NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

BULLETIN 75

GEOLOGY AND MINERAL DEPOSITS OF LYON, DOUGLAS, AND ORMSBY COUNTIES, NEVADA

(Prepared cooperatively by the United States Geological Survey)

By

James G. Moore

With a section on

INDUSTRIAL MINERAL DEPOSITS

By

N. L. Archbold

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA

1969

This page is intentionally blank.

NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

BULLETIN 75

GEOLOGY AND MINERAL DEPOSITS OF LYON, DOUGLAS, AND ORMSBY COUNTIES, NEVADA

(Prepared cooperatively by the United States Geological Survey)

By

James G. Moore

With a section on

INDUSTRIAL MINERAL DEPOSITS

By

N. L. Archbold

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA
Reno, Nevada
1969

UNIVERSITY OF NEVADA SYSTEM
NEIL D. HUMPHREY, *Chancellor*

UNIVERSITY OF NEVADA, RENO
N. EDD MILLER, *President*

MACKAY SCHOOL OF MINES
VERNON E. SCHEID, *Director*

NEVADA BUREAU OF MINES
NEVADA MINING ANALYTICAL LABORATORY
VERNON E. SCHEID, *Director*
ARTHUR BAKER III, *Associate Director*

For sale by the Nevada Bureau of Mines, University of Nevada, Reno, Nevada, 89507. Price $3.00.

CONTENTS

	Page
Foreword	vii
Abstract	1
Introduction	1
Location and accessibility	1
Physiography, relief, and drainage	1
Previous work	3
Field work and acknowledgments	3
Geologic formations	3
Metamorphic rocks	3
Age	5
Metasedimentary rocks	6
Metavolcanic rocks	6
Granitic rocks	8
Hartford Hill Rhyolite Tuff	10
Age	11
Rhyolite	11
Andesite and dacite	11
Age	12
Sedimentary rocks	12
Virginia City quadrangle	12
Pine Nut Mountains	12
Coal Valley	13
Wilson Canyon and Pine Grove Hills	13
Basalt	13
Older alluvium	14
Lake deposits	15
Hot Spring deposits	15
Geologic structure	16
Carson Range	16
Pine Nut Mountains	17
Singatse Range	19
Wassuk Range	20
Buckskin Range	20
Pine Grove Hills	21
Desert Mountains	21
Virginia Range	21
Churchill Butte	21
Wellington Hills and Sweetwater Range	22
Mineral deposits	22
Introduction	22
History of mining	22
General geology of mineral deposits	23
Mining districts	24
Ramsey	24
Talapoosa	24
Red Mountain	24
Churchill	24
Silver City (Chinatown, Dayton, Devil's Gate, Gold Canyon)	24
Mound House	25
Eldorado	25
Como (Palmyra, Indian Springs)	25
Yerington	26
Wilson (Pine Grove, Rockland, Cambridge)	28
Washington	29
Genoa	29
Buckskin (Smith Valley)	29

PAGE

Mount Siegel 29
Gardnerville (Eagle) 30
Red Canyon (Silver Lake) 30
Wellington (Silver Glance) 30
Mountain House (Holbrook, Pine Nut) 30
Delaware (Sullivan, Brunswick) 31
Carson 31
Voltaire (Eagle Valley, Washoe) 31
Industrial mineral deposits, by N. L. Archbold 31
Diatomite 32
Northern tip of Lyon County 32
Snow White, Marvel, Light Weight, and White Caps claims 32
White Horse and Pale Face claims 32
Weeks deposit 32
Gypsum 32
Ludwig mine 32
Mound House 34
Talcose, sericitic, and aluminous deposits 36
Sericite claims 36
Blue Metal prospect 36
Top prospect 36
Talco prospect 36
Barite and fluorite 36
Prison Hill 36
Brunswick Canyon 37
Boulder Hill 37
Cinders and perlite 37
Cinderlite deposit 37
Wellington district 37
Sweetwater Hills and Pine Grove Hills 37
Graphite 37
Chedic mine 37
Limestone 39
Nevada Cement Co. quarry 39
Eldorado Canyon 39
Wabuska 39
Dayton iron deposit 39
Salines 40
Wabuska 40
Clay 40
Jupiter deposit 40
Nevada Cement Co. deposit 40
Churchill Canyon 40
Silica 40
Big Crystal deposit 40
Veta Grande mine 40
Coal and lignite 40
Lewis mine 40
Eldorado Canyon 41
Dimension stone 41
Nevada State Prison 41
Eureka Canyon 41
Sand and gravel 41
References 41
Index 43

ILLUSTRATIONS

(Plates in pocket)

Plate 1. Geologic map of Lyon, Douglas, and Ormsby Counties, Nevada.
2. Location of mining districts and mineral deposits in Lyon, Douglas, and Ormsby Counties, Nevada.

FIGURES

PAGE

Figure 1. Index map showing the location of Lyon, Douglas, and Ormsby Counties 2
2. Index of quadrangle maps in Lyon, Douglas, and Ormsby Counties 4
3. Generalized columnar section of Mesozoic metamorphic rocks in southern Pine Nut Range 7
4. Outcrop of Triassic and Jurassic metavolcanic breccia west of Carson City 7
5. Eastern limit of major Mesozoic batholiths in Nevada and California 9
6. Looking north toward south flank of Desert Mountains 14
7. Ruins of old Fort Churchill 16
8. View of steep east front of Carson Range 2 miles north of Genoa 17
9. Surface of major fault exposed in gravel quarry at east base of Carson Range 1 mile south of Genoa 18
10. Steep east front (fault scarp) of Pine Nut range north of Wellington 18
11. Steep east front of Singatse Range 7 miles south of Yerington 20
12. West-dipping Tertiary sedimentary deposits on west flank of Pine Grove Hills just south of Wilson Canyon 20
13. Portal of Sutro Tunnel at southern base of Virginia Range in northwestern Lyon County 25
14. Anaconda Co.'s Yerington open-pit copper mine as it appeared in early 1961 27
15. Geologic map, vicinity of Ludwig mine, Lyon County 33
16. General geology in vicinity of Mound House gypsum deposit, Lyon and Ormsby Counties 35
17. Geologic map, vicinity of Boulder Hill fluorite deposit, Douglas County 38

TABLES

PAGE

Table 1. Geologic column of Triassic and Jurassic rocks of Sweetwater Range 5
2. Value of mineral production through 1965 in Lyon, Douglas, and Ormsby Counties 22
3. Production of Anaconda's Yerington mine through 1965 28
4. Production of Minnesota Iron mine through 1966 in long tons 29

This page is intentionally blank.

FOREWORD

Nevada Bureau of Mines Bulletin 75, "Geology and Mineral Deposits of Lyon, Douglas, and Ormsby Counties, Nevada," is one of a series of county studies on the geology and mineral resources of Nevada. The study is part of a cooperative program between the Nevada Bureau of Mines and the U.S. Geological Survey. The geologic mapping, the study of the metallic mineral deposits of the area, and the major portion of the report, are the work of James G. Moore of the U.S. Geological Survey. The Bulletin contains, also, a section on industrial mineral deposits prepared by N. L. Archbold of the Nevada Bureau of Mines.

Gold was first discovered in Nevada near the mouth of Gold Canyon near Dayton in 1850. Interest created by this discovery of placer gold stimulated exploration that resulted in discovery in 1859 of the rich silver-gold ores of the Comstock lode in Storey County. Subsequent placer operations during the next 80-odd years, together with lode mines in Lyon County's Silver City district, at the southern end of the Comstock lode, account for more than $13 million of the three-county area's mineral production.

In 1950, the development of a large, low-grade copper deposit by the Anaconda Co. heralded resumption of mining in the Yerington district, an earlier producer of high-grade copper ores. Open-pit mining by the Anaconda Co. began in 1953. Production has been increased in recent years and the property has become the second largest mining operation in the State. As of the end of 1965, the Yerington district had accounted for more than 80 percent of the $316 million mineral production of the three-county area.

Mineral exploration activities have increased greatly in this part of Nevada during the past decade, and a large deposit of iron ore has been discovered near Yerington by the Columbia-Geneva Steel Co. The continuing interest in the area, as shown by many of the nation's mining companies, indicates a potential for future mineral discoveries. It is hoped that the present Bulletin will aid in understanding the area's complex geology and further discovery of its mineral resources.

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

June, 1969
Mackay School of Mines
University of Nevada

This page is intentionally blank.

GEOLOGY AND MINERAL DEPOSITS OF LYON, DOUGLAS, AND ORMSBY COUNTIES, NEVADA

By James G. Moore

ABSTRACT

Lyon, Douglas, and Ormsby Counties are three adjacent, relatively small counties in western Nevada in the obtuse angle formed by the California-Nevada border. Within the counties are the Pine Nut Mountains, Singatse Range, Buckskin Range, Pine Grove Hills, and parts of the Carson Range, Wassuk Range, Desert Mountains, Virginia Range, and Sweetwater Range.

The entire tricounty area is within the borders of the Cretaceous Sierra Nevada batholith and pre-Cretaceous rocks are present only as roof pendants in the batholith. The pre-Cretaceous rocks are Triassic and Jurassic in age and are predominantly metamorphosed volcanic rocks (chiefly andesite) and volcanogenic sedimentary rocks. Limestone and gypsum are interbedded with the clastic and volcanic rocks.

Overlying the granitic and included metamorphic rocks is an extensive sequence of Cenozoic volcanic and interbedded sedimentary rocks. In general, this sequence begins with widespread rhyolite tuffs, up to several thousand feet thick, which are considered to be Miocene in age. Overlying the tuff is a thick sequence of andesitic and dacitic rocks, largely breccias, with thick sequences of intercalated lacustrine and fluviatile sediments of Miocene and Pliocene Age. The latest general period of volcanism extruded basaltic flows which cap parts of some of the ranges and are mainly Pliocene or Pleistocene in age.

The tricounty area is within the Basin and Range province, and most of the mountain ranges are bounded on one or both sides by basin-range normal faults. The main north-trending ranges in the area, with the possible exception of the Carson Range, are tilted west, and are bounded by major east-dipping normal faults on their east sides. The two east-trending ranges, Desert Mountains and the eastern Virginia Range, are uplifted more by warping than faulting and are probably younger. The main rivers of the area are consequent to the structure and cross the ranges in structually low sites.

The first gold in Nevada was discovered in Lyon County in 1850. Since that time mineral commodities valued at more than $300,000,000 have been produced from the three counties. The chief production has been silver and gold from the Silver City district (southern end of the Comstock Lode) and copper from the Yerington district. In addition, iron, tungsten, lead, zinc, gypsum, clay, basalt cinders, perlite, limestone, cement, sandstone, graphite, sodium sulphate, diatomite, and coal have been produced.

The three counties, particularly Lyon County, have become increasingly important in Nevada's mineral industry in recent years. They produced 0.1 percent of the State total in mineral commodities in 1950, 27 percent in 1960, and 31 percent in 1965. The discovery of a new iron deposit near Yerington in 1960, and completion of the State's first cement plant in 1964, promise a bright future.

INTRODUCTION

LOCATION AND ACCESSIBILITY

Lyon, Douglas, and Ormsby Counties are in western Nevada, in the obtuse angle formed by the California-Nevada border (fig. 1). Ormsby and Douglas Counties lie west of Lyon County, which is elongate north-south. The three counties were mapped as a single unit because of their irregular and interlocking shapes (pl. 1).

The area of the three counties is bounded on the north by Washoe and Storey Counties, on the northeast by Churchill County, on the southeast by Mineral County, and on the west by four counties in the State of California, Placer, El Dorado, Alpine, and Mono Counties.

Together Lyon, Douglas, and Ormsby Counties cover 2,877 square miles. Lyon County includes 2,012 square miles; Douglas, 724 square miles; and Ormsby, 141 square miles. Population of the tricounty area (1960 census) was 17,687.

The main routes of travel in the area are U.S. Highways 395 and 50. Highway 395 extends south through Carson Valley in the western part of the area. Highway 50 generally follows the Carson River east across the northern part of the mapped area. State Route 3 follows the West Walker River east across the central part of the area to the town of Yerington, and State Route Alternate 95 connects Yerington with Schurz on the east and U.S. Highway 50 on the north. The areas between these hard-surfaced roads are generally well served by a network of improved and unimproved dirt roads. The most inaccessible mountain range in the tricounty area is the Pine Grove Hills.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The area of the three counties lies within the western Great Basin on the east side of the Sierra Nevada. The east slope of the Sierra Nevada along the western margin of the mapped area is complex and irregular, and the physiographic and structural break between the

Figure 1. Index map showing the location of Lyon, Douglas, and Ormsby Counties.

Sierra Nevada and the Basin and Range province is gradational. In fact, a continuity of Cenozoic structure exists between the Sierra Nevada and the desert ranges to the east. The main crest of the Sierra Nevada south of Lake Tahoe trends northwest about parallel with the California-Nevada State line. The east slope of the range, however, is cut by a number of major north-trending normal faults delineating north-trending ranges which are connected to the main mass of the Sierra Nevada on their south ends but diverge from the range northward. Four master fault-block ranges of this type, in effect north-trending spurs from the Sierra Nevada, are present in the mapped area. These are, from west to east: (1) Carson Range, (2) Virginia Range—Pine Nut Mountains—Wellington Hills—Sweetwater Range, (3) Singatse Range—Pine Grove Hills, and (4) Wassuk Range. Each of these merges at its southern end with the Sierra Nevada near the California line. And each of these master fault-block ranges, with the possible exception of the Carson Range, is tilted west.

Aside from small perennial streams, the area is largely dependent on water from four rivers which head on the east slope of the Sierra Nevada in California and flow east. The most northerly is the Truckee River, which drains from Lake Tahoe and flows north and east through Reno to Wadsworth and north to Pyramid Lake. Much of the water is now diverted from the lake by a canal leading south to Lahontan Reservoir in northeastern Lyon County.

The two forks of the Carson River head in the Sierra Nevada south of Lake Tahoe and join near Minden in Carson Valley. The river flows north and east past Dayton into Lahontan Reservoir. Before the reservoir was built, the Carson River flowed east into Carson Sink. Now water from the reservoir irrigates a large area near Fallon in Churchill County before going into the sink.

The West Walker River heads in the Sierra Nevada near Sonora Pass and flows north on the west side of the Sweetwater Range. Eastward the river cuts through the southern Pine Nut Mountains at Hoye Canyon and the Singatse Range at Wilson Canyon. It flows north through Mason Valley past Yerington, swings around the northern Wassuk Range, and flows south into Walker Lake.

The East Walker River heads in the Sierra Nevada west of Bridgeport and flows northeast around the south end of the Pine Grove Hills. It flows north between the Pine Grove Hills and the Wassuk Range and meets the West Walker River near Yerington.

PREVIOUS WORK

Some of the earliest geologic work in the State of Nevada was done in and adjacent to the area of this report. Much of the early work stemmed from the interest in mining brought about by the first Nevada gold discovery at Dayton in 1850 and by the subsequent discovery of the famous Comstock Lode in 1859.

The earliest geologic mapping in the area is that of the United States 40th Parallel survey (King, 1878), which included the northern part of what is now Lyon County. A part of Becker's map (1882) of the Comstock Lode includes part of Lyon County.

An index on plate 1 shows the location of geologic mapping since 1900. Free use has been made of this mapping in compiling the geologic map of the counties (pl. 1). However, all previous mapping has been more or less modified as a result of field checking and transferring to the Army Map Service topographic base.

FIELD WORK AND ACKNOWLEDGMENTS

Four months were spent in the field in the summer of 1958, and one month in the summer of 1959. The work was supported cooperatively by the Nevada Bureau of Mines and the U.S. Geological Survey. Geologic mapping was recorded on the series of 15-minute topographic quadrangle maps which cover the area of the counties (fig. 2) and was compiled on the Army Map Service Reno and Walker Lake sheets (1:250,000).

The writer is indebted to the previous workers whose maps and data have been used in compilation of the tricounty map. The work of R. L. Rose, J. H. Halsey, and R. L. Christiansen has been used most extensively (pl. 1). Stratigraphic data of J. H. Halsey and D. C. Noble are reproduced in table 1 and figure 14 as examples of detailed studies in local areas; inclusion of their data does not imply formal acceptance of their stratigraphic nomenclature by the U.S. Geological Survey.

Personnel of the Nevada Bureau of Mines and the U.S. Geological Survey have helped in all stages of the work. Ira Lutsey of the Bureau of Mines and Donald C. Ross of the Geological Survey have been especially helpful.

The help of the Anaconda Co. and the Standard Slag Co. in providing production figures is gratefully acknowledged.

GEOLOGIC FORMATIONS

METAMORPHIC ROCKS

Mesozoic metamorphic rocks older than the major granitic instrusive bodies of the Sierra Nevada batholith are widely distributed in the area of the three counties. The metamorphic rocks occur in roof pendants and septa surrounded by the younger granitic rock. Fossil evidence indicates that the metamorphic rocks are predominantly Late Triassic and Early Jurassic in age. The metamorphic rocks occur in relatively small areas, generally only a few miles in extent, although the

largest, on the west slope of the southern Pine Nut Mountains, may be as large as 20 miles long and 6 miles wide.

These pregranitic rocks are metamorphosed partly as a result of heat from, and deformation by, granitic intrusion. Rocks of the larger masses of metamorphic rocks are less thoroughly recrystallized and metamorphosed than those of the smaller and thinner masses. Generally the metamorphic rocks are in the low and medium grades of metamorphism. In the larger masses, the rocks, especially siltstones and shales, appear to be very little affected.

In the pregranitic sequence, metavolcanic rocks are slightly more abundant than metasedimentary rocks. Commonly, the rocks are intimately interbedded, and the twofold division on the geologic map (pl. 1) into metavolcanic and metasedimentary rocks is based on the dominant lithologic type in a given area.

Figure 2. Index of 15-minute, topographic quadrangle maps in Lyon, Douglas, and Ormsby Counties.

Metasedimentary rocks originally consisted mainly of shale, siltstone (commonly tuffaceous), and limestone, but these are interbedded with sandstone, graywacke, dolomite, gypsum, and small amounts of chert. Intercalated with them, also, are conglomerate and sedimentary breccia that may have originated as submarine mud flows.

The metavolcanic rocks are predominantly metaandesite and metadacite, largely volcanic breccia. Metabasalt and metarhyolite are also common. The metavolcanic rocks are interbedded with marine sediments, commonly derived from volcanic rocks that probably were partly of submarine origin. The rarity of pillow lava, however, and the association of volcanic rocks with gypsum deposits, suggest that part of the volcanic rock was formed in a terrestrial or near-shore environment.

Age

Mesozoic fossils have been collected from many localities in the metasedimentary rocks of the tricounty area (Moore, 1960). During the course of the reconnaissance mapping, five new fossil localities were found, and enlarged collections were made from two old localities. Most of the fossils are Triassic (generally Late Triassic) and Early Jurassic in age. The large part of the strata appears to have been deposited close to the Triassic-Jurassic boundary, but Noble (1962) cites evidence suggesting that rocks of the southern Pine Nut range extend into the Upper Jurassic or Cretaceous Systems. No beds of Paleozoic Age have been found in the mapped area.

In general, a sequence dominated by metasedimentary rocks underlies a sequence dominated by metavolcanic rocks. This relationship is apparent in the Sweetwater Range (table 1), in the area north of Carson City (Zones, 1958), in the Virginia City quadrangle just north of the county area (Thompson, 1956, p. 48), and in the southern Pine Nut range (Noble, 1962). At Yerington, however, the metasedimentary rocks in general overlie the metavolcanic rocks (Knopf, 1918, p.

Table 1. Geologic column of Triassic–Jurassic rocks of Sweetwater Range. After Halsey (1953).

Age	Map unit	Description	Approximate maximum thickness (feet)
Early Jurassic	Topaz Lake—east group	Basic to acid keratophyric and normal volcanic flows, intrusives, and tuffs; interbedded basin sediments—varved lake beds to fanglomerates; metamorphosed to greenschist facies.	1,500
	Uplift, folding, final disruption of the Mesozoic geosyncline		
	West Walker River—Lost Canyon Creek group	Intermediate and basic keratophyric flows, intrusives, and tuffs; minor interbedded tuffaceous sediments; metamorphosed to albite–epidote–amphibolite facies.	3,000
	Warping, possible block faulting, erosion		
	Antelope Valley—east group	Basic and intermediate keratophyric flows, sills, and tuffs; interbedded tuffaceous marine pelitic rocks, gravels, and limestone; overlie thick older pelitic rocks; minor normal basic volcanics; series intruded by quartz keratophyres; metamorphosed to albite–epidote–amphibolite facies and amphibolite facies.	4,000
	Southeast Pine Nut Mountains group	Keratophyres overlying(?) a thick dolomite series; metamorphosed to the greenschist facies.	?
	Topaz Lake—west group Rodriguez Canyon group	Geosynclinal sediments: thinly bedded quartzo–feldspathic rocks; minor pelitic and calcareous horizons; all somewhat tuffaceous; minor normal volcanic rocks and tuffs; metamorphosed to greenschist facies and albite–epidote–amphibolite facies.	2,000 2,000
	Levitt Meadows group	Fine to coarse marine and terrestrial sediments; minor volcanics; metamorphosed to albite–epidote–amphibolite facies.	4,000
	Lobdel Lake group	Thinly bedded calcareous silts; locally fossiliferous; metamorphosed to albite–epidote–amphibolite facies.	3,000
	Sweetwater Summit group	Thinly bedded calcareous silts, minor limestones and basic volcanics; metamorphosed to amphibolite facies.	2,000
Late Triassic	Boulder Hill mine group Smith Valley mine group	Thick dolomites, thinly bedded quartzite, and limestone, locally fossiliferous; minor younger keratophyres; metamorphosed to the greenschist facies.	1,500 1,000

13) and in every area much of the sedimentary rock contains material of volcanic origin. Moreover, in most of the areas the stratigraphy and structure of these rocks are little understood and the mutual relations of the rock units are doubtful.

Metasedimentary Rocks

The metasedimentary rocks are largely derived from volcanic rocks; siltstone, shale, sandstone, and graywacke are common and contain volcanic material. Limestone and limy clastic rocks are also common, and gypsum is present at three localities. The sedimentary rocks are somewhat metamorphosed; the siltstones and shales show the least effects of metamorphism. In some areas adjacent to intrusive contacts, the rocks are intensely metamorphosed, as at Yerington (Knopf, 1918, p. 16).

Because of the separation of the individual masses of pregranitic rock, the complex structure, the uncertain age relationships, and the likelihood of rapid facies changes, no attempt has been made to correlate individual units from one mass to another. Instead, several of the more complete sections of these Mesozoic rocks will be described.

The metamorphic rocks of the Yerington district were the first to be studied in detail (Knopf, 1918) in the tricounty area, and much of our knowledge of these rocks is still based on this early work. Of the approximately 8,000 feet of pregranitic rock exposed in the Yerington district, about one-half is of sedimentary origin. The principal sedimentary rocks are limestone and quartzite (Knopf, 1918, p. 16). Shale is present, though not common, but a large amount of calc-silicate hornfelses and garnetite was probably derived from limy and dolomitic shaly rocks. A bed of gypsum 450 feet thick is present on the west slope of the Singatse Range near the Ludwig mine. It is underlain by quartzite and overlain by limestone and grades at depth into anhydrite. Volcanic rocks are commonly interbedded with the sedimentary units.

Hill (1915, p. 55) studied the metamorphosed sediments in the Red Canyon area of the Pine Nut Mountains, an eastward projection of the largest mass of metamorphic rock. He reports the section measured in Red Canyon as follows:

	Feet
Thick-bedded white crystalline limestone..	100– 300
Thin-bedded dark-gray to black argillites with some lenses of white quartzite....	800–1,000

The largest area of pregranitic rocks in the tricounty area, about 20 by 6 miles in extent, is on the west slope of the southern Pine Nut Mountains, as given above. This mass is oriented in a north-northwest direction. The general outline of the metamorphic rock suggests that probably much of Carson Valley is underlain by metamorphic rocks.

Noble (1962) has divided the Mesozoic metamorphic rocks of the southern Pine Nut range into six formations (fig. 3) representing an approximate aggregate thickness of 24,000 feet. Of these formations, Noble states:

> "The Oreana Peak and Gardnerville Formations, composed of 5,500 to 6,000 feet of marine carbonate and clastic rocks and interbedded volcanic material, were deposited during the Late Triassic and Early Jurassic. These formations were warped and eroded near the end of Early Jurassic time. During the Middle and/or Late Jurassic the Preachers Formation, composed of 600 to 800 feet of lithic arenite, probably marine, was laid down. The Preachers Formation is conformably overlain by the Veta Grande Formation, composed of 200 to 1,100 feet of felsic lapilli tuff and volcanic sandstone, 450 to 1,500 feet of andesite, and 3,000+ feet of coarse volcanic conglomerate and breccia, all of continental origin. The terrane was subsequently warped, eroded, and probably faulted; and the Middle and/or Late Jurassic Gold Bug Formation, composed of 1,200+ feet of lava and welded tuff of intermediate composition, was deposited. The Late Triassic to Middle or Late Jurassic rocks were then folded into a series of moderately tight folds that now plunge gently south and southeast.
>
> Following erosion, the Double Spring Formation, composed of at least 10,000 feet of felsic to intermediate lapilli tuff, welded tuff, and lava, was deposited. Fossil and structural evidence date the formation as Late Jurassic and/or Early Cretaceous."

Table 1 is a composite geologic column after Halsey (1953) of the Triassic and Jurassic rocks of the Sweetwater Range and adjacent areas. The Sweetwater Range crosses the California-Nevada border and only the northern part, in southern Lyon and Douglas Counties, is in the mapped area. This geologic column illustrates the large volume of volcanic debris that is present in the Triassic-Jurassic sequence.

Metavolcanic Rocks

Metamorphosed volcanic rocks interbedded with the Triassic and Jurassic sedimentary rocks occur abundantly over the area of the counties and have been the source of many of the sedimentary rocks. Rhyolite, andesite, and basalt are common among the volcanic rocks, though andesite breccias are the most abundant. Andesite, predominantly coarse volcanic breccia, is abundant in the large metamorphic septum west of Carson City (fig. 4) and at Prison Hill. Here the breccia is massive with poorly defined bedding. The individual blocks of andesite are commonly larger than 1 foot in diameter and are locally tectonically stretched. Interbedded with the breccia are crossbedded and stream-channeled volcanically derived sands.

Metamorphosed volcanic breccias are well exposed

Age	Rock unit	Thickness in feet	Description
Upper Jurassic and/or Lower Cretaceous	Double Spring Formation	10,000 plus	Acid to intermediate lapilli tuff and flows. Includes some intercalated welded tuff, volcanic sandstone, calcareous fresh-water tuff, and marine limestone.
	Gold Bug Formation	900+	Rhyodacite and dacite flows.
		50-3,000	Welded rhyodacite-dacite lapilli tuff.
Middle and/or Upper Jurassic	Veta Grande Formation	3,000 plus	Coarse to fine massive-bedded volcanic conglomerate and breccia with minor poorly sorted, interbedded feldspathic wacke.
		200-1,500	Pyroxene andesite.
		100-450	Feldspar-rich volcanic sandstone.
		100-800	Rhyolite-rhyodacite lapilli tuff.
	Preachers Formation	600-800	Well-sorted lithic arenite and wacke; steep cross-bedding locally present.
Lower Jurassic	Gardnerville Formation	300	Volcanic conglomerate with interbedded siltstone, volcanic sandstone and limestone.
		3,000	Thin-bedded carbonaceous and pyritic siltstones with volcanic tuff and flows (10-15%) and carbonate (5-10%).
?			
Upper Triassic	Oreana Peak Formation	400	Thick to medium-bedded marine limestone.
		0-8,000	Mafic to intermediate volcanic breccia, lava, and tuff with associated sediments.
		1,600	Massive to thin-bedded white to bluish-grey to black marine limestone, dolomitic limestone, and dolomite.
		700+	Marine and continental tuff-breccia, greenstone, and interbedded sediments.

Figure 3. Generalized columnar section of Mesozoic metamorphic rocks in the southern Pine Nut Range. After Noble.

on Lone Mountain just northeast of Carson City. The individual clasts of these breccias have been so stretched tectonically that their three diameters are in a ratio of 2:3:6 (Zones, 1958, p. 11). The long and intermediate axes are parallel to the plane of schistosity, and the longest is parallel to the direction of the lineation, which is most commonly down the dip of the schistosity. The elongation of these clasts indicates the extensive stretching and squeezing which the entire volcanic unit has undergone at this locality.

Andesite breccias are also well exposed on Highway 395 south of Double Spring Flat. Many of these volcanic rocks are relatively little metamorphosed and may be readily mistaken for altered Tertiary volcanic rocks. Andesites, particularly volcanic breccias, are abundant in the Singatse Range south of Yerington and in the Mason Valley buttes northeast of Yerington.

Metamorphosed basaltic rocks are probably next in abundance to those of andesitic composition. The metabasalts are generally massive and structureless and are predominantly flows, although breccias and tuffs are present. Pillow basalt appears to be rare.

Figure 4. Outcrop of Triassic and Jurassic metavolcanic breccia in hills west of Carson City. Note porphyritic fragments of volcanic rock.

The mafic minerals of the basalt are recrystallized to amphibole, epidote, and less commonly, chlorite. Most of the plagioclase is albite-oligoclase, but remnants of labradorite are not uncommon.

Metabasalts are well exposed in the canyon of the Carson River east of New Empire. And to the north in the Comstock Lode district, the bulk of the pre-Tertiary volcanic rock is metabasalt (Thompson, 1956, p. 48). Smaller masses of metabasalt are present in nearly all of the larger areas of metavolcanic rock shown on the geologic map.

Metamorphosed rhyolites are also common among the pre-Tertiary volcanic rocks. Rock of this kind called soda rhyolite-felsite or keratophyre has been studied and described in the Yerington district by Knopf (1918, p. 13–16). A large proportion of these rocks is of pyroclastic origin, and tuffaceous and brecciated textures are well preserved. Many, however, are dense aphanitic rocks with hornfelsic textures that have been so thoroughly recrystallized that their origin is obscure. Outside of the Yerington district, metarhyolitic rocks are well exposed at Sweetwater summit, and in the southern Pine Nut Mountains.

GRANITIC ROCKS

Approximately 430 square miles of the area of the geologic map (pl. 1) is underlain by granitic rocks. Because the granitic rocks exceed the pregranitic metamorphic rocks in area by more than 2 to 1, they are considered to be the eastern continuation of the Sierra Nevada batholith. The percentage of granitic relative to pregranitic rock drops off rather abruptly to less than 50 percent at the longitude of Walker Lake east of the tricounty area, as indicated in figure 5. Lyon, Douglas, and Ormsby Counties lie wholly within the area that is predominantly batholithic.

The granitic rocks are predominantly quartz monzonite and granodiorite, although alaskite, granite porphyry, aplite, and mixed dark-colored rocks are present. On the geologic map (pl. 1) the granitic rocks have been separated into three units: (1) granite porphyry, (2) porphyritic quartz monzonite, and (3) undivided nonporphyritic quartz monzonite, granodiorite, and hybrid mafic rocks. In general, the porphyritic quartz monzonite is older than the granite porphyry and younger than the undivided granitic rocks.

Granite porphyry is a general term applied to a rather distinctive group of rocks with a fine-grained to aphanitic groundmass and phenocrysts of K-feldspar, plagioclase, and, frequently, quartz. The phenocrysts are generally small (2 to 4 mm), but in some places K-feldspar phenocrysts may attain 2 cm in length. The chief mafic mineral is hornblende (commonly surrounded by an opaque rim or altered to epidote), and biotite is generally absent (Knopf, 1918, p. 22). In addition to the intrusive bodies of porphyry shown on the map, the rock is common in swarms of dikes, especially in the Yerington district. Some of the areas of porphyry prove to be intrusive complexes of many intrusive masses and dikes of differing mineralogy and texture. Small porphyry intrusions, too small to be shown on the map, are present in the western Buckskin Range (Reeves and others, 1958, p. 51–52).

The main masses of granite porphyry occupy an east-west belt in the central part of the tricounty area. In addition to the porphyries of the Yerington district (with which the disseminated copper deposits are associated), porphyries occur southeast of Yerington in buttes on the east side of Mason Valley, and west of Yerington in the Pine Nut Mountains and Buckskin Range.

The porphyries include the youngest and probably the shallowest plutonic rocks of the area. In the Yerington district they cut all other pre-Tertiary rocks. And in this district, the ore deposits are spatially and probably genetically related to the granite porphyry.

Because porphyritic quartz monzonite is distinctive and easily separable from the other granitic rocks, it was mapped as a separate unit. The porphyritic quartz monzonite is characterized by large K-feldspar crystals, commonly larger than 1 inch in length and in places as large as 6 inches. The phenocrysts are set in a coarse-grained matrix (average grain size about 5 mm) of plagioclase, quartz, and K-feldspar. Biotite is the most abundant varietal mineral. The rock is relatively light colored (Color Index about 10) and is similar to the Cathedral Peak Granite described by Calkins (Matthes, 1930, p. 126) in the Yosemite region, 30 miles south of the mapped area.

Three intrusions of porphyritic quartz monzonite occur within the tricounty area. One crops out near Yerington in the Singatse Range and also in the buttes to the east. Another lies northwest of the Yerington district in the northern Pine Nut Mountains and is oriented generally east-west. The third crops out on both the west and east flanks of the southern Pine Grove Hills and is apparently continuous between, under the cover of Tertiary volcanic rocks. The three intrusions are in a line trending approximately west-northwest more or less parallel to the regional grain of much of the pre-Tertiary rock of this region. They are generally younger than the major units of undifferentiated granitic rocks. Knopf (1918, p. 20) has shown that the quartz monzonite (porphyritic) of the Yerington district is younger than the granodiorite, though it is cut by aplite and quartz monzonite porphyry. The large porphyritic quartz monzonite intrusion of the Pine Grove Hills is clearly seen to be younger than, and intrusive into, the granodiorite in the canyon of the East Walker River.

The granitic rocks mapped as undivided, nonporphyritic quartz monzonite, granodiorite, and hybrid mafic rocks occupy the largest group of Mesozoic intrusive rocks shown on the map. The dominant or average rock type of this unit is darker and less silicic than the porphyritic quartz monzonite, and is probably

Figure 5. Eastern limit of major Mesozoic batholiths in Nevada and California. West of the line more than 50 percent of exposed pre-Tertiary rock is granitic.

granodiorite. Included within this general map unit are a number of separate intrusive masses.

HARTFORD HILL RHYOLITE TUFF

In the Virginia City quadrangle, the oldest Tertiary formation is the Hartford Hill Rhyolite Tuff (Thompson, 1956). The formation attains 1,000 feet in thickness in the Virginia City area and is composed of vitric-crystal tuffs, tuff-breccia, and welded tuff. In the Yerington district (30 miles southeast of Virginia City), Knopf (1918) has described a thick rhyolitic sequence at the base of the Tertiary section. The rhyolitic sequence at Yerington is about 4,000 feet thick and is composed of rhyolitic tuffs and breccias with interstratified well-bedded volcanic grits.

Reconnaissance mapping has shown that similar rocks occur widely in the northern part of the mapped area. The Hartford Hill Rhyolite Tuff can be traced almost continuously from the Comstock district south across the Carson River to the north slope of the Pine Nut Mountains. Small erosional remnants cap the high peaks of the range. Small masses of rhyolite tuff also occur in scattered exposures southwest from the Comstock district near the Carson City airport, at Lakeview Summit, and in the Carson Range. The Hartford Hill Rhyolite Tuff has been traced east and north from Virginia City and is well exposed in the Truckee River Canyon almost as far east as Fernley (Robert Rose, oral communication, 1958).

The rhyolite tuff of the Yerington district covers large areas in the northern Singatse, Buckskin, and Wassuk Ranges (Smith, 1904). Because of the lithologic and stratigraphic similarity of this sequence to the Hartford Hill Rhyolite Tuff in its type locality—1 mile northwest of Silver City—and because of the discontinuous patches of similar rhyolitic tuff between the Yerington district and the type locality, the rhyolitic rocks of the Yerington district are considered to have been originally continuous with the Hartford Hill Rhyolite Tuff. The formation as mapped in the counties is widely distributed over an area of approximately 2,000 square miles. Over much of this area, however, it was never deposited or was removed by erosion before deposition of younger rocks.

The eastern and northern limits of the Hartford Hill Rhyolite Tuff are not known. The southern limit appears to be near lat 38°30′ N., the western limit near the crest of the Carson Range. Rhyolitic rocks are present in the Pine Grove Hills and the Sweetwater Range (Halsey, 1953) in the southern part of Lyon County. These rocks are mapped separately from the Hartford Hill on the geologic map because there is some doubt that they were ever continuous with it.

The Hartford Hill Rhyolite Tuff is commonly light pink to dull purple in color, though locally it may be brown, gray, or white. The sequence is composed of alternating units of crystal-vitric tuff, tuff breccia, welded tuff, and pumice tuff. In the Yerington district, volcanic sandstone is interbedded with the tuffs. The crystal-vitric tuffs are the most resistant, and in the areas of rhyolitic rocks bordering Mason Valley, they form the higher ridges. This rock is rich in crystals, which commonly make up 50 percent of the rock.

In outcrop much of the rock is nearly structureless. The most obvious structure is a crude platy parting, commonly in two sets which define crude columns. These columns are perpendicular to the indistinct bedding, which is defined by planar orientation of biotite flakes, by flattened lenses of pumice, by tabular rock fragments, and by streaks of black glass.

The mineral content of the Hartford Hill Rhyolite Tuff is generally uniform. The crystals, in order of decreasing abundance, are plagioclase, K-feldspar, quartz, and biotite. Over much of the mapped area the proportion of these crystals appears to be relatively constant, but actual measurements were not made. In some horizons of the unit, however, the mineralogy changes; quartz and K-feldspar are rare or absent, and instead, pyroxene and hornblende are common with the plagioclase and biotite. This difference was observed both near Yerington, at the base of the section (Knopf, 1918, p. 24) and on the east side of Mason Valley, rather high in the section. Although the welded base of the formation near Yerington contains pyroxene and hornblende and no quartz, the mineral change seems to be gradational upwards into the normal mineral assemblage.

In the Yerington district Knopf (1918) has described a series of basal latite vitrophyre flows and a series of overlying quartz latite lavas which underlie the main rhyolitic sequence. He points out that these lavas have well-developed columnar jointing and marked flow structure (Knopf, 1918, p. 25); the black porphyritic glass which occupies the bottom of the section attains a maximum thickness of 100 feet and is widespread.

During the course of the reconnaissance mapping, a similar basal glassy unit was found in many places, including Lakeview Summit on Highway 395 and the northern Wassuk Range, over 40 miles distant. Moreover, the basal glassy unit is completely gradational with overlying pyroclastic units, and under the microscope its glass is seen to be composed of flattened, though still recognizable, shards. At some localities, as 8 miles east of Yerington, the basal unit is only partly welded with irregular zones of black, glassy rocks. Apparently the glassy unit represents only the basal, more completely welded portion of a tuff unit of ash flow origin. Other horizons of welded, glassy tuff are present higher in the section, presumably near the base of other cooling units.

The rocks included within the Hartford Hill Rhyolite Tuff have many features in common. In every place studied, they lie at the base of the Tertiary section and rest directly on either granitic or metamorphic rock, except in the Virginia Range, where Rose (1959, p. 1744) has described 300 feet of underlying claystone, and near Yerington, where they rest on a conglomerate

as much as 50 feet thick. In many places the tuff grades downward into a basal glassy layer. Although there are local changes in the mineralogy of the tuffs, in general the mineralogy is uniform. No other types of volcanic rocks have been seen interbedded with the tuffs.

The alternation of lithified and unconsolidated tuffs, the presence of interbedded sediments in the Yerington district, and the presence in some places of other glassy layers indicate that the tuff sequence represents more than a single volcanic eruption. The formation probably represents eruption of ash flows from several vents over a relatively short time.

Age

In the Virginia City quadrangle, Thompson (1956, p. 50) states that the Hartford Hill Rhyolite Tuff is probably Oligocene, but may be in part or entirely Eocene, since it underlies the Alta Formation, from which Axelrod (1949) has described fossil leaves suggesting Oligocene Age.

Ten miles east of Yerington, vertebrate fossils have been found in rocks that are closely associated with the rhyolitic rocks. As reported by Merriam (*in* Knopf, 1918, p. 27), these fossils suggest a middle Miocene to middle Pliocene Age.

Evernden and James (1964) have dated, by the K-Ar method, three samples of the Hartford Hill Rhyolite Tuff, one from Silver City and two from a locality 5 miles southwest of Wadsworth. The determined ages are remarkably consistent, all indicating eruption of the tuff 22.7 to 22.8 million years ago. According to the Holmes time scale (Holmes, 1960), this would fall within the early part of the Miocene Epoch. Because of the questionable nature of the paleontologic evidence, the age of the Hartford Hill Rhyolite Tuff is considered to be early Miocene.

RHYOLITE

Rhyolitic rocks apparently unrelated to the Hartford Hill Rhyolite Tuff occur in scattered areas across the mapped area. Included in this group are intrusive rocks, lava flows, and tuff deposits. The stratigraphic relations of most of these rocks are only poorly known.

In northern Lyon County, a rhyolitic unit capped by basalt is exposed along the shores of Lahontan Reservoir. Less than 10 percent of the rock is made up of phenocrysts of quartz, plagioclase, and biotite. The lack of fragmental texture and the presence in places of contorted flow structure suggest that this rhyolite orginated as a lava flow.

In eastern Lyon County, rhyolitic rocks are present in and near the Desert Mountains. In the southeast corner of Churchill Valley, an isolated hill composed of glassy, flow-banded rhyolite is probably a plug dome. Within the Desert Mountains, a series of rhyolitic tuffs and flows is overlain by andesitic and basaltic rocks.

Rhyolitic rocks also crop out in large areas in southern Lyon and Douglas Counties. On the crest and west slope of the Pine Grove Hills, rhyolitic rocks lie directly on the granitic basement of the range. Much of this rock is dense and stony, commonly with contorted banding and with no fragmental or shard texture, and is consequently believed to be rocks of rhyolitic lava flows. However, tuffs are also abundant among the rhyolitic rocks of the Pine Grove Hills. Much of the rhyolite is underlain by a layer of pumice tuff, commonly about 50 feet thick.

ANDESITE AND DACITE

Andesite and related volcanic rocks are abundant and widespread in the counties, and occupy more exposed area than any of the other Tertiary units differentiated on the geologic map. The andesites are a heterogeneous and varied group of rocks. They include rhyodacite, dacite, andesite, and basalt. In the field, andesite appears to predominate, but the average rock type may actually be dacite. Field determinations, being based on the mineralogy of phenocrysts in volcanic rocks, can commonly give somewhat erroneous results as to the general chemical composition of the rock. Microscopic examination and specific gravity determinations show that many of these rocks are more siliceous than indicated by the mineralogy of their phenocrysts.

Probably the largest proportion of the andesitic rocks are crudely bedded or unbedded coarse breccias and agglomerates that contain blocks of volcanic rocks of varying color and lithology. Flow breccias and lava flows are also common. Tuffs and volcanically derived sandstone reworked by streams are commonly interbedded within the coarser volcanic rocks. Dikes and pipelike intrusions of andesite and dacite cut the sequence in many places.

The andesite sequence is commonly associated with thick sections of Tertiary sedimentary rocks. In the southern Singatse Range and the southern Pine Nut Mountains, a sequence of andesitic rocks several thousand feet thick is overlain by Tertiary sedimentary deposits. In the Desert Mountains, however, the sedimentary deposits are under the andesitic rocks, and in the Coal Valley area the sedimentary section is overlain, underlain, and interbedded with andesitic rocks (Axelrod, 1956).

In the Virginia City quadrangle (Thompson, 1956) and the eastern Virginia Range (Rose, 1959), an older sequence of altered andesitic rocks, called the Alta Formation, can be distinguished from younger unaltered andesitic and dacitic rocks. Such altered and propylitized andesites are present in other areas in the mapped region as an older sequence of andesites. They have not been separated on the geologic map. Altered and silicified volcanics are especially conspicuous in the canyon of the East Walker River at the extreme southern end of Lyon County. They are also present in the northern Pine Nut range in the Como mining district and in the northern Sweetwater Range (Halsey, 1953).

Many small intrusions of andesitic and dacitic rock occur in the mapped area. These intrusions are more conspicuous where they cut pre-Tertiary rock than

where they intrude other similar-appearing Tertiary volcanic rocks. In the Carson Range, many such dikes and plugs cut the granitic rocks; most of these intrusions are too small to show on the geologic map. Several small andesite dikes are well exposed in the deep roadcuts along U.S. Highway 50 east of Lake Tahoe, and the highway goes through a tunnel cut in one of the larger of these intrusions at Cave Rock on the east shore of Lake Tahoe.

Age

Extrusion of andesitic and dacitic rocks apparently occurred intermittently over a considerable span of middle Tertiary time in the tricounty area. As a generalization, the volcanic rocks older than the andesites are rhyolitic and those younger are basaltic. Hence, the andesites represent the intermediate stage in the progressive decrease in silica of the Cenozoic volcanic rocks of the area.

The andesitic and dacitic rocks are commonly interbedded with Tertiary sedimentary beds. Eruption of these volcanic rocks probably blocked drainages and contributed to the formation of lakes and resultant deposition of sediments. Most of the Tertiary sedimentary rocks are Miocene and Pliocene in age, and the andesitic and dacitic rocks are considered to be of about the same age. However, Axelrod (1949) considered fossil leaves in the Sutro Member, which is interbedded with the Alta Andesite in the Virginia City quadrangle, as not younger than Oligocene in age; but this determination appears too old, since the underlying Hartford Hill Rhyolite Tuff is apparently early Miocene (Evernden and James, 1964).

SEDIMENTARY ROCKS

Tertiary sedimentary rocks occur widely in western Nevada interbedded with volcanic rocks, predominantly andesite and dacite. These beds have been studied in some detail since the time of the 40th Parallel survey and were first called the Truckee Group in the Truckee River Canyon above Reno north of the area of the three counties (King, 1876, map V, and 1878, p. 412–423). Vertebrate, invertebrate, and plant fossils found in the strata indicate that most of them are Miocene and Pliocene in age.

The Tertiary sedimentary rocks of western Nevada were deposited in isolated basins. The rocks commonly show rapid facies changes and inconsistent stratigraphic relations with persistent volcanic units. Axelrod (1956, p. 8) states: "The common practice of indiscriminately applying such formation names as Esmeralda, Truckee, and Humboldt over wide areas in Nevada finds little support in field evidence." These rocks therefore are called Tertiary sedimentary rocks in this report, and the lithology and age criteria of each major group will be discussed separately to the extent that it is possible to do so. A precise correlation of the beds from one sedimentary basin to another must await a detailed study of the problem.

In general the Tertiary sedimentary rocks are lake and stream deposits composed of tuffaceous shale, diatomaceous shale, siltstone, sandstone, and conglomerate, interbedded with volcanic conglomerate and volcanic breccia. Limestone, calcareous tufa, chert nodule beds, coaly beds, and diatomite are present in some places. Rapid facies changes are common in the sediments of a small area, and the overall thickness of a single section may be as great as 8,000 feet, as at Aldrich Station in the extreme southeast corner of Lyon County (Axelrod, 1956, p. 23).

Almost without exception the Tertiary sedimentary rocks are the softest and least resistant to erosion of any major unit among the pre-Pleistocene rocks. Where they occur in large areas, they are reduced to low relief. In many places the soft character of these rocks has allowed streams to erode them to a surface at grade and to deposit a layer of stream or pediment gravels. Subsequent uplift and dissection produced terraces and buttes capped by gravel, which is more resistant than the underlying sediments. Many of the areas shown on the geologic map as Tertiary sedimentary rocks are actually largely covered by these thick deposits of gravel.

Virginia City Quadrangle

Thompson (1956, p. 55) assigned Tertiary sedimentary rocks in the Virginia City quadrangle a few miles north of the tricounty area to the Truckee Formation because of their similarity to rocks in the Hot Springs Mountains and to rocks near Verdi in the Carson Range called the Truckee Group by King (1878). The rocks of the Truckee Formation here range from shale to conglomerate and contain beds of diatomite. The thickness of the sediments is probably greater than 3,000 feet. Axelrod (Thompson, 1956, p. 56) has concluded that the beds near Virginia City are early Pliocene in age as the result of a study of fossil leaves from the sediments.

Pine Nut Mountains

An extensive series of Tertiary sedimentary rocks are exposed on the west flank of the Pine Nut Mountains and in Pine Nut Valley. These rocks overlie the granitic bedrock and are capped by a widespread layer of Quaternary gravels within the range. Westward they are overlapped by the recent sediments of Carson Valley. The thickness of the Tertiary sediments is not known but is believed to be greater than 1,000 feet.

Most of the sediments are well-bedded, fine-grained lake deposits composed of tuffaceous mudstone, siltstone, and shale. Lenses of sand and gravel are interbedded with the finer grained sediments. Under the microscope, volcanic glass is seen to make up a large part of the finer grained sediments, indicating that much of the material was derived from volcanic ash either erupted directly into the basin of deposition or carried in by streams.

No fossils have been found in the Tertiary sedimentary rocks of the Pine Nut Mountains. They are known to be post-Cretaceous and earlier than the extensive faulting and tilting which has blocked out the range in its present form. The rocks are very similar lithologically to the Pliocene Truckee Formation exposed a few miles north near Virginia City.

Coal Valley

A thick section of late Tertiary sedimentary rocks is present in Coal Valley in the extreme southeast corner of Lyon County and in adjacent Mineral County. These rocks have been mapped and described by Axelrod (1956), and the following brief description is based largely on his work.

The sedimentary rocks form a west-dipping homoclinal section 8,200 feet thick between the southern Wassuk Range and the Pine Grove Hills. The fault on the west is of great displacement, probably greater than 5,000 feet. The younger sediments were laid down against this rising fault scarp, for they become progressively coarser toward the fault. The age of this faulting is early Hemphillian (early Pliocene), although there has been later recurrent movement along this fault (Axelrod, 1956, p. 36).

Axelrod (1956, p. 23) has separated this sedimentary sequence, which he named the Wassuk Group, into three formations (in ascending order): (1) Aldrich Station, (2) Coal Valley, and (3) Morgan Ranch. The Aldrich Station Formation (4,050 feet thick) is a fluviolacustrine deposit of siliceous shale, punky diatomaceous shale, siltstone, sandstone, and volcanic pebble beds. The formation contains both vertebrate and plant fossils. The vertebrates include *Pilohippus,* Camelidae, *Nannippus,* and *Mastodonts.* The plant fossils include 35 species of trees and shrubs. The fossils indicate a Barstovian and Clarendonian (late Miocene and early Pliocene) Age for the formation.

The Coal Valley Formation (3,325 feet thick) is a fluviolacustrine deposit consisting of soft lake beds, sandstone, conglomerate, and sedimentary breccia. Andesite and andesitic sediments are commonly interbedded. The formation contains a unique flora of aquatic plants (Berry, 1927), and fossil mammalian remains are known from 13 localities. These include *Pliohippus* and *Nannippus tehonensis.* The formation is Clarendonian and Hemphillian (early and middle Pliocene) in age.

The Morgan Ranch Formation (700 feet thick) is composed of fanglomerate, sandstone, breccia, and some pumice. The deposit was derived chiefly from the rising granitic highland on the west. No fossils have been found in the Morgan Ranch, but Axelrod (1956, p. 35) considered it to be Hemphillian (Pliocene) in age on the basis of its stratigraphic position and its apparent correlation with the beds containing the Yerington fauna, collected along the Old Reese Road 22 miles north-northwest of Coal Valley (Stirton, 1939).

Wilson Canyon and Pine Grove Hills

A large area of predominantly west-dipping Tertiary strata are present on the west flank of the southern Singatse Range and the northern part of the Pine Grove Hills. An excellent section of these rocks may be observed west and south of Wilson Canyon in the Singatse Range. South of the canyon these sedimentary rocks are probably more than 3,000 feet thick and are composed primarily of channeled stream deposits: sandstone, siltstone, and conglomerate. Interbedded tuffaceous shale, mudstone, and clay are probably of lacustrine origin.

South of Wilson Canyon, the basal strata rest on a massive flow of hornblende andesite about 300 feet thick that overlies a thick succession of andesite flows and breccias. Several hundred feet of poorly consolidated sediments overlie the hornblende andesite and are in turn overlain by coarser sediments composed of andesitic debris and interbedded with lenses of andesitic conglomerate and breccia up to approximately 100 feet thick. In places the thinner beds of andesitic conglomerate are encrusted with opaline material. The lower several thousand feet of sediment are composed primarily of andesitic and tuffaceous material. However, the upper part of the section as exposed south and west of Wilson Canyon is composed of detritus of albitized quartz monzonite similar to that exposed at the eastern end of Wilson Canyon.

South from Wilson Canyon, the sediments become finer grained in general and fine-grained lake beds and diatomite are more common. About 6 miles south of the canyon, beds of gastropod-bearing limestone and limy mudstone are abundant. At one place, a bed of calcareous tufa about 100 feet thick was observed.

Strata north and south of the west end of Wilson Canyon are a favorite hunting ground for both plant and animal fossils. Petrified trees and stumps are abundant. Vertebrate fossils have been found in this area and to the south along the Mickey Canyon Road. Wilson (1936) has described a small collection of rodents and Macdonald (1959) a rich fauna of mammals. Macdonald states (p. 886): "Although the material is scattered and the stratigraphy is highly complicated by faulting, I believe that the various faunules can be considered as a single unit." He considers the fauna to be early Hemphillian (middle Pliocene) in age.

BASALT

Basaltic rocks, predominantly lava flows, are widespread in the mapped area, especially in Lyon County. Dark-colored, generally fine-grained volcanic rocks are mapped in this group and include true basalt, basaltic andesite, and fine-grained andesite.

In general, the basaltic rocks are young in the volcanic sequence and overlie the major rhyolitic and

andesitic units. Locally, however, minor rhyolitic and andesitic units may be interbedded with the basalt or be younger than it. The basalts are generally of late Pliocene or early Pleistocene Age, and represent the last major period of volcanic activity in the tricounty area. The age assignment is based on the fact that the basalt overlies both andesitic rocks and sedimentary deposits which are dated in parts of the county area as Miocene and Pliocene. The basalt lava flows west of Dayton, which originated at vents on McClellan Peak, have been correlated by Thompson (1956, p. 57, pl. 3) with the Lousetown Formation of late Pliocene or early Pleistocene Age. Similarly, basalts of Lousetown character occur east of the Virginia City quadrangle and cap the Virginia Range as far east as State Highway Alternate 95. These rocks have been correlated with the Lousetown Formation by Rose (1959). Basalt flows that cap the Singatse Range southwest of Yerington and overlie gravels are considered by Knopf (1918, pl. 1) to be Pliocene(?) in age.

Basalt flows, probably of about the same age as those described above, are among the youngest flows in the lava plateau in the southern Pine Grove Hills. Because of the inaccessibility of this area, the limits of the basaltic rocks were not determined, and the basalt has been included with the predominant andesitic rocks on the geologic map.

Relatively young flows overlie Tertiary andesitic and sedimentary rocks in the northeastern Pine Nut Mountain and adjacent Desert Mountains (fig. 6). Extensive minor faulting has offset the surface of the basalt and produced fault scarps and small closed basins, some with nearly 200 feet of closure.

Figure 6. Looking north toward south flank of Desert Mountains. Higher parts of range are capped with basalt. Steam is issuing from Wabuska Hot Springs, recently drilled as part of a commercial power development program.

H. G. Ferguson (written communication, 1958) considers the basalt in the eastern part of Lyon County to be predominantly Pleistocene, but also recognizes that some is Pliocene and Recent. He further points out that some older basalt is interbedded within the older Miocene and Pliocene andesitic rocks.

Older basalts attain considerable thicknesses in the Virginia Range. They are mapped with the andesitic rocks on the geologic map. Rose (1959) has mapped these older basalts separately and correlated them with the Chloropagus Formation described by Axelrod (1956) from the Red Mountain area 15 miles to the southeast, and considered by Axelrod to be late Miocene and early Pliocene in age.

In general these basalts appear to have flowed out in relatively thin flows over areas of slight to moderate relief. Since extrusion, much of the basalt has been warped, tilted, and faulted, and hence is useful in recording late Cenozoic structural movements. Many of the louderbacks (Louderback, 1904; Davis, 1930) of western Nevada belong to this general basalt unit.

Most of the basalt is recent enough that the dimensions and surfaces of the original lava flows are not obliterated and the overall continuity of the flow units is not entirely disrupted and complicated by extensive faulting. Also, fault scarps are still preserved in the basalt and fault-induced closed depressions have not been destroyed by downcutting or alluviation. Hence, faulting is especially well shown and preserved in the basalt, which is at an optimum age to record faulting: young enough that extensive offset has not completely obscured the reference surfaces, and old enough to have undergone considerable offset. For this reason, more faults are mapped in the basalt than in the other formations, except perhaps for the older alluvium which also displays many small fault scarps.

OLDER ALLUVIUM

Older alluvium, chiefly gravel, is present in many places within the mapped area. This material is distinctive because it shows little relation to the present pattern of erosion and deposition, having been deposited instead at an earlier stage in the development of the ranges. The material mapped as older alluvium includes sediments deposited during a broad span of late Tertiary and Quaternary time.

One of the most extensive occurrences of the older gravels is as pediment gravels capping the nearly unconsolidated Tertiary sediments. After these sediments were deposited, and later strongly faulted and tilted, they were reduced to graded pediment surfaces because of their soft and unconsolidated character. The pediment gravels which mantle these surfaces are commonly preserved as erosional remnants. Such gravel-capped surfaces are present in nearly every range but have been mapped only where they are especially thick or conspicuous.

Some of the older alluvium was deposited by the ancestral Carson River as flood-plain deposits, well exposed in roadcuts on U.S. Highway 395 four miles south of Gardnerville. The river gravels are more than 50 feet thick and contain well-rounded cobbles up to 6 inches in diameter. The broad terrace 3 miles south of Gardnerville (now occupied by the Dresslerville Ranch Indian Reservation) is a rivercut surface mantled by older gravels.

Mapped with the older alluvium are the Pleistocene(?) (Stock, 1936, p. 26) lakebeds exposed in the quarry within the walls of the Nevada State Prison just east of Carson City. The well-cemented lacustrine sandstone which crops out at the prison has been extensively quarried as a building stone. The skeletal remains, as well as footprints, of birds and mammals are preserved in the sandstone. Some of the best preserved tracks are those of the extinct ground sloth, Mylodon, but tracks of mammoth, horse, bison, deer, peccary, wolf, possibly sabre-tooth tiger, and many species of birds are also present.

LAKE DEPOSITS

A large part of the mapped area was covered by pluvial lakes during the latter part of the ice age. By far the largest of these was Lake Lahontan. At its highest level, Lake Lahontan covered approximately 8,422 square miles (Russell, 1885, p. 31), of which roughly 500 square miles are in the area of this investigation. The lake occupied the lowlands near Wadsworth, Fernley, Lahontan Reservoir, and Silver Springs and the valley of the Carson River upstream to Dayton. It extended south through Churchill Canyon into Mason Valley, which was inundated as far south as Yerington. An arm of the lake reached downstream on the main Walker River to include Walker Lake and adjacent areas.

The level of Lake Lahontan fluctuated considerably in the Quaternary Period and several maxima are recorded as wave-cut strand lines. The highest level was 4,380 feet above sea level and is shown on the geologic map. Below it lacustrine sediments and tufa deposits are abundant. Along this highest level of the lake, prominent wave-cut benches are magnificently displayed on mountain slopes, and wave-built terraces and bars are developed in areas of gentler slope. Morrison (1964) has mapped the lake deposits in detail east of Lyon County in the Carson Desert.

Broecker and Orr (1958, p. 1028) have determined by radiocarbon measurements that one high-lake period occurred between 24,000 and 16,000 years ago, when the lake stood at about 4,190 feet above sea level. The lake then fell to a low point at about 4,010 feet 13,000 years ago, and rose to its highest level, 4,380 feet, 12,000 years ago. Since that time, the lake has been continuously lowering with minor variations. Prior to the earlier high-level period the lake had a long and complex history. The three largest remnants of Pleistocene Lake Lahontan—Pyramid Lake, Walker Lake, and Carson Sink—now stand at 3,802 feet, 3,993 feet, and 3,908 feet, respectively.

Smith Valley also contained a late Pleistocene lake, Lake Wellington (Hubbs and Miller, 1948, p. 42), of which Artesia Lake is a small remnant. This lake attained an elevation of slightly more than 4,800 feet, at which point it overflowed south across a low divide into the valley of the West Walker River and thence flowed into the main Lake Lahontan near Yerington. Outflow lowered the outlet approximately 20 feet.

In the northwest corner of the map is Washoe Lake, a remnant of a larger Pleistocene lake which included both Washoe and Little Washoe Lakes and drained northward into the Lake Lahontan system. This lake was as high as approximately 5,100 feet, though at present it is 5,029 feet, having downcut its outlet about 70 feet since its high-water stage.

Below the high-level lines of these Pleistocene lakes, lake deposits are abundant and attain thicknesses of several hundred feet. The highest level of the lake is shown on the geologic map (pl. 1), but the lake deposits are not mapped separately. In general the lake sediments become finer grained away from the shore line, and toward the center are generally clay and fine silt. Near the shore line, sand and gravel are common. Along the shore line, especially on steep and exposed coasts, calcareous tufa commonly forms encrustations a foot or more thick on older rocks. Where the shore line is on a gently sloping area, wave-built terraces (fig. 7), bars, and spits are common, and gravel pits have been developed in several of them.

In some places, the Pleistocene lake floors as well as parts of the neighboring ranges are mantled by sand dunes. These wind-blown deposits are built largely of material from the unconsolidated lake sediments. The dunes commonly migrate downwind across basin floors and up into neighboring ranges.

HOT SPRING DEPOSITS

A relatively large number of thermal springs are present within the mapped area. Thirteen hot springs are shown on the geologic map (pl. 1), and several other large springs are present in adjacent areas, particularly along the east front of the Sierra Nevada. In addition, hot-spring terrace deposits are present in several localities, indicating the site of now-extinct mineral springs. One of the largest of these is 2 miles south of Dayton. During the Comstock days, travertine from this terrace was burned for lime used in mortar.

Most of the existing hot springs are located at the east base of the ranges. Since the major ranges of the area are tilted west and bounded by a major fault on their east sides, thermal waters apparently are channeled to the surface along these large fault zones.

Springs also tend to occur at salients on the range fronts. Wallys Hot Spring is located at a valley-extending point on the east scarp of the Carson Range, and Nevada Hot Springs is at a similar point on the east

scarp of the Pine Nut Mountains. Pack (1927) has shown that hot springs along the west front of the Wasatch Range in Utah are similarly arranged at salients on the range front. He has shown that the springs on these points are situated at topographic lows on the trace of the main fault line and that the logical point for waters traveling along the fault plane to reach the surface would be at the lowest point. A study of the topographic position of the hot springs in the tricounty area shows the same relation to be true.

Figure 7. Ruins of Old Fort Churchill (1860–1869), constructed on floor of Pleistocene Lake Lahontan of adobe bricks made from lake-deposited silt and clay. Modern building in background is built on Lahontan beach terrace.

GEOLOGIC STRUCTURE

The geologic structure of the exposed rocks in Lyon, Douglas, and Ormsby Counties is complex. Most of the deformation occurred in two general periods: one preceding and accompanying the emplacement of the Cretaceous granitic rocks, another in late Tertiary and Quaternary time causing normal faulting, warping, and tilting.

The complex structure of the pre-Tertiary rocks was not mapped in detail. These rocks have been folded, sheared, and recrystallized partly as a result of the intrusion of the Sierran granitic complex, and metamorphism has obscured much of the pregranite structure. However, from studies of areas to the east which have not been so extensively deformed, a complex history of Mesozoic diastrophism is revealed prior to the emplacement of the Cretaceous granitic rocks (Ferguson and Muller, 1949).

The record of late Tertiary and Quaternary normal faulting, tilting, and warping is well preserved. The four largest mountain ranges of the counties—Carson, Pine Nut, Singatse, and Wassuk—are all large fault blocks, and all, with the possible exception of the Carson Range, are tilted west and bounded on their east flanks by prominent normal faults. Each of these ranges has a steep eastern front; uplift on the eastern edge of the blocks has been accomplished along a series of major normal faults arranged in a zigzag or en echelon pattern. Movement on these and related faults has probably occurred from late Tertiary to the present time.

Broad range-front warps are present in nearly every range in addition to the steep scarps caused by normal faulting. Downdrop of the basin relative to the range crest is commonly accomplished along these warps, which are commonly characterized by numerous small antithetic faults bounding small blocks, each tilted valleyward.

The east trend of the Desert Mountains and Virginia Range sets them apart from the other ranges of the tricounty area, as well as from those of much of the Basin and Range province, where ranges generally trend nearly north. These two ranges show two other features which contrast with the other seemingly typical ranges of the mapped area: (1) they appear to owe their uplift more to upwarping and less to faulting and tilting than the north-trending ranges, and (2) they are capped by much more extensive areas of Tertiary rocks than the north-trending ranges; this suggests that they originated later and were uplifted less.

CARSON RANGE

The Carson Range bounds the basin of Lake Tahoe on the east. It is a north-trending range in the western part of Ormsby and Douglas Counties. The range extends north of the Ormsby County line for about 25 miles and terminates at the Truckee River Canyon. Southwest of the California State line, the Carson Range merges with the main Sierra Nevada.

The Carson Range is underlain almost entirely by pre-Tertiary rock; in this it differs from the other ranges in the mapped area, all of which have large areas covered by Tertiary and Quaternary rocks. Presumably the Carson Range has had greater uplift, and consequently more extensive stripping of its covering of younger rocks.

The granitic rocks of the Carson Range appear to be quite uniform over broad areas, suggesting that the individual intrusive masses are large and relatively homogeneous. The area between the two large mapped metavolcanic pendants appears to be underlain by a single intrusion. The large pendant of metavolcanic rocks west of Genoa is elongate north-northwest and is parallel to the dominant structural grain of the pre-Tertiary rocks. The metavolcanic pendant west of Carson City, however, is somewhat anomalous in that it is elongate westward and has northeast-trending bedding and schistosity.

The details of Cenozoic structure in the Carson Range are incompletely known because of the scarcity of Tertiary rocks in the range which might serve as marker horizons. In general, the range is horstlike and is flanked by impressive fault scarps. The crest of the

range is approximately 9,000 feet high, and the floor of Carson Valley on the east and the bottom of Lake Tahoe on the west are at about 4,800 feet. Thompson and Sandberg (1958, p. 1277) point out that the east front of the Carson Range represents an alternating series of large faults and folds. In the mapped area the east front of the range is a large fault scarp from Stewart south, and a broad warp from Stewart north.

The southern part of the range, from Stewart south to the California State line, presents an impressive fault scarp more than 4,000 feet high (fig. 8). At the base of this scarp is a recent fault scarp approximately 44 feet high (fig. 9), dipping 36° (Lawson, 1912) to 60° E. and extending for about 10 miles near the town of Genoa. The time of formation of this scarp is certainly very recent, yet it was in existence in 1854 when the first settlers arrived in the area. The map pattern of this prominent bounding fault in the southern Carson Range is irregular; the fault segments are generally between 1 and 2 miles long and form a zigzag pattern.

Near the town of Stewart, the east front of the Carson Range changes rather abruptly from a simple fault scarp to a more complex range front in which downwarping and distributive faulting have played an important part. Warping is prominent in the east front of the range from near Stewart north to Washoe Valley at the north limit of the mapped area.

The warp is marked by an eastward-facing salient and by gentle gradients in the range front. A small gravity gradient in this same area measured by Thompson and Sandberg (1958, p. 1277) suggests also that the range in this area is bounded by a fold. This warped area is cut by swarms of west-dipping normal faults. Such mountain-down faults are common in other warped areas along the Sierra Nevada front (as for example, west of Bishop, Calif.).

Warping or distributive faulting is well shown at Lakeview Summit at the northern border of Ormsby County. Here the Hartford Hill Rhyolite Tuff caps granitic rocks at an elevation of slightly more than 5,000 feet. The same tuff occurs westward in erosional remnants up to an elevation of over 8,000 feet on the crest of the Carson Range.

Much of the bedrock in the broad warp west of Carson City is extremely deeply weathered. The granitic rocks exposed in deep cuts along highway 50 west of Stewart are weathered to over 100 feet. This suggests that the mountain front in this region is not an eroded fault scarp, as it is a few miles to the south, but rather a downwarped ancient erosion surface which has been subjected to weathering for a longer period of time.

North of the mapped area, the east front of the Carson Range passes again into a zone uplifted by normal faulting (west of Washoe Valley) and then again into a broad fold (southwest of Reno) (Thompson and Sandberg, 1958, p. 1277).

PINE NUT MOUNTAINS

The Pine Nut Mountains are the largest and most complex mountain mass in the area mapped. This range is the first range east of the Sierra Nevada (Carson Range) and is separated from the Sierra by Eagle Valley and Carson Valley, a broad alluviated basin containing the towns of Carson City, Stewart, Gardnerville, Minden, and Genoa. The Pine Nut Mountains block is 35 miles long, trends north, and is bounded on the north by the Carson River and on the south by the West Walker River. However, the part bearing the name Pine

Figure 8. View of steep east front of Carson Range 2 miles north of Genoa. A Recent fault scarp is visible near base of range.

Nut Mountains is only the central segment of a longer mountain range which, though complex, may be considered a single structural unit. The continuation of the range to the north is the Virginia Range, and to the south, the Wellington Hills, the Sweetwater Range, and finally the main mass of the Sierra Nevada.

Figure 9. Surface of major fault exposed in gravel quarry at east base of Carson Range 1 mile south of Genoa. The fault plane dips about 60° east and separates sheared plutonic metavolcanic rock from recent slope wash. (Photograph by R. E. Wallace.)

The pre-Tertiary rocks of the range are largely quartz monzonite and granodiorite which are almost certainly continuous with the Sierra Nevada batholith a few miles west in the Carson Range. Metamorphic rocks of Triassic and Jurassic Age are widespread, and the largest mass of metamorphic rock in the tricounty area is in the southwest part of the Pine Nut Mountains. In general, the bedding of the metamorphic rocks strikes slightly west of north and dips steeply. The Pine Nut Mountains are a broad mountain block sharply upfaulted on the east and tilted west. Much of the eastern front of the range presents a steep fault scarp very similar to the east front of the Sierra Nevada near Genoa (fig. 10). Thermal springs are present at several localities at the base of this scarp.

The Hartford Hill Rhyolite Tuff occurs in erosional remnants on the Pine Nut Mountains at an elevation of 8,800 feet and higher, and 4 miles east it crops out at 5,600 feet in the western Buckskin Range. Hence the displacement on the major fault zone at the east base of the Pine Nut Mountains is at least 3,200 feet; total displacement is probably considerably greater because the rhyolite tuff of the Buckskin Range dips west about 40°.

Actually the Pine Nut Mountains comprise several orographic blocks, each bounded by north-trending normal faults downthrown on the east. The displacement on these faults drops the west-tilted blocks down successively on their west sides and tends to produce a much smaller structural relief than would be produced by tilting of one large single block. As a result of these blocks being tilted individually, the Pine Nut Mountains have several north-trending crest ridges with high mountain valleys between. Pine Nut Valley and Mineral Valley are the two largest of these structural depressions. On the western flank of the range, the granitic basement has been brought to the surface in three smaller west-tilted blocks, each bounded on the east by east-dipping normal faults.

Figure 10. Steep east front (fault scarp) of Pine Nut range north of Wellington.

Gravity surveys (Don Mabey, written communication, 1961) show that the bedrock floor of Carson Valley west of the Pine Nut Mountains is west-tilted, and that the thickest section of valley fill is considerably west of the center of the valley. West tilting of Carson Valley has continued to very recent time and caused the Carson River to flow in its present anomalous course on the west side of the valley rather than in the middle. Carson Valley is interpreted as the alluviated backslope of the Pine Nut block and has participated in the general westward tilting of the entire block.

Much of the west flank of the range is covered by a

sequence of Tertiary lake and stream deposits at least several hundred feet thick. These soft sediments are in turn capped by Quaternary gravels over broad areas. Most of the Tertiary strata dip moderately westward. Tilting is accomplished along a series of north-trending normal faults upthrown on their west side. In several places northeast of Gardnerville, displacement along these faults has been sufficient to expose the granitic rock which underlies the sediments.

The Tertiary sediments and Quaternary gravels of the western slope of the range are cut by swarms of north-trending normal faults of small displacement. These faults offset the sediments and gravels a few feet to about 20 feet and produce small fault scarps. They are apparently late Quaternary in age. Most of these faults are downthrown on their east sides similar to the dominant faults which have produced the gross topographic features of the range. However, many faults downthrown on the west are present and the mixture of the two types of faults produces a small-scale horst and graben structure.

At its southern end, north of Hoye Canyon, the Pine Nut range is cut by an important east-northeast-trending normal fault downthrown on the south. The vertical displacement on this fault must be greater than 4,500 feet because north of the fault the base of the Tertiary rocks is greater than 8,000 feet in elevation and south of the fault, the Tertiary sediments are probably at least 2,000 feet thick and their base is at about 3,500 feet above sea level. A very similar large fault on line with this one cuts the Singatse Range near Wilson Canyon 10 miles to the east. Very likely this is part of the same large fault system.

The West Walker River has crossed both the Pine Nut range and the Singatse Range near these east-northeast-trending faults in structurally and topographically low regions. Hence, even though the river is now incised in deep canyons, it apparently was orginially consequent and crossed the ranges in topographically favorable areas. Since establishment of the course, incision of canyons has kept pace with continued uplift of the ranges.

A broad structural and topographic sag separates the northern Pine Nut range from the Virginia Range to the north. The Carson River follows this sag in crossing the Pine Nut-Virginia mountain system. The Hartford Hill Rhyolite Tuff is exposed along the Carson River at an elevation of 4,500 feet. Four miles north of the river it is exposed on McClellan Peak at 7,400 feet and south of the river it caps the Pine Nut range to well above 7,000 feet. Hence the Carson River, like the West Walker River, crosses the range at a point which is structurally low.

SINGATSE RANGE

The Singatse Range is a prominent north-trending range about 25 miles long in the southern part of Lyon County. The range is flanked on the east by Mason Valley and on the west by Smith Valley and Churchill Canyon. The continuation of the range to the south of Wilson Canyon is called the Pine Grove Hills. On the north the range terminates in part at Churchill Canyon and merges to the northeast with the Desert Mountains.

The Singatse Range is primarily a west-tilted fault block consisting of pre-Tertiary granitic and metamorphic rocks capped by several thousand feet of west-dipping Hartford Hill Rhyolite Tuff, andesite, sediments, and basalt. In the northern half of the range, the Hartford Hill Rhyolite Tuff is overlain by small areas of andesite and dacite, predominantly breccia. In the southern part of the range, the pre-Tertiary rocks (chiefly granitic) are locally capped by andesite and basalt. The andesite occurs as a thick sequence of flows and tuff-breccia in the vicinity of Wilson Canyon, and probably indicates the close proximity of a major volcanic center.

An extensive series of west-dipping lake and stream deposits flank the southern part of the Singatse Range and part of the Pine Grove Hills farther south. Abundant mammalian fossils of Pliocene Age have been collected from these beds. The sediments overlie the andesitic breccias in the vicinity of Wilson Canyon; near the west end of the canyon they are locally interbedded with the breccia.

The east front of the Singatse Range is an irregular fault scarp. The trend of the fault traces is quite variable, and the general pattern is zigzag, similar to the main fault scarps of the Carson Range and Pine Nut Mountains. Near the center of the range, where it is capped by thin flows of basalt (fig. 11), displacement on several faults has lowered the base of the basalt from about 6,000 feet to the valley floor on the east at 4,400 feet.

Gravity data suggest that Smith Valley on the west side of the Singatse Range is the alluviated backslope of the Singatse tilted block. The lowest Bouguer gravity, and hence the deepest part of the basin, is measured on the west side of Smith Valley. Similarly, two gravity traverses show that the deepest part of Mason Valley, east of the Singatse Range, is on its west side. Hence, the pattern of ranges and basins tilted down on their west sides is repeated across the mapped area.

The Singatse Range is cut by a large number of normal faults, many of which offset the pre-Tertiary-Tertiary contact as much as several thousand feet (Knopf, 1918, p. 28). The major faults are parallel to the range and are downthrown on the east; only a few of these are shown on the geologic map. Other important faults trend nearly at right angles to the trend of the range, and the two sets of faults cut the range into mosaiclike blocks. This mosaic structure of the range is best displayed in the Yerington district, where blocks capped by rhyolite tuff have been downdropped among the pre-Tertiary rocks.

At the southern end of the Singatse Range, a major cross fault, downthrown on the south, crosses the range (fig. 12). The West Walker River crosses the range in

Figure 11. Steep east front of Singatse Range 7 miles south of Yerington. Late Tertiary basalt flows which cap range are downfaulted to about level of road in right background.

Wilson Canyon, which parallels this fault, but the river remains a few hundred yards north of the fault (on the upthrown side). The river is believed to have crossed the range originally at the structurally low zone south of the fault (on the downthrown side). But incision of the river and general erosional lowering of the terrain caused the outcrop of the south-dipping fault to migrate south of the river.

WASSUK RANGE

The Lyon-Mineral County boundary passes along the western slope of the Wassuk Range, although only a small part of the range is in Lyon County, it will be discussed briefly since some of the critical evidence on the Cenozoic structure of the range is present in Lyon County. The range is asymmetrical in section, with a steep fault scarp on the east and a long gentle backslope to the west. Thick sequences of rhyolite tuff east of Yerington on the northwest flank of the range consistently dip west. The thick Tertiary sequence in the Coal Valley area in southeastern Lyon County also dips west over a broad area. Hence, the Wassuk Range, like the other north-trending ranges of the county area, is a large west-tilted block. However, the dip of the bedded rocks on the west flank of the range is from 10° to 65°, with large areas averaging 30°. Such a dip cannot be sustained across the entire range without a break, and hence the range is probably cut by many faults downthrown on the east which tend to reduce the structural relief induced by the westward tilting.

BUCKSKIN RANGE

The Buckskin Range is a small, north-trending mountainous area 10 miles long at the north end of Smith Valley. The range lies between the Pine Nut range and the Singatse Range. It is separated from the Pine Nut range on the west and north by Churchill Canyon (not to be confused with Churchill Valley 15 miles northeast) and from the Singatse Range on the east by an ill-defined structural basin called Lincoln Flat.

Figure 12. West-dipping Tertiary sedimentary deposits on west flank of Pine Grove Hills just south of Wilson Canyon. In center of photo, deposits are in fault contact with andesite (which normally underlies the sediments).

The Cenozoic structure of the Buckskin Range is complex. Several prominent east-trending faults bring the pre-Tertiary rocks into contact with Tertiary rocks. In general, the range is a west-tilted fault block. The pre-Tertiary rock crops out in greatest abundance along the east front of the range. Much of the middle of the

range is capped by the Hartford Hill Rhyolite Tuff, and Tertiary sediments and Quaternary gravels cap the west slope. The Tertiary rocks dip consistently west.

The fault or fault system which separates the Buckskin Range from the Pine Nut range apparently has a very great relative downward displacement on the east. Rhyolite tuff and sediment in the Buckskin Range dip toward this fault at 25° to 50°. West of the fault, the base of the rhyolite is uplifted to 9,000 feet, or more than 3,000 feet above the valley floor. Displacement on the fault is probably greater than 5,000 feet.

PINE GROVE HILLS

The Pine Grove Hills are the southern extension of the Singatse Range structural block. The Hills are bounded on the north by the canyon of the West Walker River (Wilson Canyon) and on the south by the canyon of the East Walker River.

The general Singatse-Pine Grove structural block widens out to the south and becomes more complex structurally. In general the Pine Grove Hills constitute a west-tilted fault block. The range is broader and more complex than the other fault-block ranges. The northern and southern ends of the Hills best show the west-tilted nature of the block. Toward the center, the structure is more horstlike, with a central plateau of granitic rocks flanked on east and west by Tertiary sedimentary and volcanic rocks.

As previously described, the West Walker River at the north end of the Hills flows through a canyon incised in an older structurally low region. Similarly, the canyon of the East Walker River at the southern end of the Hills is cut in a favorable structural sag. In the southernmost corner of Lyon County, the river follows a broad structural trough in which Tertiary sedimentary rocks are downwarped and preserved, whereas to the north and south, the strata are apparently uplifted and removed by erosion. Toward the southeast corner of Lyon County, the river closely parallels (pl. 1) a northeast-trending fault of great displacement which has downdropped the thick Tertiary sequence of Coal Valley on the east. Oddly, the river is confined to the west, or upthrown, side of this fault (in exactly the same manner as in Wilson Canyon 25 miles northwest). It is believed that the river first found its way through the range on the eastern, or downthrown, side of this fault, and that through general erosion of the entire region, the outcrop of the fault migrated east because of the east dip of the fault. Hence the East Walker River is at present about 1 mile west of the fault outcrop. If the fault is dipping at 45°, the general lowering of the entire surface in this region since establishment of the river on the fault would be approximately 5,000 feet. The East Walker River, like the other major rivers in the area, is consequent, and has sought out a structurally favorable spot to cross the range, rather than being antecedent or superposed.

DESERT MOUNTAINS

The east-trending Desert Mountains (fig. 6) are in northern Lyon County and extend east into Churchill County. The range separates Mason Valley on the south, drained by the Walker River, from Churchill Valley on the north, drained by the Carson River.

The Desert Mountains are unique in the mapped area because of their east trend, which is nearly at right angles to the north trend of the other major fault-block ranges. Furthermore, the range is notable because of the large proportion of Tertiary, relative to pre-Tertiary, rocks exposed (pl. 1).

The Desert Montains appear to owe their elevation more to upwarping and less to faulting and tilting than do the main north-trending ranges of the mapped area. In general, the range appears to be a broad warp with an east-trending axis. The basalt capping the range is warped down more on the north than on the south flank, and pre-Tertiary rocks are exposed only on the south flank. Hence, uplift by faulting was presumably more important on the south margin of the range than on the north, and the range is tilted slightly north. The greater abundance of Tertiary rocks in the Desert Mountains, as compared with the other north-trending ranges, suggests that the range originated later and was uplifted less than the other ranges.

On the southern flank of the Desert Mountains, late Tertiary or Quaternary basalt overlies poorly consolidated Tertiary rocks. Landslides are common in this area and large masses of the basalt have slid down the southern flank of the range.

VIRGINIA RANGE

The eastern Virginia Range is an irregular northeast-trending mountainous area north of the Carson River and south of the Truckee River. Most of the range lies in Storey County, but the east end north of Churchill Butte is in Lyon County.

The range is composed of a thick Cenozoic sequence, predominantly of volcanic rocks, which caps Mesozoic metamorphic and granitic rocks; the Mesozoic rocks crop out mainly at the southern base of the range. The Cenozoic section, which aggregates a maximum of 10,900 feet in thickness (Rose, 1959), is moderately warped and faulted. The greater abundance of pre-Tertiary rocks on the south flank of the range suggests that the range is slightly north-tilted like the Desert Mountains to the south.

CHURCHILL BUTTE

Churchill Butte is an isolated mountain mass in the northern part of Lyon County north of the Desert Mountains between the Carson River and U.S. Highway 50.

A fairly large area of Mesozoic siltstone, argillite, and slate intruded by granitic rocks is exposed on the northeast side of the butte. Andesite and younger basalt on top of the pre-Tertiary rocks are warped and cut by

numerous faults. The dominant west dip of the volcanic rocks, as well as the predominance of pre-Tertiary rocks on the east side of the butte, indicates that Churchill Butte is the exposed part of a west-tilted fault block.

WELLINGTON HILLS AND SWEETWATER RANGE

The north-trending Wellington Hills are the continuation of the Pine Nut Mountains south of the canyon of the West Walker River (Hoye Canyon). The Wellington Hills merge southward into the higher Sweetwater mountains near the California State line. Farther south in California, the Sweetwater mountains merge into the Sierra Nevada northwest of Bridgeport.

The Wellington Hills and Sweetwater Range are predominantly west-tilted fault blocks. Like the other ranges, particularly the Pine Nut Mountains, these ranges are not tilted as a single unit, but as a large number of small fault blocks, generally tilted west. The ranges are cut by many normal faults commonly trending north. Most of these faults dip east and are downthrown on the east.

MINERAL DEPOSITS

INTRODUCTION

Despite its relatively small size, the tricounty area, especially Lyon County, has contributed substantially to the mineral production of the State of Nevada. Through 1965, the three counties produced $316,086,-230 in mineral commodities (see table 2). In 1958, the counties produced 23 percent of the State total; in 1960, 27 percent; and in 1965, 31 percent.

Table 2. Value of mineral production through 1965 in Lyon, Douglas, and Ormsby Counties.

Period	Lyon	Douglas	Ormsby[3]
Pre-1941[1]	$32,005,359	$292,388	.....
1941–1950[2]	2,160,688	3,968	$10,988
1951–1960[2]	138,099,567	8,278,300	394,815
1961–1965[2]	125,999,171	8,469,633	371,354
Total	$298,264,785	$17,044,289	$777,156

[1]Data from Couch and Carpenter, 1943, p. 14.
[2]Data from U.S. Bureau of Mines Minerals Yearbooks 1941–1965. Production for years 1941 to 1952 includes only figures for gold, silver, copper, lead, and zinc.
[3]Figures withheld and not totaled for 1960, 1963, and 1965 to avoid disclosing company confidential data.

The Yerington district has been the largest producing district in Lyon County, having accounted for more than three-quarters of the mineral production of the county. The Anaconda Co.'s Yerington open-pit mine is the second largest copper producer in Nevada. From the time the mine began production in 1953 through 1965, over 800,000,000 pounds of copper had been produced. In addition to copper, Lyon County has produced a large amount of gold and silver. Much of this is from the Silver City district of the Comstock Lode and from placer operations near Dayton on gravels containing gold washed down from the Comstock Lode, which is largely in Storey County.

The Minnesota iron mine in Douglas County has produced well over a million tons of ore for foreign shipment since major production began in 1952.

Considerable published data are available on the mineral deposits and mineral production of Lyon, Douglas, and Ormsby Counties. *Mining Districts and Mineral Resources of Nevada* by Lincoln is a summary of mining activity in the State up to 1923. *Nevada's Metal and Mineral Production* by Couch and Carpenter, 1943, is a general review of mineral production in the State from 1859 to 1940. Two Bulletins of the Nevada Bureau of Mines have been used extensively in compiling data on mineral production of the counties: (1) *Mineral Resources of Storey and Lyon Counties,* by Stoddard and Carpenter, 1950; and (2) *Mineral Resources of Douglas, Ormsby, and Washoe Counties,* by Overton, 1947. For mineral production occurring after the publication of these Bulletins, data were assembled from cited publications, from the U.S. Bureau of Mines Minerals Yearbooks and preliminary reports, from data of the U.S. Geological Survey, and from visits and correspondence of the author.

HISTORY OF MINING

The history of mining in Nevada began in May of 1850, when placer gold was first discovered near the present site of Dayton in northwestern Lyon County. This placer gold was worked for several years, and eventually led to the discovery of its source in 1859 at the Comstock Lode. The major part of the Lode is north of the county line in Storey County, but the Silver City district is in Lyon County and constitutes the southern end of the Comstock fault system. The history of the Silver City district is intimately tied to the general history of the Comstock Lode. Up until 1905, most of the mining of the tricounty area was done in the Silver City region. However, during the early excitement of the Comstock in the 1860's and 1870's, the surrounding countryside was heavily prospected and several small mining districts were formed. These include the Yerington, Talapoosa, Como, Wilson, and Washington districts in Lyon County; the Genoa, Red Canyon, and Mountain House districts in Douglas County; and the Voltaire and Carson districts in Ormsby County. Also during this period, some low-grade coal deposits were developed in the Eldorado district for use in the Comstock region.

Prior to 1907, production from the Yerington district was small and intermittent and was devoted primarily to the production of copper sulfate for use in reduction of the silver ores of the Comstock Lode. Since then, four main periods of activity have elevated the Yerington district to the second most important copper producer in the state. These periods were: 1912–1913,

with a production of approximately $3,500,000; 1917–1919, with $7,000,000; 1927–1928, with $3,000,000; and 1953–1965, with over $250,000,000 (and every indication of continuing). This latest large production is from Anaconda's open-pit operation at Weed Heights.

In the early 1920's, and again from 1940 to 1943, considerable gold production came from large-scale dredging operations on the gravels in Gold Canyon near Dayton. From 1941 to 1943, the Dayton Dredging Co. reported dredging 3,603,276 cubic yards with a recovery of $1,115,752. The company used a 1.5-million-pound dragline with a 180-foot boom and a 14-cubic-yard bucket, reportedly the largest ever used in gold placer work.

The Como district production came mainly in two periods, 1919–1920 and 1935–1936, and by 1940 more than half a million dollars in gold and silver had been produced. During World War II, a premium on tungsten stimulated many small properties to a limited production. Most of these properties are in the Tungsten Hills or Gardnerville district.

In the early 1950's, two significant mining events occurred in the mapped area. The Minnesota mine began sizable production of iron ore for export (60,000 tons in 1952–1953) and the Anaconda Co. began large scale open-pit mining at its Yerington porphyry copper deposit in 1953. From that time through 1965, both these mines have had large production. The Minnesota mine has produced more than 3 million tons of ore and the Yerington mine more than 800 million pounds of copper.

In the summer of 1960, a large contact-metamorphic iron deposit was discovered by Columbia-Geneva Steel Co., 8 miles southeast of Yerington. In early 1961 the company was engaged in exploratory drilling of the deposit.

GENERAL GEOLOGY OF MINERAL DEPOSITS

Most of the mineral deposits of the tricounty area fall into four general groups, distinguished on the basis of age of formation, which also divides them roughly into commodity groups and genetic groups. The general age groups are: (1) Triassic and Jurassic, (2) Cretaceous, (3) Tertiary, and (4) Quaternary.

Deposits formed during the Triassic and Jurassic Periods are relatively minor in the mapped area. Gypsum (as at Mound House and Ludwig) is the principal mineral resource of this age. The gypsum was presumably deposited as evaporite-type deposits in shallow basins and lagoons. The common association of volcanic rocks (chiefly andesitic) suggests these basins were on the shores of volcanic terrain. At Mound House, gypsum has been redeposited in Quaternary terraces below the main outcrop of gypsum and was mined because of ease of working.

Limestone is a second commodity of Triassic and Jurassic Age. It is not present in continuous beds, but rather in discontinuous lenses interbedded with volcanic rock and volcanically derived sediments. Limestone is especially important because many later ore deposits, principally copper, iron, and tungsten, utilize limy rocks as their host. Hence, even though many of these deposits are Cretaceous in age, their formation was made possible by the deposition of limy rocks in the Triassic and Jurassic Periods.

Within the tricounty area, the greatest mineral production has come from deposits probably formed in the Cretaceous Period or those associated with the intrusive granitic rocks related to the Sierra Nevada batholith. These include the contact metasomatic deposits formed near the contact of the granitic rocks with limy sedimentary rocks, vein deposits, and deposits formed within the granitic rocks themselves as the Yerington porphyry copper deposits. The principal copper, iron, and tungsten deposits of the area are of this type, as are probably some of the gold, lead, zinc, and graphite deposits. The Yerington copper deposits are related in age and genesis to quartz monzonite intrusions (Knopf, 1918). Iron deposits of the Minnesota mine and the Dayton region form at the contact of granitic rocks and limy sedimentary rocks. Similarly, numerous contact metamorphic deposits of tungsten, especially in the Pine Nut Mountains east of Gardnerville, belong to this general age group. Deposits in the Churchill, Wilson, Washington, Genoa, Buckskin, Mount Siegel, Gardnerville, Red Canyon, Wellington, Mountain House, Delaware, Carson, and Voltaire districts are probably largely related to the intrusion of the granitic rocks.

Important mineral deposits of the mapped area are Tertiary in age. Many of these deposits appear to be related to the intrusion of shallow igneous bodies, the fluids from which have mobilized and deposited metals in fissure veins. These deposits are generally in veins or fracture zones in country rock, which is commonly intensely altered and silicified. The Comstock Lode is probably the most celebrated of this type of deposit in the West. It is considered by Thompson (1956, p. 72) to be probably Miocene in age. Other gold-silver fissure vein deposits of Tertiary Age are in the Ramsey, Talapoosa, and Como districts.

In addition to vein-type deposits, two coal deposits which have had small production are present in Tertiary rocks. These are in the Eldorado Canyon district and Coal Valley beds in the Washington district. Small deposits of diatomite, clay, basalt cinder, perlite, and pumice also occur in the Tertiary rocks of the area.

Many of the deposits of Quaternary Age are reworked older deposits. Placer gold found in Quaternary gravels has been derived from older deposits, as at the Comstock Lode. And the gypsum deposits at Mound House have been reworked from a large outcrop of Mesozoic gypsum.

Other Quaternary deposits include the large amounts of sand and gravel dug for road metal and concrete aggregate. The quarries of disintegrated granite at the

east base of the Carson Range have produced large quantities of this material. A large volume of well-cemented Quaternary arkosic sandstone has been quarried at the Nevada State Prison and used in the construction of many of the public buildings at Carson City, including the State Capitol. In recent years, basalt cinders have been dug from the vent area of the Pliocene or Pleistocene basalt flow northeast of Carson City. The cinders are used as a light-weight aggregate in concrete and concrete blocks.

MINING DISTRICTS

Ramsey

The Ramsey district is in northern Lyon County on the east flank of the Flowery Range and about 18 miles northeast of Dayton (pl. 2). Couch and Carpenter (1943) list a production of $373,325 for the period prior to 1940.

Gold and silver are present in altered Tertiary volcanic rocks, principally the Hartford Hill Rhyolite Tuff and overlying andesites. Ore occurs in silicified fracture zones in the volcanic rocks.

The Ramsey-Comstock mine, in the northern part of the district, was the original discovery and largest producer. The ore occurs in an east-trending silicified fracture zone 40 feet wide. The vein quartz in this zone carries some gold, but most of the production was from cross fractures within the vein.

Talapoosa

The Talapoosa gold, silver, and copper mining district is in northern Lyon County 4 miles northwest of Silver Springs. Couch and Carpenter (1943), list production prior to 1940 as $12,401. For the years 1939–1942, a production of 7,530 tons valued at $304,151 was reported to the State.

The country rock of the district is the Hartford Hill Rhyolite Tuff, which is cut by andesite dikes and capped by basalt. The rock is intensely altered and silicified, and gold occurs along east-striking, south-dipping, silicified shear zones.

Red Mountain

The Red Mountain district is in northwestern Lyon County and overlaps into Storey County. Couch and Carpenter (1943) report no recorded production prior to 1940.

The Red Mountain district has several small bodies of iron ore developed in metasedimentary rocks near intrusive contacts. The Dayton iron deposit is a hematite-magnetite contact metamorphic deposit in a series of metamorphosed and folded sedimentary rocks near contacts with granitic rocks (Reeves and others, 1958, p. 58). There is no recorded production.

The deposit was purchased by Utah Construction and Mining Co. in 1951, and by 1961 the company had drilled 63,000 feet of exploratory holes. As a result of this extensive work, much is known about the complex geology of the deposit. According to Roylance (1966), the metasedimentary rocks were intruded by Cretaceous diorite, granodiorite, and quartz monzonite and thrown into an anticline overturned to the northeast. Magnetite and minor pyrite have selectively replaced the limestone beds in the metasedimentary sequence. The granodiorite is intimately associated with the mineralized areas and is believed to be the source of the ore-carrying fluids.

Subsequent surface oxidation of the deposit reaches to a depth of more than 100 feet and has converted much of the primary magnetite to hematite. Also in the oxidized zone, much of the pyrite has been leached, and the sulfur content of the ore averages only a few hundredths of 1 percent, whereas in the deeper, unoxidized zone sulfur averages 3.7 percent.

The Pearl Harbor tungsten mine is 10 miles east of Dayton on U.S. Highway 50. The deposit is in a layer of tactite 3 feet wide and 100 feet long in a small pendant of hornfels in granitic rocks. In 1943, some 241 tons of ore, averaging 0.89 percent WO_3, were shipped.

Churchill

The Churchill district is in the vicinity of old Fort Churchill on the Carson River, and includes prospects south of the river as well as some on Churchill Butte north of the river. Couch and Carpenter (1943) list a production through 1940 of $101,412.

Scheelite occurs at several places among the pre-Tertiary rocks on Churchill Butte north of old Fort Churchill. The B, H, and V mine on the south side of the Butte contains scheelite mineralization in silicated limestone near a contact with granite. Thirty-eight tons of sorted ore, assaying 0.6 percent WO_3, were shipped in 1943–44.

On the east slope of Churchill Butte, a prospect has exposed streaks of scheelite-bearing tactite at the contact between granite and a small limestone pendant. Seventy-five tons of sorted ore, estimated to contain 0.75 percent WO_3, were concentrated on tables at a small mill near Weeks.

On the north side of Churchill Butte, showings of scheelite were found in 1939 at several prospects.

Silver City (Chinatown, Dayton, Devil's Gate, Gold Canyon)

The Silver City district is in western Lyon County northwest of Dayton and is actually that part of the southern continuation of the Comstock Lode which is in Lyon County. Production of the district is difficult to separate from that of the Comstock district, since much of the ore mined in the Comstock district was hauled into Lyon County for milling. Couch and Carpenter (1943) give the recorded production of the district through 1940 as $12,740,785. In 1940 the Oro-Neva Dredging Co. reported production of $127,577 in placer gold and silver; this does not appear in Couch's data. In 1941–1943 the Dayton Dredging Co. recovered $1,115,752 in placer gold, making total production from the district $13,984,114.

The first gold discovered in the Silver City district

was panned in 1850 from the south end of Gold Canyon, near Dayton, by members of an immigrant train bound for California. This was the first discovery of gold in what is now the State of Nevada. Placer mining continued in the area for the next 9 years, and in 1859 gold was discovered in place at the outcrop of the Comstock fault near Gold Hill 2 miles north of the Lyon County boundary. This discovery precipitated the rush to the Comstock region, which eventually produced about $400,000,000 in silver and gold.

The silver-gold deposits of the Comstock district have been described by Becker (1882), Giannella (1936), Stoddard and Carpenter (1950), and Thompson (1956). The deposits are associated with several large normal faults which dip about 45° E. and were mineralized probably beginning in Miocene time (Thompson, 1956, p. 72). The main north-trending Comstock fault does not extend into Lyon County, but a southern branch, the Silver City fault, and many cross faults have been productive in Lyon County. Two of the most productive mines on the Silver City fault are the Dayton and Daney. The Oest mine is located on the Haywood or Oest fault, which is an east-trending cross fault.

Large quantities of hot water hampered mining operations in the mines of the Comstock Lode, and enormous volumes of water were pumped to keep the mines open. In 1865 the Nevada Legislature passed an act giving Adolph Sutro an exclusive franchise to build a tunnel 20,498 feet long to drain the mines. The portal of the tunnel is in Lyon County a few miles north of Dayton at an elevation of 4,479 feet (fig. 13). The tunnel was completed in 1878, at which time the rich ore bodies were already mined out, and several shafts were as much as 1,500 feet deeper than the tunnel level.

Figure 13. Portal of Sutro Tunnel at southern base of Virginia Range in northwestern Lyon County. The 4-mile long adit was built in 1869–78 to drain deep mines of Comstock Lode. A stream of water still issues from portal, though adit is badly caved. Andesite outcrops of the Kate Peak Formation are visible on ridge in background.

In addition to the deep lode mining on the Silver City and related faults, large-scale dredging and placer mining have been productive in the Silver City district. The Gold Canyon Dredging Co. produced $309,750 from 3,000,000 yards of gravel southwest of Gold Canyon in 1920–1923.

In 1940 the Oro-Neva Dredging Co. produced $127,577 in placer gold. From 1941–1943 the Dayton Dredging Co. produced $1,115,752 from an area 2,000 feet wide and 2,200 feet long on the north side of U.S. Highway 50 within the townsite of Dayton.

Mound House

The Mound House district is in extreme western Lyon County adjacent to Ormsby County. Couch and Carpenter (1943) list recorded production prior to 1940 as $451,982. Most of the production was gypsum and is described herein by Archbold on the section on Industrial Mineral Deposits.

Eldorado

The Eldorado district is in Eldorado Canyon on the western border of Lyon County south of Dayton. Couch and Carpenter, 1943, record no production for the district prior to 1940.

The Eldorado district was established in the early 1860's for the development of Tertiary coal deposits to be used in the Comstock district. Several hundred tons of coal were marketed despite the fact that the coal beds are thin and the coal poor in heating qualities. Analysis of the coal shows 20 percent moisture, 11 percent ash, 41 percent volatile hydrocarbons, and 28 percent fixed carbon (Stoddard and Carpenter, 1950, p. 78).

Como (Palmyra, Indian Springs)

The Como district, at the crest of the northern Pine Nut Mountains, 15 miles east of Gardnerville, was named for the old town of Como, formerly county seat of Lyon County. Couch and Carpenter (1943) list recorded production prior to 1940 as $511,540.

The district was discovered in the early 1860's, and the area excited considerable interest because of the similarity of the geology with that of the Comstock Lode. Gold and silver-bearing quartz veins cut altered Tertiary andesites. The main quartz veins trend east and contain silver as chloride, free gold, and traces of copper; at fairly shallow depths, part of the silver occurs in tetrahedrite.

The Boyle tunnel was driven several thousand feet to intersect one of the larger veins, the Rapidan, in an effort to develop the vein as well as drain the mines. However, at the lower levels the Rapidan vein was not rich and consisted largely of clay with small quartz lenses.

The Hulley-Logan mine is on the western extremity of one of the Como veins.

North of the Como mines and on the east slope of the range, the Pony Meadows mines are located along a

series of gold and silver veins. In 1929 a small mill was constructed to treat the ores from this area.

Yerington

The Yerington district covers a large area with the town of Yerington at its center. The district includes nearly the entire Singatse Range as well as the buttes in Mason Valley and the northwestern Wassuk Range. Couch and Carpenter (1943) list the production of the district through 1940 as $17,003,283, chiefly from copper. Since then, Stoddard and Carpenter (1950) have reported a 1944–1945 production of $11,000 from the McConnell mine and $40,000 from the Western Nevada mine. From 1953 through 1965, Anaconda's Yerington open-pit mine produced $255,154,480 in copper. This makes a total district production through 1965 of approximately $272,208,763.

The ore bodies of the Yerington district are contact-metamorphic replacement deposits in limy sedimentary rocks, and porphyry copper deposits in plutonic rocks. The oldest rocks of the district are metamorphosed Triassic andesite, soda rhyolite-felsite, and limestone, with subordinate quartzite, shale, and gypsum (Knopf, 1918). They aggregate at least 8,000 feet in thickness, of which volcanic rock makes up 3,200 feet. The Triassic rocks were intruded, probably during the Cretaceous Period by granodiorite, quartz monzonite, and quartz monzonite porphyry. The intruding granitic rock intensely metamorphosed the Triassic rocks, and metalliferous solutions probably related to it moved along faults and favorable zones, producing the mineral deposits.

The Bluestone mine is on the east slope of the Singatse Range 2 miles west of Mason. Copper ore occurs in a garnetized mass of limestone lying in fault contact with granodiorite. Chalcopyrite and pyrite are disseminated through the ore zone, which is composed principally of epidote and some garnet. The main production from the mine was from 1917 through 1920, when 400,000 tons with a gross value of $3,570,000 were reported. In 1924 the mine was taken over by the Mason Valley Mines Co. and its additional production was credited to that company.

The Mason Valley copper mine is 1 mile southeast of the Bluestone mine and 1 mile west of Mason. Primary chalcopyrite with pyrite occurs in a garnetized limestone in a zone more than 1,000 feet long and 150 to 300 feet wide; the zone is in contact with felsite tuff and andesite. Surface ore of copper carbonate and minor cuprite and native copper was present to a shallow depth, and was originally mined for use in the Washoe smelting process in the Comstock district.

From 1912 to 1930, the Mason Valley mines produced 1,701,794 tons of ore with a gross value of $2,735,881, including production from the Bluestone mine after it was taken over by the company in 1924. The Malachite mine joins the Mason Valley mine on the south, and its production was also credited to the Mason Valley Mines Co.

The McConnell mine, less than 1 mile southwest of the Mason Valley mine, contains a copper ore body in garnetized limestone. From 1912 through 1914, the mine produced 14,702 tons having gross value of $106,785, and in 1944 and 1945, produced 700 tons valued at $11,000.

The Homestake mine, 2 miles southwest of the McConnell mine, shipped a small tonnage of copper-silver ore about 1940.

The Western Nevada copper mine, half a mile south of the McConnell mine, is on the south end of the main copper belt on the east flank of the Singatse Range. The ore occurs in garnetized limestone. Early production from the mine was small, but 3,700 tons of ore valued at $40,000 were mined during 1944 and 1945.

The Ludwig mine is on the west base of the Singatse Range 2 miles west of the Bluestone mine. Copper ore occurs at the contact of limestone and garnetite. In 1906 and 1907, a production of $184,000 from 3,000 tons of ore was reported. In 1912 and 1913, railroad shipments, mainly from the Ludwig mine, amounted to 180,000 tons valued at $1,800,000.

Within 200 feet of the Ludwig copper mine, a large mass of gypsum is present interbedded in Triassic rocks. This gypsum has been intermittently mined since 1911, and the deposit is discussed in the section on industrial minerals.

The Douglas Hill copper mine is half a mile southeast of the Ludwig mine. Chalcopyrite and pyrite occur in small lenses erratically distributed in a massive body of garnet. From 1883 to 1891, production totaled $271,804. From 1911 through 1914, 68,905 tons of ore were produced.

The Casting copper mine is about 1 mile south of the Ludwig mine. In the mine, chalcopyrite occurs at the contact of garnetized rock with limestone. In the zone of surface enrichment, chalcocite, covellite, chrysocolla, and copper carbonate are present. To 1914, 29,000 tons of ore were mined, and in the war period of 1916 through 1919, 128,000 tons valued at $2,250,000 were produced. Total production was 454,637 tons valued at $4,265,942.

The Montana Yerington mine is 2 miles north of the Bluestone mine. This property is on a vein which occurs in a fault zone cutting grandodiorite. From 1912 to 1914, 2,000 tons of chalcopyrite ore of 5 percent copper are said to have been shipped.

Anaconda's Yerington ore body is 1 to 2 miles west of Yerington and is partly covered by the alluvial plain at the base of the Singatse Range. The mine was formerly called the Empire Nevada mine, which reported a production of 11,038 tons valued at $95,647 from 1918 to 1920. The mine is entirely within granitic rocks, primarily quartz monzonite porphyry, though development of the open pit (fig. 14) has shown that the granitic rocks represent several intrusive pulses, and are in turn cut by a variety of dikes. The primary sulfide minerals, pyrite and chalcopyrite, occur as minute grains in the groundmass of the porphyry, in feldspar

Figure 14. Anaconda Co.'s Yerington open-pit copper mine as it appeared in early 1961. Pit is located at east base of Singatse Range 1.5 miles west of Yerington. Company town of Weed Heights is visible behind pit on left and parts of crushing and leaching plant on right. Light-colored rock capping the range in left background is Hartford Hill Rhyolite Tuff which dips west (away from observer).

and quartz phenocrysts, and as narrow seams. Generally chalcopyrite is slightly more abundant than pyrite. Small amounts of bornite and covellite are present, and primary chalcocite has been detected microscopically (Wilson, 1963). Molybdenite is rare, and no appreciable gold or silver is present.

In the zone of high-grade mineralization, the porphyry is intensely silicified, but elsewhere it is only moderately altered; wall rocks show albitic alteration (Wilson, 1963).

In 1950 Anaconda had proved by drilling that 60,000,000 tons of ore averaging between 0.9 and 0.95 percent copper were present. More than half of this was oxide ore in which the predominant mineral is chrysocolla (Parsons, 1957, p. 227). The oxide ore overlies sulfide ore and generally the lower limit is distinct. Aside from the chrysocolla, cuprite, tenorite, malachite, and azurite are present in limited amounts (Wilson, 1963).

The oxide ore is treated by leaching with sulfuric acid in a plant adjacent to the mine. The sulfuric acid is manufactured at Yerington from low-grade sulfur ore (28 percent sulfur), which was mined at the Leviathan mine 6 miles west of Topaz Lake in California. The copper in the leach solution is recovered in the form of metallic precipitate by passing the solution through vats filled with iron scrap.

Beginning in 1961, the Anaconda Co. began processing sulfied ore in newly completed concentrators, and by 1963 about two-fifths of the annual copper production was from sulfied ore (table 3). From the beginning of the Anaconda operation in 1953 through 1965, 803,224,674 pounds of copper valued at $255,154,480 were produced.

The Blue Jay copper mine is located in low hills 4 miles east of Yerington. Ore occurs in a shear zone in granodiorite and consists of oxidized copper minerals at the surface and chalcopyrite at depth. There is no reported production.

The Guild Placer mines are about 7 miles northwest of Yerington and 4 miles east of the Minnesota mine in the Buckskin Range. Placer gold occurs in gravel and has been worked from shafts and open-pit mines. Other placer mines include the Guild-Bovard property 2 miles east of the Buckskin and several prospects on the west slope of the Singatse Range.

The Eastern iron prospect is located 1 mile east of the Guild Placer mines (Reeves and others, 1958, p. 68). The prospect is in a small veinlike body of magnetite in granodiorite.

Wilson (Pine Grove, Rockland, Cambridge)

The Wilson district is in southern Lyon County and includes mines in the Pine Grove Hills as well as those east of Pine Grove Flat in the Cambridge Hills. Couch and Carpenter (1943) list a recorded production from the district through 1940 of $778,734.

The mines of the Pine Grove Hills area, including the Wilson mine, the Wheeler mine, and the Rockland mine, occur in a dark, sheared granodiorite cut by dikes of granite porphyry and capped by Tertiary rhyolite. The mines produced mainly gold with some silver. The ore bodies of the Wilson and Wheeler mines occur as quartz stringers and lenses in zones of intense crushing and alteration. The ore of the Rockland mine occurs in a vein cutting both granodiorite and a rhyolite dike.

The Wilson mine was discovered in 1866 and from 1870 to 1899 produced 7,623 tons of ore with a gross value of $220,368. The Wheeler mine produced 6,038 tons of ore with a gross value of $165,911 from 1873 to 1878. The Rockland mine produced 2,747 tons of ore from 1870 to 1879 with a gross value of $74,503; 42,597 tons from 1915 to 1917 with a gross value of $263,071; and 443 tons from 1933 to 1934, with a gross value of $43,037.

The Cowbody tungsten mine is on the west flank of the Pine Grove Hills 4 miles west of the Rockland mine. The mine is located in a metamorphic septum between two granitic intrusions. Scheelite occurs in tactite irregularly developed in a fairly continuous band of marble 25 to 75 feet wide. In 1941, 10 tons of ore were shipped, and in 1943, 112 tons averaging 0.79 percent

Table 3. Copper production of the Anaconda Co.'s Yerington mine through 1965.

Year	Copper in Pounds: Precipitates	Concentrates	Total	Average price per pound (cents)	Value
1953	1,850,674	.....	1,850,674	28.8	$532,990
1954	54,250,266	.....	54,250,266	29.7	16,112,330
1955	70,647,114	.....	70,647,114	37.5	26,492,670
1956	65,021,590	.....	65,021,590	41.8	27,179,020
1957	56,320,696	.....	56,320,696	29.6	16,670,930
1958	53,275,169	.....	53,275,169	25.7	13,691,720
1959	40,448,929	.....	40,448,929	29.8	12,053,780
1960	85,391,545	.....	85,391,545	30.6	26,129,810
1961	57,761,201	5,015,455	62,776,656	29.2	18,330,780
1962	52,731,565	21,240,901	73,972,466	29.8	22,043,790
1963	49,153,802	37,224,791	86,378,593	29.9	25,827,200
1964	40,669,785	35,205,735	75,875,520	31.2	23,673,160
1965	45,440,900	31,574,556	77,015,456	34.3	26,416,300
Total	672,963,236	130,261,438	803,224,674	.....	$255,154,480

WO_3 (88 units). During 1963, the mine produced some lead ore which contained recoverable lead and silver.

The Jackrabbit and Smith Valley lead and zinc mines are 6 miles southeast of Wellington on the northwest flank of the Pine Grove Hills. There has been a small unrecorded production.

In the Cambridge Hills, east of the Pine Grove Hills, are many small gold and silver mines and prospects, including the Cambridge mine. These are included here in the Wilson district, even though they were at one time recognized as the Cambridge district.

The Owen iron deposit (Reeves and others, 1958, p. 76), 2 miles south of the Cambridge deposits, contains several veins of magnetite in pre-Tertiary metavolcanic rock. The veins attain a width of 2 to 4 feet and can be traced for more than 300 feet.

Washington

The Washington district is in the extreme southern corner of Lyon County, on both sides of the East Walker River. Couch and Carpenter (1943) list no recorded production prior to 1940.

Most of the deposits of the area occur in the quartz veins in a porphyritic quartz monzonite which crops out in the river canyon and the bluffs to the west. The district was organized in 1861 and small properties were worked for silver chloride, gold, and copper ores. In 1950 uranium minerals were discovered in the Washington district mainly on the west side of the river. Radioactive material was found in deposits of four types: (1) quartz veins carrying small amounts of copper, lead, and silver minerals; (2) partly altered granite adjacent to quartz veins; (3) gouge zones; and (4) hot springs (Staatz and Bauer, 1953). The deposits are too low in grade and small in size to be of value at present.

Genoa

The Genoa district is on the east scarp of the Sierra Nevada west of the town of Genoa. There is no recorded production from the district.

Interest in the district began as early as 1860, and a considerable amount of work was done without encouraging results. Copper, silver, and gold prospects are located in limy metasedimentary rocks which have been intruded by the granitic rocks of the Sierra Nevada batholith.

Buckskin (Smith Valley)

The Buckskin district lies in the Buckskin Range, a small highland area east of the northern Pine Nut Mountains. Recorded production of the district prior to the beginning of large-scale iron mining at the Minnesota mine in 1944 was $81,035. From 1944 through 1966, the Minnesota mine produced 3,719,000 long tons of ore (table 4). Calculated at $4.50 per ton (Reeves and others, 1958, p. 36), this amounts to a value of $16,736,000 for the mine, and a district value of $16,817,035.

The Buckskin mine, which is the oldest in the district, is located on the southeast side of the range 5 miles northwest of Ludwig. The mine has produced gold and copper from veins and replacement deposits in Mesozoic sheared and altered andesite.

Table 4. Production of Minnesota iron mine through 1966 in long tons. Data to nearest 500 tons.

Year	Long tons
1944	1,500
1945	
1952	60,000
1953	
1954	9,000
1955	18,500
1956	273,000
1957	309,500
1958	235,500
1959	315,000
1960	379,000
1961	282,000
1962	178,000
1963	330,000
1964	410,500
1965	460,000
1966	457,500
Total	3,719,000

The Minnesota mine, well described by Reeves, Shawe, and Kral (1958), currently operated by the Standard Slag Co., is by far the largest producer in Douglas County (table 4). The mine is located on the east base of the Buckskin Range 6 miles northeast of the Buckskin mine. The mine is in Triassic and Jurassic metasedimentary and metavolcanic rocks which have been intruded by granodiorite and quartz monzonite porphyry. The metamorphic rocks from oldest to youngest form an apparently conformable sequence: limestone, quartzite, hornfels, conglomerate, limestone (in part dolomitized), and felsite.

In the early 1920's, the property was developed as a copper mine, and not until 1943 was development of the iron ore attempted. The Standard Slag Co. has operated the mine since 1952.

Mount Siegel

The Mount Siegel district is situated near the crest of the Pine Nut Mountains, 2.5 miles north of Mount Siegel and at the south end of Pine Nut Valley. Couch and Carpenter (1943) show a recorded production value of $3,510 for the district, but other sources put the figure at over $100,000.

The Slater placer mine is in Quaternary gravels, which blanket much of the crest and western slope of the Pine Nut Mountains. The gold, in part occurring as nuggets, is disseminated through gravel and sand; some of the gold is held above true bedrock by layers of hardpan and clay. Production from the mine has always been hampered by a shortage of water.

Gardnerville (Eagle)

The Gardnerville district is located on the southwest slope of the Pine Nut Mountains approximately 10 miles southeast of Gardnerville. Couch and Carpenter (1943) record production from the district prior to 1940 as $29,448.

The Ruby Hill mine is 11 miles southeast of Gardnerville and 1.5 miles west of Sugar Loaf. Copper ore occurs in fractures cutting meta-andesite. The mine was discovered in 1908 and has had a small production.

The Veta Grande mine is 2.5 miles west of the Ruby Hill mine and half a mile east of the site of Carters Station on U.S. Highway 395. The mine occurs in a very large quartz vein, in places greater than 50 feet thick. The vein cuts metavolcanic rocks with interbeds of thin-bedded metasedimentary rocks. The vein contains silver in streaks of argentite and stephanite, and minor amounts of gold.

The Gardnerville tungsten mine is on the west slope of the Pine Nut Mountains, 2 miles north of the Ruby Hill mine. This mine was opened in 1937 by Nevada Tungsten Corp., and a mill was built which processed 723 units of WO_3. The scheelite is in tactite that partly replaces a 6-foot bed of dolomite.

The Tungsten Hills mine is 1 mile north of the Gardnerville mine at the site of the old Cherokee mine. It was worked during 1943–1944 by several lessees for a combined production worth $25,013. Scheelite is found in thin beds of tactite replacing impure limestone interbedded with hornfels.

The Last Laugh and Divide mines are located on the ridge crest 1 mile west of the Tungsten Hills mine. The mines, located in 1943, had a small production during 1943 and 1944.

The Monarch mine produced a small amount of gold in the early period of activity in the Gardnerville district, and a small amount of gold and silver in 1958.

Silver ore was shipped from the Danite mine, just south of the Veta Grande mine in 1964.

Red Canyon (Silver Lake)

The Red Canyon district is located in the southeastern part of the Pine Nut Mountains within and adjacent to Red Canyon. Couch and Carpenter (1943) record production from the district prior to 1940 as $102,818, all of which has come from the Winters and Longfellow mines.

The Longfellow deposit is located 9 miles northwest of Wellington near the crest of the southern Pine Nut Mountains at the site of the town of Bullionville. The first ore mined from the Pine Nut Mountains was hauled from this property in 1862 and milled in Virginia City. Gold, galena, and chalcopyrite are associated with pyrite and specular hematite in quartz veins cutting quartz monzonite. The Washoe claim is just south of the Longfellow mine and consists of east-trending quartz veins cutting quartz monzonite.

The Winters mine is located on the north slope of Oreana Peak 3 miles north-northwest of the Longfellow mine. The ore body is a veinlike replacement in limy argillite and carries galena, stibnite, pyrite, and chalcopyrite.

The Red Canyon claims are near the mouth of Red Canyon at the east foot of the Pine Nut Mountains. Here limy metasedimentary rocks are cut by quartz monzonite; pyrite, chalcopyrite, and pyrrhotite are present in the contact metamorphic deposits.

The Lucky Bill mine, 2 miles south of the Winters mine, is in fractured quartzite with disseminated pyrite. Argentiferous galena, quartz, and stibnite, together with pyrite and chalcopyrite, occur irregularly along fracture zones (Hill, 1915, p. 62).

Wellington (Silver Glance)

The Wellington district includes small mines and prospects in the southern Pine Nut Mountains and the Wellington Hills. Total reported production of the district was $6,099 prior to 1940 (Couch and Carpenter, 1943).

Several mines, which were first developed in the late 1800's, are located in the granitic rocks of the southern Pine Nut Mountains. The Imperial claims, 5 miles west of Wellington, contain gold with pyrite and galena in north-trending quartz veins. The Taylor Hill (Yankee Girl) mine, 2 miles northwest of Wellington, contains gold and copper-bearing quartz veins which strike N. 50° E. The South Camp mine, 6 miles northwest of Wellington, contains several quartz veins which strike N. 5° E. The veins cut quartz monzonite near dikes of quartz monzonite porphyry and andesite.

Several mines and prospects occur in limy metasedimentary rocks in the Risue Canyon area 10 miles south of Wellington. The Arrowhead mine contains primary copper sulfide in replacement deposits in the metamorphic rocks. Gold and tungsten deposits have also been reported in this area.

The Boulder Hill mine on the east scarp of the Wellington Hills 4 miles south of Wellington has produced a small amount of silver ore. The mine is especially interesting because of a veinlike mass of fluorite which caps the ridge above the mine.

In scattered areas in the Wellington district some occurrences of perlite have been prospected. These are present along the West Walker River in Hoye Canyon and in the low rhyolitic hills at the northern tip of the Sweetwater Range.

Mountain House (Holbrook, Pine Nut)

The Mountain House district is located in the southwestern Pine Nut Mountains east of Holbrook Junction on U.S. Highway 395. Couch and Carpenter (1943) list $6,754 as the recorded production prior to 1940. The chief production has been from the Willard-McDonald gold-silver mine 1 mile northeast of Holbrook Junction.

Delaware (Sullivan, Brunswick)

The Delaware district lies east and south of the Carson River in and near Brunswick Canyon. Couch and Carpenter (1943) list no recorded production for the district prior to 1940. Since then there has been a small production, mainly of tungsten and iron.

The Bessemer mine in Brunswick Canyon contains a deposit of magnetite and hematite on a southeast-trending mineralized fault (Reeves and others, 1958, p. 61). The ore occurs in Tertiary andesite flows and breccia. Less than 1,000 tons of ore were shipped, mainly in the interval 1944–1954, to be used in high-density concrete ship ballast.

The Capitol iron deposit is 1 mile northwest of the Valley View mine and east of the southern end of Prison Hill (Reeves and others, 1958, p. 66). Magnetite and hematite occur in veinlike bodies along fault zones in hornblende diorite near a contact with limestone. There has been no production from the property.

On McTarnahan Hill, 2 miles east of Prison Hill on the west flank of the Pine Nut Mountains, are several small tungsten mines and prospects. In this region, limy shale, slate, and hornfels are intricately intruded by granitic rocks, and scheelite occurs in tactite developed near the contact. The Valley View prospect is on the west slope of McTarnahan Hill. During 1943 a 34-ton shipment of 0.6 percent WO_3 ore was made. The Valley View claims have also been prospected for lead and silver, and for mercury, which occurs as cinnabar with jarosite in a 3-foot fracture zone (Bailey and Phoenix, 1944, p. 158).

The Alex Eske tungsten property is located on the east and north flanks of McTarnahan Hill. Small replacement bodies of massive hematite are associated with tungsten-bearing tactite. There has been no production.

The Dixon manganese-tungsten deposit is located in the northern Pine Nut Mountains 4.5 miles south of Dayton. The deposit is in Tertiary rhyolitic tuffs which probably belong to the Hartford Hill Rhyolite Tuff. The tuffs strike northward and dip to the west at moderate angles. Where the tuff is locally brecciated and intensely silicified, it contains veinlets of tungsten-bearing manganese oxide. There has been no production from the property.

The Comstock Extension gold-silver mine is in the upper Brunswick Canyon area 1 mile northeast of the Bessemer mine. The mine contains fissure veins in andesite containing gold and silver.

The United Mining Co. copper mine is located 3 miles southeast of McTarnahan Hill and occurs near the contact of granitic and metamorphic rocks.

The Bunker Hill mine, 1 mile north of the Valley View mine, has been intermittently worked for gold and copper.

Carson

The Carson district includes the southern slope of the Virginia Range and the sandstone quarry at Nevada State Prison. Couch and Carpenter (1943) list no recorded production for the district prior to 1940.

North of Carson City in the southwest edge of the Virginia Range, many small deposits are present near the intrusive contact of granodiorite and limy metasedimentary rocks. Gold, copper, lead, and silver were prospected in the early days, and more recently small shows of tungsten have been reported.

The Carson River has commanded attention as a potential producer because of the large quantities of Comstock tailings, quicksilver, and amalgam discharged into it from the many mills from Empire to Dayton. None of the many efforts to recover this material have been economically successful.

Voltaire (Eagle Valley, Washoe)

The Voltaire district is situated on the east slope of the Sierra Nevada west and southwest of Carson City. Couch and Carpenter (1943) list no recorded production for the district prior to 1940. However, a small production is known from the district.

The Premier mine, 2 miles west of Carson City at the east base of the Sierra Nevada, is partly in limy quartz-mica schist whose foliation strikes generally northward and dips 60° W. Copper-bearing sulfide minerals occur in massive quartz bodies and in the schist near the quartz. Silver and gold are reported to be present, and traces of antimony, bismuth, lead, and cobalt.

In the early history of the district, several small gold mines were active. Small deposits of arsenic, silver, and copper have also been worked sporadically.

INDUSTRIAL MINERAL DEPOSITS

By

N. L. Archbold, *Nevada Bureau of Mines*

Industrial mineral or nonmetallic deposits in Lyon, Douglas, and Ormsby Counties are not as well known as the metallic deposits despite their importance in terms of dollar value produced; therefore, a reconnaissance study of the deposits was undertaken. An effort was made to locate all deposits referred to in the geologic literature on Nevada. Additional deposits were found by reference to the files of the U.S. Bureau of Mines, and still others were located from information furnished by prospectors and from records on file with the various County Recorders. Some deposits may have been missed, but their exclusion here in no way reflects upon their present or potential value.

No effort will be made in this discussion to review general characteristics, uses, processing, or marketing of the various commodities. Such information is available in one of the following references:

"Industrial Minerals and Rocks," 1960, American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, N.Y.

"Mineral Facts and Problems," 1965, U.S. Bureau of Mines Bulletin 630.

"Mineral and Water Resources of Nevada," 1964, Nevada Bureau of Mines Bulletin 65.

Testing of individual deposits for conformity to market specifications, as well as exploration for new deposits, is the function of individual users of the specific commodities. Thus, no testing nor exploration were undertaken during this reconnaissance study of the industrial minerals.

Diatomite

Diatomite is a sedimentary accumulation of the siliceous remains of microscopic aquatic plants. It is characteristically light colored, soft and friable, with an extremely low density. Mineable diatomite beds occur at various horizons in Tertiary sedimentary rocks in Nevada. In Lyon, Douglas, and Ormsby Counties, the known deposits are confined to northern Lyon County, where they are included as parts of the Tertiary sedimentary rocks on the geologic map (pl. 1). Because of its nonresistant character, diatomite is easily eroded and covered by thin alluvial deposits, thus significant deposits may lie beneath the covered areas shown on the geologic map.

Northern tip of Lyon County

Diatomite crops out over an area of more than 1 square mile along the county line about 10 miles southeast of Fernley. The area has been explored by means of numerous shallow trenches but has yielded relatively little production.

Exposures of diatomite occur in two smaller areas west of the area described above: one, about 1.5 miles west; the other, about 3 miles west. Diatomite in these smaller areas of exposure seems less pure and has not been extensively explored.

Snow White, Marvel, Light Weight, and White Caps claims

The Snow White, Marvel, Light Weight, and White Caps placer claims cover an area of 1 square mile south of Churchill Butte and about 5 miles west-southwest of Weeks. Diatomite is exposed in several shallow open cuts, but most of the area is covered by alluvium and exposures are not adequate to show the areal extent of the diatomite, its total thickness, or relation to the surrounding rocks.

White Horse and Pale Face claims

Diatomite crops out along a canyon on the south side of Cleaver Peak about 3 miles north-northwest of Wabuska. Several bulldozer cuts expose the diatomite and interbedded tuffaceous rocks at intervals for an estimated 2,000 feet. The diatomite, however, appears complexly faulted and is probably at the surface only in small fault blocks. Younger, vesicular basalt overlies much of the area, and talus covers most of the slopes, thus obscuring the actual extent of the diatomite.

Weeks deposit

The Weeks diatomite deposit is east of U.S. Highway Alternate 95 and about 3 miles south of the Weeks siding on the Southern Pacific Railroad. Diatomite is poorly exposed along the bottom and sides of a canyon that trends northward; the area of outcrop is about 700 feet wide and nearly a mile long. Unweathered diatomite is exposed in several trenches and one pit some 15 feet deep and 100 feet across. The diatomite appears to be in a nearly flat-lying unit within Tertiary volcanic rocks. Total thickness is not exposed, but general topographic relations and scattered exposures indicate a thickness of about 30 feet. Considerable amounts of gray tuffaceous material are interbedded with the diatomite, and individual diatomite samples seem to have a relatively high specific gravity. Some material from this deposit was shipped to the Nevada Cement Co. at Fernley during 1965.

Gypsum

Two gypsum deposits in Lyon County have produced gypsum estimated at $1,000,000. Both deposits still retain some reserves, but these reserves are diminished by gradational changes to anhydrite at depth.

Ludwig mine

The Ludwig gypsum mine is on the west side of the Singatse Range about 7 miles west-southwest of Yerington. When visited in August of 1965, the mine was inactive but still owned principally by Ideal Cement Co. Previous descriptions of the mine have been published by Rogers (1912), Jones (1912), Knopf (1918), and Stone and others (1920). The following description is taken partly from these sources.

In the mine area, a gypsum bed is faulted into close association with a copper lode so that both gypsum and copper have been mined. The general surficial geology is illustrated in figure 15. Lithologic units crop out as belts trending north-northeast, separated by faults or intrusive contacts that dip steeply to the east-southeast. From east to west, these belts are: (1) quartzitic sedimentary and volcanic rocks intruded by quartz monzonite, (2) marble, (3) gypsum, and (4) quartz monzonite.

The eastern belt consists of metamorphosed rocks believed to represent fine-grained siliceous and felsitic volcanic rocks of Mesozoic Age. These are separated from the marble on the west by a fault with an average dip of 70° SE. A quartz and limonite gossan marks the outcrop of a copper-bearing lode that is localized in the fault zone. This gossan is as much as 80 feet wide and can be traced for about 600 feet on the surface. Close to the hanging wall of the lode, the rocks of the eastern belt have been locally metamorphosed to garnetites. Locally, the metamorphic rocks are intruded by quartz monzonite. This is illustrated in the northern part of the belt, shown on figure 15, and is reported by Knopf (1918) on the deeper levels of the copper mine. Porphyritic quartz monzonite, which crops out in this eastern belt, has been altered in part by silicification and sericitization, and contains disseminated pyrite crystals.

Marble forms the footwall of the copper lode; it

Figure 15. Geologic map, vicinity of Ludwig mine, SE¼ sec. 27, T. 13 N., R. 24 E., Lyon County.

extends north of the copper lode as a belt 100 to 200 feet wide between metamorphic rocks and quartz monzonite on the east and gypsum on the west. In the area of the copper lode, the marble is cut by a transverse fault which causes the disappearance of the gypsum belt and a much wider outcrop of marble. The marble is very coarse grained and strongly brecciated. Lime silicate and sulfide minerals are disseminated through the marble, particularly in the vicinity of the copper lode. Bedding in the marble dips 50° to 70° SE, nearly parallel to the fault that bounds it on the southeast.

Gypsum crops out in an exposed belt about 500 feet wide and 1,500 feet long. It is separated from marble on the east by a fault zone that contains gouge 20 to 40 feet thick. This fault parallels the one along which the copper lode occurs, but southward, both it and the gypsum appear to terminate against the transverse fault mentioned earlier. The northern limit of the gypsum belt has not been mapped, but the gypsum probably terminates against a fault or intrusive contact not far north from the edge of the open pit shown on figure 15. The gypsum is bordered on the west by unaltered quartz monzonite, but the actual contact is not exposed. The contact between gypsum and quartz monzonite is inferred to be intrusive, but there is a possibility that it is a fault. According to previous descriptions of the underground geology, it can be inferred that the gypsum gives way to anhydrite along a gradational, undulating contact about 200 feet below the surface.

Mound House

Both rock gypsum and gypsite have been mined in the Mound House area about 6 miles northeast of Carson City. Two kettle plants were once active at Mound House, manufacturing plaster from the gypsum and gypsite. Between 1914 and 1920 the Pacific Portland Cement Co. produced an unrecorded tonnage of gypsum valued at $451,982 (Couch and Carpenter, 1943). In 1965 small amounts of gypsum were being produced for use mainly as soil conditioner.

Jones (1920) published an excellent description of the deposits. Thompson (1956) mapped the area immediately to the north, and Schryver (1961) mapped the area of the deposits. The following description is taken mainly from these three authors with minor modifications. Interested readers should check the earlier references for more detailed descriptions.

A geologic map, slightly modified from Schryver (1961), and covering the area of gypsum and gypsite, is shown in figure 16. Rock units in the area are of three main age groups. Metamorphosed Triassic and Jurassic igneous and sedimentary rocks constitute the oldest group. The metamorphic rocks are unconformably overlain by a complex group of Tertiary volcanic rocks. The Mesozoic and Tertiary rocks are covered locally by Quaternary basalt and unconsolidated surficial deposits.

Most of the Triassic and Jurassic rocks consist of metamorphosed andesite and diorite with minor amounts of more acidic types. Preservation of pyroclastic features shows that most rocks were volcanic, but since the entire mass is metamorphosed to resemble diorite in hand specimens, some of the dioritic rock may be intrusive. Characteristically these metamorphosed igneous rocks contain epidote along fractures. Outside the mapped area shown on figure 16, the metamorphic rocks include slate, schist, and hornfels, at least in part interbedded with the older volcanic rocks.

Limestone and gypsum also occur within the Triassic and Jurassic rocks in the Mound House area. They occur together in a fault block about 3,000 feet long and 1,500 feet wide in the SW¼ sec. 24 and the NW¼ sec. 25 (fig. 16). The block of limestone and gypsum is probably bounded by faults, but the possibility exists that the contact of limestone and gypsum with diorite is partly intrusive. Jones (1920) reported drill records showed that the gypsum grades to massive anhydrite about 300 feet below the surface, or 200 feet below the bottom of the main quarry. Schryver (1961) mapped a fault contact between limestone and gypsum; Jones (1920), on the other hand, states that they are interbedded. In the main pit area, the gypsum may actually be an intrusive or diapiric mass in the limestone. In places the gypsum mass contains large blocks of limestone that might have been included during forcible injection of the gypsum. The contact between limestone and gypsum has not been mapped in detail, and additional work is needed to determine their true relation.

The Tertiary volcanic sequence in the vicinity of the gypsum and gypsite deposits comprises four main units; numerous other units have been mapped outside the area shown on figure 16. The oldest volcanic unit, the Hartford Hill Rhyolite Tuff, unconformably overlies the Triassic and Jurassic rocks and consists of rhyolitic to dacitic flows and pyroclastics with some interbedded tuffaceous units. Pyroxene and hornblende-bearing andesites of the Alta Formation lie above the Hartford Hill. Locally the Alta contains coarse breccia units similar to some found in the next higher unit, the Kate Peak Formation. The Kate Peak is also andesitic; it contains agglomerates, flows, and intrusive bodies distinguished from the underlying Alta mainly by their more silicic composition and less dense texture. Vitrophyric units are locally present in the Kate Peak Formation. Several small areas of fine-grained basaltic to andesitic rocks in the Mound House area have been correlated with the Lousetown Formation by Schryver (1961) even though they lack the olivine typical of the Lousetown at its type locality 6 miles north of Virginia City.

Quaternary deposits consist of a basalt flow, gypsite, and alluvium with minor landslide debris, talus, and terrace gravels. The basalt flow covers a strip along the western margin of the map area and appears to originate from a cinder cone to the northwest of the map area. The flow is characterized by a vesicular top, thin and platy flow layers in the central part, and a massive basal part with local zones of flow breccia.

Figure 16. General geology in vicinity of Mound House gypsum deposit, Lyon and Ormsby Counties.

Gypsite occurs as units covering terraces in the alluvium. At least seven different terrace levels are present. According to Jones (1920), the gypsite on these terraces was originally 5 to 15 feet thick. Much of this gypsite has been removed in later mining. There is little doubt that the gypsite was derived from erosion of the older gypsum and deposited along shore lines on the edge of standing water that lay to the southeast of the gypsum body.

Talcose, Sericitic, and Aluminous Deposits

Several deposits of talcose, sericitic, or aluminous materials occur in Lyon and Douglas Counties. Mineralogically these consist of chlorite, pyrophyllite, sericite, andalusite, and corundum in varying amounts.

Sericite claims

Fine-grained, soft, micaceous material crops out on the Sericite claims near the State line in Douglas County about 7 miles southwest of Topaz Lake. Several small prospect pits constituted the only evidence of work when the deposit was visited in 1965. The main deposit is a sericitic layer 10 to 12 feet thick striking to the north and dipping steeply to the west in a series of metamorphosed Triassic and Jurassic volcanic rocks. The sericitic layer crops out for a distance of about 100 feet and is covered on both ends by alluvium or talus. Other exposures of the sericitic material occur in the same general area. X-ray analysis of a single sample showed the presence of fine-grained muscovite with quartz. Microscopic examination revealed the presence also of finely disseminated opaque material and a trace of tourmaline.

Blue Metal prospect

The Blue Metal or Blue Danube prospect is at the south end of the Buckskin Range in Douglas County about 12 miles west of Yerington. The U.S. Bureau of Mines did some exploratory and laboratory work on the deposit in 1945, and the following description is condensed from Binyon's (1946) report on that work. The deposit has had no production.

Country rock at the Blue Metal property consists of weakly metamorphosed Mesozoic andesite intruded by later lamprophyre dikes. The andesite shows widespread silicification and sericitization. Most of the sericitic alteration is along shear zones in the andesite, and corundum-andalusite mineralization is confined to the sericitized zones. The dominant shear zone on the Blue Metal property strikes N. 25°–30° E. and dips steeply to the northwest; it is about 50 feet wide and at least 300 feet long. Corundum-andalusite bodies are scattered within the main shear zone but are largely confined to a zone measuring 50 by 75 feet on the surface, the zone tested by the U.S. Bureau of Mines. In the outcrop, corundum and andalusite occur as aggregates, up to 2 or 3 feet across, of minute, poorly formed crystals. The highest grade material from the outcrop consisted of a sericitic matrix containing quartz, rutile, and 18 to 23 percent, by weight, andalusite and corundum. An adit driven 70 feet vertically below the outcrop of the corundum-andalusite bodies showed that the minerals were absent from the shear zone at that depth.

Beneficiation tests by the U.S. Bureau of Mines showed that abrasive-grade corundum was not recoverable from the deposit, but that material suitable for the manufacturing of high-alumina refractories might be recovered.

Top prospect

The Standard Slag Co. has a deposit of pyrophyllite on their Top claims, about three-fourths of a mile southwest from the Minnesota iron mine in the northeast corner of Douglas County. The pyrophyllite deposit has been explored in bulldozer trenches and one open cut. The main body occurs as a replacement deposit in metamorphosed, quartzitic sedimentary or pyroclastic beds of presumed Triassic or Jurassic Age. As exposed, the pyrophyllite body is about 100 feet across. Other, smaller deposits are reported in the same general area. The material is white to light gray, massive and slightly iron-stained on fracture surfaces. The X-ray diffractogram from a single specimen shows that some sericitic material is associated with the pyrophyllite.

Talco prospect

The Talco prospect is on Luhr Hill, about 2.5 miles southeast of Yerington. Talcose material occurs along a shear zone that strikes N. 50° E. and dips 35°–40° NW. in coarse-grained, porphyritic quartz monzonite. The shear zone is poorly exposed on the surface and can be traced for less than 100 feet. An incline exposes the shear zone for about 30 feet down the dip. Talcose material along the shear is about 3 feet thick where it is exposed at the top of the incline. The light-green to white talcose mineral has been referred to as pyrophyllite (Stoddard and Carpenter, 1950, p. 95), but the X-ray diffraction pattern of one sample closely matched that of the magnesium-aluminum chlorite, leuchtenbergite, formed by replacement of the quartz monzonite along the shear zone. All stages of replacement are evident from fresh quartz monzonite through bleached, weakly altered rock to massive green leuchtenbergite.

Barite and Fluorite

Barite and fluorite occur only sparingly in Lyon, Douglas, and Ormsby Counties despite the widespread occurrence, especially of barite, in Mineral County to the southeast. The northeast-trending belt of barite deposits in Mineral County (Archbold, 1966) does not extend into the region covered by this report.

Prison Hill

Small pods of barite are exposed in prospect pits on a knoll at the north end of Prison Hill about 2 miles east of Carson City. The barite is not well exposed but seems to form isolated pods several feet across in metamorphosed andesitic rocks of Triassic or Jurassic Age.

Brunswick Canyon

Overton (1947) refers to a deposit of barite at the Yerington iron mine in Brunswick Canyon. This deposit could not be located during the reconnaissance; therefore, it is not shown on plate 2.

Boulder Hill

The Boulder Hill mine is on the east scarp of the Wellington Hills about 4 miles south of Wellington. The mine itself has produced a small amount of silver but is included in the section on industrial minerals because of two large fluorite-bearing jasperoid masses that crop out on the slope about 1,200 feet southwest and 2,200 feet south of the mine.

A geologic map of the area around the Boulder Hill mine is shown in figure 17. Principal lithologic units exposed in the area consist of a block of Triassic and Jurassic sedimentary rocks intruded by granodiorite and faulted against a series of Tertiary volcanic rocks lying to the west. The Triassic and Jurassic sedimentary rocks are limestone and weakly metamorphosed shaly to siliceous rocks. These sedimentary rocks are cut by numerous high-angle faults, which also form the contacts between limestone and shaly or siliceous sedimentary rocks. Bedding in the various fault blocks dips moderately at diverse angles, not measured in the reconnaissance mapping. Two brecciated jasperoid bodies replace limestone along one of the faults. The larger jasperoid body is 500 feet long and as much as 150 feet wide. The smaller mass, which lies about 2,000 feet south, is 400 feet long and about 50 feet wide. Both jasperoid bodies are nearly vertical, but may not extend to any appreciable depth.

Small masses of granodiorite intrude the sedimentary rocks. Two such intrusives are shown on figure 17, but other, smaller ones may have been missed during the reconnaissance mapping.

The block containing the sedimentary rocks is bounded on the east by a basin-range fault and an alluvium-filled valley. On the west, the block of sedimentary rocks is faulted against a series of Tertiary volcanic flows that dip 30°–45° W.

Faults in the sedimentary rocks have been prospected for silver. Minor fluorite is found in most of the prospect pits, but the largest amount of fluorite is associated with the northern jasperoid. Fluorite forms veinlets, fills vugs, and is disseminated throughout the jasperoid. Locally, fluorite forms a major part of the rock and imparts a very fine-grained crystalline appearance. The largest crystals of fluorite are up to half an inch across but most are less than a quarter of an inch across. Reported analyses of the fluorite-bearing jasperoid range from 24 to 70 percent CaF_2.

Cinders and Perlite

Cinders and perlite are of limited importance in Lyon, Douglas, and Ormsby Counties. Only one deposit was being actively mined in the early part of 1966.

Cinderlite deposit

Early in 1966, the Cinderlite Corp. was mining a volcanic cinder cone in the northern tip of Ormsby County about 5 miles north of Carson City. Black and reddish brown cinders are mined separately, sorted into size groups, and used primarily for light-weight aggregate in building products or for decorative purposes.

Wellington district

Perlite deposits in Hoye Canyon along the West Walker River about a mile southwest of Wellington have received slight attention by prospectors. Perlite occurs within a unit of agglomeratic and columnar andesite that crops out in cliffs along the west side of the canyon. The andesite, which is up to 100 feet thick in the area of the perlite deposits, unconformably overlies Tertiary sedimentary rocks and is in turn covered by additional Tertiary sedimentary deposits. Locally, the basal part of the andesite is tuffaceous. The andesite is exposed as a northward-trending strip about 1,000 feet wide; it dips about 40° W., whereas the overlying strata dip about 20° W. Perlite is in the form of elongate bodies up to 1,000 feet long, 100 feet wide, and 50 feet thick that trend east to northeast. Two such bodies are in the SW¼ sec. 3 and another is in the SW¼ sec. 10. Much of the perlite in the SW¼ sec. 10 occurs as rounded masses up to 3 feet across in a matrix of partly devitrified perlite; this matrix forms about 20 percent of the total mass. None of the perlite bodies is uniform throughout. A single sample was analyzed some years ago by the U.S. Bureau of Mines with the following results:

Chemical Composition

SiO_2	68.2%	MgO	0.4%
Al_2O_3	13.8%	K_2O	4.07%
Fe_2O_3	1.79%	Na_2O	3.4%
CaO	1.7%	Loss on ignition	3.4%

Expansion —14 mesh at 1800° = 30%
Expansion —14 mesh at 2200° = 65%

Sweetwater Hills and Pine Grove Hills

Perlite deposits have also been prospected in low hills of rhyolite at the north end of the Sweetwater Hills and along the east base of the Pine Grove Hills. Neither of these areas was examined during this reconnaissance survey.

Graphite

Chedic mine

The Chedic graphite mine about 3 miles southwest of Carson City has also been called the Voltaire mine and the Carson Black Lead mine. According to Overton (1947), the mine was opened by Walter Chedic in 1903 and for some years thereafter graphite was produced, under the name of the Carson Black Lead Co., for use in pigments, foundry facings, and lubricants. Graphite was mined from an open pit about 120 feet long, 20 feet deep, and 35 feet wide. The graphite formed a lense or bed enclosed in metasedimentary

Figure 17. Geologic map, vicinity of Boulder Hill fluorite deposit, Douglas County.

schist and gneiss that dips to the north. An andesite dike crops out in the south face of the quarry on the footwall side of the graphite, but its relation to the graphite body is not known. The graphite body is about 10 feet thick in the west end of the pit but was said to be as much as 35 feet thick in the pit area. Talus and vegetation cover most of the area around the main pit, but graphite is exposed in a cut 200 feet east of the main pit and in another cut about 600 feet east of the main pit. The graphite may be continuous between all three exposures or may form only discontinuous lenses along the strike. The graphite is the "amorphous" variety, and according to the publication, "Mineral Resources of the United States" for 1913, it contains 30 to 50 percent graphitic carbon.

Limestone

Limestone is widespread in Lyon, Douglas, and Ormsby Counties, where it occurs mainly within the areas mapped as Triassic and Jurassic metasedimentary rocks (pl. 1). Some limestones, however, are of Cenozoic Age. No effort was made during this reconnaissance to sample and analyze the many exposures of limestone. Mostly, the limestone has not been prospected nor utilized; however, minor amounts have been used from two localities in the past and Nevada's only cement plant presently obtains its limestone from a quarry in Lyon County.

Nevada Cement Co. quarry

The following description of the Nevada Cement Co. quarry near Fernley is copied from a recent paper by Stephenson (1966):

> "The Fernley limestone deposit is located 4 miles south of Fernley in hills on the northeast flank of the Virginia Range. This deposit is a unique source —a freshwater lake deposit of Late Tertiary age that was laid down during a local sedimentary interlude in what was dominantly a volcanic epoch.
>
> "The limestone is exposed in a single irregular outcrop area about 2.5 miles long, elongated northwest-southeast and covering a total area of about 1.1 square miles. Highway U.S. 95 Alternate is just off the west end of the deposit. Elevations range from 4,350 feet at the base of the lowest exposures on the northwest to 5,100 feet at the crests of the limestone ridges in the east-central part. Mining is on claims located for Nevada Cement Co. in 1962. The present quarry is in the east part of the area, and the truck haul to the plant is about 7 miles.
>
> "The formation consists of light-tan to brown fresh-water limestone interbedded with marl and water-laid tuff. Tentatively it is correlated with the Esmeralda-Truckee-Humboldt formations of late Miocene or early Pliocene age. Individual beds or masses of limestone range from a few inches to many feet in thickness, and typically the thicker beds form prominent bluffs on the steep slopes. In places marl and tuff make up the greater part of the formation.
>
> "Except at the west end, where the formation is in contact with late alluvium, the deposit is entirely surrounded by Tertiary volcanic flows, pyroclastics, waterlaid tuffaceous sediments, and bench gravels. Structurally, the formation occupies the eroded crest of a broad, low anticline. On the north the volcanic rocks dip uniformly northward or northeastward at angles of 10° to 30°; on the south the structure is more complicated, and it may be that a major strike fault cuts the south part of the crest. Within the anticlinal structure the limestone is locally folded and is cut by many normal faults, mainly of relatively small displacement.
>
> "The limestone varies widely in texture and appearance but roughly comprises three chief types: (1) a hard, finely crystalline variety, (2) a hard, very fine earthy variety, and (3) a soft, granular variety. The content of calcium carbonate is variable, ranging from less than 65 percent to more than 90 percent in the better rock, which is uniformly low in iron, alumina, magnesia, and alkali. Most of the marls and tuffs are low in carbonate, but minor amounts of this material necessarily are mined with the limestone without deleterious effects. The kiln feed is held at 76 percent calcium carbonate without difficulty.
>
> "Much of the limestone is relatively high in silica, which ranges from 6 percent to more than 30 percent and averages about 19 percent. The silica occurs as chalcedonic or flinty quartz that forms small, irregular lenses, stringers, and blebs, or that lines small drusy cavities in the limestone. Irrespective of the wide variations in percentages of calcium carbonate and silica from place to place, the two occur in a remarkably uniform relationship whereby they consistently total 95 percent to 97 percent of the material in any given sample. In combination with the low-alkali clay they form a raw mix that is easy to control and that produces a high quality, low-alkali cement."

Smaller exposures of limestone occur in the hills to the southeast of the Nevada Cement Co. quarry. These appear geologically similar to the deposit described by Stephenson.

Eldorado Canyon

Near the north end of Eldorado Canyon, 2 miles south of Dayton, a travertine terrace has been built up by surface deposition from hot springs, now inactive. During the active mining on the Comstock Lode, the travertine was burned for lime in several stone kilns.

Wabuska

Limestone crops out in the area around the old Thompson smelter, about 2 miles northwest of Wabuska. According to Stoddard and Carpenter (1950), a small vertical kiln was operated in the 1910's at Wabuska to convert a limited tonnage of the limestone to lime.

Dayton iron deposit

The Dayton iron deposit is about 12 miles west-southwest from Silver Springs and near the border of Lyon County. Iron ore occurs mainly within a host limestone

which crops out in the general area. Rose (1959) sampled a Mesozoic marbleized limestone body enclosed in granodiorite in sec. 6, T. 17 N., R. 23 E. Analysis of this marble gave the following results: CaO, 48.84 percent; MgO, 0.26 percent; K_2O, 0.024 percent; Na_2O, <0.05 percent; Fe, 0.71 percent; R_2O_3, 11.24 percent; insolubles (mainly SiO_2), 10.06 percent.

A Pleistocene limestone bed about 15 feet thick crops out in the area described above. Analysis of a sample gave the following results: CaO, 51-89 percent; MgO, 0.44 percent; K_2O, 0.028 percent; Na_2O, <0.05 percent; Fe, nil; R_2O_3, 5.68 percent; insolubles (mainly SiO_2) 8.22 percent.

Salines

Wabuska

The Wabuska salt marsh is just north of Wabuska in Lyon County. In the 1930's sodium sulfate was recovered by the American Sodium Corp. and shipped to Washington and Oregon for use in paper processing. In 1959 Magma Power Co. drilled three wells in the area as potential sources of geothermal energy.

Russell (1885) gives the following as the sequence of layers near the surface of the marsh:

White, hard crust of sodium sulfate, sodium chloride, calcium carbonate, and other deposits	1–2 inches
Soft clayey sodium sulfate, calcium sulfate, calcium carbonate, and other deposits	2–7 inches
Clear crystals of sodium sulfate, with some earthy impurities, resting on saline clay	6–8 feet

Samples of mixed sodium chloride and sodium sulfate from the surface incrustation reportedly show minor amounts of potash but no lithium, rubidium, cesium, nitrate, phosphate, or borate salts.

Clay

Jupiter deposit

The Jupiter clay pit is on the west side of U.S. Highway 95 Alternate about 2.5 miles south of the Weeks crossing of the Southern Pacific Railroad in Lyon County. The deposit is mined intermittently by the Industrial Minerals and Chemical Co. of Berkeley, Calif. Since 1936 the deposit has yielded 1,000 to 2,000 tons of clay per year. Clay crops out over an area about a quarter of a mile across and is well exposed in a shallow pit some 700 feet long and 120 feet wide. The total thickness of the clay is not exposed but is at least 20 feet in the pit area. The country rock is Tertiary andesite. In the pit, clay grades upward into relatively fresh andesite, and fragments of altered andesite are sparsely distributed throughout the upper part of the clay deposit. Chloritized and argillized phenocrysts are still evident in some samples of the clay. There can be little doubt that the clay is the product of hydrothermal alteration processes. The clay contains selenite gypsum as veinlets filling fractures and as disseminated crystals. The X-ray diffraction pattern of a sample showed lines for both a kaolin-type clay and a montmorillonite-type clay; the clay however has no appreciable swelling capacity.

Nevada Cement Co. deposit

Clay for the manufacturing of cement is obtained by the Nevada Cement Co. from a deposit of sedimentary clay about 2 miles south of their limestone quarry and 6 miles south of Fernley. Stephenson (1966) reports that the clay contains 15 to 28 percent alumina. The higher alumina clay typically has about 52 percent SiO_2, 7 percent Fe_2O_3, 7 percent CaO, and 3 percent MgO with a low alkali content.

Churchill Canyon

Churchill Canyon has a small playa at its intersection with another drainage about 6 miles west of Wabuska. Sedimentary clay and silt have been scraped from the surface of the playa for use in sealing tanks and reservoirs, particularly at the Minnesota mine.

Silica

Big Crystal deposit

The Big Crystal silica deposit is on the north side of Nye Canyon about 16 miles southeast of Wellington and 2 miles east of State Route 22. The deposit, which caps the top of a small hill, consists of massive, milky to clear quartz in a granitic host rock. The quartz appears to be in one large lens and one or more scattered, smaller lenses, but contacts with the host rock are not well exposed. The main quartz body dips steeply northwest; it is at least 30 feet wide and 150 feet long. A smaller lens lies parallel to the main body about 50 feet to the southeast. The deposit would probably be capable of yielding a high purity silica with a high brightness in the finely crushed product, although some sorting might be necessary to remove slightly iron-stained fragments. Only small pits and trenches have been dug on the property, and more thorough exploration might reveal that the deposit is larger than presently indicated.

Veta Grande mine

The Veta Grande mine is about 11 miles southeast of Gardnerville and half a mile east of the site of Carters Station on U.S. Highway 395. The mine occurs in a very large quartz vein, in places greater than 50 feet thick. The vein cuts metavolcanic rocks with interbeds of thin-bedded metasedimentary rocks. The vein contains silver in streaks of argentite and stephanite, and minor amounts of gold. Quartz from the mill tailings has been processed into a powdery product of high purity and brightness.

Coal and Lignite

Lewis mine

The Lewis coal mine is in the southeastern corner of Lyon County about 2.5 miles southeast of the Lewis ranch. The deposit has been known since the early 1900's but has had no significant production because of its remote location and the low rank of the coal. Most

work on the property has been confined in two small areas lying about 2,000 feet apart along the strike (about N. 15° E.) of the seam. The northern workings consist of an incline driven 400 feet westward down the dip of the seam with some short lateral exploratory drifts. To the south, two adits, 700 and 900 feet long, have been driven along the strike of the seam. Stoddard and Carpenter (1950) report that there has also been some unsuccessful drilling for petroleum on the property.

The Lewis deposit is contained within a Miocene and Pliocene sequence of tuffs, conglomerates, sandstones, and shales designated by Axelrod (1956) as the Coal Valley Formation. The main outcrop of coaly material is evident for about 4,000 feet along a strike of N. 15° E., is as much as 6 feet thick, and dips 20°–40° W. One or two nearby but less prominent seams have not been explored. In outcrop, the coaly seam looks like a thin-bedded lignitic shale with thin coaly layers and numerous thin seams and veinlets of gypsum. In deeper parts of the exploration adits, the material reportedly improves in quality and consists of layers of shale, "bone," and sub-bituminous or lignitic coal up to one foot thick. Reported analyses of air-dried samples are with the following ranges: moisture, 15–25 percent; volatiles, 24–30 percent; fixed carbon, 15–40 percent; ash, 16–44 percent; sulfur, 3–5 percent.

Eldorado Canyon

The Eldorado district in Eldorado Canyon south of Dayton was established in the early 1860's for the development of Tertiary coal deposits to be used in the Comstock district. Several hundred tons of coal were marketed despite the fact that the coal beds are thin and the coal poor in heating qualities. Analysis of the coal shows 20 percent moisture, 11 percent ash, 41 percent volatile hydrocarbons, and 28 percent fixed carbon (Stoddard and Carpenter, 1950).

Dimension Stone

Various rock types have been used as building and ornamental stone, especially in the Carson City area. Several small stone suppliers are established in Carson City, but generally there are no major rock quarries. The volume of dimension stone quarried in Lyon, Douglas, and Ormsby Counties is small because of the great distance from major population and construction areas.

Nevada State Prison

The largest dimension stone quarry is at the Nevada State Prison about 1.5 miles east of Carson City. Light-yellowish-gray, horizontally bedded sandstone was first quarried about 1862; much was subsequently used in early buildings in Carson City and Reno as well as at the prison itself. The arkosic sandstone is coarsely bedded and the beds are nearly horizontal. It is probably Pleistocene in age and contains well-preserved footprints of birds and animals. Smith (1912) believed the rock to have been cemented by the action of a neighboring hot spring.

Eureka Canyon

Light pink rhyolite slabs are quarried at the mouth of Eureka Canyon where it enters the Carson River Canyon, about 3 miles southwest of Dayton. The rock slaps are useful as decorative stone facing.

Sand and Gravel

No sand or gravel deposits were examined during the reconnaissance work for this report. Pits are, however, scattered throughout Lyon, Douglas, and Ormsby Counties, where the sand and gravel are used largely by the State and County Highway Departments for road building and maintenance. Plate 2 shows the location of some pits.

Most sand and gravel deposits in the three counties fall into one of three types: pediment gravels, stream or lacustrine deposits, and decomposed granite. Pediment gravels cover the low, gentle slopes along the margins of most mountain ranges. These gravels are most abundant but are characteristically angular, poorly sorted, and of diverse lithology. They are generally crushed and sorted for use in road construction. Stream or lacustrine deposits are formed along stream channels or on beaches of ancient lakes. Particles in these deposits are normally more rounded and better sorted; moreover, they commonly contain less diversity of lithologic types. Decomposed granite occurs in areas where granitic bed rocks have been deeply weathered. This material packs well to a smooth surface.

REFERENCES

Archbold, N. L., 1966, Industrial mineral deposits of Mineral County, Nevada: Nevada Bur. Mines Rept. 14.

Axelrod, D. I., 1949, Eocene and Oligocene formations in the western Great Basin (abs.): Geol. Soc. America Bull., v. 60, p. 1935–1936.

....., 1956, Mio-Pliocene floras from west-central Nevada: California Univ. Pubs. Geol. Sci., v. 33, p. 1–322.

Bailey, E. H., and Phoenix, D. A., 1944, Quicksilver deposits in Nevada: Nevada Univ. Bull., v. 38, no. 5, Geol. and Min. ser. no. 41.

Becker, G. F., 1882, Geology of the Comstock Lode and Washoe district: U.S. Geol. Survey Mon. 3.

Berry, E. W., 1927, The flora of the Esmeralda formation in western Nevada: U.S. Natl. Museum, v. 72, art. 23.

Binyon, E. O., 1946, Exploration of the Blue Metal corundum property, Douglas County, Nevada: U.S. Bur. Mines Rept. Inv. 3895.

Broecker, W. S., and Orr, P. C., 1958, Radiocarbon chronology of Lake Lahontan and Lake Bonneville: Geol. Soc. America Bull., v. 69, p. 1009–1032.

Couch, B. F., and Carpenter, J. A., 1943, Nevada's metal and mineral production (1859–1940, inclusive): Nevada Univ. Bull., v. 37, no. 4, Geol. and Min. ser. no. 38.

Davis, W. M., 1930, The Peacock Range, Arizona: Geol. Soc. America Bull. 41, p. 293–313.

Evernden, J. F., and James, G. T., 1964, Potassium-argon dates and the Tertiary floras of North America: Am. Jour. Sci., v. 262, p. 945–974.

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada: U.S. Geol. Survey Prof. Paper 216.

Gianella, V. P., 1936, Geology of the Silver City district and the southern portion of the Comstock Lode, Nevada: Nevada Univ. Bull., v. 30, no. 9; Nev. Bur. Mines and Mackay School of Mines Bull. no. 29.

Halsey, J. H., 1953, Geology of parts of the Bridgeport (California) and Wellington (Nevada) quadrangles: Ph.D. thesis, California Univ. (Berkeley).

Hill, J. M., 1915, Some mining districts in northeastern California and northwestern Nevada: U.S. Geol. Survey Bull. 594.

Holmes, Arthur, 1960, A revised geological time scale: Edinburgh Geol. Soc. Trans., v. 17, pt. 3, p. 183–211.

Hubbs, C. L., and Miller, R. R., 1948, The zoological evidence: Correlation between fish distribution and hydrographic history in the desert basins of western United States, pt. 2 *of* The Great Basin: Utah Univ. Bull., v. 38, no. 20, p. 18–166.

Jones, J. C., 1912, The origin of the anhydrite at the Ludwig mine, Lyon County, Nevada: Econ. Geology, v. 7, p. 400–402.

....., 1920, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697.

King, Clarence, 1876, Annual report upon the geological exploration of the fortieth parallel from the Sierra Nevada to the eastern slope of the Rocky Mountains: U.S. Geol. Expl. 40th Parallel, Atlas.

King, Clarence, 1878, Systematic geology: U.S. Geol. Expl. 40th Parallel, v. 1.

Knopf, Adolph, 1918, Geology and ore deposits of the Yerington district, Nevada: U.S. Geol. Survey Prof. Paper 114.

Lawson, A. C., 1912, The recent fault scarp at Genoa, Nevada: Seismol. Soc. America Bull. 2, p. 193–200.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada: Reno, Nev. Newsletter Publishing Co.

Louderback, G. D., 1904, Basin Range structure of the Humboldt region: Geol. Soc. America Bull., v. 15, p. 289–346.

Macdonald, J. R., 1959, The middle Pliocene Mammalian fauna from Smith Valley, Nevada: Jour. Paleontology, v. 33, no. 5, p. 872–887.

Matthes, F. E., 1930, Geologic history of the Yosemite Valley: U.S. Geol. Survey Prof. Paper 160.

Moore, J. G., 1960, Mesozoic age of roof pendants in west-central Nevada: U.S. Geol. Survey Prof. Paper 400–B, p. B285–B289.

Morrison, R. B., 1964, Lake Lahontan: Geology of southern Carson Desert, Nevada: U.S. Geological Survey Prof. Paper 401.

Noble, D. C., 1962, Mesozoic geology of the southern Pine Nut Range, Douglas County, Nevada: Ph.D. thesis, Stanford Univ.

Overton, T. D., 1947, Mineral resources of Douglas, Ormsby, and Washoe Counties: Nevada Univ. Bull., v. 41, no. 9, Geol. and Min. ser. no. 46.

Pack, F. J., 1927, Structure of thermal springs on the Wasatch fault: Am. Jour. Sci., v. 14, 5th ser., p. 409–418.

Parsons, A. B., 1957, The porphyry coppers in 1956: New York, Am. Inst. Mining, Metall. and Petroleum Engineers.

Reeves, R. G., Shawe, F. R., and Kral, V. E., 1958, Iron ore deposits of west-central Nevada: Nevada Bur. Mines Bull. 53, pt. B.

Rogers, A. F., 1912, The occurrence of gypsum and anhydrite at the Ludwig mine, Lyon County, Nevada: Econ. Geology, v. 7, p. 185–189.

Rose, R. L., 1959, Cenozoic stratigraphy of the Virginia Range near Wadsworth, Nevada (abs.): Geol. Soc. America Bull., v. 70, no. 12, p. 1744–1745; and Geology and mineral resources of the Curtiss–Wright property in the Virginia Range, Nevada: Nevada Bur. Mines open-file report.

Roylance, J. G., Jr., 1966, The Dayton iron deposits, Lyon and Storey Counties, Nevada, *in* Papers presented at the AIME Pacific Southwest Mineral Industry Conference, Sparks, Nevada, May 5–7, 1965: Nevada Bur. Mines Rept. 13, pt. A, p. 125–141.

Russell, I. C., 1885, Geological history of Lake Lahontan: U.S. Geol. Survey Mon. 11.

Schryver, R. F., 1961, Geology of the Mound House area, Ormsby and Lyon Counties, Nevada: M.S. thesis, Nevada Univ.

Smith, D. T., 1904, Geology of the upper region of the main Walker River: California Univ., Dept. Geology Bull., v. 4, p. 1–32.

Smith, W. S. T., 1912, Origin of the sandstone at the State prison near Carson City, Nevada (abs.): Geol. Soc. America Bull., v. 23, p. 73.

Staatz, M. H., and Bauer, H. L., 1953, Uranium in the East Walker River area, Lyon County, Nevada: U.S. Geol. Survey Bull. 988–C.

Stephenson, E. L., 1966, Raw materials for the Nevada Cement Company plant at Fernley, Nevada, *in* Papers presented at the AIME Pacific Southwest Mineral Industry Conference, Sparks, Nevada, May 5–7, 1965: Nevada Bur. Mines Rept. 13, pt. B, p. 45–50.

Stirton, R. A., 1939, The Nevada Miocene and Pliocene mammalian faunas as faunal units: Pacific Sci. Cong., 6th, Proc., p. 627–640.

Stock, C., 1936, Sloth tracks in the Carson prison: Westways, v. 28, no. 7, p. 26–27.

Stoddard, C., and Carpenter, J. A., 1950, Mineral resources of Storey and Lyon Counties, Nevada: Nevada Univ. Bull., v. 49, no. 1.

Stone, R. W., and others, 1920, Ludwig mine, *in* Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 153–155.

Thompson, G. A., and Sandberg, C. H., 1958, Structural significance of gravity surveys in the Virginia City-Mount Rose area, Nevada and California: Geol. Soc. America Bull., v. 69, p. 1269–1282.

Thompson, G. A., 1956, Geology of the Virginia City quadrangle, Nevada: U.S. Geol. Survey Bull. 1042–C.

Wilson, J. R., 1963, Geology of the Yerington mine: Mining Cong. Jour., v. 49, no. 6, p. 30–34.

Wilson, R. W., 1936, A Pliocene rodent fauna from Smith Valley, Nevada: Carnegie Inst. Washington Pub. 473, Contr. Paleontology, p. 15–34.

Zones, C. P., 1958, Petrographic and petrofabric study of the metamorphic rocks north of Carson City, Ormsby County, Nevada: M.S. thesis, Nevada Univ.

(Published and unpublished sources of previous mapping given on plate 1.)

INDEX

Aldridge Station, 12
Aldridge Station Formation, 13
Alluvium, older, 14
Alta Formation, 11, 12, 34
American Sodium Corp., 40
Anaconda Co., 22, 23, 26, 28
Artesia Lake, 15
Bridgeport, 3, 22
Brunswick Canyon, 31, 37
Brunswick district, see Delaware district
Buckskin district, 23, 29
Buckskin Range, 8, 10, 18, 20–21, 28, 29
Bullionville, 30
Cambridge district, see Wilson district
Cambridge Hills, 28, 29
Carson Black Lead Co., 37
Carson Desert, 15
Carson district, 22, 23, 31
Carson Range, 3, 10, 12, 15, 16–17, 18, 24
Carson River, 1, 3, 8, 10, 15, 18, 19, 21, 24, 31, 41
Carson Sink, 3, 15
Carson Valley, 1, 3, 6, 12, 17, 18
Cenozoic rocks, 12, 20–21, 39
Chinatown, see Silver City
Chloropagus Formation, 14
Churchill Butte, 21–22, 24, 32
Churchill Canyon, 19, 20, 40
Churchill district, 23, 24
Churchill Valley, 11, 21
Cinderlite Corp., 37
Coal Valley, 11, 12, 20, 21
Coal Valley Formation, 13, 41
Columbia-Geneva Steel Co., 23
Como, 25
Como district, 11, 22, 23, 25
Comstock district, 8, 10, 24, 25, 26
Comstock Lode, 3, 22, 23, 24, 25, 31
Cretaceous rocks, 5, 16, 23, 24, 26
Dayton, 3, 15, 22, 23, 25
Dayton district, see Silver City district
Dayton Dredging Co., 23, 24, 25
Delaware district, 23, 31
Desert Mountains, 11, 14, 16, 19, 21
Devils Gate district, see Silver City district
Districts,
    Brunswick, see Delaware
    Buckskin, 23, 29
    Cambridge, see Wilson
    Carson, 22, 23, 31
    Chinatown, see Silver City
    Churchill, 23, 24
    Como, 11, 22, 23, 25
    Comstock, 8, 10, 24, 25, 26
    Dayton, see Silver City
    Delaware, 23, 31
    Devils Gate, see Silver City
    Eagle, see Gardnerville
    Eagle Valley, see Voltaire
    Eldorado Canyon, 22, 23, 25, 41
    Gardnerville, 23, 30
    Genoa, 22, 23, 29
    Gold Canyon, see Silver City
    Holbrook, see Mountain House
    Indian Springs, see Como
    Mound House, 25
    Mount Siegel, 23, 29
    Mountain House, 22, 23, 30
    Palmyra, see Como
    Pine Grove, see Wilson
    Pine Nut, see Mountain House
    Ramsey, 23, 24
    Red Canyon, 22, 23, 30
    Red Mountain, 24
    Rockland, see Wilson
    Silver Glance, see Wellington
    Silver Lake, see Red Canyon
    Smith Valley, see Buckskin
    Sullivan, see Delaware
    Talapoosa, 22, 23, 24
    Voltaire, 22, 23, 31
    Washington, 22, 23, 29
    Washoe, see Voltaire
    Wellington, 23, 30, 37
    Wilson, 22, 23, 28–29
    Yerington, 6, 8, 10, 19, 22, 26–28
Double Spring Flat, 7
Double Spring Formation, 6
Drainage, 1–3
Eagle district, see Gardnerville district
Eagle Valley district, see Voltaire district
East Walker River, 3, 8, 11, 21, 29
Eldorado Canyon, 39, 41
Eldorado Canyon district, 22, 23, 25, 41
Eocene rocks, 11
Eureka Canyon, 41
Fallon, 3
Fernley, 10, 15
Flowery Range, 24
Fort Churchill, 16
Fossils, 3, 5, 11, 12, 13, 15, 19
Gardnerville, 15, 19
Gardnerville district, 23, 30
Gardnerville Formation, 6
Genoa, 29
Genoa district, 22, 23, 29
Gold Bug Formation, 6
Gold Canyon, 23, 25
Gold Canyon district, see Silver City district
Gold Canyon Dredging Co., 25
Gold Hill, 25
Granitic rocks, 8, 10, 16, 17, 23, 29
Hartford Hill Rhyolite Tuff, 10, 17, 18, 19, 21, 24, 27, 31, 34
Holbrook district, see Mountain House
Hot Spring deposits, 15–16
Hot Springs Mountains, 12
Hoye Canyon 3, 19, 22, 30, 37
Ideal Cement Co., 32
Indian Springs district, see Como
Industrial Minerals, 31–41
Industrial Minerals and Chemical Co., 40
Jurassic rocks, 3, 5, 6, 18, 23, 29, 34, 36, 37, 39
Kate Peak Formation, 25, 34
Lahontan Reservoir, 3, 11, 15
Lake deposits, 15
Lake Lahontan, 15, 16
Lake Tahoe, 3, 12, 16
Lake Wellington, 15
Lincoln Flat, 20
Little Washoe Lake, 15
Lone Mountain, 7
Lousetown Formation, 14, 34
Luhr Hill, 36
Magma Power Co., 40
Mason Valley, 3, 10, 15, 19, 21, 26
Mason Valley Buttes, 7
Mason Valley Mines Co., 26
McClellan Peak, 19

McTarnahan Hill, 31
Mesozoic rocks, 3, 7, 8, 9, 21, 29, 32, 34, 36
Metamorphic rocks, 3, 7, 8, 10, 18, 32, 34, 36, 37
Metasedimentary rocks, 5, 6, 24, 29, 30, 39, 40
Metavolcanic rocks, 4, 5, 6, 7, 16, 29, 30, 40
Minden, 3
Mineral production, 22–23, also under districts
Mineral Valley, 18
Minerals,
  andalusite, 36
  antimony, 31
  barite, 36
  basalt, 23, 24
  chlorite, 36
  cinders, 23, 24, 37
  clay, 23, 40
  coal, 22, 40–41
  copper, 22, 23, 24, 25, 26, 28, 29, 30, 31, 32
  corundum, 36
  diatomite, 23, 32
  dimension stone, 24, 31, 41
  flourite, 36, 37, 38
  gold, 22, 23, 24, 25, 28, 29, 30, 31
  graphite, 23, 37–39
  gypsum, 6, 23, 26, 32–36
  iron, 22, 23, 24, 29, 31, 39
  lead, 23, 29, 31
  lignite, 40–41
  limestone, 23, 26, 39–40
  mercury, 31
  perlite, 23, 37
  pumice, 23
  pyrophyllite, 36
  salines, 40
  sand and gravel, 23, 41
  sericite, 36
  silica, 40
  silver, 22, 23, 24, 25, 28, 29, 30, 31, 40
  tungsten, 23, 24, 28, 30, 31
  uranium 29
  zinc, 23
Mines, claims, prospects,
  Alex Eske property, 31
  Anaconda Co. mine, 26, 27, 28
  Arrowhead mine, 30
  Bessemer mine, 31
  B, H, and V mine, 24
  Big Crystal deposit, 40
  Blue Danube, see Blue Metal prospect
  Blue Jay Copper mine, 28
  Blue Metal prospect, 36
  Bluestone mine, 26
  Boulder Hill mine, 30, 37
  Buckskin mine, 29
  Bunker Hill mine, 31
  Cambridge mine, 29
  Capitol iron deposit, 31
  Carson Black Lead, see Chedic mine
  Casting Copper mine, 26
  Chedic mine, 37
  Cherokee, see Tungsten Hills mine
  Comstock Extension mine, 31
  Cowbody tungsten mine, 28
  Daney mine, 25
  Danite mine, 30
  Dayton iron deposit, 39
  Dayton mine, 25
  Divide mine, 30
  Dixon deposit, 31
  Douglas Hill copper mine, 26
  Eastern iron prospect, 28
  Empire Nevada, see Anaconda Co. mine
  Gardnerville tungsten mine, 30
  Guild-Bovard mine, 28
  Guild Placer mines, 28
  Homestake mine, 26
  Hulley-Logan mine, 25
  Imperial claims, 30
  Jackrabbit mine, 29
  Jupiter deposit, 40
  Last Laugh mine, 30
  Leviathan mine, 28
  Lewis mine, 40
  Light Weight claim, 32
  Longfellow mine, 30
  Lucky Bill mine, 30
  Ludwig mine, 6, 26, 32–34
  Malachite mine, 26
  Marvel claim, 32
  Mason Valley copper mine, 26
  McConnell mine, 26
  Minnesota iron mine, 22, 23, 28, 29
  Monarch mine, 30
  Montana Yerington mine, 26
  Oest mine, 25
  Owen iron deposit, 29
  Pale Face claim, 32
  Pearl Harbor mine, 24
  Pony Meadows mine, 25
  Premier mine, 31
  Ramsey-Comstock mine, 24
  Red Canyon claims, 30
  Rockland mine, 28
  Ruby Hill mine, 30
  Slater placer mine, 29
  Smith Valley mine, 29
  Snow White claim, 32
  South Camp mine, 30
  Talco prospect, 36
  Taylor Hill mine, 30
  Top claims, 36
  Tungsten Hills mine, 30
  United Mining Co. mine, 31
  Valley view mine, 31
  Veta Grande mine, 30, 40
  Voltaire, see Chedic mine
  Washoe claim, 30
  Weeks deposit, 32
  Western Nevada mine, 26
  Wheeler mine, 28
  White Caps claim, 32
  White Horse claim, 32
  Willard-McDonald mine, 30
  Wilson mine, 28
  Winters mine, 30
  Yankee Girl, see Taylor Hill mine
  Yerington iron mine, 37
Miocene rocks, 12, 13, 23, 41
Morgan Ranch Formation, 13
Mound House, 23, 34–36
Mound House district, 25
Mount Siegel, 29
Mount Siegel district, 23, 29
Mountain House, 22, 23, 30
Nevada Cement Co., 32, 39, 40
Nevada Hot Springs, 15
Nevada State Prison, 15, 24, 31, 41
Oligocene rocks, 11
Oreana Peak Formation, 6
Oro-Neva Dredging Co., 24, 25
Pacific Portland Cement Co., 34
Palmyra district, see Como district

Physiography, 1–3
Pine Grove district, see Wilson district
Pine Grove Flat, 28
Pine Grove Hills, 1, 3, 8, 13, 19, 20, 21, 28, 29, 37
Pine Nut district, see Mountain House district
Pine Nut Mountains, 3, 4, 5, 8, 10, 11, 12, 14, 16, 17–19, 20, 22, 23, 25, 29, 30, 31
Pine Nut Valley, 12, 18, 29
Pliocene rocks, 11, 12, 13, 14, 41
Pleistocene rocks, 14, 24
Population, 1
Preachers Formation, 6
Prison Hill, 6, 31, 36
Pyramid Lake, 3, 15
Quaternary rocks, 12, 15, 16, 19, 21, 23, 24, 29, 34
Ramsey district, 23, 24
Recent rocks, 14, 17
Red Canyon, 6, 30
Red Canyon district, 22, 23, 30
Red Mountain district, 24
Relief, 1–3
Reno, 3
Risue Canyon, 30
Rockland district, see Wilson district
Schurz, 1
Sedimentary rocks, 12, 37
Sierra Nevada batholith, 3, 8, 16, 18, 23, 29
Silver City, 10, 22, 24
Silver Glance district, see Wellington district
Silver Lake district, see Red Canyon district
Silver Springs, 15
Singatse Range, 3, 6, 7, 8, 11, 13, 14, 16, 19–20, 21, 26, 27, 28
Smith Valley, 15, 19, 20
Smith Valley district, see Buckskin district
Sonora Pass, 3
Standard Slag Co., 29, 36
Stewart, 17
Sullivan district, see Delaware district
Sutro, Adolph, 25
Sutro Tunnel, 25
Sweetwater Hills, 30, 37
Sweetwater Range, 3, 5, 6, 10, 18, 22
Talapoosa district, 22, 23, 24
Tertiary rocks, 12, 13, 16, 19, 20, 21, 23, 24, 26, 29, 31, 32, 34, 40
Triassic rocks, 3, 5, 6, 18, 23, 34, 36, 37, 39
Truckee Formation, 12, 13
Truckee River, 3, 21
Truckee River Canyon, 10, 12, 16
United Mining Co., 31
Utah Construction and Mining Co., 24
Veta Grande Formation, 6
Virginia Range, 3, 11, 14, 16, 18, 19, 21, 25
Volcanic rocks, 6, 7, 8, 11–12, 13–14, 23, 24, 26, 32, 34, 37
Voltaire district, 22, 23, 31
Wabuska 39, 40
Wabuska Hot Springs, 14
Wadsworth, 3, 15
Walker Lake, 13, 15
Walker River, 15, 21
Wallys Hot Spring, 15
Washington district, 22, 23, 29
Washoe district, see Voltaire district
Washoe Lake, 15
Washoe Valley, 17
Wassuk Range, 3, 10, 13, 16, 20, 26
Weed Heights, 23, 27
Weeks, 32
Wellington, 30
Wellington district, 23, 30, 37
Wellington Hills, 3, 18, 22, 30
West Walker River, 1, 3, 15, 19, 21, 22, 30
Wilson Canyon, 3, 13, 19, 20, 21
Wilson district 22, 23, 28–29
Yerington, 1, 3, 6, 15, 26, 27, 28
Yerington district, 6, 8, 10, 19, 22, 26–28

This page is intentionally blank.

This page is intentionally blank.

SPO, Carson City, Nevada, 1969

The Mackay School of Mines is the educational, research, and public service center for the mineral industry of Nevada. It is one of several colleges of the University of Nevada. The School consists of three divisions: the academic division, composed of the departments of instruction; the Nevada Bureau of Mines; and the Nevada Mining Analytical Laboratory.

The Nevada Bureau of Mines and the Nevada Mining Analytical Laboratory, as public service divisions of the Mackay School of Mines, assist in the development and utilization of Nevada's mineral resources. They identify, analyze, and evaluate minerals, rocks, and ores found in Nevada; conduct field studies on Nevada geology and mineral deposits, including oil and gas; pursue research in mineral beneficiation, extractive metallurgy, and economic problems connected with the mineral industry of Nevada; and publish reports and maps pertaining to Nevada's geology and mineral resources.

For information concerning the mineral resources and mineral industry of Nevada, write to: Director, Nevada Bureau of Mines, University of Nevada, Reno, Nevada 89507.