NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

BULLETIN 64

GEOLOGY AND MINERAL RESOURCES OF EUREKA COUNTY, NEVADA

(Prepared cooperatively by the United States Geological Survey)

By

RALPH J. ROBERTS

KATHLEEN M. MONTGOMERY

and

ROBERT E. LEHNER

MACKAY SCHOOL OF MINES

UNIVERSITY OF NEVADA

1967

NOTICE

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STATE OF NEVADA

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NEVADA BUREAU OF MINES

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FOREWORD

Nevada Bureau of Mines Bulletin 64, "Geology and Mineral Resources of Eureka County, Nevada," is one of a series of county studies on the geology, mineral deposits, and mining potential of Nevada. The study is part of a cooperative program between the Nevada Bureau of Mines and the U. S. Geological Survey. The report has been prepared by Ralph J. Roberts, Kathleen M. Montgomery, and Robert E. Lehner of the Geological Survey.

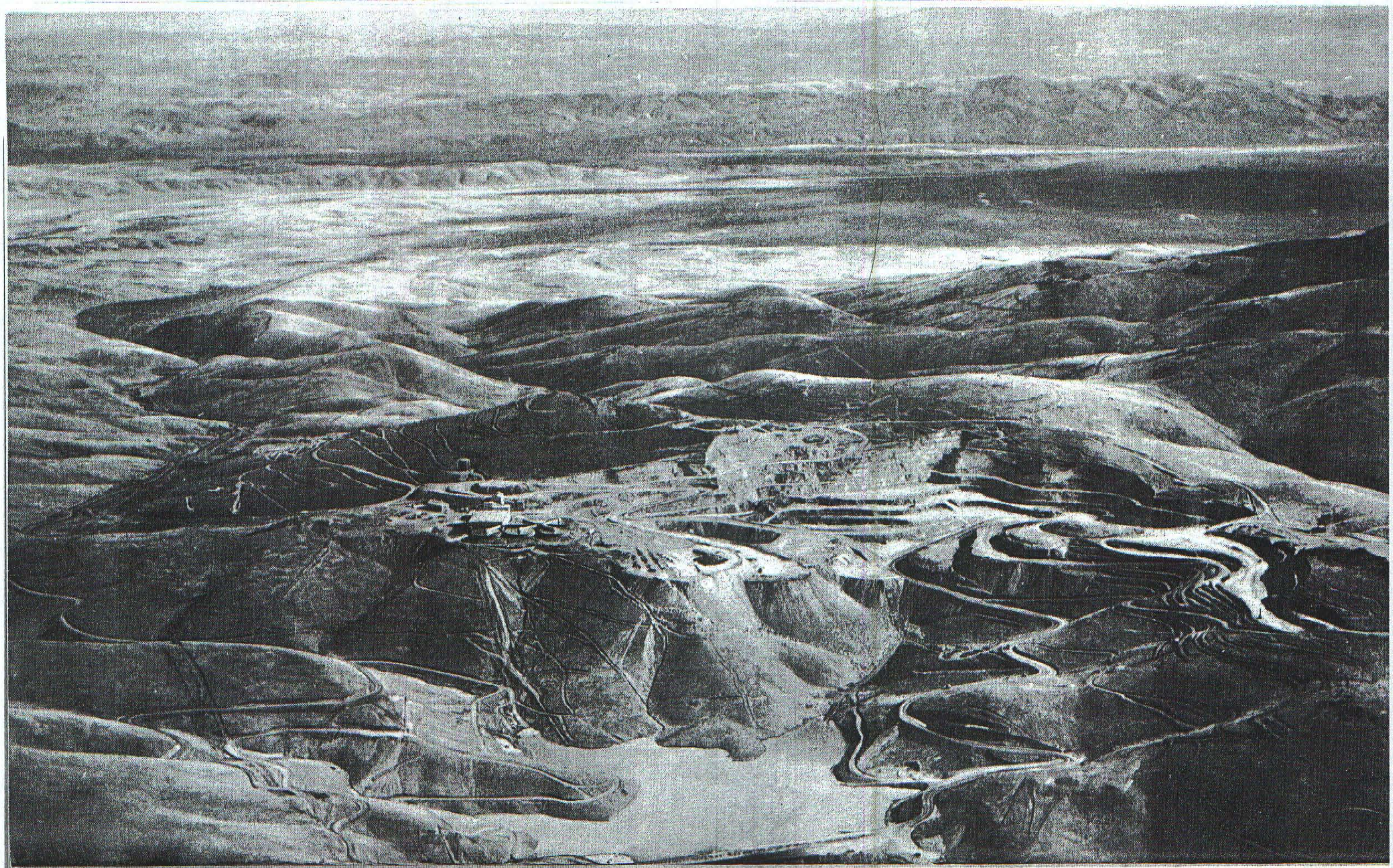
Since the discovery of silver in 1862 at Cortez and Mill Canyon, Eureka County has been an important contributor to the mineral production of Nevada. Following the early discoveries, other mineralized areas were opened in rapid succession and mineral production remained high in the county until the early 1890's, when the rich bonanzas had been worked out. However, mining activity continued through the years at a slower pace on the lower grade ores. Most of the mineral production has come from gold, silver, lead, copper, and zinc in that order. In recent years the mining of iron ore has added significantly to the value of minerals produced. The mining of industrial minerals, mainly barite, is becoming increasingly important. Petroleum is known to exist in the county but has not been found in commercial quantities.

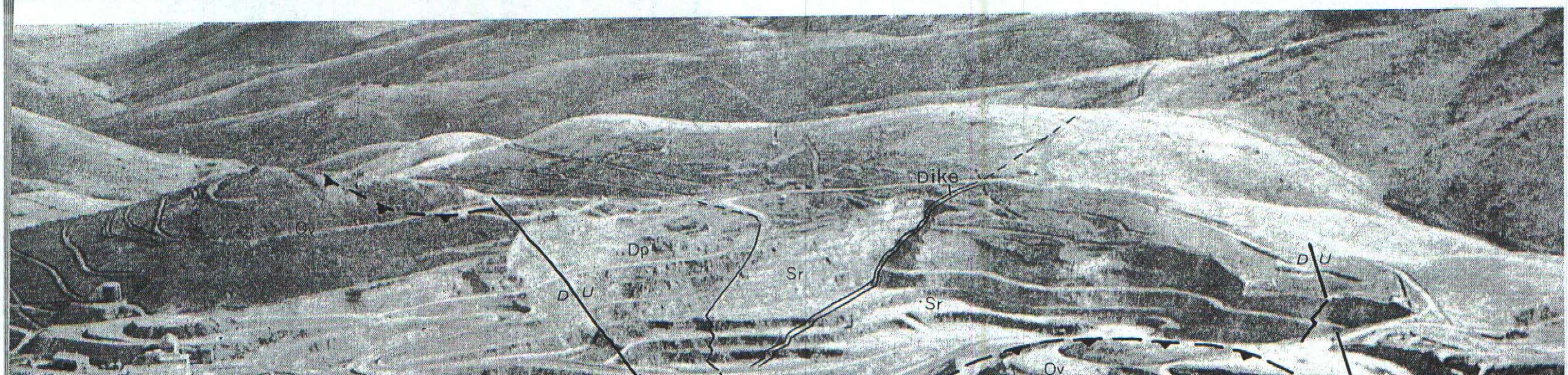
Based on geologic information obtained from the field studies made for this report, Roberts published a preliminary paper in 1960, calling attention to structural patterns of mineralization and areas favorable for prospecting. The Newmont Mining Corporation explored some of the areas suggested by Roberts and discovered a large low-grade gold deposit in the Lynn district. Mining of this deposit started in May 1965.

The profitable mining of the low-grade gold ores of the Lynn district was the beginning of what promises to be a new era in mining in Eureka County and adjacent areas. There is now much mineral exploration activity in several other areas of the county, some of which hold promise of developing into commercial operations. Bulletin 64, with its geological map and the section on "Suggestions for Prospecting," should aid materially in these efforts to discover new ore deposits.

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

March, 1967
Mackay School of Mines
University of Nevada





TOP: Looking east toward Ruby Mountains. Newmont Mining Corp.'s Carlin Gold Mining Co. operation, Lynn district, Eureka County, Nevada. Mill is flanked by dump and tailings pond (center foreground) with open cut stretching to right.

BOTTOM: Closeup of Carlin Gold Mining Co. mine and mill. Open pit is in Roberts Mountains Formation (Sr), which is overlain by the Popovich Formation (informal name used by the company) (Dp). These units have been overridden by the Valmy Formation (Ov) in the upper plate of the Roberts Mountains thrust (sawtooth line) and are cut by high-angle faults (D/U) and a porphyry dike.

GEOLOGY AND MINERAL RESOURCES OF EUREKA COUNTY, NEVADA

By

RALPH J. ROBERTS,[1] KATHLEEN M. MONTGOMERY,[1] and ROBERT E. LEHNER[2]

ABSTRACT

Eureka County, in east-central Nevada, includes the Sulphur Spring Range; the Roberts and Cortez Mountains; parts of the Tuscarora, Diamond, and Simpson Park Mountains; and the Antelope, Monitor, Shoshone, and Fish Creek Ranges. The ranges are underlain mostly by sedimentary rocks of Paleozoic Age that comprise preorogenic sedimentary rocks of Cambrian to Early Mississippian Age, belonging to two principal facies: an eastern carbonate assemblage and a western siliceous and volcanic assemblage. A postorogenic coarse clastic assemblage of Mississippian to Permian Age overlaps the other facies. One sedimentary clastic unit of Cretaceous Age is widely exposed in the southern part of the county. Volcanic rocks of Mesozoic Age occur in the central part of the county. Intrusive stocks are scattered throughout the county. Tertiary rocks include lavas, pyroclastics, and intercalated sedimentary rocks. Quaternary alluvium partly fills the valleys and extends up on the flanks of the ranges.

The Paleozoic formations were laid down in a broad geosyncline that covered most of Nevada. Subsequently these rocks were folded in Late Devonian or Mississippian time, and the western assemblage moved eastward on the Roberts Mountains thrust into juxtaposition with the eastern assemblage. Coarse clastics, eroded from an emergent highland to the west, were shed into the seaway and interfinger with calcareous rocks and shales in the southeastern part of the county.

Intermittent orogenic movements during late Paleozoic and Mesozoic time resulted in folding and thrust faulting of the overlap assemblage as well as the underlying units. In Mesozoic and Tertiary time, granitic stocks were emplaced in highly fractured areas. The ore bodies associated with the stocks are mainly silver-gold-lead-zinc replacement deposits in eastern carbonate assemblage host rocks. Deposits of gold, copper, and barite in western assemblage chert and shale have also been productive. Deposits in volcanic rocks have yielded significant production of iron ore and a small amount of silver. The major deposits are described and summarized in tables together with the minor deposits.

The recorded metal production of Eureka County was more than $78

[1]U. S. Geological Survey, Menlo Park, California.

[2]Bear Creek Mining Co., Tucson, Ariz.

million dollars up to the end of 1966, but the actual production may far exceed this figure. Values are mostly in gold, silver, lead, zinc, and copper. Production of nonmetallic minerals has been small. Deposits of sulfur, diatomaceous earth, barite, and construction materials have been worked on a small scale. Petroleum has also been found but has not been produced commercially. The outlook for future mineral production seems bright if commodity prices reach profitable levels.

INTRODUCTION

PREVIOUS WORK AND ACKNOWLEDGMENTS

Geologic work in the county dates back to 1869, when Clarence King, assisted by Arnold Hague, began geological exploration along the Fortieth Parallel. King's report on this work was published in 1878, and was followed by Hague's reports on the geology of the Eureka district in 1883 and 1892 and by Walcott's reports on the paleontology in 1884 and 1908. J. S. Curtis published a comprehensive report on the ore deposits of the Eureka district in 1884. In 1908, W. H. Emmons (1910) visited several districts in the central and northern parts of the county; Lee and others (1916) also prepared early reconnaissance maps of the northern part of the county. In 1938, a reconnaissance report by Vanderburg on the mining districts was published. Field work was begun in the Eureka district by T. B. Nolan in the 1930's and has been continued intermittently since then. In 1956 a comprehensive report of the stratigraphy was published (Nolan and others, 1956); in 1959 a geologic map of the district by Nolan and others, scale of 1:12,000, was released in the open files of the U. S. Geological Survey; and more recently a comprehensive report of the mining district was published (Nolan, 1962). In 1961, a preliminary geologic map of the county (Lehner and others) was published. From time to time, articles on mines in the county have appeared in mining journals.

Field work for this report began in 1952 under the direction of A. E. Granger, assisted by G. C. Simmons, M. M. Bell, and P. D. Proctor, and continued through the summer of 1953. When Mr. Granger left the Geological Survey early in 1954, the project was taken over by Roberts, assisted by Lehner and Bell. Field work was largely completed by the end of the 1954 season, but short revisits were made in 1956 and 1957.

In addition to field work of the authors, many geologists have furnished data used in this report. D. A. Brew, R. H. Dott, Jr., Olcott Gates, James Gilluly, A. E. Granger, K. B. Ketner, H. A. Masursky, C. W. Merriam, L. J. P. Muffler, T. B. Nolan, E. H. Pampeyan, P. D. Proctor, R. G. Reeves, F. R. Shawe, G. C. Simmons, J. F. Smith, and D. E. White, of the U. S. Geological Survey, have made important contributions. Fossil identifications and age determinations were made by J. M. Berdan, W. B. N. Berry, Josiah Bridge, R. C. Douglass, H. M. Duncan, Mackenzie Gordon, Jr., W. H. Hass, L. G. Henbest, John W. Huddle, A. R. Palmer, R. J. Ross, Jr., I. G. Sohn, and J. Steele Williams,

of the U. S. Geological Survey; Arthur J. Boncot and J. G. Johnson of the California Institute of Technology reported on Silurian and Devonian fossils from the Lynn area. Geologists of the University of California at Los Angeles, including C. A. Nelson, E. L. Winterer, M. A. Murphy, J. G. Johnson, Donald Carlisle, and J. B. Roen, made maps available and contributed valuable suggestions. E. R. Larson and L. C. Bortz, of the Mackay School of Mines, University of Nevada, also furnished detailed maps.

Officials of the Nevada Bureau of Mines were most cooperative during field work and report preparation. Vernon E. Scheid, Director; S. E. Jerome, former Associate Director; Robert C. Horton; V. E. Kral; Joseph Lintz; John Schilling; and many others furnished information or were materially helpful in processing the report for publication.

Mine owners, operators, geologists, and residents in Eureka County were unfailingly cooperative and assisted the writers in many ways. Among these are: Robert Akright, J. L. Bay, Fred Beck, A. Biale, Harry Bishop, William W. Bleazard, Benton Boyd, L. F. Campbell, John A. Cardinalli, H. B. Chessher, D. C. Curry, Willis A. DePaoli, Arthur J. Dupenon, J. Fred Eather, Travis Edgar, Ezra Edwards, John Faick, Dan Filippini, Stanley Fine, Marion Fisher, T. J. Frank, R. B. Fulton, P. E. Galli, Robert Garwood, Louis Gibellini, Hatfield Goudey, Byron S. Hardie, Sherman B. Hinckley, J. A. Hogle, W. P. Johnston, Fred Komp, R. C. Lewis, Thayer Lindsley, John Livermore, Pete Loncar, Conrad Martin, Roland Merwin, George Mitchell, Nicholas Modarelli, I. F. Moore, Robert D. Morris, Walter Paroni, Ralph Scott, K. deBenneville Seeley, L. E. Smith, Clarence F. Stone, Dean Theriot, Charles A. Vaccaro, J. B. Venturino, William Walti, Perry West, Arthur Dressher, A. J. and M. Bisoni, and the staff of the Eureka Corporation.

L. E. Davis and Roy Ashizawa of the U. S. Bureau of Mines furnished production figures for many of the mines.

GEOGRAPHIC SETTING

Eureka County is in east-central Nevada (fig. 1). In size, it ranks eleventh in the State, having an area of 4,182 square miles. The population in 1950 was 896; in 1965, 1,220.

The county seat is Eureka (pl. 1 and fig. 2), which is also the largest town. The highest point is Summit Mountain, over 10,400 feet, in the Monitor Range in the southwest corner of the county; the lowest point, 4,600 feet, is on the Humboldt River where it crosses the western county line near Dunphy.

The major mountain ranges in the county are the Sulphur Spring, Roberts, and Cortez, and parts of the Tuscarora, Shoshone, Diamond, Simpson Park, Antelope, Monitor, and Fish Creek. They are mostly north-trending linear ranges; the Cortez and Simpson Park Mountains have northeast-trending segments. Most of the ranges are bounded by fault scarps on one or both sides. Recent movement along the faults has tilted the ranges eastward and has steepened the western flanks.

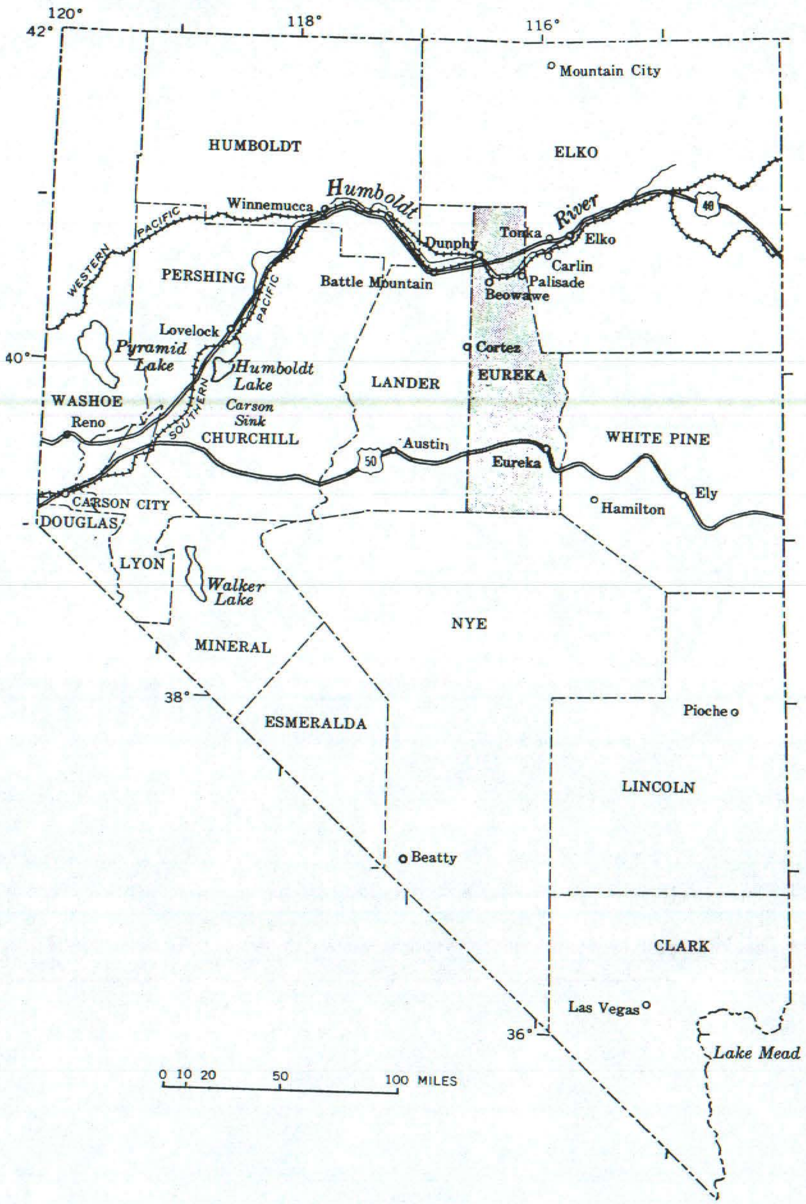


FIGURE 1. Index map of Nevada showing location of Eureka County.

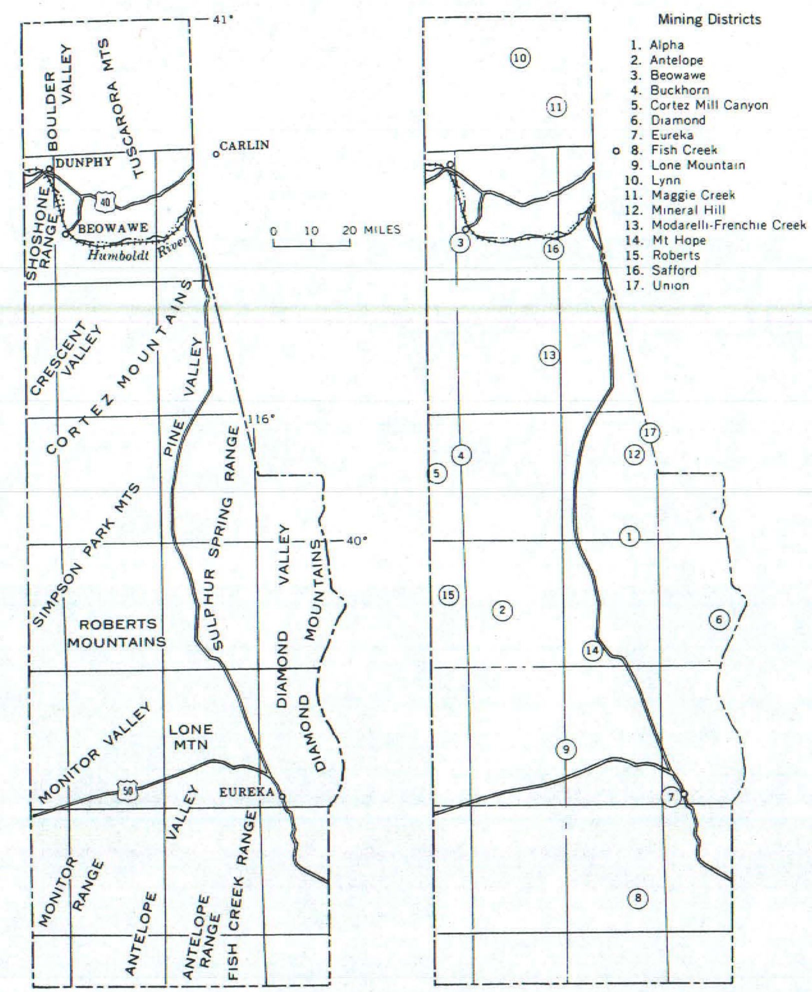


FIGURE 2. Index map of Eureka County showing location of major geographic features and mining districts.

The Humboldt River drains northern Eureka County and flows westward to Humboldt Sink, near Lovelock. Crescent, Pine, Boulder, and Maggie Creek Valleys all drain into the Humboldt. As a consequence, streams in the northern part of the county are actively cutting down, and some, such as Pine Creek, have removed most of the alluvium in their valleys, exposing beds of Pleistocene and Tertiary Age.

In southern Eureka County, Monitor, Antelope, and Diamond Valleys drain into the alkali flat in the northern end of Diamond Valley. The streams are becoming incised in the ranges but are aggrading the major valleys.

The climate in the county is typical of the northern Great Basin: the average July temperatures range between 65° and 75° in the lower valleys, becoming cooler with increasing elevation. The south end of the county averages only 13 days a year with maximums of 90° or above, while in the north the average is over 50 days a year. The highest reported temperature in the county is 108°. Much of the region, however, fails to record a 100° maximum during any given year. Winter temperatures are similar to those found in surrounding areas, averaging between 20° and 30° in the valleys. Minimums as low as 42° below zero have been recorded, but these are very exceptional. Frost may occur from September 1 through June.

The average rainfall is 10 to 15 inches over most of the county with less than 10 inches in the lowest parts and as much as 20 inches in the highest. The soils are classified as "northern gray desert." Vegetation is mostly sagebrush (*Artemisia* spp.) with piñon (*Pinus monophylla*) and juniper (*Juniperus* spp.) on the mountain slopes and greasewood (*Sarcobatus vermiculatus*) on the salt flats. Other plants include rabbit brush (*Chrysothamnus* spp.), white sage (*Eurotia lanata*), and mountain mahogany (*Cercocarpus ledifolius*).

U. S. Highway 40 crosses the northern part of the county through Emigrant Pass and the town of Dunphy; U. S. Highway 50 crosses the southern part through Eureka. Nevada State Highway 20, from Eureka to Carlin, connects the two U. S. highways. Nevada State Highway 21 extends southward from a junction with U. S. 40 east of Dunphy to Beowawe and then along the west sides of the Cortez Mountains and the Simpson Park Mountains. Gravel roads extend up many of the major valleys, and connecting graded dirt roads furnish access to most of the county.

The Southern Pacific and Western Pacific Railroads cross the county in the northern part along Humboldt River. Until 1938, the Eureka and Palisade Railroad, a narrow gauge line completed in 1875, served mining districts in the county and adjacent areas.

SEDIMENTARY ROCKS

PALEOZOIC ERA

The Paleozoic stratigraphy and structure of central Nevada have been summarized by Nolan (1928, 1943; Nolan and others, 1956), Roberts and others (1958), and Kay (1960). In general, rocks in central Nevada of Cambrian to Early Mississippian Age were laid down in a broad geosyncline (Stille, 1940): a carbonate assemblage was deposited on the east, and a siliceous and volcanic assemblage on the west. In Late Devonian and Mississippian time, during the Antler orogeny, these rocks were folded, and the western assemblage was thrust over the eastern assemblage along the Roberts Mountains thrust fault (Merriam and Anderson, 1942; Gilluly, 1954; Roberts, 1964b; 1964d). Following the orogeny, during the remainder of Paleozoic time, a clastic assemblage of rocks was shed from the orogenic belt into flanking seas, thereby overlapping the older assemblages (Roberts and Lehner, 1955; Brew, 1963). The present distribution of these three assemblages in Eureka County is shown in figure 3. Rocks of transitional lithology, intermediate between the eastern and western types, have been recognized locally in the frontal part of the upper plate of the thrust fault and are here included with the western assemblage.

Eastern Carbonate Assemblage

Rocks of the eastern carbonate assemblage underlie most of the southeastern part of the county and crop out in windows in western assemblage rocks in the central and northern parts of the county.

The stratigraphic section in the Eureka area, the classic section of carbonate rocks for eastern Nevada, was originally described by Walcott (1884) and Hague (1892) and was recently revised and redescribed by Nolan and others (1956) and by Nolan (1962). The development of nomenclature is shown in figure 4.

Rocks assigned to the eastern assemblage in Eureka County are Cambrian to Early Mississippian in age. They were deposited in a shallow-water, miogeosynclinal environment and are composed of limestone, dolomite, and minor amounts of shale and quartzite (pl. 2). The section in the Eureka area is about 14,500 feet thick: carbonate rocks constitute about 90 percent, shale 8 percent, and quartzite 2 percent.

Cambrian System

Cambrian rocks crop out in the Fish Creek, Antelope, and Monitor Ranges in the southern part of the county, in the Roberts and Cortez Mountains in the south-central part, and in the Tuscarora Mountains in the northern part. The distribution is shown on the geologic map (pl. 3).

The system comprises eight formations that have a minimum aggregate thickness of 7,130 feet. They are, in ascending order, the Prospect Mountain Quartzite, Pioche Shale, Eldorado Dolomite, Geddes Limestone, Secret Canyon Shale, Hamburg Dolomite, Dunderberg Shale, and Windfall Formation.

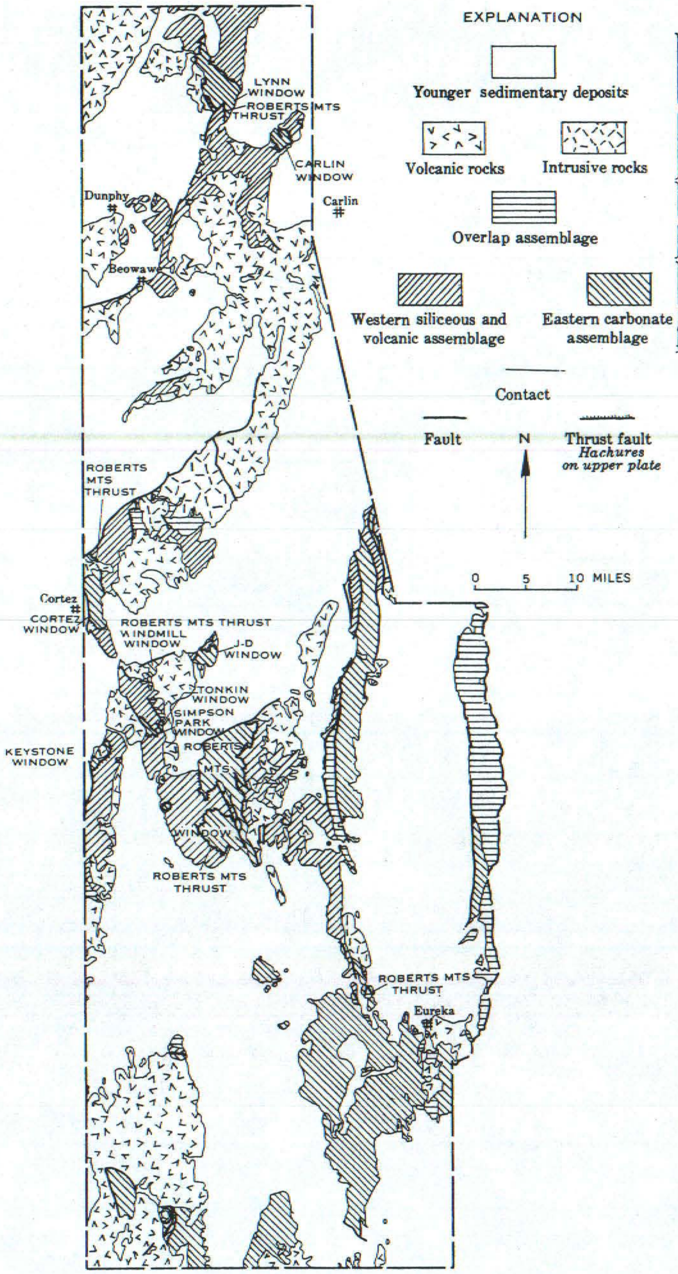


FIGURE 3. Map of Paleozoic assemblages and major structural features in Eureka County.

Prospect Mountain Quartzite. The Prospect Mountain Quartzite is the oldest formation exposed in the county. In this area it occurs only in the Eureka district and was named by Hague (1883, p. 248) for exposures on the west flank of Prospect Ridge. The base is not exposed, so the total thickness is not known, but Hague measured 1,500 feet on Prospect Ridge, and Wheeler (1944, p. 1786) reports 1,660 feet in the same general area; these measurements include 200 feet of beds that are now assigned by Nolan and others (1956, p. 7) to the Pioche Shale.

The formation is thoroughly fractured and exposures are poor; it usually forms a thick talus of small, sharply angular blocks. Nolan and others (1956, p. 6), indicate that the best exposures are in the vicinity of Cave Canyon. The rock is generally white or gray on fresh fracture and weathers brown, pink, and red. The quartz grains average about 1 mm in diameter, are cemented by silica with some ferruginous and argillaceous material, and are fairly well sorted; faint cross-laminations are visible on some weathered surfaces. Micaceous and sandy shale interbeds constitute less than 5 percent of the formation; sparse quartz conglomerate beds have also been noted (Nolan and others, 1956, p. 6).

Fossils have not been found in the Prospect Mountain Quartzite. However, because the quartzite is conformably overlain by the *Olenellus*-bearing Pioche Shale of Early Cambrian Age, the Prospect Mountain Quartzite is considered to be the same age. It is correlated with the Zabriskie Quartzite in southern Nevada (A. R. Palmer, written communication, 1962), and possibly the Osgood Mountain Quartzite in north-central Nevada (Roberts and others, 1958, p. 2821–2827).

Pioche Shale. In the area of this report the Pioche Shale is present only in the Eureka district, where it crops out as a narrow discontinuous band that extends from a short distance southeast of Prospect Peak northward along the west flank of Prospect Ridge. According to Nolan and others (1956, p. 7), the thickness is perhaps 400 to 500 feet, but there is considerable variation in outcrop width, probably due to shearing.

The Pioche Shale is composed of calcareous and micaceous shale, sandstone, and quartzite with a few intercalated beds of dark-gray limestone. Greenish or khaki arenaceous shale with local reddish-orange layers is most abundant. Near thrust faults micaceous shale is generally coarsely foliated. Where the shales are calcareous, they are gray to olive colored and are commonly fossiliferous. The sandstone and quartzite beds are reddish brown and thin bedded, and are very similar to the units of the Prospect Mountain Quartzite. The limestones found in the formation are thin bedded to thick bedded and generally are mottled dark blue; they contain abundant trilobite fragments. Some white-weathering limestone beds as much as 20 feet thick resemble beds present in the overlying Eldorado Dolomite. The Pioche Shale weathers to smooth slopes with the thick-bedded limestones forming prominent ribs.

Two fossil collections from the Pioche Shale are reported by Hague (1892, p. 42), one near the summit of Prospect Ridge on the east side of Prospect Peak a few miles southwest of Eureka, and the other about

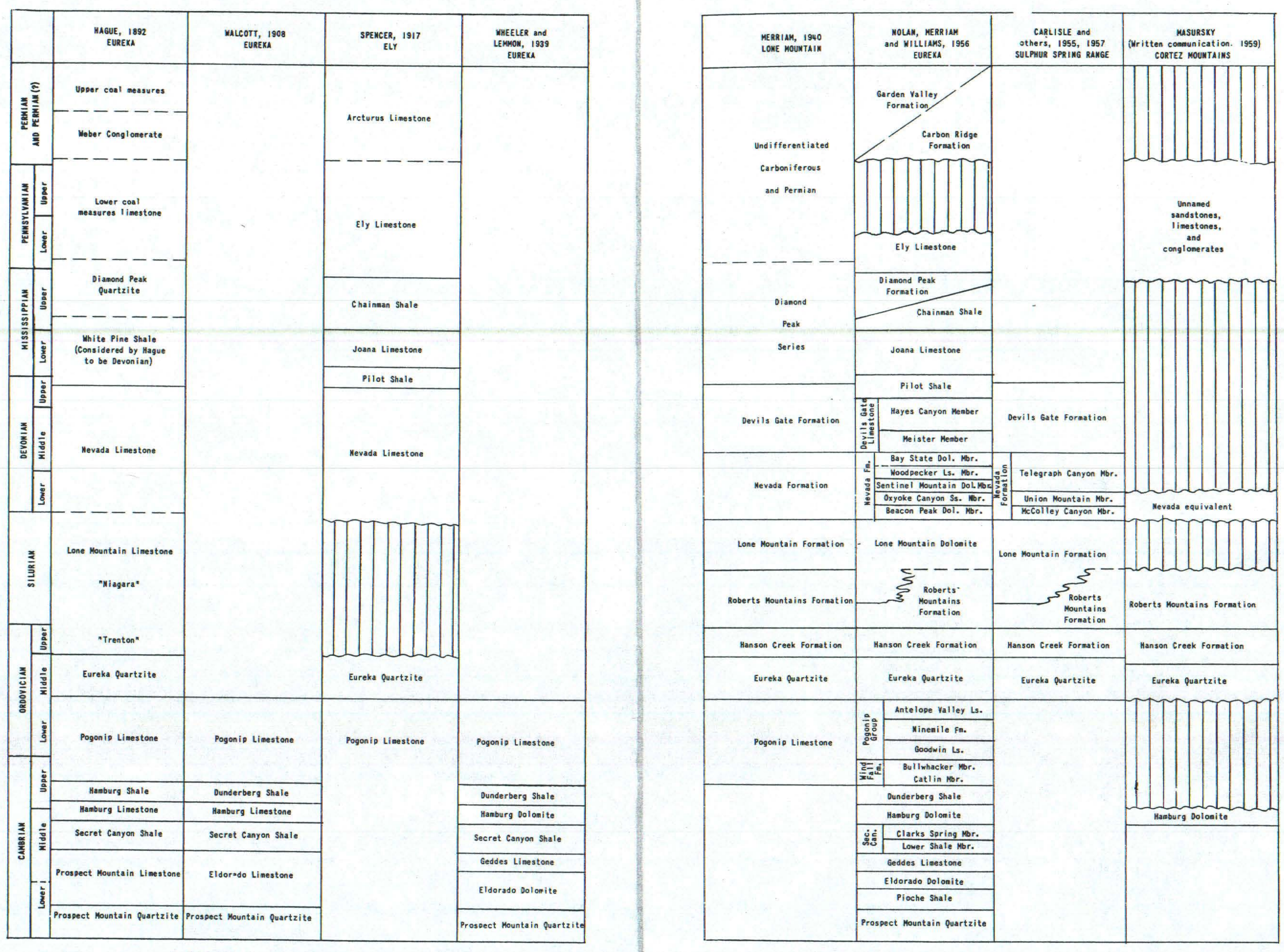


FIGURE 4. Development of stratigraphic nomenclature of Paleozoic rocks in Eureka County.

half a mile to the north. From each of these collections the trilobites *Olenellus gilberti* and *Peachella iddingsi* were identified. Wheeler and Lemmon (1939, p. 17–18) collected fragmental trilobites from the micaceous sandstones of the formation which were identified as *Olenellus* cf. *fremonti* Walcott and *Olenellus gilberti?* Meek. Additional collections of the *Olenellus* fauna made in recent years have been studied by A. R. Palmer (1960) and assigned to the Lower Cambrian.

The Pioche Shale is widely recognized in the eastern Great Basin. The formation contains Early and Middle Cambrian faunas in the Pioche district in eastern Nevada, suggesting that it transgresses time lines eastward. In southern Nevada the lower part of the Carrara Formation contains similar faunas (A. R. Palmer, written communication, 1962).

Eldorado Dolomite. The Eldorado Dolomite, originally described by Hague (1883) and Walcott (1884, p. 284–285) as the Prospect Mountain Limestone, was named by Walcott (1908, p. 184). Wheeler and Lemmon (1939, p. 20) later separated the upper part, consisting of thinly bedded, dark limestone from the Eldorado Dolomite and named it the Geddes Limestone. The restricted Eldorado Dolomite is confined to Prospect Ridge and its southerly extension in Secret Canyon to the southwest of Eureka. It appears to rest conformably upon the Pioche Shale. The exposures of Eldorado Dolomite north of the Secret Canyon divide are discontinuous because of shearing along bedding.

Wheeler and Lemmon (1939, p. 19) measured 2,000 feet of Eldorado Dolomite just south of Prospect Peak. Nolan and others (1956, p. 11) state that perhaps the best estimate is 2,500 feet, derived from a section measured on the steep west slope of Prospect Ridge just north of the Prospect Mountain tunnel.

The Eldorado consists of thickly bedded to massive pale-gray beds that range from nearly pure limestone to nearly pure dolomite. The formation is resistant to erosion and forms prominent outcrops. The most common lithologic type is a light-gray, rather coarsely crystalline dolomite; it is brecciated, vuggy, porous, and is generally textureless. Nolan and others (1956, p. 10) believe that this rock is a hydrothermal alteration product of limestone and dolomite.

Some of the dolomite occurs as alternating light and dark beds from 1 to 3 feet thick, which are believed by Nolan and others (1956, p. 10) to be of sedimentary origin. The dolomite is mostly dark blue to black and medium grained; some beds are streaked and mottled and others speckled white with calcite.

The most common variety of limestone is massively bedded, in beds 5 feet thick or more, and blue gray in color. In comparison to the dolomites it weathers with smooth surfaces. Where the limestones of the Eldorado are deformed, they are commonly marbleized and bleached white.

The Eldorado, as it is now restricted, has not yielded diagnostic fossils, but possible age assignment is limited by the late Early Cambrian Age of the underlying Pioche Shale and the middle Middle Cambrian Age of the overlying Geddes Limestone. As the Pioche Shale at Pioche contains Middle Cambrian fossils, Nolan and others (1956, p. 11) consider the Eldorado to be early Middle Cambrian in age.

Geddes Limestone. The name Geddes Limestone was proposed by Wheeler and Lemmon (1939, p. 20) for the thinly bedded limestone sequence between the massively bedded limestones and dolomites of the underlying Eldorado and the overlying Secret Canyon Shale.

The Geddes Limestone crops out as a band of variable width east of the Eldorado Dolomite from the south end of Secret Canyon north along the east side of Prospect Ridge as far as Diamond Tunnel. It is present also on both sides of the ridge from the Eureka Tunnel nearly to Ruby Hill. Discontinuous outcrops occur on the west side of Prospect Ridge south of Prospect Mountain Tunnel and on the north and northeast side of Ruby Hill.

The Geddes Limestone is a distinctive dark bluish-gray to black, well-bedded, moderately fine-grained limestone easily distinguished from other lower Paleozoic units in the Eureka district. It is carbonaceous and has very thin dark shaly partings. Beds range in thickness from one-half to 18 inches, but more commonly are between 2 and 8 inches. Nolan and others (1956, p. 12) mention small amounts of nodular black chert at the top of the formation, the only occurrence of chert in the section at Eureka below the Windfall Formation. Calcite veinlets cutting through the limestones are common. The weathered surfaces of the limestone are reddish to purplish.

Wheeler and Lemmon (1939, p. 20) measured 335 feet of Geddes Limestone along the tunnel between the mill and ore body at the Geddes and Bertrand mine. They also state that a diamond drill hole of the Eureka Corp., Ltd., cut 331 feet of Geddes Limestone. Nolan and others (1956, p. 12) report that the Geddes Limestone throughout much of the outcrop area is closely folded and faulted, and therefore the apparent thickness of the formation varies. The contact of the Geddes Limestone with the underlying Eldorado Dolomite apparently is gradational, and on the northwest nose of Prospect Ridge the two formations interfinger. The upper contact with the Secret Canyon Shale is not well exposed at the surface, but is sharp in underground exposures.

Collections of fossils from the Geddes Limestone were studied by A. R. Palmer (*in* Nolan and others, 1956, p. 12), who referred them to the middle Middle Cambrian and suggested that the Geddes is the approximate age equivalent of the Wheeler Formation in the House Range, Utah; the upper part of the Abercrombie Formation or Young Peak Dolomite of the Gold Hill district, Utah; units H or I of the Highland Peak Limestone of the Pioche district, Nevada (Wheeler and Lemmon, 1939, p. 46); and the middle part of the Preble Formation, north-central Nevada.

Secret Canyon Shale. The Secret Canyon Shale was originally named by Hague (1883, p. 255) in the Eureka district for the prominent exposures in Secret Canyon which include the strata between the Geddes Limestone and the Hamburg Dolomite. Wheeler and Lemmon (1939,

p. 23) recognized two "lithologically distinct mappable units," which Nolan and others (1956, p. 13) have designated the lower shale member and the Clarks Spring Member.

The Secret Canyon Shale crops out within the narrow belt of Cambrian strata that extends from Adams Hill southward to the southern end of Secret Canyon. Repetition of strata by folding and faulting makes measurements of thickness difficult, but Nolan and others (1956, p. 13) estimate that the thickness is about 650 feet.

The lower contact of the Secret Canyon Shale is sharp but conformable with the underlying Geddes Limestone. At the top, the formation is gradational to, and therefore conformable with, the overlying Hamburg Dolomite. The upper contact was placed at the top of the uppermost platy limestone.

The lower shale member is a fairly uniform sequence of argillaceous shale beds with little or no interbedded limestone. It is approximately 200 to 225 feet thick and is best exposed in Cave Canyon on the west slope of Prospect Ridge. The shales are commonly buff on the surface, but underground they are black. The member forms smooth slopes, and its presence in most places is indicated by small flakes and chips of brown, red, or yellow shale in the soil. The contact with the overlying Clarks Spring Member is gradational.

The Clarks Spring Member of the Secret Canyon Shale is composed dominantly of thin-bedded, platy limestone with yellow or red shale partings; it is 425 to 450 feet thick, and is well exposed in New York Canyon just north of Clarks Spring. Individual limestone beds are commonly a quarter to half an inch thick and rarely exceed 2 inches. The limestone is fine grained, argillaceous, and light gray to blue gray. Shale or clay partings, mostly yellow but some reddish, up to a quarter of an inch thick, separate individual limestone beds.

A. R. Palmer, who has studied the trilobite faunas of the Clarks Spring Member of the Secret Canyon Shale, has assigned them a late Middle Cambrian Age (Nolan and others, 1956, p. 16). Correlative beds are the Marjum Limestone in the House Range, Utah; units J(?) and K of the Highland Peak Limestone at Panaca, Nev. (Wheeler and Lemmon, 1939, p. 45–46); and the Trippe Limestone of the Gold Hill district, Utah.

Hamburg Dolomite. The Hamburg Dolomite was originally described by Hague (1883, p. 255) as the Hamburg Limestone, the ridge-forming unit that overlies the less resistant Secret Canyon Shale, and is itself overlain by the Dunderberg Shale. Wheeler and Lemmon (1939, p. 25) called attention to the fact that the Hamburg was mainly dolomite, and proposed that the unit be renamed the Hamburg Dolomite. In the Eureka district, the Hamburg is restricted, like the other Cambrian formations, to the narrow belt of rocks that extends north and south from Prospect Peak. It occurs as a continuous outcrop that forms the east wall of Secret Canyon and extends as far north as Shadow Canyon southwest of Eureka. Four smaller isolated masses of Hamburg have been mapped: on Adams Hill, on the northeast part of Ruby Hill, on Mineral Hill, and at the head of New York Canyon on Prospect Ridge.

Nolan and others (1956, p. 17) calculate a thickness of about 1,000 feet for the Hamburg in the Eureka district. In this area it is composed of gray, coarsely crystalline limestone, and dolomitic limestone; the general appearance is that of a uniformly thick-bedded formation, but textural varieties consist of banded, mottled, and spangled layers with white dolomite rods in a darker matrix. Intraformational conglomerates are present locally. The basal part of the Hamburg consists of crinkly bedded, mottled dark-blue limestone beds, which alternate with thinner beds of platy limestone typical of the upper part of the Secret Canyon Shale. Chert nodules have developed along the stratifications of this limestone; above the limestone is well-banded saccharoidal dark dolomite. The coarsely crystalline dolomites are dull gray to light gray and are commonly brecciated and filled with calcite stringers. Where the dolomites are shattered they have been altered and locally cemented by silica.

Dolomite in the Cortez Mountains at Cortez has also been referred to the Hamburg by Merriam and Anderson (1942, p. 1684); there it crops out along the base of Mount Tenabo and extends about 2 miles to the north. Similarly, dolomite was mapped by the writers in the Tuscarora Mountains about 14 miles northwest of Carlin and 4 miles south of the Lynn district, and referred to the Hamburg. Outcrops on the east flank of the range extend for a distance of several miles. The thickness of the formation could not be measured at Cortez nor in the Tuscarora Mountains because the base is not exposed.

In the Cortez area the Hamburg(?) Dolomite has been locally metamorphosed to dolomite marble and tactite adjacent to a quartz monzonite stock. The dolomite shows considerable lithological variation both vertically and laterally. Fresh surfaces are generally mottled gray or black and have a finely crystalline texture; the rock weathers to dull gray.

The partial section of the Hamburg(?) in the Tuscarora Mountains is mostly homogeneous bluish-gray uniformly bedded dolomite. Its texture is coarsely crystalline, and it contains fractures that have been healed with white calcite.

According to A. R. Palmer (*in* Nolan and others, 1956, p. 18), trilobite faunas from the base of the Hamburg are latest Middle Cambrian in age; the overlying Dunderberg Shale contains a Late Cambrian fauna, so the Hamburg is probably both Middle and Late Cambrian in age. It is equivalent to units L and Q of the Highland Peak Limestone of the Pioche district, Nevada (Wheeler and Lemmon, 1939, p. 45); the Weeks Limestone and lower part of the Orr Formation of the House Range, Utah; and Lamb Dolomite and part of the Hicks Formation of the Gold Hill district, Utah.

Dunderberg Shale. The Dunderberg Shale originally was called Hamburg Shale by Hague (1883, p. 255–256) but was renamed by Walcott (1908, p. 184) to avoid the use of Hamburg for two formations. The

Dunderberg Shale occurs only in the Eureka district, where it forms a band of outcrop that extends south from Shadow Canyon to the south end of Secret Canyon and is extensively exposed along the north side of Adams Hill. Elsewhere it occurs as slices and thin slivers in fault zones.

Nolan and others (1956, p. 19) measured 265 feet of the Dunderberg Shale on the ridge in Windfall Canyon east of the new Windfall shaft. The contact with the underlying Hamburg Dolomite has been sheared. The contact with the overlying Windfall Formation is sharp and conformable and is placed between a thick bed of shale and an overlying persistent 28-foot bed of limestone containing much black chert.

The Dunderberg consists of about equal thickness of shale and interbedded shale and limestone. The shale weathers out as small brownish to olive-colored chips or flakes, but underground it is blocky and darker colored. The shale beds range from half an inch to 6 inches in thickness and are commonly blue gray on fresh surfaces and brown on weathered surfaces. The limestones are dense to medium grained and are characterized by nodular surfaces; many show fine wavy laminations. Trilobite fragments are abundant in some beds.

The trilobite fauna of the Dunderberg, described by Palmer (1960), is middle Late Cambrian in age (late Dresbach and early Franconia) and is the approximate equivalent of part of the Mendha Formation in the Pioche district; the upper part of the Orr Formation in the House Range, Utah; and the upper part of the Hicks Formation of the Gold Hill district, Utah.

Windfall Formation. The name Windfall Formation was applied by Nolan and others (1956, p. 19–20) to strata of Cambrian Age originally included in the basal part of the Pogonip Formation as redefined by Hague (1892, p. 48–54). The Windfall Formation occurs in the Eureka district in a nearly continuous band of outcrop from the north tip of Adams Hill southward to the Windfall shaft and probably extends farther to the south along the east side of Secret Canyon. In the Monitor Range the strata referred to as Pogonip, north of Rye Grass Canyon and west of Copenhagen Canyon, may contain beds equivalent to the Windfall. In the Antelope Range, in Ninemile Canyon, strata both lithologically and faunally similar to the Windfall have been recognized by Merriam (1963, p. 14–16).

The Windfall Formation in Eureka County has been mapped only in the Eureka district. There, in Windfall Canyon, Nolan and others (1956, p. 20) have measured a thickness of 650 feet. Merriam (1963, p. 16) believes that only about 300 feet of the Windfall are represented in Ninemile Canyon in the Antelope Range, but the boundaries of the formation have not been established there.

The Windfall Formation is a sequence of massive limestones and shaly, arenaceous limestones. It has been divided (Nolan and others, 1956, p. 20) into the Catlin Member and overlying Bullwhacker Member.

The Catlin Member is 250 feet thick and consists of interbedded massive limestone and thin sandy or silty limestone. In the lower half, chert with light- and dark-gray laminations is abundant. The massive limestone beds are light gray and bluish gray, generally fine grained, and, where fossiliferous, tend to be coarse grained. They range from about 12 to 30 feet in thickness, and crop out more prominently than the thinner interbedded limestones. The thinly bedded, platy limestones are light to medium gray or blue gray and have crinkly sandy or shaly interbeds that weather brown. Some of the platy limestones show laminations.

According to Nolan and others (1956, p. 21), laminated chert has been recognized east of the mouth of Ninemile Canyon in the Antelope Range. Here the chert is in the upper part of the Catlin Member and is overlain by 150 feet of gray shale that is not recognized in the type area near Eureka, suggesting a minor facies change between the Eureka and Antelope sections.

The Bullwhacker Member consists of 400 feet of thin-bedded, tan or light-brown, sandy or shaly limestones bounded at top and bottom by massive limestones. Beds range from a quarter of an inch to an inch in thickness and are fine grained to aphanitic. They weather to bumpy and pitted surfaces and locally contain gray chert nodules. Trilobite and brachiopod fragments are abundant on bedding surfaces.

Nolan and others (1956, p. 21) report that beds similar to the Bullwhacker Member at Eureka occur in the Antelope Range; paleontologic evidence indicates that this member covers a greater time span here than at Eureka, extending across the systemic boundary.

The fauna of the Windfall Formation in the Eureka district has been determined by A. R. Palmer (*in* Nolan and others, 1956, p. 22) to be of middle and late Late Cambrian Age. Age equivalents are parts of the Mendha Formation at Pioche, the Notch Peak Limestone in the House Range, Utah, the Chokecherry Dolomite(?) in the Gold Hill district, Utah, and the Harmony Formation in the Hot Springs Range, near Golconda, Nev. (Roberts and others, 1958, p. 2827).

Ordovician System

The Ordovician strata of the eastern assemblage that crop out within Eureka County have an aggregate thickness of 2,255 to 4,055 feet and include five formations. Three belong to the Pogonip Group, which has been divided (Nolan and others, 1956, p. 24) into the Goodwin Limestone, the Ninemile Formation, and the Antelope Valley Limestone. The other two are the Eureka Quartzite and the Hanson Creek Formation.

Ordovician rocks are present in the Roberts Mountains, in Lone Mountain, in the Antelope and Monitor Ranges, in the Cortez Mountains at Cortez, in the fault block on the west side of the Sulphur Spring Range, and in the Tuscarora Mountains approximately 14 miles northwest of Carlin, Nev. Throughout most of the county the Pogonip Group, Eureka Quartzite, and Hanson Creek Formation were separated in mapping.

Pogonip Group. The term Pogonip was originally used by King during his survey along the Fortieth Parallel (1878, p. 188) for the limestone on Pogonip Ridge in the White Pine (Hamilton) district of Nevada.

Hague (1883, p. 260) restricted the Pogonip to include only strata overlain by the Eureka Quartzite and underlain by what is now called the Dunderberg Shale. Later, Walcott (1923, p. 466–467) proposed that the lower 1,500 feet be called the Goodwin Formation because it contains a Cambrian fauna; this subdivision proved unworkable. Nolan and others (1956, p. 23) redefined the Pogonip as a group from which the Cambrian Windfall Formation is excluded. The group, thus limited, includes strata between the Windfall and the Eureka Quartzite. The Pogonip Group apparently is present only in the southern part of the county in the Fish Creek, Antelope, and Monitor Ranges, in Lone Mountain, the Roberts Mountains, and in the Eureka district. The thickness in the Antelope and Monitor Ranges is as much as 3,250 feet, in the Eureka district 1,500 to 1,700 feet, and in the Roberts Mountains about 300 feet, indicating rapid northward thinning due to nondeposition or erosion. In the Cortez Mountains the Pogonip is missing, and the Eureka Quartzite rests directly upon Cambrian strata.

In the Eureka area the Pogonip Group is represented by the Goodwin Limestone, the Ninemile Formation, and the Antelope Valley Limestone (Nolan and others, 1956, p. 25–29).

GOODWIN LIMESTONE. The Goodwin Limestone consists of 900 to 1,100 feet of well-bedded, fine-grained to aphanitic, fairly massive limestone that is light blue to blue gray. In places, platy limestone beds make up part of the formation. The lower 350 feet contain light-gray to white chert, which decreases in abundance in the higher beds. Many of the massive-appearing limestone beds show irregular crinkly clay partings and lumpy bedding surfaces.

In the Monitor-Antelope Range area, beds assigned to the Goodwin Limestone include about 1,650 feet of massively bedded limestone with gray and white chert and with interbedded thinner bedded limestone.

Collections of brachiopods and trilobites from the Goodwin Limestone are regarded by G. A. Cooper (*in* Nolan and others, 1956, p. 26) to be of early Canadian (Early Ordovician) Age.

NINEMILE FORMATION. The Ninemile Formation consists of 200 to 500 feet of platy and thinly bedded fine-grained to porcelaneous limestone and shale in the Monitor-Antelope Range area. On fresh surface the limestone is olive green or greenish blue gray; it weathers to a brownish or reddish surface. The formation also contains beds of light-gray crystalline sandy limestone, limy sandstone, shale, and cherty limestone.

Fossils are abundant in the Ninemile Formation, and Nolan and others (1956, p. 27) note that it contains one of the largest and best preserved Ordovician brachiopod assemblages in the Cordillera. The formation is of late Early Ordovician Age (R. J. Ross, Jr., written communication, 1962).

ANTELOPE VALLEY LIMESTONE. The Antelope Valley Limestone is mainly thick bedded or massive, medium gray or light bluish gray, and fine grained. Some of the beds form cliffs, although less resistant thinner

bedded zones are found at the base and top of the formation. The limestone beds weather with rough surfaces; silicified fossils that stand out in relief are common. The thickness of this formation ranges from about 400 feet at Eureka to about 1,100 feet on Martin Ridge on the east flank of the Monitor Range. Merriam (1963, p. 16) considers the Antelope Valley Limestone to be of Early and Middle Ordovician Age.

Equivalents of the Pogonip Group in central Nevada are the Comus Formation of the transitional assemblage in Edna Mountain, near Golconda, the lower part of the Vinini Formation in the Roberts Mountains, and the lower part of the Valmy Formation of the western assemblage in the Sonoma Range, the Shoshone Range, and Battle Mountain (Roberts and others, 1958, p. 2831–2832).

Eureka Quartzite. The Eureka Quartzite was named and defined by Hague (1883, p. 262; 1892, p. 54) in the Eureka district, but because the formation is highly brecciated and faulted in the district, a well-exposed section on the west side of Lone Mountain has been designated the type locality in accordance with a suggestion made by Kirk (1933, p. 34). The formation underlies much of eastern Nevada and western Utah and is one of the most distinctive units in the Paleozoic section. The thickness at the type locality, according to Merriam (1940, p. 1684), is about 350 feet; in the Roberts Mountains it is nearly 500 feet; in the Sulphur Spring Range, about 100 feet (Donald Carlisle and C. A. Nelson, written communication, 1958); elsewhere in the county it ranges from 175 feet to 350 feet. In plate 3 the Eureka Quartzite is not shown separately in the Eureka district and Sulfur Spring Range, but is included with the Hanson Creek Formation.

The Eureka Quartzite is a distinctive, dense, milky white to cream-colored, sugary to vitreous quartzite that forms bold outcrops and prominent cliffs and escarpments. It is made up almost entirely of well-sorted quartz grains that range from fine to medium. The basal third of the quartzite shows crossbedding; it is usually gray on fresh surfaces and commonly weathers purplish, reddish, or brownish. The purity and uniformity of the Eureka is characteristic; it helps to distinguish it from the coarser grained and more ferruginous and argillaceous Prospect Mountain Quartzite and the more calcareous Oxyoke Canyon Sandstone Member of the Nevada Formation.

The Eureka Quartzite lies unconformably on the Hamburg(?) Dolomite in the Tuscarora Mountains and at Cortez in the Cortez Mountains. It rests unconformably on the lower part of the Pogonip Group in the Roberts Mountains. Merriam and Anderson (1942, p. 1685) report a sequence to the south in the Antelope and Monitor Ranges that includes a lower sandstone, calcareous shale and sandstone, and sandy limestones in the interval occupied by the lower Eureka farther east. The upper boundary of the Eureka with the overlying Hanson Creek Formation is commonly sharp: locally a few feet of sandy dolomite beds form a transitional zone at the contact.

The relationship of the Eureka Quartzite to quartzitic beds in the Vinini and Valmy Formations has been discussed by Roberts and others (1958, p. 2831), who suggest that the essential identity in composition and age of the Eureka with some of the quartzites in the Valmy and Vinini indicates a common source. The Valmy and Vinini were formed in a deep-water environment in western or west-central Nevada and the Eureka in a shallow-water environment in another part of the same geosyncline. Merriam (*in* Nolan and others, 1956, p. 31) suggests that the Eureka may not actually be marine but largely a subaerial deposit formed during widespread emergence with restricted marine embayments in which calcareous beds were deposited. The Eureka is remarkably uniform in lithology and grain size over eastern Nevada, western Utah, and southern Idaho, which indicates uniformity in conditions of deposition (Ketner, 1966). Ketner suggests that the Eureka was derived from the northeast and that the Valmy which is coarser and less well sorted was derived from a westerly source. Roberts suggests that the Valmy was initially deposited in northwestern Nevada and that the source was northwesterly.

The Eureka Quartzite at Cortez contains poorly preserved coral molds (Duncan, 1956, p. 217) that are not specifically identifiable; the age assignment in the Eureka district and the Monitor Range is limited by the Early and Middle Ordovician Age of the underlying Antelope Valley Formation and the Middle (?) and Late Ordovician Age of the overlying Hanson Creek Formation. The Eureka Quartzite in Nevada is considered to be Middle Ordovician in age (Gilluly, Merriam, and Cohee, oral communication, 1961).

Hanson Creek Formation. The Hanson Creek Formation was named and defined by Merriam (1940, p. 13), who separated it from the strata to which Hague (1892, p. 57) originally assigned the name "Lone Mountain limestone." It overlies the Eureka Quartzite and represents the lower or Ordovician portion of Hague's "Lone Mountain formation."

In Eureka County, the Hanson Creek is coextensive with the Eureka Quartzite. It ranges in thickness from about 300 feet in the Monitor Range to 560 feet at the type locality on Pete Hanson Creek on the northwest side of Roberts Creek Mountain, and 800 feet in the Sulphur Spring Range. (Carlisle and Nelson, oral communication, 1958). It is also prominently exposed in the Tuscarora Mountains, at Cortez, at Lone Mountain, and in the Antelope and Fish Creek Ranges. Throughout most of the county it was mapped separately, but in the Eureka district and Sulphur Spring Range the Eureka Quartzite has been included with the Hanson Creek Formation.

In the Eureka district and in the Tuscarora Mountains the Hanson Creek is a dark gray-black, massive, thick-bedded, coarse-grained dolomite which becomes thinner bedded towards the top. Near the top light-gray and black dolomitic beds are interstratified. The section at Lone Mountain is also largely dolomite, but that in the Roberts Mountains is almost entirely limestone and calcareous shale (Nolan and others, 1956, p. 33). At Cortez, the Hanson Creek Formation has lower and upper dolomite members with a thick section of limestone in between. The lower dolomite has a steel-gray, "elephant hide" texture on weathered surfaces; fresh surfaces are black. Overlying this is a thick section of light-gray, siliceous, saccharoidal limestone that weathers to buff or brown. The top of the formation is marked by a light-gray, massive, nonfossiliferous dolomite topped by a black, massive, fossiliferous dolomite bed from 5 to 15 feet thick. In the Roberts Mountains (Merriam, 1940, p. 11) the basal unit of the Hanson Creek is a dark-gray to black, medium-grained, poorly stratified dolomitic limestone 40 feet thick; it grades upward into a unit 45 feet thick of fine-textured, poorly bedded medium- to dark-gray limestone that contains calcite veinlets and small black chert nodules. This unit is overlain by 140 feet of fossiliferous thin-bedded slabby and shaly limestone, dark bluish gray when fresh and light gray on the weathered surface, and by 140 feet of poorly bedded dark-gray limestone. The upper unit is mostly fine-grained, very dark-gray, massive limestone, 180 feet thick; it is overlain by a black chert unit 15 feet thick that defines the top of the formation.

The Hanson Creek at the type locality contains an abundant fauna of late Ordovician Age that is typical of the fauna of the Fish Haven Dolomite in western Utah and the Ely Springs Dolomite at Pioche, Nev. (Nolan and others, 1956, p. 33–34). A trilobite fauna collected at Cortez by Gilluly and Masursky may be partly of Middle Ordovician Age (R. J. Ross, Jr., written communication, 1962).

Ordovician and Silurian rocks, undivided

In the southern part of the Mahogany Hills, Upper Ordovician and Silurian rocks belonging to the Hanson Creek and Roberts Mountains Formations and Lone Mountain Dolomite (Merriam, 1963) were not subdivided and are shown as a single unit in plate 3.

Silurian System

The Silurian rocks of the eastern assemblage in Eureka County include the Roberts Mountains Formation and the overlying Lone Mountain Dolomite. Together they consist of a sequence of platy limestones and massive bedded dolomites which have an aggregate thickness of 3,400 to 4,100 feet.

The Silurian rocks are present in the Eureka district, but they are so deformed and altered that it has not been possible to make detailed stratigraphic studies of them. Complete sections are found to the west in Lone Mountain, the Monitor Range, the Roberts Mountains, and the Cortez Mountains.

Roberts Mountains Formation. The Roberts Mountains Formation was named and described by Merriam (1940, p. 11–12), who separated it out of Hague's Lone Mountain Limestone; the type locality is on Roberts Creek Mountain. The formation crops out also on Lone Mountain, in the Monitor Range, in the Sulphur Spring Range, at the north end of the Simpson Park Mountains, and in the Cortez and Tuscarora

Mountains. It is of special interest to economic geologists because it is the host rock for gold ores at mines in the Shoshone and Tuscarora ranges, and at prospects north of Cortez (p. 62, 94).

The Roberts Mountains Formation consists mainly of platy, silty limestone and minor amounts of dolomite in the upper portion. In the Roberts Mountains area the formation has been divided into two members: a lower member consisting of about 1,100 feet of siliceous, dark slate-gray, fine- to medium-grained limestone with lenses and interbeds of bluish-black chert in the basal part, and an upper member composed of about 800 feet of massive, thick-bedded dolomitic limestone and some dolomite. At Lone Mountain the basal chert is present, but the overlying beds are mostly thick and dolomitic rather than platy; the platy limestones are more typical of other exposures, such as at Martin Ridge on the west side of Antelope Valley, at Cortez, and in the northern part of the county. At Cortez (Gilluly and Masursky, 1965, p. 25–29) the section is similar to that in the Tuscarora Mountains, and consists of silty limestone with a minor amount of dolomite at the top. The limestone is platy, dark gray to black, very fine grained to medium grained and weathers to light-gray angular platy chips.

The thickness of the Roberts Mountains Formation is variable: 741 feet at Lone Mountain (Merriam and Anderson, 1942, p. 1686–1687), 1,900 feet in the Roberts Mountains (Merriam and Anderson, 1942, p. 1686–1687), 500 to 650 feet in the Sulphur Spring Range (Carlisle and Nelson, written communication, 1956), and about 1,000 feet at Cortez (Gilluly and Masursky, 1965). In the Tuscarora Mountains the formation is exposed in the Lynn window; the thickness is estimated to be about 1,700 feet (Roen, 1961; Berry and Roen, 1963, p. 1123).

The Roberts Mountains Formation contains *Monograptus* in the lower part assigned by R. J. Ross, Jr. (written communication, 1959) to middle and upper Middle or Late Silurian; brachiopods and corals in the middle and upper parts are assigned a Middle Silurian (Niagaran) Age (Nolan and others, 1956, p. 37). A small collection from sec. 3, T. 36 N., R. 49 E., in Elko County contained corals and brachiopods that suggest a Late Silurian Age (W. A. Oliver, Jr., written communication, 1962; A. J. Boucot and J. G. Johnson, written communication, 1967).

Lone Mountain Dolomite. The Lone Mountain Dolomite was named by Hague (1883, p. 262–263) for exposures on Lone Mountain; it originally included all units between the Eureka Quartzite and the Nevada Limestone of previous usage. Merriam (1940, p. 10, 13–14) redefined and restricted the Lone Mountain, separating out the Hanson Creek and Roberts Mountains Formations.

The Lone Mountain Dolomite crops out in the southern part of Eureka County in the Antelope Range, Diamond Mountains, Roberts Mountains, and Sulphur Spring Range; westward, southwestward, and northwestward it apparently grades into limestone beds of equivalent age. The measured thickness at the type locality is 1,570 feet (Merriam 1940, p. 13) and at Roberts Creek Mountain, 2,200 feet (Merriam and Anderson, 1942, p. 1688.) The greatest thickness is that reported in the Sulphur Spring Range by Carlisle and Nelson (written communication, 1956) as 3,200 feet.

The contact with the underlying Roberts Mountains Formation apparently is gradational: at Lone Mountain it is within a zone between the predominantly dark-gray dolomite of the Roberts Mountains Formation and the overlying lighter gray dolomite of the Lone Mountain (Merriam and Anderson, 1942, p. 1688). In the Roberts Mountains a coarsely crinoidal dolomite was taken at the base of the Lone Mountain. The upper contact with the Devonian Nevada Formation apparently is gradational in places, but in the Diamond Mountains it is sharp with an abrupt lithologic change (Nolan and others, 1956, p. 38).

In the Lone Mountain-Roberts Mountains area the formation consists of light-gray and darker gray, fine-grained to saccharoidal dolomites and dolomitic limestones usually weathering to light yellowish gray. The formation is characteristically thick bedded to massive with bedding somewhat obscure.

Winterer and Murphy (1958) report that in the Roberts Mountains the Lone Mountain Dolomite and Roberts Mountains Formation are largely lateral equivalents: the Lone Mountain is considered to be a reef and bank complex whose original features have been largely obliterated by dolomitization, and the Roberts Mountains Formation is a deeper water, reef-flank, off-reef, and basin deposit. In the Roberts Mountains, the formations are as much as 4,500 feet thick, about four times the regional average.

The Lone Mountain Dolomite is only sparsely fossiliferous, but in the northern end of the Fish Creek Range it does contain brachiopod faunas of Late Silurian Age. Merriam (Nolan and others, 1956, p. 39–40) indicated that in the Antelope Range the upper beds may contain Early Devonian faunas; additional mapping will be required to determine the extent of these faunas.

Devonian System

Strata assigned to the Devonian System have an aggregate thickness of 3,605 to 4,905 feet in the Eureka area and are widespread throughout the county. These strata are dominantly limestone with lesser proportions of dolomite, shale, and sandstone. They have been divided into: the Rabbit Hill Limestone, the Nevada Formation, the Devils Gate Limestone, and the lower part of the Pilot Shale. The Nevada Formation has been divided into five members and the Devils Gate Limestone into two members (Nolan and others, 1956, p. 42–52). At some places in the county the Nevada Formation and Devils Gate Limestone are shown separately on plate 3 and at others are shown as Devonian sedimentary rocks undivided.

Rabbit Hill Limestone. In the Monitor Range the early part of Devonian time is represented by the Rabbit Hill Limestone. Merriam

(1963, p. 41–44) has assigned faunas in the Rabbit Hill to Early Devonian (Helderberg) and suggests that the Rabbit Hill is a distinct facies. Because of deformation and erosion its relationship to the Nevada Formation is not known, but the oldest faunas of the Nevada (Oriskany) are distinctly younger. Merriam (1963, p. 42) suggests that the Rabbit Hill may rest disconformably upon the Roberts Mountains Formation, cutting out the upper beds and possibly the Lone Mountain Dolomite, or, alternatively, that the Rabbit Hill may be partly equivalent to the Lone Mountain.

The Rabbit Hill Limestone is mostly dark gray to black, platy and flaggy limestone containing much clayey and carbonaceous material. The formation is about 250 feet thick at Rabbit Hill in Copenhagen Canyon in the Monitor Range, but structural complications made measurement of sections difficult (Merriam, 1963, p. 43). It contains a rich and varied fauna of crinoids, corals, and brachiopods.

Nevada Formation. The term Nevada was used by King (1876, map 4) and Hague (1883, p. 264–267) to designate the entire Devonian sequence in Nevada. Merriam (1940, p. 14–15) redefined and restricted the formation to the lower 2,448 feet of Devonian strata above the Lone Mountain Formation as exposed at Lone Mountain.

In the eastern part of the county the formation is composed dominantly of dolomite; in the western and northern parts it is mostly limestone and shaly limestone. In the Eureka area, Nolan and others (1956, p. 42–52) recognized three dolomite units separated by a sandstone unit and a limestone unit. They designated these units as members, which are, in ascending order: the Beacon Peak Dolomite, the Oxyoke Canyon Sandstone, the Sentinel Mountain Dolomite, the Woodpecker Limestone, and the Bay State Dolomite Members.

The Beacon Peak Dolomite Member rests disconformably on the Lone Mountain Dolomite. The type locality is in Oxyoke Canyon on the lower west slope of Beacon Peak, near the eastern boundary of the county. The member is composed of light olive-gray to slightly brownish creamy-gray porcelaneous dolomite that weathers pale gray to white. Individual beds probably average a foot in thickness. Some of the dolomite is clastic in origin. The upper half of the member includes thin brown-weathered sandstone interbeds ranging from a quarter of an inch to 6 inches in thickness. The thicker beds exhibit prominent crossbedding. The thickness of the member ranges from 470 feet at the type locality to 940 feet near the Phillipsburg mine, where it is included with Devonian eastern assemblage rocks undivided. Northwest of Eureka, the typical dolomite of the member grades into fossiliferous limestones. Detailed measurements have not been made here, but the total thickness of the interval representing this member and the overlying Oxyoke Canyon Sandstone Member at Lone Mountain and Roberts Creek Mountain is about 700 to 800 feet, which is comparable to 870 feet in Oxyoke Canyon.

The contact between the Beacon Peak Dolomite Member and the overlying Oxyoke Canyon Sandstone Member is gradational: it is placed about 15 feet above a 5-foot sandstone bed included in the Beacon Peak.

The Oxyoke Canyon Sandstone Member is named for exposures in the Canyon along the southeast slope of Beacon Peak about 7 miles southeast of Eureka. The dominant constituent is light olive-gray sandstone, weathered to shades of brown, composed of fine- to medium-grained rounded quartz grains in a dolomite cement. Beds are commonly several feet thick; many exhibit crossbedding. The lower part of the member includes a few beds of dolomite similar to those of the underlying Beacon Peak Dolomite Member. The upper part includes more abundant thicker beds of coarsely granular light-gray to white dolomite. This member may be confused with the Eureka Quartzite where the sandstone beds have become vitreous and quartzitic in areas of intense faulting, but the Oxyoke Canyon Member includes characteristic crossbedding and interbedded dolomites. The thickness of the member ranges from 400 feet at the type locality to 450 feet north of the Phillipsburg mine in the Diamond Mountains. Northwest of Eureka in the Sulphur Spring Range, the thickness of equivalent beds is believed to be about the same, but the sands are absent in the J–D and Lone Mountain windows (Johnson, 1962b, p. 543). Osmond (1962, p. 2053) believed that the sand was derived from the craton in Utah; Johnson suggests derivation from the northeast.

The contact between the Oxyoke Canyon Sandstone Member and the overlying Sentinel Mountain Dolomite Member is gradational through a 50-foot zone: the contact is placed either above the highest sandstone bed or beneath the lowest dark dolomite bed.

The Sentinel Mountain Dolomite Member is well exposed on the lower southeast slope of Sentinel Mountain, the type locality, about a mile east of the county boundary. The member is composed entirely of dolomite—coarse-grained, thick-bedded, light-gray beds alternating with faintly laminated, mottled, chocolate-brown beds. The member is 595 feet thick as mapped at the type locality. The equivalent stratigraphic interval at Lone Mountain is 600 feet thick.

The contact between the Sentinel Mountain Dolomite Member and the overlying Woodpecker Limestone Member is gradational through an interval of 100 feet.

The Woodpecker Limestone Member is named for exposures in the gulch draining the south slope of Woodpeckers Peak, which is southeast of Eureka, about half a mile outside the county boundary. The lithology of the member varies considerably, but its calcareous nature is persistent. At the type locality, the member is composed of calcareous shale and thin- to medium-bedded, fine-grained to aphanitic, platy, light-olive-gray to dark-gray limestone that commonly is silty. The characteristic pinkish or yellowish colors of weathered silty units help to identify the member from a distance. The thickness of the Woodpecker ranges from 390 to 410 feet near the type locality; in the Diamond Mountains to the north, at Black Point, it is 450 feet; at the Phillipsburg mine, 220 feet; and west of Eureka, at Lone Mountain, 450 to 500 feet.

The contact between the Woodpecker Limestone Member and the overlying Bay State Dolomite Member is sharp: the basal unit of the Bay State Member is marked by a varying thickness of light-gray dolomite sand.

The Bay State Dolomite Member is named for the Bay State mine on Newark Mountain, about 2 miles east of the county boundary. The type locality is above the mine in Mining Canyon. The member is composed of massively bedded dolomite. The basal unit is 50 to 80 feet of light-gray dolomite sand that locally contains large fragments of dolomite. Overlying the sand unit are fairly uniform, massive, dark-gray to black dolomite beds that contain abundant white cylindrical corals of *Cladopora* and *Amphipora* types and large *Stringocephalus* brachiopods. Near the top of the member, lighter gray dolomites are interbedded with the darker beds. The thickness of the member near the type locality is from 618 to 650 feet; to the south, in Oxyoke Canyon, 630 feet; to the north, near the Phillipsburg mine, 850 feet. West of Eureka, the apparently equivalent section at Lone Mountain is 800 feet thick and in the Mahogany Hills, 1,000 feet.

The contact between the Bay State Dolomite Member and the overlying Devils Gate Limestone in the Eureka area is gradational through a 50-foot zone; at the type locality of the Bay State Dolomite Member the contact is obscured by dolomitization of the basal limestone beds of the Devils Gate.

At Lone Mountain (Merriam, 1940; 1963) the Nevada Formation rests disconformably on the Lone Mountain Dolomite; the contact is marked by an abrupt transition from light-weathering, more or less massive dolomites of the Lone Mountain, to the darker, argillaceous, fossiliferous, well-bedded limestones of the Nevada. Merriam notes (1940, p. 15) that ". . . the lower 500 to 700 feet may be clearly distinguished from the higher members. The lower portion is inclined to be thinly bedded, locally of shaly character, and rich in fossils. The upper part is more heavily bedded, includes siliceous limestones, and locally exhibits repetition of massive beds of light-gray, sugary, dolomitic limestone and dark-gray, calcareous sediments. In general the upper members contain fewer fossils . . ." The contact between the Nevada Formation and the overlying Devils Gate Limestone is placed (Merriam 1940, p. 24, 25) at the top of a thin zone containing the brachiopod *Stringocephalus,* which occurs in a neutral-gray, poorly bedded, fine-grained limestone 2,440 feet above the base of the formation.

In the Sulphur Spring Range, as well as in the Pinyon Range to the north in Elko County, Carlisle and others (1957) divided the Nevada Formation (Middle Devonian) into three members, which are in ascending order: "(1) the McColley Canyon Member [which conformably overlies the Lone Mountain Dolomite], comprising well-bedded limestone, calcareous dolomite, and dolomite with no appreciable amount of quartz sand, excepting local quartzose facies at the base; (2) the Union Mountain Member, characterized by abundant quartz sand either in sandy dolomite or as vitreous siliceous quartz arenite or quartzite, but also including white crystalline dolomite and dark crinoidal dolomite; and (3) the Telegraph Canyon Member, a thin- to thick-bedded mottled dolomite in alternating light to dark-brown or dark-gray layers, and including a tongue of well-bedded gray limestone." The contact with the overlying Devils Gate Limestone apparently is conformable. Correlation with the five members described in the Eureka area by Nolan and others (1956) is shown in figure 5. Johnson (1962b, 1966) has subsequently shown that the McColley Canyon Member is Lower Devonian in age.

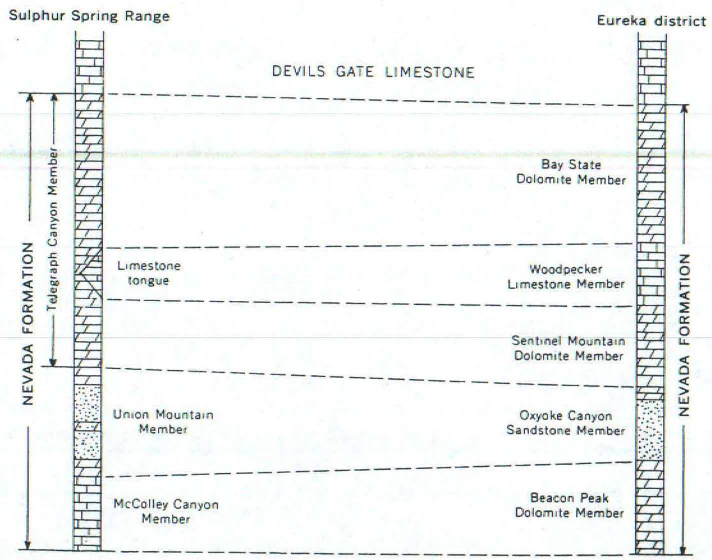
In the Roberts Mountains the lithology of the Nevada Formation is similar to that at Lone Mountain except that the upper beds, including the *Stringocephalus* zone (Merriam, 1940, p. 24) recognized at Lone Mountain, ". . . apparently are cut out by faulting or occupy brecciated belts within which stratigraphic determination is not possible (Merriam and Anderson, 1942, p. 1689)."

In the Simpson Park Mountains and northern Roberts Mountains, Johnson (1959, 1962b, 1966) mapped a partial section of Devonian rocks. He assigned the lowest unit to the McColley Canyon, which he suggested be raised to formational rank, and proposed a new name, Denay Limestone, for the Middle Devonian beds. In the Simpson Park Mountains the Denay consists of three members: a lower flaggy limestone member, 450 feet thick; a middle argillaceous limestone with dark-gray flaggy limestone and dolomite at the base, 750 feet thick; and an upper black limestone with reddish-brown dolomite at the top, 400 feet thick.

In the Cortez Mountains, Gilluly and Masursky (1965, p. 11) have assigned Devonian rocks to the Wenban Limestone which is equivalent to both the Nevada Formation and Devils Gate Limestone. The Wenban consists of three units: a lower thick-bedded, gray limestone interbedded with gray to yellow-gray argillaceous limestone 2,000 feet thick; a middle gray limestone with interbedded, yellow-weathering, argillaceous limestone 500 feet thick; and an upper thick- and thin-bedded, gray, lithographic and bioclastic limestone 500 feet thick.

In the Tuscarora Mountains, Roen (1961) mapped Devonian rocks which differ significantly from those in the Cortez Mountains. The upper beds are cut out by the Roberts Mountains thrust, but he measured a partial section of three units: a lower thick-bedded, clastic limestone that contains beds of edgewise conglomerate interlayered with sandy limestone about 450 feet thick; a middle shaly limestone containing thin-bedded silty layers 500 feet thick; and an upper thick-bedded gray limestone about 550 feet thick. In the Lynn district, Hardie (1966) has informally referred to these rocks as the Popovich Formation.

The thickness of the Nevada Formation is fairly constant in the region around Eureka but it appears to increase northwestward. Measured thicknesses are: 2,550 feet in Oxyoke Canyon (Nolan and others, 1956, p. 42), 2,448 feet on Lone Mountain (Merriam, 1940, p. 14), 2,900 feet in the Diamond Mountains in the latitude of the Phillipsburg mine, 2,400 feet on Roberts Creek Mountain (Merriam, 1940, p. 34) and more than 3,400 feet in Telegraph Canyon in the Sulphur Spring Range (Carlisle and others, 1957, fig. 2). In the Cortez area, the Wenban Limestone of Devonian Age, which is equivalent to the Nevada Formation and Devils Gate Limestone, is about 3,000 feet thick (Gilluly and Masursky, 1965, p. 11, 29).



Adapted from Carlisle and others, 1957, fig. 3, p. 2181

FIGURE 5. Correlation of members of the Nevada Formation in the Sulphur Spring Range and the Eureka district.

The age of the Nevada Formation, based on fossil evidence, is Early and Middle Devonian (Merriam, 1940); the time boundary was thought by Merriam (*in* Nolan and others, 1956, p. 47) to lie in the Oxyoke Canyon Sandstone Member and equivalent units, but Johnson (1962a,b) regards these sandy units as Middle Devonian.

Devils Gate Limestone. In redefining and subdividing the Nevada Limestone of Hague (1892, p. 63), Merriam (1940, p. 16) designated the strata lying between the *Stringocephalus* zone of the Nevada and the uppermost *Cyrtospirifer* fauna as the Devils Gate Formation. More recently the name Devils Gate Limestone has been adopted because of the dominantly calcareous nature of the formation (Nolan and others,

1956, p. 48). The type locality is at Devils Gate, 8 miles northwest of Eureka on U. S. Highway 50. The formation is also present at Lone Mountain, throughout the Mahogany Hills, and in the Diamond Mountains.

The lower part of the formation is not exposed at Devils Gate, but a total thickness of 2,065 feet was determined by combining sections measured there and at Modoc Peak, 6 miles to the southeast (Merriam, 1940, p. 16). To the north, in the Sulphur Spring and Pinyon Ranges, Carlisle and others (1957, p. 2188–2189) have measured more than 2,000 feet of beds with the highest truncated by the Roberts Mountains thrust fault. Complete sections have been measured at localities in the Diamond Mountains: on Newark Mountain, just east of the county line, 1,200 feet; northeast of Black Point, 750 feet; and east of the Phillipsburg mine, 675 feet. This indicates an eastward thinning that Nolan and others (1956, p. 49) believe may be due in part to replacement of beds by the overlying Pilot Shale and in part to nondeposition or a slower rate of deposition toward the east; the contact with the Pilot Shale is conformable.

The Devils Gate is composed largely of thick-bedded gray to blue-gray limestones that, at a distance, are easily distinguished from the underlying Nevada Formation because of their lighter color and cliffy habit. A few thinner bedded, platy or flaggy limestones are present mostly in the middle and at the top of the formation. The contact with the underlying dolomite of the Nevada Formation is gradational and in general is placed at the lowest bed of dark-gray thick-bedded limestone. The upper contact with the overlying Pilot Shale is sharp. In the southern part of the Diamond Mountains, the formation has been divided into two members.

The Meister Member was named (Nolan and others, 1956, p. 49) for exposures in the vicinity of the Meister mine on Newark Mountain. The member is about 410 feet thick and is composed mostly of thick-bedded gray to blue-gray cliffy limestone containing corals and abundant stromatoporoids. Dolomite and dolomitic limestone beds occur in the gradational zone at the base and sporadically throughout the member; they are most abundant in a 30-foot zone at the top, where they are white weathering and are interbedded with darker limestone beds. This zone commonly weathers to a bench. The next beds above it are dark-gray oolitic limestone of the Hayes Canyon Member.

The Hayes Canyon Member was named (Nolan and others, 1956, p. 49) for the previously named Hayes Canyon (Hague, 1892), now Tollhouse Canyon, which drains the west slope of Newark Mountain. The member is about 780 feet thick and is composed of limestone. The lowermost bed is dark gray and contains abundant oolites and ostracodes. Beds in the upper 300 feet are highly fossiliferous, and beds in the upper 150 feet are thinner and somewhat darker than the rest of the member.

The Devils Gate Limestone is Middle and Late Devonian in age; the time boundary is in the upper half of the Hayes Canyon Member. Correlative strata are widespread to the north, east, and south (Nolan and others, 1956, p. 51–52).

Devonian and Mississippian Systems

Pilot Shale. The Pilot Shale, as defined by Spencer (1917, p. 25–27) in the Ely district, has been recognized by Nolan and others (1956) in the Eureka area. The term applies to the lowest beds of the unit that Hague (1892) called the White Pine Shale.

In the area of this report the Pilot is present only in the Eureka area, where it crops out in the southern part of the Diamond Mountains and at Devils Gate. The thickness of the Pilot Shale in the Eureka district ranges from 315 to 425 feet; here it is included with Devonian sedimentary rocks undivided on plate 3. It rests with sharp and apparently conformable contact upon the Devils Gate Limestone. At Devils Gate 50 to 75 feet of shaly limestone and silty shale contain a fauna partly equivalent to the Pilot Shale (C. W. Merriam, oral communication, 1958); this unit was included with the Devils Gate Limestone on plate 3.

The Pilot Shale is a platy, calcareous shale, dun-colored to black on fresh surfaces, and weathers to pinkish or light yellowish brown or gray. The lower part contains much thin-bedded shaly limestone; the upper part is chiefly shale.

In the Eureka district the lower unit of the Pilot Shale has yielded conodonts of Late Devonian Age (Nolan and others, 1956, p. 53). Near Ely, Nev. (Spencer, 1917, p. 25–26; Roberts, 1942, p. 300) the Pilot has yielded fossils of Early Mississippian Age.

Mississippian System

Joana Limestone. The Joana Limestone was named by Spencer (1917, p. 24–26) in the Ely district. In Eureka County it has been recognized at only a few localities in the Eureka district and the Diamond Mountains (Nolan and others, 1956, p. 54–56). In these areas it is too thin to show separately on the geologic map (pl. 3) and, therefore, is included with overlying Mississippian rocks of the overlap assemblage. However, the formation clearly is part of the eastern carbonate assemblage. It is composed of dense, porcelaneous limestone; coarsely crystalline, sandy, crinoidal limestone; and nodular, cherty limestone. In places it includes shales similar to those in the underlying Pilot Shale. The basal contact is gradational. The contact with the overlying Chainman Shale is sharp and apparently is an erosional surface in places. Thickness varies considerably: 15 miles southeast of Eureka the formation is 135 feet thick; it thins northward and pinches out entirely near Newark Summit. Fossil collections indicate that the formation is Early Mississippian in age (Nolan and others, 1956, p. 55).

Western Siliceous and Volcanic Assemblage

Rocks of the western siliceous and volcanic assemblage occur throughout much of Eureka County as remnants of the upper plate of the Roberts Mountains thrust (see fig. 3). They range in age from Ordovician to Late Devonian, and include the Ordovician Vinini (Merriam and Anderson, 1942) and Valmy (Roberts, 1949, 1951, 1964d, 1964e) Formations and other younger rocks that as yet are unnamed. The principal rock types are shale, siliceous shale, chert, quartzite, siltstone, and minor amounts of limestone and andesitic volcanic rocks (greenstone).

The Vinini and Valmy Formations are partly equivalent units. The Vinini is mostly shale, chert, and minor greenstone, sandstone, and quartzite (Merriam and Anderson, 1942). The Valmy is interbedded shale, chert, quartzite, and greenstone (Roberts, 1964d); it is characterized by thick quartzite units that make up as much as a third of the formation. On plate 3, these formations are shown separately in some places, and in others are included in Silurian and Ordovician sedimentary rocks, undivided.

Ordovician System

Vinini Formation. The Vinini Formation was named by Merriam and Anderson (1942, p. 1693–1698) for exposures on Vinini Creek in the Roberts Mountains. The formation also is exposed at Lone Mountain and in the Simpson Park, Cortez, and Tuscarora Mountains and in the Sulphur Spring, Monitor, and Fish Creek Ranges. In the Roberts Mountains it was divided by Merriam and Anderson into two parts. The lower member consists of dark-gray, brownish-weathering bedded quartzites, gray arenaceous limestones or calcareous sandstones, and brownish-gray and greenish-brown silty sediments; some black shales also are present. Near the top of the member are lava flows and tuffs of andesitic composition, and cherty shales. The upper member is interlayered chert and black shale; chert is more predominant than the shale. The cherts are black to dark gray and greenish, lenticularly bedded, and separated by thin shale partings. The shale interbeds are graptolitic; some shales are petroliferous and can be easily ignited. Both the chert and shales weather brown, creamy white, and grayish white. The upper member weathers to smooth slopes with few outcrops.

At Henderson Summit, 30 miles north of Eureka, shales containing an abundant graptolite fauna were studied by Ruedemann (1947, p. 106–107) and were assigned a Deepkill and Normanskill (Lower and Middle Ordovician) Age.

In the Simpson Park Mountains just north of Fagin Mountain, western assemblage rocks that include the Vinini Formation are shown as Silurian and Ordovician sedimentary rocks undivided. They are principally chert and shale in the lower part of the section, overlain by quartzite, shale, and some chert, and, at the top, by shale, sandstone, and some limestone. The shale in the lower part of the section is black and gray and contains abundant graptolites. Above the black shale zone are green cherts and phyllitic shales that weather brownish. Along many of the bedding planes this zone characteristically contains green chert nodules measuring an inch in diameter. Above the green chert are brown chert and massive beds of brown quartzite. The quartzites are very resistant to weathering and form prominent ribs. Higher in the section the quartzites are less prominent, and massive beds of brown chert are interbedded with brown siliceous shales. Above these, in the Underwood Canyon area, on the west flank of the range and just outside the county boundary, are sandstones, shale, and some limestones.

In the Cortez Mountains, the upper part of the Vinini is dark-gray to dark-brown brecciated quartzite commonly containing patches of reddish-brown brecciated jasperoid. The remainder of the formation consists of black to blue-gray cherts with interbedded dolomitic and siliceous shales and lesser amounts of thickly bedded to massive, blue and black limestone. Some chert beds are a distinctive turquoise to deep-green color. The graptolite-bearing black shale facies present in the Roberts and Simpson Park Mountains is absent in the southern end of the Cortez Mountains.

In the Tuscarora Mountains between U. S. Highway 40 and the Lynn district, a thick sequence of Ordovician strata assigned to the Vinini is exposed on Marys Mountain; the dominant rock types are shale, siliceous shale, and chert. The lower slopes are underlain by tuffaceous shale containing a few cherty layers. The middle slopes are underlain by thick cherty units. North of Marys Mountain, Ordovician strata include black and brown chert and shale, dark-gray limestone, sandstone, and blue-gray siliceous tuffs which commonly have shaly partings.

North of the Lynn district the western assemblage is almost wholly made up of black chert and shale alternating with brown chert and shale. A few gray tuffaceous beds are present. Quartzite was noted locally in the section west of the district. At the head of Boulder Valley on the east side of the road near the north edge of the county, the strata consist mainly of gray shale and limestone interbedded with black and brown chert and shale.

At Devils Gate, in the north end of the Mahogany Hills, rocks assigned to the Vinini Formation are mostly black shale with some dark gray to black chert.

Valmy Formation. The Valmy Formation is thick-bedded to massive vitreous quartzite interbedded with gray, green, or black chert and black shale (Roberts, 1951, 1964d, 1964e). Quartzite makes up 20 to 30 percent of the Valmy; the percentages of chert and shale vary from place to place. In Eureka County thrust plates of Valmy were recognized in the Simpson Park and Cortez Mountains and in the southwestern end of the Dry Hills, southeast of Beowawe.

Near Beowawe the Valmy consists mainly of thin-bedded black and brown chert and shale. Thin-bedded quartzite makes up a small percentage of the section; thick beds of chert conglomerate also are present.

Exposures of the Valmy near the mouths of Brock and Cottonwood Canyons, on the northwest flank of the Cortez Mountains have been described by L. J. P. Muffler (1964, p. 5). The formation is characterized by highly contorted, thin-bedded, dark chert and mottled, dark-gray, medium- to coarse-grained, poorly sorted quartzite in which detrital chert

grains are abundant; subordinate rock types include light-gray, fine-grained quartzite, gray and black siltstone, and chert-pebble conglomerate. Graptolites collected in Brock Canyon were identified by R. J. Ross, Jr. (written communication, 1961) as Ordovician in age.

Ordovician and Silurian Systems

Rocks assigned to the western assemblage on the basis of lithology, and assigned an Ordovician and Silurian Age on the basis of fossil determinations, crop out in the Simpson Park Mountains and in the vicinity of Maggie Creek in the northern part of the county. In part these rocks belong to the Vinini and Valmy Formations, but were not mapped separately.

Silurian System

Silurian rocks of the western assemblage are mainly shale, siliceous shale, and calcareous shale containing a few thin limestone beds. In general, they seem to be less cherty than typical Vinini and lack the vitreous quartzites of the Valmy Formation.

Gilluly and Masursky (1965, p. 54) have mapped interbedded chert, shale, and silty sandstone of the Fourmile Canyon Formation north of the Cortez district; these rocks are in a thrust slice that is in contact with limestone of the Wenban Formation and quartz monzonite in Mill Canyon and has been overridden by a higher thrust plate of the Valmy Formation. The Fourmile Canyon contains graptolites that have been assigned by R. J. Ross, Jr., to the Silurian.

Silurian and Devonian Systems

At several localities in the county, rocks of western assemblage lithology are assigned to the Silurian and Devonian Systems on the basis of fossil data. In the north end of Pine Valley this map unit consists of a siliceous and tuffaceous shale that is buff or cream colored and mottled with shades of red or purple. The rock is homogeneous and rarely shows laminations or bedding. It weathers to angular chips and plates an inch or so thick. The unit has yielded graptolites ranging from Ordovician to Silurian Age (R. J. Ross, Jr., written communication, 1959) and conodonts of possible Devonian Age (W. H. Hass, written communication, 1959). It may be partly equivalent to the Vinini Formation. A similar assignment has been given rocks on the north and east sides of the Carlin window, in the Sulphur Spring Range, and near Walti hot springs in the Simpson Park Mountains. In the southern Fish Creek Range and Tuscarora Mountains, rocks previously assigned tentatively to the Vinini Formation (Lehner and others, 1961) have yielded Devonian fossils (C. W. Merriam, oral communication, 1962).

Devonian System

Strata of Devonian Age in the western assemblage have been identified at several places in Eureka County. The Devonian beds include chert, shale, limestone, sandstone, quartzite, and conglomerate.

In the Sulphur Spring Range, Carlisle and Nelson (1955, p. 1645) have mapped two clastic units that contain a Late Devonian fauna. The lower unit consists chiefly of limestone conglomerate, chert, black shale, and quartzite. The upper unit is made up of chert conglomerate, clastic limestone, and quartzite. These two units seems to grade laterally into a black chert and shale facies similar to the Devonian rocks in the Shoshone Range (Roberts and others, 1958, p. 2837).

In the northern part of the county, Devonian rocks that are unlike typical western assemblage rocks have been recognized in two localities: north of Rodeo Creek, where they consist of shale and calcareous shale, and on Marys Mountain and in James Creek Valley to the north, where sandy and calcareous shale and sandstone have yielded conodonts of Devonian Age (W. H. Hass, written communication, 1954). These rocks were emplaced in the frontal part of the Roberts Mountains thrust plate; they contain less chert and more limestone than is usual in the western assemblage and therefore more properly belong to a transitional assemblage. However, as these rocks were not mapped separately in the field, they are here included in the western assemblage.

Overlap Assemblage

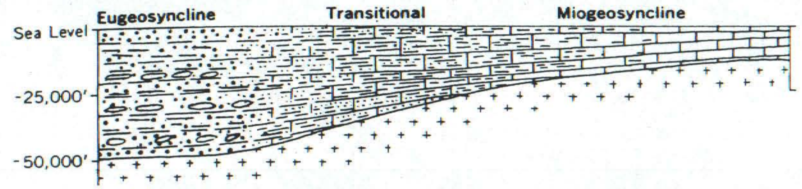
Beginning in Late Devonian time, orogenic movements, which have been called the Antler orogeny (Roberts, 1949; Roberts and others, 1958, p. 2850; 1966a) caused uplift, folding, faulting, and erosion in western Nevada (fig. 6). From the emergent belt, clastics were shed into continental and marine basins and adjoining seaways. The full extent of these deposits is not known, but they probably extended as far south as Beatty, as far east as the Ruby Range (Sharp, 1942, p. 669), as far southeast as Pioche, and as far north as Mountain City. Farther to the east the clastics grade into finer sediments that interfinger with the normal marine section; but within the orogenic belt they overlap the folded and faulted preorogenic rocks and are thus called the overlap assemblage (Roberts and Lehner, 1955). In Eureka County the overlap assemblage consists of Mississippian, Pennsylvanian, and Permian rocks (fig. 7), which are best exposed in the area between Eureka and Carlin.

Eureka-Carlin sequence

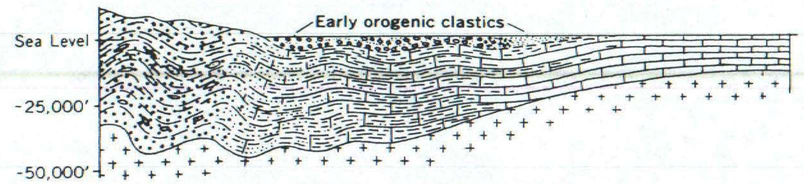
Mississippian System.

TONKA FORMATION OF DOTT (1955). The Tonka Formation was named by Dott (1955, p. 2222) for Tonka siding, on the Western Pacific Railroad about 5 miles east of Carlin in Elko County. The term was applied to a sequence of chert-pebble conglomerates with quartzite and shale interbeds. The upper part of the type section south of Tonka contains faunas of Late Mississippian and Pennsylvanian Age, but lower conglomerate beds, also included by Dott in the Tonka, crop out to the west and south. The lower beds contain a fauna of Early Mississippian Age (Gordon and Duncan, 1961).

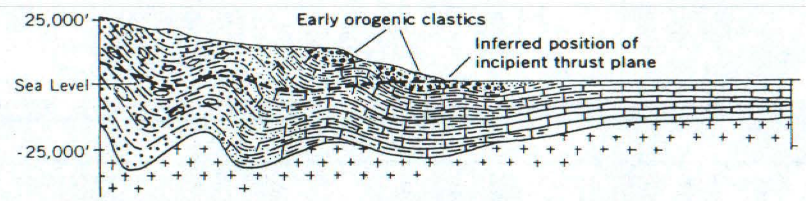
In Eureka County, beds assigned to the Tonka have been recognized



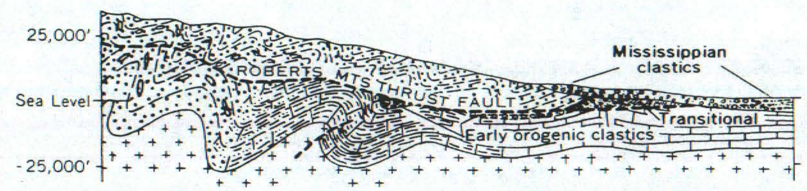
A. Near the end of the Devonian the Cordilleran geosyncline covered most of Nevada. Siliceous, clastic, and volcanic rocks were deposited in western Nevada; carbonate rocks in central and eastern Nevada; and transitional rock types in west-central Nevada.



B. Orogenic movements in early Late Devonian time caused uplift, folding, and erosion in western Nevada; clastics derived from the uplift were deposited in central Nevada.



C. Folding continued into Late Devonian and Early Mississippian, along with continued uplift.



D. The Roberts Mountains thrust plate, composed mostly of eugeosynclinal rocks, including slivers of transitional rocks, moved eastward overriding part of the early orogenic clastics and the shelf rocks.

After major thrusting, coarse clastics eroded from the emergent orogenic belt were shed into eastern Nevada and deposited partly in continental and partly in marine environments, overlapping the thrust plate and shelf

FIGURE 6. Diagram of inferred sequence of events in north-central Nevada during the Antler orogeny.

in two areas near Emigrant Pass in the Tuscarora Mountains. The formation also crops out on the east side of Pine Valley about 3 miles southeast of Palisade where interbedded shale, sandstone, and conglomerate rest on siliceous shale of Silurian and possibly Devonian Age. Only a few tens of feet of beds assigned to the Tonka are present here, but the unit thickens eastward in Elko County. The Tonka has been traced southward by J. Fred Smith and Keith Ketner (oral communication, 1959) on the east side of the Pine Valley in Elko County to a point east of Mineral Hill, where it is cut out by faults. The chert and quartzite fragments that make up the pebbles were derived from western assemblage rocks.

CHAINMAN SHALE. The Chainman Shale was named by Spencer (1917, p. 26–27) in the Ely district. The name was applied in the area of this report by Nolan and others (1956, p. 59). Exposures are in the Eureka district (Nolan and others, 1956) and the Diamond Mountains (Brew, 1961a,b; 1963). In the Eureka district, where it is mapped with Mississippian sedimentary rocks, undivided, the formation is composed mostly of black shale; it contains a few sandstone interbeds. The apparent thickness near the mouth of Secret Canyon is about 5,000 feet, but Nolan and others (1956, p. 59) state that the true thickness probably is much less. In the vicinity of Newark Summit it is about 2,500 feet thick and is composed of about 90 percent pyritiferous claystone and clayey siltstone and about 10 percent sandstone and conglomerate (Brew, 1961b). North of Diamond Peak it is about 4,000 feet thick and is composed of coarser material, including chert and quartzite pebble and cobble conglomerate, which suggests deposition closer to the source area (Brew, 1961b).

Fossil collections from the Chainman indicate that it probably is Late Mississippian in age (Nolan and others, 1956, p. 60), but according to Mackenzie Gordon, Jr. (oral communication, 1962) the lower beds may be older.

DIAMOND PEAK FORMATION. The Diamond Peak Formation (Hague, 1883, p. 268–270) is composed principally of siltstone, sandstone, and conglomerate, and lesser amounts of claystone and limestone. The type section in the Diamond Mountains, described by D. A. Brew (1961a), is about 3,525 feet thick. It conformably overlies the Chainman Shale and is conformably overlain by the Ely Limestone. In general, the lower beds are more shaly and the upper beds more conglomeratic. According to Brew (1961a), the formation is composed of the following units in ascending order: 280 feet of interstratified thick-bedded chert, quartzite, conglomerate, siltstone, claystone, and thin-bedded silicified sandstone, which forms prominent cliffs; 1,270 feet of thin-bedded siltstone interbedded with sandstone, claystone, and conglomerate, which is similar to the underlying Chainman; 240 feet of resistant thick-bedded conglomerate and overlying thin-bedded siltstone, claystone, and sandstone; 380 feet of resistant thick-bedded limestone interstratified with calcareous sandstone, claystone, siltstone and conglomerate; 570 feet of alternating

siltstone, sandstone, and conglomerate; 315 feet of siltstone, claystone, sandstone, and conglomerate; 250 feet of thick-bedded conglomerate and minor siltstone, sandstone, and limestone conglomerate overlain by poorly exposed siltstone; and 220 feet of thin- to thick-bedded limestone alternating with sandstone, conglomerate, and siltstone. The upper contact is gradational.

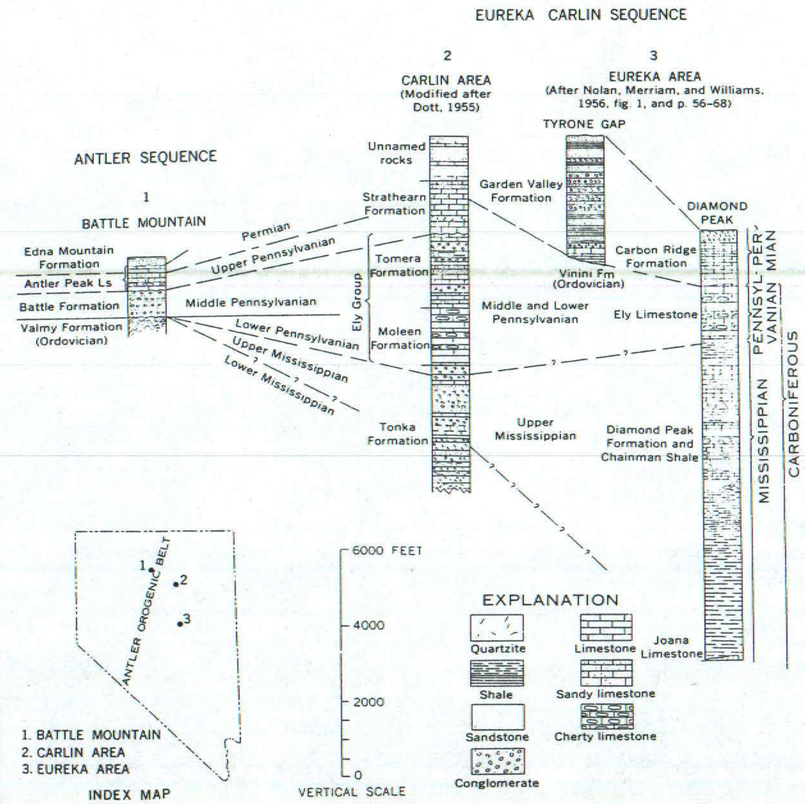


FIGURE 7. Stratigraphic columns of overlap assemblage rocks in central Nevada.

West of 116°15′ only a few outcrops of Mississippian rocks have been recognized. These are near Cortez and in the southern part of the Tuscarora Mountains near U. S. Highway 40. Masursky (oral communication, 1966) suggests that pebbly sandstone and shaly sandstone about 2.5 miles south of the Cortez townsite may be of Mississippian Age. These units are unlike any other sandstones in the region and closely resemble the sandstones at Devils Gate that have been mapped as Mississippian rocks, undivided.

Exposures of similar sandstone and conglomerate near Emigrant Pass on U.S. Highway 40 have also been mapped as Mississippian rocks, undivided. These rocks rest unconformably on deformed chert and shale of Ordovician Age.

The conglomerates of the Diamond Peak are composed mostly of chert and quartzite pebbles, cobbles, and boulders derived from western assemblage rocks, but locally limestone fragments from eastern assemblage rocks have been recognized. The pebbles, cobbles, and boulders are commonly well rounded, but in places they are subangular to angular. Nolan and others (1956, p. 58), report that:

> "The chert pebbles are perhaps the most significant and interesting element of the conglomerate beds. Green, gray, black, and white cherts are represented, and all of them can be matched lithologically with bedded cherts in the Vinini formation of the western Ordovician facies. Their presence in the Upper Mississippian strata, and not in older formations, indicates that in later Mississippian time the late Paleozoic geanticline in central and western Nevada had risen high enough and rapidly enough to shed course debris from the Vinini formation that had by then been exposed."

More specifically, the source of the chert pebbles was western assemblage rocks in the Antler orogenic belt which lay only a short distance to the west (Brew, 1963). During early stages of the orogeny, the fine clastics of the Chainman were shed into the vicinity of Eureka. As time went on and as the orogeny became more intense, coarser clastics were deposited. The Roberts Mountains thrust plate, which furnished the clastic rocks, may have overridden the basal beds of black shale and quartzite of the Chainman and Diamond Peak Formations at Devils Gate, and at one time may even have covered the site of the Eureka district.

Most of the fossils in the Diamond Peak Formation are regarded as Late Mississippian in age (Nolan and others, 1956, p. 60). According to Mackenzie Gordon, Jr. (oral communication, 1959), a similar fauna occurs in the upper part of the Tonka Formation of Dott (1955). However, the occurrence of forms usually found in Pennsylvanian rocks in association with Late Mississippian forms suggests that beds of Pennsylvanian Age may be present in the uppermost part of the formation (Nolan and others, 1956, p. 61). The Pennsylvanian Age assignment of Easton and others (1953) was based on interpretation of fossils in this part of the formation.

Pennsylvanian System.

ELY LIMESTONE. The Ely Limestone was named by Lawson (1906), p. 295) and redefined by Spencer (1917, p. 27–28 in the Ely district. The name was extended to the Eureka district by Nolan and others (1956, p. 61). The Moleen and Tomera Formations of Dott (1955, p. 2234–2248) in the Elko area are essentially equivalent to the Ely and were included by him in the Ely Group.

The Ely Limestone in the Eureka area rests with gradational contact on the Diamond Peak Formation. Above this gradational zone, about 40 feet thick, the Ely is massively bedded, bluish-gray, cherty limestone. The beds range from 5 to 40 feet thick and are separated by thin shaly layers; outcrops weather to characteristic steplike ledges. In the Eureka area and Diamond Mountains the Ely has a maximum thickness of 1,500 feet. Dott measured 1,200 to 1,300 feet of strata assigned to the Moleen Formation in the northern part of the Diamond Mountains, and about 606 feet of strata assigned to the Tomera Formation. Northward from Eureka, clastic beds, mainly shale, sandstone, and conglomerate, gradually become more abundant, and near Elko and Carlin make up a significant part of the section. Correlative beds in the Tuscarora and Cortez Mountains and at Battle Mountain are mainly conglomerate and thin limestone and calcareous shale beds.

Strata included in the Ely Limestone span a large part of Pennsylvanian time in the Ely district (Spencer, 1917, p. 28) and Diamond Mountains (Dott, 1955, p. 2269–2270). In the Eureka district, because of pre-Permian erosion, only the Early and early Middle part of Pennsylvanian time is represented.

Permian System. Permian rocks in the Eureka area are the Carbon Ridge and Garden Valley Formations, which are correlative (Nolan and others, 1956, p. 63–64). These units were mapped by Hague (1883, p. 270) as "Upper Coal measures." Dott (1955, p. 2271) has given the name "Strathearn Formation" to partly correlative strata in the Elko-Carlin area.

CARBON RIDGE FORMATION. The Carbon Ridge Formation is mostly thin-bedded sandy limestone containing sandstone beds near the base; chert-pebble conglomerate is a prominent constituent, and abundant coarse conglomerates composed of limestone and chert cobbles form the upper beds. The type locality is at Carbon Ridge, 8 miles south of Eureka. In the southern part of the Diamond Mountains the formation is 1,500 to 1,750 feet thick. Fossils include four fusulinid zones that were determined by Lloyd G. Henbest (*in* Nolan and others, 1956, p. 65–66) as Hueco (Wolfcamp) and possibly Leonard in age. Associated brachiopod and coral faunas have approximately the same time span.

GARDEN VALLEY FORMATION. The Garden Valley Formation was named for Garden Valley on the west side of the Sulphur Spring Range. It extends northward along the range into Elko County.

Nolan and others (1956, p. 67), recognize four members at the type locality at Tyrone Gap. A limestone member, 450 to 500 feet thick, made up of sandy limestone and calcareous sandstone and local chert-pebble conglomerate layers and cherty limestone beds, is the basal unit. This is overlain disconformably by a member 800 to 1,000 feet thick, composed of siliceous cobble and boulder conglomerate, sandy carbonaceous shale, and carbonaceous sandstone. The overlying reddish-brown siliceous conglomerate member, 900 to 1,000 feet thick, consists of quartzite and chert cobbles cemented by silica and is highly resistant, forming a prominent ridge through the Garden Valley and Mineral Hill quadrangles. The upper member, purple and red shales and conglomerates, is about 550 feet thick. The conglomerates are composed largely of limestone pebbles and cobbles in a silty matrix. These units extend northward into the northern part of the Garden Valley quadrangle, where they are cut out on range front faults.

The lower limestone member of the Garden Valley, according to Lloyd G. Henbest (*in* Nolan and others, 1956, p. 68), contains fusulinid faunas of late Hueco (Wolfcamp) and possibly Leonard Age and is correlative with the Carbon Ridge Formation. The upper members are presumed to be younger. Dott (1955, p. 2274) states that the conglomerate at Tyrone Gap ". . . originally continued across Diamond Valley, but graded abruptly into limestone and siltstone at the east flank and north end of the north Diamond Range."

At the north end of the Monitor Range in Twin Spring Hills and on the southeast flank of Lone Mountain, conglomerate beds have been mapped by Merriam (oral communication, 1954; 1963) and assigned to the Garden Valley Formation; in some places these conglomerates are in fault contact with eastern assemblage carbonate rocks and in others rest on chert and shale of the Vinini Formation. In Twin Spring Hills Merriam (1963, p. 58–60) recognized a lower unit of sandy and pebbly limestone about 500 feet thick and an upper unit of limestone cobble conglomerate about 4,500 feet thick; these units are separated by a sandstone, siltstone, and shale unit. Many of the limestone cobbles in the upper unit contain Pogonip Ordovician fossils and some resemble the Goodwin Limestone. This indicates that the eastern assemblage was locally emergent in this area in Permian time and furnished fragments to the Garden Valley Formation.

Michael Murphy (oral communication, 1958) reports that in the Sulphur Spring Range a conglomerate of probable Permian Age rests unconformably on eastern assemblage quartzite and limestone of Devonian Age. A short distance west, conglomerate of similar lithology rests on shale and chert of the western assemblage.

Unnamed sequence in the Cortez Mountains

Pennsylvanian or Permian Systems.

BROCK CANYON FORMATION. The Brock Canyon Formation was named by James Gilluly (Gilluly and Gates, 1965). The type section, which was measured and described by L. J. P. Muffler (1964, p. 6–14), is in the upper part of Cottonwood Canyon in sec. 34, T. 28 N., R. 49 E., where the formation unconformably overlies shale of the Vinini Formation. The Brock Canyon Formation totals about 4,900 feet in thickness and consists of four recognizable units, which are, in ascending order: (1) a conglomerate unit 300 to 750 feet thick composed of black or gray fine- to medium-grained stylolitic quartzite, black chert-pebble and -cobble conglomerate, black lithic arenite, and, locally, dolomite;

(2) a dolomite unit 750 to 1,000 feet thick composed dominantly of white to gray quartzite and characterized by dark-gray thinly laminated thick-bedded cherty dolomite; (3) a claystone unit 1,881 feet thick composed dominantly of reddish-gray claystone and yellowish-gray siltstone; and (4) an arkose unit at least 1,630 feet thick composed of gray and light-brownish-gray sandstones. Fossils are rare, but plant fragments and mollusks indicate that the sequence may be Pennsylvanian or Permian or both or even early Mesozoic in age (S. H. Mamay and E. L. Yochelson, written communications, 1960, *in* Muffler, 1964, p. 13, 14).

In the Dry Hills, north of the Brock Canyon area, are poorly exposed sedimentary rocks composed dominantly of fine-grained sandstones. Stratigraphic and structural relations are obscure, and fossils have not been reported. On the basis of gross lithology, these rocks are correlated with the Brock Canyon Formation (Muffler, 1964).

MESOZOIC ERA

Cretaceous System

Newark Canyon Formation

Cretaceous fresh-water strata were recognized at Eureka by Nolan and others (1956, p. 60–70), who named them the Newark Canyon Formation for exposures at the type locality 6 miles east of Eureka. The principal areas of outcrop are in the Eureka area, south to the mouth of Secret Canyon; in the Fish Creek Range on the west flank of the Diamond Mountains; in the northern part of the Simpson Park Mountains; and on the east side of the Cortez Mountains.

The Newark Canyon Formation in the Eureka area and on the west flank of the Diamond Mountains is lithologically heterogeneous. Silt, shale, sandstone, and grit appear to predominate, but conglomerate and fresh-water limestone are also present. Locally conglomeratic limestone beds, as much as 50 feet thick, are found at the base of the formation. The shale, sandstone, and grit are commonly carbonaceous and therefore dark in color, but locally they are reddish to brown. The conglomerates contain fragments derived from both the eastern and western assemblage source rocks, and, because they are generally resistant, they form prominent ridges. The thickness of exposed Newark Canyon Formation measured in Newark Canyon (Nolan and others, 1956, p. 70) is 1,400 feet, and at South Gate 1,400 feet; C. W. Merriam (oral communication, 1959) estimates that the formation may be 4,000 feet thick north of Eureka.

The Newark Canyon Formation has yielded a diagnostic gastropod fauna of Early Cretaceous Age, according to MacNeil (1939). Fossil fish and plant remains have also been found.

In the northern part of the Simpson Park Mountains thin limestone, shale, and sandstone units were mapped at several places. These range in thickness from a few feet to 75 feet or more, and the largest outcrop is about 2,500 feet long. The limestone is mostly light to medium gray, fine grained, and locally is porous. Plant fragments in the limestone were collected by J. G. Johnson, who forwarded them to the Geological Survey for study; Roland W. Brown (written communication, 1957) examined the material and noted *Sequoia* and *Sphenolepsis* twigs, suggesting an Early Cretaceous Age. Accordingly, the limestone units have been assigned to the Newark Canyon Formation.

On the east side of the Cortez Mountains a sequence of nonmarine sandstone and conglomerate mapped by Regnier (1960, p. 1193) as the Rand Ranch Formation and previously considered to be Tertiary(?) in age is assigned to the Newark Canyon Formation on the basis of plant and pollen studies by J. A. Wolfe and E. B. Leopold (*in* Averitt, 1961, p. A–33).

CENOZOIC ERA

Tertiary System

In the Cortez and Simpson Park Mountains, thick deposits of poorly sorted gravels occur over broad areas. In the Horse Canyon area of the Cortez Mountains, these gravels lie on a surface with a minimum relief of at least 1,300 feet and must have a minimum stratigraphic thickness of the same order (Gilluly and Masursky, 1965, p. 82). The gravels are composed of pebbles and boulders of Paleozoic rocks, welded tuff, and quartz monzonite. They are overlain by basaltic andesite flows and are probably Pliocene or possibly Miocene in age.

Tertiary and Quaternary Systems

In the valleys of Maggie Creek and Pine Creek are Pliocene and Pleistocene lacustrine deposits that Regnier (1960) has mapped as the Carlin Formation and the Hay Ranch Formation. The Carlin Formation, in the Maggie Creek area, is composed dominantly of soft, tan to reddish, muddy, tuffaceous sandstone and siltstone interbedded with conglomerate; subordinate types are vitric tuff and ash, diatomite, limestone, and calcareous shale. The formation is early Pliocene in age and is considered to be correlative with the middle member of the Humboldt Formation of Sharp (1939). The Hay Ranch Formation, in the floor of Pine Valley, is composed of clay, vitric tuff, limestone, and tan tuffaceous siltstone and sandstone, which interfinger with conglomerate. These deposits are considered to be middle Pliocene to middle Pleistocene on fossil evidence.

Quaternary System

Older alluvium

Alluvial fans that flank the mountain ranges are composed largely of poorly sorted debris. The main period of fan building probably took place during late Tertiary and Pleistocene time following major uplift. In places, such as Pine Valley, subsequent erosion has exposed the underlying beds.

Younger alluvium

Deposits of younger alluvium cover the valley floors and the lower slopes of the ranges. In the northern part of the county, which is drained by the Humboldt River, younger alluvium is confined largely to present stream channels. In the southern part, where interior drainage terminates in Diamond Valley, younger alluvium covers the entire valley floor. In upper reaches of stream channels poorly sorted coarse sands and gravels predominate; in the lower reaches fine sands and silts predominate; in basins such as Diamond Valley, fine silts and clays predominate.

Playa deposits

Playa deposits, mostly silts and clays with local sand and gravel lenses, cover parts of Crescent and Diamond Valleys. In Diamond Valley these deposits are saline and were worked for sodium chloride during the 1870's for use in metallurgical processes at Eureka.

Sinter deposits

Calcareous and siliceous sinter are being deposited by hot springs. The calcareous deposits occur at Bruffey Hot Springs in sec. 14, T. 27 N., R. 52 E., where prominent spring terraces have been built. Siliceous sinter is being deposited around the Beowawe Geysers, in sec. 17, T. 31 N., R. 48 E., and at Walti Hot Springs, in sec. 33, T. 23½ N., R. 48 E. At Walti Hot Springs, deposition of sinter is largely restricted to the main spring outflow channel. At the Beowawe Geysers, terraces of silica are being actively built around several spring and geyser orifices and silica is being deposited as nodules in basins around springs. The general character of the water is shown in table 1.

The Beowawe Geysers have been described by Nolan and Anderson (1934):

> ". . . thermal activity in the region is largely restricted to the surface of a sinter terrace about half a mile long, 100 feet or less in width, and 200 feet above the valley fill. Some pulsating hot springs . . . are found on the valley floor at the foot of the terrace. Geysers are the most spectacular features of the sinter terrace, although they are much less numerous than fumeroles. Hot springs are also moderately abundant.
>
> "Although the terrace is composed chiefly of sinter, it is clear that in several places blocks of basalt from the steep slopes above have fallen on the terrace and been covered by sinter . . . Near the northeast end of the terrace, there are remnants of an old porous sinter deposit on the slope above. These show by their layering that the sinter has been built up by the accretion of material rather than by the alteration and leaching of the lava. The layers are slightly tilted. This occurrence of old sinter above the level of the present terrace suggests that there has been renewed movement along the fault that forms the boundary between ridge and valley . . ."

According to the News Letter of the Nevada Mining Association dated Nov. 15, 1964, the Sierra Pacific Power Co., Reno, Nev., has drilled two test holes to determine the potential for steam power at Beowawe. One hole was 150 feet deep and the other, 1,500 feet; temperatures as high as 385°F were reported in the deeper hole (W. J. Wright, oral communication, 1964).

TABLE 1. Analyses of water collected from hot springs and geysers in Eureka County, Nev.

(Parts per million)

	1 Horse-shoe Ranch	2 Beowawe Geysers	3 Beowawe Geysers	4 Beowawe Geysers	5 Beowawe Geysers	6 Hot Springs Point	7 Bruffey Hot Springs	8 Shipley Hot Spring	9 Walti Hot Springs	10 Bartho-lomae Hot Spring
°F	136.4	204.8	-------	-------	-------	138.2	150	90	163	130
°C	58	96	-------	-------	-------	59	65.56	32.22	72.78	54.45
pH	7.0	9.5	-------	-------	-------	6.8	7.0	7.2	6.9	8.5
SiO_2	58	373	449	413	418	72	.58	40	75	87
Al	-------	.0	0	} trace	trace {	-------	-------	-------	-------	-------
Fe	-------	.04	trace			0.04	-------	0.01	0.02	0.02
Mn	-------	0.0	-------	-------	-------	0.09	0.00	0.00	0.00	0.00
Ca	22	0.8	2	trace	trace	54	52	57	60	2.2
Mg	5.8	.0	0	0	0	38	16	21	13	1.7
Ba	-------	-------	-------	-------	-------	-------	0.0	-------	-------	-------
As	-------	-------	0	-------	-------	-------	-------	-------	-------	-------
Na	136	230	239	} 216	282 {	277	39	29	48	6.5
K	17	16	33			51	8.7	5.9	15	0.7
Li	.0	1.3	-------	-------	-------	1.0	0.2	0.0	0.0	0.0
NH_4	6.4	0.5	4?	-------	-------	-------	-------	-------	-------	-------
HCO_3	378	116	129	244	512	928	287	279	282	126
CO_3	0	149	173	84	trace	0	0	0	0	10.0
SO_4	62	89	97	84	91	116	27	35	62.	18
Cl	27	30	47	30	70	49	14	21	13	6.5
F	5.0	15	11	-------	-------	6.9	0.7	0.2	2.4	4.0
Br	-------	0.4	-------	-------	-------	-------	-------	-------	-------	-------
NO_3	-------	0.4	-------	-------	-------	3.3	0.1	0.0	0.1	0.0
PO_4	-------	-------	-------	-------	-------	0.0	-------	0.1	0.1	0.0
S_2O_3	-------	-------	1	-------	-------	-------	-------	-------	-------	-------
B	.81	2.0	?	-------	-------	1.6	0.25	0.26	0.17	0.08
H_2S	-------	5.5	0	-------	-------	-------	-------	-------	-------	-------
Sum, as reported	718.01	1028.94	1192.00	1071.00	1373.00	1373.00	445.53	488.47	450.79	262.70

1. Hot spring on Horseshoe Ranch, 1 mi N.E. of Beowawe, Sec. 32, T. 32 N., R. 49 E., collected by D. E. White, analyzed by H. C. Whitehead and J. P. Schuch, U.S.G.S. H_2S estimated in the field.
2. Beowawe Geysers, pool below terrace, Sec. 17, T. 31 N., R. 48 E., collected by D. E. White, analyzed by H. C. Whitehead, U.S.G.S. SiO_2 gravimetric; also reported: Sr, 0 ppm; I, 0.0 ppm.
3. Beowawe Geysers, small geyser, Sec. 17, T. 31 N., R. 48 E., collected by T. B. Nolan and G. H. Anderson, analyzed by E. T. Allen, Geophysical Laboratory (Nolan and Anderson, 1934, p. 227). B, As, and H_2S reported as B_2O_3, AsO_4, and S.
4. Beowawe Geysers, hot spring, Sec. 17, T. 31 N., R. 48 E., collected by R. F. Garnett, Beowawe, analyzed by S. C. Dinsmore, Univ. of Nevada (Nolan and Anderson, 1934, p. 227).
5. Beowawe Geysers, geyser, Sec. 17, T. 31 N., R. 48 E., collected by R. F. Garnett, Beowawe, analyzed by S. C. Dinsmore, Univ. of Nevada (Nolan and Anderson, 1934, p. 227).
6. Hot Springs Point, Sec. 11, T. 29 N., R. 48 E., collected by G. C. Simmons, analyzed by C. G. Mitchell, U.S.G.S.
7. Bruffey Hot Springs, Sec. 14, T. 27 N., R. 52 E., collected by D. F. Hewett, analyzed by R. Brennan, U.S.G.S.
8. Shipley Hot Spring, Sec. 23, T. 24 N., R. 52 E., collected by G. C. Simmons, analyzed by C. G. Mitchell, U.S.G.S. Temperature estimated.
9. Walti Hot Springs, Sec. 33, T. 23½ N., R. 48 E., collected by G. C. Simmons, analyzed by C. G. Mitchell, U.S.G.S.
10. Bartholomae Hot Spring, Sec. 28, T. 18 N., R. 50 E., collected by G. C. Simmons, analyzed by C. G. Mitchell, U.S.G.S.

VOLCANIC ROCKS

Volcanic rocks are present over large areas of the county (see fig. 3). The oldest may be those in the northeastern Dry Hills, which Muffler (1964, p. 14) believes may be Permian on the basis of stratigraphic relations in the Frenchie Creek quadrangle. These rocks are composed almost entirely of dellenite (quartz latite). In lithology and uniformity of lithology they contrast sharply with Mesozoic volcanics in the Cortez Mountains. However, for the purposes of the county map, they are included with the Mesozoic rocks in one unit.

In the northern Cortez Mountains and southern Tuscarora Mountains there is a Jurassic or Cretaceous sequence of volcanics. Previously these rocks were thought to be Tertiary in age (Shawe and others, 1962; Lehner and others, 1961). However, dinosaur bones collected by J. Fred Smith and Keith Ketner of the U. S. Geological Survey and assigned a Jurassic or Cretaceous Age by Barnum Brown of the U. S. National Museum (Edward Lewis, written communication, 1961) were found in the uppermost beds on the east flank of the Cortez Mountains, and farther east the sequence is overlain by Lower Cretaceous rocks. The total thickness of the sequence is uncertain, but Muffler (1964) estimates that in Pony Trail Canyon, on the west flank of the range, the section probably is 3,500 feet thick, with much of the lower part missing, and that in the Frenchie Creek and Big Pole Creek areas it may be as much as 10,000 feet thick. Muffler recognized three informal members: (1) a lower volcanic wacke member in which the rocks are uniform, fine to medium grained, usually light brown, and thin bedded; (2) a middle ash-flow tuff member composed of predominant white silicic ash-flow tuff and subordinate green ash-flow tuff and current-bedded sandstone; and (3) an upper flow member composed of predominant maroon and black rhyolite and rhyodacite flows and subordinate green and white flow breccias. Iron deposits of the Modarelli-Frenchie Creek district occur in the upper flow member.

Tertiary volcanic rocks crop out over wide areas of the county; they are probably more widespread than any other pre-Quaternary rock unit. East of Cortez the range is capped by basaltic andesite flows that dip gently eastward (Gilluly and Masursky, 1965, p. 82–83). In Fourmile Creek eight flows have been recognized that aggregate 350 feet thick. Diabase (doleritic) dikes that cut Paleozoic rocks south of Brock Canyon may represent fissures along which the andesite was extruded. Similar flows cap the west flank of the Shoshone Range west of Beowawe.

In the north end of Pine Valley a Tertiary sequence rests unconformably on the Mesozoic volcanic sequence of the Cortez Mountains. These rocks have been mapped and described by Regnier (1960). They consist of the following in ascending order: (1) 700 feet of water-laid tuffs, tuffaceous conglomerates, and sandstones that may be early Miocene or late Oligocene or older; (2) 2,000 feet of lapilli tuff, volcanic breccia, lava flows, vitric tuffs, diatomites, shales, and limestones that contain late Miocene vertebrate fossils; (3) 500 feet of brownish-red rhyolite flows that are late Miocene or early Pliocene; and (4) basalt plugs that intrude the Miocene rocks of the second unit. Late Pleistocene or Recent welded tuff occurs as scattered patches on the west side of the valley, and has been mapped as Quaternary volcanic rocks, undivided.

In the Fye Canyon area of the Simpson Park Mountains, the volcanic rocks have been determined by radiometric analysis of biotite by the potassium-argon method to be 36.8 million years old (G. H. Curtis, *in* Gilluly and Masursky, 1965, p. 81) which is near the Eocene-Oligocene boundary. These rocks consist of flow-banded and auto-brecciated rhyolite with a mass of hypersthene andesite flow-breccia near the base. The base is not exposed but presumably rests on the Vinini Formation. No tuffs have been recognized in this area.

Welded tuffs in the northern Toiyabe Range a few miles southwest of Cortez in Lander County are regarded by Masursky (1960, p. B281) as early Tertiary in age; G. H. Curtis (*in* Gilluly and Masursky, 1965, p. 78) obtained a radiometric date of 31.5 million years (Oligocene) on these rocks. The rocks occupy an east-west graben thought to have been actively sinking during volcanism.

In the Roberts Mountains, Merriam and Anderson (1942) recognized the following sequence in ascending order: (1) rhyolitic tuff and breccia up to 700 feet thick, (2) andesitic lava flows up to 200 feet, and (3) thick flows of quartz latite. In one place a dark-gray pyroxene andesite flow overlies the quartz latite. In another, poorly stratified tuff contains angular fragments of quartz latite. Olivine basalt apparently is the youngest volcanic unit in the area. All of these rocks are assumed to be Tertiary in age, but positive evidence is lacking.

In the Eureka district, Nolan (1962) mapped and described the following volcanic sequence: (1) hornblende andesite flows associated with intrusive andesite that yielded zircon reported by Howard Jaffe and others (1959, p. 73) to be about 50 million years old—middle Eocene, (2) rhyolite flows and tuffs of Oligocene or Miocene Age (Jaffe and others, 1959, p. 73; K. E. Lohman, *in* Nolan, 1962, p. 17), and (3) andesite and basalt flows of late Tertiary or Quaternary Age.

In the eastern and southeastern part of the Mineral Hill quadrangle, basaltic volcanic rocks of possible Quaternary Age (Donald Carlisle and C. A. Nelson, written communication, 1957) crop out on the east flank of the Sulphur Spring Range. These volcanic rocks appear to be volcanic cones and flows slightly modified by erosion.

INTRUSIVE ROCKS

Intrusive rocks in Eureka County are Jurassic, Cretaceous, and Tertiary in age. Quartz monzonite and granodiorite are dominant, but one fairly large body is composed of alaskite. Recent detailed study has been concentrated on the masses that underlie much of the Cortez Mountains.

Intrusive rocks in the central Cortez Mountains have been mapped and described in detail by Muffler (1964) and Gilluly and Masursky (1965). The bulk of these rocks are plutons that consist of dominant granodiorite and adamellite (quartz monzonite) and subordinate diorite, monzodiorite, tonalite, alaskite, and quartz albitite. Probably related to the plutonic episode are dikes and irregular masses of altered dacite or rhyodacite porphyry. These rocks are considered to be Early Cretaceous(?) in age, because they intrude the Pennsylvanian or Permian Brock Canyon Formation but do not metamorphose the Early Cretaceous Newark Canyon Formation. The igneous body in Mill Canyon is composed dominantly of biotite quartz monzonite, but it ranges in composition from quartz diorite to alaskite, the alaskite facies apparently being younger than the main mass (Gilluly and Masursky, 1965). Radiometric age determination by G. H. Curtis of the University of California at Berkeley indicates an age of 151 million years (Jurassic). Northward, in the Dry Hills, the intrusive rocks are mostly granodiorite and fine-grained monzodiorite that Muffler (1964) believes are related to the Early Cretaceous(?) plutons in the Cortez Mountains.

Quartz monzonite also occurs on the north side of the Humboldt River, near the Barth mine, in sec. 1, T. 31 N., R. 50 E. Specimens collected from an exposure 1,800 feet west of the mine, in a railroad cut, are light reddish brown and medium to fine grained. In hand specimen orthoclase is conspicuous, and hornblende, plagioclase, and small amounts of quartz also can be distinguished. The following analysis was obtained from Shawe, Reeves, and Kral (1962):

Quartz monzonite near Barth Mine

(Analysts, H. F. Phillips, P. L. D. Elmore, and S. M. Berthold, U. S. Geological Survey.)

Analysis, in percent

SiO_2	61.5
Al_2O_3	15.0
Fe_2O_3	2.1
FeO	3.6
MgO	3.6
CaO	4.4
Na_2O	2.7
K_2O	4.0
TiO_2	0.88
MnO	0.08
P_2O_5	0.32
H_2O	1.8
S	n.d.*
CO_2	0.15
Cl	0.25
F	0.08
	100.46

*Not determined.

The stock in the Keystone window in the Simpson Park Mountains is largely granodiorite. The rock is medium to dark gray and medium grained, and commonly it contains phenocrysts of plagioclase, quartz, hornblende, and biotite. The plagioclase was identified under the microscope as andesine (about An_{30-35}). The hornblende is altered to chlorite and epidote and locally is replaced by biotite. The phenocrysts are set in a finely granular groundmass of intergrown quartz, orthoclase, and a little plagioclase. Accessory minerals are pyrite, pyrrhotite, magnetite, epidote, sphene, and apatite. The age of the stock is not known; the youngest rock it intrudes is Devonian.

The intrusive body in the northern part of the Diamond Mountains also is granodiorite. The rock is gray and medium grained to medium coarse grained. Feldspar, mainly plagioclase, quartz, and biotite are recognizable in hand specimens. Thin sections show that the rock consists mainly of plagioclase (An_{35-40}), quartz, and orthoclase; greenish-brown biotite and green hornblende are the mafic minerals. Determination of lead-alpha ratios in zircon from this stock indicates that it is 30 ± 10 million years, probably Oligocene, in age (T. W. Stern, written communication, 1958).

The intrusive body that cuts through Wood Cone Peak in the Fish Creek Range is composed of finely granular granodiorite porphyry. The rock is brownish gray to tan in outcrop and contains prominent phenocrysts of biotite and plagioclase. Under the microscope the groundmass is seen to be composed of plagioclase, quartz, and a little orthoclase(?). The plagioclase is largely altered to clay minerals and locally is replaced by calcite and epidote. The biotite is generally quite fresh but is partly chloritized. The age of this rock is not known; the youngest rock that it intrudes probably is Silurian.

In the Eureka district, Nolan (1962) mapped quartz diorite just south of Ruby Hill, quartz porphyry east and north of Adams Hill, and intrusive andesitic rocks east of Prospect Ridge. Deformation of the Early Cretaceous Newark Canyon Formation in this area suggests that the quartz diorite is younger than the Newark Canyon, and the age of zircons in the quartz diorite was determined to be 62 ± 12 million years (Late Cretaceous) (Jaffe and others, 1959, p. 73). The quartz porphyry is believed to be approximately the same age. The intrusive andesitic rocks probably are Eocene (Jaffe and others, 1959, p. 73) and are related to extrusive equivalents (Nolan, 1962, p. 15).

Mount Hope and two lower hills to the north, a few miles west of the south end of the Sulphur Spring Range, are plugs of rhyolite porphyry (Merriam and Anderson, 1942, p. 1708–1709, 1718–1719). Fresh samples of the Mount Hope rock are composed of scattered smoky quartz phenocrysts and pale cream-colored sanidine phenocrysts in a very finely crystalline white groundmass; plagioclase and mafic minerals are absent. In the northern two plugs, plagioclase is an important constituent, and scattered biotite and garnet crystals are characteristic.

Rhyolite sills and dikes too small to show on plate 3 have been noted in the area northwest of Mount Hope (Merriam and Anderson, 1942, p. 1709), in the Lynn window (Roen, 1961, p. 80), and in the Cortez Mountains north of Frenchie Creek (Muffler, 1964).

Diabase (dolerite) dikes too small to show on plate 3 occur as an extensive swarm trending northwestward across the northwest side of the Cortez Mountains south of Little Cottonwood Creek (Muffler, 1964). A similar swarm cuts through the Roberts Mountains. These dikes probably are feeders of extensive basalt flows that occur in the Shoshone Range and Cortez and Simpson Park Mountains (Gilluly and Masursky, 1965, p. 82–85).

In the Lynn window, the small stock of unknown age that intrudes Eureka Quartzite and Hamburg Dolomite is extremely weathered. According to John Roen (1961, p. 77–78), it is a granite:

> "In thin section the rock has a medium-grained hypidiomorphic granular texture and is composed of about 54 percent euhedral and subhedral potash feldspar, 28 percent anhedral quartz, 10 percent euhedral plagioclase and 8 percent hornblende, biotite, apatite, zircon and sphene. The potash feldspar consists of partially kaolinized orthoclase and minor amounts of microcline and perthite. The plagioclase is oligoclase-andesine; the An content ranging from 28–31. The green hornblende has ragged edges and some grains are altered to biotite. The primary biotite which contains a few zircon inclusions is altered to chlorite in some places."

The large body that forms Whistler Mountain, north of Devils Gate, has been described by Merriam and Anderson (1942, p. 1707–1708, 1717–1718) as a muscovite alaskite stock. It is composed of fine-grained quartz, feldspar, and muscovite. The rock resembles aplite, but its texture in thin section is that of alaskite. Just south of the main peak of Whistler Mountain, it contains tourmaline nodules up to 2 inches in diameter. At the south end of the stock, on the north side of Devils Gate, are a number of sills 20 to 50 feet thick that are regarded as offshoots of the main stock. The time of intrusion is not known, but it certainly occurred after the Roberts Mountains thrusting, inasmuch as the stock intrudes the Vinini Formation and the sills intrude quartzite and shale assigned to undifferentiated Mississippian Chainman and Diamond Peak Formations.

STRUCTURE

North-central Nevada has been tectonically active since Precambrian time. No record of Precambrian orogeny has been recognized within the county itself, but in the East Humboldt Range, 30 miles to the east, the sharp contrast between foliated gneissic rocks of probable Precambrian age (King, 1878; Misch, 1960) and unmetamorphosed to moderately metamorphosed Paleozoic carbonate rocks indicates Precambrian orogeny. During the Paleozoic Era at least three orogenic episodes occurred: the earliest was prior to Middle Ordovician time; the second was the Antler orogeny in Late Devonian to Early Pennsylvanian time; the last was the Sonoma orogeny in Late Permian time. In the Mesozoic Era disturbances took place in Cretaceous time and may have continued into early Tertiary time. Block faulting that produced the present topography probably began in Oligocene time and continued throughout Tertiary and Quaternary time.

PALEOZOIC OROGENY

The earliest disturbance recognized in the Paleozoic rocks of Eureka County is indicated by an unconformity at the base of the Eureka Quartzite in the Cortez and Roberts Mountains, which was caused by uplift in Early Ordovician time. This uplift may have been a westward continuation of the east-west arch (Roberts, 1960b; Roberts and others, 1965; Roberts, 1966) that extended from the Uinta Mountains to Gold Hill, Utah, which was intermittently active from Ordovician to Devonian time. Nolan and others (1956, p. 38, 41) also noted an unconformity at the base of the Devonian Nevada Formation in the Eureka area, but this unconformity may not be present northwest of Eureka.

The second orogenic episode, the Antler orogeny, disrupted the pattern of sedimentation that prevailed during early and middle Paleozoic time, and ushered in a new cycle of sedimentation that was characterized by coarse clastics shed eastward and westward from the orogenic belt (Roberts and others, 1958; Roberts, 1964b, 1964d, 1965, 1966). Clastic units of Late Devonian Age interlayered with western assemblage rocks represent the earliest orogenic deposits derived from local western sources. In Early Mississippian time, during the main orogenic pulse, the Roberts Mountans thrust plate moved eastward and southeastward, bringing siliceous and volcanic rocks of the western assemblage over the carbonate assemblage. The rocks both above and below the thrust were deformed during thrusting. Merriam and Anderson (1942, p. 1702) suggest that the folding began during an early phase of the orogeny and was accentuated during thrusting. Folds within the thrust sheet in some places are broad and in others closely spaced, isoclinal, and overturned. Folds in the lower-plate carbonate rocks generally trend northward in Eureka County; they are generally broad, but because much of the area is overlain by younger rocks their extent is not known.

In Eureka County and adjacent areas, windows of carbonate rocks are aligned in northwest-trending belts (Roberts, 1957, 1960a, 1964a, 1964c, 1966). These windows were formed in part by doming of the Roberts Mountains thrust during or shortly after thrusting, but may have been intensified much later during deformation and emplacement of igneous bodies in late Mesozoic and early Tertiary time.

The Antler orogenic belt emerged during deformation and uplift, and a flood of postorogenic clastic debris was shed eastward into the adjacent sea. The first sediments deposited in the basin were shales, sands, and conglomerates of the Chainman Shale (Roberts and Lehner, 1955; Brew, 1963), the Tonka Formation of Dott (1955), and correlative rocks; as relief in the source area increased, coarse sand and gravels of the upper Chainman and the Diamond Peak Formations were shed into the basin.

Near Devils Gate the upper plate of the Roberts Mountains thrust is in contact with the Devils Gate Limestone and with beds of sandstone, pebble conglomerate, and shale that have been assigned to the Chainman and Diamond Peak Formations. This suggests that the toe of the upper plate here moved into the depositional basin and overrode the orogenic clastics.

By Early Pennsylvanian time the emergent area of the orogenic belt was eroded to low relief and was shedding fine debris into the eastern seaway; these fine clastics interfinger with calcareous rocks along the 116° meridian in Eureka and Elko Counties. By Middle Pennsylvanian time the calcareous facies extended west of Eureka County and overlapped the orogenic belt (Roberts, 1964b; Gilluly and Masursky, 1965, p. 90).

Orogenic movements continued intermittently into Late Pennsylvanian and Permian time, causing uplift and erosion of previously deposited clastics. The presence of Ely Limestone and correlative units on the east side of Pine Valley in the Pinyon Range (in adjacent Elko County) and southward in the Diamond Mountains, and their absence in western Eureka County suggest Late Pennsylvanian uplift of local extent. Related epeirogenic movements during Late Pennsylvanian resulted in uplift and erosion of Middle and Late Pennsylvanian beds over much of eastern Nevada and western Utah (Dott, 1955, p. 2255–2256; Steele, 1960, p. 94, chart 1 and pl. 4). The Sonoma orogeny in northwestern Nevada in Late Permian time (Silberling and Roberts, 1962) probably contributed clastic rocks to the upper parts of the Carbon Ridge and Garden Valley Formations. Deformation of Permian rocks in the Diamond Range (Brew, 1961b, p. C113–C115; Brew, 1963; Larson and Riva, 1963) may reflect in part continued movement in latest Permian time.

MESOZOIC OROGENY

By the beginning of the Mesozoic Era the Antler and Sonoma orogenic belts probably were eroded to low relief, but local emergent areas furnished debris to flanking seas during Triassic and Jurassic time. In Middle or Late Jurassic time, volcanism and related intrusive activity heralded orogenic disturbances in the area of the Cortez Mountains (Muffler, 1964; Gilluly and Masursky, 1965); intrusive activity throughout the region continued into Early Cretaceous time (Nolan, 1962, p. 13; Ferguson and Muller, 1949). Deformation prior to deposition of the Newark Canyon Formation (Early Cretaceous) caused folds and thrusts in the Eureka area (Nolan, 1962, p. 28).

The Newark Canyon Formation was deposited in a basin characterized by crustal instability (Nolan, 1962, p. 28). The sediments range from coarse conglomerate to siltstone and limestone; rapid facies gradations suggest areas of high relief alternating with areas of low relief. Possibly the topography of Newark Canyon time resembled the basin and range topography of the present day, and may reflect an early stage of basin-range structure.

During Late Cretaceous or early Tertiary time the Newark Canyon Formation was folded and locally cut by normal faults in the Eureka district. None of these faults contain ore bodies (Nolan, 1962, p. 28–29).

CENOZOIC OROGENY

Orogenic movements during Tertiary and Quaternary time consisted mainly of high-angle faulting and tilting of basin and range blocks accompanying and following volcanism; only locally was folding significant.

Masursky (1960, p. B281–B283; Gilluly and Masursky, 1965) has recognized in the Cortez area that basin and range fault trends in Oligocene(?), Miocene, and post-early Pleistocene are differently oriented. In Oligocene time an east-west fault trough was filled by welded tuff and interbedded clastics about 8,000 feet thick; during late Miocene to early Pleistocene a trough trending N. 20° W. developed across the earlier trough and was filled with andesitic volcanic rocks and clastics. Younger faults that bound the present ranges strike north-south and N. 70° E. Displacement may be as much as 10,000 feet. The faults are dominantly of Pliocene-Pleistocene Age, although some may have originated earlier.

Most of the ranges in northern Eureka County have been tilted eastward or southeastward. Such tilting is well shown by the Shoshone Range, Cortez Mountains, and Simpson Park Mountains. These ranges have clear-cut fault scarps on their western sides, whereas their upland topography merges gradually with the valleys on their eastern sides. The tilting took place in post-early Pleistocene time during the period of latest faulting.

GEOPHYSICAL STUDIES

Regional gravity and magnetic surveys have been made of the northern part of Eureka County and adjacent areas as part of the Geological Survey's program of geologic investigations in central Nevada (Mabey, 1964; Philbin and others, 1963). These surveys were made to determine the form and amplitude of the variations in the gravity and magnetic fields (Mabey, 1966) and to relate them to the regional geology.

Gravity observations were made at 125 stations, and the data were contoured on a 5-milligal interval. The largest Bouguer gravity anomalies are lows produced by the density contrast between the lighter Cenozoic rocks and the generally denser older rocks. Diamond, Antelope, Pine, and Crescent Valleys reflect gravity lows that indicate the presence of several thousand feet of unconsolidated fill. The anomalies are asymmetric; the minimum values are displaced eastward in response to eastward tilting of the valley floors. Gravity highs occur over exposures of Paleozoic rocks. Values on bedrock generally increase northwestward in accordance with a decrease in regional elevations. Density contrasts between carbonate and siliceous and volcanic Paleozoic rocks are also reflected in regional gravity gradients. Under ideal conditions the gravity anomalies produced by the density contrasts might be used, along with other geophysical methods, to help determine the thickness of the upper plate of the Roberts Mountains thrust.

The magnetic survey was made with an ASQ–3A magnetometer flown along north-south flight lines, 1 mile apart, 9,000 feet above sea level (Mabey, 1966). The dominant feature of the magnetic map is a high, trending N. 25° W. The maximum amplitude is about 500 gammas; on the northeast it is generally flanked by a magnetic low. The anomaly is mostly over Cenozoic volcanic rocks or alluvium, but in the Cortez and Roberts Mountains it coincides with a swarm of steeply dipping diabase (dolerite) dikes that are probably feeders for the basaltic andesite flows. Ground measurements over these dikes indicate that they are highly magnetic. Magnetic highs were also noted over volcanic rocks in Table Mountain and on the east side of the Sulphur Spring Range south of Union Summit. Magnetic highs are also found over bodies of intrusive granitic rocks such as the granodiorite north of Cortez (Philbin and others, 1963). At the south end of Garden Valley north of Mount Hope, three small igneous bodies are exposed; a single magnetic high covers these areas, indicating that they may coalesce and form a single mass at depth. Other magnetic anomalies that may be related to intrusive granitic bodies are 4 miles northeast of the Buckhorn mine, 5 miles northeast of the Antelope district, a mile southeast of Mineral Hill, and 14 miles northwest of Mineral Hill (pl. 1).

GEOLOGY OF THE MOUNTAIN RANGES

TUSCARORA MOUNTAINS

The Tuscarora Mountains are the northern prolongation of the Cortez Mountains. They extend from the Humboldt River northward beyond the border of Eureka County for a distance of 30 miles. The highest point is Marys Mountain (7,703 feet) in the Beowawe quadrangle.

The southern part of the Tuscarora Mountains is underlain by Tertiary volcanic rocks which extend northward along the range crest to Marys Mountain. Chert and shale of the siliceous and volcanic assemblage are exposed along the flanks of the range in the southern part and north of Marys Mountain; these rocks dip gently westward in most places and appear to be little deformed. In the Lynn and Maggie Creek areas, carbonate assemblage rocks are exposed in windows.

The Lynn window, which has been described by Roen (1961) and Hardie (1966), is about 3 miles long and a mile wide. The oldest carbonate unit exposed is dolomite and limestone assigned to the Hamburg Dolomite. The youngest is Devonian in age. These rocks are offset by numerous faults and cut by intrusive bodies; a northeast-trending fault zone contains a major gold deposit at Newmont's Carlin gold mine (Hardie, 1966). Other faults that strike northwest and north are locally mineralized.

The Carlin window is roughly circular in outline and is about 2 miles in diameter. The window exposes thin-bedded limestone of the Roberts Mountains Formation of Silurian Age and overlying Devonian rocks, which dip gently eastward.

Volcanic rocks in the Tuscarora Mountains are andesite flows, which have been intruded by dioritic or granodioritic stocks, and a younger sequence of interlayered andesite, rhyolite, and tuff. On the lower slopes of the range these younger volcanics interfinger with tuffs and clastic sediments.

SHOSHONE RANGE

Near Beowawe two spurs of the Shoshone Range project into Humboldt Valley. Both are capped by basaltic andesite that strikes north-northeast and dips southeast. Along the north and east sides of the spurs are western assemblage Paleozoic rocks assigned tentatively to the Valmy Formation. These consist mainly of chert and shale and massive quartzite layers; quartzite pebble conglomerate that underlies the ridge just southwest of Beowawe is the host rock for ore at the Red Devil quicksilver property.

North and northeast of Beowawe low hills connect the Shoeshone Range with the Tuscarora Mountains. Near Dunphy these hills are mainly underlain by chert, shale, and quartzite tentatively assigned to the Vinini Formation. A small body of granitic rock cuts these western assemblage rocks about 2 miles east of Dunphy.

CORTEZ MOUNTAINS

The Cortez Mountains extend from the Humboldt River near Palisade for 40 miles southward to Horse Creek Valley. Mount Tenabo, the highest point, reaches an altitude of 9,162 feet.

The northern part of the range is underlain principally by volcanic and intrusive rocks that have been described by Muffler (1964). The volcanic rocks contain the ore bodies at the West (Barth) and Modarelli mines. The central part of the range is underlain by western assemblage chert and shale of Ordovician and Silurian Age. These rocks are complexly folded and form part of the Roberts Mountains thrust sheet; 3 miles north of Cortez the sole thrust zone is exposed along the Beowawe road in Lander County. In the Brock Canyon area the western assemblage rocks are overlain by conglomerate, limestone, and dolomite that have been assigned to the Brock Canyon Formation by Muffler (1964) and are believed to be partly correlative with the Garden Valley Formation.

Along the county line at Cortez eastern assemblage rocks are exposed in the Cortez window (Gilluly and Masursky, 1965). The oldest unit is the Hamburg Dolomite, which is overlain by Eureka Quartzite. The intervening Upper Cambrian and Lower Ordovician beds either did not cover this area or were eroded prior to deposition of the Eureka. The youngest rocks in the window are Devonian in age. In the north end of the window the sedimentary rocks have been intruded by quartz monzonite and granodiorite. The principal mineral production in the Cortez district is from the Hamburg Dolomite just below the Eureka Quartzite.

The southeast flank of the Cortez Mountains is underlain by flows of basaltic andesite (Gilluly and Masursky, 1965). These flows dip gently eastward and extend down into Horse Creek Valley. The Buckhorn mine is in a north-striking fault zone that cuts the basaltic andesite. Rhyolite plugs and flows crop out east of Cortez near the crest of the range (Gilluly and Masursky, 1965, p. 85–87).

SIMPSON PARK MOUNTAINS

The Simpson Park Mountains lie between the Cortez Mountains and the Roberts Mountains. Except for windows of eastern assemblage rocks, the Simpson Park Mountains are made up largely of western assemblage chert, shale, and quartzite assigned to the Vinini Formation and to unnamed Ordovician and Silurian units; volcanic and pyroclastic rocks underlie much of the northern and southern parts of the range. Structure is complex. East of Underwood Canyon the western assemblage Paleozoic rocks are folded into a northward-plunging anticline that strikes N. 10° to 20° W. diagonally across the crest of the range about 4 miles north of Fagin Mountain. Between this point and the Keystone window on the north, the rocks are apparently folded into northward-striking anticlines and synclines superposed on westward-dipping beds.

In the vicinity of McClusky Pass the structure in the older rocks is obscured by volcanic rocks and gravels. The Tonkin window of eastern assemblage Devonian limestone extends for nearly 2 miles along the crest of the range. On the south the window is complexly faulted with alternating slivers of Devonian limestone and chert and shale assigned to the Vinini Formation (Johnson, 1959, 1962b, 1966). A mile and a half east of the crest a partly exposed window, also composed of Devonian limestone, crops out near Indian Creek. On the north Permian limestone and conglomerate rest unconformably upon the Vinini Formation; on the south the Permian rocks are in fault contact with Devonian limestone, which is in thrust contact with chert of the Vinini Formation.

At the north end of the Simpson Park Mountains two other areas of Paleozoic rocks have been mapped in the Windmill and J–D windows. In the Windmill window are the Roberts Mountains and Nevada Formations; in the J–D window are Devonian limestone, dolomite, and shaly limestone of the Nevada and Devils Gate Formations. These rocks dip eastward 15° to 35° and appear to form a homoclinal sequence broken by normal strike faults.

Remnants of limestone, sandstone, and shale of the Newark Formation cap the Paleozoic rocks near the head of Fye Canyon and north of McClusky Pass. Basaltic andesite, which is probably related to basaltic andesite of the Cortez Mountains, covers the range north of Tonkin. On the west the andesite is in fault contact with Devonian limestone and the Garden Valley Formation.

ROBERTS MOUNTAINS

The Roberts Mountains are roughly triangular in outline and are more than 13 miles wide and 16 miles long. The highest point is Roberts Creek Mountain, which reaches an altitude above 10,000 feet; Western Peak in the northwestern corner of the range is over 9,000 feet high. On the southeast flank low foothills join the Sulphur Spring Range.

The Roberts Mountains are essentially an eastward-tilted block composed of western assemblage rocks with a belt of windows of eastern assemblage rocks through the central part, overlapped on the east by volcanic rocks.

The eastern assemblage rocks exposed in the windows are probably connected at shallow depths and are collectively referred to the Roberts Mountains window. The oldest rocks exposed are limestone and dolomite containing Late Cambrian and Early Ordovician faunas. They are overlain by the Eureka Quartzite, Hanson Creek Formation, Roberts Mountains Formation, Lone Mountain Dolomite, Nevada Formation, and Devils Gate Limestone.

Western assemblage rocks which override the carbonate rocks are preserved as remnants within the range and underlie alluvium on the east flank. Both the lower and upper parts of the Vinini Formation (Merriam and Anderson, 1942), consisting of complexly deformed chert, shale, sandstone, and volcanics, are present. Near the thrust they have been sheared and brecciated through a zone ranging from a few feet to 50 feet thick.

Volcanic rocks crop out in the southern and eastern parts of the range. They include early rhyolite tuffs and breccias as much as 700 feet thick (Merriam and Anderson, 1942, p. 1709) overlain by andesite flows up to 200 feet thick and quartz latite that is probably a welded tuff. The youngest volcanics are pyroxene andesite flows.

SULPHUR SPRING RANGE

The Sulphur Spring Range lies between the Roberts Mountains and Diamond Valley. The range is narrow, from 2 to 3 miles wide at the south end, widening to 4 to 6 miles at the north end. Crest line altitudes are mostly from 7,000 to 8,000 feet; the highest point is an unnamed peak above 8,300 feet, 2.5 miles east of the mining camp of Mineral Hill.

The range is composed mainly of eastern assemblage rocks of Ordovician to Devonian Age which at one time probably were covered by the Roberts Mountains thrust plate and therefore are considered to be windows in the upper plate. Along the west flank and at the northern end of the range, remnants of the upper plate of the thrust are infolded with eastern assemblage rocks. In the southern part rocks of the overlap assemblage form the west flank of the range. Volcanic rocks flank the central part of the range.

Eastern assemblage units recognized in the range by C. A. Nelson and others (written communication, 1958) include the Eureka Quartzite, Hanson Creek Formation, Roberts Mountains Formation, Lone Mountain Dolomite, and Nevada Formation. Throughout most of the range these units dip eastward at moderate to steep angles. On the east they are mostly in fault contact with alluvium and volcanic rocks; on the west they are in fault contact with the Garden Valley Formation (overlap assemblage) and western assemblage rocks. The Garden Valley was

originally deposited upon the western assemblage in this area, but Michael Murphy (oral communication, 1958) reports conglomerate that resembles the Garden Valley resting on Devonian limestone and quartzite on the east side of Union Summit just east of the Eureka County line. This indicates that at least locally the Roberts Mountains thrust plate had been eroded by Permian time permitting overlap of Permian units on the carbonate assemblage.

The Roberts Mountains thrust, which is well exposed in the Mineral Hill mine workings, strikes N. 15° W. and dips 50°–60° SW. Eastern assemblage limestone assigned to the Devils Gate Limestone is structurally above chert and shale containing Ordovician fossils, and it is apparent that the thrust is overturned eastward. In the northern part of the range in Bruffey Canyon the western assemblage rocks are folded and faulted but are in normal succession.

Andesite flows and associated silicic tuffs crop out near the Alpha Ranch and east of Bald Mountain.

DIAMOND MOUNTAINS

The Diamond Mountains are on the eastern border of the county, extending southward from Railroad Pass to the vicinity of Eureka. The range crest altitudes are mostly from 7,500 to 8,500 feet; the highest point is Diamond Peak (10,614 feet).

The Diamond Mountains are composed mainly of Paleozoic rocks of the eastern, western, and overlap assemblages. Eastern assemblage rocks predominate in the southern part and the overlap assemblage rocks in the northern part. Western assemblage rocks have been mapped by Larson and Riva (1963) at several places along the west side of the range. Small patches of Cretaceous sedimentary rocks crop out in the southwestern part of the range and volcanic rocks flank the range at the south end.

The carbonate rocks of the eastern assemblage are mostly dolomite and limestone of Silurian and Devonian Age. These units crop out in northwestward-trending belts and in most places dip steeply. Near Monroe Canyon these rocks are locally overturned toward the east, but to the south the folding is more open. High-angle reverse faults parallel the folds.

The overlap assemblage rocks in the northern part of the range include the Chainman, Diamond Peak, Ely, and Carbon Ridge Formations. These rocks parallel the range and are folded into a broad syncline whose axis is near the crest; locally the western flank of the syncline is overturned eastward (Dott, 1955).

The western assemblage rocks include quartzite, chert, and shale that occur in fault contact with the associated carbonate rocks, mostly of early Paleozoic Age, but are locally in contact with Permian rocks (Larson and Riva, 1963).

FISH CREEK RANGE

The Fish Creek Range lies southwest of the Diamond Mountains and extends southward into Nye County. The northern part of the range is made up largely of eastern assemblage carbonate rocks of Late Cambrian to Devonian Age. The formations represented are those in the Pogonip Group as well as the Eureka, Hanson Creek, Lone Mountain, Nevada, and Chainman and Diamond Peak Formations, undifferentiated. These units in general strike northward and dip eastward at low angles, with local steep dips along faults. Remnants of the Vinini Formation crop out at several places in thrust contact with autochthonous rocks. The most extensive remnant begins at Devils Gate and extends about a mile to the south; others have been mapped in the east foothills of the range.

The southern part of the Fish Creek Range, south of the Fish Creek Ranch road to Antelope Valley, is made up partly of Paleozoic sedimentary rocks of Ordovician to Devonian Age and rocks tentatively assigned to the Newark Canyon Formation of Cretaceous Age; rocks tentatively assigned to the western assemblage are also present. Volcanic rocks crop out along the eastern edge of the range and in the valley a few miles to the east.

A northeast-trending fault zone separates the Pogonip Group from the Nevada Formation in the northern part of this area. The fault zone contains slivers of the Eureka Quartzite and Hanson Creek Formation (not shown on map). A wedge of Lone Mountain Dolomite is also exposed along this fault zone. The linearity of the east side of the range and the steep face along the edge of the valley indicate the presence of faults on which the southern Fish Creek Range was uplifted. Numerous other faults are present and in general those with the most displacement trend N. 5° to 25° E.

Volcanic rocks along the east flank of the range consist of a heterogeneous assemblage of silicic tuffs, agglomerates, and flows. In general white to pink rhyolitic tuffs, more than 100 feet thick, underlie a dark-green agglomerate, about 100 feet thick, which is overlain by dark, quartz-bearing flows. The volcanic sequence dips 10°–15° E. under the valley fill.

Along the west side of the range Cenozoic lake beds are exposed. The thickness of these beds is not known.

ANTELOPE RANGE

The Antelope Range lies between the Fish Creek Range and the Monitor Range and extends southward into Nye County. Most of that part of the range that is within Eureka County is underlain by carbonate rocks assigned to the Pogonip Group. Along the county line, these rocks are overlain by volcanic rocks consisting largely of andesitic flows and pyroclastics.

MONITOR RANGE

The Monitor Range extends into the southwestern corner of the county. Summit Mountain near the north end, with a maximum elevation of 10,476 feet, is the highest point in the county. The range is covered mostly by volcanic rocks; Paleozoic rocks are exposed on the east flank, in Charnac Basin, and in an isolated exposure at the extreme north end of the range. In the Copenhagen Canyon-Martin Ridge area the rocks generally dip 30°–40° west and northwest. Copenhagen Canyon lies on the trace of a north-trending normal fault, downthrown on the east (L. C. Bortz, written communication, 1958). Martin Ridge and the area west of the canyon are cut by numerous east-west normal faults. On the slope west of the canyon, the Vinini Formation has been thrust over the Nevada Formation and is in turn overthrust by the Antelope Valley Limestone of the Pogonip Group; still higher on the slope, another thrust fault separates the Vinini and Roberts Mountains Formations. Overlying the Vinini are postorogenic Pennsylvanian rocks.

At the extreme north end of the range, conglomerate assigned to the Garden Valley Formation is overlain by Cretaceous rocks of the Newark Canyon Formation and overlies Ordovician rocks of the Vinini Formation. At the south end the Vinini is in thrust contact with rocks of the Pogonip Group.

In Charnac Basin, limestone, chert, and shale have been assigned to the Pogonip Group by C. W. Merriam (1963), who has suggested that as they differ markedly from the Eureka section, they may represent a transitional facies.

MINERAL RESOURCES

The most valuable mineral resources of Eureka County thus far have been metallic deposits; the principal commodities in order of decreasing value have been gold, silver, lead, copper, and zinc. Nonmetallic deposits, which yielded only small production during the early days, have become increasingly important. The county has substantial reserves of barite and diatomite; construction materials and clays are widespread.

The mining districts in Eureka County are discussed briefly here. Some properties in each district are described in detail; all are summarized in table 14. The districts are listed alphabetically in both the text and the table. Production data given in district production tables have been reviewed through 1966.

METALLIC MINERALS

Metallic minerals in Eureka County occur in four principal geologic settings:

1. Deposits in carbonate rocks: gold-silver, lead-zinc-silver, silver-lead veins, manganese-nickel, and antimony.
2. Deposits in chert and shale: gold-copper, quicksilver, and vanadium deposits.
3. Deposits in volcanic rocks: iron, and silver-lead veins.
4. Placer deposits: gold.

Deposits in Carbonate Rocks

Deposits in carbonate rocks commonly are related to intrusive bodies of igneous rock. The ore generally occurs in or near fracture systems that may be pre-intrusive or related to the intrusion. Such deposits are in the

Eureka, Cortez, Roberts, and Lynn districts. It has been noted (Roberts, 1957, p. 4; 1960a; 1964a,c; 1966) that these districts are in windows of the Roberts Mountains thrust plate and that they are aligned northwestward. The windows represent upwarps possibly formed over deep-seated basement structures.

Gold-silver deposits

Gold-silver deposits in carbonate rocks have yielded a significant production in the county. They occur mainly in the Eureka district and are on the periphery of the main lead-zinc producing area. The deposits are characterized by simple sulfide mineralogy, chiefly pyrite, which is commonly oxidized on the upper levels to limonite and hematite. Most production has come from the oxidized ores; sulfide ores generally have been too low in grade for profitable operation.

Lead-zinc-silver deposits

Lead-zinc-silver deposits have been the most productive in Eureka County. During the early days of the Eureka district, silver-rich oxidized ores accounted for most of the production, but lead was also important, and some deposits contained as much value in gold as in silver. During World War II, base metals were important, but in the future gold from ore bodies of the Carlin type probably will dominate mineral production in the county.

The ore bodies are irregularly shaped, tabular, lenticular, and chimney-like bodies that range from a few feet to several hundred feet in dimension. Ore produced on Ruby Hill, in the Eureka district, between 1871 and 1891 ranged in value from $30 to $300 a ton with an average value of $50 to $60 (Vanderberg, 1938, p. 37). Of this average, lead amounted to about $20, gold about $14, and silver about $22.

Silver-lead veins

Silver-lead veins have been mined in the Antelope, Cortez, and Diamond districts. The veins consist of pyrite, galena, sphalerite, tetrahedrite, and other sulfides; the principal value generally is in silver. Most of the veins are narrow, and production has been small; but some high-grade shoots have been found, principally in the oxidized zone.

Manganese-nickel deposits

The Gibellini mine in the Fish Creek district is in limestone that contains an ore body composed of manganese oxides with secondary zinc and nickel minerals.

Antimony deposits

Antimony prospects have been explored in shallow workings in the Antelope district. The deposits consist of small masses of stibnite and stibiconite, a hydrated oxide of antimony, in shear zones in limestone.

Deposits in Chert and Shale

Ore deposits in chert and shale of the western assemblage include gold-copper deposits near the Roberts Mountains thrust and barite deposits within the upper plate. Gold-copper deposits in these rocks have not yet

yielded large production in Eureka County, but in nearby parts of Elko and Lander Counties such deposits have notable production. Barite deposits in Eureka County have yielded a small production.

Gold-copper deposits

Gold-copper deposits in Eureka County include the Copper King and Number Eight mines in the Lynn district, which occur within or near the Roberts Mountains thrust fault. The gold-copper metallization occurs in crushed and sheared zones along the thrust.

Quicksilver deposits

Quicksilver deposits have been mined in the Beowawe district where cinnabar occurs in pebble conglomerate, quartzite, and shale as veinlets and coatings in cavities and on breccia fragments.

Vanadium deposits

Vanadium deposits occur in black marine phosphatic shale of Devonian Age near the Gibellini mine on the east flank of the Fish Creek Range (Davis and Ashizawa, 1959). These shales in Eureka County are mostly in the frontal part of the Roberts Mountains thrust plate and represent a transitional facies that was originally deposited west of Winnemucca (Roberts and others, 1958, p. 2817); Ordovician shales of the transitional assemblage near Golconda, 15 miles east of Winnemucca, also are vanadiferous (Davidson and Lakin, 1961b), which suggests that the environment in which this assemblage was deposited was favorable to the accumulation of vanadium. Enrichment may have taken place during diagenesis and later during weathering.

Vanadiferous shales also occur in Mississippian units of eastern Nevada and western Utah (Davidson and Lakin, 1961b). These deposits may have been derived from the Devonian vanadiferous shales and transported eastward by powerful currents, such as density currents. In this way transport could be accomplished without significant dilution.

Deposits in Volcanic Rocks

Deposits in volcanic rocks include iron deposits and silver veins in the north end of the Cortez Mountains. The iron deposits have yielded more than one million tons of ore, mined partly for flux and partly for iron ore. The silver veins have yielded only a small production; they are similar to the silver veins in carbonate rocks and in part may have formed at the same time.

Iron deposits

The iron deposits at the Barth mine in the Safford district and in the Modarelli-Frenchie Creek district occur near the contacts of intrusive bodies and replace volcanic rocks along bedding planes and faults (Shawe, Reeves, and Kral, 1962).

Silver veins

Silver veins in the Safford district occur in andesite. Most of the veins are narrow and nonpersistent, but some ore has been mined and shipped.

The primary minerals are tetrahedrite, pyrite, galena, sphalerite, and other sulfides in a gangue of quartz, barite, and manganocalcite.

Placer Deposits

Gold

Placer deposits in the Lynn district have yielded a small but persistent production of placer gold in Lynn, Sheep, and Rodeo Creek Valleys (Vanderburg, 1936, p. 49–53). The gold apparently is derived from mineralized shear zones in the upper plate of the Roberts Mountains thrust fault from the thrust zone, and from fault zones that cut carbonate rocks below. Placer deposits in Maggie Creek also are credited with a small production.

Suggestions for Prospecting

Ore deposits in the county were localized by major structural features; some of these features have been studied in a preliminary way, and certain areas can be outlined that are more likely than others to contain ore bodies. The major mining districts in north-central Nevada are aligned in northwest-trending belts (Roberts, 1957, 1960a, 1964a,b,c; 1966). The Battle Mountain-Eureka belt passes through the southern and central parts of the county and the Lynn-Pinyon belt through the northern part. The Battle Mountain-Eureka belt includes the Battle Mountain, Cortez, Roberts, Lone Mountain, and Eureka mining districts. The Lynn-Railroad belt includes the Lynn and Maggie Creek districts in Eureka County. The ore deposits are mostly in carbonate rocks that are now exposed in windows through the upper plate of the Roberts Mountains thrust. The windows are the result of doming that occurred partly during or after thrusting and was later intensified during the emplacement of igneous bodies; their alignment indicates that they are controlled by major zones of structural weakness. The nature of the deformation and time of its beginning are not fully understood, but clearly these zones contained conduits along which igneous rocks and related ore-bearing fluids rose. The zones probably extend to great depths and may date back to Precambrian time.

The mineral belts and windows within the mineral belts are favorable areas for prospecting in Eureka County and adjacent areas (Roberts, 1964a,b,c). Mineral deposits may occur in the upper plate of the Roberts Mountains thrust, in the thrust breccia itself, and in the carbonate rocks below. Thus far the carbonate rocks have been most productive in districts such as Eureka (Nolan, 1962) and Cortez (Gilluly and Masursky, 1965). The Roberts Mountains Formation of Silurian Age is particularly significant to economic geologists, as it is the host rock for gold ores at the Gold Acres mine in the Shoshone Range (Ketner *in* Gilluly and Gates, 1965); at the Carlin, Bootstrap, and Number Eight mines in the Tuscarora Mountains (Roen, 1961; Hardie, 1966; Hausen and Kerr, 1966); and at prospects north of Cortez (Erickson and others, 1966). The reasons why gold was precipitated from ore-forming solutions by the

Roberts Mountains Formation is not clear, but a combination of physical and chemical factors may be responsible.

The search for concealed ore deposits within the mineral belts has been intensified during recent years, and studies by the Geological Survey, in cooperation with the Nevada Bureau of Mines, have been carried on in many places. In recent years studies by Erickson and others (1961; 1964; 1966) on the fringes of the Cortez-Mill Canyon district revealed geochemical anomalies in western assemblage chert, shale, and limestone in the upper plate of the Roberts Mountains thrust and in carbonate rocks below; these rocks have been hydrothermally altered along faults and fractures and contain anomalous amounts of copper, lead, zinc, arsenic, molybdenum, bismuth, and silver; gold anomalies north of Cortez are of potential significance (Erickson and others, 1966). These geochemical anomalies may indicate areas where metallization may be found at depth. Investigations in these areas should be preceded by detailed geologic mapping and accompanied by geophysical surveys. Aeromagnetic surveys are especially useful in reconnaissance studies; the Roberts Mountains, Sulphur Spring Range, Cortez Mountains, Simpson Park Mountains, and Shoshone Range have been surveyed recently by Philbin and others (1963). Their map has been generalized and reduced to a scale of 1:250,000 for inclusion in a report by Roberts (1964a, fig. 5); a further reduction of the map is included in Roberts, 1966, fig. 9. The prominent linear anomaly that trends N. 25° W. and cuts diagonally across Eureka and Lander Counties is probably caused by a swarm of diabase dikes (H. A. Masursky and D. R. Mabey, oral communication, 1964). Broad aeromagnetic highs on the flanks of the prominent linear anomaly are mostly caused by intrusive bodies. Some of these volcanic and intrusive bodies have been mapped, but some do not crop out. The broad anomalies in the vicinity of mining districts (see Philbin and others, 1963, and Roberts, 1964a, fig. 5) are mostly due to small intrusive bodies; the mining districts are commonly on the flanks or noses of the aeromagnetic anomalies. Further exploratory work may be warranted on other parts of the flanks or noses.

Other areas that should be carefully evaluated for concealed ore bodies are listed below:

1. Aeromagnetic anomaly about 4 miles northeast of the Buckhorn mine. Philbin and others (1963) show a broad northwest-trending aeromagnetic high in this area that may be partly related to Tertiary volcanic rocks but in part may have been caused by intrusive bodies that crop out north of the volcanics.
2. Aeromagnetic anomaly about 5 miles northeast of the Antelope district. Philbin and others (1963) show a north-trending aeromagnetic high in this area.
3. Aeromagnetic anomaly a mile southwest of Mineral Hill. Philbin and others (1963) show a north-northeast-trending aeromagnetic high in this area.

4. Aeromagnetic anomaly in Pine Valley about 14 miles northwest of Mineral Hill. Philbin and others (1963) show a broad aeromagnetic high that may be related to a body of magnetic material such as iron ore or an intrusive body.

5. A broad aeromagnetic anomaly northwest of Mt. Hope outlined by Philbin and others (1963). This area is mostly underlain by siliceous rocks of the upper plate of the Roberts Mountains thrust, but carbonate rocks that crop out nearby indicate that the thrust plate may be locally thin.

6. The aeromagnetic anomaly near lat 40°00′ and long 116°00′ partly shown by Philbin and others (1963). This anomaly may be due partly to basaltic volcanic rocks on the east side of the Sulphur Spring Range, or partly to intrusive activity.

7. Whistler Mountain intrusive body has only a few scattered prospects, but upper-plate rocks on the west flank should be carefully checked.

8. Alluviated areas adjacent to mining districts in the ranges should be examined by geochemical and geophysical methods (Nolan, 1950; Jerome, 1964). Pediment areas locally extend out far from the ranges and can be prospected with relative ease.

9. Targets within areas of carbonate rocks. The major ore bodies at Eureka and Cortez are in Cambrian dolomites. These may be found at depth elsewhere and should be explored wherever possible in areas of significant metallization in overlying units.

History of Mining

The first mineral discoveries in this part of Nevada were made in 1862 when silver ore was discovered at Cortez and Mill Canyon. The Diamond district and, shortly afterward, the Eureka district were organized in 1864 (Curtis, 1884, p. 3). Development was slow because of metallurgical problems, but these were solved in 1869, and production rapidly increased. Further impetus was given by the completion of the Central Pacific (now Southern Pacific) Railroad across the State in 1869 and the Eureka and Palisade Railroad in 1875. Production continued at a high rate until 1887, then began to fall off as the rich bonanza ores were gradually exhausted.

Meanwhile other districts were discovered: in 1868, Mineral Hill; in the 1870's, Fish Creek, Mount Hope, and Maggie Creek; in the 1880's, Safford and Union; in the 1900's, Antelope, Modarelli-Frenchie Creek, Lynn, and Buckhorn. None of these has approached the Eureka district in magnitude but several have yielded notable production (table 2).

During recent years relatively low metal prices and high costs had discouraged mining operations. However, with the profitable mining of low-grade gold ores, which began in 1965 in the Lynn district, a new era was introduced, and it seems likely that mining will remain at a high level for some time to come.

Mining Districts

Alpha district

The Alpha district is on the west slope of the Sulphur Spring Range in Tps. 23, 24, 25 N., R. 52 E. The area can be reached from Route 20, which parallels the range a few miles west of the district. Properties in the district are the Prince of Wales mine (sec. 28, T. 24 N., R. 52 E., unsurveyed), the Old Whalen mine (sec. 34, T. 25 N., R. 52 E., unsurveyed), and a number of other workings.

The early history of the district is unknown. Exploratory work has been carried on at several deposits over a long period, but shipments have been small. Shipments of ore from the Prince of Wales mine were noted for the years 1909, 1912, and 1917 (U. S. Geol. Survey, Mineral Resources of the United States), and a small production from the Old Whalen mine was reported, but accurate figures for the district are not available.

The metallic mineral deposits of the area are replacement deposits in limestone controlled apparently by faults of a northerly trending system. Silver, lead, zinc, and copper minerals in a gangue of calcite, dolomite, and barite are found in shear zones and as replacements of beds close to shear zones near the faults. Several deposits are on the fault planes. Sulfide minerals are oxidized to a depth of a few hundred feet.

Antelope district

The Antelope district is on the west flank of the Roberts Mountains. The area can be reached by gravel roads from U. S. 50, 17 miles to the south; U. S. 40, 40 miles to the north; and Nevada State Route 21, 6 miles to the west. Mining properties in the district include the July (sec. 3, T. 23 N., R. 50 E.), Belmont (secs. 14, 15, T. 23 N., R. 49 E.) and Blue Eagle (sec. 36, T. 23 N., R. 49 E.) groups of claims.

The district was discovered during early operations at Eureka, and although many deposits have been prospected (Angel, 1881) none has had significant production to date.

The ore deposits in the area are mainly lead and zinc minerals that replace limestone along faults and bedding. Ore bodies discovered thus far are small. According to the U. S. Bureau of Mines Minerals Yearbooks, shipments in 1950 contained 42 ounces of silver, 10,000 pounds of lead, and 13,400 pounds of zinc, with a total value of $3,304; in 1951, 219 ounces of silver, 32,300 pounds of lead, and 109,700 pounds of zinc, with a total value of $25,734. Antimony deposits have been prospected on the Blue Eagle claims (Lawrence, 1963, p. 68–69), but no production has been reported. Production was not reported in the period 1952 through 1957.

Beowawe district

The Beowawe district is a mile south of Beowawe and can be reached from U. S. Highway 40 by Nevada State Highway 21.

The area is mainly underlain by chert, shale, quartzite, and pebble conglomerate of the Valmy Formation.

TABLE 2. Production of gold, silver, copper, lead, and zinc from Eureka County, Nev.[1]

[1873–1903 from Vanderburg, 1938, p. 12, compiled from quarterly assessment roles of the county assessors; 1904–1931 from U. S. Geol. Survey and U. S. Bur. Mines, Mineral Resources of the United States for the given years; 1932–1966 from U. S. Bur. Mines Minerals Yearbooks for the given years, and U. S. Bur. of Mines, Mineral Resource Office.]

Year	Tons of ore	Value
1873	49,277	$1,858,413.42
1874	60,534	2,388,724.19
1875	90,217	3,430,904.66
1876	50,326	2,177,070.67
1877	68,085	2,696,420.24
1878	134,382	6,257,225.57
1879	115,277	3,948,723.43
1880	89,291	3,402,828.31
1881	77,005	3,168,543.91
1882	72,587	2,592,680.63
1883	70,510	1,999,414.69
1884	68,657	1,462,246.82
1885	55,352	1,191,771.93
1886	45,302	1,022,993.93
1887	69,347	1,216,547.78
(Tailings)	4,382	33,920.93
1888	44,361	987,388.83
1889	31,752	1,179,468.66
Total	1,196,644	$41,051,288.60

Year	Value of gold	Value of silver	Total
1890	$302,000.00	$748,000.00	$1,050,000.00
1891	308,000.00	751,000.00	1,059,000.00
1892	185,000.00	445,000.00	630,000.00
1893	100,000.00	250,000.00	350,000.00
1894	(no figures given)	....	....
1895	62,000.00	158,500.00	220,500.00
1896	68,650.00	157,300.00	225,950.00
1897	92,058.00	820,292.00	912,350.00
1898	74,097.00	520,563.00	594,660.00
1899	179,100.00	485,660.00	664,760.00
1900	76,800.00	493,265.00	570,065.00
1901	95,456.00	448,948.00	544,404.00
1902	91,189.11	531,930.55	623,119.66
1903	92,198.72	565,333.63	657,532.35
Total	$1,726,548.83	$6,375,792.18	$8,102,341.01

Year	Gold		Silver		Copper		Lead		Zinc		Total
	Ounces	Value	Ounces	Value	Pounds	Value	Pounds	Value	Pounds	Value	
1904	....	$44,296	....	$93,220	13,963	$1,380	513,032	$20,404	....	....	$159,300
1905	753	15,586	78,475	47,399	64	10	525,304	24,689	12,020	$709	88,393
1906	2,462	50,911	77,552	51,960	6,653	1,283	1,014,244	57,812	492	30	161,996
1907	8,424	174,147	252,889	166,907	144,825	28,965	2,992,117	158,582	3,075	181	528,782
1908	8,339	172,396	140,551	74,492	79,985	10,558	2,330,048	97,862	....	....	355,308
1909	21,027	434,672	187,710	97,609	101,500	13,195	4,346,535	186,901	....	....	732,377
1910	3,942	81,489	36,047	19,466	721	91	672,801	29,603	....	....	130,649
1911	5,390	111,434	15,273	8,095	2,617	327	61,136	2,751	....	....	122,607
1912	....	128,190	28,307	....	19,861	....	230,710	....	....	....	159,258
1913	....	17,182	56,996	....	55,385	....	498,104	....	....	....	82,110
1914	....	306,852	164,202	....	6,800	....	391,690	....	13,439	....	414,521
1915	....	334,047	186,583	....	15,813	....	1,299,085	....	61,053	....	500,040
1916	....	114,752	143,686	....	79,066	....	2,804,981	....	34,935	....	426,972
1917	....	30,282	72,269	....	72,841	....	1,783,933	....	....	....	263,136
1918	....	35,743	66,977	....	67,618	....	1,197,292	....	....	....	204,430
1919	....	22,621	68,523	....	40,713	....	1,179,723	....	....	....	170,585
1920	....	63,760	84,006	....	121,029	....	2,487,210	....	....	....	376,572
1921	....	50,833	45,904	....	206,948	....	776,943	....	....	....	158,395
1922	....	40,438	49,866	....	69,681	....	592,430	....	....	....	132,295
1923	....	87,017	87,459	....	646,870	....	1,398,929	....	....	....	351,748
1924	....	31,250	49,414	....	160,344	....	1,776,927	....	....	....	227,516
1925	....	35,281	101,843	....	25,955	....	4,331,011	....	....	....	486,444
1926	2,871	....	....	....	....	....	....	....	....	....	642,703
1927	....	....	....	....	....	....	....	....	....	....	[2]406,494
1928	2,714	56,139	816,512	477,659	51,199	7,373	1,296,707	75,209	....	....	616,380
1929	2,396	49,558	512,610	278,018	41,917	7,377	1,191,478	75,063	17,270	1,140	411,156
1930	806	16,668	61,465	23,664	10,784	1,402	402,977	20,149	....	....	61,883
1931	985	20,372	5,685	1,649	2,565	233	126,010	4,662	....	....	26,916
1932	1,326	27,447	10,133	2,858	1,940	122	124,934	3,748	....	....	34,175
1933	751	15,535	21,892	7,662	1,990	127	57,220	2,117	....	....	25,441
1934	2,461	86,030	21,143	13,668	14,358	1,149	296,738	10,979	....	....	111,826
1935	4,062	142,203	46,251	33,243	22,217	1,844	484,662	19,386	....	....	196,676
1936	4,858	170,030	79,287	61,408	8,000	736	296,000	13,524	....	....	245,698
1937	10,929	382,515	135,058	104,467	6,000	726	320,000	18,880	....	....	506,588
1938	8,909	311,815	139,564	90,223	4,000	392	258,000	11,868	....	....	414,298
1939	10,344	362,040	158,376	107,504	8,000	832	132,000	6,204	....	....	476,580
1940	8,403	294,105	147,395	104,814	12,000	1,356	118,000	5,900	....	....	406,175
1941	3,289	115,115	41,635	29,607	4,000	472	50,000	2,850	8,000	600	148,644
1942	1,039	36,365	17,903	12,731	2,000	242	30,000	2,010	....	....	51,348
1943	231	8,085	3,530	2,510	....	....	14,000	1,050	80,000	8,640	20,285
1944	379	13,265	12,946	9,206	80,000	10,800	206,000	16,480	400,000	45,600	95,351
1945	40	1,400	16,380	11,648	12,000	1,620	156,000	13,416	2,408,000	276,920	305,004
1946	57	1,995	43,429	35,091	42,000	6,804	294,000	32,046	7,410,000	940,020	1,015,956
1947	148,148	5,180	64,606	58,468	20,000	4,200	690,000	99,360	1,804,000	218,284	385,492
1948	147	5,145	41,688	37,730	11,900	2,582	576,300	103,158	81,700	10,866	159,481
1949	106	3,710	14,597	13,211	2,100	414	138,500	21,883	231,700	28,731	67,949
1950	408	14,280	31,469	28,481	3,200	666	162,200	21,897	660,500	93,791	159,115
1951	8	....	672	....	....	....	160,700	....	1,363,100	....	278,070
1952	2	....	338	....	100	....	109,500	....	633,100	....	123,125
1953	66	....	1,954	....	400	....	6,300	....	....	....	5,019
1954	183	....	12,995	....	400	....	67,700	....	45,800	....	32,505
1955	1,964	....	124,532	....	19,000	....	1,853,600	....	180,300	....	486,828
1956	20	....	466	....	162,400	....	11,200	....	281,200	....	112,901
1957	36	....	4,600	....	266,700	....	....	....	....	....	85,700
1958	6,780	237,300	210,912	190,887	232,700	61,253	5,952,300	696,419	11,000	1,122	1,186,981
1959	1,550	58,310	32,343	29,272	7,200	2,210	828,100	95,232	86,700	9,971	194,995
1960	2,332	81,620	25,018	22,643	8,900	2,857	405,800	47,479	196,500	25,348	179,947
1961	940	32,900	9,982	9,228	2,700	810	172,700	17,788	157,200	18,078	78,804
1962	194	6,790	5,484	5,950	2,300	708	179,900	16,551	252,800	29,072	59,071
1963	....	....	874	1,118	....	....	111,900	12,085	998,300	114,805	128,008
1964	....	....	1,231	1,592	500	163	23,600	3,092	811,500	110,364	115,211
1965	128,500	4,497,500	3,691	4,772	3,900	1,381	52,100	8,128	780,400	113,938	4,625,719
[2]1966	241,249	8,443,715	3,641	4,708	1,653	595	143,210	21,481	455,677	66,073	8,536,572
Total	501,820	$17,880,311	4,876,819	$2,374,838	3,010,275	$177,255	50,704.521	$2,078,698	19,479,761	$2,114,283	$29,454,504

[1]Figures for early years incomplete.
[2]Estimated.

Red Devil mine. The Red Devil mine is in secs. 6, 7, T. 31 N., R. 49 E., about a mile south of Beowawe. Cinnabar was discovered in 1924 by R. S. Harris and C. M. Wilkinson, who staked the Red Devil group of claims. In 1928 the claims were acquired by the Nevada-Mexico Mining Corp., and a 30-ton rotary furnace was installed. According to Vanderburg (1938, p. 19), operations continued until September 1929; 132 flasks of mercury were produced. The Sacramento Gold and Quicksilver Mining Co. acquired the property in 1932 and reported a small production. Bailey and Phoenix (1944, p. 78) credit the property with 149 flasks through 1943.

The property is developed by 1,400 feet of underground workings. Two adits (fig. 8), separated 100 feet laterally and 50 feet vertically, have been driven northwestward to explore a silicified zone. The upper adit extends N. 60° W. for 155 feet and lateral drifts have been driven both north and south for a total distance of 320 feet. The upper level workings are connected by raises to three glory holes. The lower adit extends N. 68° W. for a distance of 400 feet and has approximately 160 feet of lateral workings. Shafts connect both levels with the surface.

Cinnabar, the only ore mineral, occurs in pebble conglomerate, quartzite, and shale of the Valmy Formation. In places these rocks have been highly brecciated along faults and subsequently have become silicified. Commonly the pebble structure shows clearly despite silicification, but the quartzite and shale generally have been converted to porcellanite. The cinnabar forms veinlets, lines cavities, and coats breccia fragments.

Buckhorn district

The Buckhorn district is on the east side of the Cortez Mountains in the southwest corner of T. 27 N., R. 49 E. (unsurveyed), about 6 miles northwest of Cortez and 28 miles south of Beowawe. The district is in siliceous shale of Tertiary(?) Age (I. G. Sohn, written communication, 1961), which is overlain by thin andesite flows. The Buckhorn mine accounts for most, if not all, of the district's production, which totals more than $1 million (table 3). Most of the value has been in silver and gold.

Buckhorn mine. The first claims in the district were staked in the winter of 1908–1909 by Joe Lynn, W. S. McCrea, William Ebbert, and John Swan. In 1910, the claims were sold to George Wingfield and associates, who organized the Buckhorn Mines Co. (Vanderburg, 1938, p. 19). The company blocked out a low-grade gold-silver ore body and in 1913 built a power plant at Beowawe and a cyanide plant at the mine. The mill began operating early in 1914, but by early 1916, ore amenable to the cyanidation process was exhausted and the equipment sold. Except for a small production in 1931 and 1932 by lessees, the mine was inactive until 1935, when it was reopened by Pardners Mines Corp., New York. Pardners installed a flotation mill to handle sulfide ores and operated the mine until the end of 1937. In January 1938 the mine and mill were reported closed permanently, and the equipment was offered

for sale. In recent years the property has been in the hands of lessees, and production has come from the dumps. Production was not reported in the period 1950–1957.

The mine workings (pl. 4) consist of two glory holes, a 1,750-foot haulage adit, and extensive underground workings. The north glory hole is 450 feet long, 125 feet wide, and 45 feet deep; the south glory hole is 650 feet long, 245 feet wide, and 120 feet deep. Exploration has been extended to a depth of 120 feet.

TABLE 3. Production of gold, silver, and copper from the Buckhorn district, Eureka County, Nev.

(Figures from U. S. Bureau of Mines Minerals Yearbooks and Vanderburg, 1938, p. 21. Years not given are years of no production reported.)

Year	*Gold (ounces)*	*Silver[1] (ounces)*	*Copper (pounds)*	*Total value*
1910	282	2,660	19	$7,285
1914	13,485	107,248	....	338,068
1915	14,026	106,081	....	343,726
1916	2,703	24,327	....	72,021
1931	132	978	....	3,017
1932	54	471	....	1,241
1936	....	....	....	(2)
1937	6,653	54,446	300	275,005
1938	551	4,489	....	22,187
1939	270	2,270	....	10,991
1940	533	4,912	....	22,148
1941	329	3,347	....	13,895
1950	6	49	....	254
Total	39,024	311,278	319	$1,109,838

[1]Figures rounded off to whole numbers.
[2]Figures not released by company for publication and not included in total.

The ore bodies are in breccia zones along a reverse fault that strikes N. 5° W. and dips 75° E. Andesite and siliceous shale of Tertiary(?) Age adjacent to the fault have been extensively argillized for a length of 1,800 feet and width of 200 feet. The ore mineral is pyrite containing silver and gold in kaolinized rock. The pyrite is oxidized to a depth of 100 feet.

Cortez-Mill Canyon district

The Cortez-Mill Canyon district is in T. 26 N., R. 48 E., in the Cortez Mountains about 30 miles south of Beowawe. The first claims were located in 1862 (Hague, 1870, p. 405). Ore originally was hauled to Austin for treatment, but in 1864 a stamp mill was erected (Whitehill, 1875, p. 47). Later, in 1869, an 8-stamp mill was put into operation in Mill Canyon. In 1886 a new mill was constructed. Emmons (1910, p. 101) estimates that production up to 1908 was about $10 million, mainly from the Garrison mine (Cortez mine, pl. 1). The properties in the district were operated intermittently by various companies until 1919, when they were taken over by the Consolidated Cortez Silver Mines Co., now known as the Cortez Metal Co. A mill of 125 tons daily capacity was erected in 1923 and enlarged in 1927; operations continued until 1930. Production since 1902 is summarized in table 4.

In 1959 the American Exploration and Mining Co. took over the Cortez Metals Co. The old workings were reopened and exploratory

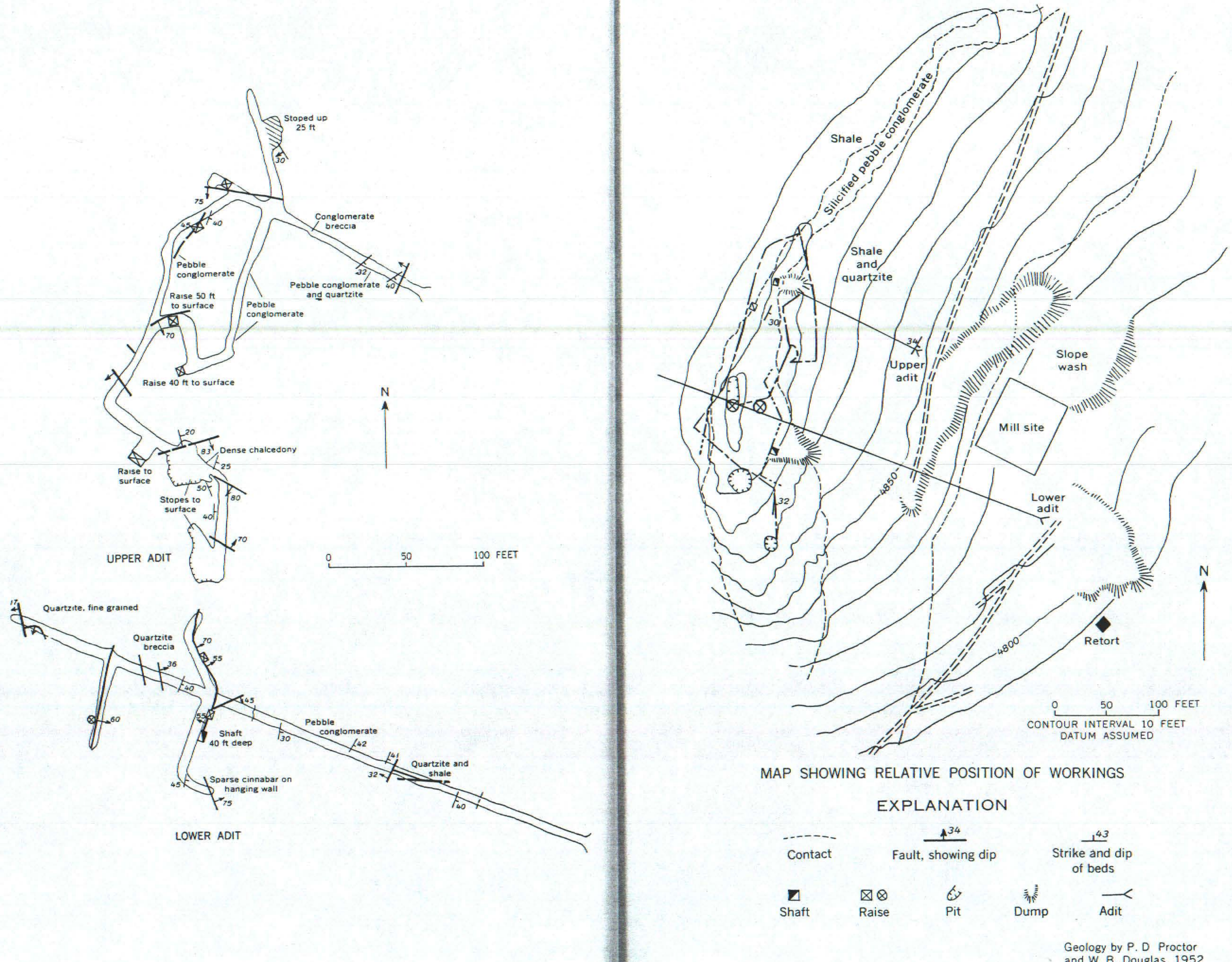


FIGURE 8. Maps of the Red Devil mine, Beowawe district.

drilling was begun in 1963 near the portal of the Garrison tunnel. The hole reached a depth of 1,500 feet in dolomite and limestone. Additional exploratory work is being planned in the old workings along the rake of the ore bodies previously stoped (Hatfield Goudey, oral communication, 1964).

In 1960 Erickson and others (1961) studied geochemical anomalies on the pediment on the west side of the Cortez window in Lander County about 2 miles west of the Eureka County line. About 500 samples were collected along a northwest-trending belt parallel to the Roberts Mountains thrust that extends from the NW¼ sec. 1, T. 26 N., R. 47 E., about 4 miles west of the range front. Anomalous amounts of lead, molybdenum, silver, zinc, arsenic, bismuth, and manganese were found in upper-plate rocks and in breccia along the thrust zone. At the same time, samples were also taken in the lower-plate carbonate rocks north and northeast of this area in Lander and Eureka Counties; these samples contained anomalous amounts of arsenic, tungsten, zinc, lead, molybdenum, beryllium, and silver (Erickson and others, 1964, p. B92). These anomalies are in areas previously prospected, but not productive on a large scale. The anomalies indicate areas worthy of detailed study and possible exploration.

In 1964 the American Exploration and Mining Co. jointly with three other mining companies, in cooperation with the Office of Minerals Exploration (OME), began exploration in the area of the anomalies. About 27,000 feet of rotary and diamond drilling was planned to explore targets in the upper plate of the Roberts Mountains thrust, in the thrust breccia, and in the carbonate rocks below (Hatfield Goudey, oral communication, 1964). Preliminary results of this work are encouraging.

In 1966 gold values were found in silicified zones in the Roberts Mountains Formation in sec. 19, T. 26 N., R. 48 E.; this area was being investigated by the American Exploration and Mining Co. and the Geological Survey in late 1966 (Erickson and others, 1966).

The Cortez-Mill Canyon district is in eastern assemblage rocks which are exposed in the Cortez window. These rocks have been intruded by a quartz monzonite stock about 3 miles long. The Cortez area lies on the south side of the stock and the Mill Canyon area on the north. Western assemblage rocks are exposed on the north side of Mill Canyon and west and south of the Cortez-Mill Canyon district.

The principal ore bodies in the district are in Hamburg(?) Dolomite and Eureka Quartzite, which strike northeastward and dip about 25° E. The ore is mainly in pipes and irregularly shaped bodes related to east-west faults and fractures; some bodies follow quartz porphyry dikes that strike N. 80° E., and others follow bedding (manto deposits) (Gilluly and Masursky, 1965).

According to Emmons (1910, p. 104), the primary minerals are galena, stibnite, pyrite, sphalerite, stromeyerite [$(AgCu)_2S$], and tetrahedrite (gray copper). Secondary silver chloride, accompanied by iron

TABLE 4. Production of gold, silver, copper, lead, and zinc from the Cortez-Mill Canyon district, Eureka County, Nev.

(Figures from U.S. Bureau of Mines Minerals Yearbooks and Vanderburg, 1938, p. 24. Years not given are years of no production reported.)

Year	Gold (ounces)[1]	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1902	289	214,094	5,907	12,564	---------	$ 120,686
1903	858	149,343	3,100	20,489	---------	99,332
1904	490	115,902	13,963	16,726	---------	79,330
1905	97	37,540	64	56,827	---------	27,354
1906	67	8,792	---------	21,315	---------	8,487
1907	42	5,000	---------	---------	---------	4,175
1908	73	18,700	7,773	9,095	---------	12,828
1909	284	40,459	1,000	10,721	---------	27,493
1911	27	7,712	2,022	31,970	---------	6,337
1912	295	52,429	803	46,893	---------	40,584
1913	282	54,196	1,581	83,791	---------	42,503
1914	192	44,185	402	179,599	---------	35,463
1915	817	67,873	2,543	84,068	---------	55,692
1916	268	42,139	1,373	36,922	---------	36,162
1917	161	26,950	7,434	148,741	---------	40,367
1918	102	31,578	4,614	160,030	---------	46,178
1919	1	11,387	780	63,358	---------	16,272
1920	22	7,872	1,084	45,945	---------	12,908
1921	12	8,416	368	24,959	---------	9,829
1922	35	39,386	2,764	26,625	---------	41,948
1923	272	172,466	2,216	30.705	---------	149,529
1924	714	423,163	5,021	67,041	---------	304,295
1925	672	366,350	2,419	46,417	---------	272,514
1926	742	345,381	3,308	38,580	---------	234,406
1927	304	544,646	13,770	176,959	---------	328,055
1928	443	785,980	25,031	364,617	---------	493,713
1929	515	493,766	17,990	435,990	---------	304,460
1930	40	44,423	1,768	37,252	---------	20,014
1931	14	618	---------	1,636	---------	519
1932	(2)	(2)	(2)	(2)	---------	(2)
1933	74	18,424	1,368	25,640	---------	9,023
1934	7	341	---------	240	---------	464
1935	3	3,829	142	1,268	---------	2,919
1936	(2)	(2)	(2)	(2)	---------	(2)
1937	670	16,772	700	5,800	---------	36,850
1938	3,563	32,085	1,000	27,000	---------	146,786
1939	6,354	64,683	2,700	27,000	---------	267,846
1940	3,726	82,585	6,700	78,500	---------	193,819
1941	839	9,145	2,000	19,600	8,000	37,821
1942	451	6,598	2,000	15,400	---------	21,751
1943	84	48	---------	---------	---------	2,974
1944	32	1,554	---------	7,000	9,200	3,834
1947	43	21,493	1,900	33,000	11,000	27,438
1948	40	26,716	2,200	50,700	21,100	37,937
1949	20	10,534	1,000	15,400	---------	12,864
1951	(2)	(2)	(2)	(2)	---------	(2)
1953	6	1,945	400	6,300	---------	2,911
1954	35	12,985	400	67,700	45,800	27,316
1955	33	10,906	200	42,600	19,500	19,847
1957	13	3,662	---------	---------	---------	3,769
1958	26	3,770	100	1,500	---------	4,524
Total	24,149	4,488,821	151,908	2,704,483	114,600	$3,732,126

[1]Figures published in 0.00 ounces gold have been rounded off to whole ounce.
[2]Figures not released for publication, not included in total.

and manganese oxides and copper carbonates, was an important constituent of the oxidized ores. Gangue minerals are quartz and calcite. Mill-run ore in the early days contained 30 to 80 ounces of silver and up to 0.75 ounce of gold per ton.

The ore bodies were mined from surface outcrops to the 1,200 level. Figure 9 shows the variety of shapes of ore bodies in the Cortez mine. Ore bodies along east-west fractures have been the most productive to date. They dip 45°–80° and range from 1 to 20 feet in width, averaging about 7 feet (Vanderburg, 1938, p. 26). Those of the 5th and 7th levels were most productive; the largest mined had a stope length of 630 feet, a width of 5 to 15 feet, and a maximum vertical extent of 220 feet.

Diamond (Phillipsburg) district

The Diamond district is about 16 miles north of Eureka on the west flank of the Diamond Mountains. According to Vanderburg (1938, p. 28), the first discoveries were made by Phillips in 1864. A few tons of ore were hauled to Austin for treatment in 1866. Sporadic attempts to rework the mines in later years were not encouraging, though activity was noted as late as 1955.

The workings are in limestone and dolomite of Silurian Age, which dip steeply westward and are overturned. The ore bodies, which follow fault zones, have yielded lead-silver ore. Tetrahedrite, galena, and pyrite are the principal sulfides. Total production from the district has been about $250,000 (table 5).

TABLE 5. Production of gold, silver, copper, lead, and zinc from the Diamond (Phillipsburg) district, Eureka County, Nev.

(Based on production figures reported in U. S. Bureau of Mines Minerals Yearbooks.)

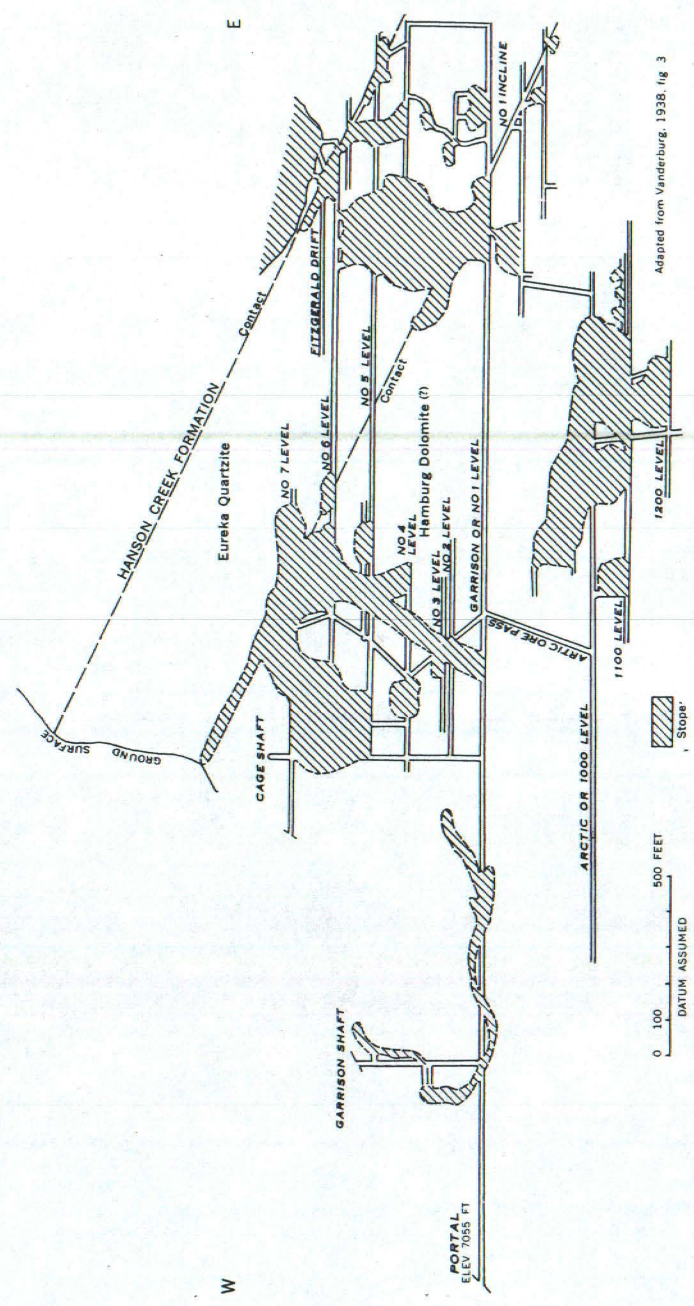
Year	*Gold (ounces)*	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Zinc (pounds)*	*Total value*
1936	....	....	....	....	....	(1)
1938	5	8,004	....	8,200	....	$15,727
1940	21	19,924	....	....	....	14,903
1947	2	20,086	4,500	521,000	....	94,217
1948	....	....	....	....	....	(1)
1949	3	2,802	1,100	83,100	9,800	17,203
1954	....	....	....	....	....	(1)
1955	....	1,082	1,200	142,800	160,700	42,470
Total	31	51,898	6,800	755,100	170,500	$184,520

[1]Figures not released by company for publication, not included in total.

Phillipsburg mine. The Phillipsburg mine is in sec. 35, T. 22 N., R. 54 E. Values are in lead and silver, but production has been small despite many attempts to work the property. Workings (fig. 10) consist of an adit in Silurian dolomite that intersects a vein 300 feet from the portal. The vein strikes north and dips 30°–55° W.; stopes extend to the surface and locally below the level. The vein is mostly quartz with pockets of iron oxides and lead and copper carbonates. A few relict kernels of tetrahedrite, stibnite, galena, and pyrite were noted.

Eureka district

The Eureka district is in Tps. 18 and 19 N., R. 53 E., in the southeastern part of the county. The total value of metals (table 6) was estimated by Nolan to be about $122 million (1962, p. 56–59). Although



Adapted from Vanderburg, 1938, fig 3

FIGURE 9. Composite longitudinal section of the Cortez mine, Cortez-Mill Canyon district.

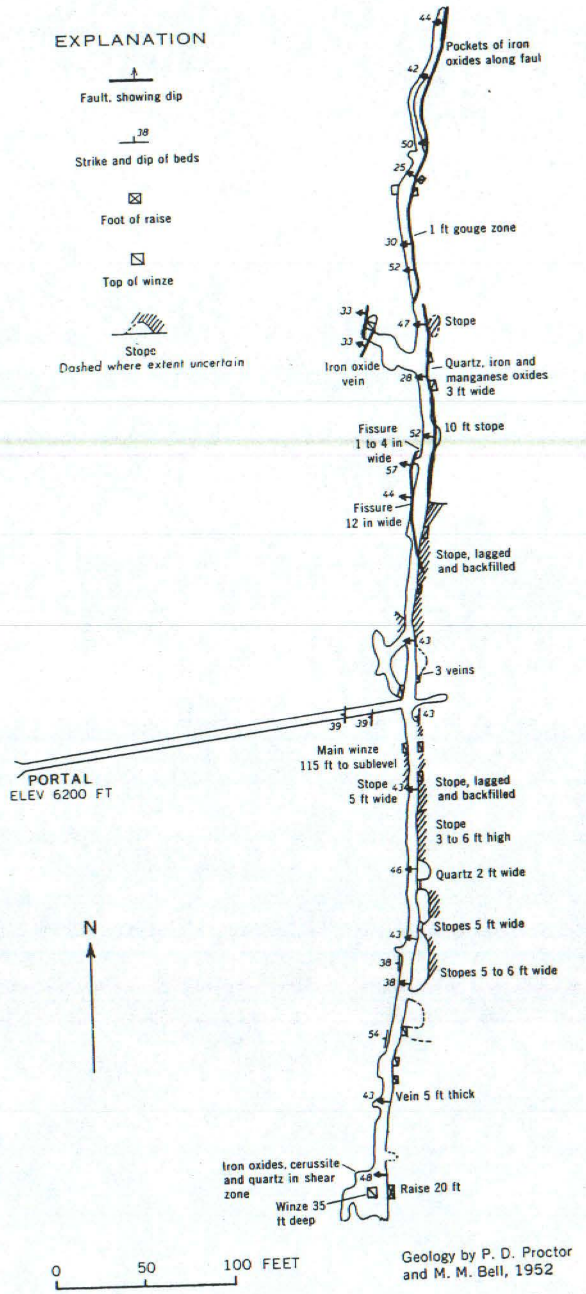


FIGURE 10. Map of the Phillipsburg mine, Diamond district.

recorded production figures are considerably lower, it remains first in production among the mining districts of the county.

The first mineral discovery in this area was made in New York Canyon near the Seventy Six mine on September 12, 1864 (Curtis, 1884, p. 3), by a prospecting party from Austin composed of W. O. Arnold, W. R. Tannehill, G. T. Tannehill, J. W. Stotts, and Moses Wilson (Angel, 1881, p. 425). The ore was a rich combination of silver and lead, but it was not amenable to current amalgamation processes, so the property was not developed. In 1865, Alonzo Monroe, M. C. Clough, and Owen Farrell located the Buckeye and Champion mines on what is now known as Ruby Hill. In the next three years a few claims were located; but for lack of suitable smelters, the district remained on the verge of abandonment until 1869, when one of Nevada's most violent mining booms, the "White Pine rush," occurred at Hamilton, about 40 miles southeast of Eureka in White Pine County. As the excitement died down, prospectors turned their attention to the Eureka district, and by the end of the year 354 claims had been located, compared to 43 the year before. In July 1869, Major W. W. McCoy and two assistants, R. P. Jones and John Williams, devised a workable smelter; and by December they proved that "smelting, under skillful direction, was more profitable in this district than in any other yet tested in the State of Nevada." (Angel, 1881, p. 430).[1]

By July 1870, Eureka was growing rapidly and locations in the district numbered about 1,000; 12 furnaces and 40 mines were operating in the area between Ruby Hill and Secret Canyon. The ore mined at this time averaged $76.73 per ton (Angel, 1881, p. 430). In 1870 and 1871, two companies were formed that ultimately became the major producers in the district: the Eureka Consolidated Mining Co., which bought the Champion and Buckeye mines, and the Richmond Consolidated Mining Co., which purchased adjoining claims that included the Richmond mine.

In 1875, the Eureka and Palisade Railroad (later the Eureka-Nevada Railway) was completed from Eureka to Palisade, on the Central Pacific line, which was by then across the State. Vanderburg (1938, p. 31) notes that the population of Eureka by that time was about 7,000. About 1885, production began to drop as the bonanza ores were depleted; and by 1891, because of the decline in the price of silver, high operating costs, and restrictions on local charcoal production, the Richmond and Eureka smelters were shut down and the ore shipped to distant smelters.

In 1906, the U. S. Smelting, Refining, and Mining Co., of Boston, consolidated the Richmond and Eureka properties under the Richmond-Eureka Mining Co., which operated the mines until 1910, when the railroad spur to the mine washed out.

The most recent work in the district has been carried on by two companies: the Eureka Corp., Ltd., which leased the Richmond-Eureka

[1]The McCoy furnace was the first successful treatment in America of argentiferous lead ore (Angel, 1881, p. 430–431).

TABLE 6. Production of gold, silver, copper, lead, and zinc from the Eureka district, Eureka County, Nev.

(Figures from U.S. Bureau of Mines; Vanderburg, 1938, p. 34-35; Nolan, 1962, p. 58-59. Years not given are years of no production reported.)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1866 to 1901[1]	--------	-----------	-----------	------------	------------	$ 95,000,000
1902	3,743	96,287	-----------	903,875	------------	165,462
1903	3,876	95.596	-----------	577,748	------------	147,065
1904	1,653	44,772	-----------	496,306	------------	79,970
1905	652	36,341	-----------	416,308	------------	54,991
1906	2,396	68,760	6,653	992,929	------------	153,379
1907	8,371	152,872	115,557	2,936,672	------------	452,686
1908	8,338	109,826	72,477	2,310,572	------------	337,174
1909	20,307	179,315	90,100	4,340,768	------------	711,388
1910	3,412	33,349	702	672,801	------------	118,238
1911	4,920	5,584	-----------	27,570	------------	105,915
1912	5,643	18,546	2,394	195,036	------------	137,227
1913	640	24,173	3,053	287,959	------------	40,970
1914	893	28,441	2,379	194,803	------------	42,098
1915	1,092	34,308	5,653	393,526	------------	59,457
1916	1,874	80,657	41,420	1,290,448	------------	191,033
1917	974	39,708	31,771	693,757	------------	121,188
1918	1,337	51,980	63,517	1,142,937	------------	176,461
1919	1,015	66,459	40,713	1,179,723	------------	165,520
1920	3,018	78,878	120,268	2,457,094	------------	367,058
1921	2,384	45,886	206,948	776,943	------------	156,824
1922	1,895	44,925	68,450	501,980	------------	120,949
1923	4,149	84,068	645,715	1,345,409	------------	343,803
1924	1,478	48,552	160,344	1,776,927	------------	226,237
1925	1,539	101,703	25,955	4,326,303	------------	482,472
1926	3,894	153,979	66,194	5,568,282	------------	631,317
1927	2,372	75,223	38,988	2,263,168	------------	239,384
1928	2,250	30,530	26,168	932,090	------------	122,194
1929	1,819	27,760	20,874	755,488	------------	103,677
1930	694	17,037	9,016	365,725	------------	40,361
1931	416	4,040	2,565	124,374	------------	14,616
1932	453	9,380	1,120	122,516	------------	15,755
1933	155	3,408	622	31,300	------------	5,587
1934	1,449	18,094	13,332	295,056	------------	74,312
1935	2,299	40,972	20,644	482,033	------------	130,902
1936	3,181	60,830	5,597	283,828	------------	172,020
1937	3,004	62,120	4,300	292,900	------------	170,991
1938	4,437	84,732	1,000	208,500	------------	219,759
1939	3,232	40,538	500	103,700	------------	145,563
1940	3,787	35,087	200	36,500	------------	159,344
1941	2,074	23,915	-----------	21,600	------------	90,827
1942	382	11,291	-----------	14,600	------------	22,377
1943	124	3,479	-----------	14,000	80,000	16,504
1944	347	11,392	80,000	199,000	390,800	91,517
1945	33	16,380	12,000	156,000	2,408,000	304,759
1946	40	43,428	42,000	294,000	7,410,000	979,360
1947	16	22,783	13,400	136,000	1,793,000	260,530
1948	44	197	5,400	12,500	37,500	10,116
1949	45	1,242	-----------	36,900	216,900	35,425
1950	31	3,670	319	28,734	3,040	7,883
1951	7	672	-----------	10,500	10,400	4,562
1954	935	62,176	-----------	984,883	------------	187,628
1955	1,930	111,893	7,500	1,655,500	------------	418,286
1956	3,047	138,245	-----------	2,047,657	------------	451,835
1957	2,713	88,112	-----------	1,451,882	------------	319.436
1958	12,179	325,183	-----------	9,648,324	1,708,180	1,539,624
1959	1,184	35,224	-----------	1,137,925	163,611	165,492
1960[2]	2,290	24,959	-----------	395,950	------------	160,477
1961[2]	738	9,939	2,700	151,700	49,100	57,100
1962[2]	194	4,942	900	88,000	5,600	21,169
Total	148,283	3,173,838	2,079,408	60,589,509	14,276,131	$107,358,254

[1]Estimated, Nevada Bureau of Mines.
[2]Published with permission.

Mining Co. property in 1937, and the Consolidated Eureka Mining Co., which has been operating the Diamond mine.

The geology of the district has been described in detail by T. B. Nolan (1962). The area has been divided into several structural blocks separated by fault zones of large displacement. Most of the significant ore bodies are in the Prospect Ridge block, which is bounded on the west by the Spring Valley fault zone and on the east by the Hoosac fault. Within the block the major structures are three thrust zones, a transverse fault, and several normal faults. Remnants of two folds are involved in the thrust zones, and the thrust zones themselves are broadly folded.

The ore bodies are replacement deposits in limestone and dolomite of Cambrian Age, which Nolan (1962, p. 30–40) classifies as follows: irregular, bedded, fault-zone, disseminated, and contact metasomatic deposits. Irregular replacement deposits in the oxidized zone above the water table have yielded the major production thus far. The principal minerals in this zone are cerussite, anglesite, mimetite, plumbojarosite, limonite, calamine (hemimorphite), wulfenite, and smithsonite in a gangue of calcite, aragonite, siderite, and quartz. Most of the oxidized ores are earthy and reddish to yellowish. Solution caves are common, especially at the tops of the bodies. Caves and water courses connecting caves have usually been followed in prospecting new ground. Sulfide bodies, at or below the water table, have been productive locally in deeper workings. The minerals are pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, molybdenite, and tetrahedrite.

The most productive properties in the district are in three general areas—Ruby Hill, Adams Hill, and Prospect Ridge. Ruby Hill and Adams Hill are shown in plate 5; Prospect Ridge extends south of the area shown. Other properties, which have been inactive for many years, are in New York Canyon and on the east flank of Hamburg Ridge.

Ruby Hill. The Ruby Hill area is in sec. 22, T. 19 N., R. 53 E. Nolan (1962) estimates that the total value of production from this area probably is about $100 million. Almost all of the ore bodies have been in brecciated Eldorado Dolomite that forms the upper plate of the Ruby Hill thrust zone. These rocks are cut by the Ruby Hill normal fault, which trends northwest and displaces the rocks nearly 2,000 feet (Nolan, 1962) downward on the northeast. The bonanza ores mined in the early days of the district were oxidized deposits in the upthrown or footwall side of the Ruby Hill normal fault at its intersection with the Ruby Hill thrust zone. Figure 11 shows the extent of these workings as mapped by Curtis (1884, pl. III).

Sulfide ores have been found in the downthrown side of the Ruby Hill normal fault, but working below the water table has presented problems. Exploratory drilling (Binyon, 1946; Sharp, 1947; and Nolan, 1962) in the 1940's by the Eureka Corp., Ltd., and the U. S. Bureau of Mines from the 900 level of the Locan shaft (fig. 12), revealed zinc-lead sulfide ores in the Eldorado Dolomite, some 2,000 feet below the surface. The Eureka Corp. sank the Fad shaft to mine these ores, but the overwhelming flow of water encountered in lateral workings on the 2,250

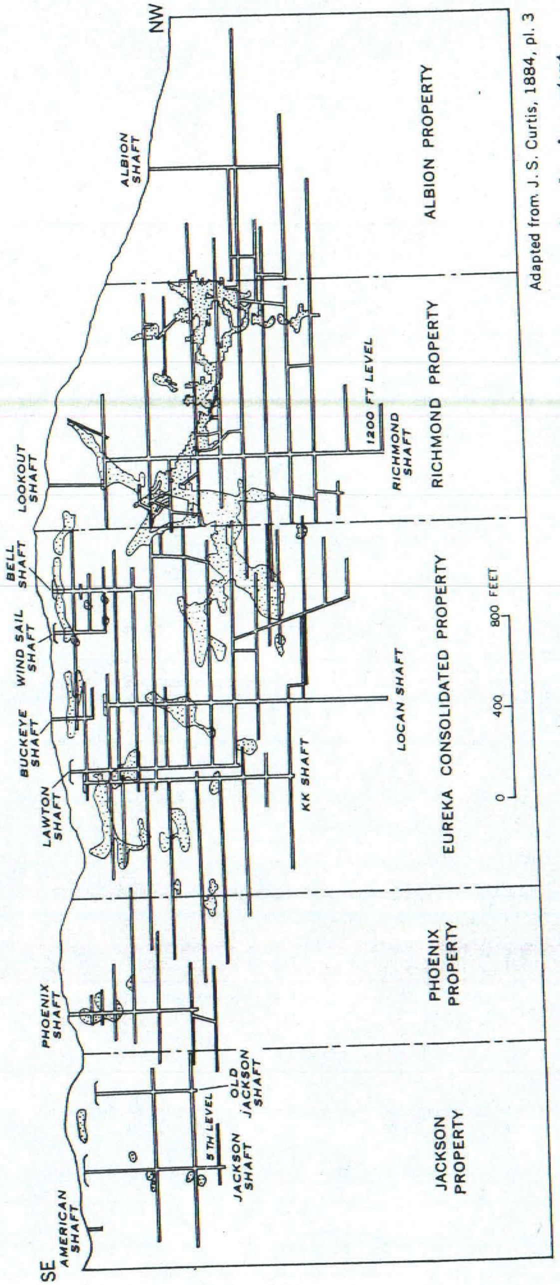


FIGURE 11. Generalized section through the Ruby Hill mines, along the Ruby Hill fault, Eureka district, showing extent of workings in the 1880's. Stippled areas represent stoped ore bodies.

level in 1948 forced the company to abandon the shaft. According to Nolan (1962), ". . . the apparent necessity to pump more than 15,000 gallons of water a minute for a protracted period of time prevented development," although "it seems probable that a large tonnage of sulfide ores of good grade is present . . ."

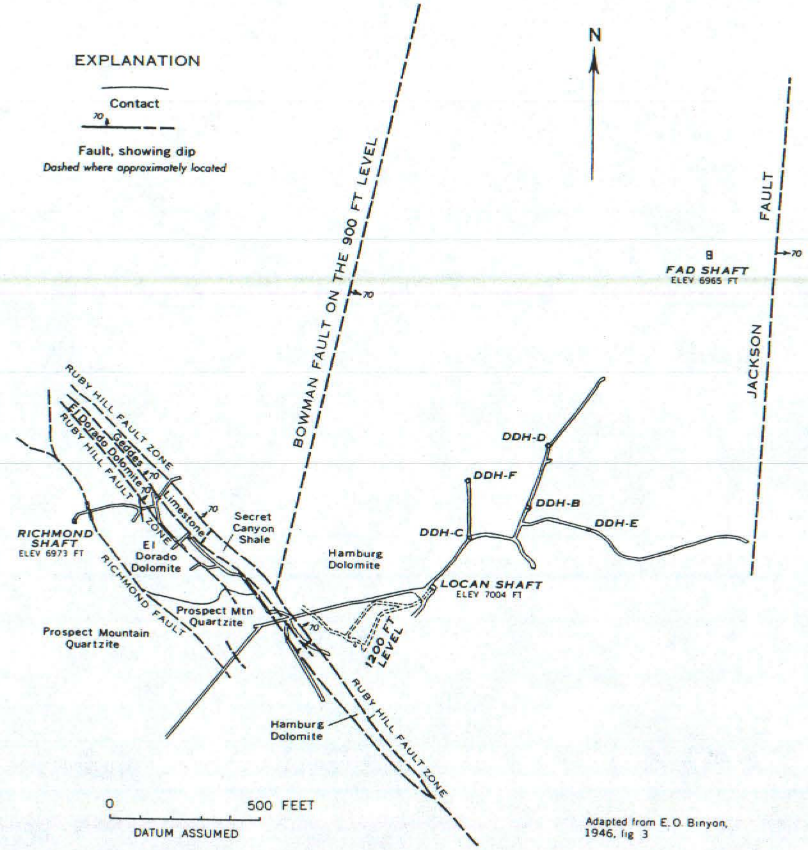


FIGURE 12. Map of the 900 level of the Locan shaft, Eureka district.

Following the flooding of the Fad shaft in 1948, the ground-water conditions in the vicinity of the shaft were studied jointly by the Eureka Corp., Ltd., and the Defense Materials Procurement Agency (Nolan, 1962, p. 60). W. T. Stuart (1955) of the U. S. Geological Survey was able to observe drawdown and recovery tests at both the Fad and Locan shafts and in five nearby drill holes and to calculate the pumping requirements for lowering the water table sufficiently to permit mining in the area within two years. He calculated that two pumping sites would be required and that initially a capacity of 8,000 gallons per minute (gpm) would be required at the Fad shaft, decreasing to 5,750 gpm after nine months, and that the capacity at the second site would range from zero at the beginning to 10,030 gpm during the last year and a quarter. He also concluded that the combined final pumping rate of 15,780 gpm could be decreased by only about 1,100 gpm after dewatering had been achieved.

In 1960 the Richmond-Eureka Mining Co., Hecla Mining Co., Eureka Corp., Newmont Mining Corp., and Cyprus Mines Corp., entered into an agreement to continue development drilling to determine value and tonnage of ore reserves more precisely than previously known, and to reopen the Fad shaft and drive a crosscut to the ore body to obtain metallurgical samples. In early 1964 the area around the shaft was grouted and opened to the 2,250 level. By 1965 the crosscut, driven in thoroughly grouted ground, had reached 800 feet from the shaft. A water door was installed 150 feet from the shaft (W. P. Johnston and R. C. Horton, oral communication, 1964).

Adams Hill. Adams Hill adjoins Ruby Hill on the north; most of the productive properties are in sec. 15, T. 19 N., R. 53 E. The total value of ore from this area is difficult to estimate, but a minimum figure approaches $5 million.

The ore bodies on Adams Hill are some distance above the Ruby Hill thrust zone in rocks of the Hamburg Dolomite, Windfall Formation, and Pogonip Group, which dip gently northward. The area has been intruded by an igneous mass, which Nolan (1962) mapped as quartz porphyry. Most of the ores mined have been oxidized, although sulfides were present at the 1,050 level of the TL shaft.

The TL shaft (fig. 13) was sunk by the Eureka Corp., Ltd., after a drilling program revealed ore at depths ranging from 700 to 1,100 feet. The shaft was sunk to 1,127 feet, and levels were established at 850, 950, and 1,050 feet below the collar (Johnson, 1958). Production began in 1956, but in 1957 the company encountered difficulty in finding smelters to treat the ore, which contained arsenic. In April, 1958, the complex nature of the ore and the prevailing low prices of metals forced the company to close the mine; the lower workings were allowed to flood (Eng. Mining Jour., 1958). Shipments were also made in 1959: total production amounted to more than 32,000 tons having a gross value of $1,650,000 (Nolan, 1962, p. 63).

TABLE 6a. Production of gold, silver, copper, lead, and zinc, TL shaft (Richmond-Eureka Mining Co.), Eureka district, Eureka County, Nev.

(Figures furnished by U. S. Bureau of Mines. Published with permission of the owners.)

Year	*Tons*	*Gold (ounces)*	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Zinc (pounds)*
1957	12,220	6,708	153,166	10,849	4,469,658	809,715
1958	18,321	6,373	201,049	19,609	6,067,977	898,460
1959	2,063	745	23,834	5,209	699,924	62,851

The TL shaft collar is in quartz porphyry. Below this the shaft passes successively through Dunderberg Shale, Hamburg Dolomite, and Secret Canyon Shale. In the workings the sedimentary rocks strike N. 20°–30° W. and dip 20°–40° NE., and are cut by north- and northeast-trending faults. The ore bodies thus far discovered trend northward, apparently following a steeply dipping fracture zone. To some extent the ore is controlled by bedding.

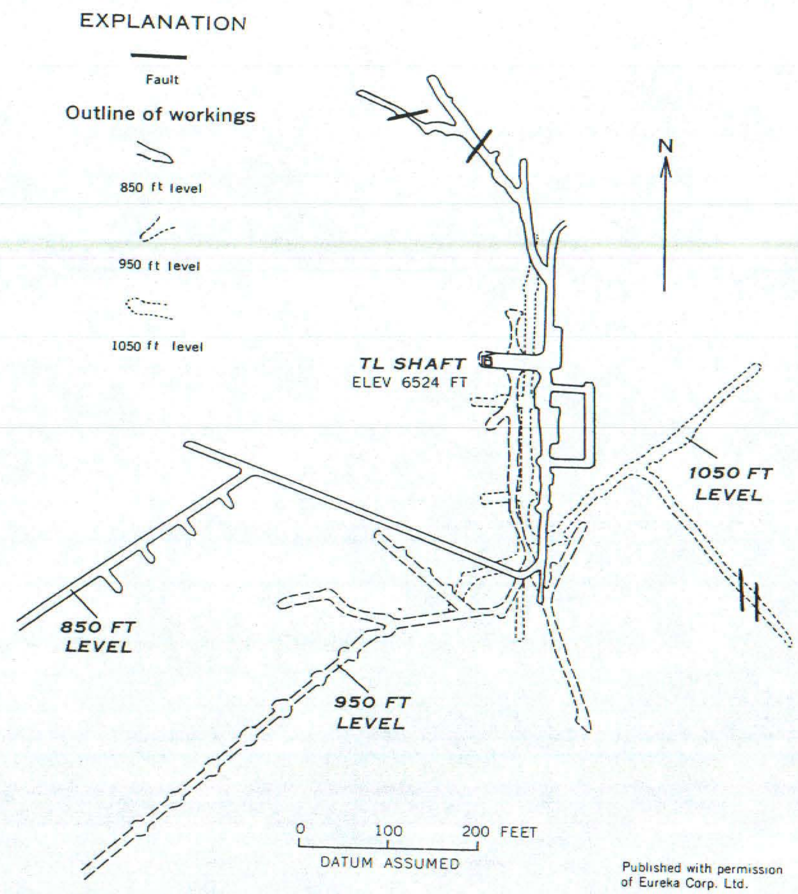


FIGURE 13. Composite map of the TL shaft workings, Eureka district.

Minerals in the ore on the 850 and 950 levels are anglesite, cerussite, smithsonite, plumbojarosite, and iron oxides in an altered dolomitic gangue. On the 1,050 level, local pods of galena, sphalerite, arsenopyrite, and pyrite have been found. Ore mined during development was reported to average about 17 percent lead, 0.5 ounce of gold, and 10.7 ounces of silver per ton (Nolan, 1962, p. 64).

Prospect Ridge. The Prospect Ridge group of mines is south of Ruby Hill. Total recorded production through 1956 is valued at $3,754,642 (Nolan, 1962). The most productive properties in the group are in sec. 34, T. 19 N., R. 53 E. The ore has been found in brecciated Eldorado and Hamburg Dolomite west of the Jackson-Lawton normal fault and above the Diamond Tunnel thrust zone (Nolan, 1962). The ores are similar to those of Ruby Hill, but contain more siliceous material and more gold. The average ton of ore shipped from the Diamond mine in 1954 through 1956 contained 28 percent lead, 39.7 ounces of silver, and 0.751 ounce of gold (Nolan, 1962, p. 69).

The Diamond mine is owned and operated by the Consolidated Eureka Mining Co. of Salt Lake City. The main access is the Diamond Tunnel, in SW¼ SE¼ sec. 34, T. 19 N., R. 53 E. The workings (pl. 6) have been described in some detail by Nolan (1962, p. 69). The ore is in Hamburg Dolomite, which dips steeply eastward and which is cut by several sets of normal and reverse faults. The faults apparently control to some extent the localization of ore minerals. Past production has been from caves and solution cavities, which are lined with oxidized minerals—jarosite(?), cerussite, and mimetite—which contain some gold and some unidentified silver minerals (R. W. Osterstock, written communication, 1955). The bottoms of the caves are generally filled with dolomite rubble and oxidized ore that has been recemented by calcite and iron oxide to form what is locally called "cave breccia." In the breccia, relict pyrite, galena, and arsenopyrite were noted in places, but generally throughout the mined area, oxidation has been complete.

In 1953, the company, in cooperation with the Defense Minerals Exploration Administration (DMEA), undertook rehabilitation of part of the older workings and initiated an exploration program. In August 1954, a new ore body was discovered on the 320 level (pl. 6). Between 1954 and 1962, 17,040 tons had been shipped; this ore averages 0.79 ounce of gold and 26.7 ounces of silver to the ton and 19.7 percent lead.

In 1962–63 the company, in cooperation with the Office of Minerals Exploration (OME), set up an exploration project on the 650 level and later deepened a winze to the 1,300 level; about 2,200 feet of drifting and crosscutting were made on this level. Currently, the company is drilling below the 1,300 level (Sherman B. Hinckley, oral communication, 1964). Production figures are presented in table 7.

TABLE 7. Production of gold, silver, and lead from the Diamond mine, Eureka district, Eureka County, Nev.

(Published with permission of Consolidated Eureka Mining Co.)

Year	Dry tons	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1954	1,195	935	62,176	....	943,664	....
1955	2,620	1,894	110,231	....	1,403,814	....
1956	4,010	3,047	138,245	....	2,047,657	....
1957	3,431	2,713	88,112	....	1,451,882	....
1958	361	310	3,487	....	61,503	....
1959	1,476	1,319	13,475	....	251,751	....
1960	2,762	2,290	24,959	....	395,950	....
[1]1961	980	738	9,939	2,700	151,700	49,100
[1]1962	205	194	4,942	900	88,000	5,600
Total	17,040	13,440	455,566	3,600	6,795,921	54,700

[1]Figures furnished by U. S. Bureau of Mines.

Slag and speiss dumps. According to Vanderburg (1938, p. 47), slag and speiss dumps in the vicinity of Eureka contain more than a million tons of material from former smelting operations. The average analyses[1] are as follows:

Slag		Speiss[2]	
SiO_2	23.67	Fe	57.02
FeO	58.32		
Al_2O_3	1.64		
PbO	3.51		
Pb	3.26		2.18
Bi	none		
CuO	1.08		1.06
ZnO	4.44	Zn	.07
MnO	.23		
Mo	.32		2.31
As	.25		32.95
Sb	none		.13
S	2.19		3.34
CaO	4.78		.34
MgO	1.27		
Ag	.58 oz. ton		8.01 oz. ton
Au	tr.		.43 oz. ton

[1]Analyses by F. Claudet, London (Vanderburg, 1938, p. 47–48).
[2]Speiss is a term used for arsenical slag, a basic arsenide of iron.

Fish Creek district

The Fish Creek district is in the Fish Creek Range in the southeastern corner of the county. The district includes a number of mining properties on the west flank of the range in T. 18 N., R. 51 E.; T. 18 N., R. 52 E.; and T. 17 N., R. 52 E. The Gibellini manganese-nickel mine, on the east flank of the range in T. 16 N., R. 52 E., also is included. The range is composed of limestone and dolomite of Ordovician, Silurian, and Devonian Age, cut in a few places by granodiorite porphyry dikes.

The first claims in the district were located in the late 1800's by James Butler and Angelo Belli. Only a few records of production are available; the U. S. Bureau of Mines Minerals Yearbooks show production for 1938 and 1955 only:

	Gold (ounces)	Silver (ounces)	Lead (pounds)	Total value
1938	.....	238	7,300	$400
1955	233	.....	6,900	1,239

Antelope claims. The Antelope group of claims is in secs. 17 and 18 (unsurveyed), T. 17 N., R. 52 E. In 1881, Butler patented two claims known as the North and the South Antelope (Vanderburg, 1938, p. 48). The group now includes 11 claims owned by Stanley Fine and others, of Eureka.

Workings consist of at least one adit and raise, a number of shafts, inclines, and winzes. Production reported for the district for 1955 came from these claims. Production was not reported for 1956 or 1957.

The property is in shaly limestone, possibly of the Pogonip Group, which, north of the mine, is intruded by granodiorite porphyry. Two fissure veins, called the North and the South Antelope, range from 1 to 5 feet in width. The oxidized zone contains silver, lead, and zinc minerals; relict sulfides include pods of pyrite, galena, and sphalerite.

Gibellini mine. The Gibellini mine (Niganz, Black Iron) is in S½

SW¼ sec. 35, T. 16 N., R. 52 E. (unsurveyed), on the east flank of the Fish Creek Range about 27.5 miles south of Eureka (Binyon, 1948, p. 2). Claims were first located in 1942 by L. P. Gibellini of Eureka, Nev. Workings consist of a shaft 37 feet deep, an adit 176 feet long, several shallow pits, and some trenches.

The deposit is in Devonian limestone which generally strikes northwest and dips 20°–35° SW in the area. Faults trending northwest, northeast, and east offset these rocks. The manganese-nickel body is on the footwall of a fault that strikes northeast and dips 28°–45° NW in the workings (fig. 14).

The ore body is composed mainly of pyrolusite and dense nodules of psilomelane; secondary zinc and nickel minerals are probably present. According to Binyon (1948, p. 8), a sample collected for metallurgical tests contained the following:

Constituent	Mn	Fe	Ni	Co	Zn	Cu	Mo	V_2O_5	Ba	Cao	S	Insol.	Al_2O_3
Percent	18.5	3.0	1.7	0.3	3.2	0.12	0.11	0.88	3.7	2.3	0.2	41.6	6.0

On the adit level the ore body is roughly triangular in shape and has a maximum length of 120 feet and a width of 60 feet. The ore has been explored above the adit level in a raise and sublevel (fig. 15) and below the adit level in a winze.

The average grade of ore in the workings is about 9.5 percent manganese, 2.8 percent zinc, and 1.22 percent nickel. A shipment of 95.4 tons of selected ore made in 1953 to the Combined Metals Co. mill at Caselton, Nev., was reported to contain 31.6 percent manganese. Another shipment of 45. 9 tons with reported content of 36 percent manganese was sent to the Wenden, Ariz., buying depot, but was rejected because of high copper content. According to Binyon (1948, p. 6), tests by the Bureau of Mines indicated that the minor metals could be concentrated along with the manganese by conventional ore-dressing methods, but that hydrometallurgical processes would be necessary for recovery of the minor metals from the concentrate.

Vanadian deposits in black shale of Devonian Age nearby were explored by the Siskon Co. in 1960–61. An open cut was made by bulldozers and churn drill holes were put down.

Bisoni and Bisoni-McKay property. Vanadium deposits in sheared and contorted black shale south of the Gibellini mine at the Bisoni and Bisoni-McKay properties were explored by the Union Carbide Nuclear Co. in 1958–59 (Davis and Ashizawa, 1959; Davidson and Lakin, 1961a, 1961b; P. E. Galli, oral communication, 1960; Hausen, 1960). The shale is interlayered with bedded chert and calcareous shale and a little limestone, and therefore is transitional in lithology between eastern and western types. On the geologic map, these rocks are included with undifferentiated western rocks. The chert has yielded spores assigned by Estella Leopold (written communication, 1961) to the Lower Paleozoic, and the limestones have yielded brachiopods assigned to the Devonian by C. W. Merriam (oral communication, 1962). The sharp contrast

in facies between these rocks and nearby Devonian limestone and dolomite, and their complex deformation, indicate that they are part of the upper plate of the Roberts Mountains thrust, which has been preserved by downfaulting. Similar rocks in nearby Nye County are interpreted as being in thrust contact with underlying carbonate rocks.

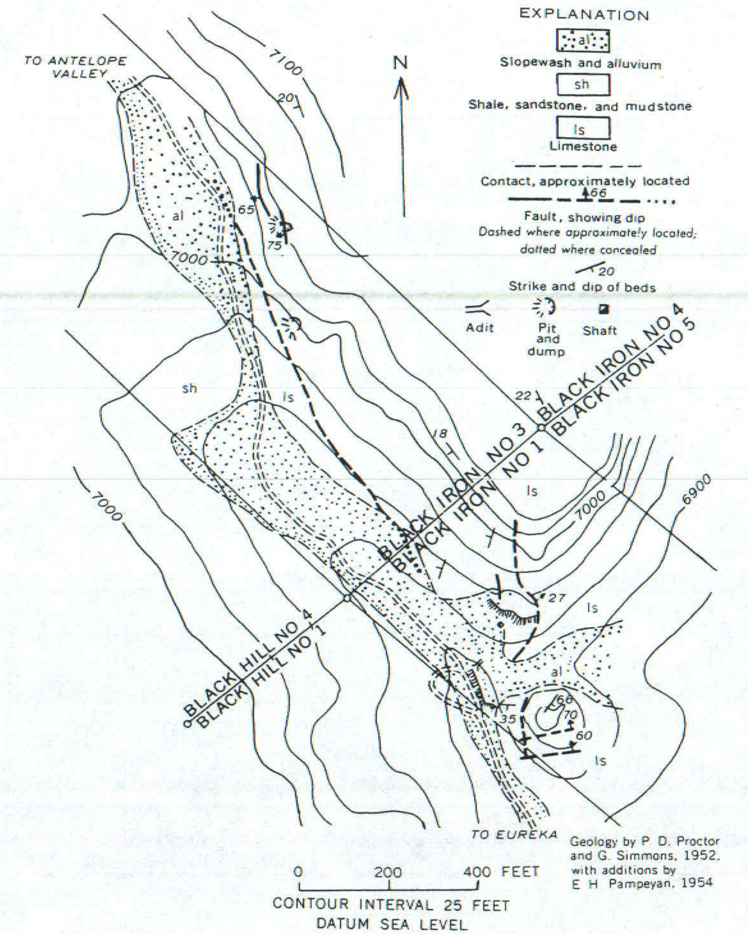


FIGURE 14. Map of the Gibellini mine area, Fish Creek district.

The vanadium minerals are associated with bituminous phosphatic marine shales. Secondary vanadium minerals, including schoderite, ($2Al_2O_3 \cdot V_2O_5 \cdot P_2O_5 \cdot 16H_2O$), vashegyite ($Al_4(PO_4)_3 \cdot (OH)_3 \cdot nH_2O(?)$), metahewettite ($CaV_6O_{16} \cdot 3H_2O$), and wavellite ($2AlPO_4 \cdot Al(F,OH)_3 \cdot 4\text{-}5H_2O$) have been found locally in the oxidized zone (Hausen, 1962, p. 638).

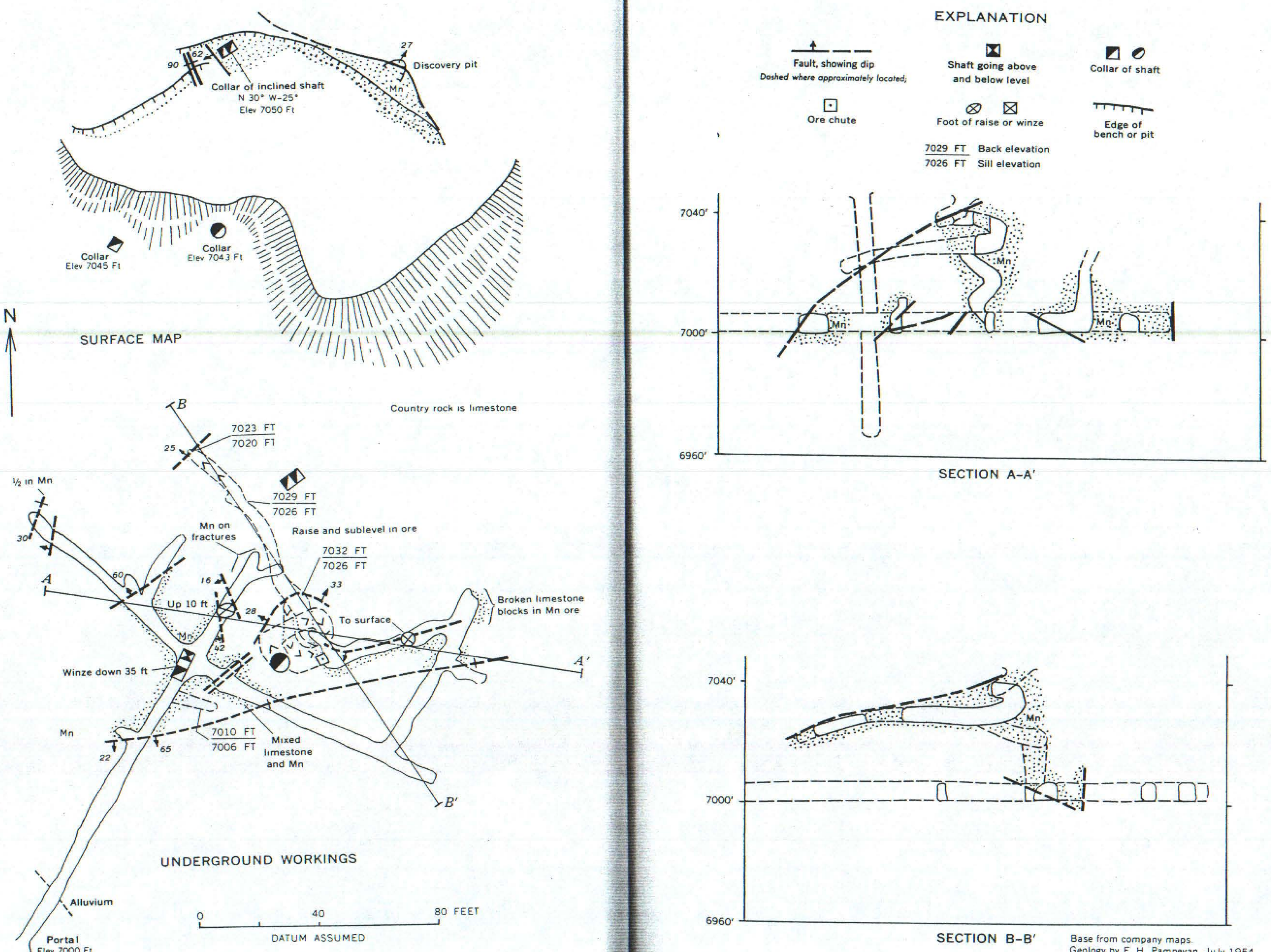


FIGURE 15. Map of the Gibellini mine, Fish Creek district.

Reese and Berry. A fluorite-beryllium prospect southwest of Eureka near McCullough's Spring (sec. 24, T. 18 N., R. 52 E., unsurveyed), was being explored in 1961 by the Union Carbide Nuclear Co. (P. E. Galli, oral communication, 1961; Holmes, 1963). The ore is mostly fluorite and beryl in a thrust zone between the Eureka Quartzite and Silurian limestone and dolomite. According to Robert C. Horton (oral communication, 1964), the company has given up its option.

Lone Mountain district

The Lone Mountain district (fig. 16) is on the north flank of Lone Mountain in the unsurveyed portion of T. 20 N., R. 51 E. The first claims in the area were located about 1920, but production was small until 1942, when high-grade zinc carbonate ore was discovered on the Mountain View claim (D. C. Arnold and R. W. Osterstock, written communication, 1951).

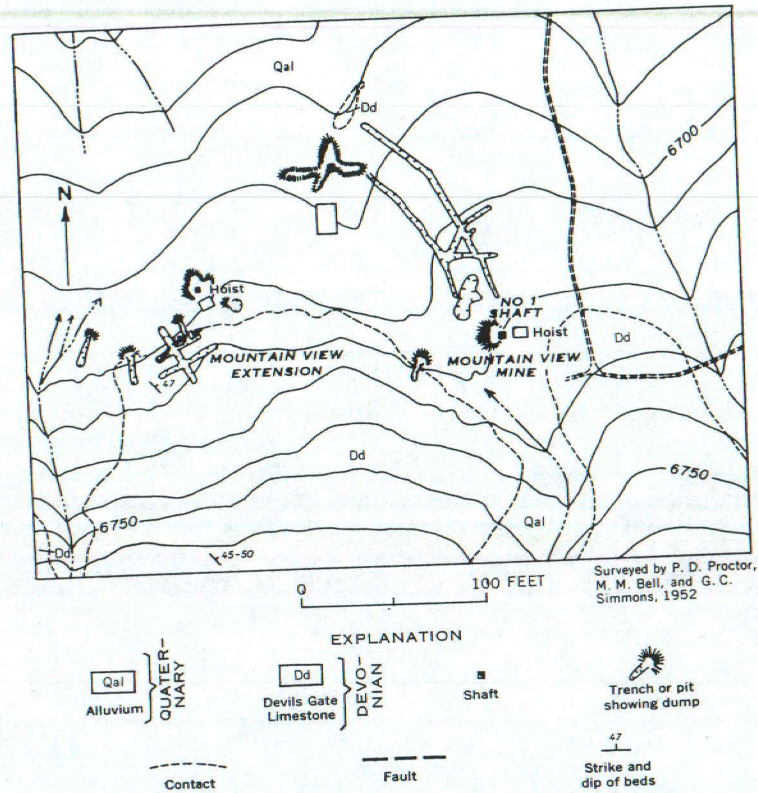


FIGURE 16. Map of the Lone Mountain mining district.

Lone Mountain is an isolated range composed of eastern assemblage carbonate rocks ranging from Ordovician to Devonian in age. Marginal remnants of shale and chert assigned by C. W. Merriam (written communication, 1960) to the Vinini Formation have been mapped on the northeast and southeast sides and indicate that Lone Mountain is a window eroded through the Roberts Mountains thrust.

The ore is in dolomite of the Devonian Devils Gate Limestone, which, in the mine area, strikes northwest and dips northeast. The dolomite has been highly brecciated and is cut by calcite veins. The ore bodies apparently are localized in breccia zones at the intersections of two sets of faults: one set strikes northeast and dips southeast, and the other, less prominent, strikes northwest and dips southwest.

Mountain View mine. The Mountain View mine is owned by Mr. and Mrs. Charles Vaccaro of Eureka, Nev. The workings (fig. 17) consist of a shaft and drifts at the 44-foot and 82-foot levels. Three ore bodies have been mined. Production in 1942–43 totaled 2,284 tons, averaging 28.8 percent zinc and 4 percent lead.

The ore minerals are mainly secondary, including principally smithsonite, zincite, hydrozincite, and a little cerussite, malachite, and azurite. Sphalerite, galena, chalcopyrite, and pyrite have been found locally. The gangue minerals are dolomite, calcite, and iron and manganese oxides.

The ore bodies range from small pods to masses containing several thousand tons. A stope on the 82-foot level yielded 1,000 tons of ore averaging about 28 percent zinc and 4 percent lead from a block 55 feet long and as much as 30 feet wide. Another stope, 45 feet long and 12 feet wide, yielded a few tons of ore during development work. A third stope is 30 feet long and as much as 20 feet wide; the ore is estimated to average 14 percent zinc and 1 to 2 percent lead. Other ore bodies were discovered during a diamond-drilling program carried on by the U. S. Smelting Co. during the 1940's. Production is shown in table 8.

TABLE 8. Production of silver, copper, lead, and zinc from the Lone Mountain district, Eureka County, Nev.

(Based on production figures reported in U. S. Bureau of Mines Minerals Yearbooks and furnished by U. S. Bureau of Mines; published with permission.)

Year	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Zinc (pounds)*	*Total value*
1943	23	....	114,315	114,622	$10,242
1944	....	....	18,964	184,305	16,261
1948	....	....	8,200	37,500	6,299
1949	42	....	28,500	216,900	31,170
1950	....	....	....	....	(1)
1951	840	....	109,000	1,243,000	245,878
1952	338	100	109,500	633,100	123,055
1956	427	....	11,200	281,200	40,668
1960	56	....	5,900	81,800	11,393
1961	24	....	21,000	108,000	15,292
1962	185	....	87,500	242,400	37,625
1963	874	....	111,900	998,300	128,008
1964	1,231	500	23,600	811,500	115,211
Total	4,040	600	649,579	4,952,627	781,102

[1]Production reported; figures not released, not included in total.

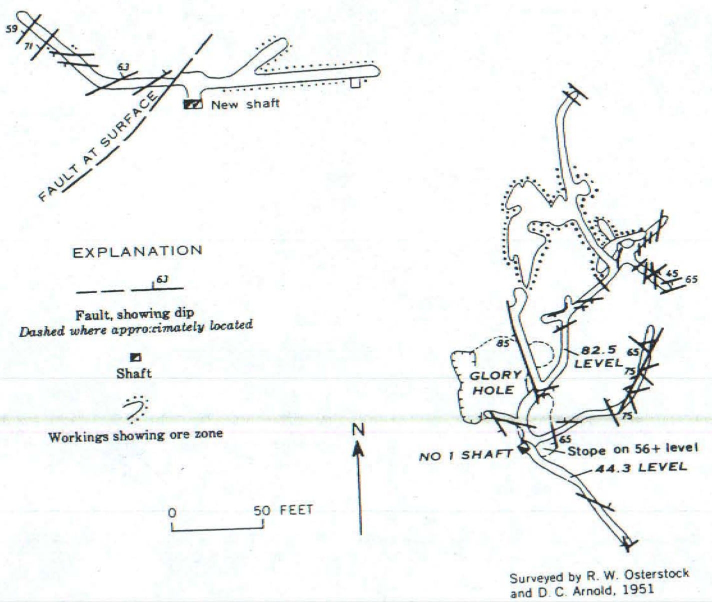


FIGURE 17. Map of the Mountain View mine, Lone Mountain district.

Lynn district

The Lynn district is in T. 35 N., Rs. 50 and 51 E., in the Tuscarora Mountains in northern Eureka County, approximately 19 miles by surfaced road northwest of Carlin in Elko County. The district includes lode mines near the crest of the mountains, placer mines on both flanks, and a turquoise-copper-gold property on the west side of the district (pl. 7). The first discovery of placer gold was made in 1907 by Joe Lynn, who located the Bulldog claim at the head of Lynn Creek.

Historically, the placer mines had been more productive than the lode mines, but in 1965 the Carlin Gold Mining Co., a Newmont subsidiary, put into operation a cyanide mill of 2,000 tons daily capacity. This operation resulted from the discovery of a large body of low-grade ore by Newmont geologists in areas recommended for prospecting by the U. S. Geological Survey (Roberts, 1960a). Total production from the district up to 1966 was about $13 million (table 9).

The Lynn district is on the north flank of the Lynn window (Roberts and others, 1958, p. 2834, fig. 4; Roberts, 1960a, p. B19, fig. 9.1; Roen, 1961) which includes eastern carbonate assemblage rocks that range in age from Cambrian to Devonian. In ascending order, these are the Hamburg Dolomite, Pogonip Group, Eureka Quartzite, Hanson Creek Dolomite, Roberts Mountains Formation, and an unnamed Devonian limestone which has been informally called the Popovich Formation by

Hardie (1966). At the Carlin gold mine, the Roberts Mountains Formation contains the principal ore deposits.

The Lynn window was overridden by the Roberts Mountains thrust plate, which carried chert, shale, and quartzite of the Vinini Formation over the carbonate rocks. In the Lynn district, the thrust strikes northwestward and dips northeastward; on the west side of the district it strikes northward and dips westward; on the east and south sides the thrust is concealed by deposits of Tertiary and Quaternary Age. Locally the thrust plate is cut by small stocks and dikes of quartz monzonite or granodiorite.

TABLE 9. Production of gold, silver, and copper from the Lynn district, Eureka County, Nev.

(Figures from U. S. Bureau of Mines Minerals Yearbooks and U. S. Bureau of Mines, Mineral Resource Office.)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Total[1] value
1932	811	88	....	$16,794
1933	521	44	....	10,795
1934	1,005	145	415	35,242
1935	971	126	170	34,089
1936	603	53	....	21,146
1937	602	74	600	21,200
1938	353	41	....	12,382
1939	459	162	300	16,206
1940	335	27	....	11,744
1942	206	14	....	7,220
1943	23	3	....	807
1945	7	....	....	245
1946	17	1	....	596
1947	....	....	....	(2)
1948	55	3	....	1,928
1949	38	3	....	1,333
1952	2	....	....	70
1953	60	9	....	2,108
1954	148	10	....	5,189
1956	66	5	....	2,315
1957	....	....	....	(2)
1958	....	....	....	(2)
1959	118	9	....	4,138
1960	42	3	....	1,473
1961	202	19	....	7,088
1965	128,499	88	....	4,497,579
1966	241,246	NA[3]	....	8,443,610
Total	376,389	927	1,485	$13,155,297

[1]In terms of recovered metal.
[2]Production reported; figures not released for publication, not included in total.
[3]Not available.

The carbonate rocks of the window have been complexly broken by high-angle faults that trend north, northwest, and northeast. The thrust plate contains many shear zones that parallel the Roberts Mountains thrust fault and the plate is also cut by high-angle faults. One of these high-angle faults is the Big Six fissure that strikes N. 30° E. and dips 68° NW., and parallels the range crest for a length of 800 feet. The crushed zone along the fissure ranges in width from 2 to 15 feet, and is defined mainly by iron oxide staining. A second shear zone, locally referred to as the Divide fissure, occurs 200 feet west of the northern end of the Big Six fissure. The Divide fissure has been traced for 300 feet along the strike. Some shear zones contain veinlets of quartz and most of them contain iron oxide derived from the oxidation of pyrite and other sulfides. Bismuth sulfide and oxide are reported to have accompanied gold in the rich ore (Lincoln, 1923, p. 94).

Big Six mine. The Big Six mine was located in 1907 by W. E. Barney. In 1917 the Lynn Big Six Mining Co. built an amalgamating mill on the site and later sold the property to the Beaver Crown Consolidated Mining Co. Since 1937 the property has been operated mostly by lessees. Development consists of an inclined shaft, several adits, and other workings, totaling about 5,000 feet. The Big Six adit, near the head of Lynn Creek, extends 800 feet westward and intersects the Big Six fissure zone about 100 feet below the outcrop. The Big Six incline, 150 feet west of and 70 feet above the Big Six adit, follows the westerly dip of the Big Six fissure zone. Both workings were caved when visited in 1952. The Bull Moose adit (fig. 18) is 200 feet north of the Big Six adit. The workings extend southwestward from the portal for a distance of 160 feet, then northwestward for 200 feet to where they are caved. The Talbot adit, now caved, is near the head of Sheep Creek; workings total about 1,400 feet.

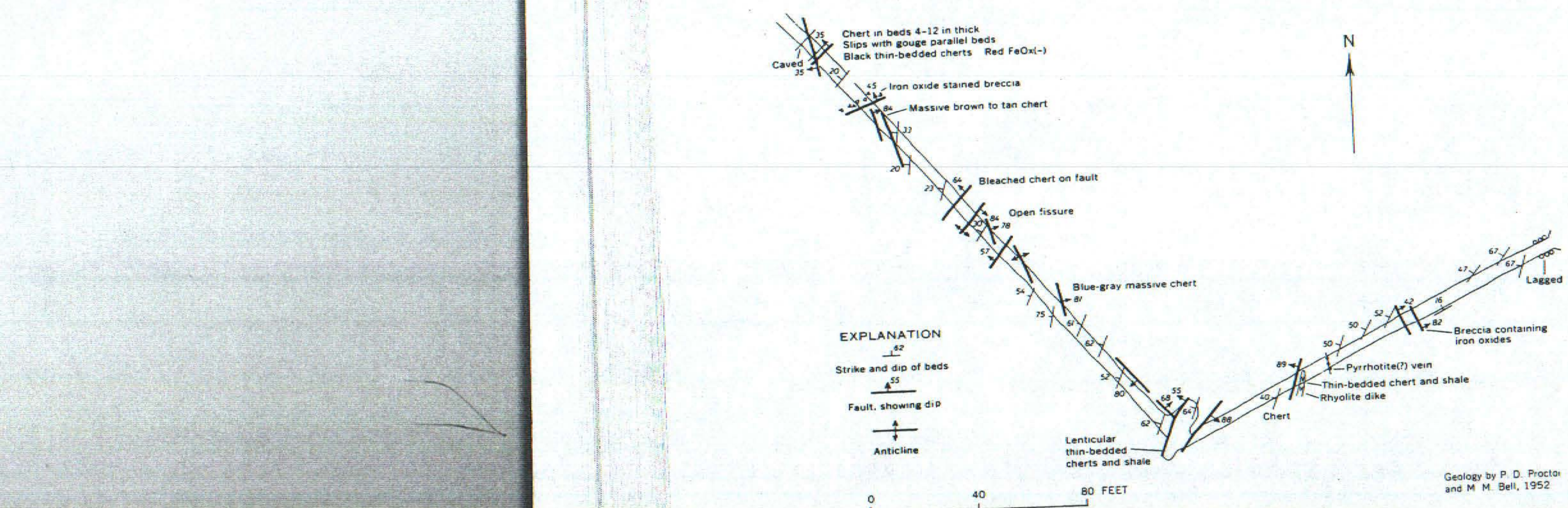


FIGURE 18. Map of the Bull Moose adit, Lynn mining district.

Carlin mine. Newmont's Carlin mine, 9 miles northwest of Carlin, in the Lynn district, was discovered in 1962 by geologists of Newmont Exploration Co., Ltd., on the southwest side of Popovich Hill in sec. 14, T. 35 N., R. 50 E. The property is approximately 1 mile south of the Big Six mine, and is southeast of the Sheep Creek placer. The principal ore bodies found thus far are in silty limestone of the Roberts Mountains Formation of Silurian Age, which is overlain by shaly and sandy clastic limestone of Devonian Age. Both of these units have been overridden by the upper plate of the Roberts Mountains thrust fault, which crops out a few hundred feet north of the workings. In this area the thrust fault

has a sinuous trace that trends westward and dips northward (see Frontispiece).

The ore bodies, which were discovered by drilling, follow a northeastward-striking fault zone that dips steeply; the host rocks were fractured along the fault zone and along subsidiary faults that strike northwestward and northward. The ore is largely oxidized and consists mainly of iron oxides and clay minerals in altered silty limestone; the ore ranges in color from light yellow to brown, reddish brown, and red; zones of jasperoid and chalcedonic silica are associated with the ore. A few specks of pyrite and cinnabar were noted in the ore, and locally, galena, stibnite, and sphalerite have been identified. Gold and silver values in the ore vary considerably from place to place (Hardie, 1966; Hausen and Kerr, 1966).

By 1965, the ore bodies had been explored by more than 250,000 feet of rotary and diamond drilling, and more than 3 million tons of overburden had been stripped preparatory to mining (Mining Cong. Jour., 1965, p. 27, 30).

Morning Glory prospect. The Morning Glory antimony-gold prospect is in sec. 13, T. 35 N., R. 50 E., about a mile south of the Carlin mine. The workings consist of a shaft estimated to be 30 feet deep and open cuts that explore a northwest-trending shear zone in dolomite of the Hanson Creek Formation. Pods of stibnite and antimony oxides as much as 3 feet wide have been stoped from the shaft and adjoining workings. Some of the material mined has been sorted and piled near the workings. A sample of the sorted ore showed 0.15 ounce of gold and 8.2 ounces of silver to the ton (K. Seeley, written communication, 1964).

Placer workings. Placer gold has been obtained from the channels of Lynn, Sheep, and Rodeo Creeks. According to Vanderburg (1936, p. 83), the richest gravels are at the upper end of the ravines, where the gold is coarse and rough. Smaller gold particles, associated with abundant black sand, occur in the lower portions of the ravines. In general, the gravel channels are narrow, shallow, and in most places covered by barren slope wash.

The gold probably is derived from mineralized shear zones in chert and shale of the Vinini Formation in the upper plate of the Roberts Mountains thrust. During late Tertiary time, the gold was weathered from veins and concentrated in channels, which have been dissected by present-day streams.

Placer operations are handicapped by lack of water. Sluice boxes generally are used during the spring, when surface water is available, and dry-washing machines are employed during the remainder of the season, which lasts six to seven months of the year.

Lynn Creek channel extends eastward from the lode mine area for about 4 miles. The lower 1.5 miles of channel are in Maggie Creek Valley. The placer gravels in the upper 2.5 miles average about 25 feet in width and range from 10 to 28 feet in depth; this part of the channel contains little unworked ground. The gravels contain a large number of medium- and large-sized boulders and some clay. The gold was largely concentrated in the 4 feet of gravel above bedrock and the depth to bedrock averaged about 15 feet. The slopes adjacent to Lynn Creek canyon have also yielded placer gold by dry-washing; Vanderburg (1936, p. 91) reports that the pay streak was the first 1.5-foot thickness of alluvium lying on bedrock.

According to Vanderburg (1936, p. 90), "The gold shows signs of wear and as a general rule it is fairly coarse, although no large nuggets are found. The largest nugget found in the district some years ago was worth $21. In 1935 the largest nugget found had a value of $13." The grade of material worked in 1935 ranged from $1.50 to $8.00 per cubic yard. In 1952 the gravels at the mouth of Lynn Creek canyon were being worked by the Ura Gold Mines Co. Here the gravels are about 9 feet deep, 180 feet wide, and average from 44 cents to $1.00 in gold value per cubic yard, according to the operating company. The gravels are processed through a trommel screen mounted on a self-propelled ¾-yard drag line. Trommel under size is processed through sluice boxes and the concentrate is further refined by hand-panning.

Sheep Creek drains the western part of the lode mine area. The upper part of the creek drains southward for 2,500 feet, then turns westward; the gravels in this part have been thoroughly worked. The channel is narrow and the gravels range from 25 to 40 feet in width; the pay streak is reported to be 1 to 2 feet thick lying on bedrock. Overburden is 4 to 8 feet in thickness and contains abundant boulders up to 1 foot in diameter. Both dry-washing and wet-washing methods have been used to recover the gold. According to Vanderburg (1936, p. 87), the Sheep Creek placers have consistently yielded from 150 to 250 ounces of gold per year. Rodeo Creek drains the lode mine area to the northwest; placer operations have been confined mainly to the upper reaches of the channel.

Number Eight mine. The Number Eight turquoise mine is 4 miles west of the main part of the Lynn district, on the west flank of the Tuscarora Mountains. The property consists of several claims owned by the Edgar Bros. of Battle Mountain. Turquoise of gem quality has been produced on a small scale since 1929. Estimates of total production range as high as $1,500,000 (Murphy, 1964, p. 207).

The workings explore the Roberts Mountains thrust zone, which here separates chert, shale, and quartzite of probable Ordovician Age in the upper plate from limestone of Devonian(?) Age in the lower plate. The turquoise is in lens-shaped bodies and seams distributed along the fault zone in yellowish-brown clay (mostly montmorillonite). Other copper minerals, including malachite and azurite, accompany the turquoise and locally replace the limestone along fractures below the thrust zone. The turquoise bodies range in weight from a few pounds to several hundreds of pounds. One 150-pound nodule of gem-grade turquoise was mined in 1954 (Murphy, 1964, p. 207). A few tons of oxidized copper ore from pockets in the limestone were shipped in the 1930's, according to Travis Edgar (oral communication, 1955).

In 1959 low-grade gold ore was discovered along the Roberts Mountains thrust fault at the Number Eight mine (R. D. Morris, oral communication, 1959). A 100-ton cyanide mill was erected on the property in 1960 by the M. M. and S. Exploration Co. of Carson City and was operated for a short time; in the fall of 1961, the mill was modified by the Sierra Nevada Co. and 800 tons were treated; 202 ounces of gold and 19 ounces of silver were recovered. In 1964 the property was purchased by Kerr-McGee Oil Industries, Inc.

Maggie Creek (Schroeder) district

The Maggie Creek district, also known as the Schroeder district, is in T. 34 N., R. 51 E., in the Tuscarora Mountains, about 11 miles northwest by gravel road from Carlin.

The earliest prospecting in the district, according to Vanderburg (1938, p. 62–63), was in the 1870's. In 1913 three mines were active, producing 134 tons of gold-silver-copper-lead ore with an average value of $97 per ton. No production is recorded for the period 1914–33; in 1934–40 the production totalled $45,575. Total recorded production, which does not include 1952 and 1953, is nearly $250,000 (table 10). Barite was discovered in the district in 1930, and Vanderburg (1938, p. 64) reports barite shipments over a five-year period (see Nonmetallic Minerals in this report).

TABLE 10. Production of gold, silver, copper, and lead from the Maggie Creek district, Eureka County, Nev.

(Based on production figures reported in U. S. Bureau of Mines Minerals Yearbooks.)

Year	*Gold (ounces)*	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Total value*
1932	....	....	....	....	(1)
1935	788	433	1,158	403	$27,990
1952	....	....	....	....	(1)
1953	....	....	....	....	(1)
1955	1	37	10,100	....	3,835
1956	14	462	162,400	....	69,928
1957	23	938	266,700	....	81,931
1958	32	2,517	215,700	27,200	63,309
Total	858	4,387	656,058	27,603	$246,993

[1]Figures not released for publication, not included in total.

The principal geologic feature in the area is a roughly circular window, the Carlin window, exposing Silurian Roberts Mountains Formation and Devonian limestone, surrounded by chert, shale, and quartzite of the upper plate of the Roberts Mountains thrust. On the east and south sides, the thrust plate has been faulted down against carbonate rocks. Tuffaceous sediments and alluvium overlap the older rocks on the east and west.

Maggie claims (Gold Quarry). The Maggie claims consist of three unpatented claims and a patented railroad section, sec. 35, T. 34 N., R. 51 E. (Vanderburg, 1938, p. 63). The workings are in the upper plate of the Roberts Mountains thrust, which borders the Carlin window. The ore is in iron-stained sheared and fractured quartzite and chert; a shipment of 59.7 tons in 1936 assayed 0.417 ounce of gold and 0.88

ounce of silver to the ton (Vanderburg, 1938, p. 63; L. E. Smith, oral communication, 1961). Byron Hardie (oral communication, 1964) reports that the property was acquired by the Newmont Exploration Ltd. in 1962, and that exploratory drilling was carried on during 1963 and 1964. The results of this drilling have not been announced.

Nevada Star (Good Hope). The Nevada Star mine workings are in sec. 27, T. 34 N., R. 51 E., west of Maggie Canyon in Silurian limestone. According to Emmons (1910, p. 87) and Vanderburg (1938, p. 64), the deposit is a vein 3 to 6 feet wide that strikes northwest and dips steeply northeast. The vein contains pockets of galena and lead and copper carbonates; the principal values were lead and silver. Workings include an inclined shaft, reported to be 250 feet deep, and shallow shafts. Barite veins are associated with the silver-lead veins.

Copper King mine. The Copper King mine (fig. 19) is approximately in the SW¼ SW¼ sec. 27, T. 34 N., R. 51 E. Development consists of two adits, a two-compartment shaft 200 feet deep with several hundred feet of laterals, and several pits and trenches. A pit 85 feet long, 65 feet wide, and 100 feet deep was dug in 1957–58, from which 158 carloads of ore were shipped. The ore averaged $3.50 per ton, mostly in copper. Oxidized copper minerals, principally chrysocolla, malachite, azurite, and cuprite, occur along shear zones in chert, shale, and limestone of the western assemblage. The general strike of the ore-bearing zone is about N. 60° E.; it dips steeply northwest. Of mineralogical interest is the presence of faustite, a zinc aluminum phosphate similar to turquoise, which occurs on the main level of the mine as apple-green veinlets and nodules in altered wall rock consisting mostly of quartz and kaolinite (Erd and others, 1953).

Mineral Hill district

The Mineral Hill district is in the northeast corner of T. 26 N., R. 52 E., about 5 miles east of State Route 20, on the west flank of the Sulphur Spring Range. The town of Eureka is 55 miles south. The district was discovered in 1868 by John Spencer, Amos Plummer, and associates from Austin, Nev. (Emmons, 1910, p. 95–99; Vanderburg, 1938, p. 51–57). Ore was at first hauled to Austin for treatment (Hague, 1870, p. 407); later a 15-stamp mill and Stetefeldt furnace were erected (Vanderburg, 1938, p. 51). In 1870 the property was sold to G. D. Roberts and William Lent; in 1871 it was sold to the Mineral Hill Silver Mining Co., Ltd. This company erected an additional 20-stamp mill, and continued to operate until 1872; production by lessees continued until 1876. The property is now owned by the Mineral Hill Consolidated Mining Co. Total recorded production from the district has been about $2,500,000 (table 11).

The Mineral Hill district (pl. 8) is underlain mainly by Devonian limestone, which strikes north and dips steeply westward; locally it is overturned and dips steeply eastward. On the east the limestone is in contact with chert and shale of the Vinini Formation; Emmons (1910, p. 96) considered that this was a normal sedimentary contact, but

mapping by the staff of the Department of Geology, University of California at Los Angeles, showed that it is a thrust fault, probably the Roberts Mountains thrust, which is locally overturned to the west in this area. The principal ore bodies are in crushed and fractured limestone adjacent to the thrust. Jasperoid is found at many places generally replacing limestone in the fractured zone. A few narrow dikes of altered igneous rocks cut the limestone.

TABLE 11. Production of gold, silver, copper, lead, and zinc from the Mineral Hill district, Eureka County, Nev.

(Figures from U. S. Bureau of Mines Minerals Yearbooks and Vanderburg, 1938, p. 21. Years not given are years of no production reported.)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
Pre-1913	....	....	....	....	....	$2,162,951
1913	94	6,539	42,889	100,287	....	16,953
1914	1	2,238	3,424	20,381	....	2,513
1915	22	25,071	7,445	821,009	61,053	60,608
1916	....	....	....	....	....	128,800
1917	18	27,837	2,448	1,062,996	....	115,384
1918	7	7,422	2,869	48,941	....	11,804
1935	3	891	103	958	....	777
1936	....	248	....	....	....	210
1937	....	101	....	....	....	78
1938	....	903	....	....	....	584
Total	145	71,250	59,178	2,054,572	61,053	$2,500,662

The primary ore minerals are tetrahedrite, galena, sphalerite, molybdenite, and pyrite in a gangue of calcite, barite, and silicified limestone. Secondary minerals include silver chloride and bromide, pyromorphite, cerussite, copper carbonates, agentite, stephanite, and iron and manganese oxides (Emmons, 1910, p. 98). The ore mined during 1871 averaged about 140 ounces of silver a ton, but in subsequent years it declined considerably and yielded as little as 25 ounces of silver a ton.

The ore bodies were mined in a zone 1,200 feet long and as much as 300 feet wide. Stopes are 10 to 40 feet wide and extend to 150 feet below the surface. The principal stopes are the Star Chamber, Live Yankee, Austin, and Giant. The ore bodies mostly dip about 40° eastward following the fractured zones. The Giant stope, about 50 feet in diameter, had many small offshoots.

Modarelli-Frenchie Creek district

The Modarelli-Frenchie Creek district is in Tps. 28 and 29 N., Rs. 50 and 51 E., on the crest of the Cortez Mountains. The district includes the Modarelli iron mine and a number of prospects (fig. 20).

Modarelli mine. The Modarelli mine is in sec. 30, T. 29 N., R. 51 E., about a mile east of the crest of the Cortez Mountains. Access is by 9 miles of gravel road from State Highway 20; the nearest shipping point is Palisade, 26 miles by road to the northeast. Water is available from local springs.

The deposit was discovered in 1903 by Amos Plummer and associates. It was relocated in 1905 by O. H. Hershey (1908, p. 535) for M. L. Requa, of San Francisco, in the name of the Amarilla Iron Co. and was originally called the Amarilla deposit. The property is now

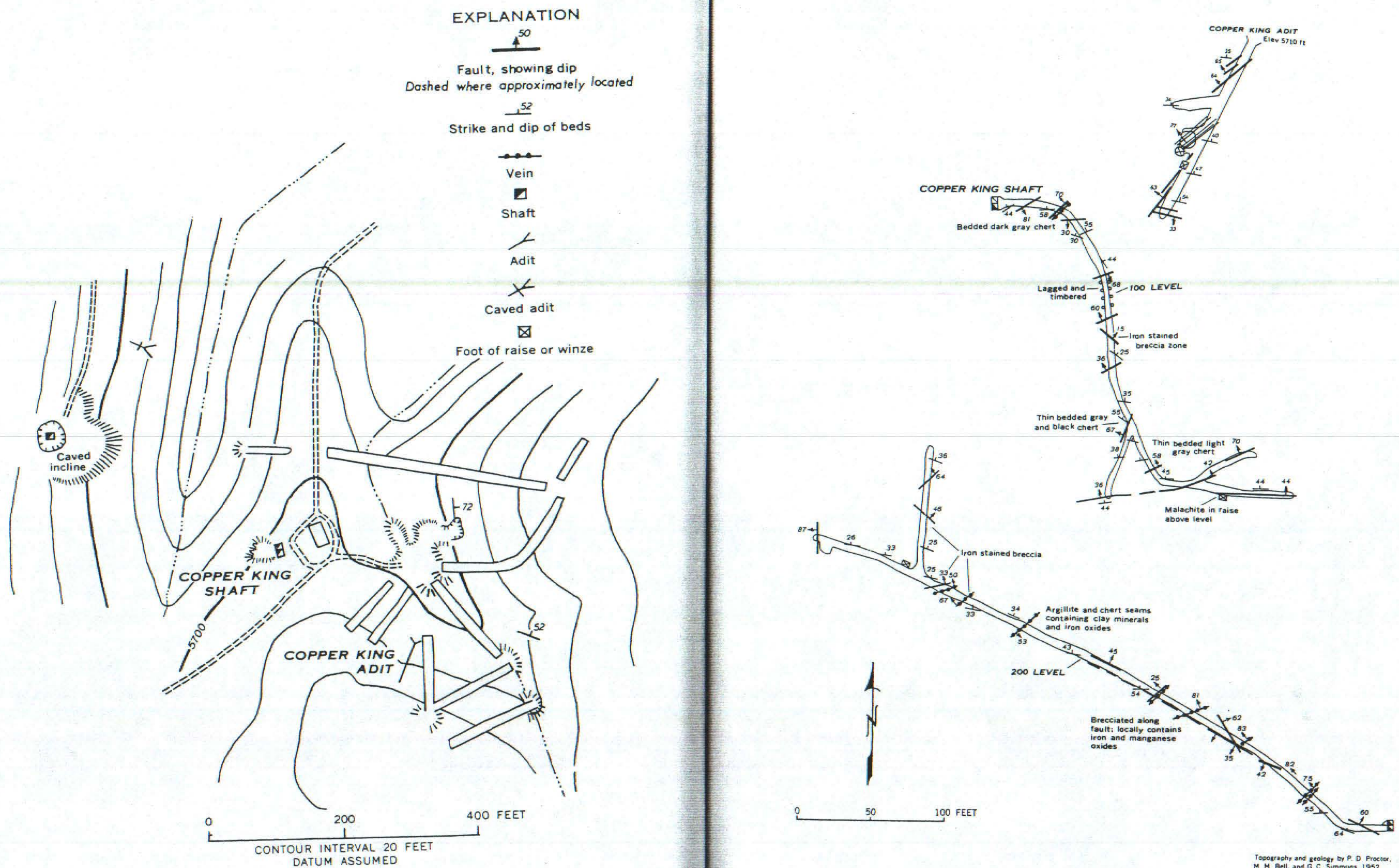


FIGURE 19. Maps of the Copper King mine, Maggie Creek district.

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named for Nicolas Modarelli and sons, who purchased the claim around 1946. In 1951 the J. R. Simplot Co., of Boise, Idaho, leased the property, located additional claims, and commenced mining. Production in 1951–52 totaled 263,000 long tons of ore averaging 57.8 percent iron (Shawe and others, 1962). In 1955–56, 118,000 long tons were shipped, and in 1959–61, 14,900 long tons. Total production through 1961 was 395,900 long tons (Muffler, 1964).

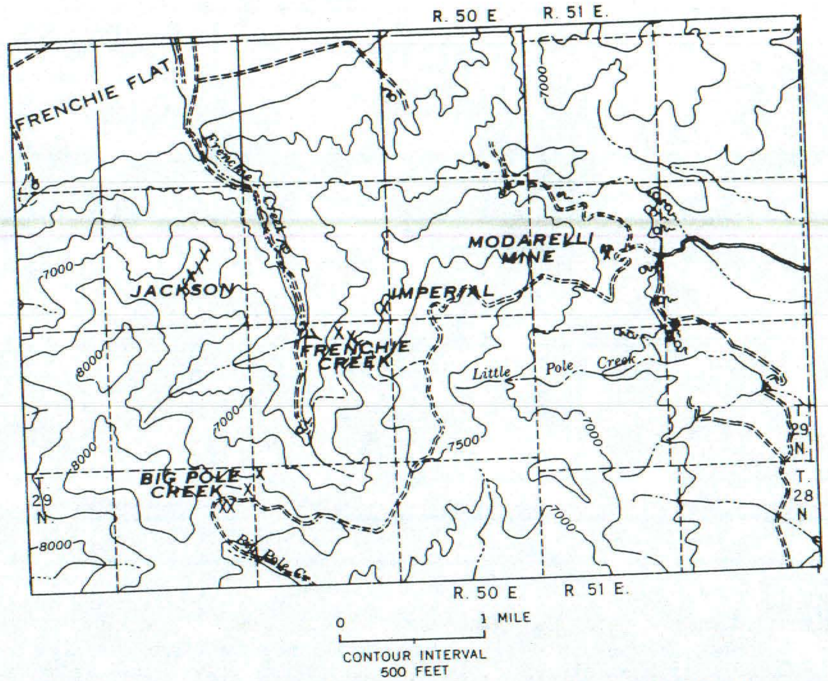

FIGURE 20. Map of the Modarelli-Frenchie Creek mining district.

The ore occurs as replacement of rhyodacite and rhyolite in Mesozoic volcanic flows (Muffler, 1964) and is localized at intersections of northwest- and northeast-trending faults that cut the area. Boundaries of the deposits are generally sharp, so that ore can be mined selectively. The dominant ore mineral is martite (hematite pseudomorphous after magnetite); gangue minerals are quartz, calcite, and apatite. Hershey (1908, p. 536) reported 6 to 7 percent phosphorus in samples from parts of the deposits; but, according to Kral (1947), none of the samples obtained during exploration by the U. S. Bureau of Mines in 1945 contained comparable amounts, although some specimens contained large amounts of fine-grained apatite.

The principal ore body is roughly triangular in plan and dips about 60° northeastward (pls. 9 and 10). The northeast side is 1,400 feet long; the south side, 900 feet; and the west side, 1,100 feet. The highest grade deposits are in the southeast half of the body. Mining has been from eight levels and several sublevels of an open cut. Several small iron ore bodies are exposed northwest and south of the main body (Shawe and others, 1962).

Mount Hope district

The Mount Hope district is on the southeast side of Mount Hope in the unsurveyed portions of T. 22 N., Rs. 51 and 52 E., 21 miles north of Eureka and 57 miles south of Palisade. Nevada State Highway 20 passes within a mile and a half of the main workings.

The district is in chert and shale of the Vinini Formation and conglomerate and limestone of the Garden Valley Formation. These rocks have been intruded by a rhyolite plug that forms Mount Hope.

Lead-zinc minerals were first discovered in this area in 1870 by Basques, who operated charcoal furnaces at Eureka. The only productive property in the district has been the Mount Hope mine.

Mount Hope mine. The Mount Hope mine consists of workings in four areas (pl. 11): the Lorraine workings, the Whim shaft, the Mount Hope No. 1 adit, and the Mount Hope No. 2 adit.

The major workings in the Lorraine area were opened in 1886. In 1890 Thomas Wren drove the Mount Hope No. 2 adit; Wren also sank the Whim shaft. In 1926 the U. S. Smelting, Refining, and Mining Co. drove the Mount Hope No. 1 adit, and in 1928 the property was optioned to the Universal Exploration Co. Universal prospected by churn and diamond drilling and purchased the property in 1930. Additional exploratory work was done by a number of lessees until the early 1940's, when Callahan Zinc-Lead Co. obtained a long-term lease and initiated an extensive drilling and development program, including the construction of a power plant and concentrating mill. Exploration in 1943, 1944, and 1945 included a drilling program conducted by the U. S. Bureau of Mines (Matson, 1946). The first concentrates were shipped in 1945, but the mine was shut down in 1947 after a fire destroyed the powerhouse. Production was not reported in the period 1947–57. Total production has amounted to more than $1 million (table 12).

The Lorraine workings consist of a main adit (O level) about 240 feet long and two shafts 90 and 135 feet deep with drifts on the 30-, 50-, 85-, and 130-foot levels, the total workings amounting to 1,769

TABLE 12. Production of gold, silver, copper, lead, and zinc from the Mount Hope mine, Mount Hope district, Eureka County, Nev.
(Based on production figures reported in U. S. Bureau of Mines Minerals Yearbooks.)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1941	....	4	1,000	....	....	$121
1944	27	4,377	....	6,526	349,130	50,034
1945	17	16,205	12,682	128,864	2,276,275	286,676
1946	....	....	....	....	....	(1)
1947	39	43,111	43,993	305,713	7,564,049	998,562
Total	83	63,697	57,675	441,103	10,189,454	1,335,393

[1]Production reported; figures not published, not included in totals.

feet (Matson, 1946, p. 5). The Whim shaft is 90 feet deep. The No. 1 adit is about 800 feet long and has about 3,255 feet of drifts, crosscuts, raises, and winzes. The No. 2 adit is 1,350 feet long and has about 1,745 feet of subdrifts, crosscuts, and raises. The mine workings explore the contact of an alaskite stock with the Paleozoic rocks. The ore bodies are replacement deposits in limestone roof pendants that have been wholly or partly engulfed by the alaskite stock. The principal ore minerals are marmatite, ferruginous sphalerite, galena, pyrrhotite, and chalcopyrite. The principal gangue minerals are calcite and garnet. A composite sample of ore from the No. 1 adit was analyzed by the U. S. Bureau of Mines with the following results (Matson, 1946, p. 6):

Constituent	Zn	Cd	Cu	Pb	Fe	S	CaO	MgO	Al_2O_3	Insol.
Percent	13.45	.6	.1	.05	10.6	13.2	12.8	3.6	1.8	50.4

	Ounces per ton
Au	trace
Ag	0.96

Roberts district

The Roberts district is on the west side of the Simpson Park Mountains. Devonian limestone, which has been intruded by granodiorite, is exposed in the Keystone window. The Keystone mine is the only productive property in the district. Many other prospect pits have been dug in altered zones along faults and intrusive contacts.

Keystone mine. The Keystone mine (fig. 21) is in the NE¼ sec. 26, T. 24 N., R. 48 E., about a mile northeast of Walti Hot Springs. The workings consist of two adits and shallow surface trenching along a contact between intrusive granodiorite and limestone of Devonian Age. According to White (1871, p. 44), the mine was discovered in 1870 by Roberts and Tucker; it is now owned by Fred Komp and Ezra Edwards of Beowawe, Nev. The amount of production during the early days is not known. A mill erected about 1910 operated a short time and then was dismantled. Shipments made in 1948, 1949, and 1962 yielded the following:

Year	*Tons*	*Silver (ounces)*	*Lead (pounds)*	*Copper (pounds)*	*Zinc (pounds)*	*Total value*
1948	44	44	10,400	----------	10,000	$3,285
1949	29	16	3,100	----------	5,000	1,124
1962	41	357	4,400	1,400	4,800	----------

Production was not reported for the period 1950 through 1961.

The primary ore minerals are sphalerite, galena, pyrite, and a little chalcopyrite in tactite, formed along the granodiorite contact. Near the surface the galena was said to be argentiferous (Whitehill, 1875, p. 61); at a depth of 25 feet copper ore was found.

The ore bodies are lenticular pods in tactite. In the lower adit tactite, limestone, and granodiorite with sparse sulfides are exposed. In the upper adit, about 1,500 feet S. 60° E. from the lower adit, tactite layers with galena, sphalerite, pyrite, and chalcopyrite have been stoped above the level for a length of 30 feet, width of 5 feet, and height of 15 feet. This stope is probably the source of the ore shipped in 1948–49.

Safford district

The Safford district is in T. 31 N., R. 51 E., in the northern part of the Cortez Mountains. The first mineral discovery in the district was the Barth iron deposit at the mouth of Safford Canyon (fig. 22), which was located prior to 1869, probably by surveyors mapping the railroad route along the Humboldt River (Browne, 1869). The district is named after Benjamin Safford, who discovered silver ore on the site of the present Onondaga property in 1881 (Vanderburg, 1938, p. 59).

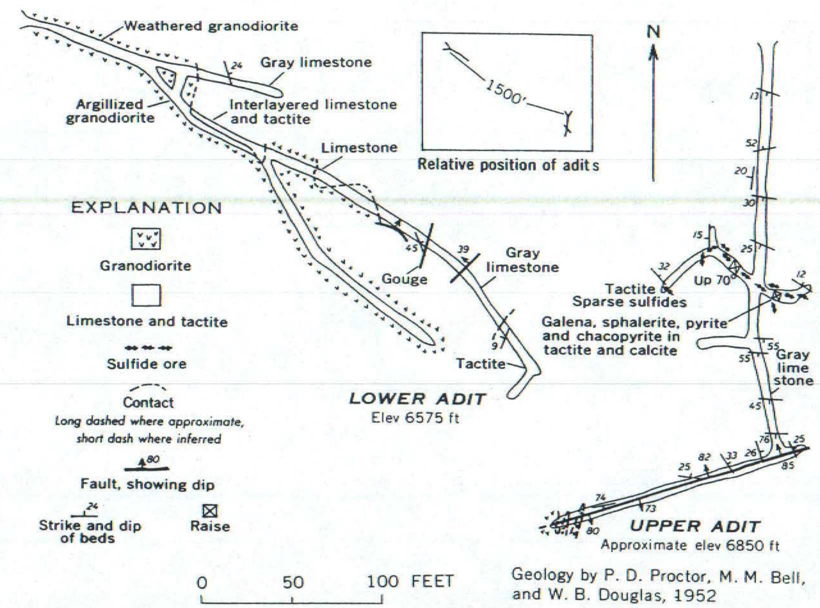

FIGURE 21. Map of the Keystone mine, Roberts district.

Production of iron ore from the Barth mine has had an estimated total gross value of about $8 million. The value of silver produced in the district is a little more than $227,000. Table 13 shows the only figures available for gold, silver, copper, and lead.

Ore occurs in the older of two volcanic sequences that crop out in the area.

Barth mine. The Barth mine, also known as the West iron mine (Jones, 1913; Vanderburg, 1938, p. 62), is in sec. 7, T. 31 N., R. 51 E., at the mouth of Safford Canyon. The main lines of the Southern Pacific and the Western Pacific Railroads pass within a few hundred feet of the mine, which is served by a railroad spur. There is an unpaved road leading to the property from the west.

Between 1903 and 1918, the American Smelting and Refining Co. leased the property from the southern Pacific Land Co. and produced from the mine 544,295 tons of ore with a gross value of $1,912,956 (Couch and Carpenter, 1943).

The workings in 1962 (fig. 23) consisted of an open pit measuring some 800 by 1,000 feet across and about 70 feet in depth.

TABLE 13. Production of gold, silver, copper, and lead from the Safford district, Eureka County, Nev.[1]

(Based on production figures reported in U. S. Bureau of Mines Minerals Yearbooks and U. S. Bureau of Mines, Mineral Resource Office.)

Year	*Gold (ounces)*	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Total value*
1934	.5	1,372	510	....	$944
1936	....	....	....	....	(2)
1937	....	1,545	100	21,300	2,464
1938	....	9,072	2,000	7,000	6,383
1939	....	10,285	4,500	1,300	7,510
1940	1	4,860	5,100	3,000	4,217
1941	47	5,224	1,000	8,800	5,980
1947	....	237	200	....	256
1965	1	2,230	1,800	200	3,588
1966	....	2,450	682	2,143	3,734
Total	49.5	37,275	15,892	43,743	35,076

[1]Breakdown of figures for earlier years not available.
[2]Figures not released by company for publication and not included in total.

The ore occurs as replacement deposits in andesitic volcanic rocks of Mesozoic Age which dip gently westward (Shawe and others, 1962; Reeves, 1964). Quartz monzonite intrudes similar rock about 1,800 feet west of the pit. The ore mineral is massive hematite containing small scattered apatite crystals. At the hanging-wall contact the ore is magnetic, and it is inferred that magnetite originally was a constituent of the ore. The ore body at the surface was about 1,000 feet long and 200 feet wide with a 45° NE. dip to vertical; about 200 feet below the surface the deposit tapers to 50–100 feet thick. Andesite forms the wall rock on the south and west; Quaternary gravel and sand rest on the ore on the north and east. The footwall of the ore body is undulatory, and the hanging wall is smooth. Veins of iron oxides extend into the footwall, cementing brecciated andesite.

In 1954 the Southern Pacific Land Co. resumed exploration and found that the ore body extended northwest of the old workings under the Humboldt River channel (Shawe and others, 1962). The river was later diverted and in 1960 shipments of iron ore were resumed from the property by the Nevada Barth Corp. (U. S. Bur. Mines, 1961, p. 654; Charles S. Winston, oral communication, 1964).

Shipments through 1964 are summarized below.

[Figures furnished by Overseas Central, Inc. Published by permission.]

	Long tons (wet)
1961	201,272
1962	152,217
1963	129,731
1964 (Jan.-Sept.)	115,431
Estimated Fe content	63–64%.
Estimated moisture content	4%.

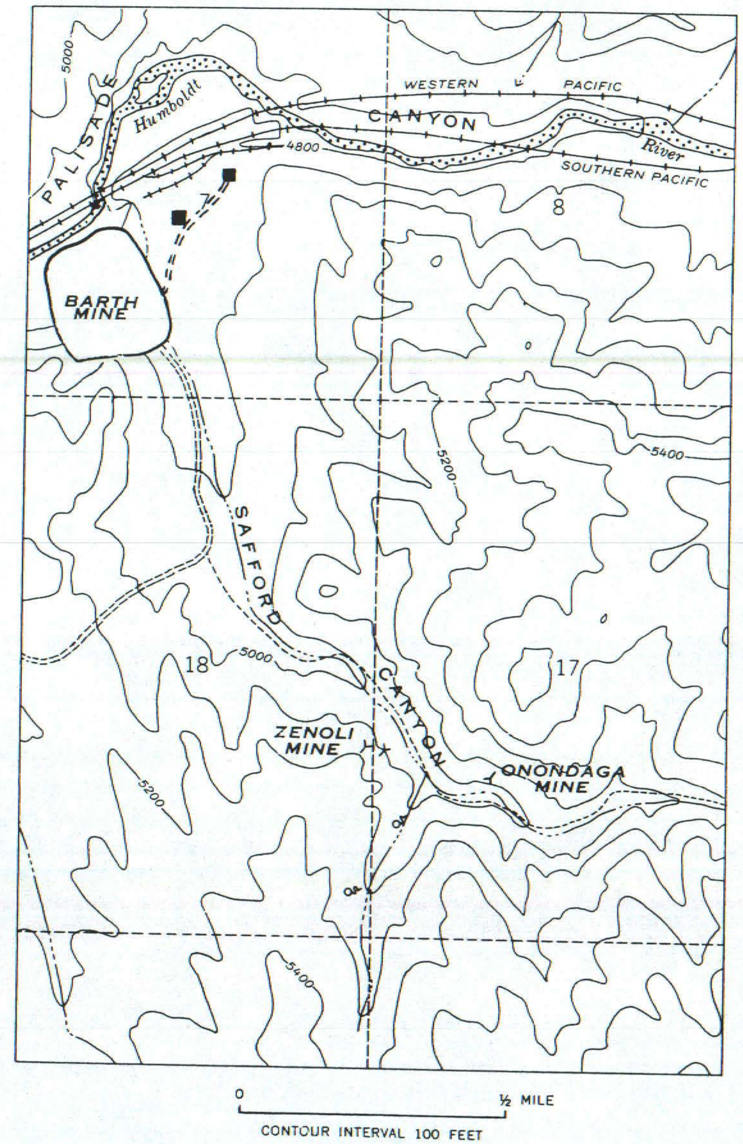

FIGURE 22. Map of the Safford mining district.

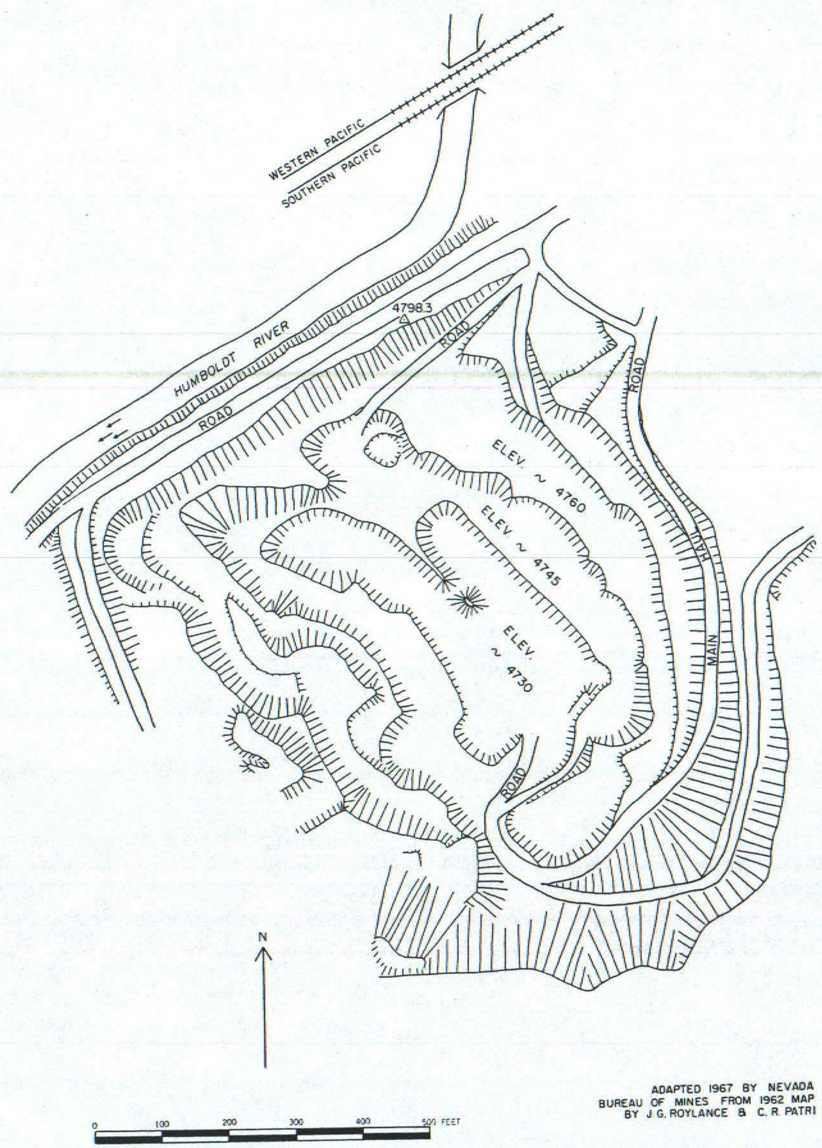

FIGURE 23. Map of the Barth (West) mine, Safford district.

Zenoli mine. The Zenoli mine is in the SW¼ sec. 18, T. 31 N., R. 51 E., in Safford Canyon, about a mile from the Barth mine (fig. 24). The property was located in 1883 by Gabriel Zenoli and Francisco Thoma (Vanderburg, 1938, p. 59), and the Zenoli Silver Copper Co. was formed in 1907 (Emmons, 1910, p. 111). During 1907 and 1908, shipments totaled 1,439 tons of ore valued at $67,162 (Couch and Carpenter, 1943, p. 64). The mine was relocated in 1930 by Nicolas Modarelli and sons, of Beowawe, as part of the Morning Glory group of claims.

The workings consist of four adits, shafts, and connecting drifts and crosscuts, totaling about 3,000 feet (Vanderburg, 1938, p. 60). The ore is in barite-carbonate veins containing sphalerite, galena, chalcopyrite, and pyrite in andesitic volcanic rock, which covers much of this area. The principal values have been in silver, but the ore also contains significant amounts of copper and zinc and a little antimony (Lawrence, 1963, p. 70).

Onondaga mine. The Onondaga mine is in the SW¼ sec. 17, T. 31 N., R. 51 E., on the north side of Safford Canyon, about a quarter of a mile east of the Zenoli property. Benjamin Safford located the mine in 1881. In 1921 it was relocated by Charles W. Pratt, of Palisade, and in 1935 was taken over by the Silver Bromide Mining Co. of Salt Lake City. In 1937 Silver Bromide was leased to H. G. Brown, P. R. Jones, and L. W. Vernon (Vanderburg, 1938, p. 61). The property apparently includes the Ruby and Malachite claims described by Emmons (1910, p. 112). Development consists of several adits, a shaft, and other workings, totaling about 2,000 feet (fig. 25). The ore is pyritized andesitic volcanic rock. Silver has been the most valuable constituent of the ore, which also contains minor amounts of lead, copper, and gold.

Union district

The Union district (pl. 12) is in the Sulphur Spring Range about 45 miles by road north of Eureka in unsurveyed land in T. 26 N., R. 53 E. The first mineral discovery in the area was made by James Lindsay in 1886 (Vanderburg, 1938, p. 64). A small smelter was erected in 1887 and several hundred tons of ore were treated. Between 1915 and 1918 the Union Mines Co. operated the property.

The district is underlain by chert and shale assigned to the Vinini Formation which have been thrust upon limestone of Devonian Age. The ore deposits occur in the limestone in and near north- and east-trending fracture zones. Most of the production of silver-lead ore has been from the oxidized zone.

Union Mines Company. The Union Mines Co. owned by W. P. Fairman and associates of Philadelphia, Pa., holds 12 patented claims in the district. The property is developed by four shafts, 200, 250, 300, and 550 feet deep, and 4,000 feet of other workings. Production between 1915 and 1918 totaled 7,088 tons valued at $175,802; in 1951 production was 375 ounces of silver and 9,000 pounds of lead valued at $1,896; in 1955 production was 381 ounces of silver and 5,800 pounds of lead valued at $1,221.

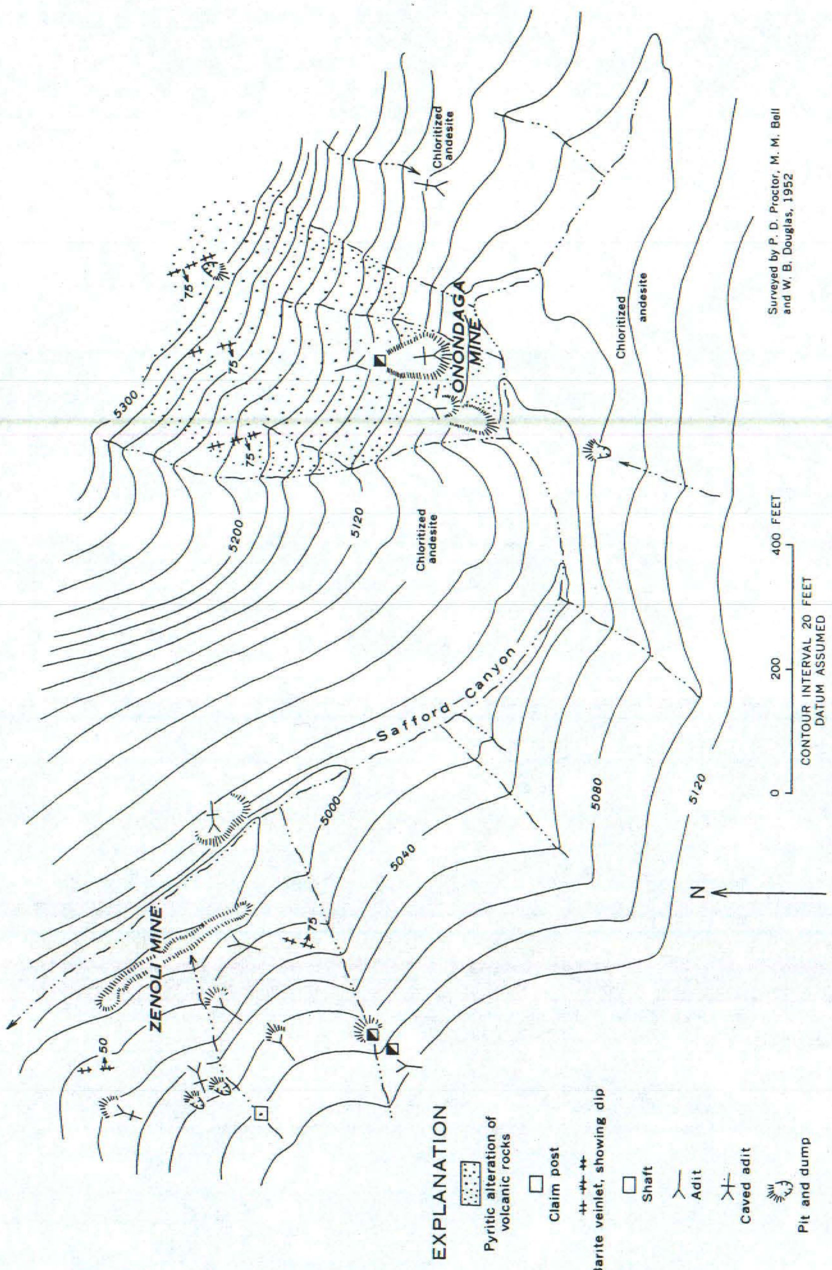

FIGURE 24. Map of the Zenoli-Onondaga area, Safford mining district.

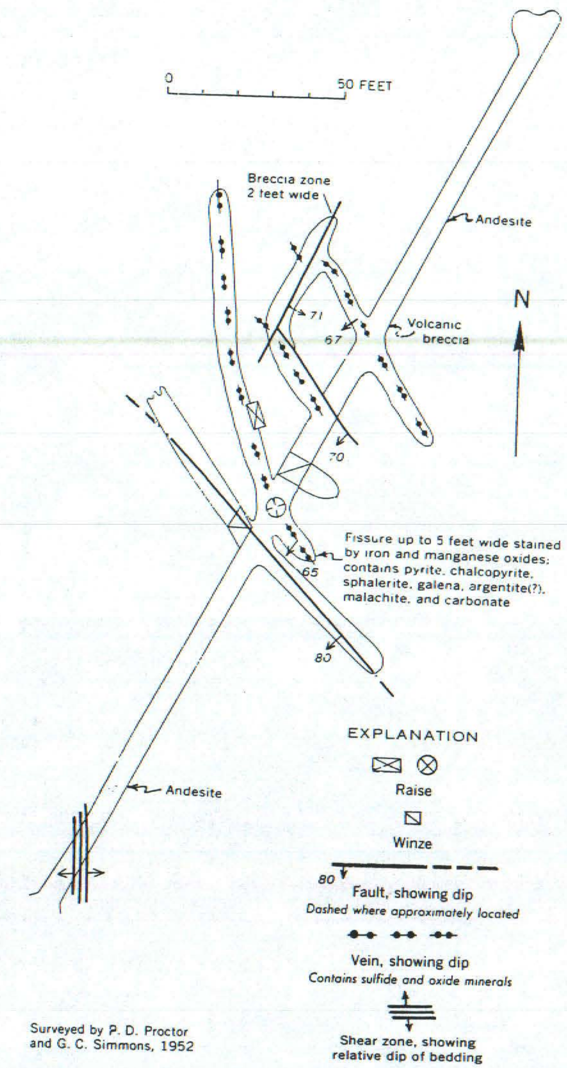

FIGURE 25. Map of the Onondaga mine, Safford district.

The ore occurs as irregular replacement bodies in limestone. Most of the ore shipped averaged 25 percent lead, 10 to 12 ounces silver, and 15 percent iron (Vanderburg, 1938, p. 65).

NONMETALLIC MINERALS

Nonmetallic minerals contributed comparatively little production during the early days of mining in Eureka County, but salt from Diamond Valley was used in the chlorination process for recovery of silver during the 1870's. More recently, production of barite has been significant, and exploration for petroleum has been carried on at several places. Deposits of materials useful in the construction industry are widely distributed throughout the county; they are principally quarried by County and State agencies for use on roads. Rock also is quarried for use as track ballast by a contractor for the Southern Pacific Railroad.

Deposits of limestone and dolomite in Eureka County are widespread, and may be of future value in industrial processes. The Eureka Quartzite, which crops out in the southern part of the Lynn district and in other parts of the county, likewise may become a valuable resource.

Deposits of perlite are reported in eastern Eureka County near Carlin; no production has been reported (Gemmill, 1964, map, p. 235). Pumicite deposits southwest of Carlin in sec. 25, T. 32 N., and R. 51 E. have been mined intermittently (Vanderburg, 1938, p. 58; Horton, 1964b, p. 240).

Asphaltite

According to Anderson (1909), veins of asphaltite cut sandstone and shale on the east side of Pine Valley about 15 miles south of Palisade. The veins strike N. 75° W. and dip 50°–60° NE., and are as much as 16 inches wide.

Prof. Walter S. Palmer at the Mackay School of Mines laboratory, Reno, Nev., analyzed specimens of the asphaltite and found that it contained vanadium (Vanderburg, 1938, p. 57):

	Percent V_2O_5
Original sample	0.16
Ash and impurities	6.4
Minus 20-mesh ash	24.8

Another sample (Vanderberg, 1938, p. 57), analyzed by the Union Assay office in Salt Lake City, gave the following result:

	Percent
Gold	Trace
Silver	None
V_2O_5	0.918
U_3O_8	.097

Barite

Barite deposits have been noted in the Maggie Creek and Alpha districts (Horton, 1962; 1964a, p. 177–179) and a number of other localities in the county. The Maggie Creek mine, which has been described by Vanderburg (1938, p. 64), is in the E½ NE¼ sec. 27, T. 34 N., R. 51 E., on the west side of Maggie Canyon. Massive barite occurs in a vein in shaly limestone that strikes S. 30° E., dips 70° E., and averages 10 feet in width. Impurities are iron oxides and silica. Total production is over 10,000 tons with a specific gravity of 4.2 (Horton, 1962). On the south end of the Good Hope group of claims is a vein that was mined by the Industrial Minerals and Chemical Co. of Berkeley, Calif., in 1935–36 (Vanderburg, 1938, p. 64). Three veins have been explored; the main vein strikes N. 25° W. and dips 75° NE.; along the vein, stopes are as much as 20 feet wide and 40 feet high in fractured chert and limestone. The barite filled fractures for the most part but locally replaced limestone.

The Alpha prospect (Horton, 1962) is at the Old Whalen mine, in the SW¼ sec. 34, T. 25 N., R. 52 E. Deposits also have been noted in the Lynn district (Gianella, 1940, p. 298) and at the Bear mine in the Union district.

Diatomaceous Earth

Diatomaceous earth deposits have been reported (Vanderburg, 1938; Olson, 1964a, p. 191) in the hills "several miles north and northwest of Palisade." The deposits are said to be extensive, and claims have been staked on them, but to date there has been very little production. Diatomite beds have also been mapped in Tertiary sediments on the south side of Lone Mountain (C. W. Merriam, oral communication, 1958).

Petroleum

Exploratory drilling for oil has been carried on sporadically in Eureka County for several years, but as yet no commercial quantities have been discovered. The first interest was in the vicinity of a live oil seep in sec. 11, T. 27 N., R. 52 E., on the Bruffey Ranch. The oil presumably rises from the Vinini Formation along a north-south fault that can be traced for several miles on the surface. The site was first drilled in the spring of 1951 (Lintz, 1957a, p. 42). Since then a number of holes have been drilled in the area by the Eureka Oil Co. and the Eureka Leasing and Drilling Co., but oil has not been reported (Lintz, 1957a, p. 42; Grace M. Nolan, written communication, 1959). The Nepple and Ebert No. 1 Government well, sec. 3, T. 27 N., R. 52 E., was abandoned in 1955 at a depth of 4,900 feet; oil was not reported (Lintz, 1957b, p. 245; Grace M. Nolan, written communication, 1959). The Last Frontier No. 1 Damele well, sec. 6, T. 26 N., R. 51 E., was abandoned in 1957 (National Oil Scouts and Landmen's Assoc., 1958), although shows of oil were reported in Tertiary rock; total depth at the end of 1956 was 3,500 feet (Lintz, 1957b, p. 245). The Shell Oil Co. No. 1 Diamond Valley well was abandoned in 1956 at a total depth of 8,042 feet (Lintz, 1957b, p. 245); the top of Paleozoic rock was logged at 7,485 feet (Johnson, 1959, p. 152); oil was not reported.

Along Vinini Creek and at other localities in the Roberts Mountains, Merriam and Anderson (1942, p. 1696) noted that the upper part of the Vinini Formation contains black organic shales that can readily be ignited; oil yield on distillation of selected samples was above 25 gallons per ton. The possibility of oil accumulation in fault traps within thrust plates in this area is recognized, but structural complexity has discouraged exploration.

Salt

The northern end of Diamond Valley is a playa that becomes a shallow lake following rainstorms and heavy run-off in the spring; normally the water stands a few feet below the surface. The surface is encrusted with salts containing about 60 percent NaCl, and the muds are saturated with brine, reported by Whitehill (*in* Vanderburg, 1938, p. 65) to contain about 12 percent salt.

These deposits were worked during the 1870's for salt used in the chloride process of silver extraction from oxidized ores at Eureka, Mineral Hill, and Hamilton (White Pine County). The salt was at first obtained by collecting the surface incrustations, but later evaporating pans were installed, which had a capacity of 5,000 pounds of salt daily (Lincoln, 1923, p. 89; Horton, 1964c, p. 253).

Sulfur

Sulfur deposits at Hot Springs Point (fig. 26) in NE¼ sec. 11, T. 29 N., R. 48 E., about 10 miles southeast of Beowawe, have been explored during recent years but no production, except for mineral specimens, has been recorded. The rocks in the area are mainly quartzite, shale, and chert of the Valmy Formation which, half a mile to the north, are overlain by basaltic or andesitic flows of Tertiary Age.

The sulfur, associated with gypsum and iron oxides, forms veins and breccia filling sporadically distributed in fractured and altered rock along a northeast-trending range-front fault. Hot springs, which apparently rise along the same or parallel faults, emerge just northwest of the area. The deposit has been explored by shallow cuts and short adits. Small amounts of cinnabar and antimony oxides occur in the deposit (Olson, 1964b, p. 257).

FOSSIL DATA

During the course of field work in Eureka County, many collections of fossils were made. Most of these were studied by paleontologists of the U. S. Geological Survey, who prepared reports listing the forms present and their ages if determinable. No attempt was made to collect fossils from all sedimentary units exposed in the county; most collections were made to confirm or establish age assignments of units that might be mistaken for others during rapid reconnaissance. Only a summary of the reports is given here.

Numbers used for identification, such as 54 F 83, are field collection numbers. The same numbers appear on plate 3 to show locations from which specific fossils were recovered. Additional identification, such as (D 148 €O), has been given to specimens that are now part of the permanent collection of the Paleontology and Stratigraphy Branch of the

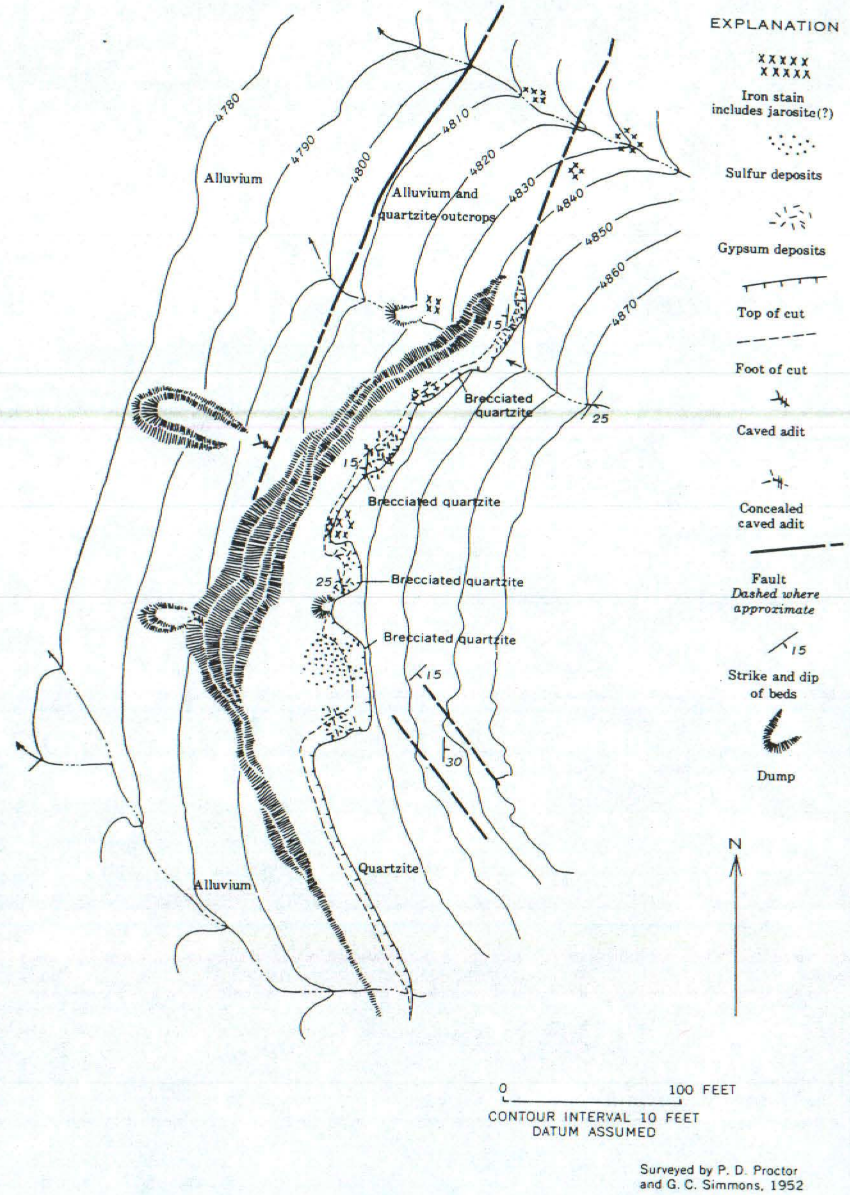

FIGURE 26. Map of sulfur deposit at Hot Springs Point.

U.S. Geological Survey in either the U. S. National Museum, Washington, D. C., or the Federal Center, Denver, Colo.

Fossils are arranged according to decreasing age within their appropriate assemblages and time periods. Names of U. S. Geological Survey paleontologists responsible for identifications are given below each description.

A large number of the fossils collected are graptolites. Figure 27 shows their relative ages and how they fit into the standard sections of the eastern United States and Wales.

EASTERN ASSEMBLAGE

Pogonip Group

54 F 23 (D 148-ЄO) NW¼ sec. 11, T. 16 N., R. 48 E., 7,600 ft. elev., south side of Brock Canyon west of Charnac Basin, Monitor Range, Roberts Mountains quadrangle.

Orthidiella? sp. Very doubtfully referred on the basis of one pedicle valve.

Paranileius? cf. *P. ibexensis* Hintze.

Caryocaris? sp.

Dolomitic rock of this sample does not look like the upper Pogonip to the east, but I believe it is correlative with that unit.

R. J. Ross, Jr.

54 F 24 SE¼ sec. 11, T. 16 N., R. 48 E., 8,200 ft. elev., Charnac Basin south of Brock Canyon, Monitor Range, Roberts Mountains quadrangle.

This collection contains a *Raphistoma* (range, Middle Ordovician to Silurian) and numerous cross sections of *Palliseria*. The specimens are incomplete, but insofar as one can tell they are conspecific with *Palliseria longwelli* (Kirk) which is "... highly characteristic of a fairly narrow zone within the upper portion of the Pogonip. This is of Chazy age. . . ." (Kirk, 1929, p. 1).

E. L. Yochelson

54 F 28 NE¼ sec. 3, T. 16 N., R. 52 E., Fish Creek Range, Bellevue Peak quadrangle.

Etching this collection in hydrochloric acid produced a gastropod representing a new genus related to *Maclurites* and an incomplete specimen of *Trochonema* or, less likely, *Lophospira*. This does not prove Ordovician Age but suggests strongly that your tentative age assignment (Pogonip Group) may be correct.

E. L. Yochelson

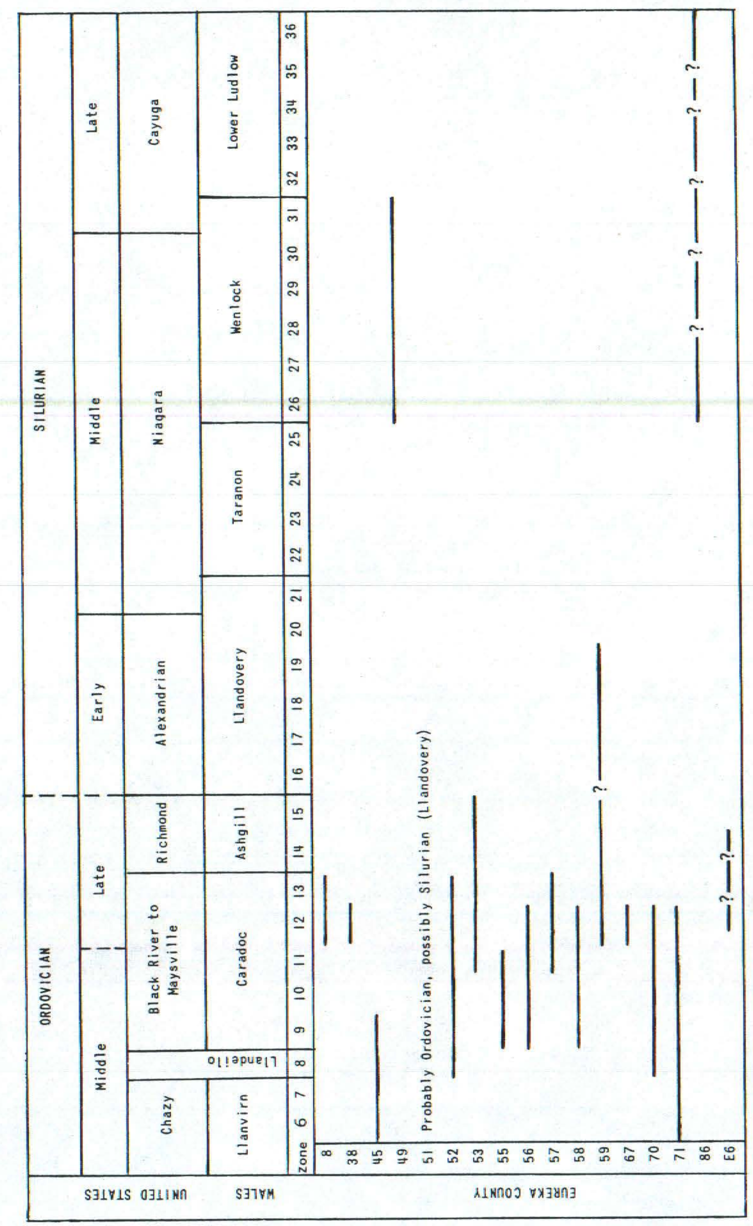

FIGURE 27. Chart showing relationship of graptolite zones of Wales (Elles and Wood, 1914) and United States and ranges of collections from Eureka County. Compiled by R. J. Ross, Jr.

54 F 29 — Sec. 7, T. 16 N., R. 49 E., 7,800 ft. elev., Charnac Basin, Monitor Range, Antelope Peak quadrangle.

Orthidiella cf. *O. longwelli* Ulrich and Cooper.
Orthis cf. *O. paucicostata* Ulrich and Cooper.

These two species are found high in the Pogonip Group of Nevada. Originally described from Frenchman Flat, 700 feet below the Eureka Quartzite.

R. J. Ross, Jr.

Hanson Creek Formation

54 F 68 — Tuscarora Mountains, J. Ammann photo index 29 NW, photo 34N–12.

Streptelasma trilobatum (Whiteaves)
Streptelasma sp.
Favosites sp.
Catenipora sp.
Palaeophyllum sp.

This association is typical of the Fish Haven Dolomite and parts of the Hanson Creek Formation of Late Ordovician Age.

J. M. Berdan

Roberts Mountains Formation

53 G 9 (4804–SD) — T. 34 N., R. 51 E., unsurveyed, Carlin Window, Maggie Canyon, Tuscarora Mountains.

Contains a rich silicified fauna of corals, brachiopods, ostracodes, bryozoa, and other forms which have a distinct Silurian aspect and appear similar to collections made from the Roberts Mountains Formation in the type area.

J. M. Berdan

54 F 30 — NW¼ sec. 20, T. 25 N., R. 49 E., Simpson Park Mountains, Horse Creek Valley quadrangle.

Monograptus sp.

Silurian lower part of Roberts Mountains Formation.

C. W. Merriam

54 F 31 — NW¼ sec. 20, T. 25 N., R. 49 E., Simpson Park Mountains, Horse Creek Valley quadrangle.

Monograptus sp.

Silurian. Lower part of Roberts Mountains Formation.

C. W. Merriam

54 F 86 — Sec. 27, unsurveyed, T. 34 N., R. 51 E., in Maggie Creek.

Monograptus sp.

Specimens are poor but definitely *Monograptus*. They seem to resemble *M. dubius* or *M. vulgaris*, but this is little more than inference. If correct, it would suggest correlation with British Wenlock and/or Lower Ludlow. This in turn might suggest Lone Mountain rather than Roberts Mountains.

R. J. Ross, Jr.

54 Fa (USNM 12732) (Not shown on map) — T. 36 N., R. 49 E., Elko County, Nev. Lynn Window No. 1, Boulder Creek area. Talus at foot of bluff on east side of road, north of 41st parallel. Coll.: A. J. Boucot, July, 1966.

Ptychopleurella sp.
Dolerorthis sp.
Skenidioides sp. (very fine ribs)
Dicaelosia sp.
Dalejina sp.
Resserella sp.
Isorthis sp.
Conchidium aff. *bilocularis* (abund.)
Conchidium sp. (fine ribs)
Kirkidium? sp.
Gypidula sp.
Morinorhynchus? sp.
Ferganella sp.
Atrypa sp.
Atrypella sp. (small)
Cryptatrypa "triangulata"
Spirigerina sp.
Gracianella plicumbra (v. abund.)
Nucleospira sp.
Meristina sp.
Howellella sp. (strongly plicate)
misc. nonbrachs.

The collection from locality 12732 is of Ludlow Age and closely resembles collections of the same age found between 130 and 295 feet above the base of the Roberts Mountains Formation, east of Birch Creek on the north flank of the Roberts Mountains. The latter horizons overlie beds with lower Ludlow (*M. nilssoni-M. scanicus* zone) graptolites, which were identified by Bill Berry.

A. J. Boucot and J. G. Johnson*

*Now at California Institute of Technology.

54 Fa (USNM 12733) (Not shown on map) — T. 36 N., R. 49 E., Elko County, Nev. Lynn Window No. 2, Boulder Creek area. Top of bluff about 200 feet east of west edge, north of 41st parallel. Coll.: A. J. Boucot, July, 1966.

Schizophoria sp.
Salopina cf. *crassiformis*
Howellella? sp.
Gypidula sp.
indet. brach.
Atrypa sp.

The collection from locality 12733 is of Gedinnian (Early Devonian) Age and closely resembles the fauna from the upper 600 feet of the Roberts Mountains Formation, east of Birch Creek.

A. J. Boucot and J. G. Johnson*

Devonian Eastern Undifferentiated

54 F 37 (4950–SD) — T. 34 N., R. 51 E., northeast of Maggie Canyon.

Ostracodes:
Chironiptrum sp.
New genus aff. *Halliella*
Tubulibairdia
Birdsallella

Conodont:
Icriodus latericrescens Branson and Mehl

Coral:
Favosites sp.

Although the ostracodes could be either Lower or Middle Devonian, the conodont indicates a Middle Devonian Age, according to W. H. Hass. A similar ostracode association, including the new genus aff. *Halliella,* occurs in one of James Gilluly's collections from the Cortez Mountains (4933–SD).

J. M. Berdan

56 EF 1 (4897–SD) — T. 35 N., R. 50 E., unsurveyed, J. Ammann photo index 29 NW, photo 34N–150, Tuscarora Mountains.

Amphipora sp.
zaphrentoid horn coral cf. *Papiliophyllum*
Leptocoelia sp. cf. *L.* infrequens (Walcott)
Tentaculites sp.

*Now at California Institute of Technology.

The rock appears to be a conglomerate . . . in which the fossils are clastic particles. The branching stromatoporoid *Amphipora* is very common in late Middle and early Late Devonian rocks of the Great Basin, but might occur in somewhat older rocks. According to Merriam (1940, p. 54), *L. infrequens* occurs in the *Spirifer pinyonensis* zone of the Nevada limestone. The chances are, therefore, that the conglomerate is not older than Middle Devonian, but as the fossils have been reworked, it is not possible to put a precise upper age limit on it.

J. M. Berdan

56 EF 2 — T. 35 N., R. 50 E., unsurveyed, J. Ammann photo index 29 NW, photo 34N–150, Tuscarora Mountains.

The collection . . . is considered to be probably from the high Middle or low Upper Devonian. The prepared material of the collection contained the following genera and species; much of the material is fragmentary (figures in parentheses indicate number of recognized specimens).

Ancyrodella sp. (1)
Bryantodus sp. (2)
Hibbardella sp. (1)
Hindeodella sp. (1)
Icriodus sp. (5)
Ligonodina sp. (2)
Neoprioniodus sp. (1)
Ozarkodina sp. (8)
Polygnathus dubia rotundiloba Bishoff and Ziegler (4)
Polygnathus pennata Hinde (12)
Roundya sp. (1)
Synprioniodina sp. (1)
Unrecognizable bar-like and blade-like fragments

. . . *Ancyrodella* (whose recorded stratigraphic range is Middle and Upper Devonian); *Icriodus* (Devonian); *Polygnathus dubia rotundiloba* (high Middle and low Upper Devonian); and *Polygnathus pennata* (Middle and low Upper Devonian).

W. H. Hass

Nevada Formation

54 F 9 — SW¼ NW¼ sec. 4, T. 23 N., R. 48 E., south southeast of Walti Ranch, Keystone Window, Simpson Park Range, Walti Hot Springs quadrangle.

In float:
Favosites sp. Silurian or Devonian.

C. W. Merriam

54 F 10 — SW¼ NW¼ sec. 4, T. 23 N., R. 48 E., south southeast of Walti Ranch, Keystone Window, Simpson Park Range, Walti Hot Springs quadrangle.

Leptaena sp.
stropheodont brachiopod
hexactinnellid spicules
Phacops sp. (large form)
Proetus cf. *nevadae*

Probably lower Nevada Formation.

C. W. Merriam

54 F 10a — NW¼ SE¼ sec. 4, T. 23 N., R. 48 E., southeast of Walti Ranch about 200 feet above 54 F 10, Keystone Window, Simpson Park Range, Walti Hot Springs quadrangle.

Chonetes cf. *deflecta*
Styliolina sp.
Phacops sp. (small form)

Probably middle Nevada Formation near base of *Martinia kirki* zone.

C. W. Merriam

54 F 11 — NW¼ SE¼ sec. 4, T. 23 N., R. 48 E., 6,200 ft. elev., southeast of Walti Ranch, south of 54 F 10a, Keystone Window, Simpson Park Range, Walti Hot Springs quadrangle.

Styliolina sp.

This appears to be the form which is abundant in the middle Nevada Formation near base of *Martinia kirki* zone.

C. W. Merriam

54 F 13 — Center, SE¼ sec. 34, T. 23½ N., R. 48 E., 7,800 ft. elev., east of Walti Ranch, Keystone Window, Simpson Park Mountains, Walti Hot Springs quadrangle.

Smooth spiriferoids, possibly *Martiniopsis* or *Athyris*.

Devonian(?). Could be *Martinia kirki* zone.

C. W. Merriam

54 F 15 — NW¼ sec. 3, T. 23 N., R. 48 E., 7,000 ft. elev., south of Walti Ranch, Keystone Window, Simpson Park Mountains, Walti Hot Springs quadrangle.

Styliolina sp.

Devonian. This form is abundant near base of *Martinia kirki* zone.

C. W. Merriam

54 F 19 — SE¼ SW¼ sec. 16, T. 24 N., R. 49 E., Tonkin Window, Simpson Park Mountains, Roberts Creek Mountain quadrangle.

Martinia kirki
Stropheodonta sp.
Receptaculites sp.

Middle Devonian. *Martinia kirki* zone. The *Receptaculites* is identical to that in the *M. kirki* zone of the Antelope Range, Nevada, being the only occurrence of this group known to me in North America outside the Ordovician. It occurs in the Devonian of Australia.

C. W. Merriam

54 F 32 — NW¼ NW¼ sec. 19, T. 24 N., R. 49 E., Simpson Park Mountains, Roberts Creek Mountain quadrangle.

Styliolina sp.

Probably Middle Devonian. This form common near base of *Martinia kirki* zone.

C. W. Merriam

54 F 33 — NE¼ sec. 18, T. 24 N., R. 49 E., north side of Pat Canyon, Simpson Park Mountains, Roberts Creek Mountain quadrangle.

Alveolites sp.
?*Cladopora* sp.
Other indeterminate corals.

Silurian or Devonian.

C. W. Merriam

54 F 35 — SW¼ sec. 7, unsurveyed, T. 25 N., R. 50 E., Simpson Park Mountains, Horse Creek Valley quadrangle.

Massive thick-walled favositid, like *Thamnopora* but not branching.

Devonian. Nevada Formation(?).

C. W. Merriam

54 F 36 — NW¼ sec. 17, unsurveyed, T. 25 N., R. 50 E., southwest flank of Red Hill, Simpson Park Mountains, Horse Creek Valley quadrangle.

Atrypa cf. *missouriensis*
Favosites sp.

Middle Devonian. Nevada Formation.

C. W. Merriam

54 F 42 — NW¼ SW¼ sec. 21, T. 25 N., R. 49 E., Windmill Window, Simpson Park Mountains, Horse Creek Valley quadrangle.

Anoplotheca cf. *acutiplicata*
Leptaena sp.
Strophonella cf. *punctulifera*
Phacops sp.
Proetus sp.
Spirifer kobehana
streptelasmoid coral
Spirifer pinyonensis?

Devonian. Lower Nevada Formation; *Spirifer kobehana* zone.

C. W. Merriam

54 F 43 — NE¼ SE¼ sec. 21, T. 25 N., R. 49 E., inlier east of Windmill Window, Simpson Park Mountains, Horse Creek Valley quadrangle.

Delicate, structured, tabulate coral resembling *Chaetetes;* no mural pores observed. Possible range, Silurian to Carboniferous.

C. W. Merriam

54 F 44 — Center sec. 16, T. 25 N., R. 49 E., 6,500 ft. elev., east side of Windmill Window, Simpson Park Mountains, Horse Creek Valley quadrangle.

Leptaena sp.
Atrypa sp.
stropheodont brachiopod
Dalmanella sp.
trilobite thoracic segments
Syringaxon sp.

Devonian. The coral *Syringaxon* is similar to one in the Helderberg Lower Devonian horizon west of Antelope Valley, Eureka County, Nevada.

C. W. Merriam

54 F 44a — NE¼ sec. 16, T. 25 N., R. 49 E., east side Windmill Window, on ridge NE of 54 F 44, Simpson Park Mountains, Horse Creek Valley quadrangle.

Gypidula loweryi
Atrypa nevadana
Schizophoria nevadenis

Devonian. Lower Nevada Formation; *Spirifer pinyonensis* zone.

C. W. Merriam

54 F 48 — NE¼ sec. 18, unsurveyed, T. 25 N., R. 50 E., in J–D Window, Simpson Park Mountains, Horse Creek Valley quadrangle.

Styliolina sp.

Devonian. Similar to form abundant near base of *Martinia kirki* zone. Middle Nevada Formation.

C. W. Merriam

54 F 50 — SW¼ sec. 17, T. 25 N., R. 49 E., Windmill Window at range front, Simpson Park Mountains, Horse Creek Valley quadrangle.

Atrypa sp.
Stropheodonta sp.
Leptaena sp.
Strophonella sp. (large form)
Proetus cf. *nevadae*
Temnophyllum sp.
Favosites sp.

Devonian. Nevada Formation.

C. W. Merriam

WESTERN ASSEMBLAGE

Vinini Formation

54 F 38 — NW¼ sec. 9, T. 24 N., R. 49 E., 6,600 ft. elev., west side of valley at upper spring, Simpson Park Mountains, Roberts Creek Mountain quadrangle.

The principal species is *Climacograptus caudatus* Lapworth, which indicates an upper Caradoc Age.

R. J. Ross, Jr.

54 F 45 (D 158 €O) Sec. 26, unsurveyed, T. 34 N., R. 50 E., Tuscarora Mountains, 11.5 mi. NW of Carlin.

Dicellograptus cf. *D. muldidens* var. *diminutus* Ruedemann
Dicellograptus cf. *D. divaricatus* (Hall)
Didymograptus? sp. If this really is a *Didymograptus* (large fragment without proximal portion), it probably is *D. superates.*
Amplexograptus sp.

Age: Zone of *Climacograptus wilsoni* or of *Climacograptus bicornis.*

R. J. Ross and W. B. N. Berry

54 F 55 (D 159 €O) SW¼ NW¼ sec. 17, T. 33 N., R. 51 E., Marys Mountain, Beowawe quadrangle.

Amplexograptus cf. *A. confertus*
Orthograptus sp. (cf. *O. truncatus* type?)

The determination is based on two specimens, one showing the reverse and the other the obverse aspect. . . I am fairly confident in suggesting that this is Llanvirn of British section (zone 6). Probably equals lower Swan Peak of northeast Utah. This *may* be equivalent to beds about 100–200 feet below the top of the Pogonip at Eureka, Nevada. . . This fauna was reviewed by Ross and Berry 7/1/59 and reassigned to Caradoc.

R. J. Ross, Jr.

54 F 56 (D 160 €O) Sec. 21, T. 33 N., R. 51 E., 6,500 ft. elev., 0.5 mi. northwest of Cherry Spring, Marys Mountain, Carlin quadrangle.

Dicranograptus cf. *D. nicholsoni* var. *longibasalis*

The present specimens are well-preserved natural molds only partly flattened. This particular variety of the species has been reported only from the lower Viola Limestone in Oklahoma by Ruedemann and Decker. *D. nicholsoni,* itself, is found in zones 9–11 (rarely in 12) of the British section; the Caradoc includes zones 9–13.

R. J. Ross, Jr.

54 F 57 (D 161 €O) SW¼ sec. 20, T. 33 N., R. 51 E., 7,100+ ft. elev., Marys Mountain, Beowawe quadrangle.

Orthograptus calcaratus
Amplexograptus sp.

The specimens of *Orthograptus calcaratus* are exceptionally good, being only partly flattened and showing the very large basal spines to good advantage.

This species ranges from zone 11 to zone 13 of the Caradoc but is most common in zone 12. This is possibly about Middle "Trentonian" of the Ordovician Correlation Chart (Twenhofel and others, Chart 2, 1954). This species is reported from the shales of the Phi Kappa Formation at Fall Creek, Hailey quadrangle, Idaho, and in the Polk Creek Shale of Oklahoma.

R. J. Ross, Jr.

54 F 58 (D 162 €O) NE¼ NW¼ sec. 25, T. 33 N., R. 50 E., near head of Marys Creek, Tuscarora Mountains, Beowawe quadrangle.

Climacograptus bicornis

Zonal range is 9–12 of British section or Caradoc. Most common in 9 and 11. Reported from the Phi Kappa Formation (Ross, 1934, p. 942–944); definitely not Chazy in age, but may be Black River or Trenton.

R. J. Ross, Jr.

54 F 59 (D 163 €O) NW¼ NW¼ sec. 25, T. 33 N., R. 50 E., near head of Marys Creek, Tuscarora Mountains, Beowawe quadrangle.

Orthograptus aff. *O. calcaratus* Lapworth
Climacograptus hastatus var. *americanus* Ruedemann
Climacograptus cf. *C. rectangularis*
Retiolites-like species
Dicellograptus sp.

This collection probably correlates with the uppermost 25 feet of the Phi Kappa Formation (Ross, 1934, p. 944–945). Of the forms listed above only the second is identified with strong confidence and it is known elsewhere only from this interval of the Phi Kappa . . .

The dating of the present collection, based as it is on uncertain identifications, is not satisfactory. In the British system *O. calcaratus* belongs in zones 11–13 (Caradoc). *C. rectangularis* equals zones 16–19 (Low Silurian). *Retiolites* ranges, depending on subgenus, from zone 12 to 33 (Caradoc-Low Ludlow). The genus *Dicellograptus* is not known above zone 15 (top of the Ordovician).

The collection cannot be older than Middle Caradoc and may be as young as highest Ordovician. I believe that this is essentially the same fauna noted by Ruedemann (1947, p. 110) which he considered bridging the Ordovician-Silurian boundary. Although he does not so state, this is the same collection as that listed by Ross (1934, p. 994–995) from the Phi Kappa Formation.

R. J. Ross, Jr.

54 F 67 (D 164 €O) Center, T. 34 N., R. 50 W., unsurveyed, Tuscarora Mountains, J. Ammann photo index 29 NW, photo 34N–126.

Climacograptus caudatus Lapworth
Mesograptus? sp.

C. caudatus is limited to zone 12 (upper Caradoc) of the British section, probably equals Sherman Fall Formation of Trenton Group. There are probably two other species and genera here. One looks like a *Mesograptus* but fits no known species I have yet discovered. I am stumped on the other possibility.

R. J. Ross, Jr.

54 F 70 (D 165 €O) Sec. 18, unsurveyed, T. 35 N., R. 51 E., Tuscarora Mountains, J. Ammann photo index 29 NW, photo 34N–10.

Climacograptus cf. *C. bicornis*
Diplograptus (Glyptograptus?) cf. *D. (G.) teretiusculus*

Identifications not certain. If correct, they indicate equivalence to Zones 9–11 of British section (Low and Mid-Caradoc). *G. teretiusculus* has been reported from the Silver Peak quadrangle of Nevada, and the Womble Shale.

R. J. Ross, Jr.

54 F 71 (D 166 €O) Sec. 13, T. 35 N., R. 50 E., unsurveyed, Tuscarora Mountains, J. Ammann photo index 29 NW, photo 34N–10.

Amplexograptus cf. *A. confertus*
Glossograptus? sp.
Orthograptus cf. *O. truncatus* var. *intermedius*

Although specimens are numerous, preservation leaves much to be desired. Identifications very uncertain. *A. confertus* and *O. truncatus* var. *intermedius* are not compatible in same collection, having quite different ranges. Can only tell that this collection belongs somewhere in interval Llanvirn-Caradoc.

R. J. Ross, Jr.

55 F 1 NW¼ sec. 17, T. 32 N., R. 51 E., at summit on Emigrant Pass, Tuscarora Mountains, Beowawe quadrangle.

Caryocaris sp.

The collection contains this phyllocarid crustacean in abundance.

Some beds of the Valmy-Vinini are packed thick with these. However, their stratigraphic value in the absence of other fossils is not certain. Best bet is Ordovician.

R. J. Ross, Jr.

58 F 6 (D 540 €O) Emigrant Pass, U. S. Highway 40, SW¼ NW¼ sec. 17, T. 32 N., R. 51 E., Beowawe quadrangle.

Dicellograptus sp.
Climacograptus sp. (large)
Climacograptus sp. (small)
Orthograptus quadrimucronatus (J. Hall)

Age: Zone of *Orthograptus quadrimucronatus.*

R. J. Ross, Jr. and W. B. N. Berry

Valmy Formation

54 F 52 SW¼ SE¼ sec. 2, T. 27 N., R. 49 E., Cortez Mountains, Horse Creek Valley quadrangle.

Glossograptus cf. *G. ciliatus*
Orthograptus aff. *O. truncatus*

These two graptolites indicate definite Ordovician Age equivalent to Llandeilo or Caradoc.

R. J. Ross, Jr.

54 F 53 (D 157 €O) SE¼ sec. 3, T. 27 N., R. 49 E., unsurveyed, 6,700 ft. elev., Cortez Mountains, Horse Creek Valley quadrangle.

Orthograptus cf. *O. truncatus*
Orthograptus cf. *O. truncatus* var. *intermedius*
Climacograptus caudatus
Climacograptus cf. *C. latus*
Dicranograptus cf. *D. rectus*

The first three of these belong in zone 12 of Ellis and Wood. The fourth is from zone 15 and the fifth does not range above zone 11. This results in favoring compromise at zone 12. The Caradoc includes zones 9–13 and is probably equal to the interval Black River through Maysville of the American section.

Your collections 54 F 38 (D 149 €O) and 54 F 52 (D 150 €O) are probably of the same age.

R. J. Ross, Jr.

Ordovician Western Undifferentiated

54 F 8 — SW¼ sec. 3, T. 23 N., R. 48 E., 6,800± ft. elev., 1.5 mi. SE of Walti Ranch, Simpson Park Mountains, Walti Hot Springs quadrangle.

Only two specimens were determinable. One of these is a very immature state of a biserial form; it could be as old as basal Caradoc or as young as Silurian. The other is a small specimen similar to *Orthograptus truncatus* var. *socialis* of Ashgillian Age. . . I can only tell that this is Ordovician and therefore Valmy or Vinini.

R. J. Ross, Jr.

Devonian and Silurian Western Undifferentiated

54 F 80 — SW¼ sec. 6, T. 31 N., R. 52 E., 500 feet northeast of Raine Ranch, 5,050 ft. elev., Carlin quadrangle.

Pelecypods, several species
Aviculopinna? sp.
gastropod indet.
chiton cf. *Gryphochiton* sp.

The pelecypods have the general form and outline that have persisted through the ages in many genera. Two fossils, however, that suggest a Paleozoic Age for this assemblage, particularly, though not necessarily, the upper half of the Paleozoic. One is the pelecypod referred with question to *Aviculopinna*. This fragmentary shell has a general outline and growth-line pattern that fits this genus. Dr. Reeside, who also has examined this collection, says that he knows no similar shell in Mesozoic and later rocks.

Finally, there is the chiton, represented by two valves, one of which is a tail valve. This has a shape known only in Paleozoic chitons. Nothing in the assemblage ties it down to a more specific date.

Mackenzie Gordon, Jr.

54 F 83 — Sec. 19, T. 27 N., R. 53 E., Sulphur Spring Range, Mineral Hill quadrangle.

Limestone pebbles in conglomerate of Devonian Age. The pebbles contain fragments of at least three species of trilobites: a species of *Pseudagnostus,* a fragmentary pygidium of a dikelocephalid trilobite, and a distinctive but apparently undescribed spinose trilobite pygidium are present. The association of *Pseudagnostus* and a dikelocephalid trilobite indicates that this collection comes from beds of Late Cambrian Age that are younger than basal Windfall and older than Goodwin of the nearby Eureka section.

A. R. Palmer

54 F 84 — Sec. 19, T. 27 N., R. 53 E., Sulphur Spring Range, Mineral Hill quadrangle.

Bryantodus sp.
Hindeodella sp.
Icriodus sp.
Polygnathus linguiformis Hinde
Polygnathus pennata Hinde
Polygnathus sp.

. . . the rocks from which this collection came are of Middle or early Late Devonian Age. *P. linguiformis* is the most common recognizable species . . . (also) found in some Middle Devonian limestones of Ohio and in the Genundewa Limestone Member of the Genesee Formation of western New York . . . (and) in the basal few feet of the Chattanooga Shale in southwestern Virginia . . .

W. H. Hass

Devonian Western

54 F 54 (4951–SD) — SW¼ sec. 4, unsurveyed, T. 33 N., R. 51 E., north side of James Creek, Tuscarora Mountains.

Icriodus sp.
Ligonodina sp.
Polygnathus dubia asymmetrica Ziegler and Bischoff
Polygnathus linguiformis Hinde

This collection is probably from high Middle or low Upper Devonian rocks. In Germany, *P. dubia asymmetrica* is reported to range from high in the Middle Devonian (Obere Stringocephalen-Stufe) to low in the Upper Devonian (Manticoceras-Stufe); and *P. linguiformis* from high in the Lower Devonian (Emsian) throughout the Middle Devonian. In the United States *P. dubia asymmetrica* has been found by me in the upper part of the West River Shale Member of the Genesee Formation in west-central New York. This shale, which is part of the standard Devonian succession of North America, occurs low in the Upper Devonian.

W. H. Hass

54 F 54a (4952–SD) — T. 33 N., R. 51 E., unsurveyed.

Contains *Ancyrodella* sp. in addition to forms listed under 54 F 54. *Ancyrodella* has a recorded range of Middle and Upper Devonian.

W. H. Hass

OVERLAP ASSEMBLAGE

Pennsylvanian Undifferentiated

54 F 3 — NW¼ sec. 30, T. 28 N., R. 49 E., unsurveyed, on west side of Brock Canyon.

The collection contains abundant pelecypods *Astartella,* and numerous small gastropods. These include *Naticopsis* sp., *Paleostylus (Pseudozygopleura)* sp., *Donaldina* sp., and *?Stegocoelia* sp.

None of the specimens are well-enough preserved to be identified specifically, but the assemblage indicates a Carboniferous Age, most probably Pennsylvanian.

E. L. Yochelson

Garden Valley Formation

54 F 5 — NW¼ sec. 32, T. 25 N., R. 49 E., head of Fye Canyon, 7,000 ft. elev., Simpson Park Mountains.

horn coral
syringoporoid coral
fenestellid bryozoan
stenoporoid bryozoan
bryozoans indet.
crinoid columnals
Productus aff. *P. inflatus* McChesney, fragments
Reticularina campestris (White), var.
Spirifer sp., fragments
Martinia? sp., fragments

Productids and reticularinas of this type are found in the Upper Mississippian (Chester) and Lower Pennsylvanian (Pottsville of Girty) in the western United States.

Mackenzie Gordon, Jr.

54 F 6 — SW¼ sec. 29, T. 25 N., R. 49 E., head of Fye Canyon, Simpson Park Mountains, 7,200 ft. elev.

dielasmoid brachiopod indet.
Rhynchopora sp.
Crurithyris? sp. indet.
Composita? sp.
trilobite pygidium fragment

This small collection suggests late Paleozoic.

Mackenzie Gordon, Jr.

54 F 7 — SE¼ sec. 29, T. 25 N., R. 49 E., Simpson Park Mountains, near Indian Ranch.

This rock contains numerous crushed specimens of *Pseudofusulina* and possibly of *Schwagerina* or *Parafusulina* though no positive evidence that any of the specimens belonging to the last genus was seen. Fusulinids of the kinds that seem to be represented in this sample are limited to rocks of Hueco and possibly of early Bone Spring Age in West Texas. They definitely belong in the Permian, but the upper limits in the Permian are not clearly determinable from the sections prepared.

L. G. Henbest

54 F 7a — SE¼ sec. 29, T. 24 N., R. 49 E., Simpson Park Mountains, 10 feet below 54 F 7.

crinoid columnals
Rhynchopora sp.
Phricodothyris perplexa (McChesney)
Cleiothyridina cf. *C. orbicularis* (McChesney)

This collection probably is Pennsylvanian in age but could be as late as Permian.

Mackenzie Gordon, Jr.

54 F 18 — SE¼ sec. 5, T. 24 N., R. 49 E., Simpson Park Mountains, near Indian Ranch, at 7,160 ft. elev.

Three fusulinid faunas were found in this collection:

Faunal aggregate 1. This consists mainly of adult shells of rather similar size (commonly 7 to 10 mm) and shape (ventricosely cylindrical) that are silicified with milky quartz. The shell structure is obscure but *Triticites* or *Pseudofusulina* sp., *Pseudofusulina* sp. aff. *P. huecoensis* Dunbar and Skinner, and *Schwagerina?* sp. are faintly recognizable. One specimen suggested *Pseudofusulina laxissima* D. & S. These lie in a rather well-graded matrix of silt texture that is not silicified and bears only a very few veins (calcite), which cut matrix and fossils alike. The silicified fusulinid shells bear a considerable number of parallel veinlets that consist of silica and that *in no instance extend from the shell into the matrix.*

Included also in this aggregate are unaltered shells of *Pseudofusulina* sp., *Schwagerina?* sp. and *?Pseudofusulina* [*Parafusulina?*] *linearis* D. & S. (fragments). These calcareous shells are more abraded and fragmentary than the silicified ones. The calcareous shells and the matrix appear to have similar origin, though grains of intermediate size (species of small foraminifers, immature fusulinid shells, shell fragments) are scarce.

Grading and redeposition are evident but on a scale that is common in fusulinid-bearing limestones.

The relation of the silicified specimens to the rest of the sediment is more definitely redepositional and conglomeratic. So far as the fusulinid specimens have been prepared and studied, both fusulinid parts of the aggregate belong in the lower to possibly the early middle part of the Permian and a considerable age difference is not indicated.

Aggregate 2. The fusulinids of aggregate 2 consist largely of somewhat aligned, adult shells of *Pseudofusulina* [*Parafusulina?*] *linearis* D. & S., an extremely slender, cigar-shaped fusulinid 10 to 14 mm long. Some sedimentary grading is evident.

Aggregate 3. This aggregate has more the appearance of being organic detritus *in situ*. The following species were found:

Climacammina sp. (thin walls)
Climacammina sp. (thick walls)
Endothyranella sp.
Boultonia sp. (abundant)
Pseudofusulina [*Parafusulina?*] *linearis*
Schwagerina [*Parafusulina?*] *gumbeli?* D. & S.
Parafusulina or *Pseudofusulina* sp.
Pseudofusublina laxissima or *Pseudoschwagerina* sp. (fragment)

Except for the presence of *Boultonia* this assemblage resembles the fusulinids found in the upper part of the Hueco Limestone and in the early part of the Bone Spring Limestone in the Sierra Diablo of West Texas. The variety of *P. linearis* in aggregate 2 is of similar origin. The recognition of *Boultonia* sp. in this country is relatively new and its age significance is uncertain. Its presence here agrees with the other evidence for the Permian Age of this sample.

L .G. Henbest

54 F 21 — NE¼ sec. 5, T. 24 N., R. 49 E., Tonkin Window, Simpson Park Mountains, Roberts Creek Mountain quadrangle.

Pebbles in Permian conglomerate.
Atrypa cf. *nevadana*
Spirifer pinyonensis
Chonetes cf. *deflecta*
Favosites sp.
Devonian Lower Nevada Formation; *Spirifer pinyonensis zone.*

C. W. Merriam

MESOZOIC ERA

Newark Canyon Formation

57 F 100 — Sec. 13, T. 24 N., R. 48 E., and sec. 24, T. 24 N., R. 48½ E., on the boundary between secs. 13 and 24, at top of ridge south of Sage Hen Canyon, Simpson Park Range, Walti Hot Springs quadrangle.

The thin section shows that at least some of the plant-like structures are pieces of coniferous twigs, encrusted with lime. These twigs resemble those of some late Early Cretaceous or early Late Cretaceous species variously assigned to *Sequoia (ambigua, condita, gracillima, gracils,* etc.), *Sphenolepis,* and others; but I cannot be certain of the identification. There seems to be no evidence of dicotyledons. My conservative guess, therefore, is that the age of the material is probably Early Cretaceous.

R. W. Brown

TERTIARY VOLCANICS

61 E 1 — NE¼ sec. 31, T. 27 N., R. 49 E., unsurveyed, Horse Creek Valley quadrangle.

Several of the specimens collected in the footwall block of the Buckhorn Mine, 500 feet NE main shaft contain impressions of smooth fresh-water ostracodes.

The preservation is too poor for identification, but the gross forms look like Tertiary or younger ostracodes. Sorry I cannot be more specific.

I. G. Sohn

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