). Most of the deposits occur along the east rim of the caldera postulated by Cornwall and Kleinhampl (1964). Several other deposits, including the original Bullfrog mine, occur along the north contact of the central domal uplift of basement rocks into the Tertiary pyroclastics. The mineralogy of the gold-silver veins is simple and consists of quartz, calcite, and finely disseminated gold-silver in scattered pyrite grains (plus small amounts of chalcocite, chrysocolla, and malachite in the original Bullfrog mine). Cerargyrite has been detected but apparently is not abundant. The ratio of gold to silver in ore mined was 1 to 8 (Lincoln, 1923, p. 162) and the average grade was $10 per ton (Kral, 1951, p. 29). Indications of radioactivity have been found at two of the gold-silver prospects but no uranium production has been reported.

The principal ore body of the district occurred in the Montgomery-Shoshone mine, near the surface, where numerous vertical fissures on the southeast side of the steeply northwest-dipping Montgomery-Shoshone fault intersected it from below. The two other most promising deposits in the district are at the Mayflower and Pioneer mines, 6 and 6.5 miles northwest of Beatty, respectively. The Mayflower deposit occurs along a fault or fissure that dips 60° to 65° SW. (Ransome and others, 1910, p. 124). The Pioneer deposit is said to be "almost identical to the adjoining Mayflower" (Kral, 1951, p. 39). The rhyolitic host rocks (welded tuffs of the Timber Mountain and Paintbrush Tuffs) of these deposits are moderately to intensely altered. Most of the other gold-silver prospects in the Bullfrog Hills are similar to, but leaner than, those described above.

In addition to the gold-silver deposits of the Bullfrog district, a small bentonite deposit at the Vanderbilt mine, 1.5 miles south of Beatty, has been operated for about 15 years by the Silicates Corp. Two bentonite bodies, 300 feet apart, occur along the footwall side of a fault that dips 50° W. (Cornwall and Kleinhampl, 1964, p. J23). The bentonite formed by intense hydrothermal alteration of welded and nonwelded rhyolitic tuff. The high-grade ore is soft, white, and has waxy pink or tan spots that probably represent replaced pumice fragments. Original phenocrysts of quartz, sanidine, oligoclase, and biotite are still visible in the bentonite. X-ray determinations indicate that the bentonitic clay is nearly pure montmorillonite.

CACTUS SPRING DISTRICT

The Cactus Spring mining district includes the north half of the Cactus Range. According to Lincoln (1923, p. 164), turquoise was discovered at Cactus Peak in 1901 and silver at the Cactus Nevada silver mine in 1904; a small amount of ore was shipped from the latter. In addition to these discoveries, showings of gold and copper were found in the area. Kral (1951, p. 41) states:

> "The ores are found in quartz veins and stringers, usually in kaolinized or silicified rhyolite. The larger veins are 2 to 4 feet wide. The mineral turquoise occurs in sheared rhyolite and is reported to be of economic importance in the area."

Total production from the district is estimated to be less than $20,000.

EDEN DISTRICT

The Eden mining district consists of three groups of mining claims on the east side of the Kawich Range at between 7,000 and 8,000 feet in elevation and 2 to 4 miles south of 38° latitude (T. 1 N., R. 50 E.). Ball (1907, p. 110) reports that the first claims were staked in 1905. Kral (1951, p. 52–54) states that shipments of gold-silver ore were made in 1906 and 1907 but that total production was probably less than $10,000. Between 1926 and 1934 exploration was carried on at three groups of claims, the Nevada Triumph group, the South Gold Mining Co. group, and the Oro Cache Mining and Milling Co. group. In addition, the Golden Crown claims were explored during 1923–1924 at the old Eden mine, where the early work referred to by Ball (1907, p. 110) was done. No production has resulted from the more recent activity, although ore assays are reported to range from $2 to $250 per ton, with many between $10 and $70, predominantly values of gold with some silver.

The gold-silver mineralization occurs along steeply dipping silicified shear zones in rhyolitic welded ash flows of the tuff of White Blotch Spring. Apparently the gold and silver occur both as native metals and in disseminated pyrite associated with the quartz veins and altered wall rock. In addition, Ball (1907, p. 111) reports the presence of ruby silver and cerargyrite (silver chloride) at the old Eden mine.

GOLD CRATER DISTRICT

The Gold Crater mining district is located 10 miles east of Stonewall Mountain and south of Stonewall Flat (T. 5 S., Rs. 45 and 46 E.). Ball (1907, p. 140) reports that the district was discovered in 1904. Kral (1951, p. 69) states:

> "Considerable work was done in the early days; however, very little production has been noted. In 1916 it is reported that 120 tons of ore shipped grossed $2,015. Couch shows a recorded production of $1,208 in 1934 from 40 tons of ore. For the past several years one man has worked in the district and made intermittent shipments. His total shipments probably gross less than $5,000."

The deposits occur in intensely altered volcanic rocks, the principal rock is a quartz latite lava, and the chief alteration is dominantly argillic with some silicification (E. B. Ekren, and others, written communication, 1966). Earlier mining in the district was for gold and silver, but about 1950 (Kral, 1951, p. 69–70) it included galena and cerussite plus gold and silver in brecciated pipes. The ore was reported by Kral to run 10 percent lead, 14 to 24 oz. silver, and $8 to $12 in gold per ton.

GOLDEN ARROW DISTRICT

The Golden Arrow district is on the west flank of the Kawich Range and extends south from 38° latitude in Ts. 1 and 2 N., R. 48 E. By the time Ferguson (1917, p. 115–121) visited the mine in 1916, most of the exploration had been done and a very small amount of gold and silver produced. Deposits were explored at the Golden Arrow, Gold Bar, and Desert shafts before 1917; a fourth at the Jeep claims 2 miles to the east was explored in the 1940's (Kral, 1951, p. 72).

The deposits consist of quartz veinlets with pyrite and occur along normal faults in the rhyolitic tuff of White Blotch Spring and in andesite. Ferguson states that silver is reported to be the principal valuable constituent; the gold content is minor. The ore is reported to have averaged $25 a ton at the Gold Bar shaft. Kral (1951, p. 72), in part quoting Couch (in Couch and Carpenter, 1943), reports that shipments of 73 tons with a value of $4,246 were produced in 1941 and 1946 and that shipments up to about 1950 totaled 900 tons averaging $18 per ton. At the Jeep claims, ore values of gold and silver are said to be about equal.

GOLDFIELD DISTRICT

All of the significant gold production in the Goldfield mining district has come from that part which lies in Esmeralda County, but numerous showings have been explored in the eastward extension of the district in Nye County (T. 2 S., R. 43 E. and T. 3 S., Rs. 43 and 44 E.). A number of the prospects are shown on plate 1 of this report, and Ransome (1909, pl. 2) shows a number of workings there. Most of the showings are in Milltown Andesite and the dacite. In this area these rocks are in part intensely altered, and thus resemble rocks of the center of the mining area. Silicified ledges generally trending southeast or northeast occur also along fissures and faults, with which ore shoots are commonly associated.

It is not believed that any significant production has come from the Nye County part of the district. Prospecting and exploration have continued intermittently in this area since the initial boom period in the early 1900's, and there has been exploration activity there in the 1960's. Ransome (1909, p. 113) and Bailey and Phoenix (1944, p. 144–145) have described a small occurrence of cinnabar on the Diamondfield property (sec. 21, T. 2 S., R. 43 E.). The cinnabar occurs as crystals in a shear zone in alunitized and silicified Milltown Andesite.

JOHNNIE DISTRICT

The Johnnie mining district is located on the northwest flank of the Spring Mountains, 3 miles northeast of Johnnie in T. 17 S., R. 53 E. It is the second largest gold-producing district in southern Nye County. Bonham (1967a) estimates production at between 10,000 and 100,000 oz. of gold. Kral (1951, p. 86) reports a recorded production through 1913 of $382,681 from 64,582 tons and quotes C. H. Labbe as stating that between 1910 and 1913 the Johnnie mine itself produced more than $1 million from 120,000 tons. The deposit is reported to have been discovered in 1890.

The gold occurs in prominent and persistent quartz veins along faults in sandstone, shale, and limestone of the Wood Canyon and Carrara Formations. The largest ore shoots are in the Johnnie mine, where the vein follows a fault between the two formations. The Overfield mine, adjoining the Johnnie mine on the southwest, has a vein that strikes N. 45° E., dips 60° SE., and may join or be a continuation of the Johnnie vein. This property has no recorded production. The Labbe mine is located 1 mile southwest of the Johnnie mine, also on a vein near or along the Carrara-Zabriskie contact but separated from the block containing the Johnnie mine by a cross fault with an apparent right-lateral horizontal displacement of more than half a mile. Kral (1951, p. 89) reports that no production has been recorded, but surface workings indicate much stoping.

The Congress mine, located about 1 mile southwest of Johnnie (T. 18 S., R. 52 E.), is included here in the Johnnie district. It is in a quartz vein along branching faults in quartzitic sandstone of the Wood Canyon Formation and along a fault between the Wood Canyon and Bonanza King Formations. Although no production is recorded, there are several thousand tons of tailings near a 10-ton stamp mill. C. H. Labbe states that most of the activity was between 1890 and 1895 and that the average grade was $8 to $16 from an ore vein 3 to 20 feet wide.

The hillside and wash below the Johnnie and Overfield mines were placered for gold in 1949 (Kral, 1951, p. 87) and in the early 1960's by sluicing with high-pressure water passed through trommels and screens to concentrating tables. The amount of gold recovered is not known. Placering on a small scale has also been done in the gulches below the Congress mine.

KAWICH (GOLD REED) DISTRICT

The Kawich or Gold Reed mining district, on the southeast flank of the Kawich Range (T. 4 S., R. 51 E.) in the Nellis Air Force Range, was discovered in 1904. Ball (1907, p. 111–113) visited the area in 1905 and described free gold as occurring in silicified monzonite porphyry in an area of complex faulting. Fresh pyrite was found below 150 feet and is probably represented by iron-stained casts near the surface. Production from the district has been small. Bonham (1967a, b) listed gold production of 1,000 to 10,000 oz. and silver production of 10 to 10,000 oz. Kral (1951, p. 92) reports a high-grade gold shipment in the late 1940's.

E. B. Ekren and others (written communication, 1966) state:

> "The principal mines are located along a northwest-trending silicified horst along which the strata have been dropped both to the northeast and southwest. The silicified zone forms a reef-like ridge, hence the original name Gold Reef. . . . None of the major mines are accessible at present; however, all the deep shafts are sunk in porphyritic dacite which appears to be the principal ore bearer. The dacite is bleached to light gray and pastel shades of yellow and pink. The gold is not visible to the eye but apparently is associated with iron oxide and pyrite."

LEE DISTRICT

The Lee mining district is located in a group of low hills on the southwest side of the Amargosa Desert, 3 to 5 miles southwest of Big Dune (T. 15 S., R. 48 E.). The exploration workings are in late Precambrian rocks of the Johnnie Formation and Stirling Quartzite. Ball (1907, p. 175) states that the mineralization consists of free gold in quartz veins and in dolomite or siderite, each heavily stained by limonite. Dolomite beds are present in both of these Precambrian formations. Apparently no ore has been produced.

MELLAN MOUNTAIN DISTRICT

The Mellan Mountain mining district covers a hill south of Mellan on the east side of Cactus Flat (T. 3 S., R. 48 E.). According to Kral (1951, p. 131–132), the most promising prospect in the district was discovered in 1930 and consists of gold with some silver in shear zones in rhyolite and shale. The deposit has been explored by a 400-foot inclined shaft and 700 feet of drifts; production prior to World War II is estimated at about $1,000. Four samples taken from stopes in the most promising areas, where the vein is 4 to 6 feet, ranged from $17 to $27 per ton. The district is now part of the Sandia rocket-testing range.

MINE MOUNTAIN DISTRICT

The Mine Mountain mining district occurs on Mine Mountain on the southwest margin of Yucca Flat (T. 11 S., R. 52 E.). Four adits and two shallow shafts indicate a modest exploration effort, according to Harley Barnes and others (written communication, 1963), who examined the workings. All the workings are in high-angle normal faults trending N. 30° E. in brecciated quartzite and silicified dolomite of the Devils Gate Limestone in the upper plate of a thrust fault. Barnes and others collected a number of samples. Only one, from a brecciated quartzite, contained significant amounts of ore minerals. A semiquantitative spectrographic analysis of this sample showed over 10 percent lead, 0.5 percent mercury, and 0.07 percent silver. Claim notices indicate exploration on Mine Mountain in 1928.

OAK SPRING DISTRICT

The Oak Spring mining district is located at the north end of Yucca Flat, south of Oak Spring Butte, and consists of tungsten and molybdenum deposits in tactite formed by metamorphism of limestone in the Ninemile Formation of the Pogonip Group near the Climax stock of granodiorite and quartz monzonite (Harley Barnes and others, written communication, 1963). According to Kral (1951, p. 138–141), exploration for tungsten and molybdenum started in 1937 and continued into the 1940's. Ball (1907, p. 128–130) reported that prospects were being developed in 1905 for gold associated with lesser amounts of silver and gem-quality chrysocolla and sparse pyrite, galena, chalcopyrite, and sphalerite.

The tactite, which contains the tungsten and molybdenum as scheelite and molybdenite, respectively, consists of garnet, quartz, pyroxene, calcite, idocrase, and epidote that formed by the metamorphism of silty limestone. The tungsten and molybdenum mineralization are said to be concentrated along certain beds and fracture zones. The best showings are on the Tamney property known as the Climax claims. Kral (1951, p. 139) states:

> "Sampling by the U. S. Vanadium Corporation indicated one ore body of 175-foot length having 1.08 percent tungstic trioxide for a width of 7.3 feet; another body in three parts is indicated to have a total of about 270 tons per foot of depth containing 0.53 percent tungstic trioxide; another smaller area is calculated to have about 1,000 tons to a depth of 25 to 30 feet containing 1.60 percent tungstic trioxide."

Several other groups of claims in the area have been explored. Production of 2,500 tons of ore valued at $4,000 has been reported from the Garnetyte claim.

The Michigan Boy claims, 6 miles southeast of the center of the district, contain a deposit of argentiferous galena along a vein 8 to 24 inches wide in calcareous shale (Kral, 1951, p. 140–141). The vein can be traced for several hundred feet by exposures in surface workings. Samples from dumps contain 11 to 16 oz. silver per ton and 1.5 percent lead.

The Rainstorm claims are located 10 miles southeast of the main Oak Spring district. Kral (1951, p. 141) states:

> "The property is reported to contain lead, silver, and gold ore, 80 tons of which was shipped prior to World War II, and said to contain 55 percent lead, 25 ounces silver, and 0.25 ounces gold per ton. Two samples of the vein, taken by an examining engineer, averaged 31.5 percent lead, 0.07 ounces gold, and 11.6 ounces silver per ton."

Workings include a 220-foot shaft, 150-foot adit, and several open cuts.

QUEEN CITY DISTRICT

The Queen City mining district is near the south end of the Quinn Canyon Range where it is crossed by State Highway 25 and includes the Black Hawk, Oswald, and Queen City claims.

The Black Hawk mine, consisting of seven claims, is located 1 mile north of State Highway 25 in the hills on the east margin of Railroad Valley (T. 2 S., R. 53 E.). According to Bailey and Phoenix (1944, p. 154–155), the deposit was discovered in 1929 and by the end of 1943 had yielded 68 flasks of mercury. There has been no production since that time. Workings consist of a 100-foot vertical shaft with adits on two levels and two exploration pits.

The deposit occurs in silty limestone of the Nopah or Windfall Formation where it is in fault contact with quartzitic sandstone. The limestone is shown as Nopah Formation on plate 1, but lithologically it more nearly resembles the Windfall Formation, which is correlative. The cinnabar (HgS) is reported to occur in botryoidal masses with associated quartz veins.

Another mercury prospect was found by the author 2 miles southeast of the above location (T. 2 S., R. 54 E.). There are surface pits and a steeply inclined shaft in bleached and limonitized rhyolitic welded tuff. This is evidently the deposit visited by Kral (1951, p. 92) in 1941 and described by him as follows:

> "Cinnabar occurs in shears in what appears to be a highly altered andesite. The workings include a 45-foot inclined shaft with 160 feet of drifting from the bottom and 22-foot level. Only a small amount of stoping had been done from the drifting. It appears that most of the ore came from a few large surface cuts and trenches."

The Oswald claims are located 2 miles southwest of the point where State Highway 25 enters the low hills of the southern Quinn Canyon Range from the west (T. 2 S., R. 53 E.). The deposit, visited by the author in 1962, is in limestone of the Nopah (Windfall) Formation along a fault contact with quartzite. Mineralized material on the dump contains galena plus a little chalcocite, malachite, and azurite in a matrix of quartz and calcite. Kral (1951, p. 92) gives the following description:

> "The ground was located in 1938 by the present owners, Mrs. Katherine Oswald and others of Tonopah. Occurrences of argentiferous galena, smithsonite, and cinnabar are found in narrow veins and lenses in quartzite intruded by altered andesite dikes. A trial run of 1,400 pounds of selected cinnabar ore reportedly produced 14 pounds of mercury. The workings consist of a 200-foot adit, several shallow shafts and some trenching."

The Queen City claims are located 1 mile south of State Highway 25 and 1.5 miles east of the Oswald claims (T. 2 S., R. 53 E.). Several veins as much as 100 feet long and 40 feet wide of gibbsite and manganese oxides have hydrothermally replaced limestone of the Nopah (Windfall) Formation along steeply dipping fissures that strike northeast. The manganese oxides are a mixture of pyrolusite and lithiophorite (Hewett and others, 1968). Several trenches as much as 20 feet deep have revealed the veins, which seem to follow a group of anastomosing fractures in a zone 200 feet wide. Claim notices on the property indicate that they were staked in 1935. No production has been reported.

SILVERBOW DISTRICT

The Silverbow mining district is located on the west flank of the Kawich Range, 6 to 9 miles south of 38° latitude (T. 1 N. and T. 1 S., R. 49 E.). The district was discovered in 1904 (Ball, 1907, p. 109) and operated intermittently through 1941. In 1964 several mines in the district were reopened by the Tickabo Mining and Milling Co. (E. B. Ekren and others, written communication, 1966). Silver and gold were produced, with silver predominant. Kleinhampl (1964, p. 144) estimates a silver production of between 100,000 and 1,000,000 oz. Gold production is estimated by Bonham (1967a) at between 1,000 and 10,000 oz.

The mines are located along northwest- to west-trending steeply dipping faults that have dropped the Fraction Tuff and dacite lavas on the south against the tuff of White Blotch Spring and older tuffs on the north (E. B. Ekren and others, written communication, 1966). The deposits occur in and near quartz veins in the rhyolitic tuffs, which are intensely altered by silicification and kaolinization in the vicinity of the deposits. The silver occurs as cerargyrite (silver chloride), ruby silver, and stephanite disseminated in and near the quartz veins; gold occurs as the native metal (Ball, 1907, p. 109). The cerargyrite and some limonite and malachite occur as secondary, supergene minerals.

According to Kral (1951, p. 163–165), there have been four principal groups of claims worked prior to 1951. The Blue Horse mine, near the south end of the district, was worked extensively prior to 1930 along a northwest-trending quartz vein 2 to 4 feet wide. The rhyolitic welded tuff near the vein has been silicified so that the zone stands out as a ridge, which the vein follows for 1,000 feet. Workings include a 100-foot shaft, several open cuts, and a 300-foot adit along the vein.

The Silver Glance group of claims adjoins the Blue Horse mine on the north. Small ore shipments were made prior to 1925, and during 1940–1942 160 tons of ore averaging 35 oz. silver and 0.05 oz. gold per ton were shipped (Kral, 1951, p. 164). The workings include several adits.

The Catlin claims are north of the Silver Glance claims. First ore shipments were made about 1906. Kral (1951, p. 164) reports shipment in 1941 of 241 tons of ore valued at $3,672, most of which came from reworking old dumps. Workings include an adit and several shafts 60 to 100 feet deep. Silver minerals occur in a quartz vein 2 to 8 feet wide in rhyolitic welded tuff. The silver occurs as chloride near the surface and in sulfides at depth.

The Hillside mine, near the Catlin claims, has quartz veins in rhyolitic welded tuff. There are two adits, 1,000 feet of drifts, 500 feet of raises and winzes, and several shallow shafts. In 1941, 285 tons of ore valued at $7,307 were shipped (Kral, 1951, p. 165).

In 1964 several mines in the Silverbow district were reopened by the Tickabo Mining and Milling Co., according to E. B. Ekren and others (written communication, 1966). Ekren reports:

> "Several of the prospects controlled by the Tickabo Mining Company are in Fraction Tuff and carry ore-grade values. Inasmuch as the lavas of intermediate composition are the principal ore bearers in adjacent areas, especially Tonopah where they also underlie the Fraction Tuff, the possibility exists that those lavas may be mineralized at depth in the Silver Bow area."

STONEWALL DISTRICT

The Stonewall mining district is on the north slope of Stonewall Mountain (T. 5 S., Rs. 43 and 44 E.) about 15 miles southeast of Goldfield. According to Lincoln (1923, p. 183), the district was prospected for gold and silver as early as 1905 and small shipments were made in 1911 and 1915. According to Ball (1907, p. 88), gold values ranging from a trace to $6 per ton were found in a quartz vein along a prominent normal fault striking N. 65 E. and dipping 70° N. that bounds the north end of the mountain. The quartz vein is in rhyolitic welded tuff and intrusive quartz latite and in places is 40 feet wide; elsewhere it branches into a number of parallel veins. The quartz is stained by limonite and azurite; some pyrite was found. Similar veins were found in similar rocks at other places on Stonewall Mountain.

Kral (1951, p. 165–166) reports that the Sterlog claims at the northwest corner of Stonewall Mountain have a 240-foot shaft on a vein with silver mineralization and a 1-mile adit driven south from Stonewall Flat to intersect the vein 500 feet below the collar of the shaft. The adit was driven in the early twenties; the property was later abandoned.

TOLICHA DISTRICT

The Tolicha mining district includes the Clarkdale area (T. 8 S., R. 45 E.), 6 miles west of Tolicha Peak, and the Quartz Mountain area (T. 7 S., R. 47 E.), 4 miles east of Tolicha Peak. Initial prospecting was done in the Quartz Mountain area about 1905, but the first significant discovery was in 1917, when rich gold ore was found (Lincoln, 1923, p. 184) on the Landmark-Life Preserver claims. Lessees are said to have shipped gold-silver ore valued at $750,000 from these claims in the early thirties (Kral, 1951, p. 167–168). The ore was found in brecciated zones cemented by quartz along a shear zone in silicified rhyolite flows. The workings on the claims consist of several shafts, adits, and drifts totaling about 2,500 feet in length. Exploration was also carried out 3 miles southeast of these claims along a 2-foot quartz vein in rhyolite, but apparently no ore was produced (Kral, 1951, p. 168).

In the Clarkdale area west of Tolicha Peak, gold was discovered about 1933 and a shipment of ore valued at $1,000 was made in that year (Kral, 1951, p. 168–169). The gold occurred in a breccia shear zone cemented by quartz in fluidal rhyolite. Two other groups of claims were explored in the thirties in rhyolitic welded tuff about 1 mile west of the prospect described above. There has been intermittent exploratory activity in the Clarkdale area since the thirties, particularly in the years following World War II (Kral, 1951, p. 169).

TRAPPMANS DISTRICT

The Trappmans mining district is located about 4 miles east of Mount Helen (T. 5 S., R. 47 E.) in an area of Precambrian gneissic quartz monzonite and biotite schist. Ball (1907, p. 138–139) states that the district was discovered in 1904. Gold and silver were found in quartz veins cutting the gneiss. He recognized three sets of quartz veins. The oldest are lenticular and of pegmatitic origin; the two younger sets contain pyrite, as does the adjacent wall rock, and carry gold-silver in the ratio of 1:4. Some cerargyrite was noted. E. B. Ekren and others (written communication, 1966) found two shafts on the property, one in a north-trending 60-foot quartz vein, the other in a pyritized fault zone that strikes north-northeast and dips 65° W.

WAHMONIE DISTRICT

The Wahmonie mining district is located 2 miles north of Skull Mountain and 1 mile east of Jackass Flats (T. 13 S., R. 51 E.). The district must have been discovered prior to 1905, as Ball (1907, p. 140) mentions visiting the Horn Silver mine of that district in reporting his visit of 1905. In 1928 the district was rediscovered with a strike of high-grade silver-gold ore, but only minor shipments were made (Kral, 1951, p. 206–207). Apparently the precious metals occurred in or along quartz veins in an area of hydrothermally altered latite to dacite lava flows, tuffs, and volcanic breccias of the Salyer and Wahmonie Formations.

WELLINGTON DISTRICT

The Wellington mining district is located in T. 5 S., R. 46 E., 12 miles south of Cactus Spring. The deposits consist of gold with minor silver in and adjacent to quartz veins in a shear zone that strikes N. 70° E. in rhyolite and andesite or latite (Ball, 1906, p. 68). The rhyolite mentioned by Ball is probably the tuff of Antelope Springs, a rhyolitic welded tuff, and the andesite or latite are younger dikes. The host rocks are highly altered near the veins. The feldspar has been kaolinized and the biotite altered to white hydromica. Limonite is abundant due to oxidation of primary pyrite.

Kral (1951, p. 211–212) describes several groups of claims, but information concerning them is sketchy. Probably the most significant deposit is the Franz Hammel prospect, where, according to Kral (1951, p. 211), gold and silver occur in brecciated and silicified rhyolite near andesite. Mineralized rock on the dump of a 250-foot shaft contains abundant pyrite. There are also several drifts and other shallow shafts on quartz veins. Small shipments of ore are said to have been made. The Surprise group of claims, with a reported production of 100 tons, has deposits of gold and silver along quartz veins in diorite, which have been explored by two shafts and several open cuts (Kral, 1951, p. 212). The Golden Chariot claims have local high gold-silver values in quartz veins in rhyolite. This property has a 300-foot shaft.

WILSONS DISTRICT

The Wilsons mining district is located 7 miles southeast of Antelope Springs and 5 miles northeast of Mount Helen (Ts. 4 and 5 S., R. 47 E.). According to Ball (1906, p. 69), the district was discovered in 1904, and the deposits consist of northeast-trending, steeply dipping quartz veins in altered rhyolite and andesite. The rhyolite is probably the rhyolitic welded tuff of the tuffs of Antelope Springs. The quartz has been stained by limonite and malachite. Assays of $110 to $180 per ton gold and silver with a ratio of 1:5 or 6 have been reported. Workings include a 150-foot shaft and 100-foot adit (Kral, 1951, p. 218); the shaft was sunk on a 4-foot quartz vein.

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