NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN 73

GEOLOGY AND MINERAL DEPOSITS OF LINCOLN COUNTY, NEVADA

(Prepared cooperatively by the United States Geological Survey)

C.M. TSCHANZ and E.H. PAMPEYAN

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA, RENO

1970

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FOREWORD

The U.S. Geological Survey and the Nevada Bureau of Mines have for some years cooperated in a program designed to provide information on the geology and the mineral deposits of each of Nevada's counties. Bulletin 73, "Geology and Mineral Deposits of Lincoln County, Nevada," by C. M. Tschanz and E. H. Pampeyan, of the U.S. Geological Survey, presents this information for a county that ranks high in production of metallic minerals. The geology of the county suggests that the area will continue to be attractive as the site of further mineral exploration efforts.

William Hamblin, a Mormon missionary, and others located the Meadow Valley mining district in 1863. During the next few years, other mineral discoveries were made in the county, which resulted in the founding of such mining camps as Tem Piute, Bristol, Atlanta, and Pioche. The last named district was first worked for its rich silver ores in 1864, and thereafter, through a period of many years, contributed $131 million, or about 70 percent of the total county mineral production. The Pioche district has had three periods of activity during the past century. Production during the first 30 years was dominantly silver ores; during the second period, preceding and following the turn of the century, both silver and lead were important products; and during the last period, from 1928 to 1953, the production of zinc ores was of considerable economic value. The history of Pioche is an instructive example of repeated revitalization of an older mining district, which results from changing economic conditions that make the mining of minerals of lesser value and lower grade ores a profitable operation.

Bulletin 73 is issued with the hope that it will aid in greater understanding of the geology of Lincoln County and in more efficient and economical search for additional mineral resources.

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

January, 1970
Mackay School of Mines
University of Nevada

The Geology and Mineral Deposits of Lincoln County, Nevada[1]

By C. M. Tschanz and E. H. Pampeyan

ABSTRACT

Lincoln County covers an area of 10,649 square miles in eastern Nevada. It is the third largest county in Nevada. The topography is typical of the Basin and Range province, having elongate north-south mountain ranges separated by wide alluviated valleys or basins. Most of the county drains into interior basins, but part drains into the Colorado River through Meadow Valley Wash and the dry channel of White River. Most of the interior basins contain playas.

About one-third of Lincoln County is covered by Cenozoic sedimentary rocks; another third is volcanic rocks; and the remainder includes igneous, metamorphic, and sedimentary rocks that range in age from Precambrian to Triassic. Rocks representing every period except Jurassic and possibly Cretaceous are present. The Precambrian rocks, which crop out principally in the southeast corner, are granite, pegmatite, gneiss, schist, and amphibolite. The Johnnie Formation is present near the southwest corner of the county.

Paleozoic rocks in the Cordilleran miogeosyncline decrease in thickness from 32,000 feet in the western part of the county to about 7,000 or 8,000 feet in the southeast corner of the county, which is on the margin of the craton. The maximum total composite thickness of Paleozoic sedimentary rocks decreases in the same direction from 42,000 feet to about 9,000 feet. This enormous decrease is due largely to a seven-fold decrease in the Cambrian section, although the rocks deposited in each of the Paleozoic periods thin toward the southeast. The decrease in thickness is gradual across most of the county, then abrupt beyond a northeast-striking hinge line near Meadow Valley Wash. This line, an important structural element throughout most of the Paleozoic, separates the miogeosynclinal facies to the west from the marginal facies to the east. Seven units mapped in the western part of Lincoln County are not found to the east. Silurian rocks are absent east of the hinge line. The marginal facies resemble the Paleozoic rocks in the Colorado Plateau and in eastern Clark County more than they do the miogeosynclinal facies in the remainder of Lincoln County.

The following Precambrian, Paleozoic, and Mesozoic sedimentary units are shown on the detailed reconnaissance geologic map. The Precambrian is represented by the Johnnie Formation. The Cambrian units are the Prospect Mountain Quartzite, the Pioche Shale, the Lyndon Limestone and Chisholm Shale, the Highland Peak Formation, and the Upper Cambrian limestones and dolomites. In northern Lincoln County the Middle Cambrian section above the Pioche Shale consists of the Pole Canyon Limestone and a thick Middle Cambrian Shale, the Patterson Pass Shale of Kellogg (1963).

The Ordovician units consist of the Pogonip Group, the Eureka Quartzite, and the Ely Springs Dolomite. The only Silurian unit is the Laketown Dolomite. Devonian units are the Sevy and Simonson Dolomites, the Guilmette Formation, and the Pilot Shale. The dolomite units of Silurian and Devonian Age are not recognized in southeastern Lincoln County.

The Mississippian formations consist of an undifferentiated limestone unit, the Chainman Shale, and the Scotty Wash Quartzite. The shale and quartzite units pinch out southeastward but the carbonate unit does not. These rocks are overlain by a thick carbonate unit of Carboniferous Age and a similar unit of Permian Age. A unit of clastic rocks of Late Pennsylvanian Age is locally present beneath the Permian rocks. In southeastern Lincoln County a thick unit of red beds of Permian Age is overlain by the Toroweap Formation and Kaibab Limestone or by the marine limestone facies of the Moenkopi Formation of Triassic Age. Another Mesozoic unit present in southeastern Lincoln County is the Chinle Formation of Triassic Age, which overlies the Moenkopi Formation.

The Paleozoic and Mesozoic rocks described above are locally overlain by clastic and volcanic rocks, some of which may be Cretaceous in age. These rocks include 5,000 feet of second-cycle orogenic conglomerate in southwest Lincoln County, which are in turn overlain by local limestone lenses of Miocene Age or by very thick Tertiary volcanic and sedimentary rocks.

Local uplifts occurred in Late Silurian, Late Devonian, Late Mississippian, and Late Pennsylvanian time. On the whole, however, the Paleozoic was unbroken by such orogeny as marks post-Paleozoic time.

Mesozoic sediments were largely eroded over most of Lincoln County during the orogenic period that began with uplift in Late Triassic time, and culminated in thrust faulting in Late Jurassic or Cretaceous time. This orogeny was followed by the outpouring of perhaps as much as 5,000 cubic miles of volcanic rocks, largely ignimbrites, occurring intermittently during Oligocene, Miocene, and early Pliocene time. Volcanism was followed by basin-and-range faulting, after which the middle Pliocene lake beds and tuffs were deposited. Normal faulting may have resulted from collapse following volcanic eruption.

The structure is complex, with major early structures obscured by basin-range faulting and partly hidden beneath Cenozoic rocks. The oldest major structures are

1. Publication authorized by the Director, U. S. Geological Survey.

thrust faults of post-Triassic, pre-Miocene Age and are probably Cretaceous or early Tertiary. They bring sections of Paleozoic rocks, as much as 16,000 feet thick, eastward as far as 16 miles over younger rocks that are generally folded into overturned synclines beneath the thrust. Conceivably, regional thrust plates of much greater displacement exist. Possibly a third of the outcrop areas of Paleozoic rocks are above these thrusts. Most thrust faults occur in shaly layers, especially those in the Cambrian section.

One major northeast-striking strike-slip fault is inferred from shifts in facies and corresponding structures. This inferred fault, the Arrowhead Mine fault, has an apparent right-lateral displacement of about 25 miles. It may be a tear fault in a regional thrust plate or it may be a basement rift. Its orientation is consistent with a stress pattern that could have produced the pre-Miocene thrusts, but it may be younger than the thrusts. Three post-Miocene left-lateral faults, with a possible total displacement of 10 miles, occur parallel to the eastern part of the older right-lateral Arrowhead Mine fault. This late movement must have been caused by a different stress system. Besides renewed movement on the eastern part of the Arrowhead Mine fault, this left-lateral movement occurred on the Maynard Lake and Buckhorn faults.

Postvolcanic thrust(?) faults of post-Oligocene Age occur in northern Lincoln County. These, however, may be slide blocks derived from earlier thrust plates. The mountain ranges and basins were generally formed by normal faulting in late Miocene and early Pliocene time. Little structural movement is more recent than this.

The total value of the mineral production in Lincoln County through 1959 is almost $191 million, of which $106 million represents production since 1940. The principal commodities in order of decreasing value are zinc, silver, gold, lead, tungsten, copper, manganese, and perlite. Zinc accounts for about a third of the total production, gold and silver together for another third, lead for about a sixth, and tungsten for most of the remainder. The approximate production value of the five principal districts through 1958 is as follows: Pioche, $131 million; Bristol (including Jackrabbit), $17 million; Delamar and Tem Piute, each $15 million; Highland, $2 million. In six districts, 12 mines have produced more than $1 million. The combined production of the five largest mines is about $97,500,000.

The most productive deposits are mesothermal bedded replacement deposits of base metals. Other productive deposits include epithermal gold and silver veins, irregular replacement deposits of base metals, and pyrometasomatic tungsten deposits.

The ore deposits are related to the regional thrust faults. About 90 percent of the production has come from Cambrian rocks, particularly from the lowest limestone in the Paleozoic sections. The productive beds are almost certainly beneath, but near the surface of movement of, the regional thrusts. The ore deposits are probably in areas where pronounced Mesozoic uplift and erosion have occurred. The most productive districts are also in areas where intrusive rocks are most abundant. The evidence suggests that the ore deposits, like the intrusive rocks, postdate the older volcanic rocks and are probably Eocene to Miocene in age.

INTRODUCTION

Even though minerals worth almost $191 million have been produced, little has been published on the geology of Lincoln County, except for the mining districts themselves. The purpose of the present report is to provide basic geologic data to aid in the search for mineral resources, and to provide a reconnaissance geologic map of the county.

This is one of a series of reports produced cooperatively by the U.S. Geological Survey and the Nevada Bureau of Mines. A similar study is planned for each county, and ultimately all county maps will be combined into a single State geologic map. This State map will give the first clear and comprehensive picture of the geology of Nevada.

The field work on which the present report is based was done in the spring, summer, and fall of 1956, and the spring and fall of 1957 and 1958; it represents a total of 22 man-months. Inasmuch as the county covers 10,649 square miles, only a small portion of which had previously been mapped, it was necessary for the two authors to work independently in order to cover the area in the time available.

The geology was mapped on 1:60,000-scale aerial photographs taken by the Army Map Service. It was then transferred to a 1:125,000-scale topographic base map, and this map in turn was used as copy for the final county map (pl. 2).

ACKNOWLEDGMENTS

The following geologic maps and reports had previously been published: the Highland, Bristol, West, and Ely Ranges by Westgate and Knopf (1932); the Chief and Delamar mining districts by Callaghan (1936, 1937); the Groom district by Humphrey (1945); and the Pioche Hills by Park, Gemmill, and Tschanz (1958). These maps totaled about 700 square miles, less than 7 percent of the area shown on plate 2. In addition, an unpublished geologic map of 510 square miles in the southwest part of the county was made available to us by C. R. Longwell, of the Geological Survey, whose wise counsel and generous help are gratefully acknowledged. The authors

are directly responsible for all the geology shown except for that in the Highland and Bristol Ranges, which we were unable to remap because of the lack of time. The senior author is responsible for the changes made on Westgate's map. We are indebted to Roy A. MacDiarmid for permission to publish his detailed geologic map of the Bristol silver mine area.

We especially wish to acknowledge permission to use data from the detailed studies of Anthony Reso in the Pahranagat Range, of H. E. Kellogg in the Egan Range, and of P. H. Heckel in the southern Delamar Mountains. Reso's and Heckel's investigations were later than ours, and Kellogg's was partly concurrent.

The senior author was ably assisted by C. R. Willden and J. E. Carlson for three weeks in the fall of 1957.

We are indebted to many of the mining and oil people for their help and cooperation. We are particularly indebted to Paul Gemmill of Combined Metals and Reduction Co. for providing maps and geologic information on many mines and mineral deposits throughout the county. Our debt to earlier workers who measured sections and studied stratigraphic relationships is evidenced by the numerous citations in the text.

LOCATION AND ACCESSIBILITY

Lincoln County is in southeastern Nevada (fig. 1).

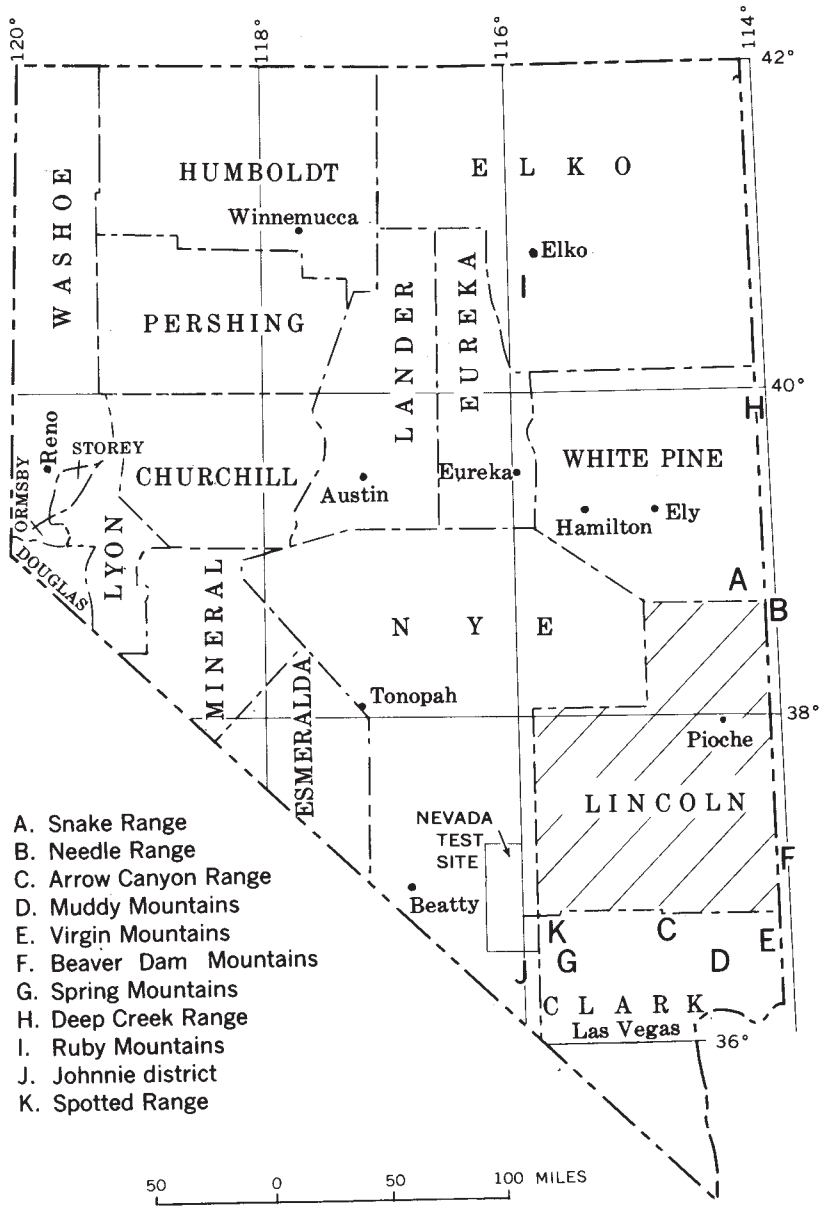


FIGURE 1. Index map of Nevada showing location of Lincoln County and other areas referred to in text.

It borders on Utah and Arizona to the east, on Clark County to the south, on Nye County to the west, and White Pine County to the north.

The county is crossed by two paved highways and a railroad, but many areas are accessible only by unimproved dirt roads or on foot. The Union Pacific Railroad follows Meadow Valley Wash north to Caliente, and then along Clover Creek eastward into Utah. A branch line connects Pioche with the main line at Caliente. U.S. Highway 93 crosses the county from north to south and Nevada Highway 25 crosses it from east to west. These are the only paved highways in the county except for short connecting paved roads to Ursine, Hiko, and a loop around the Pioche Hills.

Access to the southwest corner is difficult; travel in an area of 1,050 square miles within the Las Vegas Bombing and Gunnery Range was restricted to weekends, and then only with permission from the U.S. Air Force. Forty square miles near Groom Lake are within the Nevada Test Site of the Atomic Energy Commission, to which access is prohibited except under escort.

PHYSICAL FEATURES

Lincoln County is entirely within the Basin and Range physiographic province and has typical basin-range topography. Most of the mountain ranges trend north-south and are relatively narrow compared to the basins. The county has only two integrated permanent outside drainage systems. One of these is Meadow Valley Wash, a tributary of the Colorado River, which drains the eastern part of the county. The other is the system, now largely dry, which connects White River and the Pahranagat Valley with the Muddy River, another tributary of the Colorado. Since latest Pliocene time, these streams have removed large quantities of unconsolidated debris and cut canyons through bedrock ridges. The rest of Lincoln County drains into at least ten local interior drainage basins, nine of which contain playas or dry lakes.

The altitude of Lincoln County ranges from about 1,800 feet in the southeastern valleys to over 10,600 feet in the southern Schell Creek Range. The altitudes of both mountains and basins generally are lower in the southern half of the county than in the northern half, but the average relief does not vary greatly, the crests of the major ranges being only 3,000 to 4,000 feet higher than the adjacent basins.

The local interior drainage basins generally show little evidence of erosion or deposition since the latest Pleistocene and Recent lakes dried up. In most areas the beach lines are practically unchanged (pl. 2). There has been little erosion in the large area between the Worthington Range and the Egan Range since an extensive lake of probable Pliocene Age disappeared, except for 50 feet along White River. This evidence indicates that most topographic features are older than late Pliocene or early Pleistocene except along the White River and Meadow Valley drainage systems where older features were exhumed in Pleistocene and Recent time.

CLIMATE, VEGETATION, AND WILDLIFE

Climate and vegetation are interrelated and altitude-dependent. Lincoln County has two distinct regions of climate and vegetation. The southern part of the county, particularly at altitudes below 5,000 feet, is in the Mojave Desert province (Jaeger, 1957, p. 123-141). It is characterized by precipitation below 5 inches, high summer temperatures, and distinctive desert vegetation, including Joshua trees, Mojave yucca, creosote bush, black brush, cholla, barrel, prickly pear and many other cactuses, and agave.

The higher northern part of the county has more rainfall, colder winters and cooler summers, and steppe vegetation. The lower areas are covered by sagebrush, the higher areas by single-leaf piñon and juniper forests. The more alkali soils support shadscale, greasewood, and rabbit brush. The average frost-free growing season increases rapidly southward from 60 days at Geyser, 121 days at Pioche, and 160 days at Caliente, to more than 180 days in the valleys below 3,000 feet. The highest altitudes probably get more than 20 inches of precipitation, as shown by the presence of Ponderosa pine.

Deer, antelope, desert bighorn sheep, cougar, coyote, kit fox, Gila monster, chuckawalla, horned toad, rattlesnake, king snake, California quail, and many other birds, small reptiles, and rodents live in Lincoln County. Gila monsters, chuckawallas, and desert bighorn sheep were seen only in the low southern part of the county, and deer and antelope were seen only in the higher or northern parts of the county. Tiny minnows *(Cyprinodon)* with longitudinal stripes live in warm-spring pools at Ash and Crystal Springs.

PREHISTORY

Little is known of the aboriginal inhabitants of Lincoln County although Indian relics and petroglyphs are abundant. Probably several other Indian cultures besides the Piute (Paiute) existed, but they have never been studied in detail. In the Mormon Mountains, large circular pits that typically contain charcoal are common. These are reported to be pits in which Indians baked large quantities of the root of the agave, a relative of the century plant. Woven baskets have been found in caves containing rock paintings in the canyon of Meadow Valley Wash about 14 miles south of Caliente. Pottery fragments have been found in many places in the southwest quarter of

the county, often beneath overhanging rocks or in caves. Chipped flint fragments are abundant in the forested part of the county. Petroglyphs, including animal pictures made by chipping through the surface stain of volcanic cliffs, are common in the southern two-thirds of the county. Most of these intaglio drawings are on the surfaces of a distinctive and widely distributed spheroidally weathered ignimbrite. Petroglyphs painted with red ochre are much rarer. These were seen on limestone in the Mormon Mountains, and in the Sheep and Spotted Ranges.

HISTORY

Lincoln County was settled in the late 1850's and in the decade that followed. The oldest permanent settlemen, Ursine, was founded by Mormon cattlemen from Utah in the late 1850's. Scott (1913, p. 927) reports that several acres of grain were planted in Meadow Valley in 1858, probably near the present site of Panaca — a town founded in May 1864. Westgate and Knopf (1932, p. 4-5) state:

> "In 1863, Indians showed silver ore they called 'panacare' to William Hamblin, a Mormon missionary. Hamblin visited the place the same year and located the Panacker claim. He revisited the region the next spring with others and * * * they located the Meadow Valley mining district. * * * Indian hostilities in 1865 put a temporary stop to prospecting."

The earliest mining was in the Pahranagat district on Mount Irish near Hiko. The district was located in March 1865, and a 5-stamp mill was erected at Hiko Springs 12 miles from the mines on the west side of the Pahranagat Range. The smokestack for this mill still stands. A second 5-stamp mill and a 10-stamp mill were built at Hiko in 1867.

In 1866 Lincoln County was organized for the benefit of the miners of the Pahranagat district. Hiko was the county seat until 1871, when it was moved to Pioche. In 1909 the present county boundaries were determined when the southern part of Lincoln County was organized into Clark County.

The Pioche district, which has produced close to $133 million in silver, lead, zinc, and manganese, was organized in 1864. The first recorded production, however, was in 1869 when a 5-stamp mill was moved from Hiko to Bullionville, a mile west of Panaca. In 1872-73, Pioche had a population of over 6,000. The silver mining boom ended about 1879, and Pioche was practically abandoned until a second period of activity between 1911 and 1928. The most recent and most productive sustained period of activity was between 1937 and 1956. Since that time, production has again fallen off.

Claims were staked in the old Worthington (Freiberg), Tem Piute, Groom, Bristol, and Atlanta districts in the years before 1870. The Groom mine was discovered and located in 1864.

The now-abandoned gold camp of Delamar produced over $14 million in gold ore, chiefly between 1895 and 1909. Tem Piute, the most modern ghost town, reached a population of 500 between 1952 and 1957, after which the mine was shut down because of the decline in the price of tungsten.

The Bristol district produced over $3 million, principally in copper and lead, between 1878 and 1905. It has been active intermittently ever since. The Bristol silver mine was the only active metal mine in the county in 1959.

STRATIGRAPHY

Rocks representing the entire Paleozoic Era, part of the Mesozoic Era, and most of the Cenozoic are well represented in Lincoln County (fig. 2). Roughly equal areas are covered by unconsolidated Cenozoic deposits, Tertiary volcanic rocks, and Paleozoic and Mesozoic sedimentary rocks. Precambrian rocks are of minor areal distribution.

Geologically, Lincoln County is composed of two distinct provinces: most of the county was within the Paleozoic Cordilleran miogeosyncline; the southeastern corner of the county was on the eastern shelf of the miogeosyncline. The formations deposited in the miogeosyncline (figs. 3 and 4) are recognizable everywhere except in the southeast corner. The thickness of the Paleozoic sedimentary rocks decreases progressively southeastward toward the margin of the miogeosyncline; the Paleozoic rocks on the shelf in the southeast corner are only about one-fifth of the maximum thickness farther west.

The thinning is accompanied by drastic facies changes in some formations and a progressive pinchout of other formations by onlap onto a Paleozoic positive area that is centered in the Mormon Mountains. This thin shelf facies resembles one to the south in eastern Clark County. Nine formations of the miogeosynclinal facies are absent or unrecognizable on the Mormon Mountain arch. Thinning and facies changes occur across a northeast-striking hinge line near Meadow Valley Wash. W. B. Roberts (1956) showed that successively younger Devonian beds lie unconformably on successively older pre-Devonian beds across this line. This hinge line appears to have persisted through most of the Paleozoic Era as the boundary between the relatively positive Mormon Mountains arch and the miogeosyncline. The arch was below sea level, perhaps intermittently, during much of Paleozoic time. A relatively thin sedimentary blanket was deposited on the arch in pre-Mississippian time. Post-Early Permian

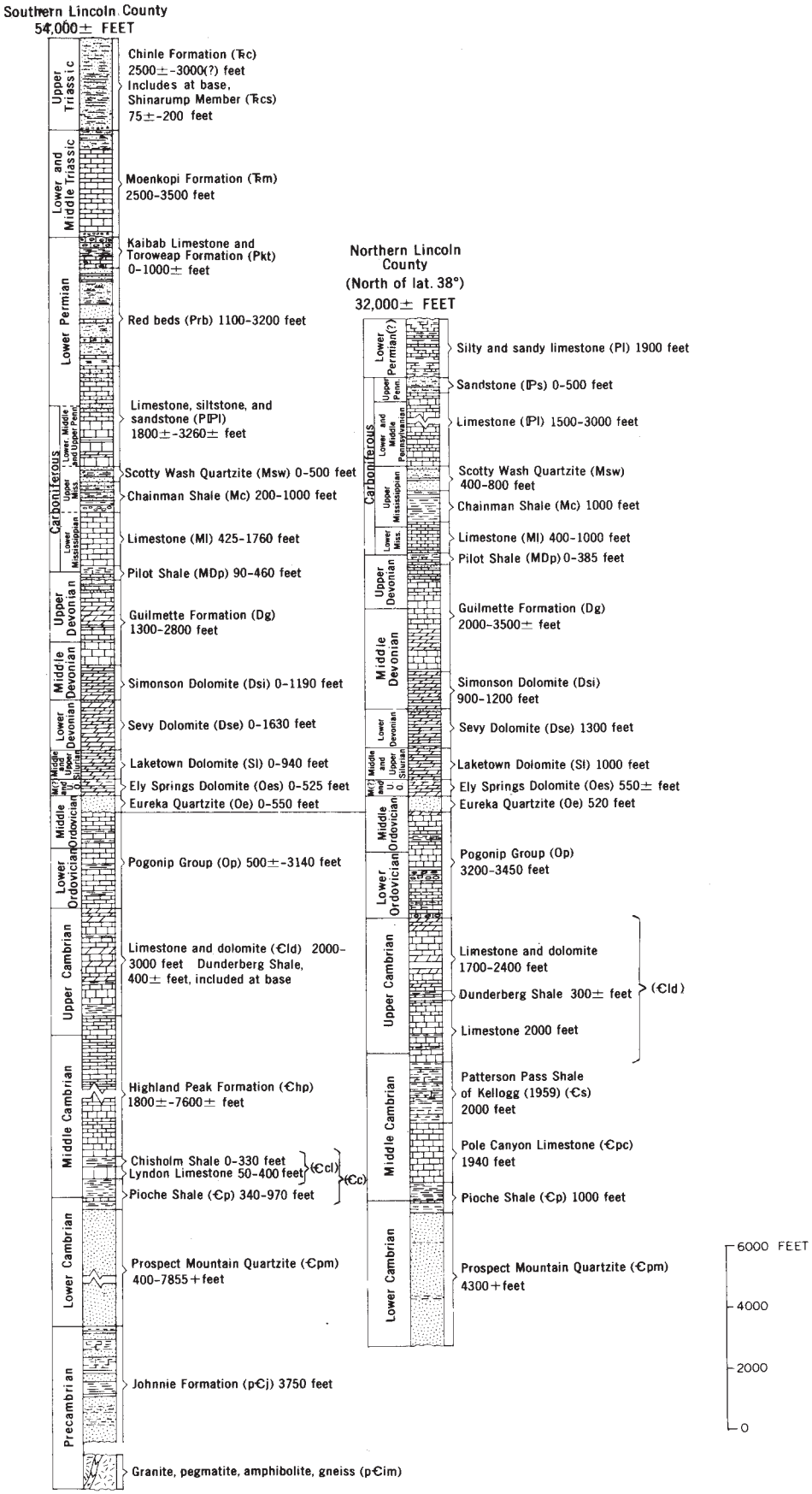


FIGURE 2. Composite stratigraphic sections of pre-Cretaceous(?) rocks in Lincoln County.

and Triassic formations that resemble those on the Colorado Plateau are confined to the southeast corner of the county.

The thickest Cambrian section in the Great Basin may well be that in the Groom Range, where it is 20,000 to 21,000 feet thick and the base of the section is not exposed. Here over half of the section is quartzite. In contrast, the Cambrian in the Mormon Mountains is only about 2,000 feet thick.

Ordovician rocks in the miogeosyncline have a relatively uniform thickness of about 3,500 to 4,400 feet. In the southeast corner of the county, however, they pinch out to a thin layer a few hundred feet thick. The Silurian rocks also decrease in thickness southeastward from about 1,000 to 0 feet.

The Devonian rocks are about 4,900 feet in the northern part of the county, as thick as 6,000 feet in the central part, and as thin as 900 feet in the southeast corner. The Devonian section in the Pahranagat Range is probably the thickest in the Great Basin.

The thickness of the Mississippian rocks increases northwestward from about 900 feet in the southeast corner to between 2,000 and 2,500 feet in the remainder of the county, the thickness over most of the county being a relatively uniform 2,000 feet. The ratio of limestone to clastic rocks increases southeastward, and in the thinnest sections clastic rocks are absent.

The thickness of the Pennsylvanian rocks appears to be relatively uniform, around 2,000 feet, but they are difficult to distinguish from lithologically similar Lower Permian rocks. The thickness of the Permian rocks ranges from 2,000 to 4,000 feet. Triassic rocks are confined to the southeast part of the county, where the maximum thickness may be as great as 5,000 feet.

Jurassic rocks are not exposed in Lincoln County, although a thick Jurassic(?) sandstone is exposed just outside the southeast corner of the county in Clark County, Nevada, and in Utah. The presence of rocks of Cretaceous Age is not proved, but the thick conglomerate series in the southwest corner of the county, which may reach a thickness of 5,000 feet, may be partly, or even entirely, Cretaceous in age. The oldest volcanic rocks in the eastern part of the county may also be Cretaceous.

The total thickness of the Tertiary rocks is uncertain, although the volcanic rocks are known to be several thousand feet thick. Tertiary sedimentary rocks in adjacent areas are reported to be as thick as 10,000 or 15,000 feet locally. In Lincoln County, however, the thickest sections are probably no more than 7,000 or 8,000 feet.

The unconsolidated Quaternary deposits exceed 1,000 feet in thickness in some valleys.

PRECAMBRIAN ROCKS

Igneous and Metamorphic Rocks

Precambrian rocks are exposed in the Mormon Mountains, where granite, pegmatite, amphibolite, and gneiss crop out in three areas, and along the west side of the Desert Range, where clastic rocks of the Johnnie Formation are present. Elsewhere, Precambrian rocks are deeply buried, except perhaps along the west side of the Groom Range, where sedimentary rocks older than the Prospect Mountain Quartzite of Cambrian Age are present.

The Precambrian igneous and metamorphic rocks crop out for 4 miles along the west side of the Mormon Mountains and for 6 miles along the eastern side of the East Mormon Mountains. In addition, a small outcrop of Precambrian granite occurs near the crest of the Mormon Mountains. Large conspicuous white dikes and sills of tourmaline-rich granite pegmatite cut amphibolite and gneiss in the eastern outcrop area. Here disseminated scheelite occurs in the amphibolite and in contact rocks containing idocrase adjacent to the pegmatite dikes. Good exposures are found in several prospects near Gourd Spring; nearby, barite veins cut the basement rocks. Vermiculite, apparently derived from amphibolite by hydrothermal alteration, is exposed for 40 feet between pegmatite stringers in a prospect at the south end of the western Precambrian outcrop.

Where exposed, the unconformity between the Precambrian igneous and metamorphic rocks and the Cambrian Prospect Mountain Quartzite is a remarkably even surface.

These Precambrian rocks have been severely metamorphosed and, therefore, probably belong to an older Precambrian series perhaps equivalent to the Vishnu Schist of Arizona. Younger Precambrian metamorphic rocks, largely quartzite and schist, have not been recognized in Lincoln County, but they are present in White Pine County to the north and perhaps in the Mojave region to the southwest.

In the Deep Creek quadrangle in western Utah, K. F. Bick (written communication, 1958) of Washington and Lee University reported that about 20,000 feet of Precambrian dolomite, quartzite, and schist lie below the Prospect Mountain Quartzite. The basal unit of this thick sequence is a 500-foot dolomite unit which conceivably correlates with the Noonday Dolomite in the Mojave region. These rocks have been subjected to a regional metamorphism that did not affect the Cambrian rocks. R. B. Nelson (written communication, 1958) of the University of Washington studied a similar thick Precambrian sequence in the northern Snake Range and southern Deep Creek Range.

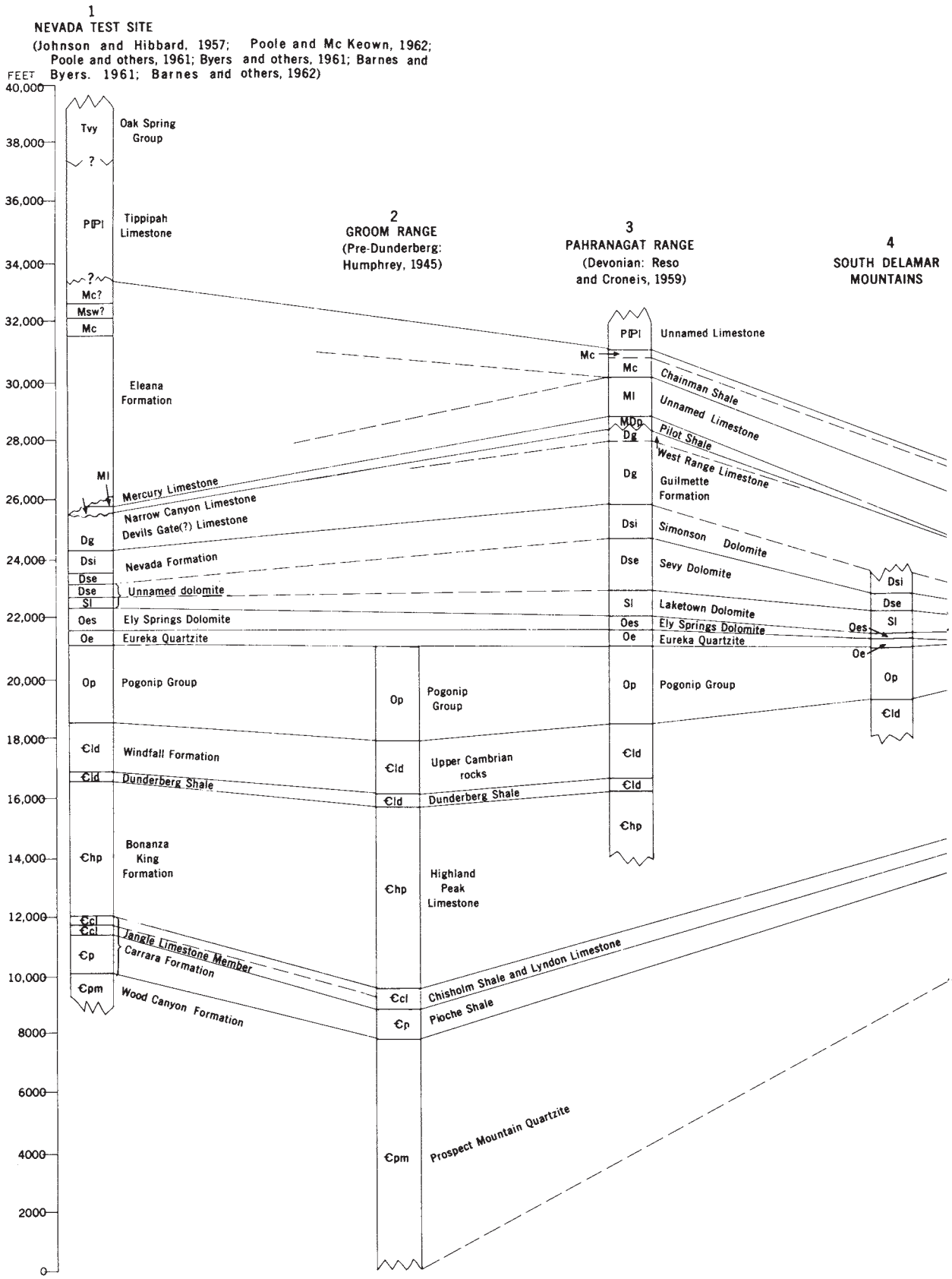
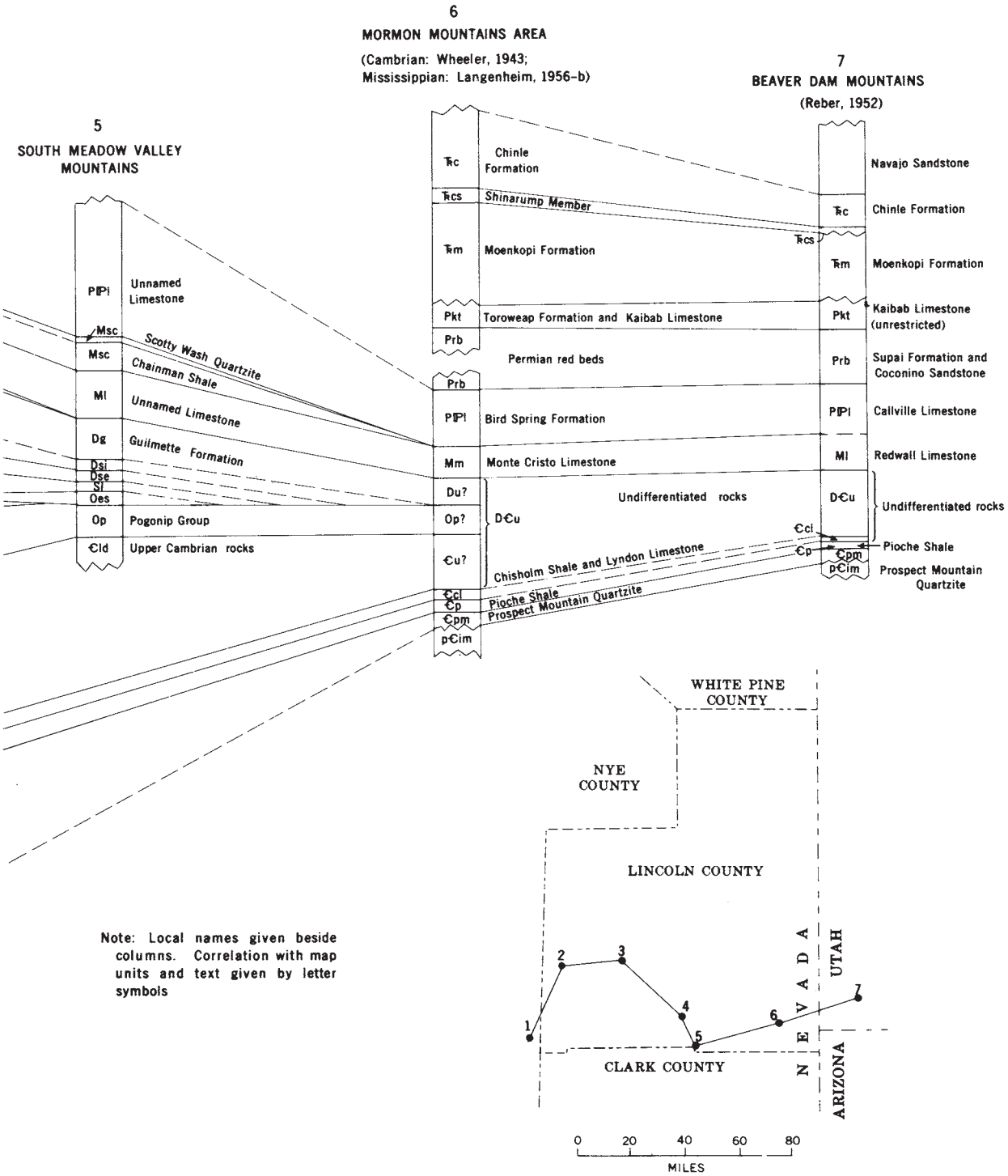


FIGURE 3. Diagrammatic stratigraphic sections showing thinning and onlap across southern Lincoln County.


5
SOUTH MEADOW VALLEY MOUNTAINS
PIPl Unnamed Limestone
Msc
Scotty Wash Quartzite
Chainman Shale
Ml Unnamed Limestone
Dg Guilmette Formation
Dsi
Dse
Sl
Oes
Op Pogonip Group
€ld Upper Cambrian rocks
6
MORMON MOUNTAINS AREA
(Cambrian: Wheeler, 1943;
Mississippian: Langenheim, 1956-b)
Ꞧc Chinle Formation
Ꞧcs Shinarump Member
Ꞧm Moenkopi Formation
Pkt Toroweap Formation and Kaibab Limestone
Prb
Permian red beds
Prb
PIPl Bird Spring Formation
Mm Monte Cristo Limestone
Du?
Op?
€u?
D€u
Undifferentiated rocks
Chisholm Shale and Lyndon Limestone
€cl
€p Pioche Shale
€pm Prospect Mountain Quartzite
p€im
7
BEAVER DAM MOUNTAINS
(Reber, 1952)
Navajo Sandstone
Ꞧc Chinle Formation
Ꞧcs
Ꞧm Moenkopi Formation
Pkt Kaibab Limestone (unrestricted)
Prb Supai Formation and Coconino Sandstone
PIPl Callville Limestone
Ml Redwall Limestone
D€u Undifferentiated rocks
€cl
€p Pioche Shale
€pm
p€im Prospect Mountain Quartzite
Note: Local names given beside columns. Correlation with map units and text given by letter symbols
WHITE PINE COUNTY
NYE COUNTY
LINCOLN COUNTY
CLARK COUNTY
NEVADA
UTAH
ARIZONA
1
2
3
4
5
6
7
0 20 40 60 80
MILES

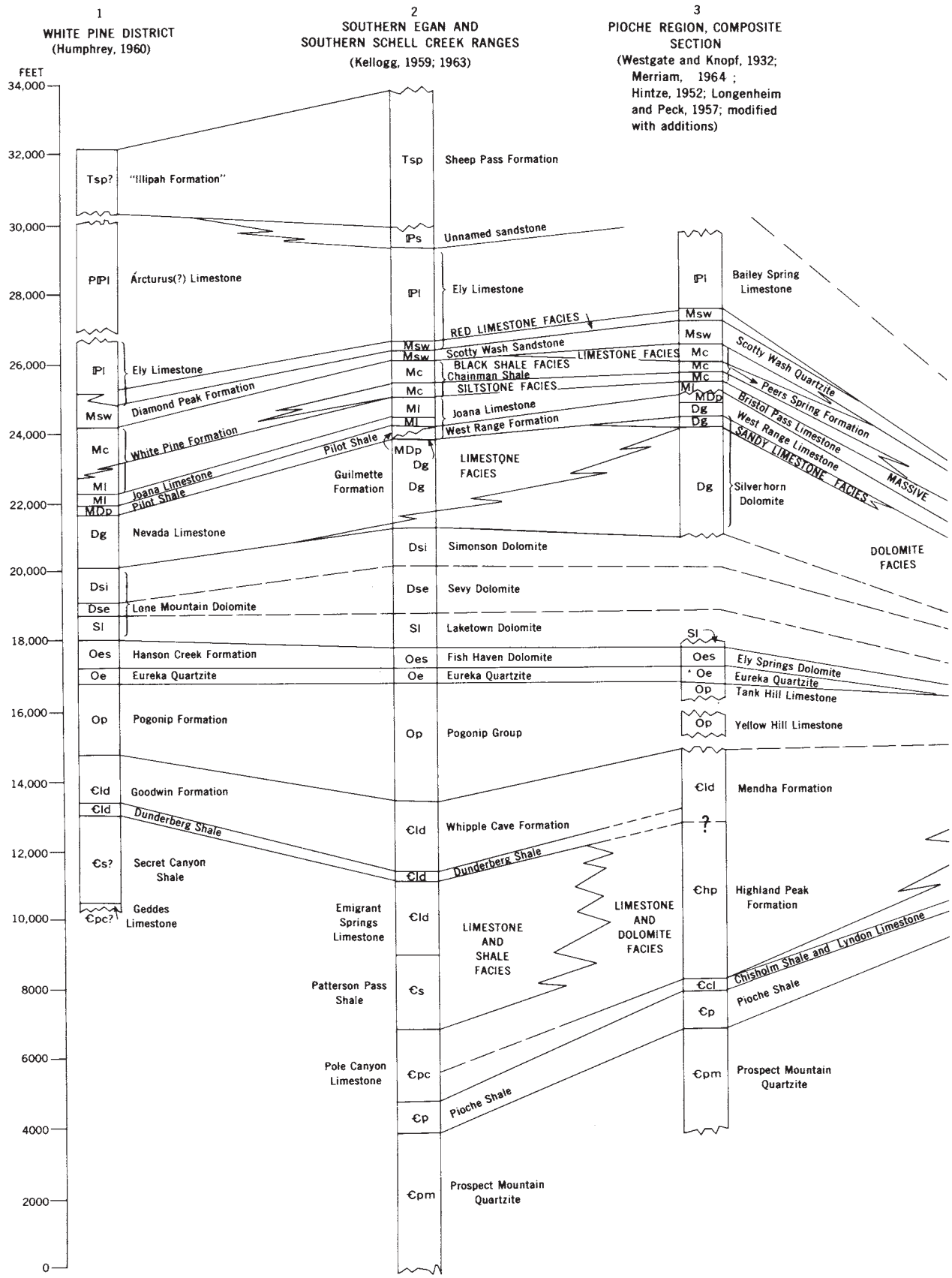
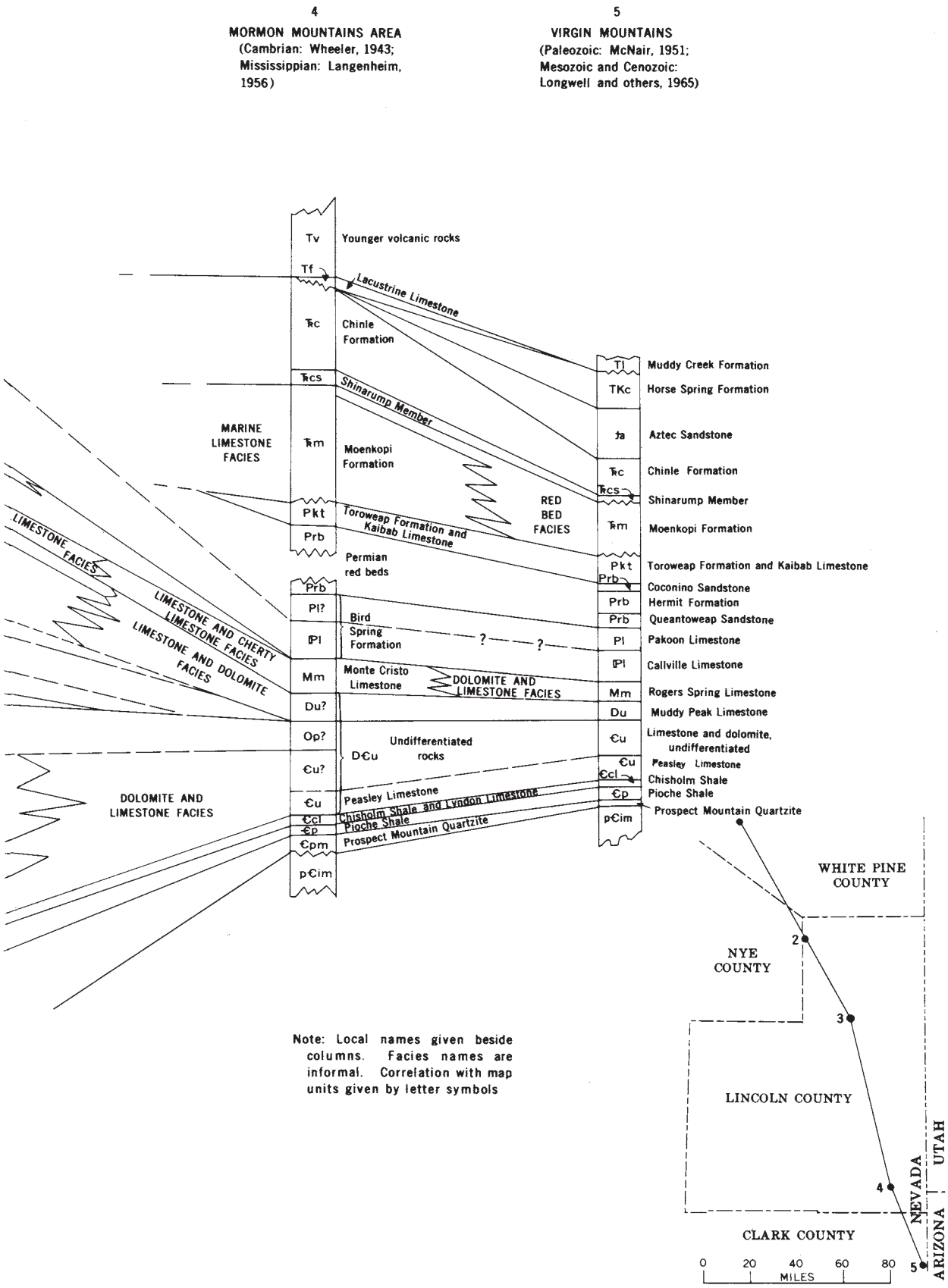


FIGURE 4. Diagrammatic stratigraphic sections and facies relations across axis of miogeosyncline in Lincoln County.


4
MORMON MOUNTAINS AREA
(Cambrian: Wheeler, 1943;
Mississippian: Langenheim,
1956)
5
VIRGIN MOUNTAINS
(Paleozoic: McNair, 1951;
Mesozoic and Cenozoic:
Longwell and others, 1965)
Tv
Younger volcanic rocks
Tf
Lacustrine Limestone
Tc
Chinle Formation
Tcs
Shinarump Member
Tm
Moenkopi Formation
Pkt
Prb
Toroweap Formation and Kaibab Limestone
Permian red beds
Prb
Pl?
Pl
Bird Spring Formation
Mm
Monte Cristo Limestone
Du?
Op?
Cu?
D€u
Undifferentiated rocks
€u
Peasley Limestone
€cl
Chisholm Shale and Lyndon Limestone
€p
Pioche Shale
€pm
Prospect Mountain Quartzite
p€im
MARINE LIMESTONE FACIES
LIMESTONE FACIES
LIMESTONE AND CHERTY LIMESTONE FACIES
LIMESTONE AND DOLOMITE FACIES
DOLOMITE AND LIMESTONE FACIES
DOLOMITE AND LIMESTONE FACIES
RED BED FACIES
Tl
Muddy Creek Formation
TKc
Horse Spring Formation
Ta
Aztec Sandstone
Tc
Chinle Formation
Tcs
Shinarump Member
Tm
Moenkopi Formation
Pkt
Toroweap Formation and Kaibab Limestone
Prb
Coconino Sandstone
Prb
Hermit Formation
Prb
Queantoweap Sandstone
Pl
Pakoon Limestone
Pl
Callville Limestone
Mm
Rogers Spring Limestone
Du
Muddy Peak Limestone
€u
Limestone and dolomite, undifferentiated
€u
Peasley Limestone
€cl
Chisholm Shale
€p
Pioche Shale
p€im
Prospect Mountain Quartzite
Note: Local names given beside columns. Facies names are informal. Correlation with map units given by letter symbols
WHITE PINE COUNTY
NYE COUNTY
LINCOLN COUNTY
CLARK COUNTY
NEVADA
UTAH
ARIZONA
0 20 40 60 80
MILES
2
3
4
5

Misch and others (1957) report that an older Precambrian metamorphic unit is exposed in the Schell Creek Range and in the northern Ruby Mountains. They also found a younger unit of tillite that was derived from the older metamorphic rocks in the Deep Creek and the Schell Creek Ranges. The third and youngest Precambrian unit, which we might include in the Prospect Mountain Quartzite, is exposed in the southern Deep Creek Range, in the Snake Range, and in the Schell Creek Range. All three Precambrian units constitute the lower plate of a regional decollement that Misch and others (1957) called the Snake Range thrust.

Johnnie Formation

Distribution

The Johnnie Formation was defined by Nolan (1929, p. 461) in the Johnnie district, eastern Nye County. It is recognized in the northwest part of the Spring Mountains, Clark County; in the Nopah and Panamint Ranges of California; and in the Desert Range astride the Lincoln-Clark county line. The northern extent of the formation is unknown. The only outcrop in Lincoln County is on the west flank of the Desert Range, where the Johnnie Formation is conformably overlain by the Prospect Mountain Quartzite.

Lithology

Nolan (1929, p. 462) described the formation as follows:

> "The lower part of the formation is composed chiefly of fine-grained quartzites, characteristically greenish or grayish green on freshly broken surfaces, in beds generally six inches to a foot in thickness. Locally, crossbedding is found in these beds. Layers of greenish shale are abundant, but are, as a rule, comparatively thin. A few shale zones, however, are as much as 250 feet in thickness, but these contain a rather large amount of sand. The upper 1,000 feet is distinguished by a much larger proportion of shales, and by the presence of two or three beds of dolomite, each about ten feet thick. Many of the shales are green in color as are those lower in the section, but shades of brown and gray are also found. The gray shales in places show a fine banding."

In general this description applies to the beds exposed in the Desert Range, the principal difference being fewer green beds and more rusty-brown and buff beds in the Desert Range than in the Johnnie district.

In the Desert Range we drew the upper contact of the formation approximately at the uppermost rusty-weathering oölitic dolomite bed in the clasic sequence because this was the only readily mappable line on the aerial photographs. Part of the section exposed below the contact is as follows:

	Feet
Prospect Mountain Quartzite	
Johnnie Formation	
Buff-colored dolomite	20
Green fissile shale	80
Reddish-brown quartzite	50
Dark-gray thin-bedded limestone	40
Thin-bedded reddish-brown quartzite with a number of rusty-brown and buff clastic limestone and dolomite beds	300+

Longwell (1965), however, placed the upper contact of the formation 715 feet higher in the section. The quartzite above the dolomite bed and all of the beds that were mapped as the Stirling Quartzite and Wood Canyon Formation by Longwell were included in the Prospect Mountain Quartzite to be consistent with our usage elsewhere in Lincoln County.

The lowest 200 feet of the exposed section in the Desert Range about 4 miles south of Lincoln County are dolomite equivalent to the Precambrian Noonday Dolomite of the Mojave region, California (C. R. Longwell, oral communication, 1960). These beds were formerly included in the Johnnie Formation.

Thickness

The base of the Johnnie Formation is not exposed in Lincoln County, but a complete stratigraphic section about 4,200 feet thick is present 4 miles south of the county line in the Desert Range (C. R. Longwell, oral communication, 1960). This section plunges northward, and near the county line the maximum exposed thickness is about 3,750 feet (C. R. Longwell, written communication, 1958). In the Nopah Range, California, Hazzard (1937, p. 306) measured a complete section that was 2,550 feet thick. The unit apparently thickens northward from there, for it is more than 4,500 feet thick at the type section where the top is a thrust fault and the base is not exposed. In the Ivanpah quadrangle Hewett (1956, p. 30) assigns a thickness of 4,200 feet to the Prospect Mountain Quartzite, but the basal 2,000 feet have the same lithology as the Johnnie Formation. The Johnnie Formation is absent in the Mormon Mountains where the Prospect Mountain Quartzite lies directly on igneous and metamorphic Precambrian rocks.

Age and correlation

The age of the Johnnie Formation has been accepted as Precambrian by the U.S. Geological Survey. Nolan (1929, p. 263) and Hazzard (1937, p. 306) had considered it to be Early Cambrian, but Wheeler (1948, p. 19) assigned the formation to Precambrian time because it was below the lowest known occurrence of *Olenellus*. To date no fossils have been found in the type Johnnie or in the

Desert Range section (C. R. Longwell, oral communication, 1961).

Correlation of the Johnnie Formation with equivalent sections elsewhere is hindered by the fact that neither the top nor the bottom of the unit is exposed in the stratigraphic section in the Johnnie district. Comparisons between the thick Cambrian clastic sections in the Groom Range and the Desert Range suggest that beds equivalent to those of the Johnnie Formation ought to be present in the Groom Range, but lithologically similar beds were not recognized. Some thin-bedded reddish-brown limestone interbedded with quartzite was found near the base of the section along the west side of the Groom Range. Carbonate beds are characteristic of the Johnnie Formation, but are not found in the Prospect Mountain section, so these beds in the Groom Range may correlate with part of the Johnnie Formation. This correlation is dubious, however. It is possible that different facies have been telescoped by major strike-slip faulting.

CAMBRIAN SYSTEM

Cambrian rocks are by far the thickest system in Lincoln County. Maximum thickness of the incomplete section exposed in the Groom Range exceeds 20,000 feet, and the complete thickness may be several thousand feet greater. In the southern Egan and Schell Creek Ranges in northern Lincoln County, the incomplete composite Cambrian section measured by Kellogg (1963) was more than 13,600 feet thick. This tremendous thickness decreases southward until the thickness of Cambrian rocks in the Mormon Mountains, the only place where the base is exposed, is only about 3,000 feet. Clastic rocks, largely quartzite, make up the lower 9,000 feet of the Groom Range section, but they constitute only the lower 1,000 feet of the Mormon Mountains section.

We have divided the Cambrian section into seven map units on the geologic map (pl. 2). These units, in ascending order, are: (1) Prospect Mountain Quartzite; (2) Pioche Shale; (3) Lyndon Limestone and Chisholm Shale, undivided; (4) Pole Canyon Limestone; (5) Patterson Pass Shale of Kellogg (1963); (6) Highland Peak Formation; and (7) Upper Cambrian rocks, undifferentiated, including the Dunderberg Shale. On plate 2 of this report Cambrian units 2 and 3 are not always shown separately and units 4 and 5 represent a different facies found only in the northern part of the county.

The facies changes that occur in the Lower and Middle Cambrian rocks transverse to the axis of the miogeosyncline are striking (fig. 4). They are especially remarkable considering the persistence of even thin units along the geosynclinal axis.

Prospect Mountain Quartzite

Distribution

The Prospect Mountain Quartzite is conformably overlain by the Pioche Shale which contains *Olenellus*; it rests conformably on the Johnnie Formation where that unit is present, or uncomformably on Precambrian igneous and metamorphic rocks where it is absent. The Prospect Mountain Quartzite is the thickest and one of the most widespread formations exposed in Lincoln County. It is correlated with the Prospect Mountain Quartzite that was first defined by Hague (1892, p. 35) from exposures in the Eureka district, Nevada.

Thick but incomplete sections of this unit are exposed in four general areas: (1) in the Groom and Papoose Ranges along the west edge of the county; (2) in the Desert Range; (3) in the Highland, Bristol, and Ely Ranges, on Chief Mountain, and in the Delamar and Pennsylvania districts, all in the east-central part of the county; and (4) in the southern Schell Creek Range at the north edge of the county. The only complete sections are the very thin one on the west flank of the Mormon Mountains and the much thicker one on the west flank of the Desert Range in Clark County.

Lithology

The formation consists chiefly of thin-bedded to massive quartzite, mostly reddish-brown to white but with some darker interbeds of micaceous shale. The massive quartzite layers are several hundred feet thick, and commonly alternate with layers of nonresistant thin-bedded quartzite and interbedded shale. A massive, white to pinkish-white quartzite several hundred to 1,000 feet thick commonly marks the top of the formation. Many shaly layers are micaceous and some green shaly layers may contain glauconite. In the Groom and Delamar districts the shale or argillite layers are as much as 200 or 300 feet thick; near Caliente, lenses of pebble conglomerate and arkosic layers are present. Many beds show ripple marks, mud cracks, worm marking, vertical worm burrows, and crossbedding. Three mappable subdivisions are present in the Groom Range but the formation is not readily divisible elsewhere.

Diabase dikes or sills of basaltic appearance intrude the formation near Caliente, Pioche, and Delamar. Kellogg (1960, p. 190) noted a "basalt flow" 2,820 feet below the top of the formation in the southern Schell Creek Range.

Weathered outcrops of the quartzite are easily recognized from a distance by their characteristic dark reddish-brown to very dusky-red color.

The upper contact with the Pioche Shale is gradational, but we drew it at the top of the continuous quartzite section. A white quartzite bed, 90 feet thick, which is underlain by 160 to 280 feet of micaceous shale and thin-bedded quartzite, we included in the Pioche Shale in the southern Schell Creek Range and in Cave Valley, but Kellogg (1963, p. 687) and Wheeler (1943, p. 1800)

included this quartzite and the underlying shale in the Prospect Mountain Quartzite. The Pioche Shale and Prospect Mountain Quartzite probably interfinger on a regional scale.

Thickness

The thickness of the Prospect Mountain Quartzite decreases eastward from more than 7,855 feet in the Groom Range (Humphrey, 1945, p. 15) to as little as 400 feet on the west side of the Mormon Mountains (fig. 3). Wheeler (1943, p. 1806) gives a thickness of 800 feet for the incomplete section on the west side of the East Mormon Mountains, just east of the Carp and Mormon Mesa Road. In the Desert Range just south of Lincoln County, C. R. Longwell, in an unpublished section, has measured about 3,185 feet of quartzite between the Johnnie Formation and the Pioche Shale. We have included this entire interval, and 715 feet of additional beds that Longwell included in the Johnnie, in the Prospect Mountain Quartzite. This gives an approximate total thickness of 3,900 feet for the Prospect Mountain in the Desert Range.

Elsewhere the thickness of the formation is not known because the base is not exposed. Between 1,000 and 1,500 feet of quartzite are exposed in the Delamar and Pioche mining districts. A very good unmeasured section in the canyon that holds the railroad spur north of Caliente is estimated to be about 3,000 feet thick. In the southern Schell Creek Range north of Patterson Pass, Kellogg (1960) found more than 4,300 feet of quartzite. The thickness in the southern Snake Range, a few miles north of Lincoln County, has been estimated to be about 3,500 feet by Drewes (1958, p. 224) and about 3,700 feet by D. H. Whitebread (oral communication, 1959). However, Whitebread tentatively includes a 500-foot argillite layer and about 200 feet of underlying quartzite in the lower part of the Prospect Mountain.

Nolan (1935, p. 6) describes a partial section of Prospect Mountain Quartzite 7 miles south of the Gold Hill quadrangle that is 4,750 feet thick. Farther south in the Deep Creek Range, however, Bick (1959, p. 1065) has restricted the Prospect Mountain to 2,950 feet of quartzite equivalent to the upper part of Nolan's section and has proposed the name Goshute Canyon Formation for 3,000 feet of unmetamorphosed quartzite and shale equivalent to the lower part of Nolan's section. The Goshute Canyon Formation of Bick (1959) in turn overlies a 20,000-foot section of Precambrian metasedimentary rocks.

The available data, therefore, indicates that the maximum thickness of the Prospect Mountain Quartzite exceeds 7,855 feet in the Groom Range, and that a thickness of 3,000 to 4,500 feet is not unreasonable for the northern part of the county.

Age and correlation

For the sake of consistent usage within Lincoln County, we included the Stirling Quartzite and Wood Canyon Formation, as mapped in the Desert Range by Longwell and others (1965), in our Prospect Mountain. According to A. R. Palmer (written communication, 1964), Stirling, Wood Canyon, and Zabriskie equivalents have been recognized in both the Desert and Groom Range sections. These sections, however, are difficult to correlate in detail.

Identifiable fossils have not been found in the Prospect Mountain Quartzite, but it is considered to be partly Cambrian and partly Precambrian on the basis of regional stratigraphic considerations. A. R. Palmer (written communication, 1963) says it is at least partly Cambrian because the basal Pioche faunas do not represent the oldest Early Cambrian known in this region, and it is partly Precambrian because there are no fossiliferous Cambrian beds in units correlative with the Stirling or lower Wood Canyon Formations.

Chisholm Shale, Lyndon Limestone, and Pioche Shale, Undivided

Distribution

The Pioche and Chisholm Shales were named by Walcott (1908, p. 1-2; 1916, p. 409) from exposures near Pioche. The Lyndon Limestone was named by Westgate and Knopf (1927, p. 820) from exposures in Lyndon Gulch on the west side of the Highland Range.

These three formations are widely distributed in the same general areas of Lincoln County as the Prospect Mountain Quartzite below, or the Highland Peak Formation above. The Pioche Shale, the thickest and most widely distributed of the three formations, is found throughout the county. The Chisholm Shale and Lyndon Limestone are not recognizable in the northern part of the county where equivalent beds occur in the lower part of the Pole Canyon Limestone (Drewes and Palmer, 1957, p. 110-114). In this area, the Pioche Shale is shown separately.

The Pioche Shale occurs throughout eastern and southeastern Nevada, in northwestern Arizona, and throughout most of the western half of Utah (Wheeler, 1943, p. 1815). The Lyndon Limestone and Chisholm Shale are more restricted, but they are found in northern Clark County (Longwell and others, 1965, p. 17) and adjacent parts of Arizona and Utah (Wheeler, 1948, p. 31-32) as well as in Lincoln County.

Lithology

The Pioche Shale consists of an interbedded fossiliferous sequence of micaceous, sandy, or argillaceous shales with a few thin sandstone and many thin limestone layers. The shales are commonly dull olive-green or brown,

although some beds are reddish or buff. The micaceous shales resemble phyllite but the mica is probably detrital. The limestone beds are as much as 50 feet thick and are usually fossiliferous, containing "girvanella" and trilobite fragments. The Pioche Shale has been subdivided informally into seven members in the mining areas around Pioche. The limestone beds, particularly the lowest bed, the Combined Metals Member of the Pioche Shale, are productive ore horizons (fig. 5). Locally this member is called the CM bed.

The formation contains a white, massive quartzite about 90 feet thick in the southern Schell Creek Range about 375 feet stratigraphically above the base. This quartzite is correlated with the so-called siliceous footwall shale at Pioche. The CM bed, the major ore bed in Lincoln County, is 240 to 375 feet stratigraphically above the base of the formation at Pioche.

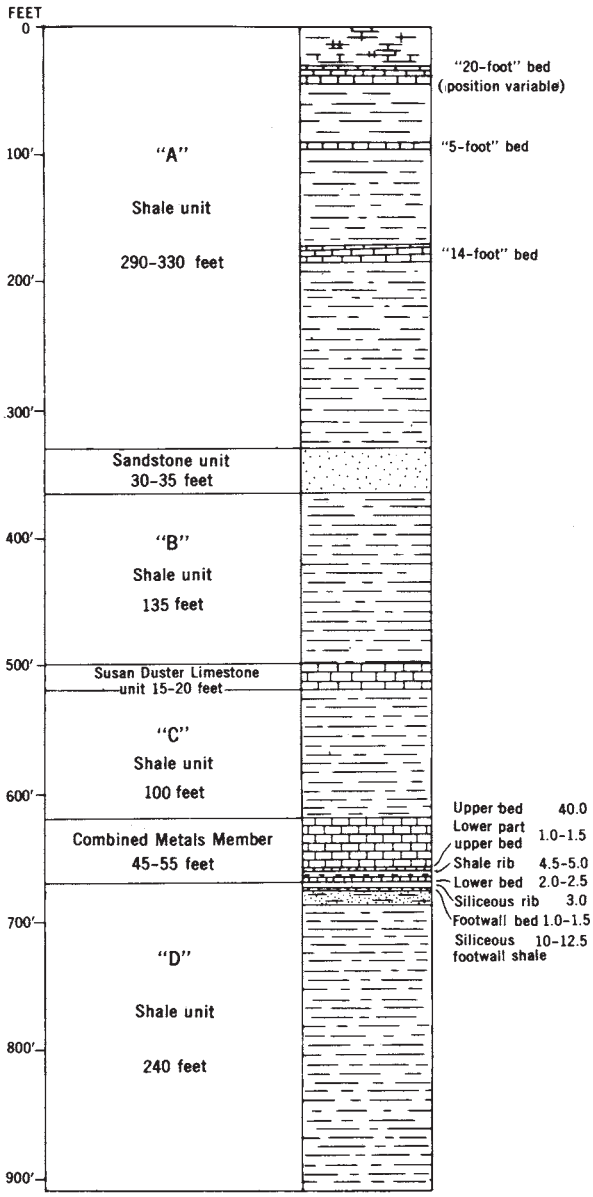


FIGURE 5. Stratigraphic section of the Pioche Shale, Pioche district.

The Lyndon Limestone conformably overlies the Pioche. It consists of massive cliff-forming limestone which has a three-part color division at Pioche — the upper and lower parts being dark gray and the middle almost white. Elsewhere these subdivisions are not recognized and there is a considerable range in both thickness and color.

The Chisholm Shale conformably overlies the Lyndon Limestone. It is a yellowish-brown, buff, maroon, or olive-green fissile shale which contains several thin buff-weathering argillaceous limestone beds. It is distinctly less micaceous and finer grained than most of the Pioche Shale, but it does resemble the upper part of the Pioche.

The shales are easily recognized because they are the only prominent slope-forming units in a thick sequence of cliff-forming formations.

Thickness

The thickness of the Pioche Shale is reasonably uniform, ranging from 890 to 970 feet along a broad belt parallel to the axis of the geosyncline which passes through the Groom, Delamar, and Pioche districts; the formation thins rapidly on either side at right angles to this belt. In the Snake Range, a few miles north of Lincoln County, the thickness ranges from 242 to 451 feet and averages 400 feet (D. H. Whitebread, oral communication, 1961), and in the Mormon Mountains it is 340 feet (Wheeler, 1943, p. 1805). In Cave Valley and the southern Schell Creek Range we found the thickness to be between 750 and 1,000 feet — far greater than the figures given by Wheeler (1943, p. 1800) and Kellogg (1960), who placed the lower contact at the top of the 90-foot quartzite. In the Desert Range, the Pioche Shale is 600 to 700 feet thick (C. R. Longwell, oral communication, 1960). At Indian Ridge, a few miles outside the southwest corner of Lincoln County, Longwell (Longwell and others, 1965, pl. 3) measured about 635 feet of Pioche Shale.

The Lyndon Limestone is 345 to 400 feet thick in the Pioche district (Park and others, 1958; Westgate and Knopf, 1932, p. 7), but it thins southward to 102 feet near Delamar (Callaghan, 1937, p. 17), to 202 feet in the Groom district (Humphrey, 1945, p. 17), to 245 to 280 feet along the west edge of the county (Johnson and Hibbard, 1957, p. 338; Barnes and others, 1962, p. 28), to about 120 feet in the Desert Range (C. R. Longwell, oral communication, 1960), and to only 50 feet in the Mormon Mountains (Wheeler, 1943, p. 1805). Beds equivalent to the Lyndon Limestone may thicken greatly north of

Pioche, but they are not recognizable unless the Chisholm Shale is present.

The Chisholm Shale thickens from 100 or 170 feet in the Pioche Hills (Merriam, 1964; Park and others, 1958), to 300 feet at Delamar (Callaghan, 1937, p. 17), to 332 feet in the Groom district (Humphrey, 1945, p. 17), to 320 feet along the southwest edge of the county (Johnson and Hibbard, 1957, p. 339), to about 200 feet in the Desert Range (C. R. Longwell, oral communication, 1960), and to 275 feet on the east side of the Mormon Mountains (Wheeler, 1943, p. 1805). It appears, however, to be absent locally on the west side of the Mormon Mountains. The Chisholm Shale apparently thins and pinches out north of Pioche.

Age and correlation

The Pioche Shale and similar equivalent formations — the Bright Angel and Ophir Shales — form a continuous lithologic unit that straddles the boundary between the Lower and Middle Cambrian in Nevada and becomes entirely Middle Cambrian to the east and southeast in Utah and Arizona by transgression of time lines (Wheeler, 1943, p. 1811-1816). The Lyndon Limestone and Chisholm Shale are Middle Cambrian.

Collection 59TF2 from the *Olenellus* zone of the Pioche Shale at the southeast end of Chert Ridge was our only Lower Cambrian collection. This collection contained two different olenellid trilobites, one of which is apparently assignable to *Bristolia,* according to A. R. Palmer (written communication, 1963). In this area the Lower Cambrian rocks are thrust on Mississippian rocks.

Pole Canyon Limestone

Distribution

The Pole Canyon Limestone was named by Drewes and Palmer (1957, p. 110) from exposures in Pole Canyon in the southern Snake Range. The formation was divided into five members, all of which can be recognized in the southern Schell Creek and Egan Ranges and in Cave Valley in northern Lincoln County, according to Kellogg (1963, p. 688); the five members, in ascending order, are A, B, C, D, and E.

Lithology

The formation is composed of alternating dark- and light-gray massive limestone beds, closely resembling the Lyndon. The color banding produces five divisions which are widely recognized in Utah and Nevada north of lat 38° N. The lithology is described in greater detail by Drewes and Palmer (1957), and Kellogg (1959).

Thickness

The thickness of the Pole Canyon in Lincoln County is 1,940 feet (Kellogg, 1960), about the same as that in the southern Snake Range.

Age and correlation

Palmer, who identified the fossils collected by Drewes and Kellogg, found Middle Cambrian fossils in members C and E. He correlated unit E with the Condor Member of the Highland Peak Formation (A. R. Palmer, written communication, 1958). Unit A is approximately equivalent to the Lyndon Limestone-Chisholm Shale-Peasley Member interval. Units B to E are therefore equivalent to the lower part of the Highland Peak Formation, but a precise correlation is not possible. The Pole Canyon Limestone is approximately correlative with the Lyndon, Chisholm, and Highland Peak A through C.

Patterson Pass Shale of Kellogg (1963)

The Patterson Pass Shale of Kellogg (1963, p. 689) is exposed in Lincoln County only on the hill south of Patterson Pass. It consists of approximately 2,000 feet of yellowish or gray shale, and calcareous mudstone with interbedded limestone; the limestone is more abundant near the top.

The shale is late Middle Cambrian in age (A. R. Palmer, written communication, 1959). It correlates with the lower shale member of the Secret Canyon Shale at Eureka (Nolan and others, 1956, p. 12-16) and the upper part of the Highland Peak Formation (fig. 4). Both the lithology and fauna indicate it is equivalent to the 160 feet of beds at the base of the Lincoln Peak Formation in the Snake Range, but most of the lower Lincoln Peak there is apparently faulted out.

Highland Peak Formation

Definition

The Highland Peak Formation of this report is identical to the Highland Peak Limestone as originally defined (Westgate and Knopf, 1932, p. 11-12) before it was restricted by Wheeler (1940, p. 17-29).

The formation consists of the 17 units of the composite section first measured and described in the Pioche district by Wheeler and Lemmon (1939, p. 37-42). These units were designated A to Q starting from the bottom, as shown in the following table. The Highland Peak Formation includes, in ascending order, the Peasley, Burrows, Burnt Canyon, Step Ridge, Condor, and Meadow Valley Members (Merriam, 1964), and the undivided upper part of the Highland Peak Formation. The name Step Ridge Member is substituted by Merriam for the Dome Limestone as used by Wheeler (1948, p. 36-40) and the name Meadow Valley Member is substituted for the Swasey Limestone (idem). The extension by Wheeler of the Dome and Swasey Limestones into Lincoln County from the House Range, Utah, is based apparently upon a mistaken correlation (C. W. Merriam, oral communication, 1958; Robison, 1960, p. 51).

Subdivision of the Highland Peak Formation

Thickness (feet)	Wheeler and Lemmon (1939)	Wheeler (1948)	Informal local names	Merriam (1964)	This report
110	Q	Highland Peak Limestone, restricted	------	Upper part of the Highland Peak Formation	Highland Peak Formation
125	P		------		
170	O		------		
243	N		McFadden dolomite		
240	M		Hillside limestone		
260	L		Tempest limestone		
115	K		Inman limestone		
425-490	J		Jackrabbit limestone		
			Gypsy limestone		
380	I		Badger dolomite		
200	H				
430	G	Swasey Limestone	Bristol limestone	Meadow Valley Member	
110	F	Condor Member of Swasey Limestone	Platy dolomite	Condor Member	
740	E	Dome Limestone	Newport limestone	Step Ridge Member	
	D	do.	False Prince "B"	do.	
190	C	Burnt Canyon Limestone	Davidson black dolomite	Burnt Canyon Member	
300-500	B	Burrows Dolomite	Davidson gray dolomite	Burrows Member	
160	A	Peasley Limestone	Davidson blue limestone	Peasley Member	

Distribution

The Highland Peak Formation crops out over large areas in Lincoln County and is particularly well exposed in the Bristol, Highland, Black Canyon, Ely (Pioche Hills), Pahranagat, Groom, Desert, and Spotted Ranges and in the White Rock and Meadow Valley Mountains. Equivalent rocks are exposed in the southern Schell Creek Range and in the Mormon Mountains.

Lithology

The Highland Peak Formation is composed of alternating layers of light- and dark-gray limestone and dolomite of several distinctive types. Common rock types include: dark-gray or black, fine-grained limestone, some mottled; light-gray, aphanitic, massive limestone; light- or dark-gray, coarse-grained, massive dolomite; white to buff fine-grained, laminated, thin-bedded, occasionally platy dolomite or dolomitic sandstone. The three most distinctive key horizons are: (1) unit C (Burnt Canyon Member), a black thin-bedded limestone with reddish mottling and fossiliferous shale seams; (2) unit F (Condor Member), a reddish-brown or buff, thin-bedded, platy, fine-grained, dolomitic sandstone and gray laminated or platy limestone; and (3) unit J, which contains a 40-foot bed of gray, thick-bedded limestone with large ovoid chert nodules in a light- and dark-banded series of limestone and laminated dolomite. Units C, F, and J are stratigraphically about 500, 1,200, and 2,400 feet, respec-

tively, above the base of the formation. The alternating dark and light bands are the most distinctive characteristic of the formation from a distance (fig. 9).

The best descriptions of the separate units of the Highland Peak Formation are given by Wheeler and Lemmon (1939, p. 45-47), Wheeler (1943, p. 1802), Humphrey (1945, p. 22-23), and Merriam (1964). Correlations and revisions in nomenclature are given by Wheeler (1940; 1948) and Robison (1960).

Thickness

A composite section measured by Merriam (1964, p. 9) in the Pioche district has a thickness of 4,500 feet. A partial section through unit I measured by Wheeler (1943, p. 1802-1804) at Delamar has a thickness of 3,115 feet, which corresponds to 2,940 feet that Merriam measured for approximately the same stratigraphic interval near Pioche. Even without additional thickening in units J through Q, the total indicated thickness at Delamar is about 4,600 feet.

The Highland Peak Formation is even thicker in the Groom district. Humphrey (1945, p. 19-23) measured a section 3,360 feet thick (including the Burrows and Peasley Members) and estimated an additional thickness of 2,000 feet, for a total of 5,360 feet. Measurements on 1:60,000 aerial photographs suggest even greater thicknesses in the magnificent steeply dipping, and apparently unfaulted section east of the Groom mine. These crude measurements suggest thicknesses ranging from 6,200 to 7,600 feet.

Johnson and Hibbard (1957, p. 339-342) measured a thickness of 2,850 feet in a faulted section of rocks in the Yucca Flat area that we consider to be equivalent to the Highland Peak Formation. This figure is hundreds of feet too small for a total because of faulting. A more detailed study in the same area by Barnes and Palmer (1961) shows that the section equivalent to our Highland Peak Formation is on the order of 5,400 feet thick. An unpublished measured section (C. R. Longwell, written communication, 1958) at Indian Ridge, 5 miles south of Indian Springs, Clark County, has a thickness of 3,618 feet for the sequence equivalent to the Highland Peak Formation.

The rocks equivalent to the Highland Peak Formation thin rapidly in the Mormon Mountains southeast of Rox (fig. 4). The equivalent section in the North Virgin Mountains measured by McNair (1951, p. 507-508, 514) is only 1,564 feet thick. The equivalent section in the Mormon Mountains is several hundred feet thicker than this, but a meaningful estimate cannot be given without fossil data.

In the House Range, western Utah, Hintze and others (1958, p. 1688) measured thicknesses of Highland Peak ranging from 5,260 to 6,340 feet between the Dunderberg and the Pioche Shales; 2,416 feet were Upper Cambrian rocks. The same stratigraphic interval in the southern Snake Range was estimated as having a thickness of 3,430 to 4,190 feet by Drewes and Palmer (1957, p. 110-119), but this section was a composite one cut by two thrust faults. In 1958, Drewes (p. 224) gave a thickness of about 3,750 feet for the same interval.

In general, the thickness of the Highland Peak Formation seems to increase westward from Pioche to Delamar to Groom and to decrease drastically southeast of Meadow Valley Wash on the Colorado Plateau (fig. 3).

Age and correlation

The age of the Highland Peak Formation ranges from early Middle Cambrian at the base to early Late Cambrian near the top. As a whole the unit is remarkably unfossiliferous, and the exact position of the boundary between Middle and Late Cambrian is unknown.

The trilobites, *Coelaspis* and *Kootenia,* were identified by Deiss (Wheeler, 1948, p. 38) from the thin shale in the Burnt Canyon Member (unit C) near Pioche and in the Groom district. These fossils place the lower 680 feet of the Highland Peak in the *Glossopleura-Kootenia* zone of the lower Middle Cambrian.

A shale of uncertain stratigraphic position near the stock on the summit north of Bald Mountain in the Groom Range contains *Elrathina* and *Bathyuriscus,* which place the shale in the *Elrathina-Bathyuriscus* zone of middle Middle Cambrian. These fossils are found in the Geddes Limestone of the Eureka district and in the highest member of the Pole Canyon Limestone in the southern Snake Range (Drews and Palmer, 1957, p. 112).

Ehmaniella was found by Longwell (written communication, 1958) about 1,500 feet stratigraphically above the base of rocks equivalent to the Highland Peak Formation in Indian Ridge near Indian Springs, Clark County. This genus belongs to the *Bolaspis-Glyphaspis* zone according to Wheeler (1948, p. 40), but this zone probably represents about the same time interval as the *Elrathina-Bathyuriscus* zone.

Fossil collections show that several hundred feet of limestone with some silty thin-bedded sections below the Dunderberg Shale belong in the *Cedaria* and *Crepicephalus* zones of the Upper Cambrian. These pre-Dunderberg rocks are about 300 feet thick in the adjoining Yucca Flat and Indian Ridge areas of Nye and Clark Counties. They are included in the Highland Peak Formation on the map except in the Pioche district, where they are probably included in the undifferentiated Upper Cambrian rocks.

Early Late Cambrian fossils belonging to the *Crepicephalus* zone were found in limestone 300 feet below the Dunderberg in the Yucca Flat area (Barnes and others, 1962, p. D 31) and in the Indian Ridge section (C. R.

Longwell, written communication, 1959). *Crepicephalus* was collected near the base of the Mendha Formation by Westgate and Knopf (1932, p. 14), and in equivalent rocks by us. These rocks properly belong with the undifferentiated Upper Cambrian rocks, but they were included with the Highland Peak Formation wherever the Dunderberg Shale could not be recognized.

The Highland Peak Formation is equivalent to the lithologically similar rocks of the Bonanza King Formation, excluding the upper 300 feet (subunit 3 of the Banded Mountain Member) of the Bonanza King, in the Nevada Test Site (Barnes and others, 1962, p. D 30-D 31).

The equivalent rocks in the southern Snake Range — the upper part of the Pole Canyon Limestone and the lower part of the Lincoln Peak Formation (Drewes and Palmer, 1957, p. 110-115) — are a totally different facies and cannot be correlated with the Highland Peak Formation (Robison, 1960). However, these rocks are lithologically like the Middle and Upper Cambrian rocks in the Patterson Pass and Shingle Pass areas in northern Lincoln County (fig. 4) where Kellogg (1963, p. 688-689) recognizes the Pole Canyon Limestone and beds equivalent to the Lincoln Peak Formation by their lithology and fauna.

Figure 6 shows the correlation of the various units

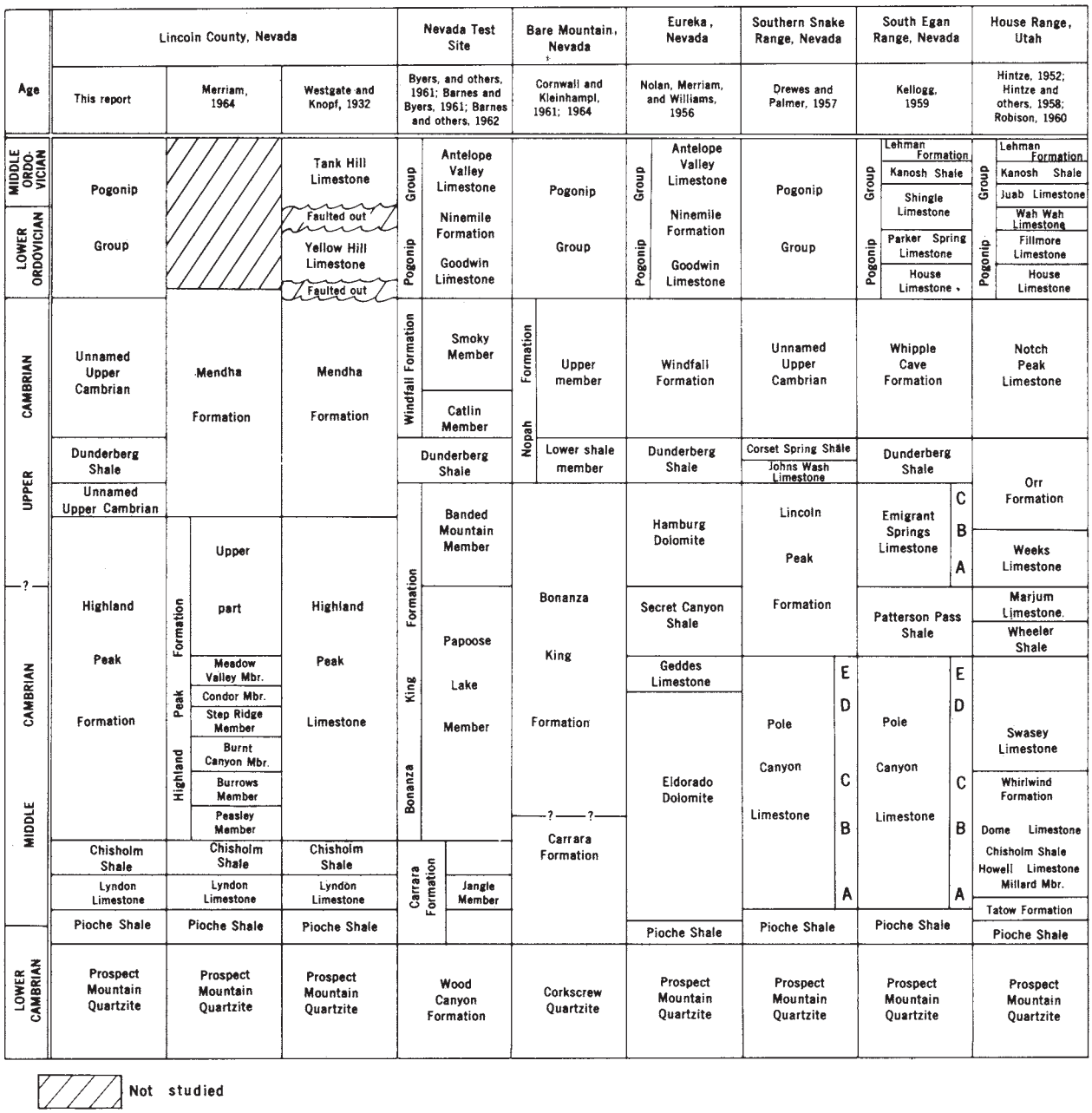


FIGURE 6. Correlation of the Cambrian and Ordovician formations in eastern Nevada and western Utah.

that make up the Highland Peak Formation.

In the Mormon Mountains, Wheeler (1943, p. 1804-1806) correlated 410 feet of dolomite and some limestone above the Chisholm Shale with the Peasley Member. The relatively thin section of Cambrian carbonate rocks here is undoubtedly partly equivalent to the much thicker Highland Peak Formation, but we were unable to recognize any of the distinctive units in the Mormon Mountains. Figure 4 shows the correlations and the informal facies names assigned to the Cambrian units in different parts of the county.

Dunderberg Shale

Distribution

Rocks closely similar to the Dunderberg Shale in lithology and fauna are widespread in the eastern part of Nevada. The Dunderberg Shale is definitely present in the southern Egan, southern Schell Creek, Groom, Timpahute, Pahranagat, and Spotted Ranges, and the Delamar Mountains. It is also probably present in the Desert and Sheep Ranges. C. R. Longwell recognized it at Indian Ridge in the northern Spring Mountains, Clark County. The Dunderberg Shale could not be shown separately on the map, but it is discussed apart from the other Upper Cambrian rocks for convenience.

Lithology

The Dunderberg Shale consists of layers of gray-brown-weathering limestone, clastic limestone, and oölitic limestone, alternating with green or brownish, platy of fissile shale. The shale may occur as partings, seams, or beds as much as 3 feet thick. The Dunderberg forms a prominent weak zone above the massive Highland Peak beds.

Thickness

Reso (1963, p. 904) measured 340 feet of beds in the Pahranagat Range which he assigned to the Dunderberg Shale. P. H. Heckel (written communication, 1960) of Rice University, assigned 344 feet of beds to the Dunderberg in the south end of the Delamar Mountains. Kellogg (1960, p. 190) measured 290 feet of Dunderberg at Patterson Pass in the Schell Creek Range and about 313 feet at Shingle Pass in the Egan Range.

Age and correlation

The Dunderberg is early Late Cambrian in age and it is correlated with the Dunderberg Shale at Eureka, in the Yucca Flat area of the Nevada Test Site, and at Indian Ridge in the Spring Mountains. It probably correlates with some part of the Mendha Formation, but an exact correlation cannot be made. The fauna and lithology are identical to those of the combined Johns Wash Limestone and Corset Spring Shale of Drewes and Palmer (1957, p. 115-116) in the Snake Range, and some of the rocks called Dunderberg in this report may be Corset Spring Shale (Palmer, 1960). The stratigraphic relationships are shown in the correlation chart on figure 6.

Typical Dunderberg fossils have been collected from the Pahranagat, Groom, and Timpahute Ranges. All the fossils were identified by A. R. Palmer (written communications, 1958, 1964).

USGS collection 2460-CO. Lower part of the Dunderberg Shale in the Timpahute Range, about 3 miles northeast of Tem Piute.

Dunderbergia nitida (Hall and Whitfield)
Homagnostus sp.
Pseudagnostus sp.
Strigambitus sp.
Morosa cf. *M. longispina* Palmer
cf. *Sphaeragnostus* sp.

USGS collection 2431-CO. South end of the Dunderberg outcrop in the Pahranagat Range.

Homagnostus sp.
Sigmocheilus pogonipensis (Resser)
Aphelotoxon marginata Palmer
Dunderbergia nitida (Hall and Whitfield)
Elviniella laevis Palmer
Pseudagnostus sp.
Taenora expansa? Palmer
Dunderbergia variagranula Palmer

This fauna is characteristic of the upper part of the Dunderberg Shale at Eureka, Nevada.

USGS collection 2678-CO. Dunderberg Shale, 3 miles east of the Groom mine.

Homagnostus tumidosus (Hall and Whitfield)
Homagnostus (unnamed species)
Housia (new species)
Pterocephalia sanctisabae (Roemer)
Pseudagnostus sp.
Linnarssonella sp.

Upper Cambrian Limestone and Dolomite, Undifferentiated

The Cambrian rocks above the Highland Peak Formation, including the Dunderberg Shale, are shown in a single map unit. This unit includes all the Cambrian rocks above the thick Middle Cambrian shale near Patterson Pass. The Upper Cambrian includes the Mendha Formation as mapped in the Pioche district (Westgate and Knopf, 1932, p. 13-14). Several hundred feet of Upper Cambrian rocks, equivalent to the upper part of the Lincoln Peak Formation, are apparently faulted out of the Mendha Formation on Arizona Peak, the type locality, according to A. R. Palmer (written communication, 1958). Merriam (1964, p. 50) states that the Mendha as mapped by Westgate also includes fault blocks of Lower Ordovician rocks. The top is everywhere a fault contact and a reliable composite section has never been worked out.

Lithology

The lower part of the undifferentiated Upper Cambrian sequence generally is reddish or yellowish, soft, silty or cherty, fossiliferous limestone that contrasts with the more massive, resistant, unfossiliferous rocks of the underlying Highland Peak Formation. The upper part is usually dark- or light-gray, partly cherty dolomite. We have not studied the lithologic sequence in detail and the lateral differences are unknown.

The lower 700 to 1,500 feet of the post-Dunderberg sequence is usually gray, light-gray, or yellowish limestone that is aphanitic to coarse grained, thin-bedded to massive, and partly oölitic. Reddish-brown shale partings and white chert are common, particularly near the base. Many layers are conglomeratic and weather rusty yellow, brown, or reddish.

The uppermost 1,100 to 1,800 feet are characteristically unfossiliferous dolomite that is banded, speckled, mottled, or striped dark and light gray. Several limestone beds are present in the upper part, and some cherty beds are present near the base. A prominent banded black-and-gray dolomite marks the upper contact in the Sheep and Desert Ranges. It forms a three-part sequence — a black band above and below with a gray band in the middle.

In the Pahranagat Range we selected the top of a light-gray cherty dolomite, which is at the base of the limestone section, as the upper contact. Reso has more recently mapped the same lithologic change as the upper contact of his equivalent post-Dunderberg unit, the Desert Valley Formation (1963, p. 905).

Some reddish, silty or oölitic, nonresistant limestone beds containing pre-Dunderberg Upper Cambrian fossils have been included in the undifferentiated Upper Cambrian rocks between the north end of the Groom Range and Mount Irish, and in the northern part of the county.

The Egan Range section is typical of the northern part of Lincoln County. Kellog (1963, p. 689-692) mapped three units. The lowest, the Emigrant Springs Limestone, consists of 2,064 to 2,232 feet of thin-bedded silty- or oölitic limestone and massive limestone with an intraformational limestone breccia at the base. The middle unit is the Dunderberg Shale, already described. The upper unit, 1,624 to 1,883 feet thick, is the Whipple Cave

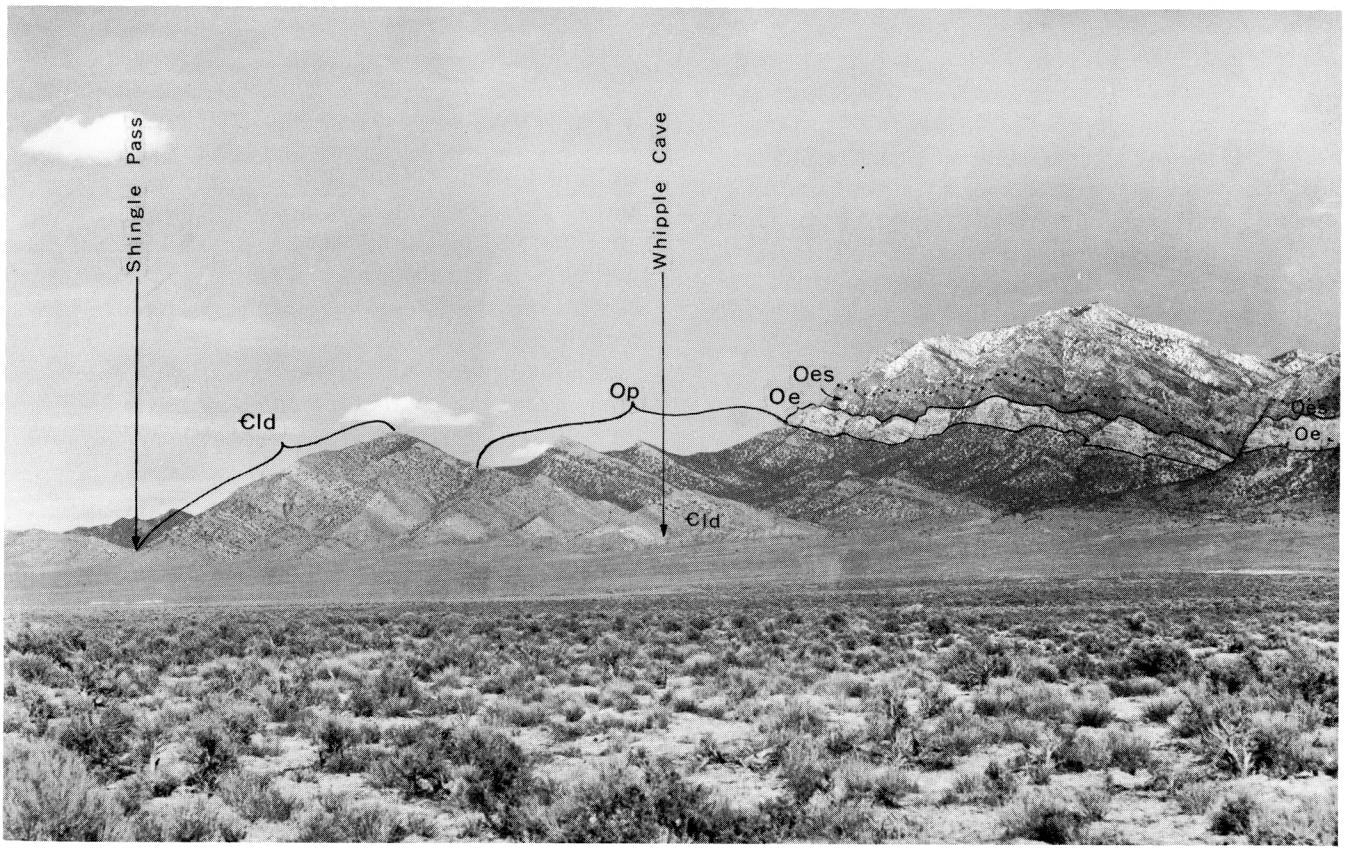


FIGURE 7. Upper Cambrian and Ordovician rocks in the west face of the southern Egan Range. View northeast from Nevada Highway 25, 2 miles north of Sunnyside. Ꞓld, Upper Cambrian rocks with Dunderberg Shale at the base; Op, Pogonip Group; Oe, Eureka Quartzite; Oes, Ely Springs Dolomite.

Formation, a basal cherty limestone overlain by a sequence of alternating dolomite and limestone. The upper part of this Cambrian section is shown in figure 7.

Thickness

The faulted section of Upper Cambrian rocks above the Dunderberg Shale in the Nevada Test Site is 1,785 feet thick, according to Barnes and Byers (1961). Kellogg (1960, p. 190) measured sections of Upper Cambrian rocks near the northwest corner of Lincoln County that totaled 3,928 to 4,228 feet. The thickness of post-Dunderberg rocks in his sections was 1,624 feet at Whipple Cave, 2 miles south of Shingle Spring in the southern Egan Range, and 1,883 feet at Dry Canyon in the Egan Range, just north of the county line (Kellogg, 1963, p. 692). The partial composite section of the Mendha Formation near Pioche is 2,125 feet thick (Wheeler and Lemmon, 1939, p. 43-44). The thickness of post-Dunderberg Upper Cambrian rocks in the Groom Range is estimated from the dip and outcrop width to be 3,500 feet. Reso (1963, p. 904-905) measured 2,200 feet on the west side of the Pahranagat Range (the Desert Valley Formation) for his equivalent unit. In the southern end of the Delamar Mountains this unit is 2,228 feet thick, according to P. H. Heckel (written communication, 1961).

In Clark County near Indian Springs, the Upper Cambrian rocks above the Dunderberg are recorded as 1,543 feet thick in an unpublished section measured by C. R. Longwell. The upper 425 feet of this section is yellowish-brown silty limestone, and the basal unit of the Ordovician is dolomite. A 52-foot thickness of pale-orange-weathering thin-bedded silty dolomite marks the top of Heckel's Cambrian section at the south end of the Delamar Mountains.

The Cambrian limestone above the Dunderberg in the southern Snake Range is more than 1,400 feet thick (D. H. Whitebread, oral communication, 1958), much more than the 224+ feet reported by Drewes and Palmer (1957, p. 116). In the House Range, the post-Dunderberg Cambrian rocks are 1,719 feet thick (Hintze and others, 1958).

Post-Dunderberg Cambrian rocks are absent in the Virgin Mountains or less than 100 feet thick, as shown by pre-Dunderberg fossils near the top of the Cambrian section, identified by A. R. Palmer (Longwell and others, 1965, p. 19). Upper Cambrian rocks are probably also thin or absent in the southeast corner of Lincoln County.

Age and correlation

The correlation of the Upper Cambrian rocks with nearby sections is shown in figure 24. The rocks of pre-Dunderberg and post-Dunderberg Age are discussed separately. The 2,000 feet of undifferentiated Upper Cambrian rocks of pre-Dunderberg Age are equivalent to much of the Lincoln Peak Formation in the Snake Range, to part of the Mendha Formation in the Pioche district, and to the upper 300 feet or more of the Bonanza King Formation in the Nevada Test Site.

The post-Dunderberg Upper Cambrian rocks are equivalent to the Windfall Formation in the Eureka district (Nolan and others, 1956, p. 19-22). The Dunderberg Shale and the post-Dunderberg strata together are approximately equivalent to the Nopah Formation in the region surrounding the Nopah Range, California (Palmer and Hazzard, 1956, p. 2497), and in the Bare Mountain quadrangle, Nevada (Cornwall and Kleinhampl, 1961). The post-Dunderberg Upper Cambrian rocks in the Nevada Test Site were assigned by Barnes and Byers (1961) to the Windfall Formation; those of the southern Snake Range were not named. Longwell and others (1965, p. 20) have correlated the equivalent rocks in the Spring Mountains with the Nopah Formation. Reso (1963, p. 904-905) named the equivalent rocks in the Pahranagat Range the "Desert Valley Formation." Kellogg (1963, p. 691) named the equivalent rocks in the southern Schell Creek and Egan Ranges the "Whipple Cave Formation."

The age of the lower 550+ feet of the undifferentiated Upper Cambrian rocks ranges from early Late Cambrian (Dresbachian) to middle Late Cambrian (Franconian). The faunal zones represented are *Crepicephalus, Aphelaspis, Elvinia,* and *Conaspis.* The upper 1,700 to 2,100 feet of this unit are generally unfossiliferous but Reso (1963, p. 905) reports a Trempleauan fauna near the middle of his Desert Valley Formation. Kellogg (1963, p. 692) also considers his Whipple Cave Formation to be Franconian and Trempleauan in age. According to A. R. Palmer (written communication, 1964) the uppermost Mendha Formation of the Pioche district contains fossils of Trempleau Age, and Merriam (1964, p. 50) reports that the original Mendha includes some Lower Ordovician strata.

Crepicephalus has been reported from the upper 300 feet of the Bonanza King Formation (Barnes and others, 1962, p. D 31; Johnson and Hibbard, 1957, p. 342), and from the lower Mendha (Westgate and Knopf, 1932, p. 14). We found it at the base of the Upper Cambrian section in the Burnt Springs Range just below our collection 2432-CO, which represents the basal part of the *Aphelaspis* zone (A. R. Palmer, written communication, 1964).

USGS collection 2432-CO. Burnt Springs Range, W½ sec. 10, T. 3 S., R. 65 E.

Aphelaspis subditus Palmer
Aphelaspis haguei (Hall and Whitfield)
Blountia bristolensis Resser

Glaphyraspis ornata (Lochman)
Terranovella brevis Palmer
Pseudagnostus sp.
Dictyonina perforata Palmer

The following fossils, identified by Christina Lochman (Wheeler, 1940, p. 34), were found near the summit of the north end of the Bristol Range in interbedded limestone and sandy shale just above the upper contact of the Highland Peak Formation:

Blountia
Coosella
Kingstonia
Tricrepicephalus
Unicaspis

Lochman placed this fauna in either a late *Cedaria* or an early *Crepicephalus* zone. *Tricepicephalus* was found just below the Dunderberg Shale on Indian Ridge, Clark County (C. R. Longwell, written communication, 1959).

In the Nevada Test Site the limestone in the upper 300 feet of the Bonanza King Formation (subunit 3 of the Banded Mountain Member) contains the following Late Cambrian forms according to A. R. Palmer (written communication, 1964):

upper part	lower part
Olenaspella paucisegmenta Palmer	*Tricrepicephalus* sp.
Hardyoides mimicus Palmer	*Kingstonia* sp.
Dicasthopyge convergens Palmer	*Kormagnostus* sp.
Listroa toxoura Palmer	
Pseudagnostus sp.	
Dytremacephalus sp.	

USGS collection 2461-CO from an isolated outcrop 6 miles southeast of Sundown Well, NE¼ sec. 35, T. 4 S., R. 55 E., represents the *Cedaria* zone according to A. R. Palmer (written communication, 1958). These fossils include:

Kormagnostus sp.
Meteoraspis sp.
Kingstonia sp.
Cedaria sp.
Deiracephalus sp.
Densonella sp.
Helcionella-like molluscs, and sponge spicules

A. R. Palmer identified the early Late Cambrian brachiopods *Paterina* sp. and *Dicellomus?* sp. from a collection made just south of Shingle Pass in the southern Egan Range. All the preceding fossils are from pre-Dunderberg strata. The Dunderberg faunas were described earlier and the post-Dunderberg faunas are described below.

The following post-Dunderberg fossils were collected by us and identified by A. R. Palmer (written communication, 1958), who stated that both collections came from latest Upper Cambrian beds correlative with the Bullwhacker Member of the Windfall Formation at Eureka.

USGS collection 2459-CO. Timpahute Range, sec. 30, T. 3 S., R. 57 E.
Briscoia sp.
Missisquoia sp.
gastropods, sponge spicules

USGS collection 2675-CO. Meadow Valley Mountains, sec. 33, T. 10 S., R. 63 E., unsurveyed.
Euptychaspis sp.
Eurekia sp.
Owenella sp.
gastropod, acrotretid brachiopod, sponge spicules

Two collections from about the same stratigraphic unit, in the overthrust latest Cambrian rocks in the Timpahute Range were identified by A. R. Palmer (written communication, 1959).

USGS collection 3223-CO. Highest picnic ground, center of sec. 32, T. 3 S., R. 57 E.
dikelocephalid trilobite

USGS collection 3222-CO. Klippe, SW¼ sec. 23, T. 4 S., R. 56 E.
apatokephalid trilobite
distinctive linguloid brachiopod called *Obolus (Westonia) iphis* by Walcott and recorded from both Late Cambrian and Early Ordovician collections in the Eureka district.

ORDOVICIAN SYSTEM

Rocks of Ordovician Age are widespread in Lincoln County. The thickest Ordovician section in the county is in the Egan Range, near Sunnyside, where Hintze (1952, p. 60-67) measured 4,400 feet of beds and Kellogg (1963, pl. 1) measured nearly 4,700 feet of beds. This section thins to about 4,200 feet in the Pahranagat Range, to about 3,800 feet in the Nevada Test Site (Byers and others, 1961), to about 2,650 feet in the Desert Range, and to about 2,200 feet in the southern Delamar Mountains and Sheep Range. It is only a few hundred feet thick east of Meadow Valley Wash. The thinning toward the southeast is accompanied by facies changes and apparently represents onlap onto a relatively stable positive area during Paleozoic time. The regional thinning may also have been emphasized and complicated by thrust faulting.

Three Ordovician units were mapped. These are, in ascending order: the Pogonip Group, the Eureka Quartzite, and the Ely Springs Dolomite. An inconspicuous regional disconformity is reported near the base of the Eureka by Webb (1956, p. 7).

Pogonip Group

Distribution

The Pogonip Group is exposed in the western half of Lincoln County. Complete sections are exposed in the southern Egan, southern Schell Creek, Pahranagat, Groom, Desert, and Sheep Ranges, and in the Delamar and Meadow Valley Mountains.

Lithology

The Pogonip Group consists chiefly of alternating grayish to brownish, thick-bedded, cliff-forming limestone and yellowish- to brownish-gray, thin-bedded, slope-forming, silty, and shaly limestone (fig. 7). The weathered surfaces of silty and sandy limestone are pale red, light brown, and dark yellowish-brown in the southwest part of the county where the climate is more arid. Fossils are abundant in some beds; others contain abundant chert lenses and nodules. Intraformational conglomerate is common and several shale layers as much as 260 feet thick are present.

The Pogonip Group could readily be divided into several mappable units but we did not attempt to do so. Hintze (1951, p. 11-12) distinguished six formations on faunal evidence at several widely separated localities in western Utah and eastern Nevada. He measured sections in the southern Egan Range near Sunnyside and in the Ely Springs Range (Hintze, 1952, p. 48-56; 60-66). Webb (1956, p. 46-52) measured partial sections in Cave Valley, and in the Egan and Pahroc Ranges. Kellogg (1963, p. 692-694) mapped five formations in the southern Egan Range, three of which corresponded to Hintze's units. Johnson and Hibbard (1957, p. 345) recognized nine distinct lithologic units in the Yucca Flat area. Byers and others (1961) later grouped these nine units into the Goodwin Limestone, Ninemile Formation, and Antelope Valley Limestone to match the standard central Nevada section.

The lithologic character of the members of the Pogonip Group in the Pahranagat Range is shown diagrammatically in figure 8. These sections were measured by Anthony Reso, who kindly gave permission to publish them. We believe that the thicker section is part of a klippe moved many miles eastward from its original location.

Near Shingle Pass in the Egan Range, the uppermost 65 feet of the Pogonip are brownish-gray thin-bedded silty dolomite. Beginning about 650 feet stratigraphically below the top of the Pogonip is a unit 600 feet thick of thin-bedded calcareous siltstone, shale, and limestone. Abundant *Receptaculites* are found in this limestone. A layer 1,150 feet thick, beginning about 530 feet stratigraphically above the base of the Pogonip Group, has many intraformational conglomerates and beds containing chert nodules (Hintze, 1952, p. 60-64).

The upper contact with the Eureka Quartzite is sharp and easily recognized. It may be a regional disconformity (Webb, 1956, p. 7), but we found no field evidence for this. The lower contact is not so clear; the boundary is generally drawn at the base of the predominantly limestone section and at the top of the predominantly dolomite section, the upper part of which is usually cherty.

In the southern third of the county, we selected as the lower contact the top of a conspicuous black and white banded dolomite sequence (fig. 9) that underlies a sequence 70 feet thick of nonresistant brownish fossiliferous limestone having some gray mottled oölitic beds. This limestone sequence contains latest Cambrian fossils. It is overlain by a sequence 400 feet thick of massive gray limestone containing thin layers of chert. The authors used the above-described contact to expedite mapping, realizing that the basal Pogonip contact in this area should be raised 70 feet to exclude the fossiliferous Cambrian limestone sequence.

In the Timpahute Range and southern Meadow Valley Mountains, the contact was drawn at the top of a nonresistant fossiliferous shaly limestone that may be the one described above. Elsewhere in Lincoln County, the base of the Pogonip was not distinctive.

Thickness

The thickness of the Pogonip Group does not change greatly throughout much of Lincoln County but it decreases slightly in the southwestern part of the county and in western Clark County, and it decreases greatly southeastward in the Mormon Mountains region. The greatest thickness — 3,390 feet in the southern Egan Range (Hintze, 1952, p. 60-65) — compares with about 2,600 feet on the west flank of the Pahranagat Range. Reso (1963, p. 905) measured 3,140 feet of Pogonip in the center of the Pahranagat Range and suggests that faulting near the base of the western Pahranagat section may account for the decrease in thickness. The thickness is 2,600 feet in the Nevada Test Site (Byers and others, 1961, p. 107-108).

The Pogonip thins rapidly south and southeast from the Pahranagat Range. P. H. Heckel (written communication, 1961) reports 1,787 feet of Pogonip Group in the southern part of the Delamar Mountains. Langenheim and others (1960) measured a thickness of 2,434 feet in the Arrow Canyon Range in northern Clark County. The thickness in a major thrust plate, which makes up the entire Sheep Range, is estimated to be 1,000 feet, about the same as in the Meadow Valley Mountains. The Sheep Range section is anomalously thin but our estimate could be less than half the true thickness, for R. J. Ross, Jr. (written communication, 1964) reported he measured a section 2,350 feet thick in the southwest end of the range in Clark County. The

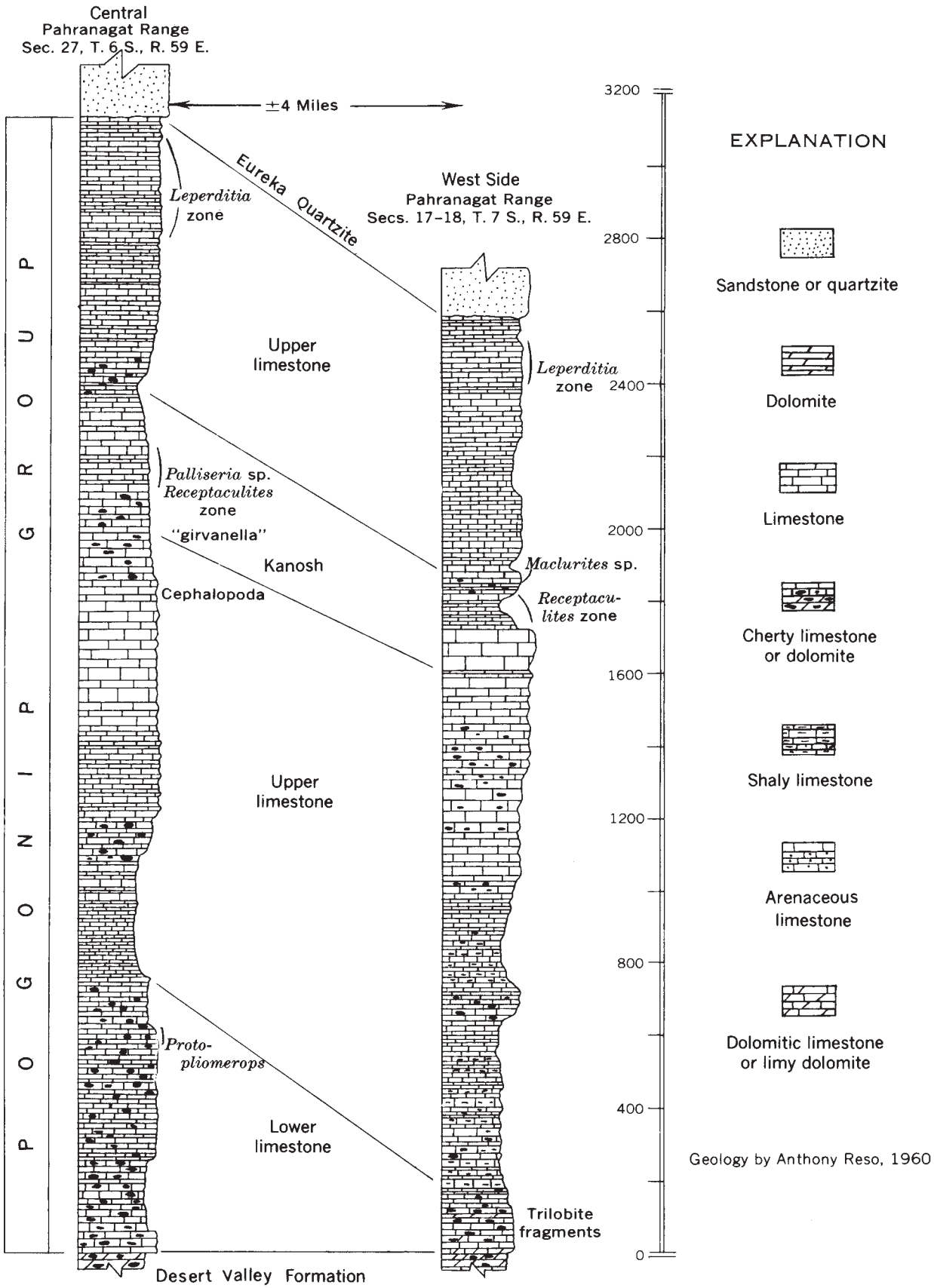


FIGURE 8. Stratigraphic sections of the Pogonip Group in the Pahranagat Range.

FIGURE 9. Faulted Cambrian and Ordovician rocks on the west side of the Desert Range, looking south from the north end of Three Lakes Valley. Ꞓpm, Prospect Mountain Quartzite; Ꞓc, Pioche Shale, Lyndon Limestone, and Chisholm Shale; Ꞓhp, Highland Peak Formation; Ꞓld, Upper Cambrian rocks with Dunderberg Shale at base; Op, Pogonip Group.

easternmost recognizable section is near lat 37°00′ N. in the East Mormon Mountains. Here the Pogonip Group may be as much as 800 feet thick.

The Pogonip Group is absent in the North Virgin Mountains (Longwell and others, 1965) and at Frenchman Mountain near Las Vegas (C. R. Longwell, oral communication, 1958). As in the Pogonip Group, southeastward thinning occurs in many other Paleozoic units.

Age and correlation

The Pogonip Group is Early and Middle Ordovician. As originally defined by King (1878, p. 188), the Pogonip Limestone included a thick sequence of Cambrian beds. The Pogonip has subsequently been redefined many times. Now, following detailed stratigraphic work (Hintze, 1951, p. 11; Easton, 1953, p. 147), the Pogonip is given group status and is restricted to the Ordovician beds of the original unit. We, as well as many other recent workers in the Great Basin, include in the Pogonip all the Lower and Middle Ordovician rocks below the Eureka Quartzite. Anthony Reso (oral communication, 1959), however, reports Ordovician(?) fossils from the upper part of the underlying rocks.

The Pogonip Group in Lincoln County includes the Yellow Hill and Tank Hill Limestones in the Pioche district (Westgate and Knopf, 1932, p. 14-16) and the Ordovician beds more than 700 feet thick, which are apparently faulted out of the type sections of these formations (Hintze, 1952, p. 48-55). The Tank Hill Limestone is approximately equivalent to the Lehman Formation of Hintze (1951), the highest of his Pogonip units. The map unit we used is equivalent to the Pogonip Group as mapped in Clark County and in the Nevada Test Site, but not as mapped in the southern Snake Range by Drewes (1958, p. 227), who included all the post-Dunderberg Upper Cambrian rocks in the Pogonip Group. The correlation of the Ordovician rocks is summarized in figure 6.

Abundant fossils date the lower part as Early Ordovician (Canadian) and the upper part as early Middle Ordovician (Chazyan). Hintze (1952, p. 5) recognized 15 faunal zones of which the lower 11 were Canadian and the upper 4 were Chazyan. Three formations, totaling about 2,000 feet in the southern Egan Range, were assigned to the Lower Ordovician by Hintze (1951, p. 18). We collected the fossils listed below from the Pogonip Group. The gastropods were identified by E. L. Yochelson (written communication, 1958). The fossils in collections D585-CO and D586-CO were identified by R. J. Ross, Jr. (written communication, 1960), who also identified the graptolites and trilobites in collection D550-CO.

USGS collection D552-CO. Base of exposed Pogonip section, south Meadow Valley Mountains, lat 37°04′ N.; long 114°46′30″ W.

"Incomplete uncoiled gastropod * * * representative of a group confined to earliest Early Ordovician * * * [possibly] equivalent to the Goodwin Limestone * * *."

USGS collection D550-CO. Trilobites, graptolites, and gastropods. Gastropods from limestone series above graptolitic shaly limestone. Desert Range, 1.5 miles south of Lincoln County on boundary of Las Vegas Bombing and Gunnery Range; lat 36°50′ N., long 115°18′37″ W.

Maclurites sp.
Palliseria sp.
indeterminate high-spired gastropod

Didymograptus? sp. (dismembered stipes)
Phyllograptus anna
Phyllograptus illicifolius cf. var. *major* undescribed variety * * *. Similar to var. *major* Ruedemann from Phi Kappa beds
Paranileus ibexensis Hintze

Of collection D550-CO, Ross (written communication, 1960) states:

> "Graptolites correlate with the zone of *Didymograptus protobifidus* (zone 5 of Elles and Wood). The trilobite is from zone I of Ross (1951) and Hintze (1952), being from high in the latter's Fillmore Limestone. Correlative beds are known in the Convict Lake area of California, in the Valmy and the lower part of the Vinini Formations of Nevada, the lowest beds of the Phi Kappa Formation of Idaho, and the lower part of the Garden City Formation of Utah. As indicated by Yochelson, this is equivalent to the lower part of the Antelope Valley Formation of the Eureka area."

USGS collection D553-CO. Upper 200 feet of Pogonip in the Groom Range, 1.5 miles north of Groom mine road, lat 37°21′ N., long 115°42′ W.

Maclurites sp.

USGS collection D585-CO. Northern Buried Hills, west side of hill 5876; limestone equivalent to the Antelope Valley Limestone.

Pliomerid trilobite pygidium
Orthidiella aff. *O. longwelli*
Bellerophontid gastropod
Cystid? stem plates

Collection 9461F1. South Meadow Valley Mountains, 12 miles due west of Vigo, near collection 57TF23; limestone equivalent to Antelope Valley Limestone.

Receptaculites (large species)
coiled nautiloid
numerous gastropods

USGS collection D586-CO. Groom Range, 4.5 miles southeast of Sundown Well, NE¼ sec. 25, T. 4 S., R. 55 E.; limestone equivalent to upper part of the Ninemile Formation or lower part of the Antelope Valley Limestone.

Kirkella cf. *vigilans*
Paranileus? sp.

USGS collection 3225-CO. East Mormon Mountains near water gap, sec. 32, T. 10 S., R. 69 E.; Pogonip Group.

> *Kirkella* identified by A. R. Palmer. Gastropod fragments identified by E. L. Yochelson as follows: "* * * low spired gastropod with a wide, sharply walled umbilicus similar to *Orospira,* a relatively young Lower Ordovician genus. A bellerophontid * * * is almost certainly *Bucanopsis,* known from Middle Ordovician to Silurian and possibly occurring also in the Lower Ordovician. Another bellerophontid shows a lanceolate cross-section and narrow umbilici. It is possible that this is *Sinuites* or *Bucanopsis.*"

Undetermined orthoid brachiopods and a few fragmentary Ordovician-type conodonts were also present.

The following fossils collected by C. L. Sainsbury from the Pogonip in the Quinn Canyon Range, Nye County, are included because they are the first reported occurrance of *Dasyporella,* one genus of the family Dasycladaceae (fossil algae), in North America (Richard Rezak, written communication, 1957).

USGS paleobotany locality no. D642. South side of west fork of Badger Creek, lat 38°08′ N., long 115°40′ W.

Dasyporella Stolley (undescribed species)
Girvanella cf. *G. problematica* Nicholson and Etheridge
Kawina (not *K. unicorna* Hintze)
Syntrophopsis?

The latter two fossils were identified by R. J. Ross, Jr. (written communication, 1957), who states they probably are equal to zone J of Ross (1951) and should correlate with the uppermost part of the Ninemile Formation or the lower part of the Antelope Valley Limestone.

Eureka Quartzite

Distribution

The Eureka Quartzite was originally named by Hague (1892, p. 262) for exposures near Eureka, Nevada, but the formation was redefined by Kirk (1933, p. 34) from better exposures on Lone Mountain. It is recognized over much of eastern Nevada, western Utah, and parts of southeastern California. The Eureka Quartzite is exposed in most of the ranges in Lincoln County west of Meadow Valley Wash. It is absent along the east side of the southern Meadow Valley Mountains and also in the Mormon Mountains.

Lithology

The Eureka Quartzite is typically a white or light-gray, vitreous, sugary, massive or crossbedded orthoquartzite of fine to medium grain. However, the color and degree of cementation are not everywhere the same. Varicolored beds of sandstone, dolomitic sandstone, and quartzite occur near the top and bottom. In the western and southern parts of the county, the lower 50 to 150 feet are composed of varicolored quartzite that commonly weathers brownish, yellowish, or yellowish-brown.

The Eureka Quartzite forms a prominent white band between dark-gray carbonate rocks; it is easily recogniz-

able from a distance (fig. 7) or on aerial photographs. The prominence of the formation makes it useful in working out complex structure, but it can be confused with some of the Devonian quartzites in areas of complex structure.

According to Hintze (1951, p. 22) the Eureka Quartzite in central Nevada rests with regional unconformity on rocks of Late Cambrian to Middle Ordovician Age. Webb (1956, p. 26) states that the upper contact of the Eureka with the overlying dolomite represents a period of nondeposition or erosion that presumably occurred during Cincinnatian time. In Lincoln County we have not seen field evidence for any break between the Eureka Quartzite and the overlying dolomite.

Thickness

The Eureka Quartzite thins regionally from northwest to southeast across Lincoln County. Webb (1956, p. 46-53), who studied the Eureka Quartzite in eastern Nevada, determined that the formation is 521 feet thick on the east side of Cave Valley, south of Patterson Pass; 513 feet in the southern Egan Range; 451 feet near Big Spring Ranch, just outside the northeast corner of the county; 465 feet in the northern part of the Pahroc Range; 344+ feet at The Narrows, north of Hiko; and 132 feet in the Arrow Canyon Range in northern Clark County. The Eureka Quartzite is 386 to 552 feet thick in the Pahranagat Range (Reso, 1963, p. 907), 153 feet thick in the southern Delamar Mountains west of Kane Springs Wash (P. H. Heckel, written communication, 1960) and only 20 feet thick or less in the west face of the southern Meadow Valley Mountains. The quartzite is absent on the east side of the southern Meadow Valley Mountains but a 10-foot-thick white dolomite marks its stratigraphic position. This marker is also absent in the southeast corner of Lincoln County in the Mormon Mountains area and in eastern Clark County. Byers and others (1961, p. 107-108) found a thickness of 395 feet of Eureka Quartzite in the Nevada Test Site.

Age and correlation

The Eureka Quartzite is nearly unfossiliferous, but has been classified as Middle Ordovician because of its position between fossiliferous Lower and Upper Ordovician rocks. C. R. Longwell reported fossils in a dolomite bed in the Eureka Quartzite in the southern Spotted Range, Clark County (oral communication, 1959), and Byers and others (1961, p. 108) list forms they found in carbonate beds near the base of the Eureka. Neither of these localities has yielded fossils that disprove a Middle Ordovician Age.

The Eureka Quartzite in Lincoln County is equivalent to the type Eureka Quartzite at Lone Mountain and to the formation as mapped by other workers in eastern Nevada. The formation is present as far west as the southern Inyo Range of California (Merriam, 1963, p. 9).

Ely Springs Dolomite

Distribution

This formation was first described by Westgate and Knopf (1932, p. 15-16) from exposures in the Ely Springs Range west of Pioche. The Ely Springs Dolomite is one of the most persistent units in the Great Basin. It or equivalent units are found throughout western Utah, most of eastern Nevada, and adjacent parts of California. Complete sections of the Ely Springs are exposed in nearly every range in Lincoln County, the major exception being the Mormon Mountains, where Ordovician rocks above the Pogonip Group are apparently absent, as in eastern Clark County.

Lithology

The Ely Springs Dolomite is a dark-gray to black, medium- to coarse-grained, fossiliferous rock that is typically cherty and occurs as distinct beds up to 5 feet thick. Some light-gray dolomite beds are present near the top. Considerable partly dolomitized gray limestone is present locally in the lower half of the formation in the Pahranagat Range; the lower 50 feet is usually limestone that contains about 30 percent chert.

The lower contact of the Eureka Quartzite is apparenly conformable and is marked by a few rusty-weathering sandstone beds and some interbedded light-gray dolomite beds. The contact with the overlying Laketown Dolomite is conformable and is drawn to represent the base of a 70- to 100-foot-thick unit of gray or buff, nonresistant, thin-bedded, silty dolomite that contrasts with the more resistant, dark dolomite units above and below. This unit is prominent only in the southwestern part of the county, but a similar unit 30 to 50 feet thick, which appears to occupy the same stratigraphic position, is present in the northern part of the county. Reso (1963, p. 907) has found Richmond fossils in these beds, however, so they should be included with the Ely Springs Dolomite.

Thickness

The thickness of the Ely Springs Dolomite decreases southwestward and southward from 527 to 495 feet in the southern Egan Range (Kellogg, 1963, p. 695) and 525 feet in the Ely Springs Range (Westgate and Knopf, 1932, p. 15) to perhaps only about 100 feet in the southwest corner of the county west of the Desert Range. About 800 feet of beds in the Nevada Test Site have been assigned to the Ely Springs Dolomite by Byers and others (1961, p. 107).

A section 770 feet thick, reported by Westgate and Knopf (1932, p. 15) from the east side of the northern

Ely Springs Range probably represents duplication of beds by faulting.

Drewes (1958, p. 227) estimates the thickness of the Ely Springs in the southern Snake Range near Lincoln County as 150 to 200 feet, but a thickness of 505 to 590 feet was reported from the east side of the Snake Range by Rush (1956, p. 22, 30). The latter figure is probably more nearly correct. The Ely Springs Dolomite ranges in thickness from 276 to 527 feet in the Pahranagat Range, according to Reso (1963, p. 907), with the thickest sections being on the east side of the range. The thickness of the unit is 414 feet in the southern Delamar range, according to P. H. Heckel (written communication, 1960), and 460 to 490 feet in the Meadow Valley Mountains about 10 miles to the southeast. The thickness is 337 to 388 feet in the Arrow Canyon Range, Clark County, according to Langenheim and others (1960). We were unable to recognize an Ely Springs lithologic equivalent — if present — in the Mormon and East Mormon Mountains.

Age and correlation

The Ely Springs Dolomite, as we mapped it, is equivalent to the formation at the type locality; to the Fish Haven Dolomite, which has been widely extended to eastern Nevada and western Utah from its type locality in southern Idaho; and to the Hanson Creek Formation at its type locality and as it is usually mapped in central Nevada. In all these places these formations are of Late Ordovician or Middle and Late Ordovician Age. However, the Ely Springs in Lincoln County is equivalent to only the lower half of the Ely Springs Dolomite as mapped by C. R. Longwell (oral communication, 1958) in the Las Vegas quadrangle. Longwell's Ely Springs unit included the 70- to 100-foot-thick silty dolomite of Richmondian Age and the superjacent dark beds that make up a third of what we include in the Laketown Dolomite.

The Ely Springs Dolomite has few fossils. Cup and chain corals and brachiopods are locally abundant and date the formation as Late Ordovician. Straight-shelled cephalopods up to 18 inches long, possibly actinoceroids like those reported by Rush (1956, p. 55) from the Snake Range, were found west of Hiko along the range front south of the Coal Valley road.

USGS collection 2416-CO from the south end of the Limestone Hills in NE¼ sec. 35, T. 7 N., R. 69 E., yielded *Bighornia* sp. and *Paucicrura* sp. (formerly *Resserella*), according to J. M. Berdan (written communication, 1957). Collection 58TF12, from a brownish-gray dolomite with black chert from the Timpahute Range, 4.6 miles southeast of Tem Piute (SE¼ sec. 3, T. 4 S., R. 57 E., unsurveyed), contains dalmanellid and sowerbyellid brachiopods that are probably Late Ordovician but might be Silurian, according to R. J. Ross, Jr. (written communication, 1958). Ross states: "Paradoxically the dalmanellid specimens are so well preserved that I have found no reference showing such slender brachiophores; that may be because this is a new species or because it is better preserved than any previously figured specimens. At any rate the material is younger than Pogonip and is probably Ely Springs. I have a slight fear it may be Silurian." In a later letter (1964) Ross stated: "The presence in this collection of sowerbyellid and dalmanellid brachiopods indicates an age of at least as young as the Middle Ordovician Porterfield Stage of Cooper (1956). Although rocks of this age are present beneath the Eureka Quartzite in much of central and southern Nevada it seems more likely that these fossils came from the overlying Ely Springs Dolomite of late Middle or Late Ordovician age."

SILURIAN SYSTEM

Laketown Dolomite

Distribution

The Laketown Dolomite was described and named by Richardson (1913, p. 410) in the Bear River Range near the Utah-Idaho border. Nolan (1935, p. 17) later described a Silurian section in the Gold Hill district and used Richardson's name, Laketown Dolomite, for it. Since then, the name has been used by most workers in the eastern Great Basin and is adopted here because it is the only name applicable to the interval we mapped. Rush (1956, p. 20-26) has divided the Silurian in western Utah into three formations which are difficult to correlate with Silurian rocks elsewhere.

The Laketown Dolomite is the only exclusively Silurian unit mapped in Lincoln County. It may be present also in other places, and would then be included in one or more of the undifferentiated map units of Cambrian to Devonian Ages shown on plate 2. Two or three lithologically distinct units, corresponding in whole or in part to the Laketown Dolomite, were recognized in the western half of the county, but could not be delineated because of the scale of the map.

The Laketown Dolomite is widely distributed in eastern Nevada, Utah, and southeastern California. In Lincoln County it crops out in the Limestone Hills, the southern Schell Creek, southern Egan, Ely Springs, Golden Gate, Timpahute, Groom, Pahranagat, Pahroc, Desert, and Pintwater Ranges, in the Worthington and Meadow Valley Mountains, and in the Buried Hills.

Lithology

The Laketown is characteristically a light- and dark-gray, medium- to coarse-grained, crystalline dolomite. It generally forms a bold three-part outcrop with dark

dolomite sequences above and below a light-gray dolomite (fig. 10). Some layers contain fossils and chert nodules. A 2-foot layer of massive chert in the lower dark dolomite in the southern Egan Range may correlate with a similar chert layer that marks the contact between the Hanson Creek Formation and the Roberts Mountains Formation near Eureka (Nolan and others, 1956, p. 37). Fossils often are more abundant in the cherty layers.

In the southwestern part of the county, a nonresistant grayish-yellow thin-bedded silty dolomite sequence about 50 to 70 feet thick is present at the base of the Laketown beneath the lower dark dolomite sequence. This dolomite contains a Richmondian fauna and should be included in the underlying Ely Springs Dolomite.

The lower third of the Laketown is generally a dark brownish-gray asphaltic dolomite, but some dark limestone is present in the Pahranagat Range, and also in the southern Meadow Valley Mountains. The middle third to half of the formation is a light-gray coarse-grained massive crystalline dolomite that contains sparse chert nodules at some horizons. The upper part of the Laketown is black, fine-grained, crystalline dolomite that weathers gray brown and has abundant chert nodules in the upper half. The upper black unit ranges from 50 to 150 feet in thickness. It is underlain locally by reefs as much as 50 feet thick composed of corals of various types (fig. 11) and *Verticillopora,* a genus of Dasycladacean algae that resembles crinoid stems.

Thickness

The thickness of the Laketown Dolomite ranges from zero to about 1,000 feet, decreasing southeastward toward the Mormon Mountains. The formation is thickest in the northern part of the county and thins gradually southward from 1,000 feet in the southern Egan Range to between 763 and 938 feet in the Pahranagat Range, according to Anthony Reso (oral communication, 1959). The thickness increases slightly southeast of the Pahranagat Range to 970 feet in the southern Delamar Mountains (P. H. Heckel, written communication, 1960) and then decreases to only 330 feet in the Meadow Valley Range 10 miles southeast. In the Arrow Canyon Range in Clark County, the thickness decreases southward from 403 to 357 feet because of pre-Devonian erosion (Langenheim and others, 1960). Silurian rocks appear to be entirely absent in the Mormon Mountains.

Silurian rocks were not mapped separately in the Nevada Test Site, but we believe that 265 to 295 feet of the undifferentiated middle Paleozoic sequence (most of unit E of Johnson and Hibbard, 1957, p. 352; Byers and others, 1961, p. 107) are equivalent to the Lincoln County Laketown.

Age and correlation

The Laketown Dolomite is apparently Middle Silurian (Niagaran) and Late Silurian (Cayugan). No Early Silurian fossils have been reported from the Laketown, although no unconformity is recognized between

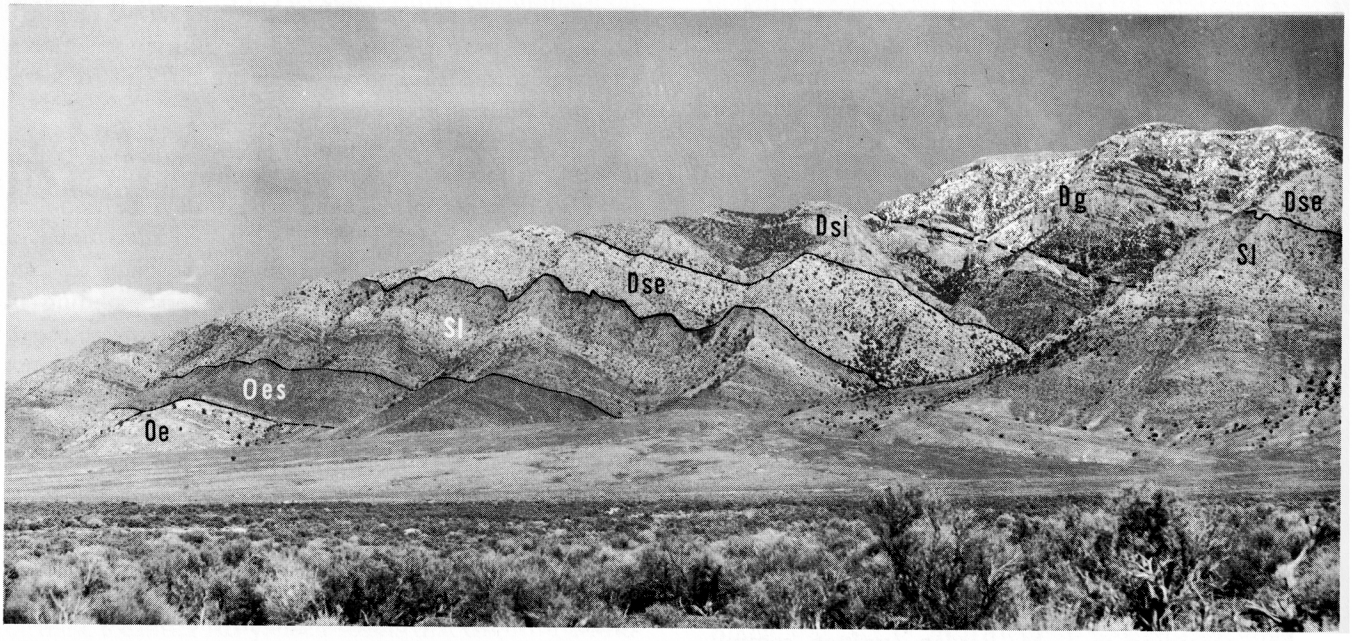


FIGURE 10. Ordovician, Silurian, and Devonian dolomite sequence above the Eureka Quartzite, west side of the southern Egan Range. View northeast from Nevada Highway 38, 3 miles south of Sunnyside. Oe, Eureka Quartzite; Oes, Ely Springs Dolomite; Sl, Laketown Dolomite; Dse, Sevy Dolomite; Dsi, Simonson Dolomite; Dg, Guilmette Formation.

FIGURE 11. Coral reef near top of Laketown Dolomite at crest of Desert Range. Lens cap is 2 inches in diameter.

the Laketown and the Ely Springs Dolomite (Middle[?] and Upper Ordovician). Waite (1956) collected an abundant Late Silurian fauna from the upper 25 feet of the Laketown in the Pahranagat Range 2 miles south of Nevada Highway 25. Reso and Croneis (1959, p. 1251) say that Waite's Upper Silurian zone is 50 to 136 feet below the top of the Laketown on the west side of the Pahranagat Range but that on the east side of the range, this zone is cut out by erosion. There seems to be an inconspicuous regional unconformity at the top of the Laketown Dolomite.

The thin Silurian dolomite exposed in the Pioche district (Westgate and Knopf, 1932, p. 16) was unnamed; only the Laketown Dolomite at Gold Hill, Utah (Nolan, 1935, p. 17), of several described Silurian formations, was both closely similar in lithology and equivalent in age to the unit we mapped in Lincoln County.

The Laketown Dolomite, as we mapped it, is equivalent to the Laketown Dolomite mapped elsewhere in the eastern Great Basin. The Lone Mountain Dolomite in Clark County, as mapped by C. R. Longwell (oral communication, 1958) 30 years ago, includes the Sevy Dolomite of Early Devonian Age as we mapped it, but excludes the lower part of Laketown Dolomite. The Lone Mountain Dolomite in the region surrounding Eureka, Nevada (Nolan and others, 1956, p. 39), is only partly equivalent to the Laketown Dolomite; an exact correlation cannot be made.

The Laketown Dolomite is perhaps equivalent to the combined Roberts Mountains Formation and the Jack Valley Formation, and Decathon Dolomite of Rush (1956, p. 20-25), and even perhaps the upper part of the Fish Haven Dolomite.

Together, the Laketown Dolomite and the Sevy Dolomite probably represent the same stratigraphic interval as the similar Hidden Valley Dolomite of McAllister (1952, p. 14-17) in the Quartz Spring area of California. These correlations are summarized in figure 13.

The most common fossils in the Laketown Dolomite are the chain and honeycomb corals, *Halysites* and *Favosites*, and small cup corals. Cylindrical corals as long as 3 feet are present in the Desert Range, and pentamerid brachiopods (*Virgiana?* sp.) have been seen in the north end of the Limestone Hills.

The alga *Verticillopora* (Rezak, 1959, p. 117-129), which occurs in the upper part of the Laketown in the Limestone Hills (Richard Rezak, written communication, 1957), also is found 300 feet below the top of the Laketown in the Confusion Range, Utah (R. K. Hose, written communication, 1959), in the Hidden Valley Dolomite of McAllister (1952), and in the Roberts Mountains Formation. C. W. Merriam (oral communication, 1959) considers that these fossils are Middle Silurian index fossils for a zone that is near the top of both the Laketown Dolomite and the type Roberts Mountains Formation and near the middle of the Hidden Valley Dolomite.

DEVONIAN SYSTEM

The Devonian section in the Pahranagat Range of Lincoln County is probably the thickest and most complete in the Great Basin.

The thickness of the Devonian rocks increases gradually southward from about 5,300 feet in the southern Egan Range (Kellogg, 1963, p. 685) to a maximum of about 6,050 feet in the Pahranagat Range, then decreases southward to about 2,700 feet in the southwest corner of the county, to perhaps 800 feet or less in the southeast corner. A section of Devonian rocks about 1,970 feet thick is present in the Arrow Canyon Range (Langenheim and others, 1960).

The Devonian rocks, largely limestone and dolomite, were mapped as three formations. In ascending order, they are the Sevy Dolomite, the Simonson Dolomite, and the Guilmette Formation. The thin sequence of Devonian rocks in southeastern Lincoln County was mapped separately; these rocks were included with Upper Cambrian and Ordovician rocks in a map unit described on page 42.

Regional studies by Roberts (1956) and others of 50,000 square miles in the eastern Great Basin show that successively younger Devonian beds lie unconformably on successively older pre-Devonian beds along a northeast-trending zone that marks the southeastern shelf of the Paleozoic miogeosyncline. The Upper Ordovician and Silurian rocks are cut out by this unconformity in southeastern Lincoln County. Thus the Upper Devonian rocks have a greater regional extent than the Lower and Middle Devonian rocks. This regional thinning is accompanied also by facies changes in the Devonian rocks, particularly in the Guilmette. Figure 4 shows the approximate distribution of these facies and the informal names we applied to them.

In Early (Sevy) and Middle (Simonson) Devonian time, Osmond (1954, p. 1927) thinks a positive area existed in the vicinity of the Snake Range where the Sevy and Simonson seem to be anomalously thin. A thin but persistent sandstone at the top of the Sevy was thought to have been derived from a gentle uplift to the south along the margin of the geosyncline (Osmond, 1954, p. 1926). The source could have been lower Paleozoic quartzites exposed in the Mormon Mountains along the margin of the craton.

The presence of abundant sandstone or quartzite and other clastic rocks in part of Lincoln County indicates the emergence of positive areas as a source of the sediments. The sandy beds are thickest and most numerous in the Pahranagat Range, where they make up about 600 feet of a sequence 1,500 to 1,600 feet thick. Sandstone is entirely absent in the northwest corner of Lincoln County as far south and east as Dutch John Mountain, but more than 200 feet of sandstone are present in the Needle Range just over the Utah line (Gould, 1959, p. 43-44). Sandstone also occurs near the top of the Guilmette Formation in the southern Snake, Bristol, West, and northern Desert Ranges, and in the Nevada Test Site. There is very little sandstone in the Meadow Valley and Mormon Mountains.

Other evidence of uplift in Devonian time is given by local unconformities in the Simonson Dolomite, Guilmette Formation, and Pilot Shale of the Egan Range. Unconformities probably exist within the thin Devonian section in the Mormon Mountains region. Reso and Croneis (1959, p. 1250) show that an unconformity exists between the Guilmette Formation, as we mapped it, and the Pilot Shale on the west side of the Pahranagat Range. Here, more than 400 feet of the Upper Devonian West Range Limestone are cut out by pre-Pilot erosion. Kellogg (1960, p. 192) found an unconformity at approximately the same horizon in the southern Egan Range.

The only published measured sections of the complete Devonian sequence in Lincoln County are those of Reso and Croneis (1959, p. 1251), Kellogg (1960; 1963), and Reso (1963). The lower 1,000 to 2,000 feet were not exposed in the areas studied by Westgate and Knopf (1932, p. 16-19) and Merriam (1940, p. 38-40).

Sevy Dolomite

Distribution

The Sevy Dolomite was named by Nolan (1935, p. 18) from exposures in Sevy Canyon in the Gold Hill district, Deep Creek Mountains, Utah. Osmond (1954, p. 1914) found that the Devonian dolomites of a broad area of east-central Nevada and western Utah are best correlated with Nolan's section at Gold Hill. Most recent workers, including ourselves, have found that the Silurian and Devonian section at Gold Hill extends into eastern Nevada almost as far south as Las Vegas.

Osmond (1957) found that the Sevy Dolomite was recognizable through an area of 100,000 square miles. This lithologic unit is recognized as far east as the Confusion Range, Utah, as far west as Eureka, Nevada, and as far south as the Inyo Mountains of California.

The Sevy Dolomite, a conspicuous and easily recognized formation, crops out in many places in the northern part of the county and in the western half. Complete sections are exposed in the Limestone Hills and in the southern Egan, southern Schell Creek, Hiko, Pahroc, Pahranagat, Golden Gate, Desert, Pintwater, and Spotted Ranges and Worthington Mountains. The formation is not exposed in the Pioche district, and these beds therefore are not included in the description of Devonian rocks by Westgate and Knopf (1932, p. 16-19).

Throughout the area studied, Osmond (1954, p. 1916) found an inconspicuous regional unconformity, differing in magnitude from place to place between the Sevy and the underlying Laketown. Reso and Croneis (1959,

p. 1251) found an unconformity between the Sevy and the underlying Laketown Dolomite in the Pahranagat Range. Langenheim and others (1960) report that an unconformity in the Arrow Canyon Range cuts out about 150 feet of the Laketown.

Lithology

The Sevy Dolomite is a remarkably homogenous, generally unfossiliferous, microcrystalline dolomite that weathers a characteristic whitish gray. It is tan, gray, or pinkish gray on fresh surfaces. The dolomite is exceedingly dense and has a conchoidal fracture. It is faintly laminated and is well bedded in layers from 6 inches to 2 feet thick; it characteristically forms steep steplike slopes.

The Sevy is readily recognized even from a distance of several miles because of its contrast with the darker dolomites above and below (fig. 10). A thin, persistent, crossbedded sandstone or quartzite 2 to 85 feet thick that weathers brown, is present at the top of the Sevy everywhere in Lincoln Couny except in the northwest corner. This sandstone appears to thicken southwestward, and, if our correlation is correct, it is about 95 feet thick in the Nevada Test Site (Johnson and Hibbard, 1957, p. 353-354). A few tens of feet of dolomite below this sandstone are commonly sandy, the amount of sand decreasing downward. In the Pahranagat Range, dolomite as much as 200 feet below the sandstone contains much sand or silt. In western Lincoln County the sandy sequence is underlain by 100 to 200 feet of yellow-gray-weathering, olive-drab, cherty, argillaceous dolomite, which is the cherty argillaceous member described by Osmond. The member is recognizable in the Nevada Test Site, where it is about 50 feet thick. The chert is reddish in the Worthington Mountains and Groom and Desert Ranges but black or brown in the Pahranagat Range. Elsewhere, the insoluble content of the dolomite is small, the greater part of it containing neither chert nor sand. The lower part of the Sevy Dolomite on the east side of the Spotted Range in sec. 33, T. 13 S., R. 56 E., contains a fossiliferous limestone bed 12 feet thick.

Osmond (1954, p. 1911-1931) made a careful study of the Sevy Dolomite; he measured three sections within Lincoln County, and six others within a few miles of its boundaries. The reader is referred to this paper for detailed stratigraphic and petrographic descriptions of the dolomite. Osmond considers the Sevy to be a primary dolomite formed from lime mud very near sea level.

We selected the top of the sandstone member as the upper contact, but Osmond (1954, p. 1920) and Kellogg (1960, p. 191) selected a little higher contact to include some Sevy-type beds above the sandstone.

Thickness

An isopach map by Osmond (1954, fig. 1) shows that the thickness of the Sevy Dolomite in Lincoln County increases southwestward from about 570 feet in the southern Snake Range and the Limestone Hills to 1,375 feet in the Pahranagat Range. Rush (1956, p. 31) found 460 feet of partly equivalent beds in the southern Snake Range, White Pine County, which he called the Kings Canyon Dolomite. More recent information, however, shows that the thickness in northern Lincoln County is fairly uniform at about 1,300 feet. In the Limestone Hills the thickness of the Sevy Dolomite measured from our map is about 1,300 feet. Kellogg (1960, p. 191) found a thickness of 1,293 to 1,323 feet in the southern Egan Range.

The thickness of the Sevy Dolomite decreases southward and southeastward from a maximum in the Pahranagat Range. Reso and Croneis (1959, p. 1251) measured five sections in the Pahranagat Range. There, thickness ranges from 1,206 to 1,630 feet. The thickness appears to increase steadily southward on the west side of the range. From the Pahranagat Range it decreases to 898 feet (P. H. Heckel, written communication, 1961), 272 feet, and 8 feet in the southern Delamar, southern Meadow Valley, and northern Arrow Canyon Ranges, respectively. The Sevy is absent in the Mormon Mountains region. In the Nevada Test Site the stratigraphic interval that we consider equivalent to the Sevy is about 875 feet thick (Johnson and Hibbard, 1957, p. 351-353; Poole and others, 1961, table 328.2; Byers and others, 1961, table 189.1). The Sevy in southwestern Lincoln County probably has a similar thickness.

Age and correlation

The Sevy Dolomite is generally unfossiliferous, but fossils belonging to the *Spirifer kobehana* zone of Merriam (1940, p. 52-53) have been reported from the limestone bed in the Sevy previously noted, and fossils occur in the lower part of the Sevy in the Pahranagat Range, according to Reso and Croneis (1959, p. 1251). These fossils are of Early Devonian (Oriskany) Age. They occur considerably below the Oxyoke Canyon Sandstone Member of the Nevada Formation west of Eureka and in the lower part of this member east of Eureka (Nolan and others, 1956, p. 46). They occur also in the upper 350 feet of the Hidden Valley Dolomite in the Inyo Mountains (C. W. Merriam, oral communication, 1959). McAllister (1952, p. 17) reports the same fossils in the upper 65 feet of the Hidden Valley Dolomite in the Quartz Spring area of eastern California. These fossils substantiate the correlation of the Sevy Dolomite with the lithologically similar Beacon Peak Dolomite Member, with the Oxyoke Canyon Sandstone Member of the Nevada Formation at Eureka, and with

the upper part of the Hidden Valley Dolomite. The Sevy Dolomite is, therefore, clearly Lower Devonian, except perhaps the uppermost few feet which may be Middle Devonian (Kellogg, 1959, p. 58).

Osmond (1954, p. 1928-1929; 1962, p. 2048) reports *Halysites* species from the Egan Range, which may possibly indicate an Upper Silurian Age for the basal part of the Sevy in east-central Nevada. Reso (1963, p. 908) has found Upper Silurian fossils 90 feet above the base of the Sevy in the Pahranagat Range and now believes that this unit ranges in age from Late Silurian to Early Devonian.

The lower part of the Nevada Formation (Beacon Peak Member) and the upper 250 feet of the undifferentiated middle Paleozoic dolomite in the Nevada Test Site resemble each other and the Sevy, according to Nolan and Merriam (Johnson and Hibbard, 1957, p. 353). The 95-foot-thick quartzite near the base (in unit A) of the Nevada Formation, as mapped by Johnson and Hibbard, probably is equivalent to the Oxyoke Canyon Sandstone Member at Eureka and to the sandstone at the top of the Sevy Dolomite. The 50-foot cherty layer below this quartzite correlates with the cherty argillaceous member described by Osmond. The limestone bed in the Sevy in the Spotted Range and the more abundant limestones below the quartzite in unit A of the Nevada Formation in the Nevada Test Site suggest that a western facies of limestone and quartzite on the west side of the county interfingers with the typical Sevy lithology to the east. We tentatively conclude that units F and G of the undifferentiated dolomite sequence and the lower 285 feet of the Nevada Formation, as mapped by Johnson and Hibbard (1957, p. 352-354) are equivalent to the Sevy of Lincoln County (fig. 13).

The beds equivalent to the Sevy Dolomite were mapped as part of the Lone Mountain Dolomite in northwestern Clark County by C. R. Longwell (oral communication, 1958), who selected the sandstone at the top of the Sevy as the upper contact of the Lone Mountain. We correlate the Sevy with member 3 of the Lone Mountain Dolomite, as mapped by Humphrey (1960, p. 26) in the Hamilton district, White Pine County. The Sevy Dolomite is apparently the approximate equivalent of the Kings Canyon Dolomite of Rush (1956, p. 26-27) in western Utah.

The Sevy Dolomite is equivalent to unit 3B of the Hidden Valley Dolomite of McAllister (1952, p. 15) in the Quartz Spring area in California, according to Merriam (*in* Nolan and others, 1956, p. 46), and perhaps to all of unit 3. The Hidden Valley Dolomite is, therefore, approximately equivalent to the Lone Mountain Dolomite as mapped by Longwell and others (1965).

Simonson Dolomite

Distribution

The Simonson Dolomite was named by Nolan (1935, p. 19) for exposures in Simonson Canyon in the Gold Hill quadrangle, Utah. Like the Sevy, the Simonson Dolomite is widely distributed in western Utah and eastern Nevada. It is found throughout all of Lincoln County except the southeast corner. Complete sections are exposed in the Limestone Hills, Egan, Seaman, Golden Gate, Pahranagat, and Desert Ranges, and the southern Delamar and Meadow Valley Mountains.

Lithology

The Simonson is composed of an alternating sequence of dark and light dolomite of several types that contrasts with the homogeneous whitish-weathering Sevy Dolomite which conformably underlies it. The Simonson was divided into four members by Osmond (1954, p. 1931-1947), from whom the following description is taken. We did not try to trace these units.

The oldest member, the coarse-grained member, is a light-tan coarsely crystalline cliff-forming dolomite 160 to 310 feet thick in Lincoln County. Several beds of Sevy-type dolomite are present in the lower part. The base of this unit is sandy in the Pahranagat Range.

The next oldest unit is the lower alternating member, an alternating sequence of whitish-gray aphanitic (Sevy-type) dolomite and predominantly brown, fine- to medium-grained dolomite of several types. The brown beds are finely laminated, homogeneous, or mottled, and locally some intraformational conglomerate beds are present. This member is 250 to 400 feet thick in Lincoln County. Local bioherms, largely composed of stromatoporoids, are common.

The third unit, the brown cliff member, is a dolomite biostrome, composed of stromatoporoids, corals, and bryozoans. The dolomite is massive and fetid, and is 70 to 180 feet thick in Lincoln County.

The youngest unit is the upper alternating member, another light and dark member which resembles the lower alternating member except that it has thicker beds and fewer laminations. Sedimentary breccias are common locally. This member is 200 to 460 feet thick in Lincoln County. Many of the darker beds contain "spaghetti" dolomite (Westgate and Knopf, 1932, p. 19). In the southern Egan and Pahranagat Ranges, the top 50 feet form a fossiliferous limestone which contains *Stringocephalus*.

Both the upper and lower contacts of the Simonson Dolomite are conformable, but local unconformities are present within the formation. Osmond (1954, p. 1946) and Kellogg (1963, p. 696) placed the upper contact at the change from dolomite to limestone, which Osmond states is about 160 feet stratigraphically above the base

of the dolomitic conglomerate bed that Nolan selected as the contact. We drew the contact at the base of the so-called yellow bed, a yellowish-gray nonresistant, silty, thin-bedded to platy dolomite that is at or near the base of the overlying limestone. In the northern part of the county this zone is inconspicuous. The uppermost part of the Simonson in the southern Egan Range is a massive limestone that contains smooth-shelled brachiopods and some stromatoporoids. These beds were included in the Guilmette Formation by Osmond and Kellogg. Reso and Croneis (1959, p. 1252) place the upper contact in the Pahranagat Range at the top of a prominent 25-foot-thick limestone layer that contains *Stringocephalus*. This is 40 to 90 feet stratigraphically below the contact we selected.

Thickness

The thickness of the Simonson Dolomite decreases from a maximum of approximately 1,200 feet in the southern Egan and Pahranagat Ranges to zero in southeastern Lincoln County. Except in the southeast corner, the thickness east of the Pahranagat Range is fairly uniform, ranging from 900 to 1,188 feet. The formation apparently thins abruptly northward, decreasing from over 1,000 feet in the Limestone Hills to about 670 feet (Osmond, 1954, p. 1931) in the southern Snake Range in White Pine County (perhaps this is the result of unrecognized faulting). It thins gradually westward from 1,188 feet in the Pahranagat Range (Reso and Croneis, 1959) to about 785 feet in the southwest corner of Lincoln County, where the unit is difficult to distinguish from the overlying Guilmette. The Simonson also thins southeastward from the Pahranagat Range to 685 feet in the southern Delamar Mountains and less than 400 feet in the southern Meadow Valley Mountains. The formation is less than 320 feet thick in the Arrow Canyon Range (Langenheim and others, 1960). The Simonson Dolomite is not recognized east of Meadow Valley Wash or in the eastern part of Clark County, but equivalent rocks may be present.

Age and correlation

The Simonson Dolomite in Lincoln County is equivalent to the formation at the type locality and as generally mapped in eastern Nevada and western Utah. The formation is Middle Devonian in age. Its exact correlation with the Sultan Limestone in Clark County is uncertain, but it is certainly included in the lower part of the Sultan in the northwest part of Clark County (Longwell and others, 1965, p. 25). The Simonson apparently pinches out farther south where the Sultan includes only beds equivalent to the Guilmette Formation.

We believe the Simonson Dolomite to be equivalent to 785 feet of beds in units A (top 175 feet), B, and C of the Nevada Formation, as mapped by Johnson and Hibbard (1957, p. 354) in the Nevada Test Site, and to be equivalent to most of the Nevada Formation in the area surrounding Eureka, Nevada (Nolan and others, 1956, p. 44).

We agree with Reso and Croneis (1959) and Kellogg (1959, p. 61-62) in their correlation of the upper three members of the Nevada Formation (the Sentinel Mountain Dolomite, the Woodpecker Limestone, and the Bay State Dolomite Members) with the Simonson Dolomite. The Sentinel Mountain and Bay State Dolomite Members resemble the two dolomite members of the Simonson that have alternating light and dark beds, but the lithologic equivalent of the Woodpecker Limestone is absent in Lincoln County.

The Simonson Dolomite appears to be the lithologic equivalent of the lower part (unit 1) of the Lost Burro Formation, in the Quartz Spring area, California (McAllister, 1952, p. 15). This formation is also recognized in the Darwin quadrangle, California (Hall and MacKevett, 1958, p. 7-8).

Poorly preserved fossils, for the most part dolomitized, are moderately abundant in parts of the Simonson Dolomite, especially in the dark dolomite beds. Beds of "spaghetti" dolomite are confined to the Devonian rocks. They are especially abundant in the Simonson Dolomite but are also found in the Guilmette Formation.

> "Three types of tubular or rodlike fossils are constituents of the 'spaghetti beds' of the Simonson and Guilmette. The most abundant is the tubular stromatoporoid *Amphipora*, which usually occurs as light-colored, straight or gently curved, unbranched rods in the dark dolomite. This form was generally identified as 'poorly preserved *Cladopora*' in early reports. The dendroid favositid corals *Cladopora* and *Thamnopora* are also found at some localities; these lack the central canal of *Amphipora*. *Cladopora* and *Amphipora* may have about the same diameter, but *Thamnopora* is commonly larger." (J. M. Berdan and Helen Duncan, written communication, 1963).

Stromatoporoids are present in the upper two members. Small cylindrical septate solitary corals and small brachiopods occur in the brown cliff member.

The Simonson Dolomite contains the following Middle Devonian fossils; C. W. Merriam identified the forms from small collections by Osmond (1954, p. 1950) from "the upper limestones of the Simonson": *Productella, Leiorhynchus* sp., *Emanuella?*, and *Styliolina* indicate an upper Nevada or Devils Gate correlation. *Atrypa* cf. *missouriensis* and *Atrypa* sp. from the Limestone Hills probably indicate upper Nevada Age. *Stringocephalus*, which indicates the approximate top of the Middle De-

vonian, has been found in both the Simonson and the Guilmette (depending on what bed is mapped as the contact). Reso (Reso and Croneis, 1959, p. 1252) maps the top of the *Stringocephalus* zone as the top of the Simonson in the Pahranagat Range. C. W. Merriam (oral communication, 1959) questions the occurrences in the Simonson.

We made three collections from the Simonson, two of which were from the Limestone Hills. These collections, USGS 4480-SD and USGS 4481-SD, from secs. 18 and 30, T. 8 N., R. 69 E., respectively, contained *Thamnopora* sp., auloporoid and horn corals, stromatoporoids, indeterminate gastropods, and *Emanuella* sp., all identified by J. M. Berdan who states (written communication, 1957):

> "According to G. A. Cooper, the brachiopod *Emanuella* suggests a correlation with the Hamilton or Tully faunas of New York. This might be the form which Merriam (Nolan and others, 1956, p. 47) has mentioned as a 'small *Martinia* cf. *kirki*,' from the base of the Woodpecker Member of the Nevada Limestone. The age of this collection is Middle Devonian."

USGS collection 4477-SD from SE¼ sec. 24, T. 4 N., R. 62 E., about 15 miles south of Sunnyside, contained *Alveolites* sp., *Cladopora* sp., *and Atrypa* sp. (lamellose type). J. M. Berdan states (written communication, 1957):

> "These * * * might be either Silurian or Devonian in age. The collection is probably Devonian and not younger than early Late Devonian (Frasnian)."

Guilmette Formation

Distribution

The Guilmette Formation was named after Guilmette Gulch in the Deep Creek Mountains, Gold Hill district, Utah (Nolan, 1935, p. 20). As mapped by us, it includes a basal nonresistant unit — the so-called yellow bed — and all the overlying rocks up to the base of the Pilot Shale. This interval includes the rocks mapped by Westgate and Knopf (1932) as Silverhorn Dolomite, and, except in the Fairview, Bristol, and West Ranges, the West Range Limestone. This stratigraphic interval is readily mappable despite facies changes that have given rise to several sets of names in this county and adjacent areas (figs. 4, 13).

Owing to the confusion in lithologic and stratigraphic correlations of the West Range Limestone, we have chosen not to use the term "West Range" in this report. The chief source of confusion is the fact that the type locality of the West Range is complexly faulted and the stratigraphic positions of the original fossil collections therein are subject to question. Detailed mapping and collecting in the type area will be required before the type West Range can be properly correlated with the West Range Limestone of Reso (1963, p. 910) and the West Range Formation of Kellogg (1963, p. 700-702). Therefore, our Guilmette, as mapped, includes the West Range Limestone of Reso (1963) in the Pahranagat Range and the lower member of the West Range Formation of Kellogg (1963) in the Egan and Schell Creek Ranges. Elsewhere in the northern part of the county, where the West Range Limestone or equivalent rocks have been recognized, we included these rocks with the Pilot Shale.

Like the other Devonian units, the Guilmette Formation extends over eastern Nevada and western Utah. It is widely exposed in northern and western Lincoln County. The Guilmette Formation or equivalent units probably covered the entire county, but in the southeast corner of the county, Devonian rocks could not be distinguished from rocks of Cambrian and Ordovician Age. Complete sections of the Guilmette are exposed in the southern Egan, southern Schell Creek, Seaman, Pahranagat, Timpahute, Desert, and Spotted Ranges, and in the Meadow Valley and Worthington Mountains.

Lithology

The lithology of the Guilmette Formation is not uniform, but the basal unit almost everywhere is the so-called yellow bed, a thin-bedded, nonresistant, grayish- or dusky-yellow, laminated, silty dolomite 50 to 70 feet thick, that may locally contain several massive dark-gray limestone beds. In the Pahranagat Range the yellow bed is 40 to 90 feet stratigraphically above a 25-foot-thick limestone layer that contains *Stringocephalus* (Reso and Croneis, 1959, p. 1252). In the Egan Range the rocks in apparently the same stratigraphic position are cliff-forming, yellowish-gray, argillaceous limestones between 240 and 384 feet thick overlain by an equal thickness of slope-forming, yellow, argillaceous and silty, thin-bedded limestone or dolomite; the base of this sequence occurs 80 feet above the bed containing *Stringocephalus* (Kellogg, 1963, p. 698). The yellow bed probably correlates with a 300-foot-thick buff dolomite and limestone bed that forms a bench above a *Stringocephalus* biostrome in the Arrow Canyon Range, Clark County (Langenheim and others, 1960). Except for the *Stringocephalus*-bearing limestone beneath it, the yellow bed generally separates dolomite below from limestone above.

Several hundred feet of cliff-forming limestone beds generally overlie the yellow bed. These include massive beds of sedimentary reef breccias up to 100 feet thick, which are largely composed of large broken stromatoporoid heads. These clastic beds are widely distributed

in the western half of the county where they are characteristic of the Lower Guilmette. Distinct bioherms are also common. Anthony Reso (oral communication, 1959) recognizes prominent table and patch reefs in the Pahranagat Range which resemble reefs of equivalent age in the subsurface rocks of Alberta, Canada.

Three distinct facies are recognized in the Guilmette; these interfinger in a complex manner, as indicated diagrammatically in figures 4 and 12. Another distinct facies very probably occurs in the southeast corner of Lincoln County and in the northeastern Clark County where rocks of equivalent age are thought to be present, but the absence of fossils prevented these rocks from being distinguished from the older Paleozoic rocks with similar lithology. The stratigraphic relations are complicated by thrust faults and unconformities that cut out as much as 1,000 feet of late Upper Devonian rocks. These relations are, therefore, not completely understood, and the facies nomenclature used herein is strictly informal and tentative.

The three distinct facies may be described as follows: a sandy limestone facies like that on the west side of the Pahranagat Range; a dolomite facies like the Silverhorn Dolomite in the Bristol, West, North Pahroc, and Fairview Ranges; and a limestone facies like the one on Dutch John Mountain or near the northwest corner of Lincoln County. These facies interfinger so that in most places the Guilmette consists of rocks belonging to two or all three of the facies. The fourth facies, of limestone and dolomite, in the southeast corner of Lincoln County, is correlated with the Muddy Peak Limestone of eastern Clark County (Longwell and others, 1965) (figs. 4, 12).

The sandy limestone facies in the Pahranagat Range consists of about 1,600 feet of limestone and dolomite that contain up to 16 sandstone or quartzite beds. The medium-grained sandstone is yellowish brown, sporadically crossbedded, and well sorted. It is about 600 feet thick and is interbedded with approximately equal amounts of limestone and dolomite. The thin peripheral part of this facies in Bristol Range is represented by the 100-foot-thick quartzite unit at the top of the Silverhorn Dolomite.

The upper part of the Guilmette in the northeast corner of Lincoln County and in the Needle Range just over the Utah line also contains abundant sandstone. Here two sandstone beds totaling 190 feet occur in the upper 460 feet of the Guilmette (Gould, 1959, p. 5). Several thin sandstone beds occur lower in a thin incomplete section which is otherwise mostly limestone. Several sandstone beds occur also in the upper part of the Guilmette in the northern Desert Range; near Mount Irish; in the Seaman and Hiko Ranges; and in the Arrow Canyon Range, Clark County.

The dolomite facies is represented by the Silverhorn Dolomite; it is 2,983 feet thick in the Fairview Range (Westgate and Knopf, 1932, p. 17) and consists principally of alternating dark- and light-gray dolomite and "spaghetti" dolomite, but it contains also a few limestone layers and several layers of quartzite or sandstone in the upper part. These dolomites are very difficult to distinguish from the Simonson Dolomite, and they may even include rocks equivalent to the upper part of that unit. At Dutch John Mountain, Kellogg (1959, p. 68) correlates the Guilmette with the Silverhorn above the *Stringocephalus* zone, which is clearly Late Devonian in age; however, the Silverhorn was originally assigned to the Middle Devonian and was correlated with the upper half of the Nevada Formation in the Eureka district (Westgate and Knopf, 1932, p. 19). The dolomite facies in the Fairview, Bristol, and West Ranges grades westward and northward into limestone. Everywhere the dolomite facies is overlain by limestone of Late Devonian Age.

The limestone facies includes some rocks equivalent to the Silverhorn Dolomite and, in the Dutch John Mountain area, to a very thick section of younger Devonian limestone that belongs in the *Cyrtospirifer* zone and still younger Devonian time. These youngest Devonian rocks are thin or absent elsewhere.

The limestone facies make up the entire Guilmette of this report near the common corner of Nye, Lincoln, and White Pine Counties, where it is about 1,900 feet thick (Kellogg, 1960, p. 192) compared to 2,750 feet of equivalent rocks on Dutch John Mountain (Merriam, 1940, p. 39-40). In the Egan Range, the limestone grades southward into dolomite and thickens at the same time, first abruptly, then more gradually until it is predominantly dolomite and 2,504 feet thick south of Trough Spring Canyon (Kellogg, 1959, p. 65).

About 1,000 to 1,300 feet of late Upper Devonian rocks that are present on Dutch John Mountain are cut out at an unconformity elsewhere in northern Lincoln County. This unconformity cuts out progressively older rocks going westward so that the *Cyrtospirifer* zone and younger Devonian rocks are thinned by pre-Mississippian erosion from 1,500 feet at Dutch John Mountain (zones A, B, and C of Merriam, 1940) to about 300 feet in the West Range, to 250 feet near Side Hill Pass in the southern Schell Creek Range, to zero north of Shingle Pass in the Egan Range (Kellogg, 1959, p. 69-70). In the Pahranagat Range, Reso and Croneis (1959) show that these rocks (West Range Limestone) thin from 390 feet on the east side of the range to zero on the west side.

Thickness

The thickness of the Guilmette Formation, as defined by us, ranges from a possible 3,500 feet to about

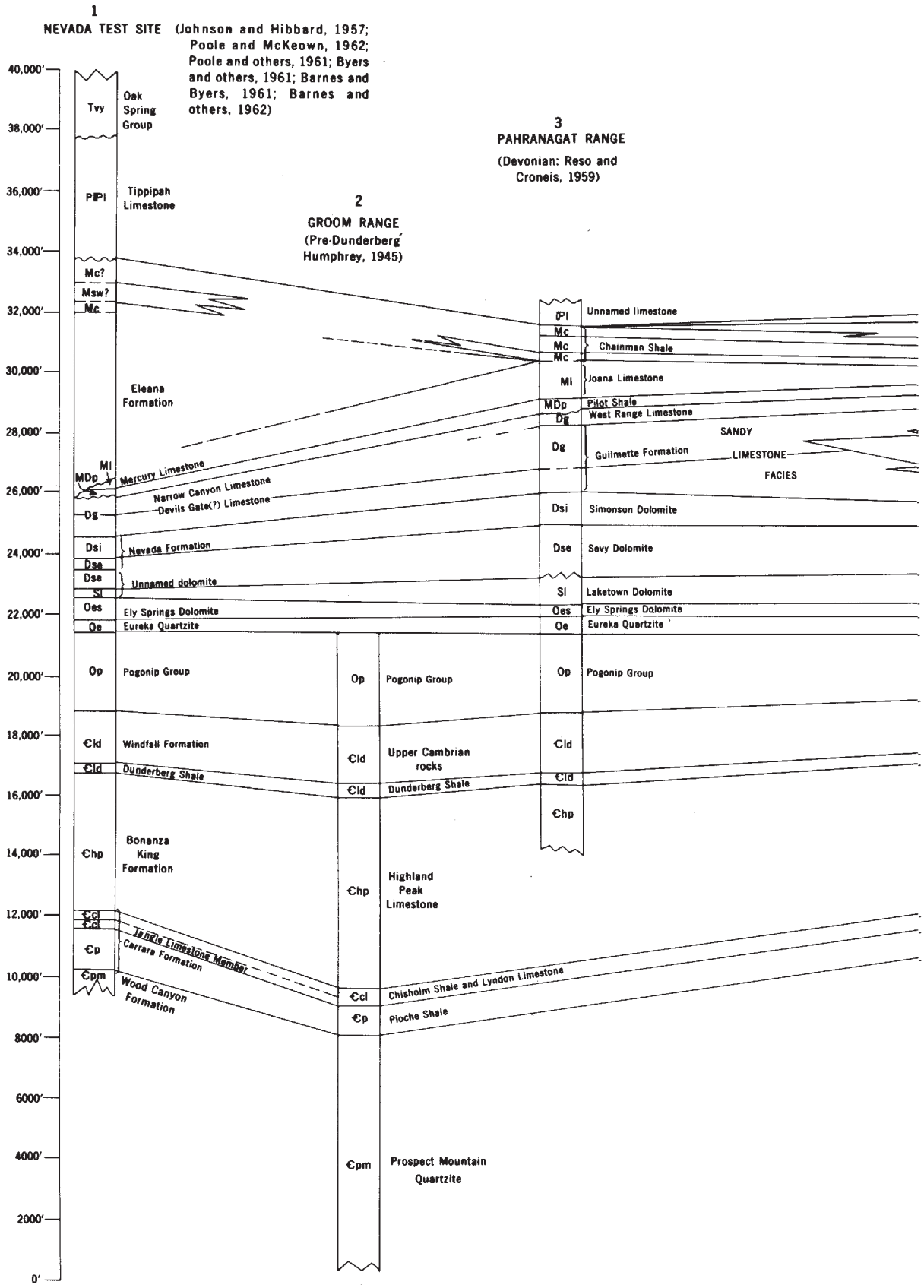
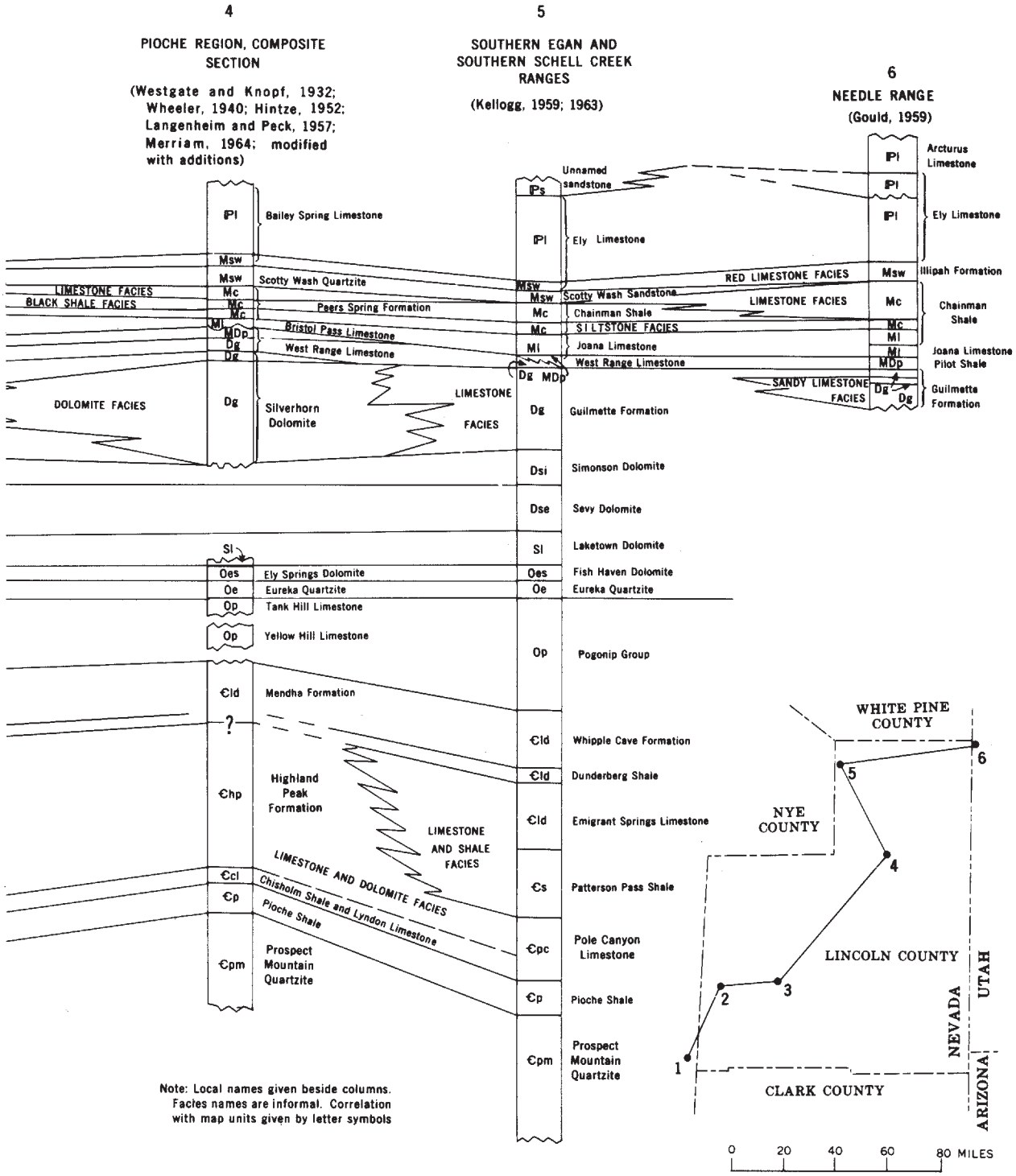


FIGURE 12. Diagrammatic stratigraphic sections and facies relations northeastward across Lincoln County.


4
PIOCHE REGION, COMPOSITE SECTION
(Westgate and Knopf, 1932; Wheeler, 1940; Hintze, 1952; Langenheim and Peck, 1957; Merriam, 1964; modified with additions)
5
SOUTHERN EGAN AND SOUTHERN SCHELL CREEK RANGES
(Kellogg, 1959; 1963)
6
NEEDLE RANGE
(Gould, 1959)
Pl Bailey Spring Limestone
Msw
Msw Scotty Wash Quartzite
LIMESTONE FACIES
BLACK SHALE FACIES
Mc
Mc
Mc
Peers Spring Formation
Ml
MDp
Dg
Dg
Bristol Pass Limestone
West Range Limestone
DOLOMITE FACIES
Dg
Silverhorn Dolomite
LIMESTONE FACIES
Sl
Oes Ely Springs Dolomite
Oe Eureka Quartzite
Op Tank Hill Limestone
Op Yellow Hill Limestone
Ꞓld Mendha Formation
?
Ꞓhp
Highland Peak Formation
LIMESTONE AND SHALE FACIES
LIMESTONE AND DOLOMITE FACIES
Ꞓcl
Ꞓp
Chisholm Shale and Lyndon Limestone
Pioche Shale
Ꞓpm
Prospect Mountain Quartzite
Note: Local names given beside columns. Facies names are informal. Correlation with map units given by letter symbols
Unnamed sandstone
Ps
Pl
Pl Ely Limestone
Msw
Msw Scotty Wash Sandstone
Mc
Mc Chainman Shale
Mc SILTSTONE FACIES
Ml
Ml Joana Limestone
Dg MDp
West Range Limestone
Dg
Dg Guilmette Formation
Dsi Simonson Dolomite
Dse Sevy Dolomite
Sl Laketown Dolomite
Oes Fish Haven Dolomite
Oe Eureka Quartzite
Op
Op Pogonip Group
Ꞓld Whipple Cave Formation
Ꞓld Dunderberg Shale
Ꞓld Emigrant Springs Limestone
Ꞓs Patterson Pass Shale
Ꞓpc Pole Canyon Limestone
Ꞓp Pioche Shale
Ꞓpm Prospect Mountain Quartzite
Pl Arcturus Limestone
Pl
Pl Ely Limestone
RED LIMESTONE FACIES
Msw Illipah Formation
LIMESTONE FACIES
Mc Chainman Shale
Mc
Ml
Ml Joana Limestone
MDp Pilot Shale
SANDY LIMESTONE FACIES
Dg
Dg Guilmette Formation
WHITE PINE COUNTY
NYE COUNTY
LINCOLN COUNTY
CLARK COUNTY
NEVADA
UTAH
ARIZONA
1
2
3
4
5
6
0 20 40 60 80 MILES

1,300 or 1,400 feet and appears to decrease in all directions from north-central Lincoln County. The thickness is 1,900 to 2,500 feet in the southern Egan Range, 2,750 feet at Dutch John Mountain, approximately 3,000 and 3,500 feet in the Fairview and West Ranges, 2,400 to 2,800 feet in the Pahranagat Range, perhaps 2,200 to 2,300 feet in the Spotted and Desert Ranges, and about 1,730 feet in the section measured by Johnson and Hibbard (1957, p. 355) in the Nevada Test Site, Nye County. The rocks equivalent to the Guilmette Formation are only about 1,600 feet thick in the Hamilton district, White Pine County (Humphrey, 1960, p. 29-30). The formation also thins gradually southeastward from the Pahranagat Range. It is about 1,300 or 1,400 feet thick in the southern Delamar Mountains (P. H. Heckel, written communication, 1961), and about 1,650 feet thick in the Arrow Canyon Range, Clark County, where we correlate with the Guilmette those Devonian rocks measured by Langenheim and others (1960) above the *Stringocephalus* zone. This thickness, however, included the Crystal Pass Limestone Member of the Sultan Limestone, which is not found in Lincoln County except perhaps in the southeast corner. The equivalent but undifferentiated rocks in the southeast corner may be only about 800 to 900 feet thick.

Age and correlation

The Guilmette Formation is Middle and Upper Devonian. The lower half of the limestone facies on Dutch John Mountain, including zones A and B of Merriam (1940, p. 39), is equivalent to the Devils Gate Formation and West Range Limestone, both Late Devonian in age, but the 750 to 1,000 feet of Devonian rocks overlying it (zone C) are younger than any rocks in the Devils Gate section (Merriam, 1940, p. 39-40, 46). All these rocks are younger than the dolomite facies or any rocks in the Guilmette Formation in the southern Egan and southern Schell Creek Ranges, but they are approximately equivalent to the upper 1,200 feet of the Guilmette in the Pahranagat Range.

Lithologically, the Guilmette Formation is similar to the type section in the Gold Hill district (Nolan, 1935, p. 20-23), which originally was believed to contain only Middle Devonian fossils. More detailed studies of Upper Devonian faunas by Merriam (1963, p. 16; Nolan and others, 1956, p. 51), however, indicate a probable Late Devonian Age for the upper part of the type Guilmette. In Lincoln County most of the Guilmette is Upper Devonian. At Gold Hill, just as in parts of Lincoln County, an unconformity occurs at the top of the Guilmette.

The Guilmette Formation, as we mapped it, is equivalent to the formation as mapped by R. K. Hose (written communication, 1960) in the Confusion Range, Utah; by Gould (1959, p. 5) in the Needle Range, Utah; and by other workers in the eastern Great Basin. Kellogg (1960, p. 192) and Reso and Croneis (1959), however, recognize a separate formation, the West Range Limestone, and they draw the upper contact at the top of the highest sandstone or at the base of the shaly limestone sequence that we include in the Pilot Shale.

The Guilmette Formation is approximately equivalent to the Sultan Limestone in southern Clark County (Longwell and others, 1965), where beds equivalent to the Simonson Dolomite are absent. The Sultan Limestone in northern Clark County, however, is approximately equivalent to the combined Simonson and Guilmette on our map. The Guilmette is equivalent to the upper 1,650 feet of Devonian rocks in the Arrow Canyon Range (Langenheim and others, 1960). These rocks resemble the Guilmette except for the 229 to 280 feet of Crystal Pass Limestone Member at the top.

The Guilmette is equivalent to the entire Devils Gate(?) Limestone in the Nevada Test Site (Johnson and Hibbard, 1957, p. 354-355) and the Devils Gate Limestone in the Eureka district (Nolan and others, 1956, p. 45-520). The Guilmette of Lincoln County is equivalent to most of the Lost Burro Formation in the Quartz Spring area (McAllister, 1952, p. 19-20) and in the Darwin quadrangle (Hall and MacKevett, 1958, p. 8) of California. The correlations of the Silurian and Devonian rocks are summarized in figure 13.

The Guilmette Formation includes both Middle and Late Devonian faunas. USGS collection 4849-SD of probable early Late Devonian fossils from the east side of Mount Irish contained *Cladopora*? sp., *Phacellophyllum* sp., and auloporoid corals, according to Jean M. Berdan (written communication, 1957)

The fossils in the following collections were identified by Jean M. Berdan in consultation with G. A. Cooper, Helen Duncan, Lloyd Henbest, Ellis Yochelson, and others (written communication, 1957).

USGS collection 4476-SD. Limestone Hills, NE¼ sec. 8 T. 9 N. R. 69 E.
- *Atrypa* sp. (finely striate type)
- Spririferoid brachiopod
- *Spongophyllum* sp. aff. *"Disphyllum" lonense* Stumm
- *Cladopora* sp.
- *Amphipora* sp.

USGS collection 4479-SD. Limestone Hills, sec. 1, T. 9 N., R. 68 E.
- *Pachyphyllum* sp. aff. *P. nevadense* (Stumm)
- *Atrypa* sp. (lamellose type)
- ramose favositid coral
- *Favosites* sp. (encrusting type)
- spiriferoid brachiopod, indet.
- pleurotomarian gastropod, indet.

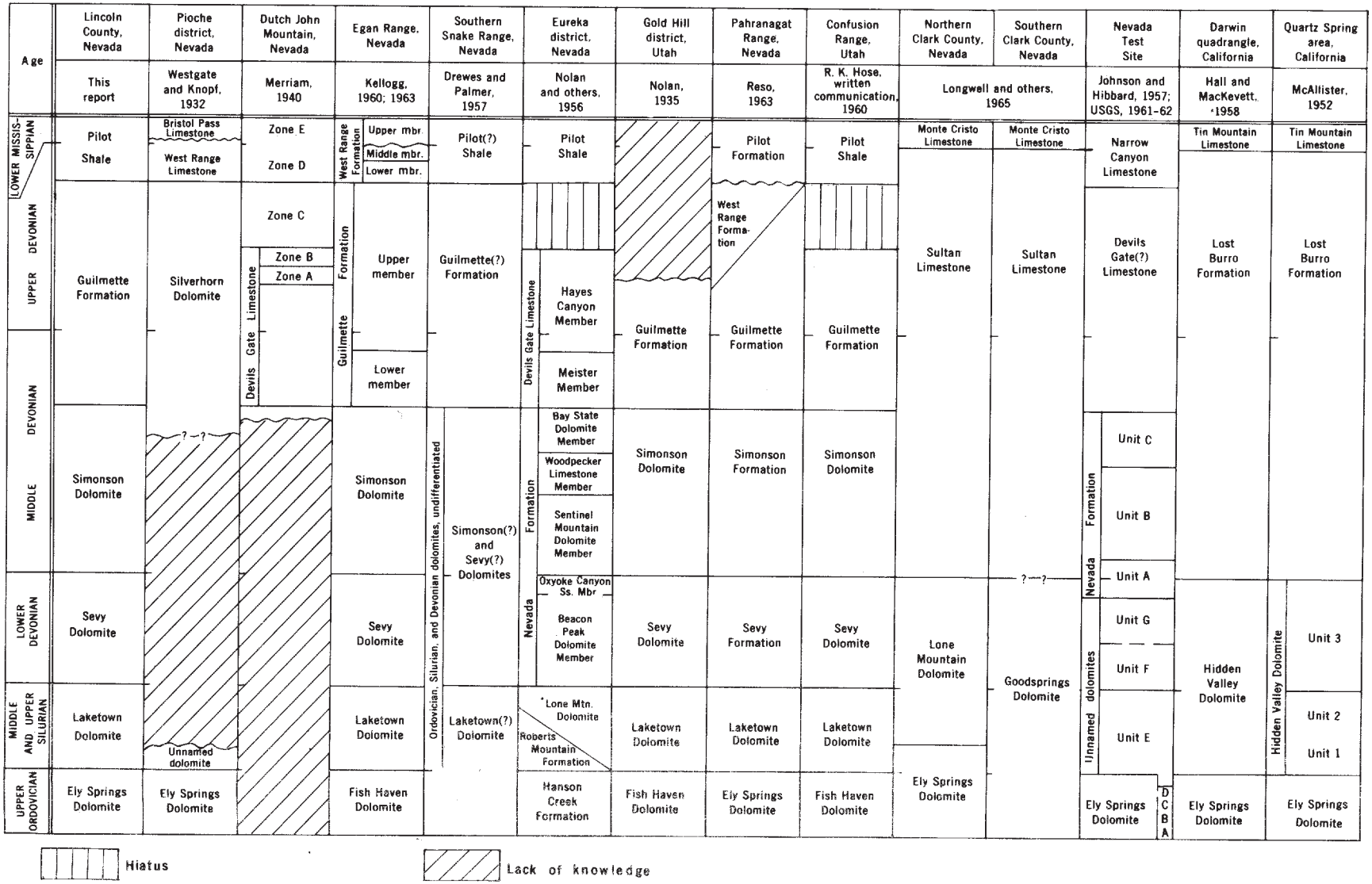


FIGURE 13. Correlation of Silurian and Devonian formations of eastern Nevada, western Utah, and southeastern California.

USGS collection 4478-SD. Hiko Range, 1 mile northeast of Crystal Springs, sec. 1, T. 5 S., R. 60 E.

Tenticospirifer? sp.
Auloporoid coral
Horn corals, indet.

USGS collection 4482-SD. Pahroc Range, sec. 28, T. 1 S., R. 63 E.

Atrypa sp. (finely ribbed type)
Pachyphyllum? sp.
Thamnopora sp.
Amphipora sp.
stromatoporoids
horn coral, indet.
gastropods, indet.

The first collection, 4476, probably correlates with a part of the Nevada Formation. According to J. M. Berdan, "*'Disphyllum' lonense* was reported by Stumm to occur from 700 to 1,500 feet stratigraphically above the base of the Nevada Formation at Lone Mountain, Nevada * * * a precise correlation is not possible."

According to Berdan, the last three collections are probably Devonian and the last two may represent the *Pachyphyllum* zone of the Devils Gate Formation of Late Devonian Age.

Undifferentiated Devonian Rocks

The Devonian rocks in the southeast corner of Lincoln County east of Meadow Valley Wash are much thinner than the equivalent rocks in the rest of the county and they apparently rest unconformably on the pre-Devonian rocks (p. 32). This Devonian sequence belongs to the thin marginal shelf facies of the miogeosyncline. In this area we were unable to separate the Devonian from the lithologically similar older Paleozoic rocks of this facies because the distinctive units of the Eureka Quartzite, Ely Springs Dolomite, and Laketown Dolomite are absent. The Devonian rocks are generally more like the Devonian rocks in areas to the south and southeast than to the Devonian rocks elsewhere in Lincoln County.

At least 550 feet of alternating light- and dark-gray dolomite, and brown dolomite of possible Devonian Age occur in the Tule Springs Hills in the upper plate of a thrust. Part of these rocks are oölitic, part are sandy, and part are dense aphanitic or laminated dolomite. These rocks, informally referred to on figure 4 as the limestone and dolomite facies, may belong to the Muddy Peak Limestone recognized in Clark County.

A white porcelaneous limestone 50 feet thick at the top of a dolomite sequence, 5 miles east of Carp, might correlate with the Crystal Pass Limestone Member of the Sultan Formation (Hewett, 1931, p. 13). This member is 229 to 280 feet thick in the Arrow Canyon Range.

These undifferentiated Devonian rocks are included on the geologic map in the undifferentiated Cambrian to Devonian limestone and dolomite unit along with units equivalent to the Cambrian and Ordovician sections described earlier.

Upper Devonian rocks are known to occur on Lime Mountain near the Utah line, and equivalent rocks probably are widely distributed northeast of the Mormon Mountains. Thin-bedded silty dolomitic limestone and dolomite of late Late Devonian Age were found half way up the west slope of Lime Mountain (p. 44). These rocks probably correlate with the Pilot Shale, to which they are similar. Similar rocks are widely distributed east of the Mormon Mountains, where they occur above a 40-foot sandstone of probable Late Devonian Age.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

Pilot Shale

Distribution

The Pilot Shale was defined by Spencer (1917, p. 26) in the Ely district. As mapped by us, it includes all the slope-forming rocks between the cliff-forming limestone in the Guilmette Formation below the unnamed Mississippian limestone above. It is widely recognized throughout eastern Nevada. Langenheim (1956a) states that the Pilot Shale is absent at Duckwater and Lund, northwest of Lincoln County, probably because of (pre-Early Mississippian) erosion. The formation is less than 50 feet thick in the Egan Range north of Shingle Pass. The Pilot Shale once covered all of Lincoln County except possibly part of the southeast corner. It crops out widely in the northern and western parts of the county and also in the Meadow Valley Mountains. Complete sections are exposed in the southern Egan, southern Schell Creek, Seaman, Golden Gate, Pahranagat, Timpahute, Desert, and Spotted Ranges; on Dutch John Mountain; and in the Worthington and Meadow Valley Mountains. The only known occurrence east of Meadow Valley Wash is on the west side of Lime Mountain.

Lithology

In Lincoln County, the Pilot Shale contains comparatively little shale and is composed mainly of thin-bedded or platy, silty limestone that weathers reddish gray to pale yellow orange, or yellowish gray. The formation forms a conspicuous, partly covered weak zone under the Mississippian limestone cliff. Bedded dark-gray chert, thin-bedded gray cherty limestone, and fine-grained sandstone occur in the lower half in western Lincoln County. A layer of dark-gray carbonaceous shale that contains limestone concretions occurs in the upper part of the Pilot Shale in the Pahranagat Range (Reso and Croneis, 1959, p. 1252).

A calcareous platy siltstone and silty limestone facies occurs in the northern part of the county. A typical section of this facies of the Pilot Shale is on Dutch John Mountain and has been described by Merriam (1940, p. 40); the upper 85 feet are thin-bedded platy calcareous shale (zone E) and the lower 300 feet are fossiliferous platy limestone (zone D). The thickness of the lower part may be as little as 60 feet in some localities.

A thicker cherty facies occurs in the Pahranagat Range and farther west as shown by the following partial sections:

Partial estimated sections of Pilot Shale.

East Pahranagat Range

	Thickness (feet)
Thin-bedded fossiliferous limestone of Mississippian Age	30
Yellow-brown-weathering shale	120-150
Thin-bedded black to purplish-black chert and brown-weathering quartzite with shaly partings	50-60
Thin-bedded yellowish-brown siltstone and sandy shale, mostly covered	70
Total	310+

West side of Spotted Range

	Thickness (feet)
Thin-bedded limestone of Mississippian Age	90
Yellowish-brown sandstone and quartzite	30
Platy thin-bedded yellowish-gray shaly limestone	80
Thin-bedded cherty limestone with 50 percent chert	40
Bedded dark-gray chert	60
Total	300±

Reso and Croneis (1959, p. 1252) found a thin but continuous layer of black shale 16 to 50 feet thick at the top of the formation throughout the Pahranagat Range.

The bedded chert ranges in thickness from about 60 feet in the East Pahranagat and Spotted Ranges to a thin but conspicuous basal bed in the Desert Range. Chert float is conspicuous between Mount Irish and the Coal Valley and Hiko Road, but chert is rare or absent north of here.

A third possible facies of the Pilot Shale consists of several hundred feet of yellow-orange calcareous siltstone or silty limestone that occur in the Timpahute and northern Seaman Ranges and on Lime Mountain. These rocks occur in thrust plates and they differ from typical Pilot Shale, but they contain questionable Late Devonian fossils (p. 44) unlike those in the Pilot. Perhaps they represent a higher horizon that has been removed from most of Nevada by the unconformity in the West Range Formation of Kellogg (1963, p. 702).

Thickness

The thickness of the Pilot Shale ranges from about 80 feet to about 460 feet. In northern Lincoln County, the thickness decreases from 385 feet at Dutch John Mountain to about 150 and 170 feet in the southern Schell Creek and West Ranges, respectively. It is approximately 110 feet thick in the Egan Range near Sunnyside and between 90 and 140 feet thick in the southern Seaman and Golden Gate Ranges. Merriam (1940, p. 40) measured 385 feet of beds on Dutch John Mountain which we include in the Pilot Shale; the upper 85 feet (zone E) of this section is probably equivalent to the thinner sections west of Dutch John Mountain.

Anthony Reso (oral communication, 1959) found that the thickness of the Pilot Shale was between 357 and 460 feet in the East Pahranagat Range and between 234 and 250 feet in the Pahranagat Range. (The figures for the East Pahranagat Range exclude Reso's West Range Limestone, which we mapped as the upper part of the Guilmette Formation.) We noted similar changes in thickness on the east and west sides of the Seaman Range. The thickness in the Spotted and Desert Ranges is perhaps 350 to 400 feet. The lower two units of a section measured by C. R. Longwell (written communication, 1956) in the Spotted Range about 7 miles south of Lincoln County show 340 feet of beds which we consider equivalent to the Pilot Shale. The thickness in the Meadow Valley Mountains is about 100 feet. On Lime Mountain the thickness of questionably equivalent beds is perhaps several hundred feet. In the Nevada Test Site (Johnson and Hibbard, 1957, p. 356) the Narrow Canyon Limestone, which we consider equivalent to the Pilot, is 175 feet thick.

Age and correlation

The age of the Pilot Shale ranges from Late Devonian to Early Mississippian. However, the only Early Mississippian fossils collected by us were included in three collections from 30 to 50 feet of thin-bedded limestone below the overlying cliff-forming (Joana) limestone. We included these beds with the Mississippian limestones.

The Pilot Shale, as mapped by us, is correlated with the Pilot in the Ely (Spencer, 1917, p. 26) and Eureka districts (Nolan and others, 1956, p. 52-53) (fig. 13). It is equivalent to zones D and E of Merriam (1940, p. 40) and probably also to the uppermost part of the type West Range Limestone in the West Range (Westgate and Knopf, 1932, p. 19-20), but the exact correlation with Westgate's formation is uncertain. On our map the West Range Limestone in the Bristol region is shown as Pilot Shale. The Pilot Shale is equivalent to the Pilot Shale of Reso (1963, p. 910), to the upper two members of the West Range Formation as mapped by Kellogg (1960,

p. 192), and to the Narrow Canyon Limestone (Johnson and Hibbard, 1957, p. 356) in the Nevada Test Site.

The following collection identified by J. M. Berdan (written communication, 1958) probably came from the lower (Upper Devonian) part of the Pilot Shale or from beds equivalent to the West Range Limestone as mapped by Reso (1959, p. 1251).

USGS collection 4970-SD, from klippe south of Coyote Peak, Timpahute Range, sec. 23, T. 4 S., R. 56 E.
- productoid brachiopods
- *Leiorhynchus*? sp.
- fragmentary orbiculoid brachiopods
- sponge spicules
- pelmatozoan debris

Of this collection Berdan states:

> "Although the fossils are too poorly preserved for positive identification, the association of *Leiorhyncus*? sp. and the productoid brachiopods indicates an age not older than Middle Devonian, and strongly suggests a Late Devonian age. The general assemblage is reminiscent of faunas found in the Pilot Shale and equivalent formations."

Thin-bedded limestone (USGS collection 7189-SD) halfway up the west side of Lime Mountain contains a large rhynchonelloid brachiopod. Helen Duncan (written communication, 1959) states:

> "This collection contains a large rhynchonelloid brachiopod that to Jean Berdan and me suggests *Paurorhyncha endlichi* (Meek). If the identification is correct, the age is late Late Devonian and that part of the rock unit is presumably a Pilot Shale equivalent."

MISSISSIPPIAN SYSTEM

Mississippian rocks are widely distributed in Lincoln County. Facies changes in the Mississippian rocks occur more abruptly than in the rocks of any other period except the Devonian. The thickness is relatively uniform over most of the county but the proportions of limestone and clastic rocks change drastically (fig. 14). The thickness of the Upper Mississippian clastic rocks decreases southward, and these clastic rocks pinch out entirely east of the Meadow Valley Mountains. Limestones increase at the expense of the clastic rocks between the Meadow Valley Mountains and the Arrow Canyon Range in Clark County, so that the total thickness does not decrease greatly southward. East of the Meadow Valley Mountains, however, the decrease in thickness is accompanied by a similar decrease in the thickness of the limestone.

Not counting the Pilot Shale, four Mississippian formations are shown on the geologic map of Lincoln County. The map units are: (1) unnamed Mississippian limestone; (2) Monte Cristo Limestone; (3) Chainman Shale; and (4) Scotty Wash Quartzite. The latter two units were combined on the map where they were too thin to show separately.

Unnamed Mississippian Limestone

Distribution

The unnamed Mississippian limestone unit consists of all the limestone between the nonresistant shales of the Pilot and Chainman. In most of the county, this interval includes a massive cliff-forming limestone, the Joana Limestone, and an unnamed overlying unit of thin- to thick-bedded, slope-forming limestone. Together these two formations form the Joana Limestone of some recent authors; but, strictly speaking, the term Joana Limestone should be restricted to the lower cliff-forming unit in order to match the Joana at its type section (Spencer, 1917, p. 26). In the southeast corner of the county, the limestone map unit consists of the thinner bedded Monte Cristo Limestone. We have informally considered these two map units as separate lithologic facies, the massive limestone (Joana) facies and the limestone and cherty limestone (Monte Cristo) facies (fig. 4), which are equivalent in age.

Limestone of Mississippian Age once covered the entire county, but outcrops are scarce in the east-central part. Complete sections are found in the southern Egan, Timpahute, Golden Gate, Pahranagat, and Spotted Ranges; on Dutch John Mountain; and in the Mormon and Meadow Valley Mountains.

Lithology

For convenience, the massive limestone facies and the limestone and cherty limestone facies will be described separately. The massive limestone facies is distinguishable in most of the county, but, toward the southeastern corner, it loses its identity and interfingers with Monte Cristo Limestone. The lower part of the massive limestone facies, the Joana Limestone, as defined by Spencer (1917, p. 26), is a massive bluish-gray, dense to coarsely crystalline crinoidal or cherty cliff-forming limestone that is 50 to 260 feet thick.

The unnamed limestone overlying the cliff-forming Joana is 200 to 700 feet thick. Characteristically, it is thin- to medium-bedded dark-gray limestone with shale partings and abundant cherty beds. Some beds contain abundant distinctive horn corals as much as 9 inches long. The unnamed limestone strata characteristically form either one or two bluffs with intervening benches.

The Monte Cristo Limestone is exposed in southeastern Lincoln County. All five members of the Monte Cristo Limestone, as defined by Hewett (1931, p. 10) in the Goodsprings district, can be recognized in the Mor-

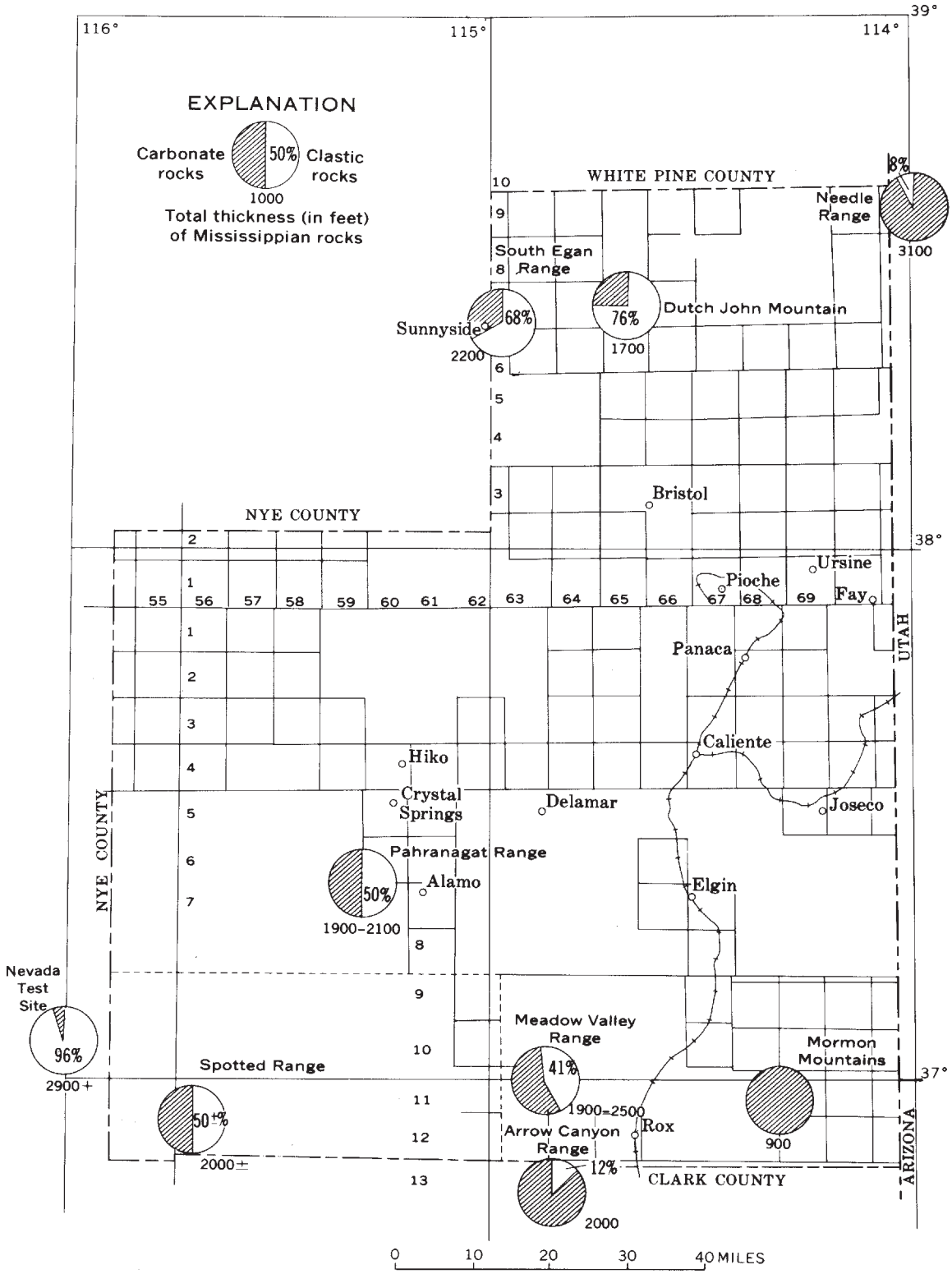


FIGURE 14. Relative proportions of carbonate and clastic rocks of Mississippian Age in and near Lincoln County.

mon Mountains. Langenheim (1956b) gave the following description of the five members in the East Mormon Mountains (sec. 31?, T. 11 S., R. 69 E.): the oldest member, the Dawn Limestone, is a chert-free black dolomite about 50 feet thick; the Anchor Limestone Member is composed of dark-gray alternating layers of nodular limestone and chert about 135 feet thick; the Bullion Dolomite Member is a massive, light-gray-weathering, cliff-forming limesone about 380 feet thick; the Arrowhead Limestone Member is a thin-bedded nodular black limestone with clay partings about 15 feet thick; the youngest member, the Yellowpine Limestone, is a coarse-grained, dark-gray, medium- to thick-bedded limestone about 305 feet thick. These members, except for the Arrowhead, are also recognizable in the Arrow Canyon Range, Clark County.

C. R. Longwell (written communication, 1959) measured a section in the Spotted Range about 7 miles south of Lincoln County, and found a thickness of 150 feet for the thick-bedded dark-gray limestone that we consider equivalent to the Joana, and 275 feet for the thin-bedded limestone that we consider equivalent to the overlying Mississippian limestones. The latter thickness is a minimum because a disconformity probably occurs at the top.

In the eastern part of Clark County, the Monte Cristo Limestone grades to a dolomite and limestone facies (fig. 4). Here the Rogers Spring Limestone (Longwell and others, 1965) contains three persistent members equivalent to the Dawn Limestone, Anchor Limestone, and Bullion Dolomite Members of the Monte Cristo Limestone and other members that vary from range to range.

Thickness

The thickness of the Mississippian limestone section increases abruptly westward from 885 feet in the Mormon Mountains to an estimated 1,500 feet in the Meadow Valley Mountains, and to 1,415 (Langenheim and others, 1960) and 1,764 feet in the Arrow Canyon Range (D. H. Duley, written communication, 1957). The thickness is 972 to 1,014 feet in the Pahranagat Range (Reso, 1963, pl. 2), 425 to 750 feet in the Spotted Range, about 400 to 650 feet at Dutch John Mountain, and 750 to 1,000 feet in the Egan Range near Sunnyside. These changes in thickness are probably partly the result of post-Joana pre-Chainman erosion, partly the result of differences in original thickness, and partly the result of major faulting. Post-Joana erosion has been recognized in the Eureka area (Nolan and others, 1956, p. 55) and in the Ely area (Langenheim, 1956a). An unconformity at the top of the Joana, however, was not found in Lincoln County.

Age and correlation

The unnamed limestone unit is Early Mississippian in age. It is equivalent to the type Monte Cristo Limestone in the Goodsprings district and probably to the Tin Mountain Limestone (McAllister, 1952, p. 20) in southeast California. The type Joana in the Ely district (Spencer, 1917, p. 26), perhaps the Joana in the Eureka district (Nolan and others, 1956, p. 54-55), and the Mercury Limestone in the Nevada Test Site (Johnson and Hibbard, 1957, p. 357) are probably all equivalent to the Joana Limestone in Lincoln County, that is, to the lower massive part of our map unit. The Bristol Pass Limestone (Westgate and Knopf, 1932, p. 20) is probably equivalent to the lower part of the type Monte Cristo.

The Joana Limestone as mapped by Langenheim (1956a), Kellogg (1963, p. 703), and Reso (1963, p. 911) is equivalent to our unnamed Mississippian limestone map unit. Langenheim and Kellogg recognized three units in the Joana Limestone; only the lowest (the Joana as we recognize it) extends over the Mississippian positive area near Ely. This unit thins westward and disappears near Eureka.

The lower part of the Perdido Formation in the Quartz Spring area (McAllister, 1952, p. 22-25) probably is an age equivalent of the upper (post-Joana) part of the unnamed Mississippian limestone.

In and near Lincoln County, the limestone contains Lower Mississippian (Kinderhook and lower Osage) fossils. The thin-bedded limestone — a unit between 30 and 50 feet thick at the base of the cliff-forming unit — contains abundant Lower Mississippian fossils. These beds might be included in the Pilot Shale by some workers. The fossils in the following collections were identified by J. T. Dutro, Jr. (written communication, 1958) except for the corals and bryozoans, which were identified by Helen Duncan.

USGS upper Paleozoic locality 17437. Thin-bedded limestone at base of Mississippian, hills northwest of Desert Range; lat 37°20′ N., long 115°42′ W.

crinoidal fragments, indet.
echinoid plates, indet.
orthotetid brachiopod, indet.
Chonetes sp.
Spirifer aff. *S. centronatus* Winchell
Punctospirifer? sp.
Camarotoechia? sp.
anbocoelid brachiopod, indet.
ostracode fragments, indet.

USGS upper Paleozoic locality 17438. Basal Mississippian limestone, west side of Desert Range, east of old north-south road, on boundary of Desert Game Range; sec. 34, T. 8 S., R. 57 E., unsurveyed.

Syringopora aff. *S. aculeata* Girty
Cladochonus? sp.
crinoidal fragments, indet.
Fenestella sp. A (large fenestrules)

Fenestella sp. B (small fenestrules)
Penniretepora sp.
rhomboporoid bryozoan, indet.
Leptagonia cf. *L. analoga* (Phillips)
Spirifer aff. *S. centronatus* Winchell
Composita sp.
rhynchonelloid brachiopod, indet.

USGS upper Paleozoic locality 17561. Thin-bedded limestone 30 feet thick below cliff of Mississippian limestone, west side of East Pahranagat Range; sec. 32, T. 6 S., R. 60 E.

Syringopora sp.
echinoderm debris, indet.
Fenestella sp.
Penniretepora sp.
Schuchertella? sp.
"*Avonia*" sp.
"*Dictyoclostus*" sp.
productoid brachiopod, indet.
Spirifer aff. *S. centronatus* Girty
Punctospirifer sp.
Camarotoechia cf. *C. metallica* White

The following Lower Mississippian collections were studied by MacKenzie Gordon, Jr., and Helen Duncan (written communications, 1957, 1963):

USGS locality 16742. Thin-bedded light-gray limestone, southern Schell Creek Range; sec. 13, T. 5 N., R. 63 E., unsurveyed.

Homalophyllites sp.
Vesiculophyllum sp.
Lithostrotionella cf. *L. microstyla* (White)
Leptagonia analoga Phillips
Spirifer cf. *S. gregeri* Weller
Euomphalus (Straparollus) sp. indet.

Helen Duncan states: "The corals are types ordinarily found in the Lower Mississippian rocks * * * of the West."

USGS locality 16741. Limestone, NE¼ sec. 26, T. 5 N., R. 62 E., unsurveyed.

Homalophyllites? sp.
Vesiculophyllum? sp.
crinoid columnals
Spirifer cf. *S. platynotus* Weller
Cleiothyridina sp.
Composita claytoni Hall and Whitfield
Straparollus (Euomphalus) sp. indet.

Helen Duncan states:

"The corals are poorly preserved but almost certainly belong to genera that are commonly found only in the lower half of the Mississippian in this region. The brachiopods look like Early Mississippian types, and the gastropod is one that ordinarily occurs in this association."

USGS collection 21463-PC. Thin-bedded limestone with trilobites from north side of southeast-trending canyon through Chert Ridge, at south base of peak 6090.

Cyathaxonia sp.
crinoid columnals and plates
Chonetes cf. *C. ornatus* Hall
Chonetes aff. *C. multicosta* Winchell
Brachythyris cf. *B. chouteauensis* Weller
Orurithyris sp.
Proetus sp.

This collection, according to Duncan and Gordon, is late Kinderhook or early Osage. The stratigraphic relations of this collection are not clear, however, for it comes from an area of complex structure.

USGS collection 21447-PC. Monte Cristo Limestone from north end of small hill in fold belt under Cambrian thrust plate, 6.5 miles N. 31° E. of intersection of U.S. Highway 93 and Kane Springs Wash.

Vesiculophyllum sp.
crinoid columnals

According to Gordon, the *Homalophyllites-Vesiculophyllum* zone is Early Mississippian (Osage) in age. These beds are equivalent in age to part of the Joana Limestone of the Ely Region.

Three other collections from Mississippian rocks were examined by J. T. Dutro, Jr., and Helen Duncan (written communications, 1959, 1960):

USGS locality 18870-PC. Light- and dark-gray limestone, black dolomite with cherty layers, and pinkish sandy beds; north Pahroc Range, sec. 35, T. 3 N., R. 63 E.

pelmatozoan debris, indet.
Rylstonia sp.
Vesiculophyllum sp.
horn coral, indet.
Chonetes cf. *C. logani* Norwood and Pratten
Camarotoechia sp.
Spirifer sp. (*centronatus-type*)

USGS locality 18876-PC. Light-gray cherty limestone above a shaly interval; north Pahroc Range; sec. 9, T. 3 N., R. 63 E.

pelmatozoan debris, indet.
actinocrinitid(?), genus indet.
Cladochonus sp.
Fenestella sp.
Penniretepora sp.

The forms in 18870-PC are definitely Early Mississippian, and according to Duncan (written communication, 1960) the *Fenestella* sp. in 18876-PC appears to be identical with the one in the following Early Mississippian collection.

USGS collection 18855-PC. Yellow-weathering thin-

bedded limestone at south end of Worthington Range, 10.3 miles N. 10° E. of Tem Piute.

Cyathaxonia sp.
Fenestella sp. (large-meshed form)
Penniretepora sp.

Chainman Shale

Distribution

The Chainman Shale, like the Pilot Shale and the Joana Limestone, was originally defined by Spencer (1917, p. 26) in the Ely district. It is widely recognized in eastern Nevada. The Chainman is thickest and best exposed in the parts of Lincoln County north and west of U.S. Highway 93. Where thick and distinct, the formation was mapped separately from the overlying Scotty Wash Quartzite; these units are too thin to distinguish in the Pahranagat Range and in the Meadow Valley and Delamar Mountains.

Complete sections are exposed on Dutch John and Grassy Mountains in the Egan, Timpahute, and Pahranagat Ranges and in the Meadow Valley and Delamar Mountains. The formation is also exposed in the Fairview, Golden Gate, and Spotted Ranges; in the Worthington Mountains; and on Chert Ridge.

We did not recognize the Chainman Shale or Scotty Wash Quartzite east of Meadow Valley Wash. However, Dobbin (1939, p. 121) reports 150 feet of calcareous sandstone, variegated shale, and thin-bedded limestone between the Mississippian and Pennsylvanian limestones in the Beaver Dam Mountains of southwest Utah. About 200 feet of similar rocks are supposed to be present in the Mormon Mountains according to an unverified report.

Lithology

The nonresistant Chainman Shale is generally poorly exposed, for it is typically in a trough or valley. The most characteristic part of the Chainman Shale is a fissile black carbonaceous shale which makes up the entire formation at the type locality near Ely. The black shale, which we informally call the black shale facies (figs. 4 and 12), forms the bulk of the Chainman Shale over much of Lincoln County. Three informal members of the Chainman can generally be recognized. The black shale facies forms the middle member where all three facies are present; where only two facies are present, it occurs in the upper part of the Chainman.

The lower member of the Chainman Shale, the siltstone facies on figures 4 and 12, is a fairly resistant calcareous siltstone or silty limestone that weathers brown but is commonly black on fresh fracture. It is about 140 feet thick on Grassy Mountain (Langenheim and Peck, 1957), about 200 feet in the Pahranagat Range (Anthony Reso, written communication, 1960), and 225 feet near Kane Springs in the Meadow Valley Mountains (D. H. Duley, written communication, 1957), where it is noncalcareous and varicolored. This unit was also recognized in the southern Egan Range, where it is as much as 300 feet thick (Kellogg, 1959, p. 83). The siltstone facies is 180 feet thick in the Needle Range (Gould, 1959, p. 40) (fig. 12).

Bedded chert is found at or near the base of the Chainman on Grassy Mountain and on the east side of the Timpahute Range, where layers of black, red, brown, gray, and green chert totaling about 60 feet occur in layers as much as 15 feet thick. About 50 feet of bedded black chert at the base of the Chainman Shale forms a dip slope on the east side of Chert Ridge. Bedded dark-gray chert also occurs below a limestone near the top of the Chainman on Chert Ridge. Several thin limestone or quartzite beds sometimes occur near the base of the formation.

The lower siltstone member is overlain by black shale which, near the base, typically contains rusty-weathering disklike concretions that contain disseminated pyrite. The thickness of the black shale is 707 feet in the Meadow Valley Mountains (D. H. Duley, written communication, 1957), 420 feet on Grassy Mountain (Langenheim and Peck, 1957), and about 250 feet in the Timpahute Range. The black shale is largely replaced by varicolored shale in the Spotted Range.

On Grassy Mountain the upper member is a silty shale unit approximately 460 feet thick (Langenheim and Peck, 1957). This unit is poorly exposed; it contains several olive-gray fossiliferous limestone beds, some sandy beds, and much gray shale. The upper part of the Chainman Shale in the East Pahranagat Range contains seven layers of limestone, 10 to 20 feet thick, and one thin quartzite layer; these layers are interbedded with an olive-gray shale. This predominantly gray limy unit is absent in the Meadow Valley Mountains where its place is taken by black shale.

In the Needle Range, Utah (Gould, 1959, p. 39-40) the upper 1,352 feet of the Chainman Shale is predominantly limestone. This unit represents our informal limestone facies (figs. 4 and 12). The upper member of the Chainman in Grassy Mountain and the East Pahranagat Range probably belong to the limestone facies.

In the Egan Range south of Shingle Pass, the formation is entirely olive-brown, gray, and black shale, except for four layers of calcareous shale that total about 90 feet. Shale that weathers brown, reddish- or yellowish-brown, and varicolored is increasingly abundant in southwestern Lincoln County.

A major facies change in the Chainman Shale occurs in the Meadow Valley Mountains where the thick black shale thins drastically in a few miles southeastward and interfingers with thin reddish-weathering shaly lime-

stone and limestone conglomerate that resemble the basal (Indian Spring) member of Longwell and Dunbar (1936) of the Bird Spring Formation. An even more pronounced facies change occurs between the Spotted Range and the Nevada Test Site. Thrust faults or unconformities may be responsible for these apparent facies changes. A probable unconformity occurs at the top of beds, which we correlate with the Chainman Shale in the Arrow Canyon Range and Meadow Valley Mountains, Clark County (Longwell and others, 1965).

Thickness

In Lincoln County the thickness of the Chainman Shale ranges from 200 to 1,000 feet. In the Meadow Valley Mountains, the Chainman thins rapidly southward and eastward from 932 feet on the west side (D. H. Duley, written communication, 1957) to about 200 feet on the east side, the same as in the Arrow Canyon Range, Clark County.

The Chainman Shale is between 900 and 1,000 feet thick in the southern Egan Range (Kellogg, 1960, p. 193), and about 1,000 feet thick on Grassy Mountain and in the Fairview and Spotted Ranges. The exposed section of the Chainman Shale and Scotty Wash Quartzite in the Pahranagat Range is about 800 feet, but the total thickness probably approaches 1,000 feet. The equivalent rocks at the base of the Bird Spring Formation are about 100 feet thick in the Spring Mountains of Clark County (Rich, 1960).

Age and correlation

The Chainman Shale is Late Mississippian in age. It is approximately equivalent to the Peers Spring Formation of Westgate and Knopf (1932, p. 20-21), who assigned it an Early and Late Mississippian Age; that assignment may be in error, however, for Langenheim and Peck (1957) believe that the Early Mississippian fossils at Peers Spring came from infaulted blocks of the Bristol Pass Limestone.

The Chainman Shale, as we mapped it, is correlated with the type Chainman in the Ely district (Spencer, 1917, p. 26) and with the Chainman in the Eureka district (Nolan and others, 1956, p. 59-60). Recent work by Mackenzie Gordon, Jr. (written communication, 1963), however, indicates that the Chainman in the Eureka district is older than the type Chainman and may actually be a temporal equivalent of the Joana Limestone locally. More strictly, the middle unit of fissile black shale in Lincoln County is the lithogenetic equivalent of the type Chainman Shale, because Langenheim (1956a) states that the upper sandy and lower calcareous silty units are missing at Ely. The Chainman is tentatively correlated with the upper part of the Eleana Formation in the Nevada Test Site (Helen Duncan, written communication, 1963). At least part of it is equivalent to the basal member of the Bird Spring Formation of Longwell and Dunbar (1936, p. 1203) in Clark County. We believe that the Chainman Shale probably can be correlated with the lower part (unit 1) of the Rest Spring Shale and the upper part of the Perdido Formation in the Quartz Spring area (McAllister, 1952, p. 24-26). Hall and MacKevett (1958, p. 9) correlate the Lee Flat Limestone of the Darwin quadrangle with the upper part of the Perdido Formation and the Rest Spring Shale at Quartz Spring and with the Chainman Shale in the New York Butte quadrangle, California.

The Chainman Shale is assigned to the Upper Mississippian (Chester) on the basis of fossils collected in the Pahranagat Range, on Grassy Mountain, in the Timpahute Range, and fossils reported from the Chainman by other workers. Langenheim and Peck (1957) at Dutch John Mountain, D. H. Duley (written communication, 1957) in the Meadow Valley Mountains, Reso (1963, p. 912) in the Pahranagat Range, and Kellogg (1960, p. 193) in the Egan Range, report *Cravenoceras hesperium* of Chester Age in the Chainman Shale. D. H. Duley (written communication, 1957) found *Rhipidomella nevadensis* in the upper part of the Monte Cristo as well as in the Chainman. According to Mackenzie Gordon, Jr., *Rhipidomella nevadensis* straddles the Mississippian-Pennslyvanian boundary (p. 56).

Table 1 lists the fossils identified by Gordon and Duncan in eight collections from the upper part of the Chainman Shale and the lower part of the overlying limestone beds. Collection 21456-PC, characterized by an undescribed species of *Diaphragmus,* is the highest Mississippian assemblage known from the Great Basin. Specimens in collections 21441-PC and 21444-PC were poorly preserved but were tentatively assigned a Late Mississippian Age. The remaining collections are late Late Mississippian in age but are not as young as 21456-PC.

The following three collections come from a little lower down in the Chainman than the preceding collections:

National Park Service loc. F-43. Chainman Shale on the southeast side of Cane Springs Wash, Meadow Valley Mountains, 24 miles southwest of Elgin, Lincoln Co., Nevada. (Collector Ed Schenk, June 1940.)

Diaphragmus n. sp.
Leirohynchus carboniferum (Girty)
Phestia cf. *P. vaseyana* (McChesney)
Edmondia sp.
Edmondia? sp.
Glabrocingulum quadrigatum Sadlick and Nielson
Rayonnoceras aff. *R. solidiforme* Croneis
Dolorthoceras sp.

Table 1. Late Mississippian collections from localities in and near Lincoln County.

Species	Collection							
	17262-PC	21440-PC	21441-PC	21444-PC	21455-PC	21456-PC	21458-PC	21460-PC
Corals:								
Caninoid gen. and sp. indet.	X							
Longiclava? sp.		X						
horn coral, gen. and sp. indet.				X	X			
Bryozoans:								
Eridopora sp.		X						
Fistuliporoid, gen. and sp. indet.		X	X					
Fistuliporoid, encrusting form	X							
Fistuliporoid? sp. indet.				X				
Trepostomatous, small encrusting form	X							
Trepostomatous, ramose form						X		
Trepostomatous sp. indet.				?				X
Stenoporoids, gen. and sp. indet.		X	X					X
Fenestella sp.				X				X
Dyscritella? sp.		X						
Cystodictya sp.		X						
Rhomboporoid, gen. and sp. indet.		X	X	X		X		
Streblotrypa sp.		X	X					
bryozoan, encrusting form, indet.					X			
Crinoids:								
crinoid columnals	X	X				X		
Brachiopods:								
Rhipidomella nevadensis (Meek)	X	X	?	X				X
Schizophoria sp. indet.	X							
Strophomenoid, gen. and sp. indet.		X			X		X	
Inflatia sp.	X				X	X	X	
Flexaria sp.	X	X			X		X	X
Diaphragmus phillipsi (Norwood and Pratten)			?		X		X	X
Diaphragmus aff. *D. phillipsi* (N. and P.)							X	
Diaphragmus n. sp. aff. *D. cestriensis* (Worthen)						X		
Ovatia sp. (medium-sized form)					X	X	X	
Ovatia sp. (small form)	X				X			
Spirifer aff. *S. leidyi* Norwood and Pratten		X						X
Spirifer sp. indet.	X		X	X			?	
Reticulariina campestris (White)		X	?	X				
Torynifer sp.						X		
Eumetria cf. *E. verneuiliana* (Hall)					X	X		
Cleiothyridina cf. *C. suborbicularis* (Hall)		X						
Cleiothyridina sp. indet.					X			
Composita sp.	X					X		
Composita? sp. indet.		X	X		X			
Beecheria sp. indet.					X			
Pelecypods:								
Myalina sp.								X
pelecypods indet.							X	
Gastropods:								
high-spired gastropod steinkern								X
Platyceras? sp. indet.					X			
Trilobites:								
glabella and fragmental pygidium					X			
Barnacles:								
borings in *Rhipidomella*	X	X						
Plants:								
Alga?	X							
reed-like fragments							X	

Table 1.—Continued

Field notes on USGS localities:

17262-PC. Clark County. Yellowish, brownish, and reddish limestone, Meadow Valley Mountains, 200 yards north of US Highway 93, 13.5 miles northwest of Glendale, Nevada.

21440-PC. Easternmost limestone outcrop in large wash, just south of Nevada Highway 25, north end of the East Pahranagat Range; NE¼ sec. 26, T. 5 S., R. 59 E., unsurveyed.

21441-PC. Bioclastic (Chainman?) limestone beneath klippe of Ordovician rocks, a quarter of a mile north of Nevada Highway 25, south end of Timpahute Range; SW¼ sec. 23, T. 4 S., R. 56 E.

21444-PC. Yellowish-brown (Chainman?) limestone beneath klippe of Devonian rocks; Timpahute Range; sec 23, T. 4 S., R. 56 E.

21455-PC. Gray medium- to coarse-grained limestone (Pennsylvanian?) on east side of Grassy Mountain, a quarter of a mile west of old road, 1.5 miles west of US Highway 93, 4 miles NNW of Pony Springs.

21456-PC. Upper Mississippian or Lower Pennsylvanian limestone up gully from Prospect in Chainman Shale, half a mile NW of 21455-PC, 1.5 miles west of US Highway 93, 4.4 miles NNW of Pony Springs.

21458-PC. Chainman Shale at prospect about 0.2 mile down gully from 21456-PC, 1.3 miles west of US Highway 93, 4.4 miles NNW of Pony Springs.

21460-PC. Nye County. Pennsylvanian limestone under overthrust Pennsylvanian limestone, south side of hill on west side of the northern Seaman Range, 13.3 miles N. 55° W. of lat 38°00′ N., long 115°00′ W.

Mitothoceras perfilosum Gordon
Mitothoceras crebriliratum (Girty)
Orthoconic nautiloid indet.
Cravenoceras hesperium Miller and Furnish
Cravenoceras n. sp.

Gordon (written communication, 1963) states:

"The presence of *Diaphragmus* n. sp. and *Glabrocingulum quadrigatum* suggests that this faunule can be correlated roughly with the upper part of the *Cravenoceras hesperium* zone in the Burbank Hills. The presence of *C. hesperium* suggests a correlation with the upper part of the Perdido Formation of the Quartz Springs area."

USGS loc. 21465-PC. Limestone at south end of Coal Valley, north end of volcanic ridge. Photo 10557.

Cystodictya sp.
Fenestella sp.
Polypora sp.
Septopora sp.
Penniretepora sp.
Stenoporoid bryozoan
rhomboporoid bryozoan
crinoid columnals
Heteralosia? sp. indet.
Flexaria sp.
marginiferid brachiopod indet.
Ovatia sp.
Leiorhynchus sp.
Reticulariina campestris (White)
Hustedia sp.
Cleiothyridina sp.
ostracodes

Of this collection Gordon (written communication, 1963) says:

"Most of the fossils in this collection belong in relatively long-ranging genera. However, both the bryozoans and brachiopods in this assemblage suggest Mississippian, rather than Pennsylvanian affinities. The age of this collection is probably Late Mississippian (Chester)."

The fossils in this collection, identified by Gordon (written communication, 1958), cannot be closely dated, but field evidence suggests that they are from the upper part of the Chainman Shale.

USGS collection 21438. Thin-bedded limestone on south side of large wash, about half a mile east of Nevada Highway 25, north end of East Pahranagat Range; sec. 26, T. 5 S., R. 59 E., unsurveyed.

fistuliporoid bryozoan, ramose form
fistuliporoid bryozoan, multifoliate form
Fenestella sp.
Polypora sp.
trepostomatous bryozoan
stenoporoid bryozoan
rhomboporoid bryozoan
crinoid columnals
Ovatia sp. indet.
Heteralosia? sp.
Inflatia cf. *I. bilobata* Sadlick
Echinoconchus? sp. indet.
Flexaria sp.
Chonetes sp. indet.
Myalina sp. indet.

Scotty Wash Quartzite

Distribution

The Scotty Wash Quartzite is the least continuous Paleozoic unit in Lincoln County. The formation was first defined by Westgate (Westgate and Knopf, 1932, p. 21) from incomplete and poorly exposed sections in the Fairview Range where it consists of reddish quartzite and some shale and limestone. We included in the Scotty Wash Quartzite all the rocks between the continuous shale in the Chainman and the continuous limestone section of Pennsylvanian Age. The Scotty Wash was mapped separately where it was thick enough to be distinguished from the Chainman Shale on the map.

Complete unfaulted sections are exposed only in the southern Egan and Timpahute Ranges and on Dutch John Mountain, but extensive exposures are found in the Fortification and Fairview Ranges; smaller outcrops are

present in the Seaman Range, in the Worthington Mountains, and on Mount Irish. The formation was not mapped separately south of Mount Irish, except for one small area on the east side of Chert Ridge, west of the Spotted Range. A feather edge of the Scotty Wash is present in the Pahranagat and Spotted Ranges and in the Delamar and Meadow Valley Mountains. The formation disappears as a mappable unit when it interfingers with the underlying shale and the overlying limestone. Locally, pre-Bird Spring erosion may have removed the quartzite in the southeastern part of the county.

Lithology

The relative proportions of quartzite and shale and the degree of cementation of the quartzite are highly changeable. The inferred facies changes are shown in figure 12. In most places the formation consists of about equal portions of inconspicuous olive-brown, gray, or red shale, with some thin limestone beds, and yellow to dark-red thin-bedded shaly crossbedded sandstone, quartzitic sandstone, and quartzite that typically weathers to a red or red-brown sandy soil. Ripple marks are common. The shales are usually covered with quartzite talus.

In the southern Egan Range near Sunnyside, three resistant quartzite or sandstone ledges each about 100 feet thick are separated by shaly intervals as thick as 200 feet. According to Kellogg (1959, p. 84-85), the lower 170 to 225 feet are quartz sandstone. This is overlain by 80 feet of shale and then by 80 feet of sandstone. In the Fortification Range the Scotty Wash Quartzite is a grayish-orange to yellowish-brown calcareous sandstone. On Grassy Mountain, the lower 75 feet of the Scotty Wash comprise a cliff-forming quartzite that is overlain by about 140 feet of less resistant, finer grained rock (Langenheim and Peck, 1957).

We include in the Scotty Wash 200 to 300 feet of yellowish-brown or reddish limestone, sandstone, and siltstone (the so-called red limestone facies, figs. 4 and 12) that Kellogg includes in the Ely Limestone. At several localities in Nye County, a few miles west of the White River and north of lat 38° N. alternating dark-red and olive-green crossbedded quartzite, red fossiliferous limestone, and orange-brown siltstone are tentatively assigned to the uppermost part of the Scotty Wash. Fossils from these red limestones near Fox Mountain, Nye County, show that they are in the *Rhipidomella nevadensis* zone. The typical Scotty Wash may be absent in these areas because of facies changes or pre-Pennsylvanian erosion. Westgate and Knopf (1932, p. 21-23) assigned similar fossiliferous rocks of Late Mississippian Age in the Silverhorn area to the base of the Bailey Spring Limestone. All these rocks make up the red limestone facies that overlies the quartzite in the Scotty Wash in the northern part of Lincoln County.

Thickness

In Lincoln County the Scotty Wash Quartzite ranges from zero to 800 feet in thickness. The thickness in the Egan Range increases from perhaps 400 feet near the White Pine county line to about 800 feet near Sunnyside. It is about 500 feet thick in the Timpahute Range, but only about 200 feet thick on the east side of Mount Irish. Westgate and Knopf (1932, p. 21) estimated a thickness of 700 feet in the Fairview Range near Silverhorn and 1,000 feet on Grassy Mountain. The latter figure seems excessive when compared to a thickness of 215 feet estimated by Langenheim and Peck (1957) for the same locality. The thickness of the map unit on Grassy Mountain is about 300 feet. Reso (1963, p. 912) measured 263 feet of beds in the Pahranagat Range which he assigns to the Scotty Wash; we found this unit too thin to map separately.

According to D. H. Duley (written communication, 1957) the Scotty Wash Quartzite on the west flank of of the Meadow Valley Mountains is 116 feet thick, compared to only 30 feet in the Arrow Canyon Range, in Clark County. Neither the Scotty Wash Quartzite nor the Chainman Shale is present east of Meadow Valley Wash, unless thin sandstone lenses at the bases of the Bird Spring Formation are equivalent.

Age and correlation

The fossils collected by Westgate in the Silverhorn and Dutch John areas show that the Scotty Wash Quartzite lies entirely within the *Rhipidomella nevadensis* zone of the uppermost Mississippian and the lowermost Pennsylvanian. According to Reso (1963, p. 912) the formation in the Pahranagat Range is Upper Mississippian, but we found Pennsylvanian fossils in beds we thought to be equivalent to the red limestone facies in that section (p. 56). D. H. Duley (written communication, 1957) states:

> "The Scotty Wash Quartzite, Meadow Valley Mountains, appears more closely related faunally with the overlying Bird Spring Formation but it is placed in the Mississippian on faunal evidence from lithologically equivalent formations."

Kellogg (1960, p. 193) assigns the Scotty Wash in the southern Egan Range a Chesterian age.

The following two fossil collections are from the red limestone facies of the Scotty Wash Quartzite just below the base of the Pennsylvanian limestone sequence near Fox Mountain, Nye County, 3 miles west of Lincoln County. They were identified by J. T. Dutro, Jr., and Helen Duncan (written communication, 1959) and Mackenzie Gordon, Jr. (written communication, 1963).

USGS locality 18868-PC. Nye County, 4 miles S. 47° W. of lat 38°15′ N., long 115°00′ W.

Cystodictya sp. indet.
Rhipidomella nevadensis (Meek)
Rugoclostus sp.
Spirifer sp.
Cleiothyridina sp.
Reticulariina campestris (White)
terebratuloid brachiopods, undet.

USGS locality 18869-PC. Nye County, 4.3 miles S. 54° W. of lat 38°15′ N., long 115°00′ W.

echinoderm debris, indet.
trepostomatous bryozoans, undet.
rhomboporoid bryozoans, undet.
Fenestella sp.
Polypora sp.
Orbiculoidea? sp.
Rhipidomella nevadensis (Meek)
Spirifer sp.
Cleiothyridina sp.
Reticulariina campestris (White)
Flexaria cf. *F. arkansana* (Girty)
Punctospirifer sp.

Collection 18868-PC represents the basal Pennsylvanian part of the *Rhipidomella nevadensis* zone and 18869-PC represents the Upper Mississippian part of the same zone (see p. 56).

A third collection from the red limestone facies exposed at the south end of Fox Mountain, Nye County, was also assigned to the Upper Mississippian by Gordon and Duncan.

USGS collection 21457-PC. Nye County. Limestone from red shale and silt sequence with a few quartzite and limestone interbeds, 6 miles S. 26° W. of lat 38°15′ N., long 115°00′ W.

Fenestella sp.
trepostomatous bryozoan, indet.
crinoidal debris
echinoid spine
Rhipidomella nevadensis (Meek) ?
Chonetes sp.
Inflatia sp.
Ovatia sp.
productoid brachiopod, indet.
Leiorhynchus carboniferum Girty (including var. *polypleurum*)
Spirifer sp. indet. (fragment)
Composita? sp. indet.
Cravenoceras? sp. indet. (Juvenile)

The Scotty Wash Quartzite is correlated with the Diamond Peak Formation in the Eureka district (Nolan and others, 1956, p. 60-61), with the upper part of the Eleana Formation in the Nevada Test Site (Poole and others, 1961), and perhaps also with part of the Bird Spring Formation (Longwell and others, 1965, p. 30) in Clark County.

PENNSYLVANIAN AND PERMIAN SYSTEMS

The limestone beds of Pennsylvanian and Permian Age have not generally been divided by workers in eastern and southern Nevada because of the lack of a persistent lithologic break near the Pennsylvanian-Permian time line. In the northern part of Lincoln County, we found it feasible to map a lithologic break which we thought, at least in a general way, separated the Pennsylvanian and Permian limestones. However, the sparse fossil evidence seems to indicate that this lithologic break markedly trangresses time lines, becoming progressively older westward. It is at least 200 to 300 feet stratigraphically below the Pennsylvanian-Permian boundary in the southern Schell Creek and North Pahroc Ranges and on Grassy Mountain. Farther west in the southern Egan and Golden Gate Ranges, a similar sharp lithologic break occurs more than 500 to 600 feet below the boundary. East of the Schell Creek Range, the lithologic break appears to occur several hundred feet up in the Permian. In the Needle Range, Utah (Gould, 1959, p. 35-36), the lithologic change is 790 feet stratigraphically above the Pennsylvanian-Permian boundary. The proportion of sand in the rocks above this lithologic break increases westward. It was not feasible to distinguish on the map any Permian rocks that may be present in the west-central and southeastern parts of the county. It is apparent that the Pennsylvanian and Permian rocks cannot yet be reliably distinguished on lithologic grounds in this part of the Great Basin.

These Pennsylvanian and Permian predominantly carbonate rocks are more restricted in their distribution than the older Paleozoic rocks. Complete sections are exposed only in the southeast corner of the county. The thickness was probably 3,500+ to more than 5,000 feet in northern Lincoln County before pre-Cenozoic erosion. In the Mormon Mountains this interval is much thinner. The thickness increases rapidly westward, across a northeast-striking hinge line near Meadow Valley Wash, from 1,500 to 1,800 feet in the southern Mormon Mountains to about 4,300 feet in the Meadow Valley range. Langenheim and others (1960) reported the thickness of the incomplete section in the Arrow Canyon Range, Clark County, as 3,434 feet. In northern Lincoln County thickening is accompanied by a great increase in the proportion of clastic rocks in the upper part of the section. In Clark County these rocks (Bird Spring Formation) thicken still more southwestward to more than 5,000 feet near Indian Springs (Longwell and others, 1965, p. 32). Rich (1960) measured a section near Lee Canyon, Spring Mountains, that was more than 6,900 feet thick; this sec-

tion was predominantly carbonate, and it had no major lithologic breaks.

The sandy facies of the Pennsylvanian were probably derived from Late Pennsylvanian positive areas. The sandy facies in the upper part of the Bird Spring Formation (Mississippian, Pennsylvanian, and Permian) along Meadow Valley Wash probably were derived from a positive area in the southeast, perhaps from an area where Lower Cambrian rocks crop out. In northwestern Lincoln County where it adjoins Nye County, the sandy facies might have been derived from a positive area to the northwest, although a positive area also existed in northeastern Lincoln County. The sand was probably derived from Upper Mississippian rocks.

Pennsylvanian Limestone

Distribution

Pennsylvanian limestone is widely distributed in the north half of Lincoln County. It crops out in the Fairview, southern Schell Creek, southern Egan, North Pahroc, Golden Gate, Timpahute, and Pahranagat Ranges, and on Grassy Mountain and the north side of Mount Irish, all areas where it is mapped separately from sandstone or silty limestone of Late Pennsylvanian or Permian Age. Pennsylvanian limestone crops out in the Fortification Range east of the Sheep Range, in the southern Delamar and Meadow Valley Mountains, and is widely exposed in the southeast corner of the county but it cannot be separated from limestone of Permian Age in these areas. Complete unfaulted sections do not occur in areas where the Pennsylvanian and Permian limestones can be separated.

Lithology

The lower contact is apparently conformable; it is clear cut in most of the county. The contact between the base of the continuous limestone section and the top of the red limestone facies of the Scotty Wash Quartzite (fig. 12) was selected as the lower contact. The upper contact, however, represents a lithologic break that does not persist throughout the county and transgresses time lines. An unconformity was not recognized in Lincoln County, but an inconspicuous one apparently occurs between the Middle Pennsylvanian and Permian (Wolfcamp) beds in the Confusion (Hose and Repenning, 1959, p. 2167) and Needle (Gould, 1959, p. 11) Ranges, Utah, and in the Eureka district, Nevada (Nolan and others, 1956, p. 63). A similar inconspicuous unconformity separates the Middle (Des Moines) and Upper (Missouri) Pennsylvanian rocks near the SE corner of T. 8 N., R. 64 E. in the southern Schell Creek Range (Steele, 1960, p. 93).

The Pennsylvanian limestone unit consists of alternating massive dark-gray cherty limestone layers that weather light gray, and thin-bedded or platy, yellowish-brown silty or limestone dolomite layers that weather gray, brown, or pale reddish gray. The unit characteristically weathers to form steplike slopes. The following incomplete estimated section in the southern Schell Creek Range, about 7 miles south of Patterson Pass, shows the characteristic lithology of the unit.

	Thickness (feet)
Permian limestone (approximate contact)	
Pennsylvanian limestone:	
Yellow-brown sandy limestone and sandstone	30
Gray thin-bedded limestone	60
Massive gray limestone with 4-inch diameter productid	10
Covered	50
Gray rough-weathering silty and sandy limestone	50
Brown fine-grained sandstone	30
Gray limestone with brachiopods	10
Brown, yellow-brown, and orange sandstone	30
Pink, pale-brown, and yellow-brown fossiliferous argillaceous limestone. USGS fossil collection 17264 collected from here to top of section	100
Massive gray limestone. USGS fossil collection 17263 collected through about 700 feet below here	30
Flaggy limestone	70
Massive gray limestone	50
Gray limestone, cherty brown-weathering limestone, and some sandy limestone	80
Massive gray limestone	30
Covered	30
Massive gray limestone	30
Cherty brown-weathering limestone	50
Covered	40
Gray silty limestone with abundant brachiopods and crinoid stems with star-shaped central perforations	100
Gray limestone with abundant ¾-inch-diameter crinoid stems and bryozoa	50
Platy gray limestone with some minute fusulinids	40
Cherty brown-weathering limestone with a 6-inch pelecypod, 3-inch brachiopods, corals, and *Chaetetes milleporaceus?*	80
Massive cherty gray limestone, ledges from 20 to 30 feet thick separated by 5- to 7-foot layers of fossiliferous, thin-bedded cherty limestone	210
Massive gray 6-foot limestone with some pink chert nodules that separates two massive gray limestone ledges that contain 30 to 40 percent chert	66
Alternating massive and thin-bedded gray limestone layers with milky pink chert nodules	40
Chiefly partly covered, thin-bedded, medium-gray, cherty, fossiliferous limestone with a few massive limestone beds, 6 feet thick	130
Fault	
Total	1,496+

Fusulinids occur as much as 1,000 feet below the top of the Pennsylvanian rocks. The upper 500 feet is nearly chert free and the uppermost 230 feet is sandy. Probably 700 to 1,000 feet of alternating thin-bedded platy and massive cherty limestones are faulted out of the base of this section.

The lower contact of the Pennsylvanian limestone is often covered. In the southern Schell Creek Range, along the Silver King and Sunnyside road 2 miles northwest of Silver King Mountain, the lowest exposed beds are thin-bedded dark-gray fossiliferous limestones. Similar rocks about 6 miles to the northeast probably are only a few tens of feet stratigraphically above the Scotty Wash Quartzite. In the southern Egan Range north of Trough Spring Canyon, 25 to 50 feet of the section between the Scotty Wash Quartzite and the white-weathering gray cherty limestone are covered. Above this hidden contact is a thick monotonous sequence of limestone beds, some with abundant rusty-weathering chert, alternating with orange- to buff-weathering, silty, platy limestone.

Kellogg (1960, p. 193) divided the Pennsylvanian section in the southern Egan Range into three parts: two members of the Ely Limestone and an unnamed sandstone unit that overlies the Ely. The lower member is predominantly fine-grained gray limestone 1,355 feet thick. It includes 200 to 300 feet of yellowish-orange interbedded limestone, mudstone, and sandstone that we believe is part of the Scotty Wash Quartzite. The upper member is 1,653 feet thick. It is yellow, brown, or pink silty limestone and siltstone. The unnamed overlying sandstone unit of probable Middle Pennsylvanian Age, which is 517 feet thick, resembles the sandstone unit in the Golden Gate Range described below. The upper contact of the sandstone is nowhere exposed.

The Pennsylvanian rocks in the Golden Gate Range near the Nye County line consist of two units; neither the top nor the bottom of this section is exposed .The lower 500 feet is predominantly gray cherty limestone (as much as 60 percent being brown-weathering chert) and the upper approximately 600 feet is predominantly sandstone — a yellowish-brown and brownish, fine-grained, calcareous sandstone — which includes a few thin beds of dark limestone containing small Middle Pennsylvanian fusulinids.

The Pennsylvanian rocks exposed in the southeast corner of Lincoln County are shelf deposits laid down near the margin of the miogeosyncline. These rocks, which are equivalent to the Bird Spring Formation of Mississippian, Pennsylvanian, and Permian Age, are only about 1,000 feet thick in the Mormon Mountains. Upper Pennsylvanian rocks are probably absent in the shelf facies, and it is not possible to pick the Mississippian-Pennsylvanian or Pennsylvanian-Permian boundaries on the basis of lithologic breaks. The following crude estimated section describes the thin shelf facies of the Bird Spring in the southern Mormon Mountains.

	Thickness (feet)
Permian red beds (approximate contact)	
Bird Spring Formation:	
Alternating beds of rough-weathering gray and brown limestone and platy layers of sandy and cherty limestone or dolomite	100-150
Light reddish-brown and brownish-gray thin-bedded sandy and shaly limestone	150
Rough-weathering, gray and pinkish-gray, cherty limestone with pinkish-gray sandy limestone at top. Contains 40 percent large, irregular, dark brownish-black-weathering, pinkish-gray chert nodules	240-260
Gray massive limestone and interbedded reddish and brownish shaly fossiliferous limestone	100
Light-brown-weathering, shaly and sandy limestone	300
Gray limestone with abundant black chert nodules	40
Total	930-1,000±

A few miles west of the section just described, the Bird Spring is considerably thicker. Along Meadow Valley Wash it contains much brownish and reddish, fine-grained, calcareous or dolomitic, silty sandstone in layers up to 200 feet thick. The sandstone is interbedded with layers of gray limestone up to 60 feet thick. The sandstone is underlain by gray and pinkish-gray limestone which contains as much as 40 percent chert.

The publications of Westgate and Knopf (1932, p. 21-23) and Longwell and Dunbar (1936) contain additional lithologic descriptions of the Pennsylvanian rocks.

Thickness

In the Egan Range, the incomplete section of Pennsylvanian rocks is 3,525 feet (Kellogg, 1960, p. 193), where an unbroken section of carbonate rocks 3,008 feet thick is overlain by 517 feet of sandstone. Incomplete sections of Pennsylvanian rocks exposed in nearby ranges have the following estimated thicknesses: southern Schell Creek Range, 2,200 feet; Golden Gate Range, 2,600 feet; North Pahroc Range, 2,500 feet; Pahranagat Range, 764 feet (Reso, 1963, p. 912). The Pennsylvanian rocks in the Nevada Test Site (Johnson and Hibbard, 1957, pl. 33) are about 2,900 feet thick. On the basis of regional correlations (fig. 3), we estimate that approximately the same thickness was once present in southwestern Lincoln County. The total thickness of the Bird Spring Formation now present in the Mormon Mountains, as indicated by the section above, may be as little as 1,000 feet. Rich (1960)

reported 2,500 feet of Pennsylvanian rocks in the Spring Mountains in Clark County; this section represents continuous deposition in Pennsylvanian time.

Age and correlation

The limestone unit is Early, Middle, and Late Pennsylvanian in age. It is approximately equivalent to the Pennsylvanian part of the Bailey Spring Limestone in the Fairview Range (Westgate and Knopf, 1932, p. 21-23) and the Ely Limestone as defined by Spencer (1917, p. 27-28) in the Ely district. The upper sandstone unit in the Golden Gate Range appears to be Middle Pennsylvanian, but lithologically it resembles the upper part of the original Ely(?) Limestone that Pennebaker (1932) included in his Rib Hill Formation of Permian Age, and also the unnamed sandstone unit of Late Pennsylvanian Age in the southern Egan Range (Kellogg, 1960, p. 193). The unit is also equivalent to the Pennsylvanian part of the Bird Spring Formation in southern Lincoln and northern Clark Counties, to the Pennsylvanian parts of the Tippipah Limestone in the Nevada Test Site (Johnson and Hibbard, 1957, p. 360-363), and to the Oquirrh Formation in Utah.

Kellogg (1959, p. 93) recognized counterparts of all three members of the Moleen Formation, and of the Tomera Formation of Dott (1955, p. 2234-2248) in the Pennsylvanian rocks of the southern Egan Range. Dott's formations were named from exposures in north-central Nevada.

The limestone unit contains Lower, Middle, and Upper Pennsylvanian fossils that were identified by Mackenzie Gordon, Jr., Helen Duncan, and R. C. Douglass (written communications, 1958, 1959, 1963). The lowest part of the limestone unit is in the upper or Pennsylvanian part of the *Rhipidomella nevadensis* zone. At several localities, however, Helen Duncan (written communication, 1963) reports that the lower beds of the Ely Limestone contain a Late Mississippian faunal assemblage. According to Mackenzie Gordon, Jr. (written communication, 1963) the Mississippian-Pennsylvanian boundary is drawn in the *Rhipidomella* zone; those beds containing *Diaphragmus, Flexaria* aff. cf. F. *arkansana* (Girty), and *Torynifer* belong in the Mississippian and those beds containing *Rugoclostus* and a largely undescribed associated fauna of productoids belong in the Pennsylvanian.

The following four collections were assigned an Early Pennsylvanian Age on the presence of *Rugoclostus:*

USGS collection 21439-PC. Thin-bedded limestone at or near base of the Pennsylvanian, north side of wash near Nevada Highway 25, north end of East Pahranagat Range; NE¼ sec. 26, T. 5 S., R. 59 E., unsurveyed.

stenoporoid bryozoan
Fenestella sp.
Rhabdomeson sp.
Streblotrypa sp.
crinoid columnals
strophomenoid brachiopod, indet.
Rugoclostus aff. *R. semistriatus* (Meek)
Reticulariina campestris (White)?
Spirifer occiduus Sadlick
Cleiothyridina cf. *C. pecosi* (Marcou)
myalinid? indet.

USGS collection 21448-PC. Lower several hundred feet of Pennsylvanian limestone, southern Delamar Mountains; NW¼ sec. 17, T. 10 S., R. 64 E., unsurveyed.

Orygmophyllum? sp.
Multithecopora sp.
Fenestella 2 sp.
trepostomatous bryozoans, indet. fragments
stenoporoid bryozoan, gen. undet.
crinoid columnals
Rugoclostus sp. A
"Marginifera" cf. *"M." roemeri* Girty
Flexaria? sp.
Linoproductus sp. A
Reticulariina campestris (White)
Spirifer occiduus Sadlick
Composita? sp. indet.

USGS collection 21450-PC. Limestone from crest of isolated hill at north end of Pahranagat Range, south side of Nevada Highway 25; 6 miles S. 63° W. of Crystal Springs.

crinoid columnals
Rhipidomella nevadensis (Meek)
Rugoclostus sp.
Flexaria sp.
Antiquatonia? sp. indet.
Cleiothyridina? sp. indet.

USGS collection 21461-PC. Pennsylvanian limestone, probably near base of unit, from west side of north Seaman Range, Nye County; 3.5 miles northwest of Sharp-Pioche road through Timber Mountain Pass.

Amplexizaphrentis sp.
large encrusting fistuliporoid bryozoan
Fenestella sp.
encrusting stenoporoid bryozoan
Hederella sp. (encrusting on productoid shell)
crinoid columnals
Rugoclostus sp.
Linoproductus sp. (small)

Spirifer occiduus Sadlick?
Reticulariina campestris (White)?
Cleiothyridina sp. indet.
Composita sp. indet.
Hustedia sp.
trilobite glabella

The fossils in collection 21439-PC come from an interval of brown siltstone, red clastic limestone, and gray shale 163 to 263 feet thick which Anthony Reso (written communication, 1960) assigns to the Scotty Wash. According to Gordon, the association of *Rhipidomella nevadensis* (Meek) with *Rugoclostus* in collection 21450-PC suggest an early Early Pennsylvanian Age for that assemblage.

Two collections which contain Early and early Middle Pennsylvanian fossils were collected from the section exposed in the Schell Creek Range on the east side of Cave Valley.

USGS collection 17263-PC. Sample collected over about 700 feet of alternating layers of fossiliferous and cherty limestone, southern Schell Creek Range; sec. 11, T. 7 N., R. 64 E.

Fusulinella sp.
zaphrentoid coral, indet.
caninoid coral
syringoporoid coral
Cystodictya sp.
Fenestella sp.
Polypora sp.
rhomboporoid bryozoan
Krotovia sp.
Grandaurispira? sp.
"*Marginifera*" cf. "*M.*" *roemeri* Girty
Flexaria sp.
Antiquatonia? sp. indet.
Leiorhynchus sp. indet.
Rhynchopora sp.
Reticulariina campestris (White)
Spirifer sp. indet.
Cleithyridina sp.
terebratulid brachiopod, indet.
Limipecten sp.

This collection contains fusulinids of late Atokan Age, according to Raymond Douglass. These are all in a single float block of slightly different matrix from the rest of the collection. The marginiferid productoid brachiopod which may be "*Marginifera*" *roemeri* Girty, described originally from the Morrowan of Texas is associated with limestone nodules perhaps from shale. The bryozoans, *Leiorhynchus*, *Spirifer*, *Reticulariina*, and the terebratuloid come from a more granular matrix, whereas that of the *Limipecten* appears irregularly platy. The syringoporoid coral and *Cleiothyridina* are in chert. The fossils represent a mixed collection of Early and early Middle Pennsylvanian Age.

USGS locality 17264. Sample collected over about 370 feet of alternating reddish-orange shaly and platy limestone and yellowish sandstone that overlies locality 17263.

Fusulinella sp.
Fenestella sp.
Septopora sp.
crinoid columnals
Orbiculoidea sp.
Chonetes sp.
Linoproductus sp.
"*Marginifera*" cf. "*M.*" *roemeri* Girty
Spirifer occiduus Sadlick
Spirifer aff. *S. brazerianus* Girty
Limipecten sp.
Euconospira sp.

The fusulinid is, according to Raymond Douglass, a late Atokan species. It is a weathered chip, without any sign of fresh break, of fine-grained brownish-gray limestone similar to the fragment in collection 17263 which contains the same species. The brachiopods, according to Gordon, include the Early and Middle Pennsylvanian species *Spirifer occiduus* Sadlick, a Late Mississippian form, *Spirifer* aff. *S. brazerianus* Girty, and a marginiferid productoid very close to the Early Pennsylvanian (Morrowan) species "*Marginifera*" *roemeri* Girty. The platy impure limestone with bryozoan fronds and *Limipecten* resembles that in collection 17263.

One collection from the Bird Spring equivalent of the Pennsylvanian limestone unit in the southern part of Lincoln County was assigned to the Middle Pennsylvanian (Desmoinesian).

USGS collection 21451-PC. Limestone from the southeast end of isolated ridge (Coyote Spring Hills) between the Sheep Range and U.S. Highway 93; sec. 34, T. 10 S., R. 62 E., unsurveyed.

Wedekindellina sp. aff. *W. euthysepta* (Henbest)
Multithecopora sp.
Polypora sp.
Penniretepora sp.
Ascopora sp.
Rhombotrypella sp.
crinoid columnals
strophomenoid brachiopod fragments
Mesolobus mesolobus decipiens (Girty)
Desmoinesia? sp.

Antiquatonia aff. *A. hermosana* (Girty)
Punctospirifer kentuckensis (Shumard)?
Reticulariina? sp. indet.
Crurithyris cf. *C. planoconvexa*
Hustedia mormoni Marcou

The five collections listed below were assigned to the Upper Pennsylvanian on the basis of fusulinids. According to Douglass, the *Triticites* sp. suggests a Late Pennsylvanian Age.

USGS collection 21453. Pink and gray limestone in overthrust sheet on west side of Timpahute Range; sec. 2, T. 4 S., R. 56 E.

Triticites sp.
stenoporoid bryozoan
productoid brachiopod fragment

USGS collection 21442-PC. Limestone, 70 feet thick, west side of old road, Timpahute Range; SE¼ sec. 6, T. 4 S., R. 57 E.

Triticites sp.
Syringopora aff. *S. multattenuata* McChesney
Rhabdomeson sp.
Rhombopora sp.
productoid brachiopod, indet.
Leiorhynchus? sp. indet.
Reticulariina sp.
spiriferoid, indet.
Crurithyris cf. *C. planiconvexa*
Hustedia cf. *H. mormoni* (Marcou)
Composita sp. indet.

USGS locality 18874-PC. Buff silty limestone interbedded with medium-bedded gray limestone, east side of Grassy Mountain; sec. 35, T. 6 S., R. 65 E., unsurveyed.

Triticites sp.
echinoid plates, indet.
Ramiporalia sp.
fistuliporoid bryozoan, indet.
Rhombotrypella sp.
Polypora sp.
Penniretepora sp.
Rhabdomeson sp.
rhomboporoid bryozoans, indet.
Linoproductus sp.
Dictyoclostus sp.
Punctospirifer sp.

USGS locality 21467-PC. Limestone with fusulinids, brachiopods, and bryozoans from Timpahute Range, west of overthrust sheet of white limestone. Thin-bedded silty limestone between two pinkish-buff shaly limestone beds.

Triticites sp.
trepostomatous bryozoans, 2 sp.
Fenestella sp.
crinoid columnals (pentagonal and round)
echinoid spines and plate
Rhipidomella sp.
Kozlowskia sp.
Linoproductus? sp. indet.
productoid, indet.
Conocardium? sp.

USGS locality 21468-PC. Limestone from upper plate of thrust fault from isolated hill in Pennoyer Valley about 4 miles northwest of Tem Piute. Contains fusulinoids.

Triticites sp.
horn coral (reworked)
stenoporoid bryozoan
crinoid columnals

One assemblage of probable Late Pennsylvanian Age or possibly early Early Permian Age was collected by us just outside of Lincoln County.

USGS collection 21462-PC. Pennsylvanian or Permian limestone from 100 to 300 feet below top of 600-foot section of buff-weathering silty and sandy limestone above a cherty gray limestone sequence, east side of Golden Gate Range, 2.6 miles north of Lincoln County line, 2 miles S. 46° W. of hill 7227, Nye County.

Pseudofusulinella? sp.
Triticites? sp.
Caninia sp., indet.
Amplexocarinia? sp. indet.
Axolithophyllum sp.
Multithecopora sp.
stenoporoid bryozoan, indet.
Chonetinella sp. indet.
sulcate chonetid, n. gen. aff. *Chonetina? rostrata* Dunbar and Condra
productoid brachiopod, indet.
Leiorhynchus sp.
Crurithyris sp.
Amphiscapha sp.

Raymond Douglass comments on the fusulinids in this collection:

> "This sample contains an unusual association of fusulinids. The abundant form present is a small *Fusulinella*-like species. Associated with it are rare specimens of a form with a thicker wall with keriothecal structures. Fusulinids with wall structures of this type are found in rocks of Late Pennsylvanian and Early Permian Age. An assignment to Late Pennsylvanian would be reasonable."

Helen Duncan points out that the corals, particularly *Axolithophyllum* sp., could be either Late Pennsylvanian

or Early Permian, with the greater probability of Late Pennsylvanian. According to Gordon, the brachiopods indicate either a Late Pennsylvanian or Early Permian Age for the collection. The similarity of the Late Pennsylvanian and Early Permian fauna is emphasized by these statements, but as the fusulinids and corals are not typical Lower Permian forms in the Great Basin, and are more like Virgilian species elsewhere in the United States, a Late Pennsylvanian Age seems more likely.

Permian Limestone

Distribution

Limestone, silty or sandy limestone, and sandstone of Permian Age (Wolfcamp) are widely distributed in the eastern Great Basin, but they have not generally been separated from the underlying Pennsylvanian rocks of similar lithology. Largely for this reason, there is no established formational name readily applicable to these rocks in Lincoln County. Rocks of Wolfcamp Age are widely distributed in Lincoln County both north of lat 38° N. and east of the Sheep Range, but these rocks were mapped separately only in the southern Schell Creek and Pahroc Ranges, and on Grassy Mountain. Elsewhere the Permian rocks are undifferentiated from the Pennsylvanian rocks.

Lithology

The Permian limestone unit is characteristically composed of grayish-pink, yellowish-brown, and grayish-orange, thin-bedded and platy, argillaceous to sandy limestone, with some calcareous sandstone layers. In the Pahroc Range, grayish-orange paper-thin silty limestone is abundant in the lower part of the exposed section. The unit characteristically breaks down into small plates and forms smooth rounded slopes.

The facies changes in the Permian rocks are not well understood, but they appear to be similar to the facies changes in the Pennsylvanian rocks. On Grassy Mountain, an eastern facies of Wolfcamp Age limestone rests directly on a similar limestone of Late Pennsylvanian Age. Upper Pennsylvanian rocks may be absent farther east. A western facies of Permian rocks is present from the Schell Creek Range westward. This facies consists of varicolored silty and sandy limestone resting on Upper Pennsylvanian rocks of similar lithology. The following estimated partial section is a continuation of the Pennsylvanian section given on page 54; it gives the lithology of the lower part of the Permian unit in the southern Schell Creek Range.

	Thickness (feet)
Lower Permian rocks:	
Gray, light-yellowish-gray, and yellowish-brown, thin-bedded, shaly and platy limestone	450
Yellowish-brown, thin-bedded limestone	30
Thin-bedded, gray, yellowish-gray and brownish-gray limestone	100
Yellowish-brown and red argillaceous limestone	70
Gray limestone	10
Total	660
Pennsylvanian rocks	

Steele (1960, p. 93) reports an almost complete Permian section in the southern Schell Creek Range including Wolfcamp, Leonard, and Guadalupe rocks, which he divides into four formations. He recognizes the Kaibab Limestone in this section and believes that the Kaibab and Toroweap Formations were once deposited over most of Lincoln County.

The general lithologic character of the Permian limestone unit in Lincoln County resembles that of units B, C, and D of the Tippipah Limestone in the Nevada Test Site (Johnson and Hibbard, 1957, p. 360-361) and the Carbon Ridge Formation in the Eureka district (Nolan and others, 1956, p. 64-65), except for the chert pebble beds in the Carbon Ridge.

Thickness

No complete section of Permian limestone is present in Lincoln County, but the incomplete section exposed in the southern Schell Creek Range is more than 1,900 feet thick. The thickness of equivalent rocks in nearby areas is as follows: Nevada Test Site (Johnson and Hibbard, 1957, p. 361), 2,170 to 2,480 feet; Ely district (Pennebaker, 1932, p. 164), 1,500 to 3,200 feet; Spring Mountains, Clark County (Longwell and Dunbar, 1936, p. 1198), 2,950 feet; Eureka district (Nolan and others, 1956, p. 65), 1,500 to 1,750 feet. Rich (1960) measured 4,500 feet of Permian carbonate rocks in the Bird Spring Formation near Lee Canyon, Spring Mountains, Clark County.

A complete section of the Permian rocks occurs west of Beaver Dam Wash, about 6.5 miles east-southeast of Lime Mountain along the Utah border, but this section has not been studied.

Age and correlation

The limestone unit is Lower Permian (Wolfcamp) in age; it is correlated with the Carbon Ridge Formation in the Eureka area, part of unit C and unit D of the Tippipah Limestone, and the upper or Permian part of the Bird Spring Formation.

According to Steele (1960, p. 93) the age ranges from early Wolfcamp into the Guadalupe, but we found no fossils to confirm the Leonard or Guadalupe Age assignment. Some beds of latest Pennsylvanian (Virgil) Age may be included locally (Kellogg, 1960, p. 193).

The fossils in the following two collections from the lower part of the Permian limestone unit in the North

Pahroc Range were identified by Mackenzie Gordon, Jr., and Helen Duncan (written communications, 1957).

USGS locality 16739. Thin-bedded, yellow-weathering limestone with some interbedded sandy limestone; SW¼ sec. 15, T. 2 N., R. 63 E.

crinoid debris
bryozoan debris, including *Fenestella*
decorticated brachiopod
derbyoid fragments indet.
Wellerella? sp.
Acanthopecten sp. indet. (fragment)

Of this collection, Duncan states: "The pelecypod has a range of Pennsylvanian and Permian . . ." The second fossil collection from the Pahroc Range came from near the same horizon as USGS 16739 but about 10 miles south of it.

USGS locality 16740. Orange-yellow-weathering, brown, thin-bedded, silty limestone; W½ sec. 31, T. 1 N., R. 63 E.

crinoid columnals
Goniocladia sp., unusually large meshwork
Goniocladid bryozoan, genus undet., ramose form
Fenestella, 2 sp.
Archimedes sp.
Polypora sp. large meshwork
Rhomboporella sp.
Productid? indet.
Spiriferinid indet.
Spirifer sp.
Hustedia sp.

Of the brachiopods in this collection, Gordon says that there is ". . . nothing against the field determinations of [Early Permian] age but little to support it." Duncan's comments on the Bryozoa are that,

> ". . . the *Polypora* closely resemble a form that occurs in the Carbon Ridge Formation of the Eureka district. In my experience, *Goniocladia* is confined to the latest Pennsylvanian and Permian. *Rhomboporella* ranges through Pennsylvanian and Permian. This is the first time I have seen *Archimedes* in an assemblage of this sort. . . . Hitherto it has not been reported in the Late Pennsylvanian or Permian of this continent, but it does occur in Russia in rocks of that age. The general aspect of this bryozoan association suggests very Late Pennsylvanian or Permian Age."

Two additional collections were made from a small klippe resting on fossiliferous Lower Mississippian rocks near the north end of the North Pahroc Range.

USGS locality 18872-PC. Buff-colored platy and silty limestone; E½ sec. 26, T. 3 N., R. 63 E.

Pseudoschwagerina sp.
stenoporoid bryozoan, genus indet.

USGS locality 18873-PC, same locality as 18872-PC.

echinoderm debris, indet.
Crurithyris? sp.

R. C. Douglass (written communication, 1959) reports that the *Pseudoschwagerina* sp. in 18872-PC indicates an Early Permian Age, probably equivalent to the middle part of the Wolfcamp series of west Texas. Collection 18873-PC was examined by Helen Duncan and J. T. Dutro, Jr. (written communication, 1959), who report no diagnostic fossils, but that, ". . . the association with 18872-PC suggests a provisional Permian age assignment."

Collection 18875-PC was made on Grassy Mountain about 20 feet stratigraphically above 18874-PC (p. 58). The lithology of the rocks at these two localities is identical, so there was no mappable boundary between them. Collection 18874-PC represents Late Pennsylvanian or earliest Permian Age and 18875-PC, according to R. C. Douglass (written communication, 1959), is dated as Early Permian based on the fusulinids.

USGS locality 18875-PC. About 20 feet stratigraphically higher than 18874-PC.

Pseudoschwagerina sp.
Ramiporalia sp.
Fenestella sp.
Polypora sp.
Penniretepora sp.

Permian Red Beds

The Permian red beds (Supai[?] Formation) and the overlying undivided Kaibab Limestone and Toroweap Formation (unrestricted Kaibab of early workers) were found by us only in the southeast corner of Lincoln County, but Steele (1960, p. 93) recognized the Kaibab in the southern Schell Creek Range in northern Lincoln County as well.

The Kaibab and Toroweap Formations were removed by pre-Moenkopi erosion west of Meadow Valley Wash, but these formations and the Permian red beds must have originally extended over most of Lincoln County east of long 115° N., according to Steele's maps (1960). The nonresistant gypsiferous and silty upper part of the red-bed section thickens westward from 100 feet or less in the Mormon Mountains to about 1,200 feet in the Meadow Valley Mountains. The lower part is chiefly sandstone and the thickness is a relatively consistent 600 feet. One section of red beds in the southern Mormon Mountains, however, may be as much as 3,200 feet thick. The undifferentiated Kaibab and Toroweap Formations thicken eastward from a feather edge in the Meadow Valley Mountains to about 1,000 feet in the Tule Springs Hills. The combined thickness of these two map units ranges from 1,800 to 4,200(?) feet.

Distribution

Red beds of Permian Age are confined to the southeastern part of the county from near Meadow Valley Wash, east to the Utah line, and as far north as the Cherokee mining district. These rocks probably were not deposited much farther west than the present exposures, but correlative rocks of similar lithology are widely distributed in a broad area to the south and southeast.

Lithology

The lower part of the red-bed unit is composed of fine-grained and very fine-grained sandstone, quartzitic sandstone, or quartzite that varies in color from reddish to pinkish to very pale brown. In the Tule Springs Hills, about 5 miles south of Lime Mountain, the exposed section of the red-bed unit is composed entirely of well-sorted pale-brown quartzite, 300 to 400 feet thick, but thrust faulting in this area may have cut out part of the section. West of the Carp and Mormon Mesa road in the northeastern Mormon Mountains, about 200 feet of pink and brown quartzite is exposed beneath a thrust. The exposures of the quartzite in the southern Mormon Mountains are similar in character and thickness to those described above, but the sandstone section west of Meadow Valley Wash is much thicker, softer, and more vividly colored. The lower part is here about 600 feet thick; in general, it is composed of pink and yellow sandstone with a few thin silty and limy beds. The lower contact in Meadow Valley Wash near Galt is gradational; it was drawn somewhat arbitrarily without faunal determinations. Locally, where erosion has completely removed the overlying Kaibab and Toroweap Formations, there is an angular unconformity at the top of the red beds.

The upper part of the red-bed unit is composed of nonresistant brick-red, pink, pale-gray, yellow, or reddish-brown silt, very fine to coarse-grained sandstone, a few thin interbedded gray limestone layers, and as many as five gypsum or gypsiferous shale layers. This part increases in thickness westward from about 50 to 100 feet in the northeast Mormon Mountains near the Carp road to about 1,200 feet on the west side of Meadow Valley Wash.

The following estimated section west of Vigo gives the lithology in greater detail from the unconformity at the top downward.

Section of Permian red beds

	Thickness (feet)
Moenkopi Formation	
Angular unconformity	
Permian red beds:	
Brown-weathering chert breccia	10±
Resistant, red and yellow, coarse-grained sandstone and sandy siltstone with some interbedded gray fossiliferous limestone. Upper third is predominantly yellow sandstone; middle third is predominantly brick-red sandstone; lower third, bounded by two thin gray fossiliferous limestone layers, is reddish sandy siltstone	400
Resistant yellow, red, and buff coarse-grained sandstone	300
Red, yellow, and gray gypsiferous siltstone. Weathers to badlands topography. Bedding contorted and indistinct	300±
Nonresistant red shaly sandstone and some crossbedded buff sandstone. Upper 20 feet is cliff-forming red sandstone	200
Alternatning yellow, buff, pink, white, and gray sandstone, gray limestone, and buff sandy limestone that weather to gentle slopes. Beds average 1 foot thick	200
Resistant orange-pink shale, yellow and pink sandstone, and buff calcareous sandstone. Pinkish-white sandstone with olive-green silt at base, and pinkish-orange soft silt and sandstone at top	80
Pink, silty, very fine-grained sandstone	80
White, yellow, buff, and pink sandstone, gray limestone, and gray and buff silty and sandy limestone in beds 2 to 10 feet thick. Unit is about 90 percent sandstone	250
Arbitrary base of red beds	
Total thickness, red beds	1,810±
Permian limestone:	
Alternating gray limestone and pink sandstone beds 2 to 4 feet thick	100
Buff to brown, slope-forming sandstone. Upper half is darker	130
Gray medium-bedded limestone	50+

Thickness

The thickest section of red beds in Lincoln County is at the south end of the Mormon Mountains where the unit, which is estimated to be possibly 2,900 to 3,200 feet thick, underlies a valley that is largely covered with reddish quartzite float. About 10 miles east of here the thickness is 1,100 to 1,800 feet, compared to the 1,810-foot thickness estimated west of Meadow Valley Wash. Elsewhere in Lincoln County the unit is incompletely exposed or faulted, and the thickness cannot be reliably estimated. Reber (1952, p. 104) estimated the thickness of equivalent rocks (Supai-Coconino) to be approximately 1,800 feet in the Beaver Dam Mountains of southwest Utah. In Clark County, the thickness ranges from 1,100 to 1,400 feet (Longwell and others, 1965).

Age and Correlation

The red beds are Early Permian and at least partly Wolfcamp in age. The red-bed unit in Lincoln County includes lithologic equivalents of the Queantoweap Sandstone and Hermit Formation of McNair (1952, p. 46-47) in northwest Arizona and possibly also a feather edge of the Coconino Sandstone. It is equivalent to the Supai Formation as originally mapped by Hewett (1931, p. 30;

1956, p. 45) in the Goodsprings and Ivanpah quadrangles, the Permian red beds in Clark County (Longwell and others, 1965), and is approximately equivalent to the beds mapped as Supai-Coconino by Reber (1952, p. 104) in the Beaver Dam Mountains. McNair (1952, p. 51) designated the red beds in the western section as Supai for lack of a better term, but the Supai here is considerably younger than the lower part of the Supai proper, which contains Pennsylvanian limestone near Peach Springs, Arizona.

Diagnostic fossils have not been found in the red beds. Two small fossil collections from thin gray limestone beds in the upper part of the red-bed unit about 2.5 miles west of Vigo were identified by Ellis L. Yochelson (written communication, 1957).

Collection 9520-F-2. Thin-bedded fossiliferous limestone interbedded with reddish and brownish sandstone and siltstone.

Pelecypod cf. *Schizodus*
moderately high-spired pleuromarian gastropod, indet.

He states: "Collection 9520-F-2 could be Paleozoic or Mesozoic."

Collection 9520-F-3. Limestone about 100 feet stratigraphically above 9520-F-2.

Pelecypod cf. *Permophorus*
high-spired gastropod indet.
bellerophontid gastropod indet.

Regarding this collection Yochelson writes:

> "Bellerophontid gastropods occur predominantly in the Paleozoic. A few species of *Bellerophon* occur in the Lower Triassic. As nearly as I can determine on this poor material, the bellerophontid is Paleozoic rather than Mesozoic * * *"

Toroweap Formation and Kaibab Limestone

Distribution

The Toroweap Formation and Kaibab Limestone are widely distributed in Clark County, in northwestern Arizona, and in southwestern Utah, but in Lincoln County, except for an occurrence in the southern Schell Creek Range, they are found only in the southeast corner. Complete unfaulted but folded sections are exposed at the south end of the Mormon and East Mormon Mountains and also east of Vigo. Both formations were largely removed by erosion west of Meadow Valley Wash before the Moenkopi Formation was deposited.

Lithology

The Toroweap and Kaibab commonly form a conspicuous double cliff that is separated by nonresistant beds, but only one cliff is distinguishable near the north end of the Tule Springs Hills and at the south end of the East Mormon Mountains. In these areas the upper or Kaibab cliff may have been eroded prior to the deposition of the overlying Moenkopi.

The lower unit, the Toroweap, consists of three members, the lowest of which is very thin and is seldom recognized in Lincoln County. This lowest member is composed of reddish and yellowish mudstone less than 15 feet thick. This is overlain by a cliff-forming gray or brownish-gray cherty limestone member which is approximately 100 feet thick. This member contains alternating cherty and chert-free layers but is, on the whole, less cherty than the lower or cliff-forming member of the Kaibab. The upper member of the Toroweap Formation is thin-bedded, gray, pink, or pale-brown shaly limestone 40 to 80 feet thick. This member contains several beds of gypsum totaling as much as 50 feet in thickness in the Tule Springs Hills. Both contacts of the Toroweap are apparently conformable in Lincoln County, but in Clark County the upper one is an unconformity (Longwell and others, 1965).

The Kaibab Limestone consists of two members. The lower member is a light-gray, cliff-forming limestone that contains up to 60 percent dark-weathering, gray, irregular chert nodules of distinctive appearance. This member is 60 to 100 feet thick along the southern margin of the county, but it may be as thick as 300 feet farther north. The upper member of the Kaibab, consisting of thin-bedded limestone and dolomite with silty partings, we rarely saw.

West of Meadow Valley Wash near Vigo, the Moenkopi Formation lies with angular unconformity on the Permian red beds. In places, along this unconformity, there is a sedimentary breccia of cherty limestone fragments that was probably derived from the cliff-forming limestone members of the Toroweap or Kaibab Formations. This unstratified limestone breccia is often found at the base of the Kaibab as mapped, but it may be a basal conglomerate more properly assigned to the overlying Moenkopi Formation. Similar breccias at the south end of the East Mormon Mountains could be interpreted to mean erosion has removed the Kaibab but not the Toroweap.

Thickness

The thickness of the combined Toroweap Formation and Kaibab Limestone increases southward from a feather edge west of Vigo to between 240 and 450 feet along the Clark County line. To the east, however, the thickness may be about twice as great just over the Utah line east of Lime Mountain. Elsewhere, the section is incompletely exposed or is faulted.

Age and correlation

The map unit used in Lincoln County is equivalent to the one used in Clark County (Bowyer and others,

1958; Longwell and others, 1965). The formations are equivalent to the type Toroweap and Kaibab Formations as redefined by McKee (1938, p. 12). Taken together, the formations are equivalent to the original definition by Darton (1910, p. 28) of the Kaibab Limestone.

We did not collect fossils from the Toroweap and Kaibab Formations because they are only sparsely fossiliferous in Lincoln County. Fossil collections elsewhere have dated both units as late Early Permian (Leonard). Steele (1960, p. 105), however, considers both formations to be Guadalupe.

TRIASSIC SYSTEM

Triassic rocks are present in the southeast corner of Lincoln County where they are between 5,000 and 6,000± feet thick. The larger figure, if correct, is nearly twice the thickness reported in the Beaver Dam Mountains of Utah (Reber, 1952, p. 105), and it is larger than the thickest Triassic section (5,000 feet) in Clark County reported by Clark (1957, p. 2198). Three units are shown on the geologic map. These are, in ascending order, Moenkopi Formation, Shinarump Member of the Chinle Formation, and the Chinle Formation.

The lower 2,500 to 3,000 feet of Triassic rocks are chiefly marine limestones or calcareous fine-grained clastic rocks. The marine limestone interfingers eastward with continental deposits, largely red beds, which everywhere make up the upper part of the section. This facies change is the dominant feature of the Triassic stratigraphy of southern Nevada.

Moenkopi Formation

Distribution

The Moenkopi Formation, like the Kaibab Limestone, is widely distributed in the southern Utah and northern Arizona areas of the Colorado Plateau and in Clark County, but it is confined to the southeast corner of Lincoln County. The western part of this vast region is occupied by the thick, predominantly marine, miogeosynclinal facies of the Moenkopi Formation, and the much larger eastern part is occupied by the thinner predominantly continental red-bed facies. The boundary between the two facies is a line that extends northeast of Las Vegas along U.S. Highway 91-93. In Lincoln County the Moenkopi lies west of this line and belongs to the marine facies (Clark, 1957, p. 2197), except for the red beds at the top.

The Moenkopi Formation is exposed west of Vigo in the Meadow Valley Mountains, in the Pennsylvania mining district, in a belt along the Clark County line at the south end of the Mormon Mountains area, and throughout a large area in the Tule Springs Hills.

Lithology

The Moenkopi Formation west of Vigo is composed entirely of marine limestone, but, farther east, tongues of red beds are generally present at the top and bottom of the section. In the Tule Springs Hills and farther north, the formation contains a thin basal unit that consists of thin gypsum layers, sandstone, pink or olive-brown shale, and an upper red-bed unit 200 to 400 feet thick. A thin basal breccia, composed entirely of Kaibab-type cherty limestone fragments, is locally present at the south end of the East Mormon Mountains. On a regional scale, the lower contact is apparently an unconformity without noticeable angular discordance (Clark, 1957, p. 2191); however, west of Meadow Valley Wash the angular discordance is locally as much as 20°.

The marine limestone section is composed chiefly of thin beds of gray, cream, pale brown, and yellowish-brown dense microcrystalline limestone with interbedded, gray, cherty, crystalline limestone; red platy limestone; orange-weathering silty limestone; and olive-brown and pink shale layers or partings.

The upper red beds are composed chiefly of brick-red to reddish-brown shale, siltstone, and sandstone that resemble the Chinle Formation. These continental deposits are absent west of Meadow Valley Wash, but they thicken farther east in Utah. The upper red beds are apparently absent near Lime Mountain.

Six members of the Moenkopi Formation are recognized in southwestern Utah (Thomas, 1952, p. 56-57). They are, in ascending order, the Timpoweap, the lower red, the Virgin Limestone, the middle red, the Shnabkaib, and the upper red. Most of these members were not recognized in Lincoln County, where the Timpoweap and lower red members are present only locally and, where present, are very thin. The Virgin Limestone Member or a similar rock makes up most of the formation. The middle red, Shnabkaib, and upper red members were not definitely recognized, but they may be present. In the section west of Vigo, all six members might be present.

Thickness

There are no published measured sections of the Moenkopi Formation in Lincoln County, but the thickness is roughly estimated from outcrop measurements on the map to range between 2,500 and 3,500 feet. Accurate estimates are difficult to make because of folding within the formation. The section west of Vigo is incompletely exposed but it exceeds 2,500 feet in thickness; 3,200 feet is probably closer to the true value. The section of the Tule Springs Hills is estimated to be 3,500 feet thick disregarding folding and faulting, but this thickness is probably several hundred feet too large. Reber (1952, p. 105) gave a thickness of 2,100 feet for the predominantly continental section of the Moenkopi Formation in the Beaver Dam Mountains, and Longwell and others (1965) report sections as thick as 1,630 feet in the South Virgin Mountains, Clark County.

Age and correlation

Fossils are not abundant in most of the Moenkopi, and our few fossil collections from the formation did not contain diagnostic forms. Star-shaped *Pentacrinus* columnals, which are considered by many oil geologists to be characteristic of the formation, are abundant locally. Limestone about 100 to 200 feet stratigraphically above the base of the formation along the tributary of Beaver Dam Wash in sec. 7, T. 41 S., R. 19 W., Utah, contained the following fossils which were identified by N. J. Silberling (written communication, 1959) as:

> "* * * poorly preserved pelecypods referable to *'Aviculopecten'* cf. *'A.' idahoensis* Meek and small, smooth, slightly sulcate terebratuloids like *Terebratula thaynesiana* Girty. Both of these species were described from the Thaynes Formation of middle and late Early Triassic age, although the latter species is probably of little age significance. *'Aviculopecten' idahoensis* has also been found in the Virgin Limestone [Member] of the Moenkopi Formation in northern Arizona."

Chinle Formation and Shinarump Member

Distribution

The Chinle Formation and the basal Shinarump Member, like the Moenkopi Formation, are widely distributed in Clark County and in the Colorado Plateau. In Lincoln County the Chinle Formation is found west of Vigo, in the Tule Springs Hills, and north of Lime Mountain.

Lithology

The Shinarump Member is composed of poorly sorted brown-weathering chert-pebble conglomerate, conglomeratic sandstone, and sandstone, between 75+ and 200 feet thick. Silicified logs and wood fragments are common, and the unit is characteristically stained or cemented by iron oxides. The conglomerate originally was formed as lenticular stream-channel deposits. The Shinarump now forms a resistant hogback with two or three ledges separated by nonresistant scree-covered intervals. North of Lime Mountain, the Shinarump is predominantly medium-grained sandstone that is much better sorted than elsewhere.

The Chinle Formation is composed chiefly of fine-grained silty sandstone, siltstone, and shale that are predominantly reddish, although some beds are variegated pinkish, whitish, or brownish. In the outcrop belt north of Lime Mountain a mauve siltstone bed a short distance stratigraphically above the Shinarump(?) contains abundant nodules of limestone. Nodules of almost pure hematite (80.5 percent total Fe as Fe_2O_3) and of manganese oxides (39 percent Mn, 7 percent total Fe as Fe_2O_3) were found in this bed at two localities, one being about 1 mile north of Lime Mountain and the other about 6 miles north of Lime Mountain under the fresh-water limestone outcrop (p. 120). The enclosing rocks might be Jurassic or Cretaceous instead of Upper Triassic as mapped, for iron nodules occur in these beds in Utah.

Thickness

The full thickness of the Chinle Formation is nowhere exposed in Lincoln County. Reber (1952, p. 105) reported an approximate thickness of 1,030 feet for the Beaver Dam Mountains, and Longwell and others (1965) state the maximum thickness in the North Muddy Mountains, Clark County, is 3,300 feet. The exposed thickness in the Tule Springs Hills, disregarding structural complications, is estimated from the outcrop width to be 2,500 feet. The total thickness is probably less than 3,000 feet.

Age and correlation

The Chinle Formation in Lincoln County is equivalent to the formation as mapped in other parts of southern Nevada and southwest Utah. We found no fossils in the Chinle; it was assigned to the Upper Triassic on the basis of its stratigraphic position and correlation with dated beds in adjacent areas.

The Chinle, as mapped, probably includes rocks correlative with both the Chinle Formation (restricted) and part of the Glen Canyon Group on the Colorado Plateau. In Clark County R. F. Wilson and J. H. Stewart (written communication, 1957) have divided into two parts the unit that has been mapped there as Chinle. The lower part, consisting of variegated claystone and light-colored sandstone, they correlate with the Chinle Formation on the Colorado Plateau. The upper part, consisting of reddish-brown siltstone, they correlate with the lower part of the Glen Canyon Group on the Colorado Plateau. These two parts doubtless exist within the unit mapped as Chinle Formation in Lincoln County.

CRETACEOUS(?) AND TERTIARY SYSTEMS

Cretaceous rocks have not been recognized with certainty in Lincoln County, but because they occur in adjacent areas, the oldest units of Cenozoic sedimentary and volcanic rock are believed to be partly Cretaceous. The Cretaceous Age of the oldest volcanic unit is inferred from its greater alteration and deformation and from the unconformity that separates it from the younger volcanic rocks. The age assignment of the unfossiliferous conglomerate unit is based only on its assumed derivation from eroded Laramide structures. Similar clastic rocks in the surrounding regions have been assigned to Cretaceous, Eocene, and Oligocene time.

Both volcanic and intrusive igneous rocks are included in the following sections in what we believe to be their proper stratigraphic positions.

Older Volcanic Rocks

The oldest volcanic rocks are much more restricted in their distribution than are the younger volcanic rocks. They crop out sporadically in a broad belt bounded by Delamar and Dry Lake Valleys on the west, Utah on the east, Leith on the south, and Pony Springs on the north. The principal areas of outcrop are: in the Meadow Valley Mountains north and east of Delamar; in the Clover Mountains on Bunker Peak and in the Pennsylvania Canyon area; in the canyons of Meadow Valley Wash and Clover Creek, especially near their intersection at Caliente; and in the Little Mountain area. Rocks of this unit may also be present in the Bristol Range near Blind Mountain, in the White Rock Mountains, and in the Fairview and Wilson Creek Ranges.

This unit consists chiefly of flows, mud flows, breccias, and tuffs, which are andesitic in appearance and mineralogy but may be latitic or dacitic in chemical composition. They are characteristically much sheared and altered, and they weather readily to form smooth rounded grus-covered slopes. The plagioclases are sericitized, and the mafic minerals are commonly either chloritized or destroyed.

East of Caliente, the older volcanic rocks are thought to be several thousand feet thick, but their thickness cannot be closely estimated. They are intruded by small dioritic and monzonitic stocks on Blind Mountain, in the Little Mountain area, and perhaps also in the Pennsylvania district, where their intrusive nature is questionable. The age of the older volcanic rocks is not definitely known, but they are considerably older than the succeeding volcanic rocks. They may be as young as Eocene, but they are probably Cretaceous or even Jurassic.

Older Clastic Rocks

Distribution

An unnamed thick unit of clastic rocks, largely cobble conglomerate, covers large areas in the Spotted, Pintwater, and northern Desert Ranges in the southwest corner of Lincoln County (fig. 15). Small areas of conglomerate also occur on the west side of the Groom Range and near Pennsylvania Canyon, just east of Meadow Valley Wash. Similar cobble conglomerate occurs beneath lacustrine limestone of Miocene Age in the North Pahroc Range and in the area of Mesozoic rocks along the Utah border. These latter conglomerates probably do not correlate with the conglomerate unit elsewhere, and in these areas they could not be distinguished on the map from the overlying lacustrine limestone.

Lithology

In the Spotted and Pintwater Ranges the evenly bedded conglomerate consists chiefly of subrounded to well-rounded, poorly sorted, yellowish-brown, fluviatile, pebble and cobble conglomerate. It is poorly cemented and characteristically weathers yellowish brown to form dissected rounded hills that are mantled with loose gravel. This mantle hides the bedding and any finer grained rocks that may be present. The clasts are chiefly Prospect Mountain(?) Quartzite, but in some beds, especially in the upper part, the clasts are largely limestone. Elliptical cobbles of varicolored chert pebble conglomerate are a conspicuous constituent of some beds, and some lenticular sand beds contain abundant clasts of red, green, and black chert. These varicolored chert and chert-pebble conglomerate clasts are probably derived from unit G of the Eleana Formation in Nye County. Much of this conglomerate, therefore, probably consists of second-cycle sediments that were first deposited in the Eleana Formation or in the Shinarump Member of the Chinle Formation. R. F. Wilson and J. H. Stewart (written communication, 1957) report that the lower 12 feet of the Shinarump is composed entirely of chert pebbles at their Spring Mountains section in Clark County.

In the north end of the Desert Range, the unit is composed chiefly of interbedded reddish-brown shale, siltstone, well-sorted sandstone, and several 10- to 20-foot beds of brownish-gray well-sorted cobble conglomerate, all of which show typical fluviatile cut-and-fill structures. These sedimentary rocks are conformably overlain by an ignimbrite series, and both these units are unconformably overlain by a thick tuff sequence.

On the east side of the Pintwater Range the lower 3,000 to 5,000 feet of the unit is a poorly consolidated brownish conglomerate with a few interlayered chert sand lenses. This conglomerate is overlain unconformably(?) by about 1,000 feet of light-gray and pink tuff breccias, pale-gray lapilli tuff, and other tuffaceous rocks. The upper 200 feet of the exposed section is well-sorted, well-rounded, moderately well consolidated, tan to pinkish-gray pebble conglomerate. The pebbles in these younger conglomerate beds are better rounded and lighter in color than the older ones. These beds may be unconformable on the older conglomerate and, if so, they may be Oligocene or even Miocene.

Sedimentary rocks similar to the Sheep Pass Formation occur on the east side of Pennsylvania Canyon east of Elgin and closely resemble the Pahroc section. The conglomerates in both sections are derived from the nearby Paleozoic rocks and indicate local structural disturbances. The section in Pennsylvania Canyon is about 500 feet thick and consists largely of pebble and cobble conglomerate, with rounded quartzite and limestone clasts, interbedded with red and brown cherty sandstone, freshwater limestone, and tuffaceous or flow rocks near the top. The matrix of the conglomerate is maroon siltstone. The entire section is overlain by volcanic rocks.

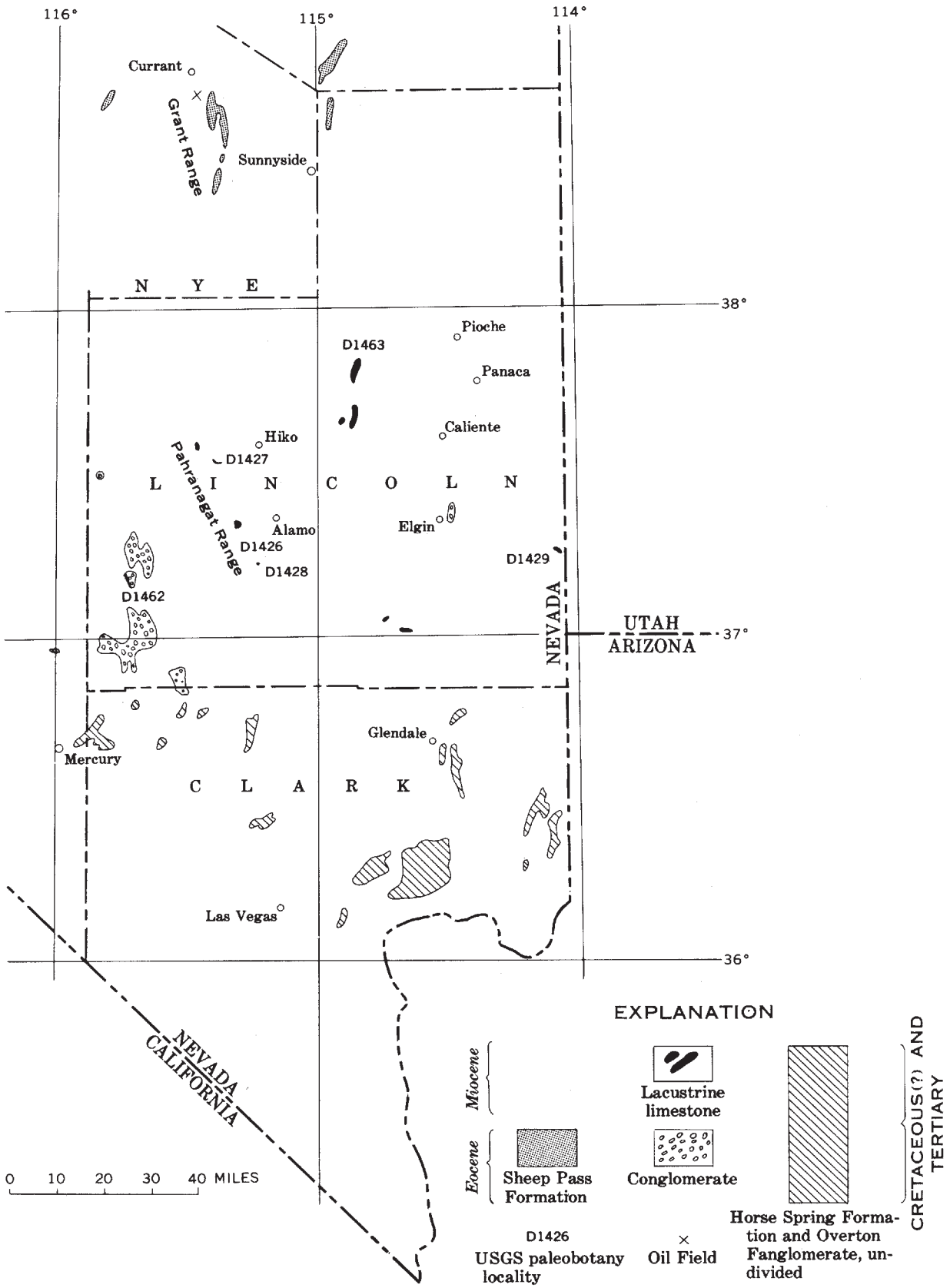


FIGURE 15. Map showing prevolcanic sedimentary rocks of Cretaceous(?) and Tertiary Age in southeastern Nevada.

Several hundred feet of conglomerate, sandstone, and siltstone overlain by gray fresh-water algal limestone about 50 feet thick, crop out at the base of the volcanic section west of Bald Mountain, on the west flank of the Groom Range.

Thickness

The thickest sections of the unnamed conglomerate are in the Spotted and Pintwater Ranges where the maximum thickness is estimated to be 5,000 to 6,000 feet, compared to less than half this thickness in the northern Desert Range, and only a few hundred feet elsewhere.

Age and correlation

The age of the older clastic rocks is not definitely known. It is probably Cretaceous or early Tertiary and may well have a wide age range from Cretaceous to Oligocene. It is conformably overlain by lacustrine limestone of Miocene Age or younger (Tschanz, 1960a).

No firm basis of correlation exists at present beyond the tenuous and uncertain one of lithologic similarity. Longwell and others (1965, p. 45) have tentatively correlated the part of this unit in northwest Clark County with the Horse Spring Formation farther east. The unit is probably at least partly equivalent to the Titus Canyon Formation of Stock and Bode (1935), of Oligocene Age, found along the Nevada-California border east of Death Valley, and to the conglomerate in the lower part of the Claron Limestone in southwest Utah. According to Cook (1965), the lower or red Claron is loosely dated as very Late Cretaceous to Oligocene, and the upper or gray Claron may be regarded as Oligocene, for the Needles Range Formation of Mackin (1960, p. 101), which is interbedded with the upper Claron in the Red Hills and Bull Valley areas of Utah, is younger than the Windous Butte Tuff of Cook (1960), specimens of which give a K-Ar age of 34 m.y. or medial Oligocene (Evernden and others, 1958).

Fossils from the basal part of the Oak Spring Group, as defined by Poole and McKeown (1962), indicate an Eocene Age, and these beds strongly resemble the type Horse Spring Formation (C. R. Longwell, oral communication, 1961).

CENOZOIC ROCKS

The stratigraphy and the thickness of the Cenozoic rocks are paradoxically less well known than the Paleozoic and Mesozoic rocks because the Cenozoic rocks are largely covered by unconsolidated Pleistocene and Recent sediments. Although little drilling has been done in the county, the meager data from wells and geophysical surveys show that the Cenozoic deposits are very thick in several basins of deposition. These data show that the maximum thicknesses of Cenozoic rocks are as great as 15,000 feet in Railroad Valley, Nye County, and about 4,400 feet in White River Valley, a few miles northwest of Lincoln County. Geophysical data suggest that about 7,000 feet of Cenozoic rocks are present beneath Mormon Mesa a few miles south of Lincoln County. Comparable thicknesses of Cenozoic rocks are present in many of the basins in Lincoln County but definite information is lacking. Probably several thousand feet of unconsolidated Cenozoic rocks are present in most of the major valleys.

TERTIARY SYSTEM

The Tertiary rocks in Lincoln County consist of four major groups: the sedimentary rocks, the younger volcanic rocks, the intrusive rocks, and the later Tertiary lake beds and unconsolidated rocks.

The first group consists of the Sheep Pass Formation of Eocene Age and the lacustrine limestone of Miocene Age. These rocks are older than the Tertiary volcanic rocks except locally where the Miocene limestone rests on volcanic rocks.

The second group consists of volcanic rocks and intravolcanic sediments composed largely of volcanic fragments. Ten prominent units or rock types are distinguished on the map, but the relative age and correlation of these units are largely unknown. The volcanic rocks are Oligocene, Miocene, and Pliocene.

The third group consists of a few small stocks and dikes of dioritic, diabasic, monzonitic, and granitic composition that intrude the older volcanic rocks.

The fourth group consists of lake beds of Pliocene Age and tilted postvolcanic gravels of unknown age. The Tertiary rocks are described in the order listed above.

Sheep Pass Formation

Distribution

The Sheep Pass Formation is limited to the Egan Range north of Shingle Pass in Lincoln County (pl. 2), but it also occurs in adjacent parts of Nye and White Pine Counties as shown in figure 15. The formation was defined by Winfrey (1958) at Sheep Range Canyon in the Egan Range, White Pine County. It is the best described Tertiary sedimentary section, and it serves as a type section with which the other rocks can be compared.

Lithology

Winfrey divided the formation into six members at the type section 5 miles north of Lincoln County. In ascending order, these members are: A, 650 feet of basal conglomerate and breccia; B, 983 feet of interbedded fossiliferous limestone, shale, and mudstone; C, 640 feet of sandstone, siltstone, shale, and gritty conglomerate; D, 730 feet of homogeneous white, siliceous, extremely fine grained siltstones and chert; E, 90 feet of fossiliferous lith-

ologic limestone; and F, 147 feet of nonresistant siltstone and claystone beds. The unconformity at the base of the formation is markedly angular.

Kellogg (1960, p. 194) was able to map all of these members in White Pine County but notes that member F thins rapidly both north and south of the type area. In Lincoln County members A, C, and E are apparently absent and the upper 150 feet of member D contain many thick chert beds (Kellogg, 1959, p. 108). The formation contains asphaltic and petroliferous material. It is the producing horizon in the Eagle Springs Unit 35-35 of the Shell Oil Co. in Railroad Valley, Nye County.

Thickness

The Sheep Pass Formation is as much as 4,000 feet thick a few miles north of Lincoln County, but it thins rapidly southward and pinches out entirely near Shingle Pass. In Lincoln County it decreases rapidly southward from a maximum of a little over 1,000 feet. About 1,900 feet were penetrated in the dry hole of Standard Oil Co. of California's County Line Unit 1, a few miles west of Lincoln County. The formation is only about 600 feet thick in Railroad Valley, Nye County.

Age and correlation

Sheep Pass Formation is Eocene; it contains an abundant nonmarine fauna (Winfrey, 1958). The mollusks were identified by D. W. Taylor (*in* Winfrey, 1960, p. 130) as "* * * lower Tertiary. Probably Eocene, perhaps as young as Oligocene." The ostracods were identified by J. A. Peterson of the Shell Oil Co. as Eocene and Paleocene types. Primitive frogs from member B were considered to be a type that ranges from middle Eocene to early Oligocene by Max Hecht of the American Museum of Natural History.

The Sheep Pass Formation cannot at present be correlated with any of the other Tertiary sedimentary rocks in Lincoln County. The rocks of similar lithology in the Pahroc and Pahranagat Ranges appear to be much younger. Part of the Sheep Pass Formation may be the same age as the older clastic rocks in the southwest corner of Lincoln County, but it is dissimilar lithologically.

Lacustrine Limestone

Distribution

The unnamed lacustrine limestone is the most widely distributed of the three Tertiary sedimentary units, even though it is by far the thinnest. The largest outcrop areas are in the North Pahroc and Pahranagat Ranges and north of Lime Mountain in the Clover Mountains, but thin lacustrine limestone crops out on the west side of the Groom Range, in the northern Desert Range, in the Meadow Valley Mountains, west of the Chief Range, and east of Pennsylvania Canyon (fig. 15).

Lithology

The lacustrine limestone generally occurs in thin isolated lenses of gray, light-gray, pink, yellow, or white, massive or laminated, dense limestone. In many places indeterminant algal remains are abundant. Generally the limestone conformably overlies well-rounded cobble conglomerate; where the conglomerate is absent, it unconformably overlies Paleozoic or Mesozoic rocks. Commonly volcanic rocks are interbedded with the limestone in the upper part of the section. In a few areas, the limestone overlies volcanic rocks, such as on the east side of Pahranagat Range north of Nevada Highway 25. Here Anthony Reso and Abraham Dolgoff (written communication, 1960) report fossiliferous limestone about 700 to 800 feet above the base of the volcanic rocks. They believe that this limestone is different from the lacustrine limestone at the base of the volcanic section farther south, but the two limestones may be the same age.

In the northern two outcrop areas in the North Pahroc Range, grayish-yellow, thin-bedded, sugary, fresh-water limestone, 100 to 150 feet thick, is underlain by an alternating series of limestone and conglomerate beds (fig. 16). Some tuffaceous layers also are present in this lower interval which is about 400 feet thick. The conglomerate is composed almost entirely of Devonian limestone and quartzite pebbles and cobbles. This fresh-water sequence thins rapidly southward and appears to pinch out in 3 miles. In the southern outcrop area, just north of U.S. Highway 93, a rhyolitic tuff, 80 feet thick, occurs at the base, and two 20-foot limestone units are separated by about 60 feet of conglomerate. At both localities an angular unconformity separates the Tertiary rocks from the underlying Paleozoic rocks, but the contact with the overlying volcanic section is gradational and conformable. All these rocks are shown as lacustrine limestone on the map.

In the Desert and Spotted Ranges, fresh-water algal limestone occurs intermittently at the top of the conglomerate unit immediately below a very thick pink and white tuff which is overlain by basalt.

Thickness

The rocks included in the lacustrine limestone unit are as much as 550 feet thick in the North Pahroc Range; elsewhere, however, the thickness rarely exceeds 100 feet, and thicknesses of less than 50 feet are common.

Age and correlation

The lacustrine limestone beds in Lincoln County are Miocene where dated; they do not usually contain visible megafossils except for nondiagnostic algae. We did not see any other fossils in the field, but Anthony Reso (written communication, 1960) found some gastropods — *"Stagnicola" palustris* (Müller) — and algae in the Pah-

FIGURE 16. Miocene fresh-water limestone (Tf) overlying conglomerate (cgl) in the North Pahroc Range. Tv, younger volcanic rocks; Pl, Permian limestone.

ranagat Range. These were identified for him by J. A. A. La Rocque of Ohio State University, who stated:

> "* * * I would venture the opinion that the * * * [limestone] is Miocene or younger but I would emphasize that this diagnosis is far from certain as it is based on a single species."

I. G. Sohn (written communication, 1959) identified a single smooth ostracod carapace in one of our samples.

The limestone does, however, contain fungispores and 33 species of pollen (table 2), which were identified by G. O. W. Kremp, who believed five of the pollen were Miocene or younger. Of samples D1426-D1429, Kremp (written communication, 1959) stated:

> "The pollen association found in the four samples is practically the same. The flora shows a dominance of pine-like pollen *(Abietineaepollenites microalatus)* associated with other coniferous pollen (*Cedripites* cf. *cedroides* and *Inaperturopollenites dubius*). The relative high frequency of Compositae pollen is remarkable. USGS records, as well as reports by other pollen workers, indicate that pollen of the Compositae appear first in sediments of late Oligocene Age; these pollen become common in the Rocky Mountain area beginning with Miocene. This would date your samples as Miocene or possibly younger."

Four additional samples were submitted. Two (one from the North Pahroc Range and one from the Meadow Valley Range) did not contain pollen. Of the other two, Kremp (written communication, 1960) stated:

> "The dominating pollen in sample 58TF 37 (D1462) is *Abietineaepollenites microalatus* (more than 50%). This is a striking similarity to your earlier samples. * * * several other pollen also are identical with those found in your earlier samples; but only a few species are the same as in the upper Oligocene Florissant lake beds of Colorado. The presence of Onagraceae pollen excludes, as far as we know, an age older than upper Oligocene and the relatively high frequence of Compositae pollen (about 5%) indicates a Miocene or younger age. * * * I suppose that your sample 58TF 37 is about of the same age as your earlier samples from Lincoln County.

Table 2. Pollen list for Miocene lacustrine limestone from six localities in Lincoln County. (Dominant, 50-100 percent; abundant, 25-49 percent; common, 10-24 percent; present, 4-9 percent; rare, 1-3 percent.)

I. Eufiliciales
- a. Polypodiaceae
  1. *Polypodiaceaesporites haardti* Potonie and Venitz (1934); Thiergart (1938). Many Polypodiaceae spores, having lost their perispore, are lumped in this organic species. Rare.
  2. *P.* sp. (type 95-71).

II. Embryophyta Siphonogama
  3. *Ginkgoretectina* aff. *punctata* Malawkina (1953). Botanical relationship unknown, probably not *Ginko*. Rare.

III. Gnetales
  4. *Ephedra* sp. (type 93-71).

IV. Coniferae
- a. Pinaceae
  5. *Abietineaepollenites microalatus* Potonie (1931); Potonie (1951). Probably *Pinus*. Dominant.
  6. *A.* sp. (type 94-42).
  7. *Cedripites* cf. *cedroides* Thomson and Pflug (1953); Potonie (1958). Morphographically similar to *Cedrus*. Rare to present
- b. Cupressaceae-Taxodiaceae
  8. *Inaperturopollenites dubius* Potonie and Venitz (1934); Thomson and Pflug (1953). Coniferous pollen, related to the Cupressaceae or Taxodiaceae. Rare.

V. Monocotyledoneae
  9. *Monocolpopollenites* sp. (type 94-40).
  10. *M.* sp. (type 94-83).

VI. Dicotyledoneae
- a. ?Piperaceae
  11. cf. *Macropiper* aff. *excelsum* Mig. in R. A. Couper (1953, p. 40, fig. 46). In its morphographic appearance, the pollen found were best compared with the above referred drawing. However, no relation to the Piperaceae may exist. Rare.
- b. Salicaceae
  12. *Tricolpites* cf. *mataurensis* Couper (1953). Perhaps related to *Salix*. Rare.
- c. ?Juglandaceae
  13. aff. *Multiporopollenites maculosus* Potonie (1931); Thomson and Pflug (1953).
- d. Fagaceae
  14. *Quercuspollenites henrici* Potonie (1931); Thiergart (1940). Probably *Quercus*. Rare.
  15. *Q.* cf. *henrici* Potonie (1931) (type 1931).
  16. *Q. microhenrici* Potonie (1931) *intragranulatus* Thomson and Pflug (1953). Present.
  17. *Q.* sp. (type 93-65).
- e. ?Hamamelidaceae
  18. aff. *Liquidambarapollenites stigmosus* Potonie (1931); Potonie, Thomson and Thiergart (1950). Only one single grain was found. As it was badly preserved its relation to *Liquidambar* is questionable.
- f. Nyssaceae-Anacardiaceae
  19. *Tricolpopollenites kruschi* Potonie (1931) *contortus* Thomson and Pflug (1953). Probably Nyssaceae or Anacardiaceae. Rare to present.
- g. ?Caprifoliaceae
  20. *Tricolporopollenites* cf. *microreticulatus* Thomson and Pflug (1953). Botanical relation uncertain, similar pollen are found in *Sambucus*. Rare.
- h. Compositae
  21. *Tricolpites* sp. (*Baccharis*-type). Morphographically similar to *Baccharis*. Present to common.
  22. *T.* sp. (type 95-81).
  23. *T.* sp. (type 94-56).
  24. *T.* sp. (type 1, undescribed). Probably Compositae. Rare to present.
  25. *T.* sp. (type 2, undescribed). Probably Compositae. Rare to present.
  26. *T.* sp. (type 3, undescribed). Probably Compositae. Rare to present.
- i. Onagraceae
  27. cf. *Jussiaea* sp. (type 94-8).
- j. ?Amaranthaceae
  28. *Polyporopollenites* sp. (type 94-28).
  29. *P.* sp. (type 94-12).
- k. Family unknown
  30. *Tricolpopollenites* cf. *densus* Thomson and Pflug (1953). Present to common.
  31. *T.* sp. (type 94-16).
  32. *T.* sp. (type 94-44).
  33. *Triporopollenites* sp. (type 95-11).

Note: Locations of the six pollen-bearing samples follow:

Sample number	Approximate locations	
D1426	Pahranagat Range	sec. 22, T. 7 S., R. 59 E., unsurveyed.
D1427	do.	sec. 18, T. 5 S., R. 59 E., unsurveyed.
D1428	do.	sec. 14, T. 8 S., R. 60 E., unsurveyed.
D1429	Clover Mountains	..... T. 7 S., R. 71 E., unsurveyed.
D1462	Jumbled Hills	sec. 25, T. 8 S., R. 56 E., unsurveyed.
D1463	North Pahroc Range	sec. 31, T. 1 N., R. 63 E., unsurveyed.

"The two pollen in sample 9371S1 (D1463) are not enough for an age determination, however, as one of them (*Abietineaepollenites microalatus*) is the dominating pollen in your fresh-water limestones and also the other pollen type, aff. *Multiporopollenites maculosus* has so far been found only in your earlier sample 58TF33 (D1426) * * *, a Miocene Age might also be supposed for this sample."

The lacustrine limestone in Lincoln County, except for that in the Sheep Pass Formation, is correlated with the lacustrine limestone in the upper part of the beds at the base of the Oak Spring Group (Johnson and Hibbard, 1957, p. 369). Recent detailed mapping in the Nevada Test Site, and paleontologic data from the Test Site and Clark County, indicate that the basal part of this limestone is Eocene (C. R. Longwell, oral communication, 1961) and can be separated from the part which had been assigned to the late Tertiary, possibly Miocene, by T. C. Yen (*in* Johnson and Hibbard, 1957, p. 369) because of the presence of poorly preserved gastropods, and to the Pliocene by D. H. Dunkle (written communication, 1956) because of the presence of the fossil fish *Fundulus*.

Younger Volcanic Rocks

Distribution

The younger volcanic rocks, as a group, consist of all the volcanic rocks that are not included with the older volcanic rocks (p. 65). Together these two units cover about a third of the area of Lincoln County. They occur in every range in the county. The younger volcanic rocks include several series of ignimbrites that were extruded intermittently during Tertiary time. The stratigraphic relations within the group are complex, because there were several periods of local structural movement and erosion. In general, the oldest rocks in the younger group are confined to local basins, and they are overlain by a series of widely distributed ignimbrite units. The group conformably overlies the Miocene lacustrine limestone except in the Pahranagat Range, where it unconformably overlies the older volcanic rocks; where both are absent, it rests unconformably on the Paleozoic and Mesozoic rocks.

Lithology

The younger volcanic rocks are predominantly an ignimbrite series that consists of welded vitric and crystal tuffs, pumice or lapilli tuffs, sillars, lahars or tuff breccias, flows, domes, and perlitic rocks that range in age from Oligocene to Pliocene. The younger volcanic rocks range in composition from basalt to rhyolite. Ten distinctive units or rock types are shown on the map, but we did not try to correlate them from range to range. It is certain, however, that many of the ignimbrite units in Lincoln County cover hundreds or even thousands of square miles, as shown by the work of E. F. Cook (1957; 1965) and J. H. Mackin (1960). Mackin states (p. 81) that individual ignimbrites have an areal extent of as much as 10,000 square miles. These workers recognize 11 ignimbrites which are widely distributed in southeastern Utah, and at least 8 of these units extend into Lincoln County, according to E. F. Cook (written communication, 1959). The correlation of the main groups of Tertiary rocks is shown on figure 17.

Eight volcanic map units are described separately below:

Andesite. Two different and widely separated volcanic units are shown on the map as andesite flows. The first is a hypersthene-augite andesite of basaltic appearance that was mapped only in the Fairview Range, although similar rocks occur elsewhere; the second is a thick reddish andesite unit that overlies a thick tuff sequence on the east side of the Groom Range.

Dark-gray or brownish-black, vesicular or amygdaloidal flows of hypersthene-augite (pyroxene) andesite crop out in the Condor Canyon, Black Canyon, Ely Springs, and Fairview Range sections (Westgate and Knopf, 1932, p. 27-32). According to detailed mapping by E. F. Cook (written communication, 1959) the basaltic andesite in the Black Canyon area is overlain by the Quichapa Formation of Cook (1957). The correlation of the basaltic andesite from range to range, however, is uncertain, and similar rock may occur elsewhere in the volcanic sequence, as in the Pine Valley Mountains, Utah (Cook, 1957, p. 59-61).

Outcrops of the reddish-brown andesite unit on the east side of the Groom Range show prominently as dark areas on the aerial photographs. The unit consists of well-layered andesite flows(?) that unconformably overlie a thick white tuff unit.

Spheroidal-weathering ignimbrite. A distinctive ignimbrite layer is widely distributed in the central part of Lincoln County. The outcrop is readily mistaken for granite at first glance. It consists of pinkish-gray welded crystal tuff of dacitic(?) composition. The unit is widely exposed in the Pahroc, Hiko, and Pahranagat Ranges and probably also occurs in the Seaman and Golden Gate Ranges and the Delamar Mountains. The total area before erosion was probably more than 1,800 square miles.

The unit forms cliffs and weathers to form brown-stained spheroidal outcrop surfaces, which are easily recognized even on aerial photographs. Large outcrops of the unit usually have several well-developed intersecting systems of vertical joints which show up on aerial photographs. Dolgoff (1963, p. 886) has measured sections of this unit which range in thickness from 450 to more than 900 feet. The unit probably is equivalent to the Hiko Tuff

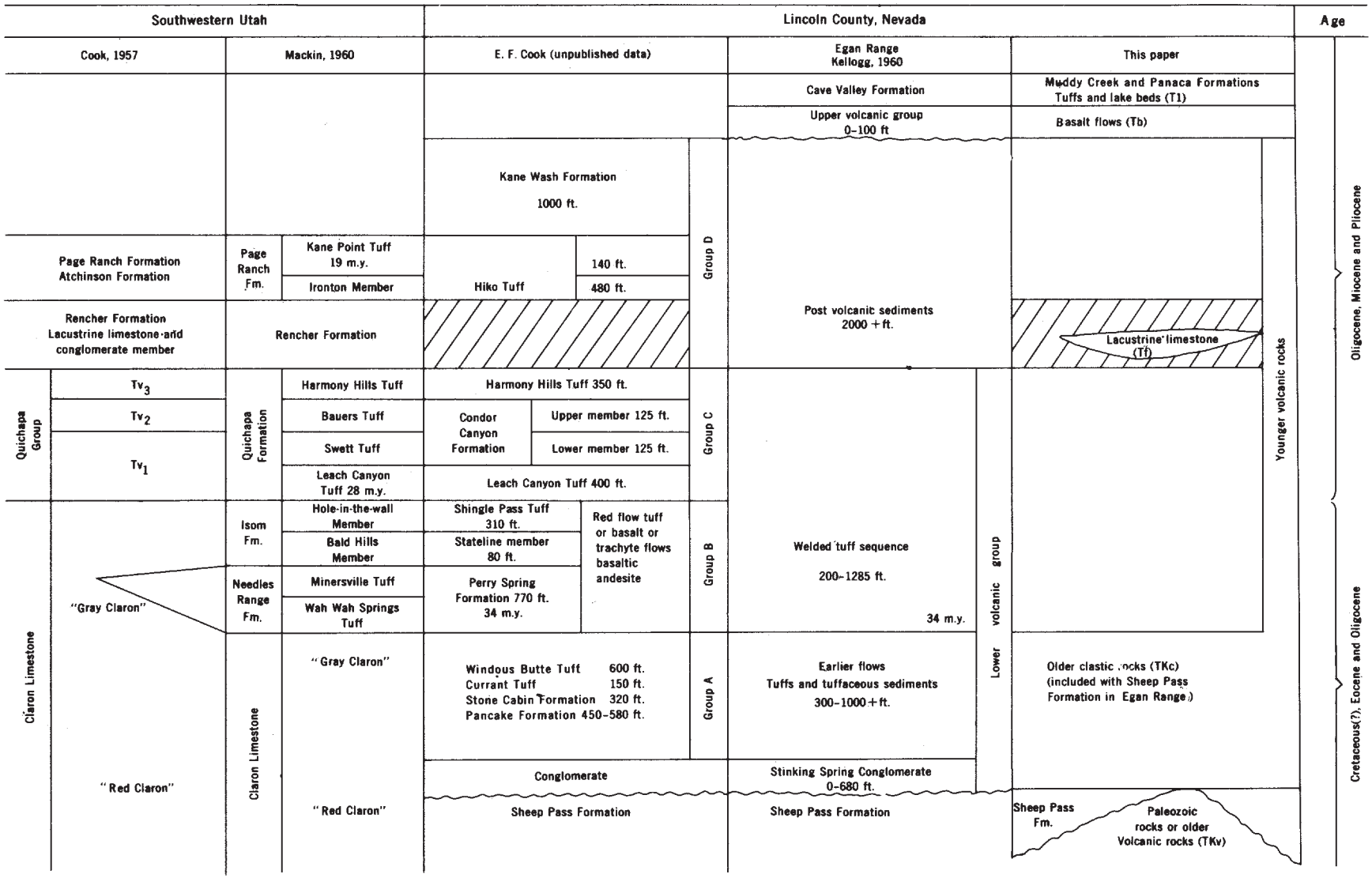


FIGURE 17. Correlation of Tertiary formations in Lincoln County, Nevada, and southwestern Utah. Geologic names listed are those of the authors and do not necessarily follow the usage of the U.S. Geological Survey.)

of E. F. Cook (written communication, 1959), which he suggests may correlate with the Page Ranch Formation of southwestern Utah.

In thin section, the rock contains up to 50 percent broken crystal fragments of quartz, potash feldspar, plagioclase, biotite, and hornblende, and a few foreign rock fragments. Staining of cut surfaces with potassium cobaltinitrite shows much potash feldspar in the devitrified groundmass.

Rhyolitic unit. A thin but prominent flow or ignimbrite unit of porous, fine-grained, gray, rhyolitic rock with opalescent sanidine phenocrysts caps many mesas near Caliente and in the region to the south and east of town. This unit forms prominent dark-gray areas on the aerial photographs. It may be derived from the rhyolite complex near Boyd in Meadow Valley Wash. Except for the basalt flows, this unit is one of the youngest volcanic rocks in the Clover and Meadow Valley Mountains. The rhyolitic unit contains abundant quartz, sanidine, and plagioclase phenocrysts in a devitrified groundmass. It does not contain textures indicative of its origin.

Biotite dacite. One or more thick units of lilac, gray, or reddish-brown dacite or quartz dacite crystal tuff containing hexagonal plates or books of biotite are widely exposed in northern Lincoln County in the southern Schell Creek, Egan, and Fortification Ranges, and in the White Rock Mountains.

The biotite is typically oriented parallel to the base of the unit. The rock contains up to 45 percent phenocrysts and abundant black glassy fragments. Near Sidehill Pass, the dacite is lilac colored and contains at least as much green hornblende as biotite; the biotite here is largely altered to iron oxides. The rock contains quartz and zoned plagioclase and has the shard texture typical of an ignimbrite.

Correlation of these rocks from range to range is uncertain because similar rocks occur at two horizons. The rock closely resembles the Harmony Hills Tuff of Mackin (1960, p. 94-95), and the unit in the White Rock Mountains almost certainly belongs to this unit. E. F. Cook (written communication, 1959) has also mapped this unit in the Condor Canyon and Black Canyon areas in the Pioche region ,and at the White River Narrows near Hiko. The Harmony Hills Tuff presumably is widely distributed in much of Lincoln County.

Rhyolite complex. A complex of intrusive and extrusive rhyolite domes, plugs, and flows was found on both sides of Meadow Valley Wash near Boyd. The geologic relations are very complex and were not studied in detail, but a complex dike flow of platy rhyolite has apparently intruded the older volcanic rocks along Meadow Valley Wash and spread out on the surface as a series of ignimbrites and flows or low extrusive domes, as shown by the concentric flow ridges on the large outcrop east of Meadow Valley Wash. Part of the rhyolite near the intrusive center has been altered to alunite and clays by solfataric action. Several hundred feet of rhyolitic and perlitic rocks between Boyd and Caliente and east of Caliente along Clover Creek appear to have been erupted from a volcanic center in the Boyd area. It is likely that the rhyolite was extruded from marginal fractures partly surrounding one or more major calderas.

Tuffs and tuffaceous sediments. Light-gray, pinkish or white, water-laid or massive airfall pumice or lapilli tuffs, sillars, and tuff breccias are common in the volcanic sections of Lincoln County. One or more thick units are exposed in nearly every range. These rocks are shown on the map, where feasible, without regard to their stratigraphic position, but not all such rocks were mapped separately. The thickest tuff unit is in the southwestern part of the county and is correlated with the Indian Trail Formation in the Nevada Test Site.

Intravolcanic sedimentary rocks. Erosion occurred intermittently in structurally active areas during the deposition of the younger volcanic rocks, and clastic sedimentary rocks largely or entirely composed of volcanic fragments were deposited in local basins. The intravolcanic sedimentary rocks are shown on the map regardless of stratigraphic position. These rocks are as much as 300 feet thick and can be distinguished from the older Tertiary sedimentary rocks by the absence of lacustrine limestone and by the abundance of volcanic fragments. Such fragments are entirely absent from the older rocks, even when they contain layers of tuff.

Color-banded volcanic gravels, siltstones, and intercalated thin rhyolite tuffs were deposited locally in the Caliente area on an irregular unconformity with at least 100 feet of relief. This unconformity probably represents a long period of erosion that followed a major period of faulting, possibly during late Laramide time. The unconformity separates the older volcanic rocks from the younger volcanic group.

A unit of postvolcanic fluviatile sediments and a few tuffaceous beds overlie the welded tuffs with apparent conformity along the east side of the Egan Range. Kellogg (1959, p. 118) states:

> "The rocks are mostly light-gray or yellowish-gray, laminated and thinly bedded sandstones and siltstones. Sand and silt particles are dominantly quartz; volcanic sands, a few vitric tuff beds, and conglomerates derived from Paleozoic sediments and Tertiary volcanics are interbedded."

These rocks are more than 2,000 feet thick near Shingle Pass. They are not shown separately on our map, but are probably included with the older gravels.

Fossils were not found in these rocks in Lincoln County, but Kellogg (1959, p. 118) reports that H. D. Harris of the Shell Oil Co. found a species of ticholeptine cf. *Ticholeptus,* a small species of camel cf. *Oxydactylus* s. l., and a larger camel in supposedly equivalent rocks in sec. 32, T. 13 N., R. 65 E., Schell Creek Range, White Pine County, Nev. (Univ. of Calif. Mus. of Paleontology, location V-5630). D. E. Savage of the University of California (*in* Kellogg, 1959, p. 118) states that they are "probably Hemingfordian to Barstovian (Middle to Late Miocene)." C. A. Repenning (oral communication, 1959) states the fossils occur in tuffaceous sandstone just above the initial volcanic unit — a white biotite tuff — which rests unconformably on the Ely Limestone. The correlation of the rocks in the Egan Range with the fossiliferous rocks, however, is doubtful.

Perlite. Deposits of perlite exist at several places in western and central Lincoln County, and most of these deposits have been described by Cochran (1951). All the deposits we saw were nearly flat-lying extrusive masses, but intrusive masses probably also exist in the county. The flows are relatively thin, averaging about 20 feet in thickness, but some flows are as much as 150 feet thick (table 8). The flows are not always associated with a particular volcanic unit, for in different places they are under- or overlain by rhyolitic, dacitic, and andesitic ignimbrites, and many of the deposits grade upward or laterally into stony flows. The perlite ranges in color from light blue gray to black and in texture from typical perlitic to granular to glassy.

Pellets of black obsidian — so-called Apache tears — up to 2 inches in diameter are abundant in much of the perlite. These pellets are thought to be residual masses of the parent glass from which the perlite was formed by imbibing meteoric waters from the adjacent rocks, perhaps while still hot, or by hydrothermal alteration, or by secondary hydration. This theory of origin is supported by Friedman and Smith's investigation (1958) of the deuterium content of water in volcanic glasses. They found that the deuterium content of the water in perlite was related to the deuterium content of meteoric water, but that the deuterium content of the water in the included obsidian was unrelated to either meteoric water or perlite water.

The obsidian pellets resist weathering and commonly are scattered over the slopes below the much less resistant perlite layers. For this reason they can be used as a guide in locating perlite deposits.

Basalt. Basalt flows of several different ages occur in most of the ranges in Lincoln County, but in most areas the basalts are the youngest volcanic rocks. The basalts are distinguished on the map where feasible, but many flows which are interlayered with the cliff-forming ignimbrites could not be shown. Among these are two basalt flows in the Black Canyon area, which have a total thickness of as much as 250 feet, and a basalt flow in the Condor Canyon area.

As many as six basalt flows are exposed along Meadow Valley Wash north of Leith. Basalt occurs near the base of the older lake beds (Panaca Formation) near Leith. The basalts generally rest unconformably on all older rocks, and they are typically overlain by tuffaceous lake beds or tuffs of Pliocene Age. The youngest basalt of all is the small cinder cone of Pleistocene or Recent Age in the Groom Range, 6 miles north of the Groom mine. The age of the basalts ranges from Miocene to Pleistocene(?), but most of them are early Pliocene.

Thickness

The total thickness of the younger volcanic rocks is unknown. A figure of about 3,900 feet has been calculated from the composite section given by E. F. Cook (written communication, 1959), but the rocks exposed in any one area seldom exceed 3,000 feet, and the average thickness is probably about 1,500 feet. The 6,000-foot thickness reported by Westgate and Knopf (1932, p. 27) in Condor Canyon is several times too large because of repetition by faulting, according to J. H. Mackin (oral communication, 1958). The total composite thickness in the western part of Lincoln County, however, is at least 5,000 feet, and as great a thickness may also be exposed in Meadow Valley Wash.

Age and correlation

The age of the younger volcanic series ranges from 34 m.y. (middle Oligocene) to perhaps Pleistocene. The earliest Tertiary volcanic rocks in most of the county are Miocene and few volcanic rocks are younger than middle Pliocene, according to the few age data available from Lincoln County and surrounding areas. The oldest volcanic rocks in the Pahranagat Range, which are thought to belong to the younger series, are dated as pre-Miocene by pollen in the overlying lacustrine limestone. The only direct dating in Lincoln County is given by this Miocene limestone, which has been dated in five localities. It generally underlies the volcanic section. An ignimbrite near the base of the volcanic section in the Grant Range, Nye County, was dated 34 m.y. by potassium-argon ratio in biotite (Evernden and others, 1958). This ignimbrite extends into the northwest corner of Lincoln County. Sediments near the base of the volcanic section in the Schell Creek Range about 18 miles north of Lincoln County contain mammalian remains of middle to late Miocene Age.

The thick tuff sequence in the Oak Spring Group in the Nevada Test Site, Nye County, which extends into southwestern Lincoln County, is dated by Eocene to Plio-

cene fossils in fresh-water limestone and tuffaceous beds on the south side of Frenchman Flat (Poole and McKeown, 1962). These beds are absent on Oak Spring Butte, but they were assigned to the basal part of the Oak Spring by Johnson and Hibbard (1957, p. 369). They contained poorly preserved gastropods of which Ten-Chien Yen (*in* Johnson and Hibbard, 1957, p. 369) stated:

> "* * * the fossil-bearing beds are probably of late Tertiary age and possibly of Miocene deposition."

These same(?) beds contain fossil fish about which A. B. Gibbons (written communication, 1959) states:

> "The fish fossils came from a horizon perhaps 150 feet above the base of a series of marly and tuffaceous beds resting unconformably on Paleozoic rocks at the southeast side of Frenchman Flat * * *."

David H. Dunkle (written communication, 1956) states:

> "Apparently all of the specimens are to be referred to the Killifish genus, *Fundulus* (family Cyprinidontidae). Of four fossil species of this genus known from the Great Basin area, these materials would seem to approach most closely *F. curryi* Miller, from rocks of probably Pliocene Age of Death Valley. However, the Nye County specimens differ regularly from *curryi* in a number of significant characteristics and probably belong to a different species —an undescribed species or subspecies.
>
> "According to Miller (1955) the four species of *Fundulus* from the Great Basin area are thought to be restricted to the interval between the Pliocene and Recent."

As a group, the younger volcanic rocks are equivalent in age to the Needles Range, Isom, Quichapa, and Page Ranch Formations (Mackin, 1960, p. 89-104) (fig. 17). The units within the group cannot be correlated at present, but we believe the youngest volcanic rocks in the southwest corner are younger than most of the rocks farther east.

The Oak Spring Group may be partly equivalent to the thick tuff sequence in southwestern Lincoln County, perhaps even to lake beds in the Panaca and Muddy Creek Formations, and to the lake beds in the White River basin (older lake beds on plate 2). This hypothesis needs to be tested by detailed studies, but it is plausible in view of the Pliocene Age of the three formations and the probability that eruptions capable of producting 2,600 feet of tuffs would blanket an immense area. A. B. Gibbons (written communication, 1959) states:

> "* * * the stratigraphic relations between the limy and fossiliferous beds southwest of Frenchman Flat and the type section of the Oak Spring rocks at Oak Spring Butte are not understood at present. * * * [In the northern part of the Nevada Test Site] limy beds do, however, seem to be equivalent to beds outcropping southeast of Frenchman Flat which are shown on the Clark County geologic map [Boyer and others, 1958] as belonging to the Horse Spring formation * * *"

C. R. Longwell (oral communication, 1961) believes that calcareous beds at the base of the Oak Spring Group consist of a basal part that is equivalent to the Horse Spring Formation and an upper part that is younger. This observation is based on fossil evidence that shows the lower part to be Eocene and the upper part Miocene(?) and younger. The lithology of the Eocene portion is strikingly similar to that of the type Horse Spring Formation.

Intrusive Rocks

Distribution

In contrast to the extrusive rocks, intrusive rocks are remarkably scarce in Lincoln County. There are three principal types of intrusive rocks — granitic, dioritic, and basaltic.

Small granitic stocks occur in the Groom, Timpahute, Worthington, Bristol, and Highland Ranges, and near the south end of Cave and Delamar Valleys. In addition, very small bodies of granitic rocks crop out north of Bristol Pass in the Fairview Range, near the Ely Valley mine in the Pioche Hills, north of Little Mountain, and near Winze Creek in the Wilson Creek Range. Granitic dikes or sills crop out in many of the mining districts, but they are especially numerous in the Delamar district.

Dioritic stocks occur in the Chief, Delamar, Pennsylvania, and Little Mountain mining districts. A plug of intrusive andesite occurs in the throat of the old volcano in the Seaman Range. These rocks resemble the volcanic rocks in texture and composition, and similar bodies have probably been overlooked in the volcanic area between Delamar and the Utah line.

The third type of instrusive rock occurs as dikes or sills of basalt, fine-grained diabase, or lamprophyre. Diabase or basalt sills, dikes, or flows occur in the Prospect Mountain Quartzite in the Delamar, Chief, Pioche, and Patterson Pass mining districts. If the basalt near the Patterson Pass is a flow, as Kellogg (1960, p. 190) believes, it is Cambrian instead of Tertiary, as perhaps is also the diabase in the Chief and Pioche districts.

Lithology

The granitic rocks belong to three types: the porphyries, the hypidiomorphic granular rocks from the stocks, and the rhyolites or microgranites.

The stock south of Delamar is an altered porphyritic

potassic granite that is composed of altered orthoclase and microcline phenocrysts with only a small amount of corroded quartz. The groundmass is fine grained and contains graphic intergrowths of two feldspars or quartz and feldspar. The mafic minerals, if ever present, have been replaced by iron oxides.

The Silver King stock contains plagioclase, quartz, orthoclase, biotite partly altered to iron oxides, hornblende, and chlorite. Plagioclase is the predominant phenocryst, but it is partly replaced by orthoclase which forms radial aggregates in the groundmass. The rock is probably a granodiorite porphyry. A dike of similar but fresher rock occurs near the Silver King mine north of the stock.

The granitic rocks near the north end of the Groom Range are sericitized rocks that contain abundant quartz, altered biotite, orthoclase, and plagioclase. The stock farthest east is a porphyritic quartz monzonite with a coarsely crystalline groundmass. The quartz in this rock is in the form of large spongy grains that fill the interstices between feldspar grains. Orthoclase forms phenocrysts up to three-fourths of an inch in diameter. The rock contains chlorite, sericite, and calcite as alteration products. The Pioche Shale near this stock has been converted to a hornfels that consists largely of potassium feldspar and quartz.

The east stock of the Worthington range is a leucocratic porphyritic granite that consists of quartz, orthoclase, and some partly altered biotite. The plagioclase is srongly zoned; it is largely oligoclase. The western stock is more mafic and more variable in composition and texture, but it was not studied in detail.

The two granite stocks in the Tem Piute district were not studied in thin section. The southern stock, around which productive tungsten deposits occur, is notably less resistant to erosion than the northern one (p. 142).

The Blind Mountain stock varies in composition from granite to quartz monzonite or granodiorite. These rocks and the contact metamorphism were carefully studied by J. L. Gillson (*in* Westgate and Knopf, 1932, p. 32-42), who deduced that this stock started to crystallize as a norite before some event caused a major shift in the course of crystallization. In this rock, orthoclase replaces both quartz and plagioclase. In decreasing order of abundance, the rock contains plagioclase, microcline, quartz, biotite, hornblende, and augite. Boron metasomatism has occurred in the contact aureole, producing abundant tourmaline, and locally ludwigite, szaibelyite, and fluoborite.

Coarse-grained pink granite crops out in the Fairview and Wilson Creek Ranges, but its age is unknown and the field relations are obscure.

Granodiorite crops out in a small area near the Ely Valley mine, and a much larger mass is exposed in the underground workings. This rock consists of 40-65 percent altered andesine and some orthoclase, 15-35 percent quartz, 10-20 percent biotite, and smaller amounts of green hornblende and chlorite. The quartz fills the interstices between the other minerals.

Granite porphyry dikes and sills occur in the Ely and Highland Ranges, where they are highly sericitized and closely associated with ore deposits. Biotite and hornblende, the original mafic minerals, have been replaced by muscovite.

In the Pioche Hills and Highland Range, dikes or dikelike masses of volcanic rocks show textures typical of welded tuffs. These bodies may be feeders for some of the ignimbrites which are so widely distributed in Lincoln County.

A dike of hornblende-biotite quartz dacite porphyry with zoned plagioclase phenocrysts as much as 1.5 inches in diameter cuts the volcanic rocks on the northeast side of Bald Mountain. These rocks contain a little orthoclase, largely in the groundmass.

Dikes and stocks of dioritic composition occur south and east of Caliente and on the east side of Silver King Mountain. These rocks have not been studied in thin section, so their mineralogy is unknown.

The diabase in the Ely Range is a dark-green, fine-grained, amygdaloidal rock that weathers rusty brown. The rock is composed of altered augite, altered labradorite, and some olivine, and has an ophitic texture. Some amygdules are surrounded by reaction rims of hypersthene. The diabase and basalt from other areas were not studied under the microscope.

Lamprophyre dikes occur in the Pioche and Comet districts and probably in many other places. In the Pioche district they are dark-green fine-grained rocks that contain augite phenocrysts up to 1 inch in diameter. Some dikes also contain abundant biotite or barkevikite; these minerals probably formed by reaction between the residual fluid and the early mafic minerals.

Age

The intrusive rocks are thought to be Tertiary and mostly postvolcanic. The dioritic rocks intrude the older volcanic rocks and are themselves intruded by microgranite or rhyolite in the Little Mountain area. The granitic stocks are generally postvolcanic and post-thrust where they can be dated, as in the Bristol Range. They are probably of several ages, but in general are post-Oligocene, pre-Pliocene. The absolute ages are unknown.

Older Lake Beds

The Panaca and Muddy Creek Formations and similar lake beds in the White River and Pahranagat Valleys are mapped as a single unit. These rocks are largely silt-

stone and clay shale and are not the lacustrine limestone of Miocene Age. The older lake beds rest unconformably on all underlying rocks, but are in part equivalent to the thick tuff sequence in the Oak Spring Group.

Distribution

The Panaca Formation is confined to the upper part of the drainage basin of Meadow Valley Wash near Caliente. The four largest outcrops are in Meadow Valley around Panaca, in Lake Valley (Patterson Wash) northeast of Pioche, in the Spring Valley drainage north of Ursine, and in the Clover Creek drainage surrounding Barclay.

The Muddy Creek Formation covers a large area in the southeastern corner of Lincoln County and in the northeastern corner of Clark County. Smaller outcrops occur at the mouth of Meadow Valley Wash, and west of U.S. Highway 93 along Coyote Spring Valley.

The outcrops in the White River drainage north and south of Hiko and the extensive outcrops in the broad White River Valley in Nye and White Pine Counties, hereafter called informally the White River lake beds, are probably equivalent to the Panaca and Muddy Creek Formations.

Lithology

The lithology was not studied in detail by us, so most of the description of the Panaca Formation is taken from the work of Westgate and Knopf (1932, p. 23-27) and Phoenix (1948, p. 34-38), and that of the White River lake beds from the work of Maxey and Eaton (1949, p. 29-33). The lithology of all the rocks included in this unit is almost identical.

The lacustrine rocks are white, pale-gray-green, light-brown, pink, and terra-cotta gravel, sand, silt, and clay. The coarse grains are seldom larger than coarse sand and consist largely of volcanic debris and fragments of the nearby Paleozoic rocks. Finer grained rocks, chiefly water-laid tuffs or tuffaceous rocks, are predominant in most areas. Beds of marly limestone are present in White River Valley, and thin white beds of either diatomite or pure volcanic ash are present near Panaca. Porcelaneous opal-cemented tuff in thin layers and concretions occurs in the butte at Panaca.

The Panaca Formation is finer grained in the center of the valley than it is toward the margins of the basins. It is generally horizontal, but locally it dips 2° or 3° toward the center of the valley. Phoenix (1948, p. 36) states:

> "In Spring Valley the Panaca formation consists almost entirely of fine volcanic detritus interbedded with layers of opaline material six inches to one foot thick."

A well on the west edge of Meadow Valley in sec. 32, T. 1 N., R. 67 E., cuts 450 feet of interbedded, medium- to coarse-grained quartzitic sand and silt. The town well at Panaca cuts layers of silt and diatomite, with interbedded lenses of angular limestone gravel, to a depth of 620 feet. A well near Patterson Wash east of Pioche cuts silt to a depth of 370 feet and then quartzitic and rhyolitic sand to a depth of 500 feet (Phoenix, 1948, p. 35-36).

Callaghan (*in* Hewett and others, 1936, p. 178-182) found a 9-foot bed of ash composed of clear volcanic glass that is exposed for a quarter of a mile near Cathedral Gorge State Park, and a 6- to 10-foot bed of white fine-grained friable diatomite, that crops out for half a mile, 1 mile east of Panaca.

Thickness

The full thickness of these older lake beds is not known. The thickness of the Panaca Formation in Meadow Valley is estimated by Phoenix (1948, p. 36) to be at least 1,400 feet. The exposed thickness of the Muddy Creek Formation is only a few hundred feet, but a total thickness of even several thousand feet is not unreasonable because of the thickness of Tertiary basin fill elsewhere in the Great Basin.

The County Line Unit 1, a dry wildcat well of Standard Oil Co. of California in sec. 19, T. 10 N., R. 62 E., White Pine County, 4 miles northwest of the corner of Lincoln County, undoubtedly cut the White River lake beds which are exposed a few miles away. The lithologic log filed with the Nevada Oil and Gas Conservation Commission reports that valley fill was cut to a depth of 1,475 feet. The log does not report the lithology above 570 feet, but we tentatively interpret the rocks between 570 and 1,475 feet to be older lake beds. They overlie volcanic rocks and probably extend almost to the surface. A well in sec. 13, T. 12 N., R. 61 E., shows that the thickness of lacustrine material is more than 1,300 feet (Maxey and Eakin, 1949, p. 18-30). The Eagle Springs discovery well of the Shell Oil Co. in Railroad Valley, Nye County, penetrated approximately 5,000 feet of medium-brown to yellow shale or siltstone that is probably equivalent to the older lake beds. These rocks are underlain by 1,450 feet of conglomerate, which overlies 855 feet of volcanic rocks.

Age and correlation

We, like C. R. Longwell and others (1965, p. 49) and Phoenix (1948, p. 35), consider the Panaca and Muddy Creek Formations to be approximately equivalent. These units are probably at least partly equivalent to the lower member of the Indian Trail Formation; to the thick tuff and basalt section in the Desert, Pintwater, and Spotted Ranges; and to the lake beds in Railroad and White River valleys. In a general way the older lake beds and equivalent rocks correlate with the upper unit of the

Humboldt Formation (Sharp, 1939, p. 154). Maxey and Eakin (1949, p. 30) state:

> "The lithology and stratigraphic position of these sediments [White River lake beds] closely resemble other lacustrine sediments studied in nearby areas, such as the Panaca formation in the Pioche district and parts of the Humboldt formation along the Humboldt River."

Stock (1921, p. 147) dated the Panaca Formation on the basis of mammalian fossils as probable Pliocene. Stirton (*in* Phoenix, 1948, p. 34) states:

> "Cannon bone fragments in the Meadow Valley *Pliohippus* display well developed distal keels more like those seen in middle Pliocene species. The beds cannot be older than late Clarendonian (lower Pliocene) nor are they as recent as *Blancan* (upper Pliocene)."

TERTIARY AND QUATERNARY DEPOSITS

Older Gravels and Older Alluvium

Distribution

Approximately one-third of Lincoln County is covered by unconsolidated Quaternary deposits that fill the basins to great depths. All these unconsolidated rocks except the lake and playa deposits, wind-blown sand, and Recent stream deposits are included in two groups of diverse clastic rocks of several ages. These rocks are shown on the map as older gravels and older alluvium, but this distinction is somewhat arbitrary in places.

Lithology

The units consist of gravel and alluvium composed of rocks eroded from the nearby mountains. For the most part, it is composed of fanglomerates deposited both in fans and in continuous aprons along the mountain fronts. Generally the gravels dip outward from the mountain fronts as much as 15°, but dips around 5° are common. The detritus derived from the volcanic terrain is commonly much finer grained than that derived from the Paleozoic sedimentary rocks. Debris from areas of quartzite is particularly coarse, as might be expected.

Thickness

The older alluvium and gravels are as much as 1,000 or 2,000 feet thick in some of the deeper basins, and at least a thousand feet have been removed by erosion along Meadow Valley Wash near Carp and Panaca.

Age and correlation

The older alluvium and older gravels probably include some rocks of late Pliocene and Pleistocene Age, but direct fossil evidence has not been found in Lincoln County. The units unconformably overlie the older lake beds as a rule, although they may include rocks of the same age in some areas. In general, the units are younger than the volcanic rocks and the basin-and-range faulting, and older than the late Pleistocene lakes. After the deposition of these rocks, the part of Lincoln County along the White River and Meadow Valley drainages must have been an alluviated surface of low relief. Streams established on this surface cut canyons as much as 1,000 feet deep through buried ridges of bedrock. Three terraces in Meadow Valley near Panaca, the highest about 900 feet above the valley bottom, record stages in this process. Such a great amount of erosion required a long period of time and suggests that the units are early Pleistocene. However, the only direct evidence is from areas outside Lincoln County. A horse tooth found by C. L. Sainsbury in the highest terrace gravel on the west side of the Quinn Canyon Range was identified as Pleistocene by C. A. Repenning (oral communication, 1959).

The older gravel on the east side of the southern Egan Range includes the Cave Valley Formation of Kellogg (1959, p. 120).

Intermediate and Younger Lake Beds

Distribution

The intermediate and younger lake beds are found in most of the nine interior drainage basins in the county that contain playas and in a few additional valleys that drain through gaps into these and other interior drainage basins. These lake beds consist of two map units, the intermediate lake beds above the highest beach lines and the younger lake beds below the highest beach lines. The late Pleistocene lakes and streams in Lincoln County are shown on figure 18.

Lithology

The sediments deposited in these lakes were largely reworked silt and clay that were first deposited in the older and larger lakes of Pliocene Age, which occupied many of these same basins. The younger lake beds include all the light-colored, fine-grained sediments below the highest beach line, which usually is clearly visible on aerial photographs. The intermediate lake beds are lithologically similar; however, they occur above the highest beach line, are more dissected, and are overlapped by older alluvium.

Thickness

The thickness of the intermediate and younger lake beds is unknown. It is probably much less than the thickness of the Pliocene lake beds, but in many basins the beds probably make a continuous section that cannot be separated.

Age and correlation

The intermediate and younger lake beds probably include sediments that range in age from Pleistocene to Recent. The rocks probably represent deposits of several

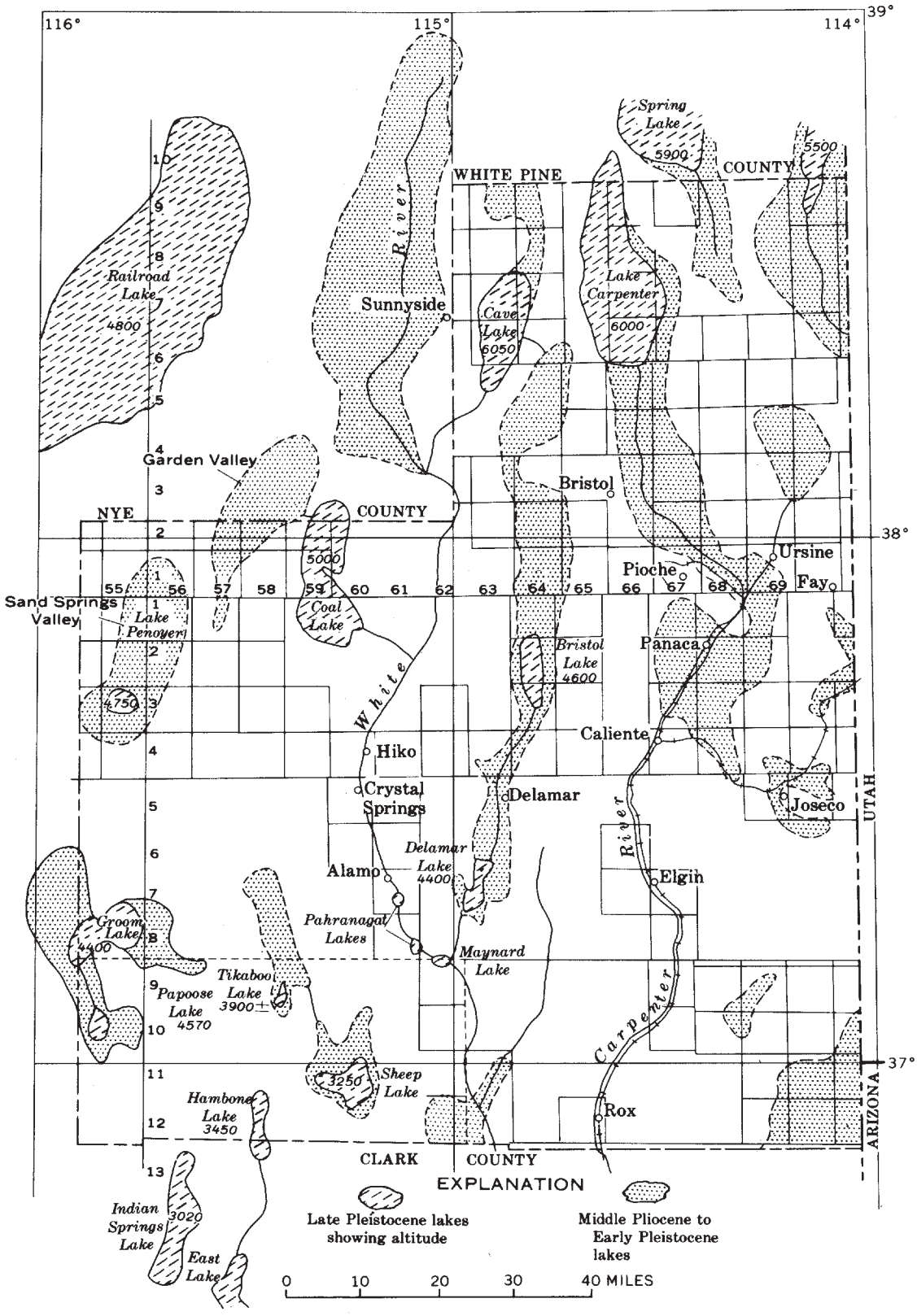


FIGURE 18. Map of Pliocene and Pleistocene lakes and streams in Lincoln County and adjacent areas.

ages. They can be broadly correlated with the deposits in Lakes Bonneville and Lahontan.

Recent Surficial Deposits

Recent sediments are divided into three units on the geologic map: Recent playa deposits, dune sand, and younger alluvium.

We included in the playa deposits only the undissected surface of the modern playas. These sediments are relatively thin deposits of largely reworked silt and clay derived from older lacustrine sediments presently exposed in the drainage basins of the playas. The amount of sediment derived directly from the surrounding mountain blocks is considered to be negligible under present climatic conditions. Nine modern playas are shown on the geologic map; their altitudes range from 6,000 feet at the north end of the county to 3,250 feet at the south end.

Dune sand was mapped in three areas: on the west side of the Sheep Range, on the west side of the Buried Hills, and in Sand Springs Valley. Each area is east of a playa from which the sand was derived. The sand is probably less than 100 feet thick.

We mapped the younger alluvium only in the Recent drainage channels; it includes reworked older alluvium and small playalike areas of reworked lacustrine sediments that occur in White River Valley. As a general rule, thin veneers of younger alluvium on lake beds, playas, older alluvium, or older gravels were included with the older deposits. None of the deposits of recent alluvium is very thick and the major valley fill is older.

Late Pleistocene Drainage

There is abundant evidence that Lincoln County was well watered in late Pleistocene (Wisconsin) time, even as recently as 10,000 years ago. Lakes were present in 10 interior drainage basins (fig. 18), and there were two major rivers — one in the drainage basin of Meadow Valley Wash and the other in the drainage basin of the White, Pahranagat, and Muddy Rivers. Lakes in Dry Lake (Bristol), Delamar, and Coal Valleys were shown on Carpenter's map (1915), and Carpenter also recognized the Pleistocene drainages of Meadow Valley Wash and White River. Interconnections apparently did not exist between most of the late Pleistocene lakes in western Lincoln County and the river systems. The high alluvial barrier which produced Maynard Lake, the lowest of the Pahranagat Lakes, may be the discharge delta from Delamar Lake. Late Pleistocene lakes in Coal and Cave Valleys also might have overflowed into the White River drainage in pluvial time or perhaps in earlier pluvial periods.

Hubbs and Miller (1948, p. 92), from whom most of the description of the late Pleistocene waterways is taken, suggested on ichthyological evidence that an early Pleistocene(?) river may have connected Railroad, Sand Springs (Penoyer), and Tikaboo (Desert) Valleys with the precursor of White River or with the Colorado River.

The pluvial lake in Cave Valley may have drained east through Sidehill Pass into Dry Lake Valley, which in turn drained into Bristol Lake, then into Delamar Lake, and finally into the White River at Maynard Lake.

Conceivably the precursor of the Carpenter River may have connected the basin in which the Panaca Formation was deposited with the Muddy Creek basin. Similarly, the ancestral White River probably occupied a basin once filled with Pliocene lake sediments. It may have drained a Pliocene lake in White River Valley. The deeply entrenched meanders of Meadow Valley Wash and the thick piles of dissected gravel near Carp suggest that the ancient Carpenter River meandered over a gentle alluviated surface that buried the ancient topography. Subsequent erosion has removed much of the unconsolidated Pliocene and Pleistocene deposits and exhumed the old bedrock surface. The highest of three terraces that cut into Panaca lake beds near Panaca is 900 feet above the present stream floor, and near Carp more than 1,000 feet of gravel have been removed. Well-developed pluvial terraces along Kane Springs Wash were probably formed by a tributary of the ancestral White River. Little erosion or deposition has occurred in the part of Lincoln County that has had interior drainage since the late Pleistocene lakes dried up.

STRUCTURE

It is difficult to generalize about the structure of an area as large and as complex as Lincoln County. The problem is made even more difficult because of the similarity of lithology and the uncertainty of correlation of the lacustrine limestones, clastic rocks, and volcanic rocks, which range in age from Cretaceous(?) to Pliocene.

The complexity of the structure in Lincoln County is shown by the generalized tectonic map (pl. 3). The major regional structural features are thrust faults and northeast-striking strike-slip faults. These are Laramide(?) structures and have much larger displacements than the post-Laramide normal faults that formed the basins and ranges. The largest thrust plates may once have extended over very large areas, if isolated remnants can be correlated. The thrust plates are shown by line patterns in plate 3. Possibly a third of the area of pre-Tertiary outcrops is underlain by major thrust faults. This term is used in a descriptive sense and does not exclude structures formed by gravity sliding.

There were at least two periods of thrust faulting. The major thrust faults are approximately Laramide, probably Cretaceous or Eocene. They are definitely

younger than the Late Triassic rocks, and they are generally older than the Miocene or younger lacustrine limestones. These thrust faults are older than the younger volcanic rocks, but their age relative to the older volcanic rocks is unknown.

The major thrust faults, though generally older than the basin-range faults, may be contemporaneous with the early movement on certain northeast-trending strike-slip (tear?) faults. Some gravity thrust faults (ecoulements) are clearly younger than the Oligocene volcanic rocks and older than the Pliocene lake beds. These faults are probably late Miocene or early Pliocene.

The last movement on the major northeast-trending strike-slip faults clearly offsets the Miocene limestone and the overlying volcanic rocks in a left-lateral sense, even though there is indirect evidence for much larger right-lateral movement in pre-Miocene time.

Nearly all of the normal faults that produced the present basins and ranges are clearly later than the major thrust faults and also later than most of the volcanic rocks. A few conspicuous normal faults of small displacement cut beds of Pliocene or Pleistocene Age. Most parts of the county, however, have been comparatively quiescent since the deposition of the Panaca and Muddy Creek Formations, in contrast to western Nevada, where most of the basin-range faults are Pliocene and younger. Evidence of the recent structural stability is corroborated by the nearly complete absence of recorded earthquakes in Lincoln County and much of the eastern Great Basin, as shown in figure 19 (Woolard, 1958).[1]

The structures will be discussed in chronological order, beginning with the thrust faults. Only the broad outline of the structure will be given in this section; the local structural details will be given in the descriptions of the individual ranges.

LARAMIDE THRUST FAULTS

The major thrust faults of Laramide age — the most conspicuous structural features in the southern and western parts of the county — are clearly older than nearby sedimentary and volcanic rocks of Eocene Age and younger. A period of erosion followed Laramide thrusting and preceded the deposition of the Eocene rocks. During this period as much as 5,000 feet of well-rounded conglomerate (older clastic rocks) were deposited. The age of the Laramide thrust faults relative to the older volcanic rocks is unknown because they do not occur in the same areas.

[1]Since this report was prepared, studies conducted by the Seismological Laboratory, Mackay School of Mines, have shown moderate seismic activity in the eastern portion of Lincoln County. In 1966, two earthquakes of magnitude 6 were recorded near Caliente. (Editors)

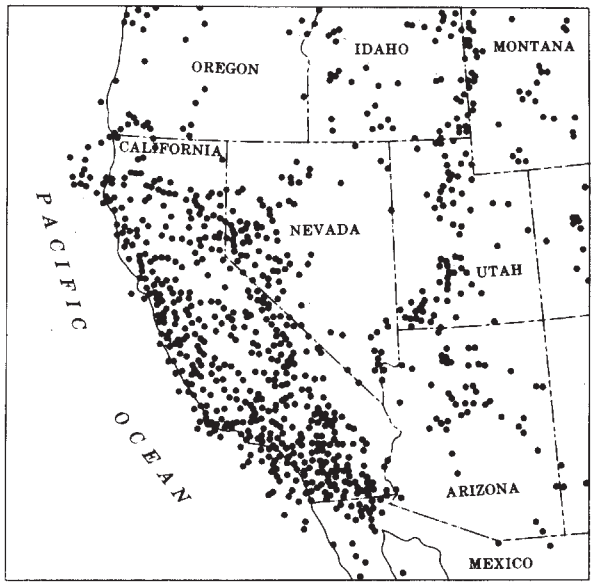


FIGURE 19. Map showing recorded earthquake epicenters in the western United States (from Woollard, 1958).

Two different types of early thrust faults occur: (1) the decollement and gravity (ecoulement) thrust, and (2) the compressional (stretch) thrust that originates in overturned folds. The initial movement of the first type of thrust probably occurred on the Pioche or Chisholm Shales. The only example of the first type is the Tule Springs thrust, the possible northern extension of the Glendale thrust of Longwell and others (1965, pl. 5). This fault brings a comparatively thin section of older Paleozoic carbonate rocks at least 15 miles eastward over younger late Paleozoic and Triassic rocks which were probably already folded and beveled by erosion (Tschanz, 1959) (fig. 20). The rocks in the thrust sheet belong to the comparatively thin shelf or transitional facies that was deposited along the eastern margin of the Cordilleran miogeosyncline which occupied Lincoln County throughout Paleozoic time. The fact that the thin facies occurs in the thrust plate limits the maximum eastward movement to less than 40 miles, unless the thick geosynclinal facies in the Meadow Valley Mountains has itself been thrust eastward. The overthrust rocks range in age from Cambrian to Pennsylvanian and resemble rocks in the Muddy Mountain overthrust in the adjacent part of Clark County.

The overthrust rocks moved along a thrust plane that was generally horizontal or undulating and that was broadly parallel to the bedding of both plates (fig. 20). The inferred open folds below the thrust seem unrelated to it. Two separate thrust plates are present, but the relation between them is uncertain. One plate, the higher of the two, is composed of Pennsylvanian and Permian rocks which are generally younger than the rocks in the princi-

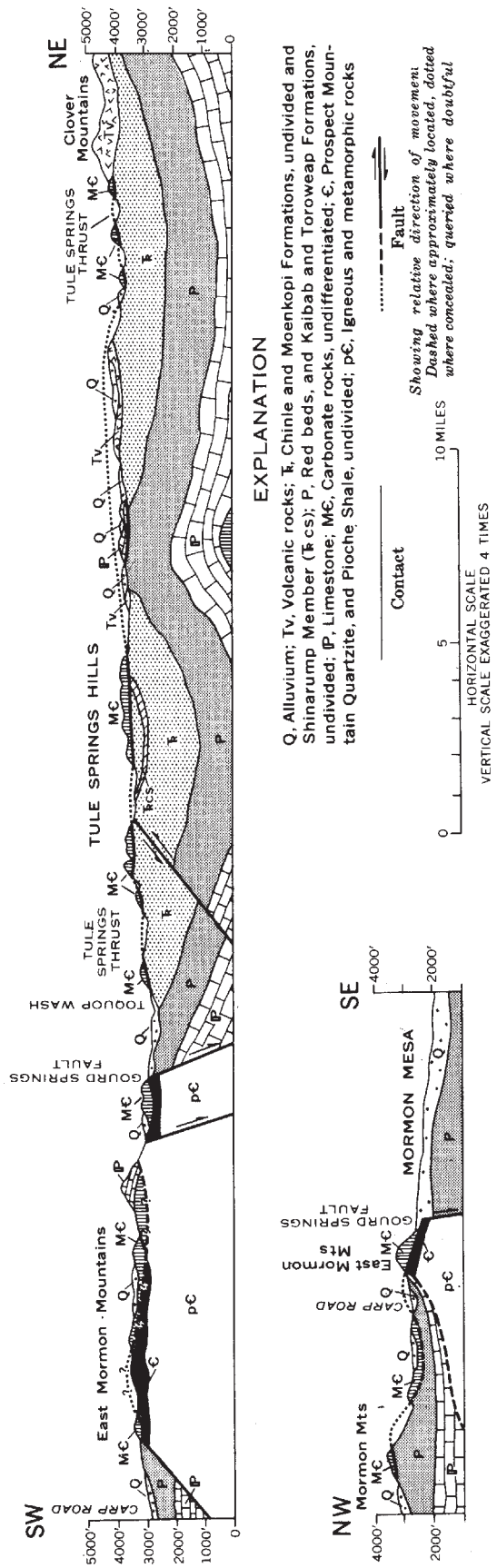


FIGURE 20. Generalized cross sections across Tule Springs thrust, southeastern Lincoln County. Lines of section are not shown on any map.

pal plate. In places it appears that the higher plate (vertically lined pattern, pl. 3) overrides volcanic rocks of Tertiary(?) Age, but the evidence is not conclusive. It is probable that more recent landsliding, perhaps of klippen, might account for these relationships. The Pennsylvanian and Permian rocks between Lime Mountain and the largest klippe appear to have been dragged eastward from the crest of an anticline along the sole of the principal plate, but the possibility that the higher plate is younger than, and unrelated to, the principal plate cannot be discounted.

It is possible that the principal thrust plate (horizontally lined pattern, pl. 3) that rests on Triassic rocks is a gravity thrust sheet (ecoulement) that slid down the east flank of a rising uplift in the Mormon Mountains area aided by confined hydrostatic pressure in a shale bed beneath the thrust. The evidence for this possibility is primarily the 3,000 feet of structural relief on the Monte Cristo Limestone across the Mormon Mountain arch.

The complex structural relationships in the Mormon Mountains are poorly understood, partly because unconformities occur in the Paleozoic section. A decollement thrust, however, may underlie the entire carbonate section in the domelike Mormon Mountain arch. Throughout most of this circular area, younger rocks appear to be thrust on older rocks. The thrust surface probably follows one of the Cambrian shales. The amount of movement is unknown. It is possible that this thrust plate (horizontally lined pattern in pl. 3) is part of the Tule Springs thrust plate, but it may instead be a separate sheet that is not far from its original position.

Thrust faults of the second type are clearly associated with overturned folds formed by compressional forces. This is not to say that the thrusts themselves are necessarily compressional features. They are exemplified by the thrusts in the Meadow Valley Mountains, in the Sheep, Pahranagat, and Spotted Ranges; on Chert Ridge; in the Jumbled Hills; and on Mount Irish (pl. 3). These thrusts have moved older rocks eastward over younger rocks that are typically drag-folded beneath the sheet to form a recumbent syncline whose overturned west limb is sometimes sheared off on a subsidiary thrust fault. The overturned synclines might also be interpreted as the lower limb of a recumbent anticline from which the thrust fault originated.

POST-OLIGOCENE "THRUST FAULTS"

Sheets and blocks of younger Paleozoic rocks, not obviously related to compressional features, rest on older Paleozoic rocks, or on Tertiary volcanic or sedimentary rocks. The origin of these features is uncertain and somewhat controversial; they might equally well be interpreted as landslides, ecoulement sheets, or thrusts of late

Tertiary Age. The term "thrust fault" is used in a purely descriptive sense in this section. Some of these sheets might be ecoulements, in part derived from Laramide thrust plates, following basin-range normal faulting. It is perhaps significant that the late thrust faults generally occur in positive areas that were deeply eroded to expose Cambrian rocks in Mesozoic time.

The typical postvolcanic thrust faults are those in a north-south belt that extends from Caliente north to the northern tip of the West and Bristol Ranges. These thrusts typically bring Middle and Upper Cambrian rocks over older Cambrian rocks and over volcanic rocks of probable Oligocene or Miocene Age.

In the West Range and in the northern Bristol Range, Devonian rocks (Silverhorn Dolomite) are thrust over Cambrian, Ordovician, and Devonian rocks, or over Tertiary volcanic rocks (Westgate and Knopf, 1932, p. 42-43). Devonian rocks are thrust onto Cambrian and Ordovician rocks along the west side of the northern Bristol Range; farther west in the West Range, they are thrust onto other Devonian rocks and onto Tertiary volcanic rocks. The plates of Devonian rocks in these areas, and a remnant in the Blind Mountain area in the southern Bristol Range, are part of a single thrust plate.

A megabreccia composed of chaotic blocks of Cambrian sedimentary rocks and Tertiary volcanic rocks has been cut by many drill holes in the valleys on either side of the Pioche Hills. This megabreccia might have been produced by Miocene or Pliocene thrusting before basin-range faulting or by landsliding following it. Paul Gemmill (oral communication, 1956) reports that, according to drill-hole data, Cambrian carbonate rocks have overridden Tertiary volcanic rocks at the Cinch mine on the east side of the Schell Creek Range at Patterson Pass.

Gravitational sliding or landsliding instead of thrusting might also explain the exotic block of Cambrian rocks, 3 miles long, that now rests on Tertiary rocks east of the Pintwater Range at the Clark County line. This block is several thousand feet up the west slope of Three Lakes Valley, and about 8.5 miles from the nearest outcrop of these rocks, which is in the Desert Range. This block probably is a remnant of a regional thrust plate of Cambrian rocks that later slid into the valley following basin-range faulting, a Quaternary(?) landslide that antedates the present ranges.

A major post-Oligocene thrust fault might be inferred on the east side of the southern Egan Range where a sheet of healed breccia of Cambrian limestone rests on Tertiary rocks. This sheet might be an ecoulement, but Kellogg (1960, p. 195) interprets this block as a basal sedimentary breccia of the overlying unconformable Tertiary unit that contains large exotic blocks. If so, no thrust fault need be inferred and the Shingle Pass fault would be interpreted as a normal fault with very large stratigraphic separation. An alternate and unlikely explanation would interpret the southern Egan Range block south of Shingle Pass as a post-Oligocene thrust plate that has moved eastward over the block north of the pass. In this case the Shingle Pass fault would be a thrust. This fault could also be a strike-slip fault and, in many ways, this seems to be the most likely explanation.

TEAR FAULTS

Several northeast-striking faults with apparent strike-slip movement are prominent structural features of the geology of Lincoln County. The most conspicuous of these are three parallel post-Miocene left-lateral faults in the Pahranagat Range south of Alamo (pl. 3). The southernmost of these faults, the Maynard Lake fault, bounds the Gass Peak thrust plate that makes the Sheep Range. The middle fault is the Buckhorn fault. The northernmost left-lateral fault — the Arrowhead mine fault — and perhaps also the Maynard Lake fault are inferred to be a reactivated portion of a much larger right-laterally distributed shear zone of approximate Laramide age. These Laramide faults will be discussed before the post-orogenic left-lateral faults.

The Arrowhead mine fault is tentatively inferred from the remarkable similarity in lithology and structure between the thrust sheet and the overturned fold belt beneath it in the Spotted and Pahranagat Ranges. Evidence at first suggests that the Pahranagat Range thrust and fold belt is the offset portion of the Spotted Range thrust and fold belt. This evidence is the unusually steep eastward dip of beds in the thrust plate in both ranges, the presence of a distinctive facies of Pilot Shale beneath the thrust in both ranges, and the anomalously great thickness of the Pogonip Group in the thrust plate in the Pahranagat Range. This thickness is about the same as in the Spotted Range thrust sheet, but it is about 600 feet greater than on the west side of the Pahranagat Range, and it is also greater than in surrounding areas. As noted earlier (p. 24), however, Reso (1963, p. 905) suggests that the difference in thickness of the Pahranagat Range Pogonip sections is caused by faulting within the basal part of the western section and not by regional thrusting.

Further support for a postulated 30 miles of right-lateral Laramide movement is given by the obvious presence of a hidden major fault south of the Papoose Range (pl. 2), and by the great apparent facies changes in the Lower Cambrian clastic rocks exposed on opposite sides of the fault in the Groom Range and in the Desert Range.

The evidence for a 30-mile eastward displacement on a thrust fault is much more conclusive than the evidence for the same displacement on a right-lateral shear zone because the right-lateral fault cannot be traced through

the intervening ranges. This difficulty is avoided by postulating that the northeasterly fault is a tear that is confined to the thrust plate. However, this requires similar Pilot Shale facies in the two ranges and requires that the fold belt in the lower plate be developed in two places. There would be no reason for a post-Miocene left-lateral fault to occur beneath a tear in a thrust plate unless the basement fault localized both. In all, the evidence makes a tear fault less likely than a basement rift.

We tentatively favor the interpretation, therefore, that the Arrowhead mine fault is a major right-lateral basement shear zone comparable to the San Andreas and Garlock faults, and the Las Vegas Valley shear zone (Longwell, 1960). Indeed, these faults may all be part of the same Laramide subcontinental shear system. It is worth noting that the trends of the Arrowhead mine fault and the Las Vegas Valley shear zone bear the same angular relationship and have the same relative directions of displacement as the San Andreas and Garlock. In both cases the northeasterly faults can be interpreted to have had left-lateral middle or late Tertiary movement, but earlier right-lateral movement. Inspection of the tectonic map (pl. 3) shows faint evidence that other northeasterly Laramide basement shear zones may exist in Lincoln County, but all these postulated shear zones have been so disrupted by later faulting and so deeply buried by younger rocks that it is hard to be sure.

It is likely that all three post-Miocene left-lateral faults, which together are named the Pahranagat shear system, reflect the older right-lateral shear. Right-lateral Laramide movement of approximately 30 miles might also have occurred along the approximate eastward projection of the Maynard Lake fault. This offset is based wholly on the tentative and unsubstantiated correlation of the Delamar Range fold and thrust belt with the Highland Range thrust (pl. 3). The only other evidence for Laramide displacement of this fault is the termination of the Laramide Gass Peak thrust against it, and the apparent thinness of the Pogonip Group in the Sheep Range compared to its thickness in the Pahranagat Range north of the fault and farther east. There is again the possibility that this postulated fault was a tear confined to a regional thrust sheet. An intrusive body and a possible major caldera near Boyd, about 8 miles south of Caliente, occur along this line, which lies near the south end of the Cambrian outcrops in the Delamar district, the Chief Range, and the Pioche Hills.

We tentatively favor the interpretation that the major right-lateral shear zones in the basement were formed during the same orogenic cycle as the Laramide thrusts and are genetically related to them. Two alternate interpretations are possible. The first would make the shear zones the cause of the thrusts, which could then develop independently on either side of the shear zones during the right-lateral movement. This view would make the thrusts a means of relief of stress in the sedimentary shell in regional blocks during the concurrent displacement along a conjugate basement shear system of subcontinental dimensions. This interpretation appeals to us because it permits the establishment of a regional structural pattern which explains how many similar and parallel fold thrust belts can arise and why so many major thrust plates end abruptly against northeasterly faults with apparent strike-slip movement. This interpretation might even obviate the 30-mile displacement along the right-lateral faults, but not this same amount of displacement on the thrusts.

The second interpretation requires the right-lateral faults to be later than the thrust and fold belts and to offset them. Even if this is the case, the right-lateral faults would not have to be much later, and they could be related to the same stress system.

These preliminary interpretations are presented here to point out the important role played by strike-slip faults, and to present a structural synthesis which can be readily proved or disproved by careful measurement of detailed stratigraphic sections in critical localities on opposite sides of the faults. The hypotheses tentatively presented, though somewhat premature, at least serve to indicate what critical localities deserve further study.

The three post-Miocene faults in the Pahranagat shear system south of Alamo have a total apparent left-lateral displacement as great as 10 miles, as measured on the spheroidal-weathering ignimbrite. Between 4 and 7 miles of vertical displacement would be required to explain the observed offset; this seems improbable to us. These faults are prominently reflected in the topography and offset both the Miocene(?) volcanic rocks, which dip eastward, and the underlying Paleozoic rocks, which dip west. However, the younger volcanic rocks (Pliocene?) to the west, though faulted, are not offset very far unless the movement is distributed over many faults, all of which are comparatively small. The structural complexities have not been worked out in detail. Much more detailed mapping of the volcanic rocks is required.

Another prominent left-lateral fault which has apparent displacement of about a mile occurs in the Pahranagat Range, in T. 4 S., R. 59 E., unsurveyed, about 3 miles north of Nevada Highway 25 (pl. 2). This fault strikes a little north of east.

Other possible strike-slip faults that strike generally east-west occur on the south side of Mount Irish and in the Timpahute Range. These faults offset the volcanic rocks. The postvolcanic movement is probably normal.

NORMAL FAULTS

There are several generations of normal faults in Lincoln County. A few cut the older volcanic rocks and the Paleozoic rocks but not the younger volcanic rocks. Most of the normal faults, however, are clearly younger than the volcanic rocks of Miocene Age and younger. In the East Mormon Mountains a few normal faults are older than the Tule Springs thrust (fig. 20), but nearly all of the basin-range faults in Lincoln County are clearly post-Laramide thrusting. Most of the basins and ranges were formed by normal faults that cut sedimentary and volcanic rocks of Miocene and early Pliocene Age. Only a few faults cut the lake beds of middle Pliocene Age, however.

Conspicuous frontal faults occur on the west side of the Meadow Valley Mountains and southern Delamar range; on the east side of the East Mormon, Pintwater, Golden Gate, and Seaman Ranges; and on both sides of the Sheep, Worthington, and Ely Ranges. These normal faults and many other frontal faults are shown in plate 3; many of them are named.

The youngest normal faults cut Pliocene and early Quaternary valley fill. Examples of this type are the conspicuous faults of minor displacement in Kane Springs Wash, and in Tickaboo, Dry Lake, Sand Springs, and Coal Valleys. These fault scarps, which are sometimes surprisingly sinuous, are probably formed by renewed late movement on old bedrock structures. The sinuous trace of the Dry Lake fault, which is a fault zone with small grabens, probably reflects the unconsolidated nature of the sediments it cuts. The position of this fault, well out from the range front, may represent a common position of frontal faults which are generally assumed to be close to the present base of the mountain blocks. A sinuous normal fault on Kellogg's map (1960) of the Egan Range, however, closely parallels the west base of the range. We have added this fault to the tectonic map and named it the Egan fault.

Most of the basins and ranges in the Great Basin province are bounded by frontal gravity faults formed in Miocene and early Pliocene time. These gravity faults are generally older than the Pliocene lake beds. In the southern part of the county, however, many ranges appear to be exhumed pre-middle Pliocene topographic features, some of which are not bounded by normal faults. The Mormon Mountains, for example, appear to be an eroded dome.

RANGE DESCRIPTIONS

An attempt has been made in the following descriptions to assess briefly the geology as it relates to the regional structure and to give further details on the stratigraphy where this is necessary to understand the regional geology. Only the larger structures are considered in these discussions, which are intended to supplement and guide careful study of the map. The purpose of these range descriptions is to provide a basis for understanding the regional structure and to present the broader regional setting for the mining districts. The ranges are described in sequence back and forth across the county beginning in the north-northwest corner and ending in the southwest corner.

Egan and Southern Egan Ranges

The Egan Range, a high rugged range in the extreme north-northwest corner of Lincoln County, extends northward 25 miles along the Nye County line. It is bounded on the east by Cave Valley and on the west by the broad White River Valley. It consists of two major east-dipping structural blocks which are discussed together for convenience. The two structural blocks are separated by Shingle Pass. The block north of Shingle Pass, here referred to as the Egan Range, is structurally complex and strikes north. The northeast-trending arcuate ridge south of Shingle Pass, here referred to as the southern Egan Range, is structurally simple. The steep scarp of both blocks is on the west. A recent fault scarp closely parallels the west base of the range (pl. 3).

The geology of this area is known from our work and from the unpublished work of several Columbia University students. Our mapping was done in the fall of 1956. H. R. Green wrote a master's thesis on the Paleozoic section in 1951. In 1953, D. I. Foster studied the stratigraphy of the Lower Pennsylvanian rocks. In 1954, J. W. James studied the Upper Mississippian and Lower Pennsylvanian rocks. H. E. Kellogg mapped the range between 1956 and 1958, and incorporated the stratigraphic work of his predecessors.

The part of the Egan Range that lies within Lincoln County is composed principally of an east-dipping homoclinal sequence of Paleozoic and Tertiary rocks that is cut by two major low-angle faults and a large number of smaller reverse and normal faults. The Paleozoic rocks range in age from Early Ordovician to Late Pennsylvanian(?). These rocks represent a fairly normal section north of Shingle Pass, except that the Pilot Shale is nearly or completely cut out by pre-Mississippian erosion and the Guilmette Formation is almost entirely limestone.

The Paleozoic rocks are unconformably overlain by the Sheep Pass Formation. The Sheep Pass contains huge isolated exotic blocks of Pennsylvanian limestone and Scotty Wash Quartzite which slid into the basin of deposition from nearby mountains, according to Kellogg (1959, p. 106).

The Sheep Pass Formation is overlain with angular unconformity by a lenticular conglomerate, the Stinking

Spring Conglomerate of Kellogg (1959, p. 111). Where the conglomerate is absent, the Sheep Pass is overlain by a series of tuffs, tuffaceous sediments, and volcanic rocks of Oligocene Age. One of the ignimbrites in this series was dated as 34 m.y. old by the potassium-argon method (Winfrey, 1958, p. 77-78). A vent for some quartz latite flows occurs in sec. 12, T. 8 N., R. 62 E.

The volcanic rocks are conformably overlain by fluviatile sediments with a few tuffaceous beds. These postvolcanic sedimentary rocks, which are as much as 2,000 feet thick, are not distinguished from the other Tertiary rocks on our map. They were dated as Middle or Late Miocene by correlation with fossiliferous beds in the southern Schell Creek Range of White Pine County (Kellogg, 1960, p. 195).

The older Tertiary rocks are overlain with angular unconformity by the Cave Valley Formation of Kellogg (1959, p. 120), which he assigns to the latest Pliocene and Pleistocene without definite evidence. These rocks are equivalent to the older gravels on our map. The basal unit of the Cave Valley is a cliff-forming well-cemented conglomerate, composed of pebbles, cobbles, boulders, and blocks up to 30 feet long of Upper Cambrian and Lower Ordovician limestone (Kellogg, 1960, p. 195). Apparently the large faulted block of Cambrian(?) limestone, which we consider to be a possible klippe or ecoulement, was mapped as part of the basal member of the Cave Valley Formation of Kellogg. This block, which is over a mile long, might be interpreted as an exotic block moved by gravity; but we feel that it can hardly be interpreted as part of a conglomerate or megabreccia.

The Nine-Mile fault, a major northeast-striking low-angle fault in the extreme northwestern corner of Lincoln County, we interpreted as a thrust (pl. 3), but Kellogg has interpreted it as a normal fault. It dips northwest 10°-22°, but it has been flattened from an original dip of 40° or 50° by eastward rotation of the whole range, according to Kellogg (1960, p. 195-196). This fault has caused a stratigraphic separation of 10,000 to 13,000 feet; it brings Pennsylvanian rocks against Upper Cambrian rocks just inside Nye County.

Another low-angle fault about 2 miles farther south, possibly an extension of the Nine-Mile fault, brings the Guilmette Formation against Upper Cambrian rocks. This fault ends just within Lincoln County in a chaotic zone where breccia containing Pennsylvanian limestone is in contact with Eureka Quartzite. This fault is considered to be a normal fault by Kellogg.

Our present knowledge of the structure permits two very different interpretations of the relations between the structural blocks north and south of Shingle Pass. One interpretation would be that the block south of the pass is a thrust plate or ecoulement which has moved eastward along the Shingle Pass fault over the block to the north, perhaps dragging eastward beneath it some blocks of Pennsylvanian limestone. This interpretation would make the Cambrian blocks klippen of a thrust or major low-angle gravity fault that was at least as young as middle Oligocene. The second interpretation, that of Kellogg's, would be that all the exotic blocks of Pennsylvanian limestone in the Sheep Pass Formation were produced by slides down nearby slopes, and that the Shingle Pass fault is a steep normal fault with a stratigraphic displacement of at least 13,000 feet.

The southern Egan Range is composed of east-dipping Paleozoic rocks that range in age from Upper Cambrian to Pennsylvanian. These rocks dip uniformly 20°-30° eastward and are, in general, little disturbed by faults that have more than 100 feet of displacement. The Pilot Shale is present and increases in thickness southward. The Guilmette Formation becomes increasingly dolomitic south of Shingle Pass. It is about 50 percent dolomite at Trough Springs Canyon, and is dominantly dolomite on Gap Mountain in Nye County (Kellogg, 1960, p. 192), where it is easily mistaken for the Simonson. Eocene sedimentary rocks, so conspicuous north of the pass, are absent south of it.

We mapped a transverse fault in Trough Springs Canyon, and Kellogg mapped many faults with minor displacement farther north. Several north-south faults cut the rocks on the east side of the range south of Trough Spring Canyon.

The south end of the southern Egan Range is bounded by a major postvolcanic transverse fault that lines up with two closely spaced faults in the southern Schell Creek Range. This fault separates the southern Egan Range from the area of complex structure to the south.

Southern Schell Creek Range

The southern Schell Creek Range in northern Lincoln County is bounded on the west by Cave Valley and on the east by Lake Valley and by Coyote Wash, which separates it from the Fairview Range, and Grassy and Dutch John Mountains. The southern Schell Creek Range intersects the southern Egan Range at the south end of Cave Valley.

The range will be described in four segments or structural blocks from north to south for convenience. These segments are: north of Patterson Pass, between Patterson Pass and Sidehill Pass, between Sidehill Pass and the Silver King Road, and between the Silver King Road and the Cherry Creek and Pioche Road. The latter road separates the southern Schell Creek Range from the North Pahroc Range, which continues the same structural trend.

The northern block is a high, structurally simple block that is composed largely of Prospect Mountain Quartzite, Pioche Shale, and Pole Canyon Limestone, and is bounded on the south by an east-west fault through Patterson Pass. The Lower and Middle Cambrian rocks generally strike north and dip moderately east except where the beds bend westward near the Patterson Pass fault. The structure along the east base of the range is complex, and the exposures are poor. Here, Cambrian rocks appear either to have slid down by gravity or to have been thrust eastward over unfossiliferous lower Paleozoic rocks tentatively identified as Laketown and Sevy Dolomites. The identification of the western outcrop of Laketown Dolomite, which is faulted against brecciated Prospect Mountain Quartzite, is questionable. Drill-hole data at the Cinch tungsten mine on the southernmost isolated outcrops of Pole Canyon Limestone(?) show that these Cambrian rocks also are faulted onto Tertiary volcanic rocks.

A series of north-south faults cut the Cambrian rocks. One just west of the range crest drops the west side down several hundred feet. A major fault, the Cave Valley fault, must exist along the west side of the range under the alluvium, and a similar fault, the Coyote Wash fault, is inferred along the east side of the range.

South of Patterson Pass the range is structurally complex. The exposed Paleozoic rocks range from the Patterson Pass Shale of Kellogg (1963) to silty and sandy limestone of Permian Age. Recently Steele (1960, p. 93) reported the presence of an almost complete Permian section and also the presence of Triassic rocks in this segment of the range. The Paleozoic rocks are partly covered by tuff breccias and biotite dacite welded tuff of probable Oligocene or Miocene Age.

The structural block along the west side of the range is composed of rocks which range in age from Ordovician to Early Mississippian. This block is bounded on the west by the Cave Valley fault and on the east by a major west-dipping north-trending reverse fault that brings the western block over rocks that range in age from Cambrian to Pennsylvanian. The stratigraphic separation on this fault increases southward as far as the outcrop of volcanic rocks. Along the northern part of the fault, displacement is in a normal sense, but along the remainder of the trace the displacement is in a reverse sense. This fault might be a strike-slip fault instead of a reverse fault.

The Chainman Shale forms a transverse depression, bounded on both sides by faults, across the crest of the range. An isolated outcrop of Chainman Shale and Scotty Wash Quartzite farther north might be a fenster, a thrust remnant, or a block dragged northward along a strike-slip fault. Detailed study is needed to choose between these alternatives. East of the Chainman Shale, a thick section of Pennsylvanian and Permian rocks has been divided into four formations by Steele (1960, p. 93), who recognizes the Kaibab Limestone among them. We mapped the Permian rocks here as a single unit.

The volcanic rocks rest on Upper Mississippian or younger rocks throughout this part of the range. The biotite dacite that caps the section may be the Harmony Hills Member of the Quichapa Formation of Cook (1957b; Mackin, 1960, p. 94-95), an ignimbrite which E. F. Cook (written communication, 1959) recognized in many places in Lincoln County.

The thickness and lithology of the Pilot Shale near Sidehill Pass are different from those of the Pilot Shale in the southern Egan Range and on Dutch John Mountain because of an unconformity. Near Sidehill Pass it consists of 137 feet of gray calcareous shale and mudstone unconformably overlain by 10 feet of limestone, which is all that is left of 750 to 1,000 feet of equivalent limestone at Dutch John Mountain.

The sedimentary rocks between Sidehill Pass and the Silver King Road range in age from Early Devonian to Early Pennsylvanian; complete sections of the Simonson Dolomite, Guilmette Formation, Pilot Shale, and Scotty Wash Quartzite are present. A granodiorite pluton and several granodiorite porphyry and rhyolite dikes cut the Paleozoic rocks near the Silver King district. Volcanic rocks overlie the Paleozoic rocks in places along the flanks of the range.

Bedding planes strike nearly north and dip gently east near Sidehill Pass, but farther south the strike of the beds swings eastward and the dip changes to northwest.

About 4 miles south of Sidehill Pass, two transverse faults bound a block of rocks ranging from the Sevy Dolomite through the Pennsylvanian limestone. These transverse faults connect with the prominent east-west fault at the south end of the southern Egan Range (pl. 3).

Several steep faults strike northwest through the range near the Silver King well. A steep fault separates Upper Mississippian and Pennsylvanian rocks from Middle Devonian rocks just north of the Silver King road. These Carboniferous rocks are interpreted to be part of the Silver King thrust sheet (pl. 3) that was dropped along normal faults to give the present outcrop pattern.

Tertiary(?) intrusions apparently followed the main periods of faulting. The long axis of the quartz diorite stock parallels the steep north-trending fault that separates upper and middle Paleozoic rocks. Several dacite porphyry dikes follow northwest-trending fissures in the Silver King district a little farther north. A rhyolite dike cuts the Scotty Wash Quartzite 4 miles south of Sidehill Pass, crosses a transverse fault, and cuts the Guilmette Formation. Another small rhyolite dike cuts the Scotty Wash Quartzite just south of the quartz diorite stock.

In the Silver King mining district, copper-lead-silver(?) minerals were localized along faults in brecciated limestone beds cut by dacite porphyry dikes.

Volcanic rocks overlie the Pennsylvanian limestones south of Sidehill Pass, west of Silver King well, and along the Silver King Road.

South of the Silver King Road as far as the Cherry Creek and Pioche Road, a distance of about 9 miles, the bedded rocks range in age from Early Ordovician to Permian(?). These rocks are locally cut by granodioritic dikes and are overlain by Tertiary volcanic rocks and Quaternary alluvial deposits. A fairly complete though faulted section, including the Eureka Quartzite, and the Ely Springs, Laketown, and Sevy Dolomites, is exposed on Silver King Mountain. The volcanic rocks that form conical Burnt Peak are at least 1,200 feet thick, and an unknown amount has probably been removed by erosion. These volcanic rocks are probably younger than those farther north in the range. The Paleozoic rocks are apparently more faulted than the volcanic rocks, but the latter were examined in much less detail.

Silver King Mountain and the hills west of it are underlain by complexly faulted Ordovician to Devonian rocks that are faulted against Upper Mississippian and Pennsylvanian rocks. The younger rocks are apparently thrust over the older rocks, but this thrust fault is exposed poorly and in only a few places. The best exposure is 10 miles west of Silver King Mountain on Fox Mountain in Nye County near the Lincoln County border. A Silver King thrust plate of Upper Mississippian and younger rocks is inferred from scattered remnants to have once covered a large area (pl. 3).

South of Burnt Peak a north-trending vertical fault separates Devonian rocks from greatly faulted Ordovician and Silurian rocks. The stratigraphic separation on this fault is between 5,000 and 10,000 feet. Farther north a parallel fault brings limestone of the Pogonip Group and Pennsylvanian limestone in the Silver King thrust plate against Sevy Dolomite. It is possible that a second thrust plate of Devonian rocks occurs in this area just as elsewhere in Lincoln County.

Several granodiorite dikes in the Pogonip Group along the east base of Silver King Mountain strike northeast and dip steeply northwest(?). They are probably related to the intrusive rocks at Silver King.

Dutch John and Grassy Mountains

Dutch John and Grassy Mountains are at the north end of the continuous mountain belt that extends 60 miles north from Caliente through the Chief, Highland, Bristol, and Fairview Ranges. They are bounded by Coyote Wash on the west and by Lake Valley on the east. Kixmiller Pass separates Grassy Mountain from the Fairview Range to the south. U.S. Highway 93 parallels the east base of the range.

Dutch John and Grassy Mountains are composed of Paleozoic rocks that are successively younger southward and range in age from Devonian to Permian. The Devonian rocks at the north end of Dutch John Mountain were studied by Merriam (1940, p. 39-40). The Mississippian limestone unit forms a dip slope on the south end of Dutch John Mountain. The low pass between Dutch John and Grassy Mountain is underlain by Chainman Shale, which can be divided into a lower calcareous siltstone, a middle black shale, and an upper sandy shale unit (Langenheim and Peck, 1957, p. 1833). The upper unit of the Chainman contains several prominent limestone layers and one also occurs in the middle unit. The quartzite part of the Scotty Wash on Grassy Mountain appears to be very much thinner than in the Fairview Range. The transitional nature of the Upper Mississippian rocks on Grassy Mountain is shown by the facies changes on figure 12. Faulted limestone of Pennsylvanian and Permian Age forms most of Grassy Mountain.

North-striking normal faults probably bound the Dutch John and Grassy Mountain block on the east and west sides. A major pre-Oligocene fault may extend through Kixmiller Pass. The structure is much more complex on Grassy Mountain than can be shown on the map.

Major unsolved geologic problems are posed by the facies changes in the Devonian, Pennsylvanian, and Permian rocks between these mountains and the southern Schell Creek Range (fig. 12). A sand-free limestone facies of the Guilmette on Dutch John Mountain is notably different from the dolomite facies (Silverhorn Dolomite) in the Bristol quadrangle about 20 miles to the south and the Devonian rocks in the southern Schell Creek Range (fig. 12). On Dutch John Mountain about 750 feet of beds, zones A and B of Merriam (1949), correlated with the West Range and Devils Gate Limestones by Merriam, were included in the Guilmette Formation by us. Above these beds, 750 feet of Devonian limestone (zone C) are also included in the Guilmette on our map. Most of these Upper Devonian rocks are cut out by an unconformity in the southern Schell Creek Range. The 385 feet of nonresistant beds in Merriam's zones D and E form the Pilot Shale as we mapped it.

The difficulty in correlating the Upper Devonian sections partly results from facies changes and partly from pre-Joana erosion that has removed much of zone C, and then progressively older beds (zones B and A) to the west, until all these rocks are absent in the Egan

Range north of Shingle Pass, as shown by Kellogg (1963, pl. 2).

The Pennsylvanian(?) rocks near the road across Kixmiller Pass contain interbedded layers of inconspicuous gray sandstone that may correlate with the Upper Pennsylvanian sandstone unit farther west. The Pennsylvanian and Permian rocks here belong to a limestone facies that grades into silty and sandy rocks farther southwest. The very thick varicolored silty and sandy rocks present in the southern Schell Creek Range are not recognized at all here; this facies is largely Permian, and most of it has probably been removed by erosion on Grassy Mountain. The facies changes in the Paleozoic rocks suggest the possibility of telescoping by thrust faulting.

Ignoring thrust faulting for the moment, the facies changes between Dutch John and Grassy Mountains and the surrounding areas could also be explained as follows: About 750 to 1,000 feet of sediments may have been deposited in a Late Devonian basin in the area now occupied by Dutch John and Grassy Mountains. Sediments were not deposited on, nor have subsequently been eroded from, the relatively positive areas to the south and west. The crest of this Devonian positive area probably was near the common corner of Lincoln, Nye, and White Pine Counties. This positive area probably disappeared in Lincoln County in Early Mississippian time, but an east-west positive area probably existed near Ely. In Late Mississippian time, the area lay between a positive area well west of Lincoln County, and a basin in the Needle Range. In Early and Middle Pennsylvanian time, a shallow basin existed west of long 115° W. This basin was on the east side of a positive area and it became deeper eastward. In Late Pennsylvanian and Permian time a positive area existed in eastern Lincoln County and western Utah, and a basin existed west of Dutch John Mountain in western Lincoln County. Between Devonian and Permian time Dutch John and Grassy Mountains appear to have been situated near a hinge line.

Although the facies changes in the Devonian rocks might thus be explained without thrust faulting, the facies changes in the Pennsylvanian and Permian rocks seem to require a thrust fault between the southern Schell Creek Range and Grassy Mountain. It is possible — as noted above — that the silty and sandy rocks have been eroded from Grassy Mountain and no other explanation is required.

The geologic map pattern and the regional facies relationships suggest that a Laramide thrust sheet of Pennsylvanian and Permian limestone is present in the southern Schell Creek Range between Sidehill and Patterson Passes. This plate may also include Upper Mississippian clastic rocks. Regional configurations suggest that it might correlate with the Silver King thrust plate (pl. 3).

Fairview Range

The Fairview Range is a group of low volcanic hills between Kixmiller Summit and Bristol Pass, and between U.S. Highway 93 and Coyote Wash.

The Fairview Range is composed largely of volcanic rocks except for isolated outcrops of much-faulted Devonian, Mississippian, and Pennsylvanian rocks in the southern part of the range. We did not remap that part of the range mapped by Westgate and Knopf (1932). The reader is referred to their paper for a more detailed description of the geology. Our work in the volcanic rocks was cursory; the only faults shown are those conspicuous on the aerial photographs. The structure of the range is fairly simple except in the Paleozoic rocks, and these need to be remapped, now that the regional stratigraphy is better understood. Both pre- and postvolcanic faults cut the Paleozoic rocks in the Silverhorn district near the south end of the range.

Coarse-grained pink granite is exposed in several prospects along a fault just east of Fairview Wash. This granite is in fault contact with Devonian rocks. It resembles granite that crops out beneath the volcanic section in the Wilson Creek Range.

The downward succession of volcanic rocks in the Fairview Range, beginning at the summit, is black-brown-weathering hypersthene-augite andesite about 200 feet thick, red vesicular andesite, gray biotite dacite, and lilac-colored biotite dacite (Westgate and Knopf, 1932, p. 31). Perlite crops out near Upper and Lower Fairview Springs in the upper part of Fairview Wash. About 5,000 tons of perlite were mined in the Fairview quarry (sec. 28, T. 4 N., R. 69 E.) before operations were transferred to the Hollinger quarry in the Wilson Creek Range (Cochran, 1951, p. 13).

Fortification Range

The Fortification Range in northern Lincoln County is the northern extension of the Wilson Creek Range. The range is bounded on the west by Lake Valley and on the east by the southern end of Spring Valley.

The high part of the range is composed of tuffaceous and dacitic volcanic rocks whose rampartlike cliffs gave the range its name. The Scotty Wash Quartzite and the Pennsylvanian limestone unit crop out for a few miles in the low northern part of the range south of the county line. The Pennsylvanian rocks continue northwestward for many miles and form a low range of hills between Lake and Spring Valleys. Both these valleys were occupied by Pleistocene lakes.

The Fortification Range is capped by a thick unit of biotite dacite welded tuff which is underlain by a thick unit of white tuff or tuffaceous breccia. The dacite might be correlated with the Harmony Hills Tuff Member of the Quichapa Formation of Cook (1957b; Mackin, 1960, p. 95). These rocks can probably be correlated with similar units in the Wilson Creek Range and perhaps also with similar rocks in the southern Schell Creek Range. The rocks are displaced by a series of normal faults which strike generally north. A horst of Scotty Wash Quartzite on the west side of the range is bounded by north-striking normal faults apparently older than the overlying volcanic rocks.

Southern Snake Range

The southern tip of the Snake Range extends into the northeast corner of Lincoln County. It is a group of low hills bounded on the west by Spring Valley, on the east by Hamlin Valley, and on the south by the Limestone Hills.

The Simonson Dolomite, Guilmette Formation, Pilot Shale, and some Mississippian limestone are exposed beneath the overlying Tertiary volcanic rocks on the west side of the range.

Thicknesses of the Devonian formations are not known, for only incomplete sections are exposed. The Pilot Shale is little more than 100 feet thick, and only a few tens of feet of Mississippian limestone overlie it. On the northeast side of hill 7186 in the Guilmette Formation, two prominent beds of pinkish calcareous sandstone 60 feet thick are separated by 30 feet of dark-gray to black limestone. Just north of the county line, sandy beds are more abundant; they are presumably higher in the Devonian section. East of hill 7186, in Big Spring Wash, the uppermost beds of the Guilmette Formation, the Pilot Shale, and the lowermost Mississippian limestone formations are exposed as an island surrounded by gravels.

The volcanic rocks consist of quartz-bearing welded tuffs and tuff breccias that conformably overlie the Paleozoic rocks. A dacite ignimbrite unit and a tuff breccia are distinguished on the map. The dacite may correlate with the Harmony Hills Tuff of Mackin (1960).

The structure of this area is relatively simple. In general, the Paleozoic and volcanic rocks dip gently eastward and are offset along at least three normal(?) faults. One of these faults, the one near the Troughs, appears to be an extension of a fault along the east side of the Limestone Hills.

Limestone Hills

The Limestone Hills, a narrow north-trending range of moderate relief in the northeast corner of the county, are bounded on the east by Hamlin Valley and on the west by Spring Valley. On the north a wind gap at The Troughs separates them from the southern Snake Range, and the White Rock Mountains lie to the south.

Geologic formations exposed in the Limestone Hills include the upper part of the Eureka Quartzite, the Ely Springs, Laketown, Sevy, and Simonson Dolomites and the lower part of the Guilmette Formation. The Eureka Quartzite and Ely Springs Dolomite are exposed only at the southeast corner. In general, these formations strike north-northeast and dip gently west, but there are some reversals in dip near the north end. The surrounding valleys are underlain by lake beds of Pliocene or Pleistocene Age that are now being exhumed and dissected. The strand line of a Bonneville-age lake is present in the extreme northeast corner of Lincoln County.

In the center of the range, a cigar-shaped horst of Laketown and Sevy Dolomites are faulted against Devonian rocks on all sides. The faults bounding this horst have near-vertical dips. South of the horst, the faults swing southeast, parallel to the contact between sedimentary and volcanic rocks. Two flat-lying areas of jasperoid are exposed along the Atlanta and Hamlin Valley road; one is silicified Sevy Dolomite and the other is Laketown Dolomite. The silicification is probably related to faulting in this area.

The north half of the range is bounded on the west by faults that are probably extensions of the north-trending faults in the center of the south half of the range. Elongate zones of breccia and silicified dolomite parallel the west edge of the hills south of The Troughs.

The east front of the Limestone Hills seems to be bounded by near-vertical faults which have moved the range relatively down as indicated by three small patches of Laketown Dolomite. North of The Troughs a possible continuation of this fault zone separates east-dipping volcanic rocks from east-dipping Devonian rocks.

White Rock Mountains

The White Rock Mountains extend slightly west of north along the Nevada-Utah border from lat 38° to the vicinity of the Millard Canyon-Camp Valley road, a distance of about 25 miles. They are bounded on the northeast by Hamlin Valley and on the southwest by Camp Valley, Spring Valley, and Eagle Valley.

The range is composed of volcanic rocks except for one area of limestone of the Highland Peak(?) Formation near the south end. The name of the range was apparently derived from the white tuff breccia which crops out in the high parts of the ridge. A distinctive gray biotite dacite, which underlies much of the southwest flank of the range, is definitely correlated with the Harmony Hills Tuff of Mackin (1960) by E. F. Cook (written

communication, 1959). The western edges of both the volcanic and carbonate rocks are overlapped by alluvium and Pliocene (Panaca) lake beds in Camp, Spring, and Eagle Valleys. The northeast flank of the range is covered with coarse alluvial deposits (older gravels?) which also cover Pliocene or Pleistocene lake beds farther north in Hamlin Valley.

Wilson Creek Range

The Wilson Creek Range is bounded on the west by Lake Valley; on the north by Spring Valley, the Fortification Range, and the Limestone Hills; and on the east by the drainages of Millard Canyon, Camp, Spring, and Eagle Valleys. It is one of the highest and most inaccessible ranges in Lincoln County.

The range is composed almost entirely of volcanic rocks, except in the Atlanta area, which is described with the mining districts (p. 162). Because of difficult access, the geology, especially in the interior of the range, was done by photogeologic methods. This was hindered by the heavy forest cover of pinon and juniper. A prominent thick white tuff unit is probably more widely distributed than shown on the map, but it could not be distinguished in the southern part of the range because of snow cover at the time the aerial photographs were flown. The structure appears to be simple, but there are undoubtedly many more faults than are shown.

Limestone of Late Cambrian or Ordovician Age crops out in the canyon north of Ursine and a little farther west. These outcrops are bounded on the west by major faults. Very small areas of Cambrian or Ordovician rocks occur in three areas along the west side of the range. Coarse-grained red granite is exposed beneath the volcanic rocks in the northern outcrop area of Paleozoic rocks, and the volcanic rocks near the southern outcrop of Eureka Quartzite contain fragments of the same granite. Possibly much of the range beneath the volcanic rocks is composed of granite.

Perlite deposits were seen in several places in the range, and a large quantity is mined at the Hollinger deposit in secs. 3 and 10, T. 3 N., R. 68 E. The perlite here is 40 to 80 feet thick; it grades upward into a brown glassy volcanic rock. This rock shows evidence of upward gaseous transfer of silica, which is deposited as chalcedony.

Bristol Range

The Bristol Range in north-central Lincoln County is structurally the northern continuation of the Highland Range. It is bounded by alluviated lowlands tributary to Dry Lake Valley and by Lake Valley.

The geology was first mapped by Westgate (Westgate and Knopf, 1932), but locally his work has been considerably modified by many later workers. We have incorporated the recent unpublished findings of R. A. MacDiarmid, who mapped the Bristol Silver mine area in detail for his dissertation at Stanford University.

The Bristol Range consists of three principal structural elements. The main mass of the range is a comparatively simple block that contains the Prospect Mountain Quartzite, Pioche Shale, Lyndon Limestone, and the Highland Peak Formation. These units crop out along the west side of the range and make up most of the high part of the mountains. A few small patches of Upper Cambrian rocks cap the highest peaks.

The north end of this block is overridden by a west-dipping thrust plate of brecciated dolomite and quartzite of probable Middle Devonian Age. This plate, the Bristol thrust plate, is probably part of the thrust plate which is exposed in the West Range (pl. 3). Near the Bristol mine the thrust has overridden Pioche Shale, Lyndon Limestone, and the lower part of the Highland Peak Formation. Chisholm Shale does not crop out in the Bristol Range and may be absent this far north. All these Cambrian rocks were assigned to the Mendha Limestone by Westgate, as were the rocks in the southern window in the thrust plate. The Ordovician Age of the rocks beneath the thrust farther north was not confirmed, but we have no reason to doubt its correctness.

A down-faulted remnant of this thrust plate in the Blind Mountain area is intruded by a quartz monzonite stock. The rocks near the stock, including volcanic rocks, are metamorphosed, which proves the postvolcanic age of the stock. The intrusive rocks and the contact metamorphism were carefully studied by J. L. Gillson (*in* Westgate and Knopf, 1932, p. 32-42).

The Cambrian rocks along the west flank of the range appear to be thrust eastward over older Cambrian rocks. This inferred thrust plate is called the Highland thrust (pl. 3). The structure between Blind Mountain and Stampede Gap is very complex, but all the Cambrian rocks above the Pioche or Chisholm Shales are locally involved in the thrusting, perhaps having been dragged beneath the Highland thrust plate, which is largely composed of Upper Cambrian rocks. The relation of this thrust to the Bristol thrust plate of Devonian rocks is unknown, but the Highland thrust plate of Upper Cambrian rocks is probably present in both the Highland Range and Pioche Hills.

The complex geology in the Highland district near the junction of the Highland and Bristol Ranges, and in the Bristol district is discussed in detail in later sections (p. 129, 147).

West Range

The West Range lies west of the Bristol Range. It is

nearly surrounded by the alluviated lowlands of Dry Lake Valley.

The range is composed almost entirely of the Guilmette Formation (Silverhorn Dolomite) and the Pilot Shale (West Range Limestone). The contacts on the geologic map and the names in parentheses are Westgate's (Westgate and Knopf, 1932). If we were to remap the range, however, we would include in the Pilot Shale only the shale and shaly limestone in the *Cyrtospirifer portae* zone that makes up the upper 160 feet of the West Range (Kellogg, 1963, pl. 2) to be consistent with our usage elsewhere. The lower 280 feet are composed chiefly of limestone that contains *Tenticospirifer keleticus* (Kellogg, 1963, pl. 2), and we included it in the Guilmette Formation where present.

The Devonian rocks are unconformably overlain by Tertiary volcanic rocks, but a plate of brecciated dolomite and quartzite along the east side of the range has apparently thrust or slid onto the volcanic rocks. Openings in the hydrothermal clay deposits in the volcanic rocks confirm this relation. The thrust dips east and cuts off several early normal faults that strike generally east-west.

Highland Range

The Highland Range in east-central Lincoln County is one of the highest ranges in the county. It is bounded on the north by Stampede Gap, and on the south by Bennett Pass, which separates it from the Chief Range. On the west are the Ely Springs and Black Canyon Ranges and Dry Lake Valley. On the east, Meadow Valley separates the range from the Pioche Hills. The range is encircled by dirt roads and in 1959 a road was built to the top of Highland Peak, altitude 9,395 feet, where a radar station was established.

The Comet mining district on the west side of the range and the Highland district near the north end of the range are described in later sections (p. 154, 147). The Highland Range was not remapped, and the reader is referred to Westgate and Knopf (1932) for additional information.

The Highland Range consists of two structural elements. The first is the simple east-tilted fault block which makes up the main part of the range. This block, which has the oldest rocks exposed along the west side, has apparently been overridden by the second structural element — the Highland thrust plate (pl. 3). The thrust plate is composed largely of Upper Cambrian rocks, mapped by Westgate as the Mendha Limestone. The west-dipping thrust fault is exposed along the west side of the range, but for part of its length the thrust plate may be dropped along normal faults. The best exposure of the Highland thrust plate is in the Black Canyon Range. The Highland thrust probably underlies Arizona Peak and the large Upper Cambrian outcrops farther south. Upper Cambrian rocks appear locally to have overridden Tertiary volcanic rocks along the flanks of the Highland Range, as they did on the flanks of the Pioche Hills and in the Black Canyon Range. These rocks probably are ecoulements, or landslides, resulting from basin-range faulting. The rocks were possibly derived from klippen of a Laramide thrust plate. The Highland thrust plate is certainly older than the Tertiary volcanic rocks in many places.

Black Canyon Range and The Bluffs

The Black Canyon Range and The Bluffs are the southern continuation of the structural element along the west side of the Highland Range and the east side of the Ely Springs Range (pl. 3), the Highland thrust plate. The Black Canyon Range is trisected by two dry washes tributary to Dry Lake Valley.

The ranges are composed of Cambrian rocks and Tertiary volcanic rocks. The volcanic rocks in the Black Canyon area were studied by Westgate (Westgate and Knopf, 1932, p. 29-30) and recently by E. F. Cook (written communication, 1959). Cook measured a section with a maximum thickness of about 2,000 feet which contained all four members of the Quichapa Formation of Cook (1957). The total thickness of the Quichapa is 1,735 feet; it is overlain by zero to 80 feet of basalt and 163 feet of brown crystal tuff. The basaltic andesite below the Quichapa was not measured.

It is likely that the Upper Cambrian rocks, including the upper part of the Highland Peak Formation, are part of the Highland thrust plate which appears to have overridden the volcanic rocks between The Bluffs and the Black Canyon Range. This plate is faulted down against Prospect Mountain Quartzite on the west side of The Bluffs and also on the northeast side of the Black Canyon Range. The nature of these faults is unknown, but the minimum stratigraphic separation is about 5,000 feet. The Bluffs would be stratigraphically beneath this postulated thrust plate.

Pioche Hills (Ely Range)

The Pioche Hills are an isolated northwest-trending range east of the Highland Range between Meadow and Lake Valleys. Meadow Valley Wash has cut a deep canyon through the southeastern part of the range.

The geology of the Pioche Hills has been mapped in great detail by Park and others (1958) and is described with the Pioche mining district (p. 125). Here, we are only concerned with the geology as it relates to the regional pattern. The Pioche Hills are composed of Cambrian rocks overlain by volcanic rocks in the eastern part of the range.

The available evidence suggests the following tentative interpretation of the structure of the Pioche Hills. The exposed rocks in the range were overridden by a regional thrust plate, the Highland thrust plate, of Upper Cambrian rocks that may include the upper part of the Highland Peak Formation. The Highland Peak Formation and even the Lyndon Limestone were locally dragged eastward along subsidiary thrusts beneath the Highland thrust. These thrusts tend to follow the shales and probably account for the structural complexities beneath the Pioche and Chisholm shown on the map of the Pioche district (pl. 4). The only remnant of this regional plate in the Pioche Hills is a small area (unmapped) of Upper Cambrian rocks recently discovered by A. R. Palmer near Mount Ely. This thrust plate was dropped by major northwest-striking normal faults along both sides of the range and is now buried by alluvium. Drill holes on both flanks of the range, however, cut a megabreccia that is composed of Cambrian limestone and Tertiary volcanic rocks (largely ignimbrites). This megabreccia rests on volcanic rocks that were not completely penetrated by a 2,400-foot drill hole west of Caselton. The megabreccia might be either a thrust breccia or remnants of the thrust plate that later slid off the Pioche Hills into the valleys on either side following normal faulting. Minor thrusting within the Pioche Hills probably represents drag beneath the overriding regional thrust plate such as has occurred in the Highland district west of Arizona Peak.

Chief Range

The Chief Range near Caliente is the southern termination of the structural element that forms the main part of the Highland and Bristol Ranges. The range is essentially an east-tilted fault block of Cambrian rocks exposed along the west side. The northern half of the range is composed of rocks ranging from Prospect Mountain Quartzite to Highland Peak Formation; the southern half of the range is almost entirely quartzite. The total thickness of the quartzite is unknown, although a continuous section is exposed in the canyon that drains the alluviated basin northwest of Caliente (p. 14). A diabase sill like the diabase in the quartzite in the Ely Range cuts the quartzite in this canyon.

The north half of the range is bounded on the west by a normal fault that probably continues northward along the west side of the Highland Range and southward beneath the volcanic rocks. An inferred thrust plate of unfossiliferous metamorphosed limestone and dolomite of possible Late Cambrian Age is exposed on the east side of the range. This is believed to be part of the Highland thrust plate so widely exposed to the north. Thrust remnants of limestone of the Highland Peak Formation locally rest on the quartzite near Caliente.

Ely Springs Range

The Ely Springs Range is an isolated range in the eastern part of Dry Lake Valley just west of the Highland Range. The range was mapped by Westgate and Knopf (1932) and their mapping has been incorporated in the county map.

The range consists of Upper Cambrian, Ordovician, and Silurian rocks, overlain on the east side by Tertiary volcanic rocks. The Paleozoic rocks are cut by a conspicuous porphyry dike and a series of north-south faults with comparatively minor displacements. The regional geology suggests the possibility that the Upper Cambrian rocks and perhaps all the Paleozoic rocks in the range, like those farther east and south, are part of the Highland thrust plate, but local evidence has not been found. The Upper Cambrian rocks dip west but all the other rocks dip east. A small block of brecciated Devonian dolomite on the western edge of the range may be a remnant of the Bristol thrust plate.

The volcanic rocks were described by Westgate and Knopf (1932, p. 30-31), who estimated a total thickness of approximately 3,000 feet.

Burnt Springs Range

The Burnt Springs Range is the southwestern extension of the structure in the Ely Springs and Black Canyon Ranges. It is bounded on the west by Dry Lake Valley, on the north and east by an alluviated lowland that drains north into Dry Lake Valley and south into Meadow Valley Wash, and on the south by a northeast-trending drainage at the northwest edge of the Delamar Mountains.

Except for an isolated hill of Ordovician rocks near the north end, the range is composed of Cambrian rocks, chiefly the Highland Peak Formation, and the undifferentiated Upper Cambrian unit. These rocks are overlain by Tertiary volcanic rocks.

The structure in the Paleozoic rocks is complex and little understood. The Upper Cambrian rocks are almost everywhere faulted against the Highland Peak Formation. It is possible that these Upper Cambrian rocks are remnants of the regional Highland thrust plate that were dropped by later normal faults. Low-angle faults were not found, however, so this interpretation is questionable. The outcrop pattern suggests that the volcanic rocks were deposited on a very irregular surface.

The entire mountain system as far north as Bristol Pass has been tilted eastward as a unit in post-Oligocene time. Throughout the eastern part of this belt, the volcanic rocks and the Cambrian rocks beneath the Highland thrust plate dip generally about 20° east. A conspicuous Recent fault scarp with a sinuous north-south trace

extends up the east side of Dry Lake Valley for about 25 miles from U.S. Highway 93. This fault, the Dry Lake fault, strikes north, in complete disregard of the present outcrop pattern, and the block on the valley side is downthrown.

North Pahroc Range

The North Pahroc Range is that part of the Pahroc Range in central Lincoln County that is north of U.S. Highway 93 and south of the Cherry Creek and Bristol road. It includes a north-south distance of about 32 miles. The range is between Dry Lake Valley and White River. Low hills just north of U.S. Highway 93 that extend westward to the Hiko Range will be called the western foothills.

Sedimentary rocks of Paleozoic and Cenozoic Age crop out, but most of the exposed rocks are volcanic. The Paleozoic rocks are locally unconformably overlain by an alternating sequence of conglomerates, fresh-water limestones, and tuffaceous sediments of Miocene Age. These rocks are conformably(?) overlain by volcanic rocks which are, in turn, overlain by Pliocene(?) lake beds and alluvium in the low areas.

The exposed volcanic sequence in the North Pahroc Range is approximately 2,000 feet thick. A few thin but persistent basalt flows near the top can be traced throughout the south half of the range.

E. F. Cook (written communication, 1959), who has measured a section of volcanic rocks along White River near The Narrows, recognizes all four members of the Quichapa Formation. However, the middle two (the Swett and Bauers Tuff Members) are thinner than they are farther east. All four units show differential compaction over a hornblende trachyte flow which forms a topographic high, according to Cook (1960, p. 138). The section of basalt and tuff below this trachyte flow can probably be correlated with the volcanic section below the basalt flows in the main part of the North Pahroc Range.

The oldest rocks exposed are the Ely Springs, Laketown, Sevy, and Simonson Dolomites, which crop out in the western foothills. The youngest Paleozoic rocks are the limestones of Pennsylvanian and Permian(?) Age exposed in the northern part. The Paleozoic rocks crop out under the volcanic cover at widely spaced intervals. Every Paleozoic formation above the Eureka Quartzite crops out somewhere in the range.

The Tertiary volcanic rocks or the lacustrine limestones rest unconformably on each formation, a fact that suggests a great deal of orogeny and erosion in pre-Tertiary time. It is difficult to unravel the pre-Tertiary structure, but faulted remnants of prevolcanic thrust plates of Pennsylvanian rocks crop out in the extreme northern part of the range. Possibly all the Pennsylvanian and Permian rocks in the range are part of the regional Silver King thrust plate (pl. 3), but this is unproved. Pennsylvanian rocks are in fault contact with Upper Devonian or Lower Mississippian limestone in two places near the north tip of the range. These are considered to be thrust remnants. The eastern remnant is several hundred feet lower in elevation than the Devonian limestone; it may have been dropped on a later normal fault. Remnants of the Silver King thrust plate occur sporadically for 28 miles northward. This plate is largely buried by Tertiary rocks and has been broken up by post-volcanic normal faulting.

In the southern half of the range the volcanic rocks are offset along several north-trending vertical or steeply east-dipping faults. The volcanic rocks generally dip west except along the east side of the range where they have been folded into a broad north-trending anticline and dip east. The structure is less distinct in the north half of the range, because the stratification of the volcanic rocks is less recognizable. In general, however, the Paleozoic rocks dip west and the Tertiary rocks dip east.

The area between the North Pahroc Range and White River is underlain chiefly by lake beds of Pliocene(?) Age (older lake beds?) which are covered by a thin veneer of gravel. The maximum exposed thickness of the lake beds is about 100 feet.

The White River fault (pl. 3), a prominent hinge or scissors fault along the west side of the range that separates Pennsylvanian and Permian rocks from volcanic rocks, can be traced continuously nearly 11 miles. It can probably be extended another 5 miles to a northwest-trending east-dipping normal fault, which apparently offsets it. The block east of the fault has been dropped relative to the west block at the north end, but raised farther south. This, however, may be an illusion caused by strike-slip movement along the fault. The volcanic rocks at the south end are offset, but not those at the north end, suggesting that those at the north end are younger. Two other north-trending faults farther west are nearly parallel to the first. Each can be traced for about 16 miles near U.S. Highway 93 to White River.

The westernmost of these faults, the Pahroc fault, when projected across White River, is the fault that bounds the east face of the Seaman Range. The total known north-south extent of this fault is 46 miles. The stratigraphic separation of the volcanic rocks on these faults is less than a few hundred feet where it can be measured. However, the displacement of the Paleozoic rocks may have been much greater. Strong evidence for the postulated older movement is given by the general east-west rather than north-south alignment of the folds,

faults, and strike of the beds on the west side. The Paleozoic rocks are truncated by the Pahroc fault, the east side of which is downdropped.

Seaman Range

The Seaman Range is bounded on the east by White River, on the west by Coal Valley, on the south by Seaman Pass, and on the north by Timber Mountain Pass in Nye County.

Devonian and Mississippian rocks ranging from the Sevy Dolomite to the Scotty Wash Quartzite crop out beneath the volcanic rocks at both ends of the Seaman Range. In the northern part of the range, these rocks dip southwest beneath the volcanic rocks. Pennsylvanian rocks crop out from near Timber Mountain Pass northward.

A thick anomalous facies of the Pilot Shale occurs near the crest of the range just north of the volcanic rocks. This facies resembles the Pilot Shale in the Timpahute Range near Coyote Peak and in the klippe a few miles farther south, but not the Pilot elsewhere. This facies was assigned to the Pilot on faunal rather than lithologic evidence, and it may include Upper Devonian rocks equivalent to the West Range Limestone. The Devonian block west of here resembles the Simonson Dolomite more than the dolomite facies of the Guilmette Formation, to which it was tentatively assigned. Kellogg (1960, p. 192) has shown that the Guilmette is predominantly dolomite south of Trough Springs in the southern Egan Range.

The Chainman Shale, the Scotty Wash Quartzite, and the Pennsylvanian limestone in the Seaman Range in Nye County appear to be thrust over Devonian rocks, but the relations are so equivocal that the converse may be true. In one place Pennsylvanian rocks appear to be thrust over other Pennsylvanian rocks. This inferred Laramide thrust plate is tentatively correlated with the Silver King thrust plate (pl. 3).

The principal postvolcanic faults are the normal faults that bound the east and southwest sides of the range. Two other normal faults that strike a little east of north bound the lobe of Quaternary (or Tertiary) rocks that extends far into the center of the range.

Several sets of prevolcanic(?) normal faults cut the Paleozoic rocks. The north-trending normal fault on the west side of the range, at the county line, is a prevolcanic fault that separates the Devonian and Mississippian rocks. This fault dips westward 45° or less and is apparently offset by several later faults. Conspicuous masses of jasperoid occur along the fault.

The principal feature of the extensive area covered by volcanic rocks in the Seaman Range is the broad dissected cone of the extinct volcano whose constituent flows or ignimbrite units dip quaquaversally from the closely jointed volcanic neck. The large size of the central area suggests a caldera, but no field evidence was found. This tremendous volcanic pile includes mudflows, lava flows, volcanic breccias, and tuff flows, all of which are superimposed on a comparatively thin layer of flat-lying ignimbrites that probably correlates with the volcanic section in the Pahroc Range. The circular outer limit of this volcanic pile, which rests on horizontal ignimbrites, is shown on the map.

Golden Gate Range

The Golden Gate Range in northwest Lincoln County is a comparatively simple westward-tilted, north-south fault block, bounded on the east by Coal Valley, on the west by Garden Valley, and on the south by Murphy Gap. The range joins the northern Seaman Range at the north end of Coal Valley in Nye County. North of this point the Golden Gate Range finally dies out in the broad expanse of White River Valley. Conspicuous features of the range are the four gaps through which the runoff from Garden Valley drained or still drains into Coal Valley playa.

The Golden Gate Range consists of two structural blocks, which will be described separately. The first of these, the eastern part of the range, is a westward-tilted block that consists of the Guilmette Formation, Pilot Shale, Mississippian limestone, Chainman Shale, Scotty Wash Quartzite, and Pennsylvanian limestone and sandstone. The oldest rocks form the steep east face of the range, which is bounded by an inferred normal fault, the Golden Gate fault (pl. 3).

The Paleozoic rocks are broken by a series of faults that generally strike N. 60°-80° E. The largest faults bound the graben block of Pennsylvanian rocks in Nye County that are dropped against the Guilmette Formation on the north and against Mississippian limestone on the south. The fault near the county line would pass through Timber Mountain Pass in the Seaman Range if projected eastward.

The second major structural element is tentatively interpreted as the northernmost extension of the Pahranagat Range thrust plate. This block contains Ordovician, Silurian, and Devonian rocks, which are faulted against Devonian and Mississippian rocks. The reverse fault that bounds this block on the east is believed to be a west-dipping thrust fault, but it was not carefully studied. The stratigraphic separation along this Laramide(?) thrust decreases from 6,500 feet at the south end to about 3,500 feet 5 miles north. This fault appears to be steep, but it would be flattened 20° - 30° if the post-thrust Tertiary volcanic rocks were rotated back to horizontal.

The east block of the Golden Gate Range might pos-

sibly represent one limb of an overturned fold. The Pahranagat Range fold belt (pl. 3) extends at least as far north as Mount Irish.

Along the west side of the range, volcanic rocks lie unconformably on progressively younger Paleozoic rocks going northward in Lincoln County. These volcanic rocks include an ignimbrite unit mapped as the spheroidal-weathering ignimbrite unit. From the county line northward, basalt apparently unconformably overlies the rest of the volcanic rocks.

Worthington Mountains

The Worthington Mountains, sometimes called the Freiberg Range, are high north-south-trending mountains in the northwest part of Lincoln County. They lie between Garden Valley on the east and Sand Springs Valley on the west. The range is bounded on the southeast by an extensive field of volcanic rocks in the northern Timpahute Range.

Every formation from the Pogonip Group to the Mississippian limestone unit is exposed in the Worthington Mountains. The youngest rocks are at the south end. The principal structure is the Freiberg thrust, a west-dipping thrust plate of west-dipping Ordovician rocks which has overridden Ordovician and Devonian rocks on the west side of the range (pl. 3). The northern limit of this thrust plate is uncertain; its trace on the map represents prominent lines visible on the aerial photographs. It appears that Pogonip limestone is thrust on Pogonip limestone at the north end of this plate. The stratigraphic separation along the thrust increases southward.

The sedimentary rocks surrounding two stocks near Freiberg are so altered that it is nearly impossible to determine their age. It is certainly possible that much of the rock identified as Pogonip limestone around these stocks is Devonian rather than Ordovician. The altered rocks are recrystallized, dolomitized, or converted to tactite. Near the stocks are many small irregular masses of granitic rocks, mafic dikes (lamprophyres?), and baked rocks of uncertain origin. Many of these metamorphic rocks are included within the area of the western stock shown on plate 2. Some of the narrow mafic dikes can be traced hundreds of feet through the altered rocks and the stocks alike.

The rocks at the north end of the range are highly faulted dolomite and quartzite, mostly of Devonian Age, judging from the corals found in them. The southern limit of these rocks is uncertain and was interpreted from photographs. Although the rocks are shown as a thrust plate that rests on limestone of the Pogonip Group, the reverse situation might as well be the case. The answer to these structural problems must await detailed work.

Many more normal faults are present than are shown on the map, especially in the southern half of the range. It is likely that frontal faults exist along both sides of the range, as suggested by the high linear range fronts. The fault inferred on the east side is named the Freiberg fault (pl. 3).

The Freiberg mining district is described in a later section (p. 172).

Quinn Canyon Range

Only the southern foothills of the Quinn Canyon Range lie in Lincoln County. They consist almost entirely of volcanic rocks. Along the Nye-Lincoln County line, northwest of the south end of the Worthington Range, however, a few isolated patches of Devonian rocks crop out from under the volcanic rocks.

The structure is relatively simple in the part of the range in Lincoln County. Elsewhere in the range more Paleozoic rocks are exposed, and they have been involved in considerable faulting, including thrusting.

Numerous fluorite deposits exist in the Quinn Canyon Range, several of which are in Lincoln County. The fluorite appears to fill fractures in brecciated (andesitic?) volcanic rocks along or near faults. Some small localized areas of silicified volcanic rock (jasperoid) have been quarried for building stone.

Timpahute Range

The Timpahute Range extends northeastward from Nevada Highway 25 through Coyote Summit almost to Mount Irish. It is bounded on the south by Tikaboo Valley, on the northwest by Sand Springs Valley, on the north by Garden Valley, and on the east by Cold Springs Wash. It includes the volcanic hills at the south end of Garden Valley. The high western part of the range is sometimes called the Tem Piute Range.

All the Paleozoic formations stratigraphically above the Dunderberg Shale are exposed in the range. The north and east parts of the range are covered by volcanic rocks, which dip generally east. The geology is complex and less understood than in most other parts of the county.

At least two major thrust plates of Laramide age are found (pl. 3). East of Tem Piute the Schofield thrust, a plate of Devonian limestone, dolomite, and quartzite, which was mapped as Guilmette Formation (although it may include other rocks), has overridden a normal west-dipping sequence that ranges from Sevy Dolomite to undifferentiated Pennsylvanian and Permian rocks. The Guilmette Formation here contains conspicuously more quartzite than in the surrounding region, except for the Guilmette on the west side of the Pahranagat

Range. Farther west this plate is apparently overridden by anoher plate of Upper Cambrian and Ordovician rocks that dip steeply east, the Lincoln thrust. Remnants of these plates overlie Upper Mississippian rocks south of Tem Piute near Nevada Highway 25.

The largest area of Paleozoic rocks appears to be bounded on the north by a major postvolcanic fault, the Tem Piute fault. An offset part of the same fault might have dropped the east-dipping volcanic rocks against the Guilmette farther to the east. Two small outcrops on the hanging wall of this fault or faults show that the volcanic rocks rest on Upper Mississippian rocks.

In the Tem Piute mining district (pl. 8), the Paleozoic rocks form a high, steep, east-tilted block that consists of rocks that range from the Pogonip Group on the west to Pennsylvanian limestone on the east. This block is bounded on the west by a major right-lateral fault. The east-tilted high part of the range may be a thrust plate that has moved over the Chainman Shale, but it is more likely to be a fenster in the two thrust plates mentioned above. On the west side of the range a block of Pennsylvanian limestone is faulted against Ordovician rocks. This block was mapped as a thrust plate, but it may be the hanging wall block of the right-lateral fault.

Groom Range

The Groom Range is bounded on the south and west by Emigrant Valley. On the southeast, the Groom road separates it from the Jumbled Hills and, on the northeast, Nevada Highway 25 through Coyote Pass separates it from the Timpahute Range. Sand Springs Valley is on the northwest. Bald Mountain, a conical volcanic peak 9,380 feet in altitude, is the highest point in western Lincoln County.

The Groom Range is a tremendous east-tilted fault block that exposes great thickness of Cambrian, Ordovician, and Devonian rocks partly buried by volcanic rocks. The west side of the block is probably bounded by a major normal fault, the Stumble fault (pl. 3). The oldest rocks, the Prospect Mountain Quartzite, are more than 7,800 feet thick and make up most of the west half of the range. The total exposed Cambrian section may exceed 20,000 feet. Conglomerate of pre-Miocene Age and fresh-water limestone of probable Miocene Age crop out from beneath the volcanic rocks on the northwest flank of the range. Similar rocks probably underlie the volcanic rocks along the southeastern side of the range.

The volcanic rocks are thought to be some of the youngest in the county, especially the tuff, the basalt, and the thick andesite unit which overlies the tuff along the east side of the range. A small cone 6 miles north of the Groom mine, the only cinder cone in Lincoln County, is probably the youngest volcanic eruption in the county.

The following estimated section gives the sequence of volcanic rocks and a crude idea of the thickness:

Volcanic sequence in the northern Desert Range, the Jumbled Hills, and the Groom Range

	Thickness (feet)
Z. Andesite(?), massive, light-colored; makes up Bald Mountain; thought to overlie unit Y	3,100-3,400
Y. Porphyritic andesite, massive, reddish-brown-weathering (Tva)	800-1,200
Unconformity	
X. Tuff and tuff breccia, massive, cavernous-weathering, white and pink; probably a pumice lapilli tuff airfall or ash flow (Tvt)	600-1,500
W. Basalt (Tb)	±200
V. Tuff and tuff breccia, massive, white (Tvt)	300-1,000
Major angular unconformity	
U. Ignimbrite series	0-2,000
Older clastic rocks	

The lowest ignimbrite unit U is thought to correlate in a general way with the volcanic section in the Pahroc Range. This unit might be Oligocene and Miocene in age. The thick section of tuff and basalt (V, W, X) of possible Pliocene Age, which rests unconformably on the older clastic rocks where the ignimbrite series was completely eroded away, probably correlates with the Piapi Canyon Formation in the Nevada Test Site, with the Panaca and Muddy Creek Formations in the rest of Lincoln County, with the similar but much thinner basalt and tuff section in the Pahranagat Range that also is unconformable on the ignimbrite, and, in a general way, with most of the basalt shown on the geologic map (pl. 2). The thick andesites(?) that rest unconformably on this tuff sequence may be younger than any other volcanic rocks in Lincoln County except the Quaternary(?) basalt cinder cone on the west side of the Groom Range.

The thick white pumiceous lapilli tuff (units V and X) with or without the interbedded basalt (unit W) thickens southeastward from the Groom Range. The tuff sequence on the east side of the Desert Range is estimated to be about 3,000 feet thick, and a comparable thickness is probably present on the west side of the northern Desert Range. On Oak Spring Butte in the Nevada Test Site, the corresponding tuff section (upper part of the Indian Trail Formation) is more than 2,000 feet thick and the top is not exposed (Johnson and Hibbard, 1957, p. 369). The 500±-foot tuff and basalt near Nye Canyon in the southwest corner of Lincoln County may represent beds that are stratigraphically higher than any on Oak Spring Butte.

The structure of the Groom Range is comparatively simple except locally in the Groom mining district and near the north end of the Cambrian outcrop. The Groom mining district is in a complexly faulted graben, the geology of which was described by Humphrey (1945). Here minor thrust plates of Prospect Mountain Quartzite have overridden Pioche Shale, and west-dipping normal faults which formed the graben have offset the thrust faults. The displacement on the normal faults is as much as several thousand feet and antedates the basin-and-range faults. The youngest faults are east-dipping normal faults of smaller displacement (Humphrey, 1945, p. 30-31).

The structure of the Cambrian rocks above the Pioche Shale in the northern end of the range is not well understood. In the high hill, rocks tentatively identified as the Highland Peak Formation may be thrust over the Upper Cambrian rocks on the north and east and on the Pioche Shale on the south. The rhyolitic volcanic rocks east of here, near the Andies quicksilver mine, are greatly altered to form clay minerals.

Papoose Range

The Papoose Range is entirely surrounded by alluviated lowlands somewhat loosely called Emigrant Valley. Three playas occur in depressions in this lowland: Groom Lake, Papoose Lake, and a playa west of the Papoose Range.

The main part of the range is entirely composed of Prospect Mountain Quartzite, except for a small area of volcanic rocks at the north end. The isolated outcrops east of the range are composed of progressively younger Cambrian and Ordovician rocks. The range is a continuation of the structures in the Groom Range. On aerial photographs of the Papoose Range the structure of the quartzite appears to be more complicated than in the Groom Range, but no detailed mapping was done.

Tenuous evidence from surrounding areas suggests the possibility that the Prospect Mountain Quartzite in the Papoose Range might be part of or, more probably, just below a regional thrust plate, the Spotted Range thrust plate, that usually has Cambrian limestone or dolomite at the base (pl. 3). Johnson and Hibbard (1957, p. 372-374) believe that the Cambrian and Ordovician rocks in the Nevada Test Site east of Yucca Flat comprise a thrust plate that rests on the Carboniferous rocks which crop out west of the Flat. The overthrust rocks include the Prospect Mountain Quartzite. In Lincoln County, the only direct evidence for a thrust plate that includes the Prospect Mountain Quartzite is on the southeast flank of Chert Ridge where Cambrian rocks including the quartzite are in thrust contact with the Chainman Shale.

Jumbled Hills

The Jumbled Hills, named because of the chaotic structure in the Paleozoic rocks, are the poorly defined hills between the Groom Range and the northern Desert Range and between Emigrant Valley and Tikaboo Valley. The highest point is hill 6470 in the southern part.

All the Paleozoic formations between the Upper Cambrian limestone and dolomite unit and the Mississippian limestone unit are exposed in one or another of the isolated areas of Paleozoic outcrop. The stratigraphic relationships of the post-Paleozoic rocks are unusually well displayed in the Jumbled Hills. The Paleozoic rocks are overlain with pronounced angular unconformity by the thick older clastic rocks unit of Cretaceous or early Tertiary Age; it contains more fine-grained rocks than the same unit farther south. The conglomerate is conformably overlain by fresh-water limestone of probable Miocene Age which is steeply tilted along the east edge of Emigrant Valley. These rocks are overlain by volcanic rocks of three principal series. The oldest are apparently the ignimbrites along the east side. The ignimbrites are overlain by tuffaceous rocks, largely pumiceous tuff, which rest conformably on the Miocene limestone where the ignimbrites are absent. The tuffs are overlain by basalts in the northern part of the area and by more ignimbrites in the western part. The tuffs on the west side of the Jumbled Hills, which are several thousand feet thick, are probably equivalent to tuffs in the upper part of the Oak Spring Group in the Nevada Test Site.

The structure of the Paleozoic rocks is mostly hidden by younger rocks, but major faults of prevolcanic and pre-older clastic rocks undoubtedly exist. The major structural features are probably Laramide. These include the thrust plate of Devonian rocks on the narrow north-trending ridge due east of Groom Lake. Perhaps the highly faulted Devonian rocks to the north and east also belong to this plate. The faults inferred between these Devonian rocks and the Cambrian and Ordovician rocks are the same age. A fault is inferred between these older rocks and the northern Desert Range. Many old normal faults are shown on the map (pl. 2).

One fault that can be dated unusually closely is the east-west fault north of hill 6470 that cuts the fresh-water limestone and older rocks, but apparently not the tuffaceous rocks.

A considerable amount of post-Miocene deformation is shown by west dips as high as 70° of the Miocene limestone and also by dips of 30° of the volcanic rocks. This deformation might have been as recent as Pliocene.

Mount Irish

Mount Irish is the mountain mass that extends northeastward between the Pahranagat Range and the Sea-

man Range. It is bounded on the north by Coal Valley, on the east by the White River drainage, on the northeast by Seaman Pass, and on the south by Logan Pass. It is bisected by the Hiko and Coal Valley road.

The range consists of two principal structural blocks. The western of these is the inferred thrust plate of flat-lying Ordovician and Silurian rocks that makes up the high plateaulike Mount Irish. This plate, part of the Pahranagat thrust plate that includes the Sevy Dolomite outcrop west of Mount Irish, is very simple structurally, and includes all the known mineral deposits in the range. The thrust plate might be correlated with the thrust plate of Ordovician rocks in the Timpahute and Worthington Ranges (pl. 3). The thrust plate on Mount Irish is bounded on the east by a north-south reverse fault that is too steep to be described as a thrust fault. It may flatten at depth, however, or be a post-thrust fault. The plate is bounded on the south by an east-trending normal fault across Logan Pass, the Logan Pass fault.

In contrast to the thrust plate, the Silurian, Devonian, and Mississippian rocks east of it are complexly faulted, but the displacement on most of these faults is not more than a few hundred feet. It was necessary to generalize the map greatly here because insufficient time and poor aerial photographs did not permit the structure to be worked out completely. The structure along the west side of this block is believed to represent the highly faulted and overturned limb of a recumbent syncline beneath the thrust plate. This is thought to be the northern extension of the overturned fold in the Pahranagat Range. Chainman Shale and a small block of Scotty Wash Quartzite occur in the compressed core of this fold. The Paleozoic rocks are unconformably overlain, locally, by lacustrine limestone of Miocene Age, and by Tertiary volcanic rocks which are both younger and older than this limestone.

On Fossil Mountain near The Narrows, the Silurian and Devonian rocks south of the peak appear to be thrust on Ordovician rocks, but the complex structure is difficult to decipher.

A post-Oligocene normal fault through Seaman Pass, the Seaman Pass fault, has dropped the south side about 600 to 800 feet. The Logan Pass fault probably extends 5 miles east of the pass, where it is offset by a major north-south normal fault.

Pahranagat and East Pahranagat Ranges

The Pahranagat and East Pahranagat Ranges in west-central Lincoln County extend 36 miles northward from the pass at the north end of Sheep Range to Logan Pass, which in turn separates them from Mount Irish. The ranges are between Pahranagat Valley and Tikaboo Valley.

Three principal structural blocks of pre-Tertiary rock elements are recognized here. From west to east these are: the east-dipping homoclinal sequence of Paleozoic rocks that makes up the high crest of the Pahranagat Range, the thrust plate on the east side of the Pahranagat Range, and the overturned fold belt in the East Pahranagat Range. These older structural blocks are buried by as much as 2,200 feet of Tertiary volcanic and sedimentary rocks in a north-trending belt between the two ranges. Certain stratigraphic as well as structural differences beween the structural blocks are outlined where needed for the structural interpretation.

The rocks in the western structural block range from the Upper Cambrian unit to the Chainman Shale. These rocks appear normal except as noted below. According to Anthony Reso's data (fig. 8), the Pogonip Group is about 600 feet thinner on the west side of the range than in the thrust plate. The Guilmette Formation contains much more sandstone than elsewhere in Lincoln County. The Pilot Shale is much thinner on the west side of the range than on the east side. Rocks equivalent to the West Range Limestone are absent on the west side of the range, although they are about 400 feet thick on the east side (Reso and Croneis, 1959, p. 1251). The missing beds are cut out along an unconformity on the west side of the range.

The rocks in the western belt are cut by many faults that strike east to northeast and a few faults that strike more nearly north.

The block on the east side of the Pahranagat Range, south of Nevada Highway 25 through Hancock Summit, is inferred to be a pre-Miocene (Laramide?) thrust plate (perhaps a downfaulted remnant of a regional plate) even though the fault on the west side dips steeply east. This inference is based on (1) a relation of the thrust plate to the fold belt east of it, which is similar to the relation between the folds and thrust elsewhere in souheastern Nevada; (2) remarkable structural and stratigraphic similarities between the structure in the Pahranagat and Spotted Ranges; and (3) stratigraphic differences. Anthony Reso (written communication, 1960) has shown that the Pogonip Group is about 600 feet thicker in the thrust plate than on the west side of the range; however, he suggests (1963, p. 905) that this difference may be due to faulting in the western section. This greater thickness is not consistent with regional thinning toward the southeast, but the thickness is about the same as in the Nevada Test Site. Structural data already presented further suggest that the source of the thrust plate was in the Spotted Range.

The thrust plate rests on Chainman Shale at the south end and rocks as old as the Guilmette Formation farther north. The rocks just above the thrust become

progressively younger northward as far as the Golden Gate Range. The overthrust rocks dip uniformly 60° to 70° northeast, the same as in the thrust plate in the Spotted Range. The overthrust rocks are about 14,000 feet thick and range from late Middle or early Upper Cambrian to probably Upper Devonian. The isolated Guilmette Formation outcrops in the volcanic rocks east of the plate are probably part of the thrust plate. The Guilmette along the west side of the fold belt near Nevada Highway 25 is probably in a subsidiary plate that was sheared off the overturned west limb of the fold beneath the regional thrust. In the Spotted Range, a similar subsidiary plate of Devonian rocks was dragged eastward beneath the major thrust plate.

The fold along the east side of the East Pahranagat Range, called the Pahranagat fold, is in formations ranging from the upper Guilmette to the Pennsylvanian limestone. The Pahranagat fold is a syncline whose west limb is overturned and partly sheared off. Conceivably the fold might represent the under limb on a major recumbent anticline that was broken by the thrust. Chainman Shale and Scotty Wash Quartzite form the core of the fold. Locally Mississippian limestone from the overturned limb has been thrust over Chainman Shale. The Pahranagat fold or the related thrust can be traced (with interruptions) northward as far as the Golden Gate Range, a distance of more than 50 miles (pl. 2). The Pahranagat fold is offset by two east-trending faults.

The relation of the Pahranagat thrust and fold belt to the Arrowhead mine fault and the Pahranagat shear system is presented in detail in the general structure section (p. 83) and need not be repeated here. It is sufficient to say the Pahranagat thrust and fold belt might represent a part of the Spotted Range thrust and fold belt offset 30 miles eastward by the Arrowhead mine fault (pl. 3), or it might be a similar structural belt that arose simultaneously on the opposite side of this shear zone.

Three northeast-striking left-lateral faults in the southern part of the Pahranagat Range are thought to be reactivated parts of the Arrowhead mine shear zone. The apparent post-Miocene displacement on the Arrowhead mine fault is about 5 miles, measured on the distinctive spheroidal-weathering ignimbrite; that on the middle one, the Buckhorn fault, is 3 miles. The displacement on the southern fault, the Maynard Lake fault, is also large, perhaps even larger than on the other two. These faults clearly offset the Miocene ignimbrites. Most of the movement, however, appears to have occurred before the youngest tuffs and basalt (Pliocene?) were extruded, because the faults are difficult to trace westward. The interpretation of the structure is tentative.

Nearly 1,000 feet of ignimbrites and pumice that overlie the spheroidal-weathering ignimbrite near Pahranagat Valley were eroded from the central part of the Pahranagat Range before about 200 feet of basalt were extruded. Farther west, basalt rests directly on Paleozoic rocks. On the west side of the East Pahranagat Range the spheroidal-weathering ignimbrite of the thrust block rests directly on Paleozoic rocks, but along the east side of the East Pahranagat Range as much as 1,000 feet of Miocene volcanic rocks and pollen-bearing lacustrine limestone underlie this unit. The lacustrine limestone is locally interbedded with pumiceous tuffs or tuffaceous sediments. In Badger Valley it overlies boulder conglomerate or rests directly on the Paleozoic rocks. North of Nevada Highway 25, Miocene limestone may overlie as much as 725 feet of spheroidal-weathering ignimbrite, according to Abraham Dolgoff and Anthony Reso (oral communications, 1960). They, however, assume two different layers of lacustrine limestone instead of the one that we believe to be present. However, all the lacustrine limestone is dated as Miocene by pollen. Unrecognized faulting has, we think, repeated both the limestone and the spheroidal-weathering ignimbrite.

The unconformities in the Tertiary rocks record major periods of erosion and uplift in late Miocene and early Pliocene time. The western part of the Pahranagat Range seems to have been a rising posi[illegible] area during most of Tertiary time.

Hiko Range

The Hiko Range parallels the east edge of Pahranagat Valley from near The Narrows to Maynard Lake. The northern half of the range is predominantly underlain by Devonian and Mississippian(?) rocks and the southern half by volcanic rocks. The Guilmette Formation here is mostly alternating light- and dark-gray dolomite, but includes brown sandy beds in the upper 100 to 200 feet. The sandy beds are more abundant here than in the North Pahroc Range.

The Paleozoic rocks are repeatedly offset by faults whose displacement is commonly less than 100 feet. Most of these faults strike northeast and are nearly vertical. Some, perhaps most of the northeasterly faults appear to be pre-Oligocene, but many other faults obviously cut the volcanic rocks. The volcanic rocks lie on the Paleozoic rocks unconformably.

The main faults in the southern part of the range are normal faults that strike slightly west of north and repeat the west-dipping volcanic sequence at least three times by dropping the east side down. The displacement on these faults is generally only a few hundred feet. These faulted volcanic rocks appear to represent the east limb of a syncline whose axis lies in Pahranagat Valley. This syncline, however, is only apparent; the dips are probably explained by the inferred Hiko fault in Pah-

ranagat Valley (pl. 3). Southeast of Alamo, a few patches of tuff appear to overlie unconformably the faulted volcanic rocks; these probably represent a late episode of volcanic activity.

The south end of the range is terminated by a northeast-striking (tear) fault, the Maynard Lake fault, part of a northeast zone of left-lateral faults that is more than 26 miles long (pl. 3).

The maximum exposed thickness of the volcanic sequence in the Hiko Range is only 300 to 400 feet. This thin sequence represents volcanic rocks that overlie unit G (below) in the thick, though partial, section in the adjacent South Pahroc Range.

South Pahroc Range

The South Pahroc Range extends from U.S. Highway 93 south about 28 miles to near lat 38°20′. The range is bounded on the east by Delamar Valley and on the west by Pahroc Valley and the Hiko Range. The main part of the range is a tilted block of volcanic rocks that dip about 15° west. An arcuate fault scarp (Pahroc fault) about 1,600 feet high separates the main part of the range from some low volcanic hills on the east side of the range. A pediment apparently extends eastward into Delamar Valley.

An incomplete section of volcanic rocks that is exposed in the scarp of the Pahroc fault has an estimated maximum thickness of more than 2,000 feet. The following estimated section describes the volcanic units near the north end of the range.

Volcanic section in the north end of the South Pahroc Range

	Thickness (feet)
I. Dark red-brown thin flow of dacite(?) with opalescent feldspar phenocrysts	50+
H. White massive crystal tuff containing abundant biotite. Upper 20 feet is red water-laid tuff that grades upward into tuff with a 2-foot black vitrophyre	100
G. Spheroidal-weathering rhyodacite(?) with abundant quartz (some pink) and lithic fragments, mostly of volcanic rocks but including black chert or silicified limestone. Lithic fragments are oriented parallel to bedding. This unit (spheroidal-weathering ignimbrite on plate 2) is as much as 900 feet thick farther west	200+
F. Massive cliff-forming gray rhyolite that weathers brown and contains some black to gray glass and lithic fragments both of which increase in volume upward	40
E. White, pink, and orange water-laid tuff or tuff breccia with clasts as much as 2 inches in diameter. Same unit recognized throughout the Pahranagat Range, where it is as much as 550 feet thick. Thickens southward from 35 feet at highway to 400 feet near perlite mine, where it contains a 20-foot layer of perlite about 100 feet below the base of the overlying unit. Farther south the unit contains some welded tuffs and some lapilli tuffs; the tuffs contain clasts of quartzite and volcanic rocks, as much as 12 inches in diameter, and pellets of obsidian and perlite as much as 2 inches in diameter	35-400+
D. Light-gray massive scoriaceous dacite(?) which weathers to sand and forms steep bouldery slopes	40
C. Massive cliff-forming gray biotite dacite(?) that weathers light brown	50
B. Pink scoriaceous rhyolitic crystal tuff. Crystals average 2 or 3 mm in diameter and make up 30 percent of the rock. Forms a weak slope	15
A. Gray-brown porphyritic andesite(?) that weathers brown and contains 25 percent biotite and hornblende phenocrysts	50

Some of the units thicken greatly within a few miles from north to south; for example, unit E (tuffs and tuffaceous sediments on pl. 2) which, south of U.S. Highway 93, increases from 35 feet to more than 400 feet within a distance of 6 miles. Additional members of different lithology are added as unit E thickens, but the units above and below remain the same. Unit G (spheroidal-weathering ignimbrite on pl. 2), which is at least 200 feet thick here, caps much of the volcanic terrain in the South Pahroc, Hiko, and East Pahranagat Ranges.

The volcanic rocks in the South Pahroc Range are probably Oligocene or Miocene in age. Pre-Miocene plant fossils were reported by Van Houten (1956, p. 2805) from the Pahroc Range. We presume these came from the prevolcanic sedimentary rocks just north of U.S. Highway 93.

The volcanic rocks west of the Pahroc fault dip west, but east of it they generally dip east. The southern third of the range is broken into several fault blocks in which the beds dip predominantly eastward. The major faults in both the South Pahroc and Hiko Ranges strike north. The Pahroc fault continues northward for about 50 miles. Several northeast-striking left-lateral faults cut the volcanic rocks at the south end of the range. These left-lateral faults are continuations of the left-lateral Pahranagat system.

Perlite is being mined from unit E in the Kopenite (Delamar Perlite) mine about 5 miles south of U.S. Highway 93.

Delamar Mountains

The Delamar Mountains are in east-Central Lincoln County between Delamar Valley and the steep-walled canyon of Meadow Valley Wash and Kane Springs

Wash; a northeast-trending drainage separates it from the Burnt Springs Range; and Coyote Springs Valley bounds it on the southwest.

The range is largely composed of volcanic rocks, but Cambrian rocks crop out in the Delamar mining district and northward along the west edge of the range. A nearly complete Paleozoic section is exposed in the southern Delamar Mountains.

The Prospect Mountain Quartzite, Pioche Shale, Lyndon Limestone, Chisholm Shale, and Highland Peak Formation are cut by many normal faults, and they are intruded by many small mafic and rhyolitic dikes and several larger bodies of mafic monzonite or granite porphyry. The geology of the Delamar mining district is discussed later (p. 138).

The volcanic rocks consist of a slightly metamorphosed andesite series near Delamar. This unit is not distinguished on the map, but it probably correlates with the older volcanic rocks. The andesite series is overlain by rhyolite and dacite, ignimbrites, and tuffs, and near Meadow Valley Wash these andesites are intruded and partly buried by the rhyolite complex. The rhyolite complex, in turn, is overlain by basalt flows and interbedded tuffs of probable Pliocene Age. Several large perlite deposits occur in the Delamar Range.

The Paleozoic rocks in the southern Delamar Range were deposited near the eastern margin of the Cordilleran miogeosyncline and are, therefore, thinner (fig. 3) than they are in the western part of the county. All the formations below the Pennsylvanian are comparatively thin, but the regional thinning is difficult to interpret because the thin formations occur in a major thrust sheet, the Delamar Mountains thrust plate (pl. 3), that has moved eastward from a region where these formations are normally thicker. The thrust fault, about 2 miles west of Kane Springs Wash, does not crop out; it is inferred from the map pattern and the overturned syncline in the Mississippian and Pennsylvanian rocks. This fold is typical of those formed beneath the thrust plate. The Upper Mississippian clastic rocks in the Delamar fold are very thin compared to the thick sections in the Pahranagat Range and in the Meadow Valley Range. They resemble the thin section in the Arrow Canyon Range, Clark County.

The west face of the southern Delamar Mountains follows a north-striking normal fault that has a displacement of about 1,000 feet. This fault, the Coyote Springs fault, intersects the eastern part of the Maynard Lake fault which, though not studied in detail, apparently consists of several parallel closely spaced normal faults that offset the volcanic rocks. These faults occur along a major Laramide right-lateral fault as described earlier (p. 100).

Unfossiliferous limestone and dolomite of probable Cambrian Age have been thrust eastward over Mississippian and Pennsylvanian rocks. However, the identification of the Paleozoic rocks between the alluviated north-trending valley and the thrust is questionable. The Delamar Mountains thrust plate is thought to be part of a regional thrust plate, the Gass Peak thrust plate, that is found in the Sheep Range. The Gass Peak thrust plate, however, cannot be correlated with the Pahranagat Range-Spotted Range thrust plate because the Pogonip Group is much thicker in the Gass Peak.

The northern limit of the Delamar Mountains thrust is not known, but, if projected, it intersects the east end of the Maynard Lake fault zone. The possibility that the Maynard Lake fault is a major right-lateral Laramide shear zone in the basement rocks was discussed earlier (p. 84). Five major Laramide thrust plates seem to end against the major shear zone inferred along the course of the Arrowhead mine and Maynard Lake faults. Post-volcanic movement on the Maynard Lake fault may have been confined to minor adjustments in post-Miocene time.

Clover Mountains

The Clover Mountains in eastern Lincoln County are bounded on the west by Meadow Valley Wash, on the north by the alluviated lowland south of Clover Creek, on the east by Beaver Dam Wash in Utah, and on the south by Tule Desert. The main ridge trends generally east-west, although one prominent north-south ridge extends into Tule Desert.

The entire mountain mass is composed of volcanic rocks except for a few small scattered areas of pre-Tertiary sedimentary rocks that were complexly faulted before the volcanic activity. Faulted Cambrian sedimentary rocks and dioritic intrusive rocks crop out in the Pennsylvania mining district. Cobble conglomerate and lacustrine limestone of Tertiary or Cretaceous Age crop out beneath the volcanic rocks east of Pennsylvania Canyon. Permian and Triassic rocks crop out in the Cherokee mine area, and Carboniferous rocks crop out at the Pittsburg and Wells Cargo mines. Two small outcrops of Cambrian(?) Age are found farther to the northeast. A thrust plate of lower Paleozoic rocks which has overridden Permian and Triassic rocks was recognized along the south edge of the volcanic field north of Lime Mountain. The overthrust rocks are part of the Tule Springs thrust plate.

The structure of the Tertiary volcanic rocks is largely unknown, but it appears to be comparatively simple. South and east of Caliente, the younger volcanic rocks consist of about 600 feet of interbedded white tuffaceous rocks and thin rhyolite flows, and welded tuffs. The basal unit rests unconformably on the older volcanic

rocks. It is a reddish or pink scoriaceous rhyolite, 80 feet thick, that is altered along the faults to chalky white clays and alunite. The tuffaceous rocks in the sequence are partly water-laid and partly massive airfall or flow deposits. The highest unit in the sequence is a dark-gray rhyolitic welded tuff with opalescent sanidine phenocrysts.

Perlite or perlitic flows occur locally near the top of the sequence. This entire ignimbrite series may have been extruded from vents near Boyd, about 15 miles due south of Caliente, where a major complex dike-flow unit of platy rhyolite formed late in the series. The complex dike-flow, shown with related flows on plate 2 as a rhyolite complex, seems to be partly a dike and partly a true flow or extrusive dome, as indicated by the concentric flow ridges on the large outcrop east of Meadow Valley Wash. Possibly the rhyolite issued from cracks that surround a major caldera. The Boyd area appears to have been a topographically high or tectonically active area during the accumulation of the rhyolite sequence. The sequence thickens north and south of the vents. The relations near Boyd are complex and have not been studied in detail, but the solfataric alteration of the rhyolite to alunite and clays also indicates proximity to the volcanic center. The southern margin of the rhyolite dome or dike-flow is spherulitic and includes rosettes of pink feldspar and abundant concentric radial spheroids of chalcedony.

The rhyolite dike-flow may be overlain by several hundred feet of rhyolitic tuff and welded tuff, and these in turn are overlain by 120 feet of thin basalt flows and by interbedded gravel or siltstone. These appear to overlie unconformably the rhyolitic rocks near Eccles.

As many as six separate basalt flows are exposed in the Meadow Valley Wash north of Leith. Here, as along Clover Creek near Minto, pinkish-buff lacustrine siltstone that resembles the Panaca Formation is interbedded with the basalt. At Minto a single basalt flow is conformably overlain by the Panaca Formation, and beneath the basalt a 40-foot layer of Panaca(?) Formation rests unconformably on both the younger and the older volcanic rocks. This unconformity appears to be a tilted peneplane, in marked contrast to the irregular unconformity between the older andesites and the rhyolites. The rhyolitic sequence in this area is much thinner, probably because of prebasalt erosion.

Cedar Range

The Cedar Range in eastern Lincoln County is bounded on the south and east by Clover Creek, on the west by Meadow Valley, and on the northeast by Deer Lodge Canyon and Goldsprings Wash.

The Cedar Range is composed of volcanic rocks, except for small outcrops of Cambrian limestone and intrusive rocks near Blue and Little Mountains, and some intravolcanic sedimentary rocks north of Nevada Highway 25. The older volcanic rocks crop out in the Little Mountain area and probably at the base of the section throughout the range, but they were not exposed everywhere. The older volcanic rocks are intruded by large bodies of diorite which may join at depth to form a single large intrusive; the diorite and the older volcanic rocks are intruded by a small granite plug, and several microgranite and rhyolite dikes. These dikes probably served as feeder channels for the rhyolitic rocks that cap the higher hills throughout the Cedar Range.

The volcanic section was not studied in detail, but it seems to resemble the section at Condor Canyon. Along Nevada Highway 25 and farther north, the lowest exposed volcanic rocks are andesites or latites that might belong to the older volcanic series. These are overlain by a thick biotite tuff capped by a resistant rhyolitic unit. The biotite tuff may correlate wih the Needles Range Formation of Mackin (1960). The volcanic rocks are cut by many more faults than are shown on the map, and a little is known of the structure.

Tule Springs Hills

The low range east of the Tule Desert and west of Bull Valley and Beaver Dam Washes is named the Tule Springs Hills. The range is arbitrarily bounded on the north by the pass on the north side of Lime Mountain and on the south by Mormon Mesa.

The geology exposed in the range can be divided into two major structural elements. The first is an autochthonous foreland block consisting of Permian and Triassic sedimentary rocks that belong to a facies transitional between the Cordilleran miogeosyncline to the west and the cratonal area on the Colorado Plateau to the east. These rocks are very similar to the section on the Colorado Plateau except that the Moenkopi Formation consists of a marine limestone facies. They have been folded into several gentle but large folds that were truncated by erosion prior to thrust faulting (see fig. 20).

The second major structural element is the Tule Springs thrust plate, which is thought to represent the northern extension of the Muddy Mountains thrust plate in Clark County. This plate consists of Paleozoic rocks, probably ranging in age from Cambrian to Pennsylvanian or even Permian. These allochthonous rocks belong to the thin carbonate facies deposited near the eastern margin of the Cordilleran miogeosyncline. They closely resemble the corresponding rocks deposited in eastern Clark County and in adjacent parts of Utah and Arizona (figs. 3, 4). This seems to limit the former position of the allochthonous rocks to no farther west than the

Meadow Valley Mountains, unless the thin facies there is also above a thrust plane.

In the Tule Springs thrust plate, the Mississippian rocks are underlain by a shaly unit probably equivalent to the Pilot Shale or West Range Limestone, and this in turn is underlain by unfossiliferous dolomites of Cambrian and Devonian Age. Probably the largest klippe consists chiefly of Devonian rocks. North of the largest klippe, the Pennsylvanian and Permian rocks are thrust over Triassic rocks perhaps by drag beneath the principal thrust or perhaps along a separate thrust. South of the largest klippe, the Kaibab Limestone and Moenkopi Formation are folded and faulted, and it is possible that these rocks have been thrust or dragged eastward beneath the principal plate. In many places in the Tule Springs Hills the volcanic rocks may possibly be overridden by the subsidiary plate of Pennsylvanian and Permian rocks, but the contacts are invariably poorly exposed. There is no doubt, however, that the Tule Springs thrust plate is older than the volcanic rocks.

East Mormon Mountains

The East Mormon Mountains are bounded on the west by the Carp and Mormon Mesa Road, on the south and east by Mormon Mesa, and on the north by the Tule Desert. A low pass west of hill 4035 separates the East Mormon Mountains from the Tule Springs Hills.

Structurally, the range is a high, narrow, east-tilted, north-striking fault block that is bounded on the south by a major northeast-striking transcurrent fault. The range consists of three principal structural elements: the basement block beneath two thrust plates, the thrust plates, and the complexly faulted block south of the northeast-striking transcurrent fault (pl. 3). The range is cut by a series of north-trending normal faults, two of which bound the range on either side.

The basement block consists of Precambrian igneous and metamorphic rocks, Lower and Middle Cambrian clastic rocks, and, in places, limestone and dolomite of pre-Mississippian Age.

The basement block has been overridden by one or more thrust plates of Paleozoic carbonate rocks. The upper plate consists of pre-Pennsylvanian rocks that probably are part of the Tule Springs thrust plate. This thrust plate has overridden Precambrian and Lower Cambrian rocks on the east side of the range, but its position on the west side of the range is uncertain. It is undoubtedly above the Chisholm Shale, and it is probably within or near the base of the Monte Cristo Limestone. The fault which bounds this plate on the east is steep and it may be a post-thrust normal fault instead of a thrust. Drag blocks of dolomite and Prospect Mountain Quartzite, however, occur along this fault.

North of the prominent gap through the range near Gourd Spring, the Tule Springs thrust plate has overridden a lower plate composed of Pennsylvanian and Permian rocks. Also in the northeastern Mormon Mountains, this lower plate is overridden by older rocks that probably are part of the Tule Springs plate. It is possible that the Tule Springs plate extends completely across the Mormon Mountain arch, for we were unable to determine its western limit. This possibility may be supported by the apparent great difference in thickness and lithology of the pre-Mississippian carbonate rocks on the west face of the East Mormon Mountains and a few miles farther north.

The east side of the East Mormon Mountains is probably bounded by a post-thrust normal fault (Gourd Spring Fault) as suggested by the straight range front (pl. 3). The west side of the range is probably bounded by a post-thrust normal fault which has dropped the overthrust rocks on the west side from a higher former position.

The northeast-striking fault at the south end of the range appears to be a right-lateral fault, perhaps a tear fault that bounds the thrust plates, for it apparently does not cut the Precambrian rocks. This fault probably also extends across the southern Mormon Mountains. If the offset of the Pennsylvanian rocks can be used as a measure, the right-lateral movement has been 7 to 12 miles. Facies changes occur across this fault in the Bird Spring Formation, which thickens from 1,800 feet or less on the south side to 4,300 feet 12 miles to the west. Detailed study of the facies changes will be necessary to interpret the structure.

Mormon Mountains

The Mormon Mountains form a subcircular mountain mass 15 to 20 miles across which is bounded on the west by Meadow Valley Wash, on the north and east by the lowland along the Carp and Mormon Mesa Road, and on the south by Mormon Mesa. East of the road lie the Tule Desert and the East Mormon Mountains. The Mormon Mountains are a broad dissected dome whose Cenozoic cover has been removed by tributaries to the Colorado River.

The dome was uplifted about 3,000 feet in post-Mississippian time. Precambrian igneous and metamorphic rocks, Prospect Mountain Quartzite, and Pioche Shale are exposed in the center, along the west side, and along the southeast edge of this dome. An undivided sequence of limestones and dolomites of Cambrian to Devonian Age, locally at least, has been thrust over these older rocks, and also over Permian red beds and Kaibab Limestone near the south end of Tule Desert. Possibly a decollement thrust everywhere separates the rocks above

the Cambrian shales from those below. The sequence from the Eureka Quartzite to the Sevy Dolomite is probably absent in the Mormon Mountains. An unconformity, possibly also a thrust or bedding-plane fault, occurs at the base of the Monte Cristo Limestone at least locally, and the discontinuity may everywhere underlie the Monte Cristo. Another possibility is that these massive Mississippian rocks have slid by gravity down the flanks of the uplift.

Still another thrust plate, or an ecoulement, is exposed on the northwest flank of the Mormon Mountains. Here Pennsylvanian limestones are thrust over or have slid down over Mississippian and older rocks and possibly also over Tertiary volcanic rocks.

In the major northeast-striking fold belt at the south end of the Mormon Mountains, Monte Cristo Limestone appears to be locally thrust southward over overturned Pennsylvanian limestone. The Monte Cristo is bounded on the north by a northeast-striking steeply dipping fault that appears to be the same as the fault at the south end of the East Mormon Mountains. The nature of this fault is unknown; it may be a right-lateral fault, as already suggested, or a post-thrust normal fault.

The structure of the Mormon Mountains is poorly understood because of the lack of detailed knowledge about the stratigraphic succession and because poor access made it impossible to visit many key localities. However, all the overthrust rocks belong to the thin facies deposited near the eastern edge of the Cordilleran miogeosyncline. This fact limits the maximum possible eastward movement at the west edge of the Mormon Mountains to about 6 miles and it is generally thought to be very much less.

The possibility should be considered that the Tule Springs thrust plate has slid eastward off the Mormon Mountain arch.

Meadow Valley Mountains

The Meadow Valley Mountains in south-central Lincoln County occupy the area between Coyote Spring Valley, Kane Springs Wash, and Meadow Valley Wash. They extend 43 miles northeastward from U.S. Highway 93 a few miles within Clark County to Elgin in Meadow Valley Wash. The west edge is bounded by a steep scarp, the highest ridges standing as much as 2,500 feet above Kane Springs Wash. The eastern part of the range is a dip slope that drops off more gradually to the rim of the canyon of Meadow Valley Wash.

Every geologic period except the Precambrian, Jurassic, and Cretaceous are represented by the rocks of the range. The following composite section gives the approximate thicknesses of the map units in the range:

	Thickness (feet)
Tertiary:	
Volcanic rocks. Thick heterogeneous section of thin white and lavender (altered?) tuffs at base	500+
Fresh-water limestone with indeterminate diatoms. Very pale-orange to cream, thin-bedded. Does not contain pollen	10-30
Dense white volcanic rock and vesicular basalt. Basalt equals half of thickness. Deposited on channeled surface. Pinches out locally	0-20
Fresh-water conglomerate	0-20
Unconformity	
Triassic:	
Chinle Formation. Shinarump Member is at least 75 feet thick	2,500±
Moenkopi Formation	2,500-3,200
Unconformity	
Permian:	
Kaibab Limestone. Basal cherty breccia only	0-10
Red beds	1,810
Pennsylvanian and Permian:	
Limestones (Bird Spring Formation)	4,274
Mississippian:	
Clastic rocks (Scotty Wash Quartzite and Chainman Shale)	[1]375-1,048
Limestones	1,500+
Pilot Shale	100-150
Devonian:	
Guilmette Formation	1,350
Simonson Dolomite	400
Sevy Dolomite	275
Silurian:	
Laketown Dolomite	330
Ordovician:	
Ely Springs Dolomite	450
Eureka Quartzite	0-20
Pogonip Group	1,100±
Upper Cambrian:	
Limestones and dolomites	1,000+

[1]D. H. Duley (written communication, 1957).

The Permian red beds part of this section is described in more detail on page 61. In the Meadow Valley Mountains are found the westernmost exposures of Permian red beds, Kaibab Limestone, and Moenkopi and Chinle Formations, and the easternmost exposures of Eureka Quartzite and Ely Springs, Laketown, Sevy, and Simonson Dolomites. This accounts for the anomalous thicknesses noted above.

The Paleozoic rocks generally represent a transition between the shelf facies in the Mormon Mountains region and the miogeosynclinal facies of the remainder of the county. The rocks below the Eureka Quartzite are generally similar but thinner than the corresponding rocks of the miogeosynclinal facies. The Eureka Quartz-

ite is less than 20 feet thick in the west face of the range, and it is absent in the east face. Farther east its former stratigraphic position is marked by a zone of white dolomite 10 feet thick. The quartzite is over 100 feet thick in adjacent ranges to the northwest and south. The Silurian and Devonian formations are thinner and generally include less clastic material than the same formations farther west or north, but these units cannot be recognized farther east. The Mississippian limestone section (Monte Cristo Limestone) in the Meadow Valley Mountains is the thickest in Lincoln County but it resembles the thinner sections in adjacent areas. D. H. Duley (written communication, 1957) found that the thickness of the Chainman Shale and the Scotty Wash Quartzite was 932 and 116 feet, respectively, 18 miles north of the Clark County line in the western Meadow Valley Mountains, but the combined thickness of these formations in the surrounding region, including the eastern Meadow Valley Mountains, is only about 200 feet. This suggests that the anomalously thick section is allochthonous. Neither unit was recognized east of Meadow Valley Wash. Pennsylvanian and Permian limestones of the Bird Spring Formation form a broad outcrop on the east side of the range. They contain more clastic material here than in surrounding areas.

Unconformities occur at the base of the Tertiary rocks, at the top and base of the Moenkopi Formation, probably also at the base of the Pennsylvanian limestone, and perhaps at the top of the Devonian rocks. These unconformities reflect tectonic movements in pre-Laramide time and may explain some relationships previously attributed to younger faulting. Unconformities related to uplift and erosion in the Mormon Mountains area may account for the facies changes in the Upper Mississippian, Pennsylvanian, Permian, and Triassic rocks that have already been noted.

The rocks of the Meadow Valley Mountains are broken by many thrust and normal faults. The major structures including the thrust faults are pre-Miocene and are overlain by the volcanic rocks. The postvolcanic faults are comparatively minor except the fault along the northwest side of the range.

Locally the incompetent beds are strongly folded. Many faults dip steeply or are vertical and trend northeastward, subparallel to the major fault responsible for Kane Springs Wash. A few cross faults transect the range. Although low-angle thrust faults were not certainly identified, post-Chinle thrusting has probably played an important part in the structural history of this area.

On the west side of the range the Paleozoic rocks generally dip gently east; near the center of the range the dips steepen to 30°-40°, and in the east half of the range, the beds form a syncline, an anticline, and an overturned anticline(?). The east or overturned edge of this block of folded rocks may represent the leading edge of an incipient thrust plate.

West of Vigo, the less competent Permian red beds form tighter folds, many of which are isoclinal and recumbent in the upper gypsiferous part. Along Meadow Valley Wash the upper Paleozoic and Mesozoic rocks dip uniformly west at an average angle of 35°, except for the tightly folded gypsiferous beds. This folding apparently represents post-Kaibab and pre-Moenkopi deformation and is related to the major angular unconformity at the base of the Moenkopi Formation.

North of Galt a small window of dark red-brown clastic rock (Chinle Formation ?) crops out under a folded sequence of Moenkopi beds. Unless the section is overturned, the Moenkopi Formation must be thrust onto the Chinle. A possible thrust or a steep reverse fault may separate the Upper Cambrian and Lower Ordovician rocks from Upper Devonian rocks. This fault has about 2,600 feet of stratigraphic separation. A narrow strip of alluvium about 8 miles west of Vigo separates Lower Pennsylvanian rocks on the west side from folded Moenkopi beds on the east. The minimum stratigraphic separation here is about 4,500 feet, of which only part can be accounted for by the covered interval. Maybe there are three thrusts from west to east, one with Cambrian and Lower Ordovician or Devonian rocks at the base, another with Pennsylvanian rocks at the base, and a third with Moenkopi at the base.

Sheep Range

The north end of the Sheep Range extends about 20 miles into Lincoln County just west of long 115°. The range is bounded on the west by Desert Valley and Sheep Mountain Lake, on the east by Coyote Spring Valley, and on the north by the Maynard Lake valley which separates it from the Pahranagat Range. It is a relatively broad, high range composed predominantly of Upper Cambrian limestone and dolomite capped by Ordovician rocks.

On the west face of the range, a thick sequence of beds dipping gently eastward is offset slightly by a few faults parallel to the face. The youngest beds, the Eureka Quartzite, are exposed in the northwest corner of the range.

The east face of the range is more deeply dissected by erosion than the west face, and it is also more faulted. The dip of the beds is more erratic on the east side, ranging from horizontal to 70° and averaging about 30° E.

Numerous steeply dipping faults that strike nearly east cut across the range. The displacement on these

faults is small, commonly less than 100 feet, and the net effect is to drop the north side down.

The Sheep Range is separated from the Pahranagat Range by a northeast-trending fault zone, the Maynard Lake fault (pl. 3), along which a large amount of right-lateral movement took place in approximately Laramide time; the post-Miocene movement has been left-lateral.

Between the north end of the range and U.S. Highway 93 lies a low range of hills here called the Coyote Spring Hills. They consist chiefly of east-dipping volcanic rocks that rest on Paleozoic rocks. At the north end of the hills, Cambrian, Ordovician, and Mississippian(?) rocks crop out from under the volcanic cover. Here the Mississippian(?) rocks have been thrust over the older rocks. At the south end of the hills, the Pennsylvanian rocks are folded into a north-striking syncline, overturned toward the east, and they are mostly covered by east-dipping lavas and tuffs. A north-trending chain of low hills composed of Pennsylvanian rocks, which are folded and overturned towards the east, appear as islands surrounded by alluvium near the Lincoln-Clark County line, east of the Sheep Range. These hills extend into Clark County, where they are considered by Longwell and others (1965, p. 76) to represent the folded block beneath the Gass Peak thrust plate. It is apparent that this fold belt and, by inference, the related thrust fault, extend north to the Maynard Lake fault. Like Longwell (1926, p. 561), we believe that the entire Sheep Range is part of the Gass Peak thrust plate which moved eastward over Pennsylvanian rocks. In Lincoln County the trace of the thrust lies buried under alluvium somewhere between the Sheep Range and the Coyote Spring Hills.

The relation of the small thrust near the Maynard Lake fault to the Gass Peak thrust is not known. Probably the small thrust is subsidiary to the Gass Peak thrust and is of minor importance.

Longwell (1930) has described recent faulting that formed a narrow graben in the alluvium along the west edge of the Sheep Range.

East Desert Range

On the east side of the Desert Range, there are two separate groups of hills. Those which lie south of Sheep Mountain Lake are named the East Desert Range, and those north of Sheep Mountain Lake are referred to as the hills east of the Desert Range.

Except for its east side, the East Desert Range is a faulted and folded complex of Upper Cambrian rocks. Numerous faults can be seen on the aerial photographs, but we were unable to decipher the structure. The east third of these hills is an east-dipping homocline in which are exposed rocks from the Upper Cambrian limestone and dolomite to Eureka Quartzite. A north-trending ridge composed of black and gray dolomites of probable Silurian and Devonian Age extends into Lincoln County between the East Desert and Sheep Ranges. The formations exposed in the ridge probably are a faulted continuation of the homoclinal sequence to the west. Patches of gravel found in the range are remnants of an old widespread alluvial cover (late Pliocene or Pleistocene), now mostly removed. The faults along the west side of the Sheep Range apparently have dropped the East Desert Range. A concealed fault separates the East Desert Range from the Desert Range. The East Desert Range, therefore, is an east-dipping tilted graben between the Sheep and Desert Ranges.

The hills east of the Desert Range are also a tilted fault block, but one much less complicated by faulting and folding. Although the pre-Eureka section here is cut by a fault that is in line with the projection of the Maynard Lake fault, an intervening ridge of Silurian and Devonian rocks is not cut. It is possible that the Maynard Lake fault is disrupted by younger faulting, or that the Maynard Lake fault does not extend this far west.

The hills east of the Desert Range are separated from the Desert Range by a hidden north-trending fault that dropped the west side. A section of tuff breccia, lapilli tuff, pumice, and tuffaceous sandstone covers this fault. Bedding in these rocks strikes N. 25° W. and dips as much as 50°, but averages about 15° E. The gravels on the east that lie unconformably on top of the tuff sequence are probably Quaternary in age, but it is possible that they may be Tertiary.

Desert Range

The northern half of the Desert Range is in Lincoln County. It is bounded on the east by the isolated groups of hills just described and by Desert and Tikaboo Valleys, and on the west by Three Lakes Valley, the Pintwater Range, and the Jumbled Hills.

The Precambrian and Paleozoic formations exposed include all those between the Johnnie Formation and the Mississippian limestone formations. Cretaceous(?) or early Tertiary conglomerate (older clastic rocks) and Tertiary volcanic rocks also occur.

The Desert Range and the Pintwater Range to the west have been described by Longwell (1945) as opposite limbs of a large north-plunging anticline whose axis can be traced southwest to near Indian Springs in Clark County (Longwell and others, 1965, p. 72). However, our mapping shows that the structure is so complex that this description seems true only in the broadest sense.

At least three sets of faults are recognized. The oldest set, which strikes north-northwest parallel to the range,

consists of one or two high-angle reverse faults, which locally cut out parts of the Upper Cambrian and Pogonip sequence. These faults have been steepened by later eastward tilting (Longwell, 1933). We believe it is at least possible that they are thrust faults. The second set strikes northeast and offsets the first set. A third set in the northern part of the range strikes north but has not profoundly disturbed the rocks.

A chaotic mass of small fault blocks and slivers exists at the junction of the Desert and Pintwater Ranges. The Eureka Quartzite, usually an ideal marker horizon, has been so thoroughly faulted that the individual blocks could not be shown at our field mapping scale (1:60,000), much less on the final map. The geology of these areas has, consequently, been greatly generalized on the map. Thrusting is suspected here, but our evidence is limited. Possibly all the rocks younger than the Eureka Quartzite or Pogonip Group may be part of a major thrust plate.

The north slopes of the Desert Range are comparatively simple in structure in contrast to those farther south. The youngest rocks of the range, the Guilmette Formation, the Pilot Shale, and the Mississippian limestone, crop out along the northern slopes.

Pintwater Range

The northern two-thirds of the Pintwater Range lie in Lincoln County; the remainder is in Clark County. The range is bounded on the west by Indian Springs Valley and the Fallout Hills, and on the east by Three Lakes Valley. Exposed in the east and west faces of the range north of the county line are Ordovician, Silurian, and Devonian rocks. Overlapping the Paleozoic rocks in Lincoln County is an unusual section of largely well-rounded, loosely consolidated gravel of pre-Miocene Age (older clastic rocks). These deposits fill an embayment in the east side of the range and cover a 50-square-mile area in the Fallout Hills.

According to Longwell (1945), the Pintwater Range forms the west limb of a large anticline, the east limb being the Desert Range. We believe, however, that this is an oversimplification. Although on the east side the beds generally dip gently west and are little disturbed, along the west side of the range the beds are highly faulted and in places overturned. Near lat 37° and farther north, Devonian rocks are abundant, commonly occurring as fault blocks or slivers. Thrust faulting in the Pintwater Range is evidenced by Devonian rocks resting on Ordovician rocks along the west side and probably in the northern half of the range.

East of the Pintwater Range and partly straddling the Clark-Lincoln County line is a low northwest-trending ridge surrounded on three sides by alluvium. The ridge is an ecoulement composed of black and white brecciated Highland Peak(?) dolomite which dips east at 30°. The west face of the ridge seems to have a rude color banding that probably represents original bedding planes; close inspection, however, shows the dolomite to be thoroughly broken into angular blocks that have been slightly rotated. This dolomite ridge is 3 miles long and half a mile wide. It rests on a thick section of conglomerate of the older clastic rocks unit which dips 25° E. The contact between these units is irregular, locally having about 3 to 5 feet of relief; it commonly contains comminuted pieces of green micaceous shale (Pioche). The dolomite above the contact is thoroughly crackled within 2 feet of the contact, but only the upper 6 inches of the underlying poorly consolidated conglomerate are disturbed. The origin of the dolomite block is unknown but is thought to have been part of a Pleistocene(?) gravity slide. The nearest similar carbonate section is 8.5 miles east in the Desert Range and there the beds dip steeply east. In Lincoln County Cambrian rocks are not exposed in the Pintwater Range, but are present above a thrust fault on the west side of the Spotted Range, about 13 miles to the west. The dolomite block may have been a part of this thrust plate, now mostly eroded, which broke loose and slid downhill over the debris in front of the advancing thrust sheet, or it may have slid later following basin-range faulting.

Other occurrences of landslide blocks with similar origins but smaller in size are present elsewhere in southern Nevada and western Arizona (Longwell, 1951) and in eastern California (H. R. Cornwall, oral communication, 1959).

Spotted Range

The Spotted Range in the extreme southeastern corner of Lincoln County is bounded on the east by Indian Springs Valley, on the southwest by the alluviated valley that drains into Frenchman Flat, Nye County, and on the north and northwest by the Fallout Hills. Most of the range is in Clark County, and only the low northern part of the range extends into Lincoln County.

The formations exposed in the northern part of the Spotted Range are the Sevy and Simonson Dolomites, the Guilmette Formation, the Pilot Shale, the Mississippian limestone unit, and the Chainman Shale. These rocks are folded into a recumbent syncline along the west side of the range. This fold belt extends at least as far north as lat 37° N. and probably joins the fold belt on Chert Ridge. The belt is probably cut off on the north by the Arrowhead mine fault (pl. 3). These folded rocks were overridden by a major thrust plate with Cambrian limestone at the base, probably the same thrust plate as the one on Chert Ridge. Devonian rocks from the overturned west limb of the syncline appear to have been sheared off and dragged eastward over Mississippian

rocks. All of these rocks are buried under a thick deposit of older clastic rocks at the north end of the range. The rocks east of the fold belt are complexly faulted. The structure is not too well understood along the east margin of the range, but a major fault brings Sevy and Simonson Dolomites on the east in contact with Mississippian limestone on the west.

The structure and stratigraphy of the folded and overthrust rocks in the Spotted Range are remarkably similar to the corresponding structure and stratigraphy in the Pahranagat Range, as described in the general structure section (p. 83). The similarity in structure is apparent on the map (pl. 2). The similarity in stratigraphy is shown most clearly by the similar and distinctive lithology of the Pilot Shale in the two ranges in contrast to the same unit elsewhere. Can the corresponding structures represent offset parts of the same Laramide structures along the Arrowhead mine fault zone with a right-lateral displacement of about 29 miles (pl. 3)? A wide fault zone in the required position is strongly indicated by three northeast-striking left-lateral faults in the southern Pahranagat Range. However, the displacement on these faults is Miocene or younger and totals between 6 and 10 miles in a left-lateral sense. Could these faults represent renewed movement along reactivated portions of an older Laramide right-lateral fault that has been largely obscured by younger structures? The answer, though not conclusive, seems to be yes. A definitive answer must await more detailed work.

Chert Ridge

Chert Ridge, in the southwest corner of the county, is a narrow north-south ridge east of Emigrant Valley and west of the Fallout Hills. It was named for the beds of black chert at the base of the Chainman Shale that cover the steep dip slope on the east side. The most conspicuous topographic feature of the range is a canyon that drains westward through the range.

Structurally the ridge is the northern continuation of the Spotted Range. The main part is best described as the upper limb of an asymmetric anticline which has its axis along the steep west scarp. The Devonian rocks at the north end may represent the overturned and sheared-off limb of an overturned syncline — the Spotted Range fold (pl. 3) — similar to those commonly found beneath the Laramide thrust sheets in this region.

The Prospect Mountain Quartzite, Pioche Shale, and Lyndon(?) Limestone at the south end of the range are thrust over the Mississippian rocks. Farther east the isolated Devonian outcrops may represent a subsidiary thrust plate torn from the overturned limb of the overturned syncline and dragged eastward beneath a plate of Cambrian rocks; this is the Spotted Range thrust plate (pl. 3). The subsidiary thrust fault, if it exists, is covered by the older clastic rocks.

Buried Hills

The Buried Hills, in the southwest corner of the county, are bounded on the west by Nye Canyon and on the east by the Spotted Range and the Fallout Hills. The north end projects into Emigrant Valley and the south end is bounded by Frenchman Flat. The highest point, Aysees Peak, reaches an altitude of 6,524 feet.

The high part of the range is largely composed of east-dipping Ordovician rocks, mostly Pogonip. Cambrian rocks are exposed intermittently on the west side. On the east side, the Ely Springs, Laketown, Sevy, and Simonson Dolomites appear to be folded into a syncline.

The Paleozoic rocks in the middle of the Buried Hills are covered by a thick orogenic conglomerate (older clastic rocks) and Tertiary volcanic rocks. The conglomerate is composed of well-rounded cobbles that are mostly quartzite. Its age may be Cretaceous, Eocene, or Oligocene. The largest area of windblown sand in Lincoln County is at the south end of the Buried Hills.

The isolated outcrops of faulted Ordovician rocks west of Nye Canyon are surrounded by an extensive field of tuffaceous and basaltic rocks of probable Pliocene Age, which may be equivalent to the Piapi Canyon Formation.

The structure of the Buried Hills is simple as far as it is known. No thrust fault was mapped within the range; however, it is conceivable that the Paleozoic rocks in the Buried Hills are part of a thrust plate, perhaps the plate that was found along the west side of the Spotted Range. A major Laramide fault must separate the Buried Hills from the Papoose Range to the north. This fault is on the projection of the Arrowhead mine fault.

MINERAL DEPOSITS

MINERAL PRODUCTION

In 1959 Lincoln County ranked fourth among the 17 counties of Nevada in the value of its mineral production. During most years it has been the largest producer of silver and zinc in Nevada, and it normally ranks second or third in the production of lead. The total gross value of all commodities produced in Lincoln County from 1869 to 1959 was almost $191 million. Approximately $167 million of this amount was in gold, silver, copper, lead, and zinc; gold and silver accounted for $60 million and base metals accounted for the rest. The principal mineral commodities in approximate order of decreasing value are zinc, silver, gold, lead, tungsten, copper, manganese, perlite, stone products, and fluorspar.

Sources of Data

The production figures given in this report have been compiled from many sources. The principal source for metal production since 1908 is the U.S. Bureau of Mines Minerals Yearbook and its predecessor, Mineral Resources. These reports list gross dollar values calculated from the quantity of recovered metals reported and the average yearly metal prices. The second major source of production data through 1940 is a compilation by Couch and Carpenter (1943) of gross production figures reported to the State of Nevada for tax purposes. These sources were supplemented by mining company records, files in the Lincoln County courthouse for years since 1940, unpublished data from the U.S. Geological Survey and U.S. Bureau of Mines (when these could be used without revealing confidential information), and production figures published in technical papers.

The production figures for Lincoln County reported by Couch and Carpenter are incomplete for the years between 1929 and 1935, and consequently the production reported for many mines is much smaller than the true value. The inaccuracies of the State and county records may be attributed to failure to report as required by law, and to reporting the net smelter return instead of the gross recovered value. As the figures from the two principal sources were usually different and could not be reconciled, the larger figure was consistently used in calculating the total production. Where necessary, gross dollar values have been calculated from the reported quantity of production and the average annual prices. The gross production value has been estimated in a few cases where only the net smelter return was available. Inevitably some estimated and reported figures are in error. Some production, especially for nonmetallic commodities, has probably been overlooked entirely because time did not permit a thorough search of the literature and of post-1940 courthouse records.

Summary of Production

The total production value and the annual production value of the principal mineral commodities since 1908 are shown in table 3. Most the production prior to 1908 was gold and silver, but the amount and value of each cannot be separated. Production of base metals prior to 1908 is known to be small, but accurate records for this period do not exist.[1] The total value of each of five commodities in table 3 exceeds $14 million and for the remaining three it exceeds $2.5 million. Zinc accounts for a third of the total value; gold and silver account for another third; and lead accounts for most of the remainder.

[1]In 1908 Lincoln County was divided into Lincoln and Clark Counties. It is difficult, therefore, to determine county production figures prior to 1908.

Table 3. Value of principal mineral commodities produced in Lincoln County, 1869-1959.

(0, no production; e, estimate; — —, no data.)

Year	Number of mines	Gold	Silver	Copper	Lead	Zinc	Total Au-Ag-Cu-Pb-Zn	Tungsten	Manganese	Perlite	Total value all commodities
1959	—	$ — —	$ — —	$ — —	$ — —	$ — —	$ — —	$ — —	$ — —	$ — —	[1]$1,485,100
1958	4	15,100	243,300	834,000	50,500	600	1,143,500	0	0	412,000	[1]1,784,000
1957	—	31,900	339,900	427,200	403,400	1,126,700	2,329,100	1,116,800	95,600	217,600	[1]3,831,300
1956	10	50,600	352,000	456,700	596,600	1,521,300	2,977,200	3,323,600	399,900	206,700	[1]7,196,600
1955	8	92,900	67,200	38,900	172,700	427,700	799,400	3,847,100	265,200	224,400	[1]5,440,900
1954	10	101,800	126,800	37,900	315,200	185,000	766,700	3,065,200	206,600	248,700	[1]4,497,100
1953	18	136,500	331,600	59,900	933,100	1,262,800	2,723,900	1,022,800	12,400	308,200	[1]4,494,800
1952	12	131,300	405,300	95,400	1,538,400	4,250,800	6,421,200	1,091,100	9,500	290,300	7,812,100
1951	13	125,400	407,700	84,800	1,804,600	5,328,100	7,750,600	100,900	— —	296,800	8,148,300
1950	12	170,100	607,300	139,300	1,931,600	5,645,600	8,493,900	0	500	195,400	8,689,800
1949	25	204,900	735,500	153,000	2,232,700	4,748,500	8,074,600	14,300	— —	175,000e	8,263,900
1948	36	176,300	764,500	212,200	2,223,700	5,129,500	8,506,200	0	— —	21,000	8,527,200
1947	16	136,600	501,300	88,600	1,125,800	3,536,100	5,388,400	125,500	— —	— —	5,513,900
1946	19	120,800	404,400	62,200	898,800	3,966,300	5,452,500	26,000	— —	— —	5,478,500
1945	13	91,000	291,500	27,300	602,300	3,870,400	4,882,500	64,500	— —	— —	4,947,000
1944	12	116,600	364,400	44,000	734,100	4,169,700	5,428,800	92,500	— —	— —	5,521,300
1943	14	93,100	364,100	70,500	519,200	2,610,600	3,657,500	89,800	— —	— —	3,747,300
1942	23	94,300	525,700	167,000	444,900	1,674,400	2,906,300	365,800	— —	— —	3,272,100
1941	36	201,300	890,200	109,300	886,800	2,158,700	4,246,300	255,500	— —	— —	4,501,800
1940	36	248,100	557,200	76,400	576,200	1,357,400	2,815,300	73,700	— —	— —	2,889,000
1939	35	253,700	349,100	70,900	303,000	596,600	1,573,300	1,800	— —	— —	1,575,100
1938	35	268,200	412,900	110,200	345,600	807,700	1,944,600	300e	— —	— —	1,944,900
1937	25	322,400	684,400	92,900	640,200	1,621,400	3,361,300	3,200	— —	— —	3,364,500

1936	31	338,100	702,700	46,400	530,200	1,204,700	2,822,100	— —	— —	— —	2,822,100
1935	34	320,600	575,600	30,600	471,500	1,072,100	2,470,400	— —	— —	— —	2,470,400
1934	28	206,500	458,700	33,300	423,300	962,900	2,084,700	— —	— —	— —	2,084,700
1933	18	56,900	76,700	10,500	140,800	351,800	636,700	— —	— —	— —	636,700
1932	10	48,700	10,700	1,600	5,700	— —	66,700	— —	— —	— —	66,700
1931	6	18,800	135,500	88,600	234,200	509,800	986,900	— —	— —	— —	986,900
1930	5	37,700	324,800	259,400	636,900	1,064,200	2,323,000	— —	— —	— —	2,323,000
1929	8	37,800	454,200	466,800	686,300	857,700	2,502,800	— —	600	— —	2,503,400
1928	15	23,200	392,800	302,500	443,900	327,600	1,490,000	— —	— —	— —	1,490,000
1927	10	15,800	215,500	187,900	248,100	156,100	823,400	— —	8,100	— —	831,500
1926	12	21,100	266,700	89,900	495,100	563,800	1,436,600	— —	50,800	— —	1,487,400
1925	17	29,700	280,200	32,500	558,400	611,800	1,512,600	— —	55,700	— —	1,568,300
1924	13	65,800	282,000	18,900	388,200	199,900	954,800	— —	87,000	— —	1,041,800
1923	10	87,200	537,700	51,200	479,000	187,400	1,342,500	— —	96,000	— —	1,438,500
1922	17	52,500	416,100	42,800	196,900	— —	708,300	— —	0	— —	708,300
1921	25	8,800	264,300	43,700	139,700	— —	456,500	— —	37,300	— —	493,800
1920	23	24,800	618,800	101,800	632,400	— —	1,377,800	— —	286,400	— —	1,664,200
1919	17	27,500	512,000	21,500	373,700	5,700	940,400	— —	195,000	— —	1,135,400
1918	12	23,200	421,300	108,600	631,500	52,900	1,237,500	— —	113,400	— —	1,350,900
1917	23	48,900	431,300	120,200	921,400	135,900	1,657,700	— —	142,500	— —	1,800,200
1916	23	34,300	367,900	198,500	714,600	268,300	1,583,600	— —	608,200	— —	2,191,800
1915	19	40,500	232,100	52,000	361,700	319,900	1,006,200	— —	519,400 e	— —	1,525,600
1914	20	57,400	225,800	87,900	233,400	56,300	660,800	— —	— —	— —	660,800
1913	22	63,700	287,000	102,500	338,900	2,800	794,900	— —	— —	— —	794,900
1912	19	152,900	467,000	81,200	484,200	4,700	1,190,000	— —	— —	— —	1,190,000
1911	14	7,600	92,600	2,200	20,500	— —	122,900	— —	— —	— —	122,900
1910	18	34,900	29,500	1,000	41,200	— —	106,600	— —	— —	— —	106,600
1909	17	333,400	116,900	22,500	64,300	— —	537,100	— —	— —	— —	537,100
1908	14	518,300	123,300	36,700	46,000	— —	724,300	— —	— —	— —	724,300
Totals[3] 1908 to 1959		$5,919,500	$19,046,000	$6,101,800	$30,221,400	$64,912,200	$126,200,900	$14,680,400	$3,190,100	$2,596,100	$149,684,700
1902 to 1907							[2]3,212,400				41,251,100
1895 to 1901							[2]9,768,200				
1884 to 1894							[2]1,096,000				
1887 to 1883							[2]2,782,700				
1870 to 1877							[2]17,934,200				
1869							[2]9,400				
Additional production prior to 1908 undistributed by year							[2]6,448,200				
Grand totals 1869-1959							$167,451,700				$190,935,800

1. Includes fluorspar, antimony, stone, sand and gravel, gem stones, mercury, and undistributed values.
2. Undistributed production prior to 1908 consists chiefly of gold and silver.
3. Totals may differ from actual sums because of rounding-off of values.

Contrary to the usual conception of mining in Nevada, the most productive period has been the last two decades. About $53 million worth of mineral commodities has been produced since 1950 and almost $106 million since 1940, compared to only about $41 million prior to 1908.

Quantity is a better gauge of production than monetary value because of the wide fluctuations of prices; consequently, the annual production since 1908, when production for each commodity was first reported, is given in terms of quantity in table 4. The total dollar value of $168,048,400 for gold, silver, copper, lead, and zinc (recalculated using average 1957 prices) gives an idea of the production in terms of the recent value of the dollar. This recalculated total value is compared to $126,200,600 for the actual total. Similar adjustment of the entire production of all commodities would increase the total value of all mineral products recovered from $190,930,400 to perhaps $225,000,000.

The shifts over the years in the most valuable metal produced and in the most productive district are worth noting. Silver, chiefly from the Pioche district, was the only important metal produced in the years between 1869 and 1894. Gold, chiefly from the Delamar district, was the principal commodity between 1896 and 1928. Lead, silver, and manganese, chiefly from the Pioche and Bristol districts, were the principal commodities between 1896 and 1928. Zinc, chiefly from the Pioche district, was the dominant metal produced between 1929 and 1953. Tungsten, almost entirely from the Tem Piute district, was the most valuable metal produced between 1954 and 1956, and it was second in value in 1953 and 1957. In 1958 copper, chiefly from a new discovery in the Bristol mine, was the most important commodity, and the production of lead, zinc, and tungsten was negligible. Such are the vagaries of mining in a changing world.

The value of production from the principal mining districts is given in table 5, and the location of these districts is shown on the index map (pl. 1). About 70 percent of the total value is shown to have come from the Pioche district; however, this total in table 5 may be several million dollars too large because it includes some production from the Highland district and, for the years from 1908 to 1915, from the Bristol district. The Bristol district is the second most productive, followed closely by the Delamar gold district and the Tem Piute tungsten district. The figures in the table do not include perlite because it is produced outside the recognized metal-mining districts. Together, the four major districts have produced $179,936,600 about 95 percent of the total. If the Hollinger perlite quarry in the Wilson Creek Range were included as a mining district, it probably would be the fifth district in rank.

Several districts would change in rank if only the production since 1908 were considered. For example, the Tem Piute district would change from fourth to second (table 5).

The production of 68 principal mines and the pertinent facts about the districts are summarized in table 6. The total value of production from the 5 largest mines is $97,500,000; that from the 10 largest mines is $128,600,000; this compares with a total production from the county of $190,900,000. Twelve mines in six districts have a total production over $1,000,000, and 19 mines have a production over $500,000.

The locations, relative production, and mineral commodities from the principal mines in Lincoln County are shown on plate 1.

METALLIC DEPOSITS

Most of the mineral production of Lincoln County, including that of the Pioche, Highland, Bristol, Delamar, Groom, Comet, Chief, and Patterson districts, came from Cambrian rocks as shown in table 7. The total production of these districts through 1958 is $168 million, about 90 percent of the total, but the Cambrian rocks cover less than 10 percent of the county. About $100 million came from replacement deposits in limestone, principally in the Pioche Shale, whose outcrops cover about 1 percent of the county. Over $42 million came from fissure veins and silicified replacement gold deposits in the lowest unit, the Prospect Mountain Quartzite, and about $28 million came from replacement deposits in the Lyndon Limestone and limestone of the Highland Peak Formation. About $2 million came from replacement veins in the Mendha Formation. The tungsten deposits in the Tem Piute district and the deposits in the Viola district are the only metallic ore bodies in post-Devonian sedimentary rocks. The Eagle Valley district is the only one that is in Tertiary volcanic rocks, even though these cover about one-third of the county and are productive in other parts of Nevada.

The metallic mineral deposits of Lincoln County are hydrothermal; they belong to six major types which may be listed as follows (in order of decreasing production): bedded replacement deposits in limestone, fissure veins and related silicified breccia deposits, irregular replacement deposits in limestone or dolomite, pyrometasomatic deposits, replacement veins, and deposits in jasperoid. The value of each type of deposit and some of the geological features are summarized in table 6. In addition to these six types, certain deposits of iron and manganese nodules of possible syngenetic origin are briefly described.

Bedded Replacement Deposits

The bedded replacement deposits are economically

Table 4. Production of principal mineral commodities in Lincoln County, 1908-1958.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Tungsten (units)	Perlite (tons)
1958	— —	— —	— —	— —	— —	0	53,900
1957	911	375,610	1,419,400	2,821,100	9,712,600	35,707	28,800
1956	1,447	388,886	1,074,600	3,800,000	11,104,500	58,102	30,200
1955	2,655	74,197	104,400	1,158,800	3,477,400	62,453	31,800
1954	2,909	140,100	128,600	2,300,800	1,712,900	48,903	34,000
1953	3,900	366,376	208,700	7,123,000	10,981,200	16,352	42,100
1952	3,751	447,786	394,100	9,555,200	25,607,000	17,102	41,300
1951	3,584	450,523	350,400	10,431,000	29,275,500	2,727	42,100
1950	4,861	671,035	669,900	14,307,800	39,757,500	0	29,100
1949	5,853	812,634	776,500	14,130,700	38,294,700	681	8,600
1948	5,038	844,681	978,000	12,422,800	38,567,700	0	3,000
1947	3,902	553,899	422,000	7,818,000	29,224,400	5,175	— —
1946	3,451	500,505	384,000	8,246,000	32,510,000	1,208	— —
1945	2,601	409,867	202,000	7,004,000	33,656,000	2,752	— —
1944	3,330	512,401	326,000	9,176,000	36,576,000	4,022	— —
1943	2,660	511,965	542,000	6,922,000	24,172,000	3,479	— —
1942	2,693	739,274	1,380,000	6,640,000	18,004,000	14,431	— —
1941	5,751	1,251,803	926,000	15,558,000	28,782,000	10,182	— —
1940	7,088	783,589	676,000	11,524,000	21,546,000	3,369	— —
1939	7,249	514,345	682,000	6,446,000	11,474,000	— —	— —
1938	7,663	638,768	1,124,000	7,512,000	16,828,000	18	— —
1937	9,211	884,832	768,000	10,850,000	24,944,000	175	— —
1936	9,659	907,351	504,000	11,526,000	24,094,000	— —	— —
1935	9,160	800,889	368,108	11,787,176	24,366,053	— —	— —
1934	5,909	709,555	415,910	11,441,164	22,392,736	— —	— —
1933	2,753	219,100	163,451	3,806,646	8,375,410	— —	— —
1932	2,354	37,827	25,073	191,406	— —	— —	— —
1931	909	467,218	973,863	6,329,860	13,416,759	— —	— —
1930	1,823	843,574	1,995,571	12,738,686	22,171,629	— —	— —
1929	1,830	852,241	2,652,115	10,894,251	12,995,496	— —	— —
1928	1,121	671,473	2,100,779	7,652,815	5,370,180	— —	— —
1927	763	380,112	1,434,702	3,938,036	2,438,395	— —	— —
1926	1,019	427,345	642,047	6,188,550	7,517,040	— —	— —
1925	1,438	403,748	229,034	6,418,524	8,049,995	— —	— —
1924	3,184	420,943	144,650	4,851,928	3,074,843	— —	— —
1923	4,219	655,776	348,466	6,842,459	2,756,118	— —	— —
1922	2,542	416,109	317,306	3,579,813	— —	— —	— —
1921	426	264,304	338,521	3,104,956	— —	— —	— —
1920	1,201	567,678	553,186	7,904,470	— —	— —	— —
1919	1,330	457,152	115,539	7,051,388	78,200	— —	— —
1918	1,122	421,310	439,767	8,893,658	581,718	— —	— —
1917	2,365	523,399	440,197	10,714,152	1,332,521	— —	— —
1916	1,660	559,045	806,938	10,356,926	2,002,105	— —	— —
1915	1,958	457,825	297,183	7,695,155	2,579,745	— —	— —
1914	2,775	408,286	660,589	5,985,679	1,104,644	— —	— —
1913	3,083	475,105	661,494	7,701,311	46,962	— —	— —
1912	7,395	759,371	492,098	10,759,685	68,128	— —	— —
1911	367	174,774	17,382	455,490	— —	— —	— —
1910	1,687	54,571	7,653	935,255	— —	— —	— —
1909	16,127	224,852	173,446	1,495,628	— —	— —	— —
1908	25,073	232,615	277,727	1,095,000	— —	— —	— —
Totals[1]	205,760	25,666,624	31,133,395	368,083,067	651,020,077	286,838	344,900

1. Pre-1908 figures combined with Clark County and not separable.

Table 5. Value of production from the principal mining districts, Lincoln County.
(e, estimate)

Rank	District	Principal commodities	Value of mineral production Prior to 1908	1908 to 1958	Total value
1	Pioche	Zinc, silver, lead, manganese	$21,343,600	[1]$111,672,800	$133,016,400
2	Bristol and Jackrabbit	Silver, lead, copper, zinc	4,800,000e	12,409,300e	17,209,300
3	Delamar	Gold	12,703,500	2,280,200	14,983,700
4	Tem Piute	Tungsten	11,400	14,910,600	14,922,000
5	Highland	Lead, silver, gold	1,500,000e	500,000e	[2]2,000,000
6	Groom	Lead, silver	———	1,083,200	1,083,200
7	Pahranagat	Manganese, silver, lead	123,700e	677,700	801,400
8	Comet	Lead, silver, zinc, manganese	4,900	759,200	764,100
9	Eagle Valley	Gold, silver	284,500e	138,500e	423,000
10	Viola	Fluorspar, silver, lead	5,000e	385,200e	390,200
11	Atlanta[3]	Gold, silver	75,000e	195,300e	270,300
12	Chief	Gold, silver	25,000e	68,700e	93,700
13	Patterson	Tungsten, silver	———	75,000e	75,000
14	Pennsylvania	Gold, copper	———	50,000e	[4]50,000
15	Freiberg	Silver, lead, tungsten	———	18,000e	18,000
16	Ely Springs	Silver	———	8,400	8,400
Total					$184,058,700

1. Includes Bristol district, 1908-1915.
2. Included with Pioche district.
3. Includes Silver Park district.
4. Included with Viola district.

the most important and have produced more than $63 million worth of ore. The bedded replacement deposits are tabular mantolike deposits in favorable limestone beds. Most of the zinc and lead, and much of the silver and manganese produced in Lincoln County came from bedded replacement deposits occurring in the Pioche, Groom, and Comet districts in limestone beds of the Pioche Shale. The largest deposit, which is typical of the group, is the sulfide deposit in the Combined Metals Member (pl. 4) between Pioche and Caselton. This deposit has produced more than $43 million from a continuous ore body extending about 9,000 feet along an east-west zone that is up to 700 feet wide (Caselton ore channel). The ore body, as developed along the Greenwood fissure, averaged 7 feet in thickness and reached a maximum of 40 feet. The principal minerals in decreasing order of abundance are pyrite, manganoan siderite, sphalerite, and galena. The ore body was zoned outward from massive sulfide near the Greenwood fissure to clean manganoan siderite at the periphery; lead and silver content decreases outward from the Greenwood fissure.

Most bedded replacement deposits in the Pioche Shale are oxidized to a depth of 300 to 900 feet in the Pioche district. These oxidized ores are not generally of economic value because zinc is leached out. Small amounts were mined for their manganese content, but large-scale efforts (begun about 1951) to produce manganese ore from the Combined Metals Member have not been successful.

Between 1918 and 1926, over 900,000 tons of manganiferous fluxing ores were mined from the Lyndon Limestone and from the Peasley Member of the Highland Peak Formation (unit A, fig. 6) in the Prince mines. Because these ores were primarily used for smelter flux, the appreciable lead and silver content in them was recovered.

The bedded replacement deposits in the Prince mine have a stratigraphic range of 1,200 feet. Seven beds were mined; these were the Peasley Member, two beds in the Lyndon Limestone, and four limestone beds in the Pioche Shale.

Siliceous bedded replacement deposits are much smaller and rarer than carbonate. Small siliceous deposits were mined from the Lyndon Limestone in the Virginia Louise workings of the Prince mine and from the Mendha Formation in the Mendha and Hamburg mines.

Epithermal Fissure Veins

Fissure veins and related silicified breccia deposits form the second most productive type of mineral deposit in the county. Included in this category are the very productive epithermal breccia-filled silver veins of the Pioche district and the gold quartz deposits of the Delamar, Atlanta, and Eagle Valley districts. The mesothermal mixed metal, base metal, or quartz-wolframite veins found in the Tem Piute, Comet, Viola, Chief, Patterson districts, and elsewhere are less productive. The vein deposits have yielded most of the gold and much of the

Table 6. Principal mines in Lincoln County arranged in order of decreasing production value.
(e, estimate)

Mine or company	District	Period of activity	Principal commodities	Type of deposit	Type of Ore	Tons of ore	Recorded value of gross production	Approximate total production	Remarks and references
1. No. 2 (Combined Metals, Caselton shaft)	Pioche	1917-1940	Zinc, lead, silver	Bedded replacement	Sulfide	510,200	$10,251,490	$.....	Couch and Carpenter (1943, p. 87); Westgate and Knopf (1932, p. 54).
		1924-1957	do.	do.	do.	3,250,000 e	43,600,000	43,600,000	C. F. Park, Paul Gemmill, and C. M. Tschanz (unpublished data, 1960).
2. Lincoln	Tem Piute	1940-1957	Tungsten	Pyrometasomatic	Tactite	1,000,000 e	14,421,000	14,421,000	
3. Bristol Silver	Bristol	1878-1958	Silver, lead, zinc, copper	Replacement	Oxidized	600,000 e	.....	13,535,000 e	Mining World (1942, v. 4, no. 2, p. 7-9); Couch and Carpenter (1943, p. 86-87).
4. Raymond and Ely No. 1	Pioche	1869-1881	Silver	Vein	Oxidized	148,000	10,293,100	13,400,000	Couch and Carpenter (1943, p. 88).
		1924-1940	.....	.....	Sulfide	.....	.....	.....	
5. Delamar	Delamar	1903-1940	Gold	Vein	Oxidized	1,226,000	13,160,000	13,160,000	Couch and Caprenter (1943, p. 87); includes tailings from mill.
		1894-1903	do.	do.	do.	1,208,000	1,085,000 e	.....	Callaghan (1937, p. 38-40).
Delamar mill		1932-1940	do.	.....	Tailings	586,000	782,000	.....	Eng. Mining Jour. (1940, v. 141, no. 8, p. 98).
6. Ely Valley	Pioche	1907-1953	Zinc	Bedded replacement	Sulfide	750,000 e	.....	9,750,000	
7. Prince Consolidated (Virginia Louise)	Pioche	1909-1938	Manganese, lead, silver	Bedded replacement	Oxidized and sulfide	782,000	7,873,000	.....	Couch and Carpenter (1943, p. 88); Westgate and Knopf (1932, p. 60).
		1909-1954	do.	do.	do.	1,226,000	8,558,000	9,650,000	
8. Meadow Valley	Pioche	1869-1912	Silver	Vein	Oxidized	88,600	5,796,000	5,796,000	Couch and Carpenter (1943, p. 88).
9. Black Metals (Day, Jackrabbit)	Bristol	1876-1927	Silver, lead, manganese	Replacement	Oxidized	259,000 e	.....	3,900,000	Net value estimated at $2,767,400 of which $2,500,000 produced before 1919.
10. Hollinger	.....	1949-1958	Perlite	Flow	.....	330,000 e	.....	2,000,000	Cochran (1951, p. 10).
11. Mendha	Highland	1873-1926	Silver, lead	Replacement vein	Oxidized	10,100	158,000	1,158,000 e	Minerals Yearbook (1907); Couch and Carpenter (1943, p. 88).
12. Groom	Groom	1915-1956	Lead, silver	Replacement	Sulfide	8,000 e	.....	1,085,000	Entire production of district assigned to mine. Humphrey (1945, p. 35). Eng. Mining Jour. (1944, v. 145, no. 4, p. 116; 1945, v. 146, no. 7, p. 126; 1946, v. 147, no. 16, p. 128).
13. April Fool	Delamar	1892-1902	Gold	Vein	Oxidized	49,500	876,800	876,800	Callaghan (1937, p. 39); includes tailings from mill.
14. Abe Lincoln and Half Moon	Pioche	1860-1880	Gold, silver, lead	Bedding vein	Oxidized	23,800	.....	840,000 e	Westgate and Knopf (1932, p. 67). Calculated from average 1893 metal prices.
15. Alps	Pioche	1869-1920	Silver, gold	Vein	Oxidized	.....	800,000	800,000	Westgate and Knopf (1932, p. 59).
16. South Paw	Pahranagat	1952-1957	Manganese	Replacement	Oxide	17,300	630,300	630,300	U.S. Bureau of Mines records.
17. Amalgamated Pioche	Pioche	1913-1937	Silver, lead	Vein	.....	38,200	557,800	557,800	Couch and Carpenter (1943, p. 87).
18. Wide Awake (Volcano)	Pioche	1919-1944	Silver, lead	Vein	Oxidized	17,000	.....	535,000	Westgate and Knopf (1932, p. 58).

Table 6. Principal mines in Lincoln County, arranged in order of decreasing production value.—Continued.
(e, estimate)

Mine or company	District	Period of activity	Principal commodities	Type of deposit	Type of ore	Tons of ore	Recorded value of gross production	Approximate total production	Remarks and references
19. Pioche Consolidated	Pioche	1887-1893, 1932-1944	Silver, lead	Vein	Oxidized	20,200	524,600	524,600	Couch and Carpenter (1943, p. 88); recorded net value.
20. Salt Lake Pioche (Apex)	Pioche	1938-1952	Silver, lead	Vein	Oxidized	15,000 e	415,500 e	500,000 e	L. C. Bacon, U.S. Bureau of Mines (written communication, 1944).
21. Pioche Silver Mining Co.	Pioche	1871-1878	Silver	Vein	Oxidized	5,400	442,000	442,000	Couch and Carpenter (1943, p. 88).
22. Comet	Comet	1924-1952	Silver, lead, zinc, gold	Vein	Oxidized and sulfide	15,700	----------	400,000 e	Estimated from district total by subtracting other production.
23. Magnet mill[1]	Pioche	1872-1875	Silver	----------	Tailings	----------	381,700	381,000	Couch and Carpenter (1943, p. 88).
24. Wells Cargo	Viola	1958-	Fluorspar	Replacement	----------	11,050	----------	363,000	Estimated total value of production, half of which was not told.
25. Poorman	Pioche	1887-1899, -1926	Silver, lead do.	Vein do.	Oxidized do.	400 ----------	---------- ----------	---------- 300,000 e	Couch and Carpenter (1943, p. 88). Westgate and Knopf (1932, p. 58).
26. Newark Silver	Pioche	1873-1879	Silver	Vein	Oxidized	6,300	289,500	289,500	Couch and Carpenter (1943, p. 88).
27. Horseshoe Gold	Eagle Valley	1900-1902	Gold	Vein	Oxidized	39,300	269,000	269,000	Couch and Carpenter (1943, p. 87).
28. Atlanta	Atlanta	Pre-1952 1953-1958	Gold do.	Vein do.	Oxidized do.	---------- ----------	---------- 151,000	---------- 190,700	Meyers (1915); Hill (1916). Minerals Yearbook (1953-1958).
29. Nevada-Utah	Pioche	1900-1911	Silver	Vein	Oxidized	28,900	187,200	187,200	Couch and Carpenter (1943, p. 88).
30. American Flag	Pioche	1872-1881	Silver, lead	Vein	Oxidized	11,800	183,800	183,800	Couch and Carpenter (1943, p. 87).
31. Yuba	Pioche	1888-1914	Silver, lead	Vein	Oxidized	4,200	178,900	178,900	Couch and Carpenter (1943, p. 88).
32. Pan American	Comet	1947-1955	Silver, lead, manganese	Bedded replacement	Oxidized(?)	17,000	----------	170,000 e	
33. Mazeppa Silver	Pioche	1872-1878	Silver, lead	Vein	Oxidized	2,700	128,900	128,900	Couch and Carpenter (1943, p. 88).
34. Schodde	Comet	1914-1918	Lead, silver	Replacement vein	----------	----------	125,000	125,000	Trengove (1949).
35. Washington and Creole	Pioche	1872-1883	Silver, lead	Vein	Oxidized	1,600	118,000	118,000	Couch and Carpenter (1943, p. 88).
36. Pioche	Pioche	1937-1938	Lead, silver	Vein	Oxidized	13,400	110,800	110,800	Couch and Carpenter (1943, p. 88).
37. North Tem Piute	Tem Piute	1957 1937-1957	Tungsten do.	Pyrometasomatic do.	Tactite do.	---------- ----------	7,500 107,300 e	---------- 114,800 e	Couch and Carpenter (1943, p. 89).
38. Chief of Hill[1]	Pioche	1872-1877	Silver	Vein	Oxidized	700	90,300	90,300	Couch and Carpenter (1943, p. 87).
39. Hamburg	Highland	1916-1924	Silver, lead, gold	Vein	Oxidized	2,700	87,100	87,100	Couch and Carpenter (1943, p. 87).
40. P. McCannon[1]	Pioche	1871	Silver	Vein	Oxidized	900	85,000	85,000	Couch and Carpenter (1943, p. 88).
41. Jumbo (Horn lease)	Delamar	1932-1935	Gold	Vein	Oxidized	900	76,200	76,200	Calculated from average price data in Callaghan (1937, p. 61).

42. J. Nesbitt and Brother	Pioche	1894-1914	----------	----------	----------	5,100	70,300	70,300	Couch and Carpenter (1943, p. 88).
43. Amador tunnel	Pioche	1872-1873	Silver	Vein	Oxidized	755	49,400	49,400	Couch and Carpenter (1943, p. 87).
44. Hackett[1]	Pioche	1872	Silver	Vein	Oxidized	257	49,300	49,300	Couch and Carpenter (1943, p. 87).
45. Cannon Gassett	Pioche	1871	Silver	Vein	Oxidized	315	46,900	46,900	Couch and Carpenter (1943, p. 87).
46. Nevada Mining	Pioche	1877-1898	Silver	Vein	Oxidized	4,100	41,100	41,100	Couch and Carpenter (1943, p. 88).
47. Gypsy and Helen groups	Eagle Valley	1937-1941	Gold, silver	Vein	Oxidized	----------	----------	40,000 e	
48. Culverwell	Pennsylvania	----------	Gold	Vein	Oxidized	----------	----------	40,000 e	Estimated value of 16 carloads gold ore.
49. Hermes Silver[1]	Pioche	1873	Silver	Vein	Oxidized	570	40,000	40,000	Couch and Carpenter (1943, p. 87).
50. Phoenix Reduction[1]	Pioche	1894-1897	Silver	Vein	Oxidized	----------	39,900	39,900	Couch and Carpenter (1943, p. 88).
51. Church[1]	Pioche	1870-1872	Silver	Vein	Oxidized	195	39,000	39,000	Couch and Carpenter (1943, p. 87).
52. Magnolia	Delamar	1892-1932	Gold	Vein	Oxidized	----------	37,700	37,700	Callaghan (1937, p. 66); total production probably greater than shown.
53. Bowen Consolidated[1]	Pioche	1872	Silver	Vein	Oxidized	286	36,200	36,200	Couch and Carpenter (1943, p. 87).
54. Pioche Union	Pioche	1924	Silver	Vein	----------	8,500	34,100	34,100	Couch and Carpenter (1943, p. 88).
55. Bliss, Mary N.[1]	Pioche	1870	Silver	Vein	Oxidized	600	33,000	33,000	Couch and Carpenter (1943, p. 87).
56. Gold Chief	Chief	1911-1940	Gold, silver	Vein	Oxidized	----------	25,000	32,000 e	Callaghan (1936, p. 26); Couch and Carpenter (1943, p. 86).
57. Snowflake group	Eagle Valley	1937-1941	Silver	Vein	Oxidized	----------	----------	31,000	Higgins (1908).
58. James & Co.	Pioche	1873-1875	Gold, silver	Vein	Oxidized	937	30,700	30,700	Couch and Carpenter (1943, p. 88).
59. Ryan, J. W.	Tem Piute	1869-1883	Silver?	Vein	Oxidized	1,700	28,500	28,500	Couch and Carpenter (1943, p. 89).
60. Tem Piute	Tem Piute	1869-1936	Silver	Vein	Oxidized	1,100	26,900	26,900	Couch and Carpenter (1943, p. 89).
61. Casey, Courtney & Doody[1]	Pioche	1871	Silver?	----------	----------	294	26,400	26,400	Couch and Carpenter (1943, p. 87).
62. Chapman[1]	Pioche	1872-1875	Silver?	----------	----------	296	26,200	26,200	Couch and Carpenter (1943, p. 87).
63. Floral mill	Highland	1875-1885	Silver?	----------	----------	8	25,400	25,400	Couch and Carpenter (1943, p. 87).
64. Polaris	Pioche	1893-1894	Silver?	----------	----------	269	24,600	24,600	Couch and Carpenter (1943, p. 88).
65. Silver Park	Atlanta	1876	Silver	Vein	Oxidized	373	23,200	23,200	Couch and Carpenter (1943, p. 86).
66. Ida May (E & F)	Bristol	1906-1918	Silver?	----------	----------	553	21,300	21,300	Couch and Carpenter (1943, p. 86).
67. Oregon Short Line	Bristol	1899	Silver?	Vein	Oxidized	268	20,500	20,500	Couch and Carpenter (1943, p. 86).
68. Cinch	Patterson	1943	Tungsten	Vein	----------	----------	----------	19,000 e	Estimated value of 750 units WO_3.

[1] Exact location unknown.

Table 7. Geological characteristics and production from the principal types of mineral deposits in Lincoln County.

District	Age of enclosing rocks	Productive stratigraphic units	Host rock type	Relation to thrust faults	Oxidation state	Principal commodities	Approximate value definitely assignable to type of deposit					
							Bedded replacements	Irregular replacement	Replacement veins	Fissure veins	Jasperoid deposits	Pyrometa-somatic deposits
Pioche	Cambrian	Pioche Shale	Limestone	Lower plate	Sulfide	Zinc, lead manganese	$53,000,000	$ 8,000,000	$2,000,000	----------	----------	----------
	Cambrian	Prospect Mountain Quartzite	Quartzite	Lower plate	Oxidized	Silver	----------	----------	----------	$26,600,000	----------	----------
	Cambrian	Highland Peak Formation, Lyndon Limestone	Limestone	Lower plate	Oxidized	Manganese, silver	10,000,000	----------	----------	----------	----------	----------
Bristol	Cambrian	Highland Peak Formation	Limestone and dolomite	Lower plate	Oxidized	Silver, copper, lead, zinc	----------	13,900,000	3,000,000	----------	----------	----------
	Cambrian	----------	----------	----------	Oxidized	Manganese	----------	200,000	----------	----------	----------	----------
Delamar	Cambrian	Prospect Mountain Quartzite	Quartzite	None	Oxidized	Gold, silver	----------	----------	----------	15,000,000	----------	----------
Tem Piute	Missis-sippian	Missis-sippian	Limestone	Lower plate	Primary	Tungsten	----------	----------	----------	----------	----------	$14,500,000
	Silurian and Devonian	Laketown, Sevy, Simonson Dolomites	Dolomite	----------	Oxidized	Silver	----------	----------	----------	200,000	----------	----------
Highland	Cambrian	Mendha Formation, Highland Peak Formation	Limestone	Upper plate	Oxidized	Lead, silver, gold	----------	----------	2,000,000	----------	----------	----------
Groom	Cambrian	Lyndon Limestone, Pioche Shale	Limestone	Lower plate	Oxidized and sulfide	Lead, silver	500,000	600,000	----------	----------	----------	----------
Pahranagat	Ordovician	Ely Springs Dolomite	Dolomite	Upper plate	Oxidized	Manganese	----------	700,000	----------	----------	----------	----------
	Ordovician and Devonian	Pogonip Group, Guilmette Formation	Limestone	Upper plate	Oxidized	Silver, lead	----------	----------	100,000	----------	----------	----------
Comet	Cambrian	Pioche Shale, Lyndon Limestone, Chisholm Shale	Limestone	Principally lower plate	Oxidized	Lead, silver, zinc, manganese	300,000	----------	----------	----------	----------	----------

	Cambrian	Prospect Mountain Quartzite	Quartzite	Lower plate	Oxidized and sulfide	Lead, silver	----------	----------	500,000	----------
Eagle Valley	Tertiary	Volcanic rocks	Latite, rhyolite	None	----------	Gold, silver	----------	----------	400,000	----------
Viola	Mississippian and Pennsylvanian	Unnamed	Limestone	None?	Primary	Fluorspar, silver, lead	----------	----------	----------	$400,000
Atlanta	Ordovician	Pogonip Group, Ely Springs Dolomite	Limestone, dolomite	?	----------	Gold, silver	----------	----------	300,000	----------
Chief	Cambrian	Prospect Mountain Quartzite	Quartzite	Upper plate	Oxidized	Gold, silver	----------	----------	100,000	----------
Patterson	Cambrian	Pole Canyon(?) Limestone, Pioche Shale	Limestone	----------	Primary and oxidized	Tungsten, silver	----------	----------	100,000	
						Approximate total value	[1]$63,800,000	$23,400,000	$7,100,000	$43,200,000	$400,000	$14,500,000

1. Figure based on recorded production definitely assignable to this type of deposit; total production probably near $100,000,000.

silver production as well as important amounts of base metals. Nearly all the production from fissure veins has come from gold and silver veins in the Prospect Mountain Quartzite in the Pioche and Delamar districts.

The silver veins in the Pioche district, the most productive fissure deposits, contain little gangue besides quartzite breccia, and they pinch out in the relatively impermeable Pioche Shale. The bonanza ore shoots that were mined in the early days occurred just below the top of the quartzite. Silver was the only important metal, but lead, which was always present, was especially abundant in and near the Yuba dike.

The next most productive deposits, the gold deposits of the Delamar district, consist of quartzite breccia cemented by cherty fine-grained quartz, veins of cherty fine-grained quartz, and silicified quartzite. These deposits contain free gold, silver, sulfides, and tellurides. The grades of the deposits in the Delamar mine, which was by far the most productive, increased downward to the 7th level, then at greater depths decreased, at first gradually, then rapidly. The average grade of ore from the Delamar mine was between $30 and $70 a ton above the 7th level, but fell to $4 or $5 at the 10th level, and to $1 or $2 in lower levels. The rich ore was probably formed by supergene enrichment of a primary protore of low grade. The gold deposits in the Atlanta and Eagle Valley districts are similar to those in the Delamar district except for the host rock, which is dolomite in the Alanta district and volcanic rock in the Eagle Valley district.

Several types of quartz veins occur in Lincoln County. Quartz-tungsten veins in Prospect Mountain Quartzite occur in several districts. Some of these are near bedded replacement beds in the Pioche Shale. Wolframite-bearing base metal veins in Prospect Mountain Quartzite occur in the Comet mine in the Comet district and in the Pioche and Patterson districts. The production from these quartz veins has been small except for moderate production from the Comet mine.

In the Prince mine in the Pioche Shale two productive quartz veins yielded about $200,000 worth of lead, silver, and gold. In the Pioche district a quartz bedding vein in the Chisholm Shale at the Abe Lincoln and Half Moon mines has produced an estimated $840,000 in gold, silver, and lead. Drill holes have penetrated quartz-sphalerite bodies thought to be veins in or near the Prospect Mountain Quartzite in the Prince and No. 1 mines in the Pioche district, but they have not been exploited.

Irregular Replacement Deposits

The third most productive type of deposit includes the irregular or chimneylike replacement deposits in limestone and dolomite, which have yielded about $23 million. These deposits have produced most of the copper

and much silver, lead, zinc, and manganese. The major deposits of this type occur in the Pioche and Bristol districts, and smaller ones have been found in the Pahranagat and Groom districts. The mineralogy of these deposits generally is more variable than that of the other types. In the Pioche district, however, they differ from the bedded replacement deposits only in form.

The irregular replacement deposits of the Bristol district, especially in the Bristol mine, are unique in several respects. They occur along four intersecting sets of fissures, and they replace brecciated limestone or dolomite of the Highland Peak Formation through a known stratigraphic range of over 3,000 feet. The ore is oxidized, and the proportion of silver, lead, copper, and zinc varies greatly from place to place. The ore bodies in this mine are irregular pipelike bodies, many of which extend from the surface to the 1,500-foot level. The ore bodies have been mined to depths as great as 2,100 feet below the surface.

The ore pipe at the Black Metals mine in the Bristol district was zoned. The core, mined in the early days, was high-grade oxidized lead-silver ore; and successive outer zones, mined in later periods of activity, contained progressively less lead and silver and more manganese. The peripheral zones were mined only for the manganese; they contained a fluxing ore similar to the fluxing ores mined in the Prince mine.

Irregular lead-silver replacement deposits in the Lyndon Limestone were mined in the Groom mine, Groom district, and in the Schodde mine, Comet district. The irregular replacement deposit in the Ely Springs Dolomite at the South Paw mine, Pahranagat district, unlike the other deposits, does not contain any valuable metal except manganese.

The irregular replacement deposits usually show a strong structural control. They generally occur along fissures or at the intersection of two or more fissures, and the genetic relation to these fissures is usually clearer than in the bedded replacement deposits. Brecciation is more significant in localizing the irregular replacement deposits than in localizing the bedded replacement deposits.

Pyrometasomatic Deposits

The pyrometasomatic deposits, notably the scheelite deposits in the Tem Piute district, have produced almost $15 million worth of ore. They occur as low-grade scheelite-bearing tactite or skarn, or as smaller richer bodies of calcite-fluorite-sphalerite-scheelite rock in the contact aureoles of granitic stocks. Because the tactite masses selectively replace certain limestone beds, they might also be classed as bedded replacement deposits. The scheelite deposits contain recoverable amounts of fluorite, sphalerite, and bismuthinite(?), as well as the tungsten.

In the Tem Piute district the economic deposits are confined to two tactite zones along the west side of one of two granitic stocks. Smaller scheelite deposits are also found in the tactite aureole of the stock on the west side of the Worthington Range and in metamorphic rocks adjacent to pegmatite dikes of Precambrian Age on the east side of the East Mormon Range. Contact metamorphic rocks are present in the Don Dale, Highland, Bristol, Pioche, Delamar, and Pennsylvania districts, but they are not known to contain tungsten deposits. A discovery of beryllium deposits containing scheelite and fluorite in the Pioche Shale of the Snake Range (White Pine County), made in 1959, should encourage further prospecting of the contact aureoles of all the granitic stocks.

Replacement Veins

Veins in which replacement, rather than open-space filling, is the dominant process are feeders for the bedded replacement deposits in many places, for example, the Greenwood or Ely Valley fissure veins in the Pioche district. Irregular replacement deposits occur along the May Day, Hillside, Gypsy, or Tempest fissures in the Bristol mine. These fissure veins and the Mendha and Hamburg veins in the Highland district are the most important deposits of this type. The total production from the replacement veins is estimated to be on the order of $7 million, but perhaps several millions of dollars assigned to the bedded replacement or irregular replacement deposits should be included here. These veins have been important sources of silver, lead, zinc, and copper.

Jasperoid Deposits

The only large deposit in jasperoid is the Wells Cargo fluorspar mine in the Viola district which will be discussed with other nonmetallic deposits on page 124. The small silver deposits in the Silverhorn district and a uranium deposit in the Atlanta district also occur in jasperoid.

Sedimentary Iron and Manganese Deposits

Nodules of hematite and of manganese minerals occur in a purplish-gray siltstone in the Chinle Formation in two places 5 miles apart near the southern edge of the Clover Mountains volcanic field, north of Lime Mountain. The iron and manganese nodules were readily sorted by hand into two products that have the following analyses, in percent:

	Manganese nodules	Hematite nodules
Mn	39.1	0.2
Fe_2O_3	7.2	80.5
Si	10.+	3.

Al	3.	3.
K	3.	——
Ca	1.5	1.5
Na	.7	.07
Ba	.6	.7
Mg	.3	.3
Ti	.15	.07
Si	.15	.015
Pb	.07	.007
Zn	.07	——
Co	.03	.003
Cu	.03	.007
Y	.015	——
Mo	.015	.003
Be	.015	——
In	——	<.02
Ni	.003	.007
V	.003	.007
Zr	.007	.003
W	<.01	——

The Fe_2O_3, Mn, and W percentages are based on chemical analyses by D. L. Skinner and Claude Huffman. The other percentages are based on semiquantitative spectrographic analyses by R. G. Havens, reported to the nearest number in the series, 7, 3, 1.5, etc. The X-ray pattern of the manganese minerals was inconclusive. It fit either cryptomelane or "a buchan mineral," according to A. J. Gude, III (written communication, 1957).

These nodules could have formed either by diagenetic and sedimentary processes or by hydrothermal replacement of limestone nodules. If they were formed by sedimentary processes, they are more likely to be widely distributed. The deposits are a potential source of both manganese and iron.

Other Types of Deposits

For the sake of completeness, several other types of metallic deposits should be briefly described. These deposits are of greater interest than their production figures would suggest. One type includes deposits in hydrothermally altered volcanic rocks, such as a low-grade disseminated quicksilver deposit in the Don Dale district, or the Larson quicksilver mine in the Viola district. Other deposits that occur in altered volcanic rocks are a uranium (autunite) prospect in the Eagle Valley district and alunite and kaolinite deposits near Boyd in Meadow Valley Wash.

Another interesting type of deposit is the low-grade disseminated deposit of secondary uranium minerals in the Panaca Formation near Panaca. Similar deposits occur in the Muddy Creek Formation in northern Clark County west of Glendale. These local concentrations of uranium minerals were probably deposited by solutions that leached uranium from the overlying tuffaceous rocks.

The tungsten-bearing manganese veins in the Tertiary volcanic rocks, near the head of Winze Creek in the Wilson Creek Range, represent another type of vein deposit. These veins contain only botryoidal manganese oxides, probably psilomelane, which contains about 7 percent barium, 3 percent tungsten, 0.7 percent strontium, and 0.15 percent thallium, according to semiquantitative spectrographic analyses.

A magnetite deposit is reported to have been found south of Barclay, but its exact location is unknown to us.

Localization of Mineral Deposits

The mineral deposits of Lincoln County clearly show stratigraphic and structural control, the evidence for stratigraphic control being particularly impressive (table 7).

Stratigraphic Control of Ore Deposition

The marked concentration of metallic deposits in the Cambrian rocks, especially in the lowest Cambrian limestone, is remarkable and requires explanation. The lowest limestone in the stratigraphic sequence, the Combined Metals Member of the Pioche Shale, is replaced in preference to higher units. The underlying Prospect Mountain Quartzite contains only epithermal veinlike deposits and is omitted from the following discussion.

The concentration of metallic deposits in the Lower and Middle Cambrian rocks may be influenced by stratigraphic, petrographic, and structural factors. The most productive Cambrian rocks are comparatively thin limestone layers interbedded with micaceous shales that are lithologically unlike the barren shales higher in the stratigraphic sequence. This fact suggests that the metal in the deposits was derived from the shale, or the metal was precipitated in these beds because of some physical characteristic not found in the higher shales, or these formations happened to be in a favorable temperature and pressure zone because of their stratigraphic position. The first and last possibilities will not be considered because of lack of data.

The Pioche Shale differs from the higher shales in that it has a greater apparent abundance of mica, feldspar, iron oxide and glauconite(?); it has chitinous (trilobite) and phosphatic (brachiopod) fossil remains; and it has coarser grain size. A. S. Lees (written communication, 1951) concluded as a result of microscopic study that the mica was metamorphic rather than detrital. The carbonaceous content of the limestone is relatively high, but the enclosing shale is less carbonaceous than the younger shales such as the Chainman. The abundance of phosphatic or chitinous fossil debris and the presence of coarse-grained carbon segregated along nodular bedding planes in the productive Cambrian limestones may have influenced deposition.

Structural Control of Ore Deposition

Structural factors have also influenced ore deposition. The Pioche and Chisholm Shales that include or are adjacent to the principal ore-bearing limestones are favored horizons for structural movement. This movement along incompetent shale beds locally shattered the adjacent massive competent limestones, thus providing channels for the lateral migration of ore-bearing solutions.

Thrust faults seem to be a major structural control of the ore deposits, because the major ore deposits of Lincoln County are found beneath major overthrust plates. The Pioche, Bristol, Tem Piute, Groom, and Comet districts are examples of ore deposits in a lower plate near an overlying overthrust sheet. Thrust faults have not been recognized in the Delamar district, but if present they are almost certainly above the ore deposits. Some minor districts, however, are in the thrust plate, but the only productive ones are the Mendha and Hamburg mines in the Highland district, and the South Paw mine in the Pahranagat district. Mineralized rocks also occur near thrust faults in the Chief and Patterson districts.

Intrusive rocks have localized many major ore deposits by acting as a source of metal or heat, or by providing channelways for the ore-bearing solutions through otherwise relatively impermeable layers. Pyrometasomatic tungsten deposits occur on the contacts of the parent granitic stocks in the Tem Piute, Freiberg, Highland, and Bristol districts.

In the Tem Piute district, the productive southern stock is notably less resistant to weathering than the barren northern stock, perhaps because it is more intensely altered. The pyrometasomatic tungsten deposits in Mississippian rocks are genetically related to the same magma as the adjacent granitic rock.

In the Pioche district, ore occurs in and near a sericitized porphyry dike known as the Yuba dike. In the Chief and Pennsylvania districts, in the Little Mountain area, and in the Delamar district, small ore deposits occur in dioritic rocks. Gold ore occurs in altered rhyolite dikes and volcanic breccia in the Delamar district; here the principal ore body occurs at the intersection of two dikes. Dikes are also associated with ore bodies in the Highland, Patterson, Tem Piute, Freiberg, Silver King (Sunnyside), and Don Dale districts. Dikes do not crop out around the Bristol mine but are increasingly abundant in progressively lower levels of the western part of the mine. Unmineralized granitic rocks crop out near the Ely Valley mine in the Pioche district, but the same rocks underground are mineralized.

The dikes generally have acted only as channels for the ore-bearing solutions rather than as sources of metal or heat. Paul Gemmill of Combined Metals and Reduction Co. (oral communication, 1950) has suggested that the brecciated porphyry dikes along the Caselton ore channel have provided conduits through thick nearly impermeable shales in the Prospect Mountain Quartzite. They have also fed the extensive bedded replacement deposits in the Combined Metals Member of the Pioche Shale where the deposits are in the hanging wall of the dikes.

Most of the intrusive igneous rocks are younger than the major thrust faults and the older volcanic rocks. The dioritic rocks are generally older than the granitic rocks. The intrusive rocks appear to be either contemporaneous with, or older than, the younger volcanic rocks and the ore deposits.

There is no evidence suggesting more than one epoch of mineralization in Lincoln County unless the quicksilver and gold deposits are later than the others. This period of mineralization was younger than the Laramide orogeny. The general association of the ore deposits with intrusive masses of probable early Tertiary Age and the general absence of ore deposits in the youngest volcanic rocks point to the Eocene through Miocene interval as the period of ore deposition.

NONMETALLIC DEPOSITS

The nonmetallic commodities of Lincoln County, in order of decreasing value of production, are perlite, fluorspar, crushed and broken stone, clay, alunite, diatomite, gypsum, marble, vermiculite, volcanic ash, and barite.

Perlite

The perlite deposits are a major resource, and Lincoln County usually ranks first in Nevada in its production. Perlite, a term which includes all expandable volcanic glass, was first produced on a commercial scale in 1948. In 1949 and 1950, Lincoln County accounted for about half of the national perlite production, and the county has remained a major source since that time.

Many large deposits of commercial quality are known and, undoubtedly, more will be found. In 1951 K. L. Cochran, in a report for the Union Pacific Railroad, estimated that the reserves of the 10 perlite deposits in Lincoln County that he studied totaled about 180,400,000 tons. We saw other large undeveloped deposits, most of which are shown on plate 1, whose total reserves exceed this figure. Table 8 describes the perlite deposits in Lincoln County. Much of this information was compiled from Cochran's report (1951) to which the reader is referred for additional details on the geology, reserves, and production.

Fluorspar

The only productive fluorspar deposit is the Wells Cargo mine, which was developed in 1958 in the Viola

Table 8. Perlite deposits in Lincoln County.

Name	Location Sec.	T.	R.	Miles from railroad	Geologic setting	Reserves, remarks, and references
Eccles and Minto	7, 8, 17	4 S.	68 E.	¼	Two adjacent deposits are probably parts of a single flat-lying mass which overlies a rhyolite flow. Minto deposit is 60 ft thick and Eccles deposit is 150 ft thick.	28,921,000 tons. Cochran (1951, p. 8-9).
Acoma (Pulcepher and Comstock)	22, 23	5 S.	70 E.	6	Deposit lies on and partly under a dark reddish andesite. Contains both "onion skin" and "sugar loaf" perlite. Deposit is over 5,000 ft long, 2,600 ft wide, and 30 ft thick.	50,550,000 tons. Cochran (1951, p. 9).
Boykin	-------	-------	-------	7-8	Probable extension of Acoma deposit.	10,000,000 tons. Cochran (1951, p. 9).
Hollinger	3, 10	3 N.	68 E.	18	Granular perlite occurs between two glassy flows and grades upward into stony lava. Deposit is 40-80 ft thick.	Original reserve of readily mineable perlite was 9,000,000 tons. Over 250,000 tons have been produced by open pit mining. Cochran (1951, p. 10).
Fairview	28	4 N.	65 E.	26	----------	Estimated reserve is 6,038,400 tons of which over 1,000,000 tons are readily mineable; 5,000 tons have been mined. Other deposits occur nearby. Cochran (1951, p. 13).
Delamar (Kopenite)	34, 27	4 S.	62 E.	35	Large, flat-lying, 20-ft thick perlite flow with obsidian pellets ("Apache tears"). Deposit is 8,500 ft long, 800 ft wide, and 20 ft thick.	15,460,000 tons. Several thousand tons have been mined by underground methods. Cochran (1951, p. 13-14).
Robb (Kane Springs)	28(?)	6 S.	65 E.	14	Flat-lying perlite flow exposed over area measuring 3,000 ft by 3,000 ft. Maximum thickness is 75 ft; average thickness is 25 ft.	At least 24,000,000 tons of which 2,400,000 tons could be open pit mined cheaply. Cochran (1951, p. 14-15).
Free	5. 6	2 N.	69 E.	14	Flat-lying flow of light-gray "onion skin" perlite lying on and partly capped by dacite flow. Deposit is 800 ft long by 300 ft wide by 25 ft thick.	1,450,000 tons. Cochran (1951, p. 15).
Johnson & Fitchett	27, 28, 29, 33, 34, 35	8 S.	66 E.	12	Lenticular inclusions of perlite 4 to 50 ft thick occur between flows that dip as much as 80°. Individual deposits contain only a few thousand tons of mineable perlite.	1,000,000 tons of measured reserves and 3,680,000 tons of indicated reserves. Cochran (1951, p. 15-16).
Leech	16, 21	3 N.	68 E.	23	Flat-lying deposit is 600 ft long, 500 ft wide, and 50 ft thick. Perlite is "onion skin" type and fairly free of contaminating material.	1,725,000 tons. Cochran (1951, p. 17).
Snow	23	1 N.	70 E.	10-13	Two deposits 3 miles apart. Smaller deposit is part of a dacite flow and is 1,320 ft long, 600 ft wide, and 50 ft thick. Larger deposit is a granular perlite flow 2,640 ft long, 1,320 ft wide, and 100 ft thick.	29,615,000 tons. Cochran (1951, p. 17-18).
Grant deposit		4.5 miles from Caliente			May be same as Eccles deposit.	14,000,000 tons.
Blue Ridge (J. O. Davis)	2	2 S.	70 E.	8	Perlite with "Apache tears" on top of water-laid tuff and under platy rhyolite tuff.	----------

district. We did not visit this mine, but it is reported to contain high-grade fluorspar in limestone that has been replaced by jasperoid. The mine produced about 11,000 tons of 70 percent CaF_2 in 1958.

Several small fluorspar deposits were found in the southern end of the Quinn Canyon Range, in the extreme northwest corner of Lincoln County. These deposits are in jasperoid and along fissures in andesitic volcanic rocks. The Quinn Canyon deposits in adjacent Nye County have been explored by core drilling and trenching but they have not been developed. By-product fluorspar has been recovered from the tungsten deposits in the Tem Piute district.

Alunite

The alunite resources of Lincoln County have not been extensively exploited. The only production has been from a deposit in altered volcanic rocks on the east wall of Meadow Valley Wash (Rainbow Canyon) near Boyd. Here a nearly vertical 8-foot-wide lens of massive pink and white alunite crops out for about 100 feet (Callaghan, *in* Hewett and others, 1936, p. 146). The deposit contains about 4.58 percent K_2O or about 38.5 percent alunite. The only recorded production is three carloads shipped for fertilizer.

Clay

The only deposits of clay that have been mined in Lincoln County are near Boyd and near Panaca (below). The American Clay Co. deposit is 1.5 miles north of Boyd on the east wall of Rainbow Canyon about 1,100 feet higher than the railroad. A 25-foot-thick lens of hard white hydrothermally altered rhyolite was mined between 1920 and 1930. According to Callaghan (*in* Hewett and others, 1936, p. 174-175), who published a map of the deposit, about 800,000 cubic feet remain.

Combined Metals Reduction Co. owns a deposit of nonswelling montmorillonite on the east side of the West Range. This deposit is in hydrothermally altered volcanic rocks beneath a thrust(?) plate of Devonian rocks.

Several other clay prospects have been examined by the U.S. Bureau of Mines, but they were not visited by us and their exact location is not known. The Buckhorn kaolinite prospect is in T. 9 S., R. 69 E. on the east flank of the Mormon Range in altered crushed limestone between an andesite dike and marble. The rock in the upper 10 feet of an 80-foot shaft is kaolinized. The Bruce high-alumina clay claims are reported to be 15 miles southeast of Carp. The clay is reported to contain as much as 39 percent alumina and to crop out intermittently for 1,000 feet. Both of these prospects were examined by the U.S. Bureau of Mines during World War II.

Diatomite

Diatomite probably is widely distributed in the intravolcanic sedimentary rocks and in the lake beds, but the only deposit that has been developed is in the Panaca Formation a mile east of Panaca in sec. 10, T. 2 S., R. 68 E. Here a bed of diatomite 6 to 10 feet thick crops out beneath 22 to 40 feet of overburden for 2,300 feet along the strike. About 2 million cubic feet is estimated to be suitable for use as a sound or heat insulator or adsorbent (Callaghan, *in* Hewett and others, 1936, p. 180-181). The deposit has been developed by Morgan and Bush, Inc., who in 1959 had a small plant in Panaca. The total production from this deposit is not known, but 512 tons of rock worth $15.39 per ton were shipped in 1952.

Volcanic Ash

Two beds of volcanic ash, each about 8 to 9 feet thick, are exposed in the Panaca Formation in the southwest corner of sec. 19, T. 1 S., R. 68 E., west of the north end of Cathedral Gorge State Park. About 5 million cubic feet of material containing 68 to 73 percent silica, up to 12 percent alumina, and less than 1 or 2 percent iron (Callaghan, *in* Hewett and others, 1936, p. 178-180) are exposed here. Forty carloads of this ash are reported to have been shipped in the 1920's, but its use is unknown.

Vermiculite

A vermiculite prospect has been located on the west flank of the Mormon Mountains, about 3.3 miles east of Meadow Valley Wash and about three-fourths of a mile south of the north end of the Precambrian outcrop. The prospect is on a 30- to 40-foot-thick layer of altered biotite schist between two minor pegmatite dikes in the Precambrian rocks.

Gypsum

Gypsum is widely distributed in the rocks of Permian Age in the southeast corner of Lincoln County. Beds of gypsum occur just above and below the limestone cliff-former of the Toroweap Formation. Gypsum of doubtful commercial quality locally occurs near the top of the Permian red beds and at the base of the Moenkopi Formation, but the best gypsum, sometimes 50 feet thick, is in most places between the cliffs formed by the Toroweap Formation and the Kaibab Limestone.

The gypsum deposits in Lincoln County were extensively prospected between 1955 and 1957, but none had been brought into production by 1960. The best deposits are west of Galt, in the Cherokee district, and in the northern part of the Tule Springs Hills.

Jones and Stone (1920, p. 158-159) stated that the gypsum deposit west of Galt (in the Permian red-bed unit) is about 2,600 feet long and 1,000 feet wide. The individ-

ual gypsum beds dip about 60° NW. and range in thickness from a few inches to 20 feet, so only about 15 percent of the deposit could be utilized.

Barite

Commercial deposits of barite are not known in Lincoln County, but barite occurs in veins in the Chief, Delamar, Atlanta, and Silver Park districts, and in the Salt Lake-Pioche mine in the Pioche district. A barite vein, heavily stained with hematite, cuts Precambrian rocks near Gourd Spring in the East Mormon Range.

Stone Products

The largest operating quarry in Lincoln County is the quartzite quarry in a canyon about a mile north of Caliente. This quarry is served by a railroad spur of the Union Pacific Railroad; it produces railroad ballast for the railroad and aggregate for contractors working on local construction projects. The uppermost part of the Prospect Mountain Quartzite is quarried here.

Small quantities of marble from the contact aureole of the Blind Mountain stock in the Bristol Range have been quarried for local use as building stone. Silicified volcanic rock has been shipped in small quantities from the Stewart quarry in the east foothills of the Quinn Canyon Range for use as ornamental building stone and aquarium stone. Some platy Upper Cambrian limestone has also been quarried for this same purpose from the northwest edge of the Groom Range. Similar rocks elsewhere are too inaccessible to be of commercial importance.

DISTRICT DESCRIPTIONS

Pioche (Ely) District

(Zinc, lead, silver, manganese)

Location

The Pioche (Ely) district is located in the Pioche Hills in the north-central part of Lincoln County. It is crossed by U.S. Highway 93 and is circled by a paved road. The district is served by a branch line of the Union Pacific Railroad, which connects with the main line at Caliente.

History and production

The Pioche district is by far the most important district in the county. The first claims were located in 1863, but the earliest production was in 1869. A stampede followed and large-scale production began the following year. In 1871 the county seat was moved to Pioche from Hiko, and by 1872 the population reached about 6,000. In 1873, Pioche, next to Virginia City, was the largest silver producer west of the Rocky Mountains. The first mining boom dwindled after 1876 and ended about 1879 after producing about $21 million, nearly all in silver. Subsequent periods of major production occurred between 1895 and 1901, 1912 and 1920, 1934 and 1953 (see table 9).

The center of production shifted from the silver or silver-lead workings in the quartzite in the first two periods of major activity, to the large low-grade manganese fluxing ores from the Prince and Virginia Louise mines in the third major period, and to the bedded replacement zinc-lead-silver deposits in the Pioche Shale in the last major period of activity. The production in this latest and greatest period of activity approached $100 million, the ore coming chiefly from the bedded replacement deposits in the Caselton ore channel and the Ely Valley mine. The total production from the district is about $133 million, but this figure includes an undetermined amount from the Highland and Bristol districts, and it may include ore shipped from other areas to the smelters at Pioche.

Geology

The geology has been studied by many geologists and will not be discussed in detail here. The reports of Westgate and Knopf (1932) and Young (1948) contain additional information. The detailed geologic map and cross sections of the district (pl. 4) are modified from Park and others (1958). Most of the geologic data given here are from unpublished data of C. F. Park, Paul Gemmill, and C. M. Tschanz.

The district is composed of complexly faulted Lower and Middle Cambrian rocks. The Prospect Mountain Quartzite, Pioche Shale, Lyndon Limestone, Chisholm Shale, and the lower eight units of the Highland Peak Formation crop out. These rocks are intruded by a few altered porphyry dikes and sills, one of which, the Yuba dike, contains ore. The district is bounded by major northeast-trending normal frontal faults on each flank of the Pioche Hills.

The Pioche Hills probably are a window in a regional thrust plate of Upper Cambrian rocks that overrode older Cambrian rocks and Tertiary volcanic rocks. The thrust fault presumably underlies the Upper Cambrian rocks on the west side of the Highland Range and on Arizona Peak (pl. 2). The only remnant in the Pioche Hills is a small fault block near Mount Ely that is too small to show on the map (pl. 4).

Beneath the valley fill, a megabreccia composed of slices and blocks of Tertiary volcanic rocks and Cambrian limestone has been found by drilling in the hanging wall of the frontal faults to extend to depths at least as great as 1,000 feet. It overlies volcanic rocks that continue to depths of more than 2,500 feet west of Caselton (pl. 4)

Table 9. Production of the Pioche and Highland districts, 1869-1958.

(0, no production; e, estimate; — —, no data)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value Au-Ag-Cu-Pb-Zn	Manganese ore (tons)	Manganese value	Total value
1958	81	27,573	1,600	180,800	3,800	$ 51,100 e	0	$ 0	$ 51,100
1957	597	140,913	60,800	2,526,200	9,475,600	1,627,100	0	0	1,627,100
1956	1,128	180,347	92,600	3,344,500	10,742,200	2,238,800	— —	— —	2,238,800
1955	433	48,427	33,500	1,047,300	3,374,700	642,600	— —	— —	642,600
1954	876	79,313	27,400	1,685,800	1,263,200	477,900	— —	— —	477,900
1953	3,287	317,628	95,100	6,712,800	10,756,000	2,534,800	— —	— —	2,534,800
1952	3,728	425,475	270,100	9,263,400	24,985,600	6,219,900	400	5,200	6,225,100
1951	3,540	415,622	226,800	9,502,800	28,700,900	7,422,500	— —	— —	7,422,200
1950	4,607	608,710	420,300	13,522,900	39,310,000	8,207,200	0	0	8,207,200
1949	5,537	708,216	437,300	13,260,700	37,301,600	7,641,500	0	0	7,641,500
1948	4,508	684,321	540,900	11,225,900	37,223,100	7,854,600	0	0	7,854,600
1947	3,703	426,229	8,300	6,973,000	28,723,200	4,996,700	0	0	4,996,700
1946	3,176	403,358	3,900	6,986,700	31,528,000	5,045,200	0	0	5,045,700
1945	2,552	350,529	3,000	5,974,000	53,149,000	4,664,700	0	0	4,664,700
1944	3,235	444,309	13,600	8,111,000	35,966,900	5,180,100	0	0	5,180,100
1943	2,360	408,721	10,700	5,884,200	23,982,100	3,406,000	0	0	3,406,000
1942	2,047	487,253	4,600	5,528,300	17,914,200	2,455,100	0	0	2,455,100
1941	3,614	929,884	34,200	13,644,900	28,782,000	3,728,200	0	0	3,728,200
1940	3,119	633,638	6,500	11,039,400	21,546,000	2,469,900	0	0	2,469,900
1939	1,406	354,432	4,400	5,928,700	11,474,000	1,165,500	0	0	1,165,500
1938	1,849	372,661	5,100	6,428,600	16,828,000	1,409,600	0	0	[1]1,609,000
1937	3,015	683,505	4,800	9,518,000	24,944,000	2,817,700	0	0	[1]3,303,100
1936	3,378	644,045	5,700	9,412,100	24,094,000	2,255,200	0	0	2,255,200
1935	4,382	554,516	9,200	9,910,300	24,366,100	2,021,200	0	0	2,021,200
1934	3,047	495,875	3,600	9,288,100	22,392,700	1,733,900	0	0	1,733,900
1933	415	170,976	22,800	6,760,000	17,901,000	[2]1,073,900	0	0	1,073,900
1932	142	17,334	2,000	147,900	— —	[2]12,700	0	0	12,700
1931	— —	— —	— —	5,784,000	1,341,600	831,000	0	0	831,000
1930	— —	— —	— —	9,736,000	22,172,000	1,763,000	0	0	1,763,000
1929	22,760	347,008	12,500	5,973,000	12,995,000	1,443,900	0	0	1,443,900
1928	10,542	165,934	73,100	2,333,200	5,370,200	581,000	0	0	581,000
1927	— —	— —	— —	1,278,000	2,438,000	298,000?	— —	— —	298,000
1926	17,047	290,761	70,100	4,840,300	7,517,000	1,159,300	11,100	15,500	1,174,800
1925	26,264	350,825	118,000	5,611,300	8,038,700	1,385,600	16,200	21,000	1,406,600
1924	63,651	394,919	123,100	4,303,400	3,074,800	888,500	16,700	72,000	960,500
1923	82,005	543,115	92,300	5,393,900	2,756,100	1,105,900	28,600	96,000	1,201,900
1922	45,829	230,034	44,600	1,863,700	— —	384,400	0	0	384,900
1921	— —	— —	— —	1,332,000	0	500,000 e	14,900	37,300	537,300
1920	20,005	333,382	122,600	6,614,300	— —	935,100	95,100	286,400	1,559,800
1919	25,523	366,634	8,300	6,917,100	78,200	810,000	84,000	193,300	1,003,300
1918	21,257	353,309	18,200	7,334,400	567,000	951,400	80,100	109,300	1,060,700
1917	41,989	450,517	40,200	9,099,600	1,332,500	1,342,700	122,900	142,500	1,485,200
1916	30,978	457,069	79,100	8,553,700	2,002,100	1,209,800	122,400	320,700 e	1,530,500
1915	39,159	454,382	295,700	7,523,900	2,579,700	[3]994,800	119,000	312,400 e	1,307,200
1914	41,752	406,927	660,600	5,983,300	1,104,600	[3]644,300	0	0	[1]657,000
1913	54,375	471,958	647,300	7,689,800	47,000	[3]780,900	0	0	780,900
1912	137,251	750,229	457,100	10,741,500	68,100	[3]1,162,100	0	0	1,162,100
1911	5,953	174,271	17,400	455,500	— —	[3]121,000	0	0	121,000
1910	18,663	49,057	7,700	935,300	— —	[3]87,300	0	0	87,300
1909	21,575	182,923	173,400	1,495,300	— —	[3]203,500	0	0	[1]210,500
1908	12,643	101,905	274,700	1,066,200	— —	[3]195,600	0	0	[1]80,600
Totals 1908-1958	808,983	17,888,699	5,698,400	316,667,000	640,210,500	$109,131,400	711,400	$1,611,600	$111,672,800

1907	493	22,450	114,000	56,800	13,600	[3]41,900				[1]183,000
1906	890	37,649	442,500	284,000		127,700				[1]172,500
1905	—	7,694	—	—	—	4,600				4,600
1901-1904[4]	—	—	—	—	—	0				0
1894-1899	—	—	—	—	—	—				[1]143,700
1890-1893	—	—	—	—	—	—				[1]655,700
1884-1889	—	—	—	—	—	—				[1]129,600
1880-1883	—	—	—	—	—	—				[1]567,000
1876-1879	—	—	—	—	—	—				[2]2,127,200
1875	—	—	—	—	—	[5]1,050,200				1,050,200
1874	—	—	—	—	—	[5]1,901,200				1,901,200
1873	—	—	—	—	—	[5]3,722,000				3,722,000
1872	—	—	—	—	—	[5]5,364,000				[5]5,462,600
1871	—	—	—	—	—	[5]3,318,900				[1]3,592,200
1870	—	—	—	—	—	[5]644,700				[1]1,629,300
1869	—	—	—	—	—	—				[1]2,800
Grand totals[6]	810,366	17,956,492	6,254,900	317,007,800	640,224,100	$125,306,600	711,400	$1,611,600		$133,016,400

1. Couch and Carpenter (1943).
2. Total value calculated from average metal price and quantities reported.
3. Includes production from Bristol district.
4. Nolan (in Hewett and others, 1936, p. 64-65) gives the recorded production between 1902 and 1932 as follows: 1,603,353 tons of ore containing 3,877,800 oz Au, 8,163,200 oz Ag, 4,023,900 lb Cu, 123,583,300 lb Pb, 86,510,100 lb Zn, with a total value of $20,294,400.
5. Pack (1906) in Lincoln (1923, p. 125; chiefly silver but includes some gold and unimportant amount of lead.
6. Total metal production from the Caselton ore channel calculated from the tonnage and average assay as reported by the company was: 143,000 oz Au, 15,795,000 oz Ag, 291,200,000 lb Pb, and 952,900,000 lb Zn. The zinc figure is large compared to recorded figures and must reflect poor recovery.

— a depth that precludes the existence of ore within a mineable distance of the surface. The megabreccia that surrounds the productive part of the district is known only from drill-hole data. It is either a thrust breccia, a chaotic sedimentary megabreccia, or a megabreccia produced by gravity sliding. Small dikes or dikelike masses of volcanic rocks with the microscopic characteristics of welded tuff occur in the Abe Lincoln mine and on the flanks of the highest peak. These are believed to be downfaulted remnants of blocks dragged beneath a postvolcanic thrust plate. This — the Highland Peak thrust plate — has since been eroded or else it has slid off the flanks of the range to form the megabreccia.

Minor bedding or thrust faults occur in the limestones above the Pioche Shale as shown on plate 2. These are presumably subsidiary drag planes beneath the inferred major overthrust. The principal movement has occurred along the Pioche Shale in the eastern part of the district. Minor thrusts have cut out the Chisholm Shale in places and grealy thinned several of the lower units in the Highland Peak.

The Cambrian rocks are offset by a series of closely spaced normal faults that successively drop the Pioche Shale from the surface on each flank of the range to a point in the center of the range below the 1,400-foot level of the Caselton shaft section (A-A′, pl. 4). The principal ore horizon is the Combined Metals Member (CM bed). It is almost continuously replaced across these normal faults between Caselton and Pioche (the Caselton ore channel) as shown by the outline of these replacement ore bodies on plate 4.

Ore Deposits

The principal ore deposits of the Pioche district are in fissure veins, largely in the Prospect Mountain Quartzite on Treasure Hill near Pioche, and in replacement deposits in limestone within and above the Pioche Shale.

The rich silver ore mined in the 1870's occurred in three main fissures in the quartzite, all of which trend nearly east-west. The early production was obtained from oxidized silver ore shoots that extended almost continuously for several thousand feet along the strike and were mined to a depth of 1,200 feet (fig. 21). The most productive vein system, the Raymond and Ely vein, splits eastward into two branches, the Meadow Valley vein and the Burke vein (pl. 4). A third large vein follows the Yuba dike, a sericitized quartz porphyry dike, that diverges eastward from the Raymond and Ely and the Meadow Valley veins. The veins are generally 1 to 4 feet thick, but they swell to 7 or even 10 feet. The largest and richest ore shoot was blind and occurred in the Raymond and Ely vein just below the Pioche Shale (fig. 21) within about 400 feet of the Yuba dike. The veins and the Yuba

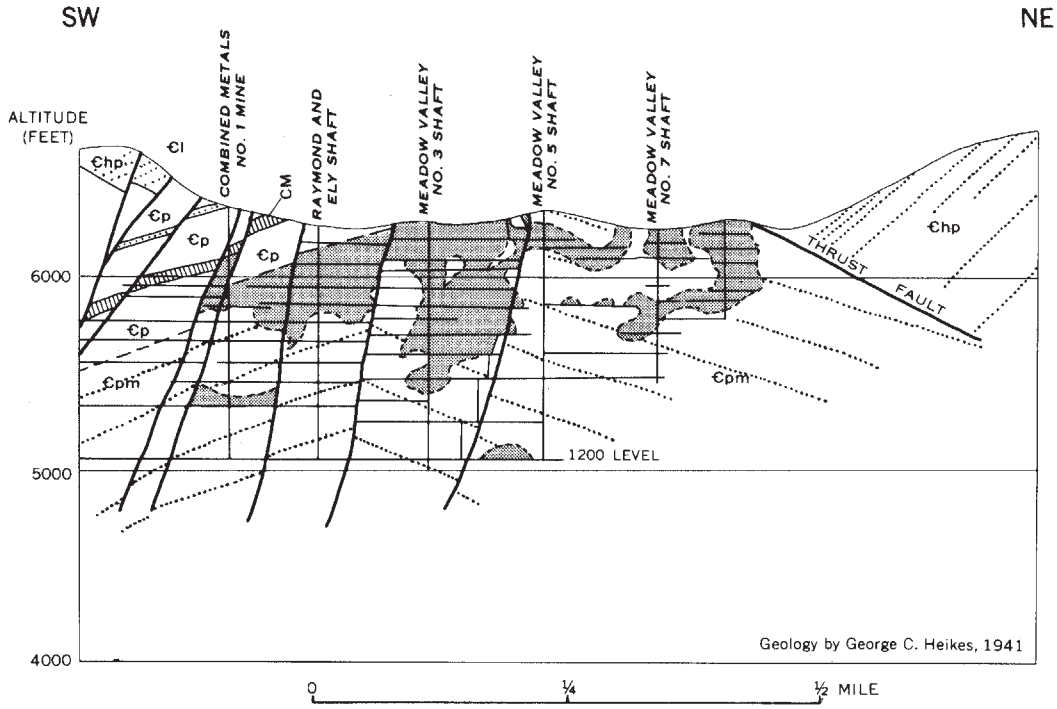


FIGURE 21. Vertical projection along a N. 75° E. line showing the silver ore bodies in the Raymond and Ely and the Meadow Valley vein systems. Ꞓpm, Prospect Mountain Quartzite; Ꞓp, Pioche Shale; CM, Combined Metals Member of Pioche Shale; Ꞓl, Lyndon Limestone; Ꞓhp, Highland Peak Formation.

dike converge westward and with depth. The ore was oxidized and the richer ore contained 75 to 150 ounces of silver per ton, chiefly as the chloride. The lead content generally ranged from 11 to 20 percent. The Raymond and Ely vein pinches out in the Pioche Shale, but ore occurs in the Greenwood vein in the Pioche Shale nearby. The latter vein contains high-grade lead-silver sulfide ore as far as 65 feet above and 130 feet below the Combined Metals Member. The Greenwood vein is a probable feeder for the bedded replacement ore bodies described below.

The bedded replacement deposits in the Pioche Shale, which have produced approximately 4,000,000 tons of ore, occur principally in the Combined Metals Member (fig. 5) within the Caselton ore channel between Pioche and Caselton, and in the Combined Metals Member and Susan Duster bed in the Ely Valley mine.

The Caselton ore channel is continuously mineralized for 9,000 feet, although it is cut by many major faults (section A-A′, pl. 4). These faults are both pre-ore and post-ore, but most are post-thrust. Between 1924 and 1952, the Caselton ore channel yielded 2,458,000 dry tons of ore from 123,458 feet of development workings. All told, about 3,250,000 tons of ore worth about $43,600,000 have been produced from the Combined Metals Member in the Caselton ore channel. The average metal content per ton of much of this ore was 0.044 ounce gold, 4.86 ounces silver, 4.48 percent lead, and 11.96 percent zinc.

The bedded replacement ore in the Ely Valley mine is similar, except that the lead content is about 1 percent and the zinc content about 10 percent. The sulfide ore contains pyrite, sphalerite, galena, manganoan siderite, and quartz. The oxidized material cannot usually be economically mined, but large reserves remain of low-grade argentiferous manganese oxide which contains a little lead and a very small amount of zinc. The sulfide bedded replacement ores have been largely mined out and mining activity was at a low ebb in 1960. In 1958 and 1959, the YZ mine on Treasure Hill was the main producing mine in the district. This mine operates through the No. 1 shaft and produces ore from silver veins in the quartzite.

Argentiferous manganese fluxing ore in the Pioche district came chiefly from open pits in the Lyndon Limestone and the lowest limestone (Peasley Member) in the Highland Peak Formation. Principal production was from the Prince mine and the adjoining property, the Virginia Louise mine. Between 1915 and 1927 these mines produced about 1,100,000 tons of manganiferous fluxing ore, which had a gross value of over $8,700,000. The average assay of these oxidized ores was 0.01 ounce gold, 2.7 ounces silver, 3 percent lead, 3.5 percent zinc, 31.5 percent iron, and 12.5 percent manganese. Considerable manganese ore was mined between 1952 and 1957, but large-

scale attempts to concentrate and process low-grade manganiferous protore at a plant erected by Pioche Manganese Co. at Caselton were unsuccessful. A large tonnage remains unmined because it is no longer in demand for use as a smelter flux.

The known sulfide ores of the district are largely worked out, and attempts to develop new reserves by drilling have thus far been unsuccessful. One chance, however, to develop major new sulfide reserves might be through exploration in the hanging wall of the No. 2 fault at the Ely Valley mine. This fault offsets the ore body an unknown distance. Exploration here is a calculated risk because: the ore body may be too small or too deep to be economic, too much water might prevent profitable operation, thrust faulting may have removed the limestone beds, and the area may be occupied by granodiorite or by a megabreccia composed of limestone and volcanic rocks. However, the potential reserves may be on the order of magnitude of 1,000,000 tons of ore containing 10 percent zinc. Exploration of a similar situation west of Caselton by drilling was unsuccessful because, even if present and mineralized, the beds are too deep. Drilling southeast of Pioche was also unsuccessful.

Data on the principal mines or groups of mines are summarized in table 10. Additional information is given in the sources cited in the last column.

Bristol and Jackrabbit Districts

(Silver, copper, lead, zinc, manganese)

Location

The Bristol district is on the west side of the north end of the Bristol Range a few miles west of U.S. Highway 93 and about 16 miles north-northwest of Pioche. The Jackrabbit district is on the east side of the range about 2 miles northeast of the Bristol district.

History and production

The Bristol district was organized April 10, 1871, but the ore deposits were discovered in the late sixties when this region was prospected shortly after the discovery of ore near Pioche in 1863 (Hill, 1916, p. 127). A smelter was built at Bristol Well in the late seventies, and later, a 5-stamp mill was built there. The Jackrabbit district was organized in 1876, but the two districts are not now considered separately.

The Hillside mine ore body was discovered in 1877 and is credited with a production of $2,000,000 between 1878 and 1906, compared to a total of about $1,000,000 from the May Day, Tempest, Gypsy, National, Vesuvius, and Great Eastern mines during the same period (Mining World, 1942, p. 8-9). All these mines are now part of Bristol Silver Mines, Inc. (pl. 5) and referred to as the Bristol Silver mine.

The Black Metals (Jackrabbit, Day) mine, which opened at least as early as 1880, is estimated to have produced $2,500,000 prior to 1906. These production figures are very much larger than the figures recorded in the Lincoln County courthouse (Couch and Carpenter, 1943, p. 86-87) which show a total production through 1940 of only $4,821,876, including the Hillside production incorrectly assigned to the Pioche district. This figure is much too small when compared with the total production through 1940 of $7,434,500 for the mines now owned by Bristol Silver Mines, Inc. (Mining World, 1942, p. 7-9). The estimated total production for the district between 1868 and 1958 is about $16,256,000 as shown in table 11.

In 1956 a major oxidized ore body was discovered in the upper levels of the Bristol Silver mine. Production from this ore body totaled more than $2,500,000 in the next 3 years. In 1959 the smelter to which the ore had been shipped for many years could no longer process the ore, and large-scale operations ceased for lack of a market within an economic shipping distance.

A major exploration drift on the 1,200 level, driven several thousand feet east of the productive part of the mine between 1952 and 1956, did not reveal any ore. This exploration project was financed equally by the mine and the Defense Minerals Exploration Administration. Ultimately, however, the drift may be extended through to the east flank. This may permit pumping costs to be reduced sufficiently to permit the ore below the water table (the 1,700 level) to be mined.

Geology

The geologic map of the Bristol and Jackrabbit districts by Westgate and Knopf (1932) was included in the county map with minor modifications. The Bristol Silver mine area was mapped in greater detail in 1941 by a group of students from the Mackay School of Mines of the University of Nevada under the direction of H. E. Wheeler and F. B. Roberts. This group concluded that the thrust plate in the Bristol Range was composed of Eureka Quartzite and Ely Springs Dolomite instead of Silverhorn Dolomite. We have followed Westgate because there is no fossil evidence, but perhaps the identification of these rocks should be considered questionable. Still more recently (1956 and 1959), R. A. MacDiarmid mapped the Bristol Silver mine area, and a geologic map was compiled from his map and Westgate's (pl. 5).

The Bristol and Jackrabbit districts are in faulted Cambrian rocks that are overridden by a thrust plate of Devonian rocks (dolomite facies of the Guilmette Formation). The Cambrian rocks include the Pioche Shale, the Lyndon Limestone, and limestone of the Highland Peak Formation. The Highland Peak contains nearly all the ore deposits. The thrust plate is part of the Bristol

Table 10. Principal mines of the Pioche district.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Caselton (No. 2 mine of Combined Metals Reduction Co.)	27, 28	1 N.	67 E.	Zn, Pb, Ag	The lower part of the Combined Metals Member of the Pioche Shale is replaced by sphalerite-pyrite-galena ore. Ore ranges in thickness from 4 to 40 ft and averages 6 ft thick. Ore bed is faulted in many places but was mined for over 10,000 ft along an east-west channel which was 100 to 1,800 ft wide. Channel is parallel to the principal vein system in the underlying quartzite and to two sericitized granite(?) porphyry dikes. Ore was mined in fault blocks from the 300- to the 1,400-ft level. The ore body terminates against the frontal fault, the hanging wall of which has been unsuccessfully explored to a depth of 2,500 ft without penetrating Tertiary volcanic rocks.	Approximately 3¼ million tons of sulfide ore with a gross value of approximately $43 million were mined between the Caselton and No. 1 shafts. The average metal content was 5 oz Ag per ton, 4.5 percent Pb, and 12 percent Zn. Sulfide ore reserves now largely exhausted, but large quantity of oxidized low-grade protore remains in upper levels in west end of mine. Westgate and Knopf (1932); C. F. Park, Paul Gemmill, and C. M. Tschanz (unpublished data, 1960).
Ely Valley	17	1 N.	67 E.	Zn	Sulfide ore containing 8-10 percent Zn and little Pb was mined from the Combined Metals Member and Susan Duster limestone bed in the Pioche Shale. Oxidized material with about 15 percent Mn and $5 in Ag and Au replaces higher limestone beds in the Pioche Shale and the Lyndon Limestone. The ore occurs in a block between two parallel faults. The ore body in the Combined Metals Member is 20-50 ft thick, about 400 ft wide, and 1,400 ft long. The known sulfide ore reserves are exhausted and the supporting pillars were mined. Favorable ground that contains the offset portion of the ore body in the hanging wall of the frontal fault has not been adequately explored.	Total value of production is estimated to exceed $9,000,000. Production is probably about 750,000 tons of sulfide ore with 10 percent Zn and less than 1 percent Pb. C. S. Bacon and L. C. Craig (written communication, 1944); C. F. Park, Paul Gemmill and C. M. Tschanz (unpublished data, 1960).
Prince-Virginia Louise-Davidson (Prince Consolidated Mining Co.)	33	1 N	67 E.	Mn, Ag, Pb	The principal ore deposits are irregular replacement bodies that occur in seven layers in a stratigraphic interval of over 1,200 ft: the Peasley Member of the Highland Peak; the Lyndon Limestone; and five limestones in the Pioche Shale. These deposits are chiefly oxidized manganiferous fluxing ores that contain about 12 percent Mn, 31 percent Fe, 3-4 percent Zn, 3 percent Pb, and 3 oz Ag per ton. High-grade lead-silver ore has been mined from two quartz veins and an irregular siliceous replacement body in the Virginia Louise workings. This ore contains 10-25 percent Pb and as much as 35 oz Ag and $2.50 Au per ton. Diamond drilling shows the presence of siliceous ore with 10 percent Zn at the contact between Pioche Shale and Prospect Mountain Quartzite.	Total production was 1,226,000 tons of ore with average grade of 3 oz Ag and 0.03 oz Au per ton, 3 percent Pb, 4 percent Zn, and 12 percent Mn. Gross production value in 1943 was $359,600 (Mining World, 1944, v. 6, no. 7, p. 14, 35) and that in 1945 was $255,100. Production of oxidized fluxing ore between 1915 and 1927 totals 1,040,000 tons with a gross value of $8,700,000. More than 20,000 tons of fissure ore with a gross value of over $200,000 have been mined. Total production estimated to be $9,650,000. Much oxidized material remains unmined. Zalinski (1913); Jessup (1913).
No. 1 (Combined Metals Reduction Co., Raymond and Ely No. 1)	27	1 N.	67 E.	Ag, Pb, Zn	Bedded replacement deposits in the Combined Metals Member for an average of 200 ft on either side of the Greenwood fissure. Ore contained 10-20 percent Zn, 6-8 percent Pb, and 6-8.5 oz Ag and 0.04 oz Au per ton. Raymond and Ely	More than $10 million worth of silver ore was mined from the Raymond and Ely vein in the early days. Millions more have been produced from the Greenwood fissure and the bedded replacement ores, but exact total production is

					vein, mined in the 1870's, contained high-grade silver-lead ore in the Prospect Mountain Quartzite, but the Greenwood ore was mostly in the Pioche Shale. The Black Ledge, a quartz-sphalerite vein that contains 12-20 percent Zn and 5-21 oz Ag per ton, was mined between the 1,200 and 1,500 level. Area is completely faulted.	unknown. Between May, 1924, and September, 1926, some 112,000 tons, with a settlement value of roughly $1,500,000, were mined, largely from the No. 1 mine. Combined Metals Reduction Co. produced 510,200 tons of ore between 1917 and 1940, worth $10,251,000 Couch and Carpenter (1943, p. 87). Westgate and Knopf (1932, p. 53-56).
Golden Eagle	33	1 N.	67 E.	Ag, Pb, Zn	Oxidized ore occurs at 8 layers in the lower part of the Highland Peak Formation and the Pioche Shale. Sulfides occur in both the Susan Duster bed and the Combined Metals Member. The rocks are complexly faulted and are cut by an altered granite(?) porphyry dike.	Sixty-three shipments of oxidized ore are reported to have had the following average metal content: 0.19 oz Au and 3.4 oz Ag per ton, 1.8 percent Pb, 1.9 percent Zn, 17.0 percent Fe, and 7 percent Mn. The sulfide ore resembles that in the Caselton and Prince mines.
Susan Duster	27	1 N.	67 E.	Ag, Mn	Oxidized manganiferous bedding replacement deposits in the Combined Metals Member and Susan Duster limestone bed.	In 1952, 1,500 tons of oxidized manganese ore were mined from the Combined Metals Member on the surface. Some of the ore contains 13 oz Ag, 1 percent Pb, 2 percent Zn, and 17 percent Mn.
Raymond and Ely Extension	23	1 N.	67 E.	-------	Combined Metals Member is mineralized but no commercial ore has been discovered.	No recorded production.
Nevada Des Moines	22	1 N.	67 E.	-------	Two-compartment 400-ft vertical shaft in Pioche Shale did not cut ore, but ore was reported in drill hole 150 ft below bottom of shaft.	No production.
Andrews and Steever	26	1 N.	67 E.	Mn	Oxidized manganese ore in fault block of Combined Metals Member.	1,000 tons of 20-25 percent Mn ore shipped to Geneva Steel in 1952. Payment f.o.b. Pioche was $1 per unit. One car exceeded 0.7 percent Zn and was rejected.
Independence	5	1 S.	68 E.	Mn	Oxidized bedded replacement manganese ore from 14-ft limestone bed in Pioche Shale. Average assay was 20 percent Mn and 20 percent Fe.	Production unknown but small. 200-ft shaft.
Mines on veins in Prospect Mountain Quartzite on Treasure Hill. Includes Raymond and Ely, Newark, Meadow Valley, Washington and Creole, Burke, Mazeppa, Yuba or American Flag, Alps, Boston-Pioche, Poorman, and many others.	22, 23, 26, 27	1 N.	67 E.	Ag, Pb	Raymond and Ely, Meadow Valley, and Burke veins strike roughly east-west and dip 50° S. Oxidized silver ore in the quartzite decreased in grade eastward and downward. Meadow Valley vein was mined continuously for 2,000 ft to a depth of 1,200 ft. The average thickness of the ore was about 2 or 3 ft. Galena and sphalerite were increasingly abundant in the lower levels. Rich lead-silver ore was mined from the Yuba dike. Three or more cross veins strike northeast at about 45° to the principal veins.	The Raymond and Ely Mining Co. produced 148,800 tons of ore worth $10,253,100 between 1869 and 1881 and the Meadow Valley Mining Co. produced 88,600 tons worth $5,795,900. (Couch and Carpenter, 1943, p. 88). The Raymond and Ely Mining Co. produced bullion valued at $13,400,000 in its 8-year life while the Meadow Valley Mining Co. produced bullion worth $5,197,900 in the same time. C. F. Park, Paul Gemmill, and C. M. Tschanz (unpublished data, 1960). In 12 months ending August 1, 1872, the district shipped $5,151,200 in fine silver bullion, only $127,200 in base bullion, and $42,600 in gold. Raymond (1873).

Table 10. Principal mines of the Pioche district.—Continued.

Name	Location Sec.	T.	R.	Commodities	Geologic Setting	Production, remarks, and references
Daly East	26	1 N.	67 E.	Au	Gold-quartz vein 1 to 4.5 ft wide in Prospect Mountain Quartzite.	Twelve carloads shipped in 1934-1935 contained an average of 0.35 oz Au and 3 oz Ag per ton.
Wide Awake and Volcano (Stindt and Donahue)	26	1 N.	67 E.	Ag, Pb, Mn	Mineralized thrust breccia in Prospect Mountain Quartzite dips 20° SE. and contains as much as 1.5 ft of argentiferous lead carbonate.	About 500 tons of 20-25 percent Mn ore shipped in 1952. Two thousand tons of silver-lead ore shipped in 1919 valued at $120,000. Westgate and Knopf (1932). The main ore shoot was discovered in 1937. About 15,000 tons, with a net value of $415,500, were mined between 1937 and 1944. Total production estimated to be 17,000 tons of ore with gross value of $535,000.
Apex (Salt Lake Pioche)	26	1 N.	67 E.	Ag, Pb	Vein strikes N. 80° E. and dips 70° S. nearly parallel to other principal veins. Principal ore shoot is offset by fault. Ore contains cerargyrite, bromyrite(?), anglesite, galena, cerussite, copper carbonates, and oxidized zinc minerals.	Produced 14,500 tons of ore averaging 0.08 oz Au, 57.4 oz Ag, and 21.5 percent Pb per ton between 1938 and 1951. Produced about $14,000 in the first half of 1952. Total estimated production about $500,000. C. F. Park, Paul Gemmill and C. M. Tschanz (unpublished data, 1960).
Half Moon and Abe Lincoln	20	1 N.	67 E.	Pb, Ag	Quartz bedding vein up to 3 ft thick in the Chisholm Shale. Properties probably are on offset segments of the same(?) vein. Vein averages 1 ft thick and occurs at base of a 3-ft limestone which is largely replaced by manganese and iron oxide ore.	23,800 tons of sorted ore containing $9 in Au, 18 oz Ag, and 17 percent Pb per ton. Westgate and Knopf (1932, p. 67; Wiltsee (1893, p. 868). Total production is estimated to be $840,000 (using average metal price in 1893).
Chisholm, Blue Eagle, Whale and Old Times (Alliance)	20	1 N.	67 E.	Pb, Ag	Bedding vein less than 2 ft thick. May be an extension of Half Moon vein.	106 tons shipped in 1938 from Chisholm mine contained about 0.5 oz Au, 12 oz Ag, and 13 percent Pb per ton.
West End group (No. 10)	16	1 N.	67 E.	Au, Ag	Six-in banded quartz vein in the Pioche Shale.	200 tons reported to have assayed $6 in Au, 7 oz Ag, and about 6 percent Pb per ton. Westgate and Knopf (1932, p. 57-58).
Demijohn	20	1 N.	67 E.	Pb, Ag	Two-ft fissure strikes about N. 80° W. and dips 70° S. Contains oxidized Pb and Mn minerals. Four-ft vein averaged 22 percent Pb and 60 oz Ag per ton.	Large production reported prior to 1907. Salt Lake Mining Review (v. 9, no. 17, p. 40).
Zero tunnel	27	1 N.	67 E.	Mn	Oxidized Mn in limestone beds in Pioche Shale.	1,268 tons of 20 percent Mn produced through October 1952.

Table 11. Production of the Bristol and Jackrabbit districts, 1875-1958.
(e, estimate; — — no data)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Manganese ore (tons) [% Mn]	Total value
1958	324	240,153	3,169,500	250,700	1,500	— —	$ 1,091,800
1957	—	— —	— —	— —	— —	— —	701,500
1956	—	— —	— —	— —	— —	— —	723,500
1955	20	18,886	70,900	110,700	101,100	— —	73,200
1954	48	50,112	99,900	457,600	410,600	— —	183,500
1953	15	40,372	113,000	357,000	323,600	— —	153,500
1952	—	— —	— —	— —	— —	— —	110,500
1951	—	— —	— —	— —	— —	— —	182,400
1950	—	— —	— —	— —	— —	— —	235,300
1949	58	84,232	328,600	594,100	451,900	— —	292,900
1948	97	125,025	404,300	707,700	523,500	— —	400,600
1947	36	100,884	400,400	332,000	264,600	— —	256,500
1946	37	78,760	377,200	471,000	515,000	— —	240,200
1945	22	48,929	195,000	376,000	436,400	— —	144,400
1944	34	59,639	311,600	598,700	603,600	— —	202,400
1943	42	98,474	530,400	817,600	182,300	— —	221,600
1942	141	242,644	1,372,900	713,300	89,800	— —	399,700
1941	179	305,799	887,000	1,880,900	— —	— —	435,600
1940	118	119,052	664,900	430,500	— —	— —	185,400
1939	162	121,587	673,900	443,100	— —	— —	179,100
1938	222	210,482	1,116,300	888,700	— —	— —	294,100
1937	156	116,416	759,300	971,000	— —	— —	244,700
1936	—	— —	— —	— —	— —	— —	164,500
1935	200	163,923	331,900	1,698,583	— —	— —	220,300
1934	—	— —	— —	— —	— —	— —	139,500
1933	32	32,190	335,700	910,127	— —	— —	67,200
1932	8	5,693	22,400	28,002	— —	— —	4,100
1931	—	— —	— —	480,000	— —	— —	152,700
1930	—	— —	1,996,000	1,996,000	— —	— —	343,700
1929	—	— —	2,638,000	2,638,000	— —	25,000 [22]	792,100 e
1928	551	496,032	2,026,000	5,075,748	— —	— —	562,800
1927	—	— —	1,392,000	1,392,000	— —	2,400 [14]	318,400
1926	—	— —	— —	1,156,000	— —	11,800 [16]	197,200
1925	53	40,894	107,600	447,715	— —	6,700 [23]	118,400
1924	—	13,215	— —	204,000	— —	2,500 [30]	64,500 e
1923	—	— —	— —	1,072,000	— —	— —	132,700
1922	—	— —	— —	1,582,000	— —	— —	211,300
1921	260	189,558	335,900	1,732,548	— —	— —	316,100
1920	215	222,160	429,000	1,254,647	— —	— —	425,800
1919	87	74,242	106,600	100,738	— —	78 [42]	118,000
1918	95	48,921	410,900	76,373	14,800	204 [40]	163,200
1917	73	45,059	381,300	155,300	— —	— —	155,300
1916	156	73,694	711,800	253,529	— —	— —	244,200
1915	included with Pioche district			— —	— —	— —	43,400
1914	included with Pioche district			— —	— —	— —	30,100
1913	—	— —	— —	— —	— —	— —	164,400
1912	4	7,100	33,600	11,900	68,100	— —	95,900
1911	11	143,600	12,100	28,100	— —	— —	79,100
1910	—	1,000	6,600	— —	— —	— —	1,400
1909	14	12,900	162,800	86,200	— —	— —	31,800
1908	14	143,400	273,400	295,000	— —	— —	124,000
1907	11	15,600	103,800	13,600	— —	— —	32,100
1906	43	37,600	442,500	284,000	— —	— —	127,700
1905	included with Pioche district			— —	— —	— —	— —
1904	48	26,500	— —	100,000	— —	— —	20,000
Totals							
1904-1958[1,4]	3,586	3,854,700	23,734,900	33,463,778	3,986,800	48,682	$12,515,400
1901-1903	— —	— —	— —	— —	— —	— —	— —
1899-1900	— —	— —	— —	— —	— —	— —	[2]33,800
1875-1898	— —	— —	— —	— —	— —	— —	[2]1,002,300
1878-1919	— —	— —	— —	— —	— —	— —	[3]6,035,000
Grand total[4]							$17,209,300

1. Company records for Bristol mine show total production of 4,433,800 oz Ag, 22,722,100 lb Cu, 35,943,800 lb Pb, and 40,570,800 lb Zn between 1924 and 1955 inclusive.. Zinc was penalized and little or no return was received from it.
2. Couch and Carpenter (1943).
3. Company figure for 1879-1919.
4. Totals do not agree owing to incomplete data.

regional thrust plate (pl. 3) that apparently overrides Tertiary volcanic rocks in the West Range (Westgate and Knopf, 1932, p. 43).

A north-trending normal fault — the Iron Mine fault — which dips about 45° E., separates the productive part of the district in the Highland Peak Formation from the older Cambrian rocks on the west. The Iron Mine fault is offset eastward by the May Day fault along which many of the ore bodies were formed. Each of four sets of intersecting fissures contains oxidized ore of a different type. The principal fissures in each set are the May Day, which strikes N. 80° E. and dips 45° S.; the Tempest, which strikes N. 80° E. and dips 70°-80° S.; the Gypsy-National, which strikes north to N. 25° E. and dips 70°-80° E.; and the Lead-Zinc, which strikes north to N. 20° W. and has nearly vertical dips (Westgate and Knopf, 1932, p. 69).

Ore deposits

The ore deposits of the Bristol-Jackrabbit district are irregular, veinlike, or pipelike, replacement deposits that generally occur along the four fissure systems listed above. The biggest ore bodies were along the May Day fissure, where some extend almost continuously from the surface to the 1,700 level, a vertical distance of about 1,200 feet. Ore extends below the water table (altitude 5,790 feet), which is about 30 feet below the 1,700 level, but excessive pumping costs have so far prevented mining. The ore bodies of the district have a known stratigraphic range of about 3,000 feet (almost the full thickness of the Highland Peak Formation) in this area and a vertical range in altitude of about 2,200 feet, as shown in the cross section in figure 22. The lowest known ore is about 2,000 feet stratigraphically above the Combined Metals Member. About 70 percent of the ore has come from unit G of the Highland Peak Formation, which is locally called the Bristol limestone. Large amounts of ore were also produced from unit M, the so-called Hillside limestone. Ore may well replace limestones in the Pioche Shale just as in the Pioche district, but the economic value of such deep ore is doubtful. Ores in the Combined Metals Member would be 2,000 feet below the floor of Dry Lake Valley.

The highest ore body both stratigraphically and in altitude is the Hillside ore body near the crest of the Bristol Range (fig. 22). It occurs along a N. 60° E. fissure which dips steeply southward near the surface but flattens to an average of 40° in the lower levels. This ore shoot was about 120 feet long, 16 feet wide, and was mined to a depth of about 400 feet. It contained two distinct types of ore — a narrow band of oxidized lead-silver ore on the hanging wall separated by a limestone sliver from 6 to 10 feet wide of oxidized copper ore. The foregoing description is from Hill (1916, p. 134-135).

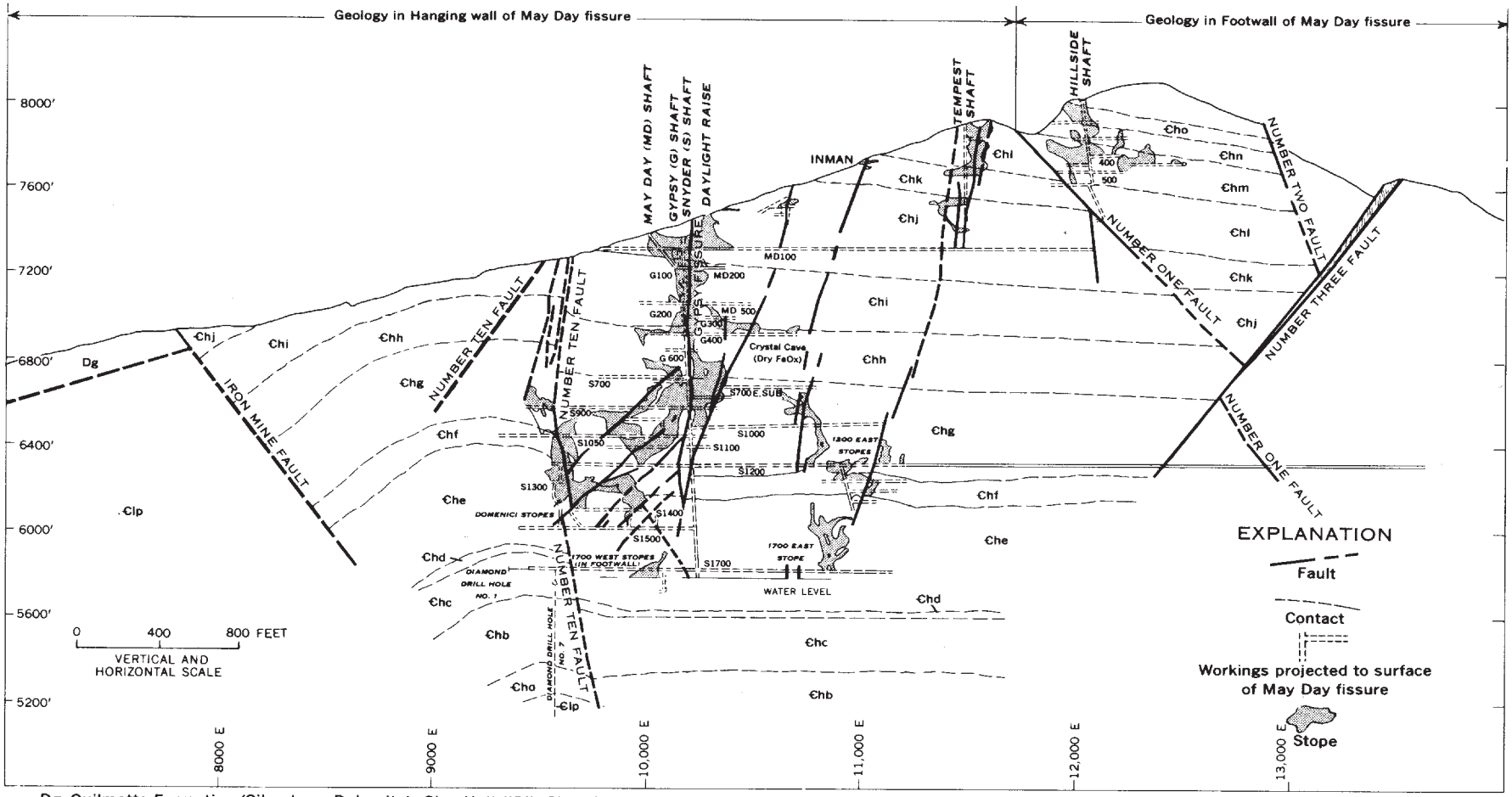
The May Day ore body increased from a length of 40 feet and a thickness of 6 feet or less at the outcrop to a length of 250 feet and a maximum thickness of 30 feet at a point 86 feet below the outcrop. Where the ore was widest it clearly replaced a breccia (Westgate and Knopf, 1932, p. 69). No other ore was found laterally along the May Day fissure, but an ore pipe extended continuously at depth along the intersection with the Gypsy fissure to the 1,200 level. Farther east ore occurs intermittently between the surface and the 1,700 level near the intersection of the Tempest and the May Day fissures. Farther west ore was mined between the 900 and 1,500 level between the No. 10 fault and the Gypsy fissure.

The Black Metals mine is the only important mine on the east side of the range. The ore body is a vertical pipe, concentrically zoned, from which bedded replacement deposits extend into the gently dipping limestones of the Highland Peak Formation at three horizons. The ore pipe occurs along a breccia zone about 25 feet wide, which strikes N. 25° E. The center of the ore pipe contained rich lead-silver ore, but successive exterior zones were progressively richer in manganese and leaner in lead and silver. The last ore to be mined was valuable only for manganese. It carried 15 to 20 percent manganese, 3 ounces silver, and 0.8 percent lead, about the same as the fluxing ore from the Prince and Virginia Louise mines in the Pioche district.

Between 1924 and 1937, the Black Metal mine shipped 25,000 tons of ore to the Columbia Steel Co., with the following average assay: 0.01 ounce gold per ton, 3.5 ounces silver per ton, 21.7 percent manganese, and 0.54 percent zinc with a net mine value of $99,400. Between 1919 and 1924, 23,700 tons of bedded replacement ore with a net mine value of $150,500 gave the following average assay: 12 ounces silver per ton, 0.6 percent lead, and 8.6 percent manganese. Fifty-four tons from this deposit contained 0.1 ounce gold per ton, 329 ounces silver per ton, 2.1 percent bismuth, 36 percent lead, and 6.5 percent copper. The company estimates that more than 200,000 tons of ore were mined from 1878 to 1919 with an estimated net mine value of over $2,500,000. County records for the Day Silver Mining Co. reported by Couch and Carpenter (1943, p. 86, 88) show a total production between 1879 and 1886 of 11,449 tons of ore with a gross value of $324,000; these figures include production from the Onondaga mine, mistakenly credited to the Pioche district.

Accepting the company figures, this gives a total production (net mine value) for the mine of about $2,767,400, and the gross value (using the ratio of net to gross for the Bristol Silver mine) would be much greater — around $3,900,000.

The principal mines are described in table 12.



Dg, Guilmette Formation (Silverhorn Dolomite); Ꞓho, Unit "O"; Ꞓhn, dolomite (McFadden); Ꞓhm, limestone (Hillside); Ꞓhl, limestone (Tempest); Ꞓhk, limestone (Inman); Ꞓhj, limestone (Jackrabbit); Ꞓhh, dolomite (Badger); Ꞓhg, limestone (Bristol); Ꞓhf, dolomite (Platy); Ꞓhe, limestone (Newport); Ꞓhd, limestone (False Prince "B"); Ꞓhe, Burnt Canyon Member (Davidson Black limestone); Ꞓhb, Burrows Member (Davidson dolomite); Ꞓha, Peasley Member (Davidson Blue limestone); Ꞓlp, Lyndon Limestone and Pioche Shale, undivided. (cf: Plate 5)

Geology by Mackay School of Mines, Paul Gemmill, E. B. Young, 1943. Modified by C. M. Tschanz, 1960

FIGURE 22. Vertical projection along an east-west line showing ore bodies and geology in the hanging wall of the May Day fissure, Bristol Silver mine.

Delamar (Ferguson) District
(Gold, silver)

Location

The Delamar (Ferguson) mining district is on the west slope of the Delamar Range about 29 miles southwest of Caliente and 15 miles by dirt road south of U.S. Highway 93.

History and production

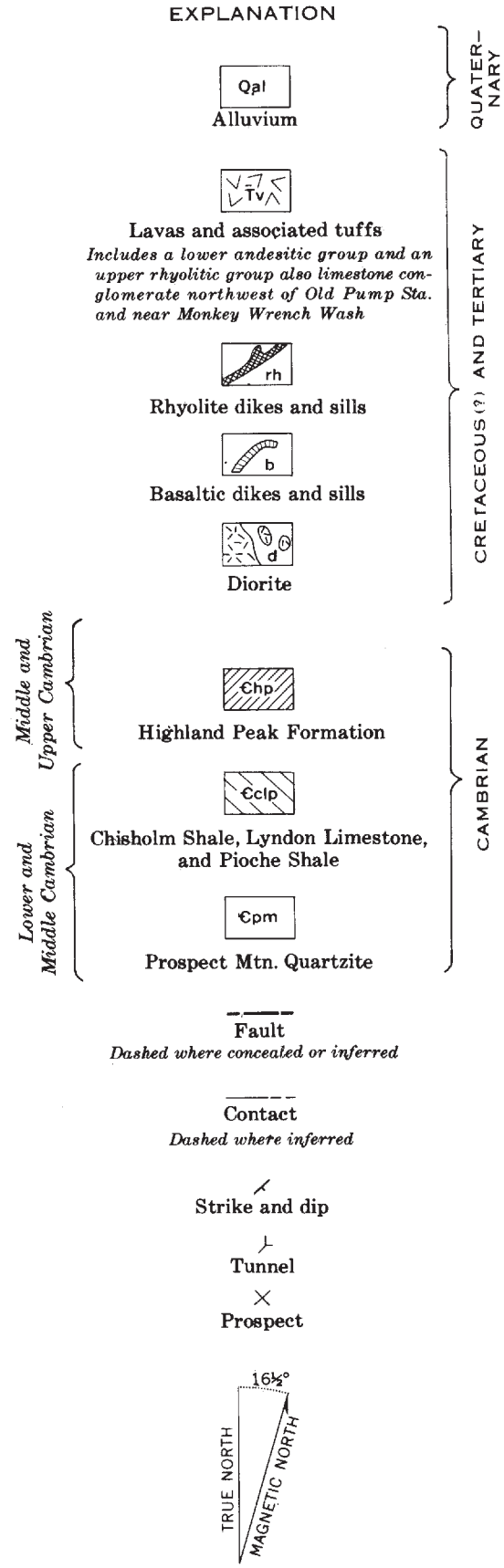
The following description of the history, geology, and ore deposits of the Delamar district is taken almost entirely from the excellent comprehensive report on the district by Callaghan (1937). This report needs no elaboration beyond adding more recent data on production, largely from tailings, and a few notes on more recent discoveries.

Ore was first discovered in 1891 by the Ferguson brothers, farmers from the Pahranagat Valley. The district was organized in 1892, and a town called Helene, which boasted a newspaper in 1894, grew near the Magnolia mine (fig. 23). Delamar became the principal town when the Delamar mine was developed. In 1893 Captain De Lamar purchased the principal claims and began the active development that made the district the premier producer of gold in Nevada shortly after 1894.

Development was under adverse conditions, for all material had to be transported by mule team to and from the railroad at Milford, Utah, about 150 miles away, until the railroad reached Caliente in 1902. Water for the camp was pumped by three wood-fired pumping plants up a lift of about 2,100 feet, from Meadow Valley Wash about 12 miles east of Delamar. The mines were dusty, and silicosis claimed the lives of many miners.

Production through 1902, when the Bamberger-Delamar Gold Mining Co. was organized, was $9,500,000. The new company acquired most of the claims, remodeled the mill, built an electric power line from a new power plant on Meadow Valley Wash, and operated until 1909 when the mine was permanently closed. Production during this 7-year period amounted to $3,400,000. The town and equipment were then dismantled and moved. The population declined from 904 in 1910, to 78 in 1920, and 17 in 1930. The ghost town is shown in figure 24.

The district was inactive between 1909 and 1931. In 1932 retreatment of the tailings began. Between 1932 and July 1940, 586,000 tons of tailings were milled, from which gold valued at $781,500 was recovered (Eng. Mining Jour., 1940, p. 98). Since 1942 the total recorded production has been less than $33,000. The total production from the Delamar district has been $14,983,700 as shown in table 13.



Geology

The Delamar district is in an area of Cambrian sedimentary rocks, which are intruded by Cretaceous(?) and Tertiary rhyolite, quartz monzonite (shown as diorite on geologic map), and basalt dikes and sills. These rocks are partly covered by volcanic rocks. Essentially all of the productive ore deposits in the district are in the Prospect Mountain Quartzite, but one outlying gold deposit, the Easter mine, is in Tertiary volcanic rocks a few miles east of the district, and a few prospects are in the Pioche

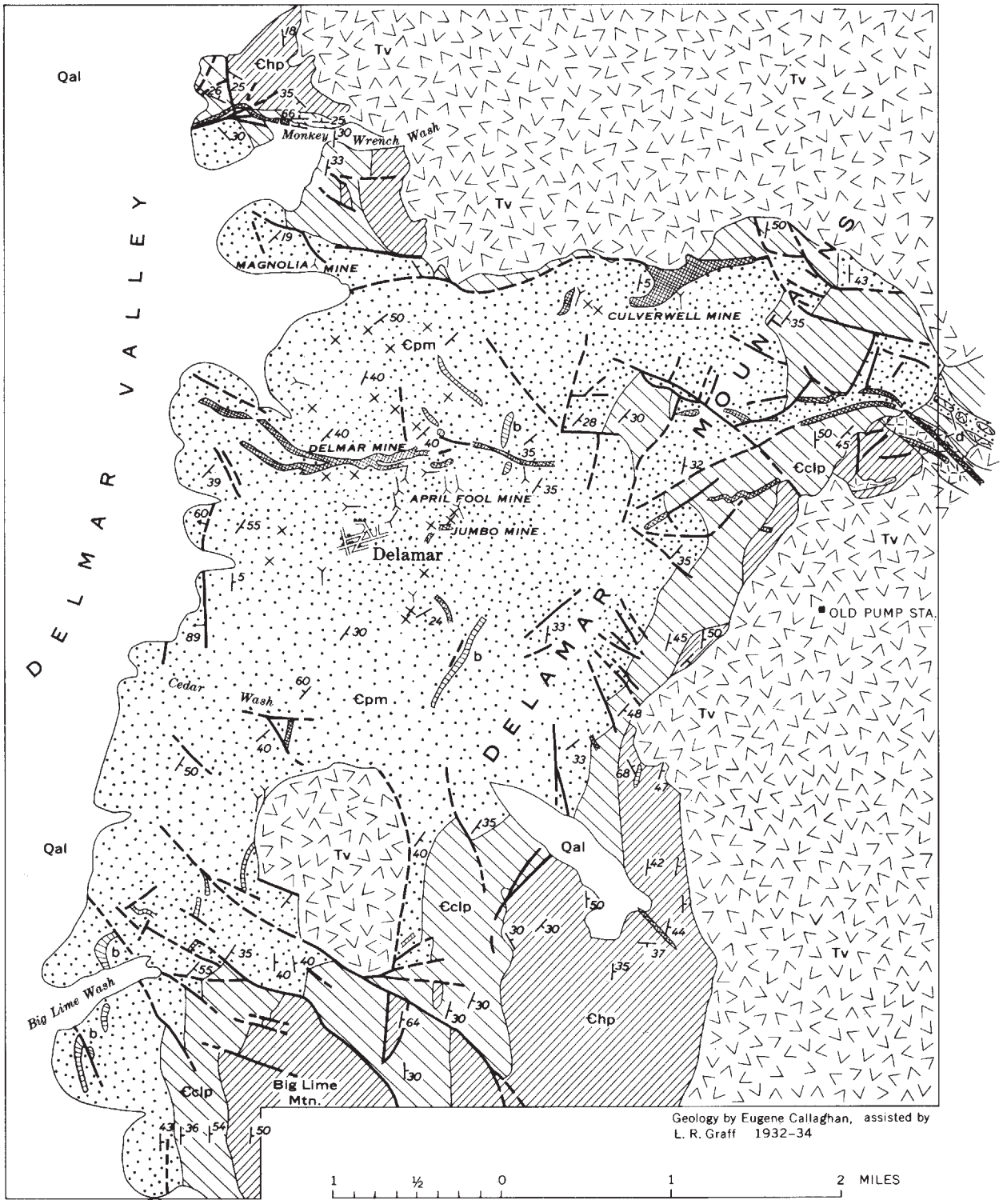


FIGURE 23. Geologic map of the Delamar district.

Table 12. Principal mines of the Bristol and Jackrabbit districts.

Name	Location (unsurveyed) Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Bristol Silver Mines, Inc. Includes the Bristol, Home Run, Vesuvius, Day Mine Lease, Iron, National, and Great Eastern	29, 30, 31	3 N.	66 E.	Ag, Pb, Cu, Zn	Irregular replacement bodies of oxidized ore along four intersecting fissure systems in limestone of the Highland Peak Formation contain Ag, Pb, Cu, and Zn in greatly varying amounts. The ore shoots have a known vertical range of 2,200 ft and a stratigraphic range of about 3,000 ft.	Total combined gross production value is estimated to be $13,535,000. The production between 1906 and 1919 was 33,500 tons with a net value of $535,000. Since 1919 the company has produced about 450,000 tons of ore worth about $10,000,000. Total production from Hillside mine estimated to be $2,300,000. The May Day produced ore worth $317,400 between 1906 and 1919. The Tempest, National, Vesuvius, and Great Eastern mines have not produced much ore. Metal production between 1924 and 1955 was 4,433,800 oz Ag, 35,943,800 lb Pb, 40,570,800 lb Zn, and 22,722,100 lb Cu. Average grade of ore is about 12 oz Ag, 0.015 oz Au, 5 percent Pb, 5.5 percent Zn, and 3 percent Cu. Since 1956 the ore has averaged 15 oz Ag, 4 percent Pb, 6 percent Cu. Hill (1916, p. 124-137); Westgate and Knopf (1932, p. 67-73).
Black Metals (Jackrabbit, Day). Includes Onandaga	29	3 N.	66 E.	Ag, Pb, Mn, Bi	High-grade oxidized lead-silver ore in limestone of the Highland Peak Formation in and near a fissure that strikes N. 25° E. The rich ore was cerussite and cerargyrite and ranged from a few inches to 4 ft in thickness. Bedded replacement deposits 1 to 20 ft thick occur at three horizons along the fissure. Most of the Pb-Ag ore was produced from pipe-like shoots at fissure intersections. The peripheral zones of these pipes, outward from the center, are progressively leaner in Ag and Pb and richer in Mn.	Total production estimated to be 259,000 tons with a net value of $2,767,400 of which 200,000 tons and $2,500,000 were produced prior to 1919. Recorded production value is much less. Couch and Carpenter (1943, p. 86, 88); Hill (1916); Westgate and Knopf (1932).
Ida May (E and F)	30	3 N.	66 E.	Ag, Pb, Cu, Zn	Replacement deposits generally similar to Bristol mine but smaller.	Only recorded production is 553 tons of ore in 1908 with gross value of $21,300. Couch and Carpenter (1943, p. 86).
Lucky Star (Giant)	19	3 N.	66 E.	Pb, Ag, Mn	Vein containing lead ore strikes N. 50° W. and dips 50° SW. Mn mineralization extends as far as 50 ft into the wall rock. Small amounts of replacement ore along bedding.	Some ore averaging 28 percent Mn shipped in 1952.
Pioche-Bristol (Cutt)	20	3 N.	66 E.	Pb, Ag	Vein strikes N. 55° E., dips 70° S., and crops out for 750 ft. Ore is argentiferous galena and cerussite.	Westgate and Knopf (1932, p. 73).
Monarch (Atlas)	8(?)	2 N.	66 E.	Pb, Cu, Ag	Flat quartz vein follows bedding in gray dolomite in upper part of the Highland Peak Formation. Ore contains galena, jarosite, malachite, and tenorite. Vein pinches and swells from several inches to 3 ft.	
Woodbutcher	13(?)	2 N.	65 E.	Ag-Au	High-grade silver-lead pockets in quartz vein.	Shipped 62 tons of gold-silver ore in 1939 Mining World (1940, v. 2, no. 2, p. 31).

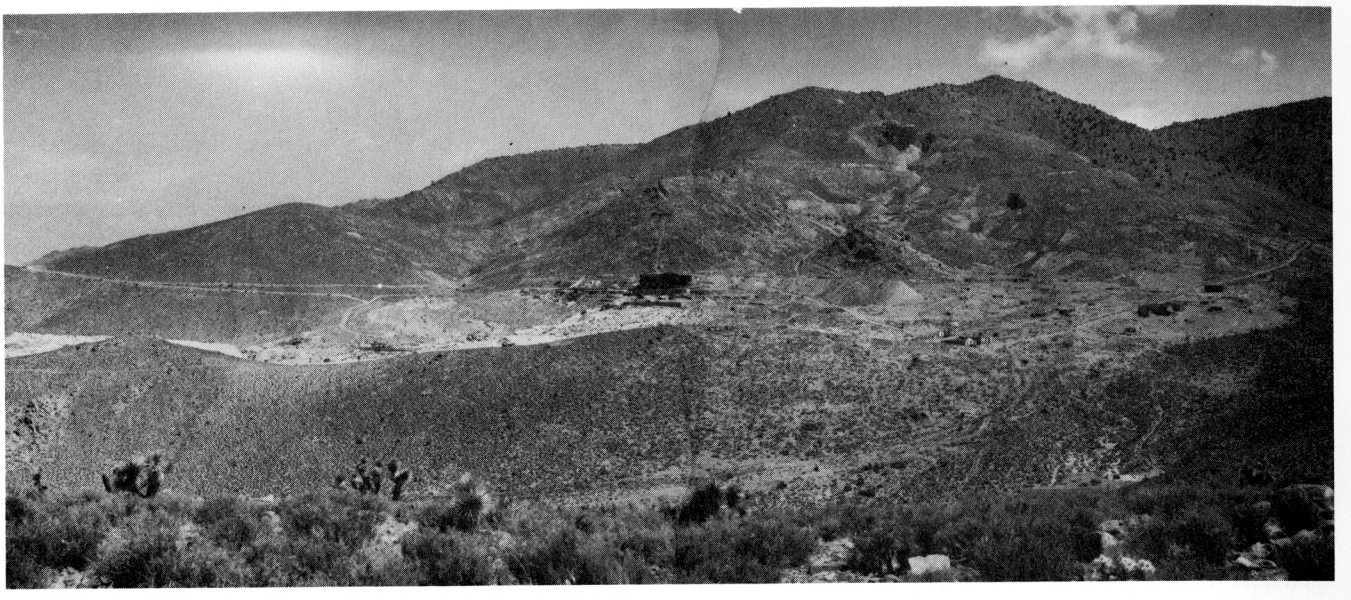


FIGURE 24. Ghost town of Delamar showing the glory hole of the Delamar mine. View north.

Table 13. Production of the Delamar district, 1892-1950.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Total Value
1950	201	156	200	— —	$ 7,200
1949	151	104	100	— —	5,400
1948	111	203	— —	500	4,200
1947	56	38	1,500	— —	2,300
1946	160	164	— —	— —	5,700
1942	317	1,028	— —	— —	11,800
1941	1,554	2,807	1,000	— —	— —
1940	3,495	13,760	600	1,400	132,200
1939	5,294	19,643	100	— —	198,600
1938	5,369	20,480	100	— —	[1]207,200
1937	5,426	16,608	200	— —	[1]206,500
1936	— —	— —	— —	— —	[1]196,300
1935	4,129	11,536	100	400	[1]184,000
1934	2,521	8,693	900	600	93,800
1933	1,926	7,673	100	700	42,500
1932	2,183	14,134	500	6,700	49,300
1910 to 1928	907	4,380	— —	— —	21,600
1909	14,924	41,542	— —	— —	330,100
1908	24,419	37,762	— —	— —	524,800
1907	20,748	19,305	— —	— —	[1]522,500
1906	28,810	22,930	— —	— —	610,900
1905	30,921	22,753	— —	— —	[1]710,000
1904	29,524	33,028	— —	— —	[1]674,300
1903	30,573	78,573	— —	— —	665,000
1902[2]	3,531	42,693	— —	— —	94,400
1901[3]	— —	— —	— —	— —	[1]623,500
1900	— —	— —	— —	— —	[1]1,016,900
1899	— —	— —	— —	— —	[1]1,253,400
1898	— —	— —	— —	— —	[1]1,703,700
1897	— —	— —	— —	— —	[1]2,183,100
1896	— —	— —	— —	— —	[1]1,934,900
1895	— —	— —	— —	— —	[1]640,200
1894	— —	— —	— —	— —	[1]32,600
1893	— —	— —	— —	— —	[1]26,100
1892	— —	— —	— —	— —	[1]11,400
Totals	217,250	419,993	5,400	10,300	$14,983,700

1. Couch and Carpenter (1943).
2. Nolan (in Hewett and others, 1936, p. 62) stated, "Recorded production, 1902-1932, 763,461 tons of ore yielding 186,540,54 oz Au, 317,000 oz Ag, 576 lb Cu, 7,341 lb Pb, valued in all at $4,029,886."
3. Production in 1892-1901, as compiled by Callaghan (1937) from records of the county assessor, amounted to 573,207 tons of ore valued at $9,454,034.

Shale or in limestone of the Highland Peak Formation. The Cambrian rocks dip southeast at an average angle of 35°, and they are cut by many normal faults of comparatively small displacement.

The rocks in the lower part of the volcanic sequence generally consist of altered rocks of andesitic composition of Cretaceous(?) or Eocene Age. The upper part consists of rhyolite of Tertiary Age that probably unconformably overlies the older andesitic rocks. The oldest intrusive rocks are probably the dikes and small stocks of quartz monzonite that resemble diorite in the field. Basalt dikes and sills and two ages of rhyolite dikes and sills intrude the quartzite. The early rhyolites are pre-ore; the late are post-ore.

Ore deposits

Four types of epithermal gold ore occur in the district, three of these in the quartzite. The ores consist of quartzite breccia cemented and partly replaced by cherty quartz and gold; small veins of cherty quartz which contain local concentrations of free gold and sulfides; bedded quartzite, not obviously mineralized, in which gold was apparently deposited on bedding planes and small fractures; and volcanic breccia and rhyolite dikes brecciated and cemented by comb quartz, which holds free gold and oxidation products of former sulfides.

Most of the large ore shoots in the Delamar mine — the most productive mine — were cemented quartzite breccia. These shoots typically occurred in brecciated quartz near, but not in, the Delamar vein which is within a mafic dike. The second type, cherty quartz veins, was mined in the Hog Pen, April Fool, Jumbo, and Culverwell workings. The Magnolia vein cuts volcanic breccia and rhyolite dikes which are silicified and partly replaced by adularia. The Easter mine, between the Delamar district and Meadow Valley Wash, is in sheeted rhyolite which contains many east-west veins of gold-bearing cherty quartz. The average ratio of gold to silver was about 1:3. The deposits were classified as Tertiary epithermal silver-gold deposits.

The gold content of the Delamar ore bodies increased down to the 7th level, reaching $30 to $70 per ton; but the value then decreased to only $4 to $5 on the 10th level, and to $1 or $2 in the unoxidized pyritic ore below the 10th level. Emmons (1902, p. 671) concluded that the rich ore was formed by secondary enrichment. Occasional rich silver ore was found near the surface. In 1908, 4 tons, mined 25 feet below the surface, contained 1,400 ounces of silver and 6 ounces in gold (Salt Lake Mining Review, 1909, p. 39).

The mines are briefly described in table 14. Callaghan's report contains more complete descriptions and geologic maps of the mines.

Tem Piute District

(Tungsten, silver, fluorspar, zinc)

Location

The Tem Piute district is in the Timpahute Range, about 85 miles by road west of Caliente and about 100 miles east of Tonopah. The south end of the district is crossed by Nevada State Highway 25, and a well-graded dirt road leads from the pavement to Tem Piute. The major ore deposits are at the north end of Coyote Peak about 6 miles north of the highway. The old silver workings are on the southwest side of the range.

History and production

The district was prospected for silver in the 1860's, but the first production (table 15) was recorded from 1869 to 1883 (Couch and Carpenter, 1943, p. 85). Lincoln (1923, p. 128) reports that the ores of the district were discovered in 1868 and worked for silver in the seventies. Subsequently the district was inactive for about 40 years.

The first scheelite claims were staked in 1916 and relocated in 1936. In 1937 more claims were staked, and 250 tons of ore were mined and milled in a small mill near the claims. In 1939 construction of a 40-ton mill was started, and mill operations by Lincoln Mines, Inc., began in February 1940. Capacity of the mill was increased to 75 tons in 1941. By the end of 1943 the mill had treated 56,700 tons of ore and 3,400 tons of tailings that contained 31,445 units of WO_3. The Lincoln mine was leased by Atolia Mining Co. in June 1945 and operated until September 1948 when the lease was surrendered to the owners, who continued small intermittent operations until 1951. The property was then acquired by Wah Chang Mining Corp., and a new era began. A new 700-ton mill was completed in 1953 and operations were continuous until August 1957, when the mine and mill were closed because Government tungsten purchases for stockpiling were ended.

Tem Piute, a modern camp, which had about 500 inhabitants in 1956, was, by 1958, deserted and largely dismantled. A power line completed only a few months before operations ceased, the mill, and most of the mine equipment were dismantled and sold. Thus a drama as old as mining has once again been enacted.

During its heyday, the Lincoln mine was the second largest tungsten mine in Nevada and its total production rivaled fabled Delamar. Total production from the district is about 1,000,000 tons of ore, which averaged about 0.45 percent WO_3, or about 287,000 units, worth about $14,700,000. In 5 years, the Wah Chang mill produced $12,180,700 worth of tungsten concentrates.

The North Tem Piute mine of the Schofield brothers is half a mile south of the Lincoln mine. The first claims

Table 14. Principal mines of the Delamar district.
[Location of principal mines shown on geologic map of district (fig.23.)]

Name	Commodities	Geologic setting	Production, remarks, and references
Delamar (Jim Crow, Monitor, Hog Pen, Gold Cup)	Au, Ag	Five principal ore shoots were mined along Delamar (Monitor) vein which extends 2,700 ft and has an average strike of N. 18° E. Several smaller shoots occur in veins at right angles to the Delamar vein. Most of the ore consisted of quartzite breccia which was cemented by cherty quartz. Only the Hog Pen ore shoot contained free gold. All stopes had assay limits and only part of the breccia was ore. Pyrite, tetrahedrite, chalcopyrite, bornite, chalcocite, and a telluride(?) occur in the cherty quartz as minute grains. Gold values decreased rapidly below the 10th level.	Total production was $12,854,600 up to 1933. About 1,312,000 tons of ore worth $12,064,900 were mined in addition to 586,000 tons of tailings from the Delamar mill which were retreated with the recovery of $781,500 in gold (Eng. Mining Jour., 1940, p. 98). Total length of mine working on 15 levels is estimated at between 20 and 35 miles. Callaghan (1937, p. 50-58); Emmons (1902).
April Fool (Swifter)	Au, Ag	Vein strikes N. 30° E., approximately parallel to the Delamar vein, and lies 500 to 700 ft east of it. The principal ore shoots are opposite those in the Delamar mine. Vein is offset along a late rhyolite dike. Ore consists of silicified quartzite breccia and veinlets of comb quartz. The April Fool vein is mineralized for a length of 3,000 ft and a depth greater than 700 ft.	Total production between 1892 and 1899 was 24,600 tons of ore and 24,900 tons of tailings worth $876,800. There is more than a mile of mine workings. Callaghan (1937, p. 58-60).
Jumbo (Horn)	Au, Ag	Jumbo vein strikes N. 15° W. and dips 68° W. Ore shoot was 90 ft long and consisted of a rich cherty quartz vein 6 in wide and adjacent rock. The rich ore contains cerargyrite and gold. Pyrite, sphalerite, galena, tetrahedrite, and barite occur in a vein that strikes N. 22° E. and dips 63° N.	Between 1932 and 1935, some 876 tons of ore worth about $76,200 were shipped. Callaghan (1937, p. 60-64).
Magnolia	Au, Ag	Ore in a dike or plug of volcanic breccia that strikes N. 18° W., is at least 1,100 ft long, and averages 100 ft wide. The breccia apparently follows a fault in Prospect Mountain Quartzite, along which later movement permitted intrusion of rhyolite dikes. The dikes and breccia were then fractured and mineralized. The ore shoot trends northerly, dips 80°-90° E., pitches about 65° N., and averages 160 ft along the level; ore occurred in lenses and pockets in this shoot. The ore is comb quartz which contains free gold, cerussite, pyromorphite, mimitite, and manganese and iron oxides.	Reported production of 470 tons worth $37,700 prior to 1902 seems too small. A total of 272 tons of ore was shipped in 1921, 1927, and 1932. Of this, 48 tons were worth $1,100. Semiquantitative spectrographic analyses of one grab sample of sulfide ore show traces of Ag, Cu, Bi, and Zn. Callaghan (1937, p. 66-68).
Culverwell	Au, Ag	Two converging veins striking S. 40° E. and S. 50° E. The latter is about 2 ft thick.	Five tons of ore shipped in 1933 contained 1.44 oz Au and 2.31 of sulfide ore show traces of Ag, Cu, Bi, and Zn. Callaghan (1937, p. 68-69).
Flagstaff	Au	Silicified breccia zone along N. 70° E. and N. 25° W. fractures.	Callaghan (1937, p. 64-66).
Easter	Au, Ag	East-west veinlets of cherty quartz cutting sheeted rhyolite. Sheeted zone is over 100 ft wide.	Thirty-eight tons containing 0.95 oz Au and 3.94 oz Ag per ton were shipped in 1933.
Delamar Zinc	Zn	Inclined shaft in limestone of the Highland Peak Formation near volcanic contact cuts material that contains 15-30 percent Zn and 6 percent Pb.	No recorded production.
Peggy Lee	Zn(?)	Prospect in limestone of the Highland Peak Formation near volcanic contact. No ore minerals visible.	Five miles north of Delamar. Three miles from Delamar Zinc.
100-foot inclined shaft	Cu	Copper-stained shear zones near top of Prospect Mountain Quartzite. Principal shear strikes N. 30° W. and dips 60° W.	One mile north of Monkey Wrench Wash.
Manganese prospects	Mn	Several pits and two 25-ft shafts in limestone near fault contact between Prospect Mountain Quartzite and Highland Peak Formation. Up to 5 ft of spongy manganese oxides.	

were located in 1928. Total production has been about 3,300 tons of ore, which contained 1,986 units of WO_3.

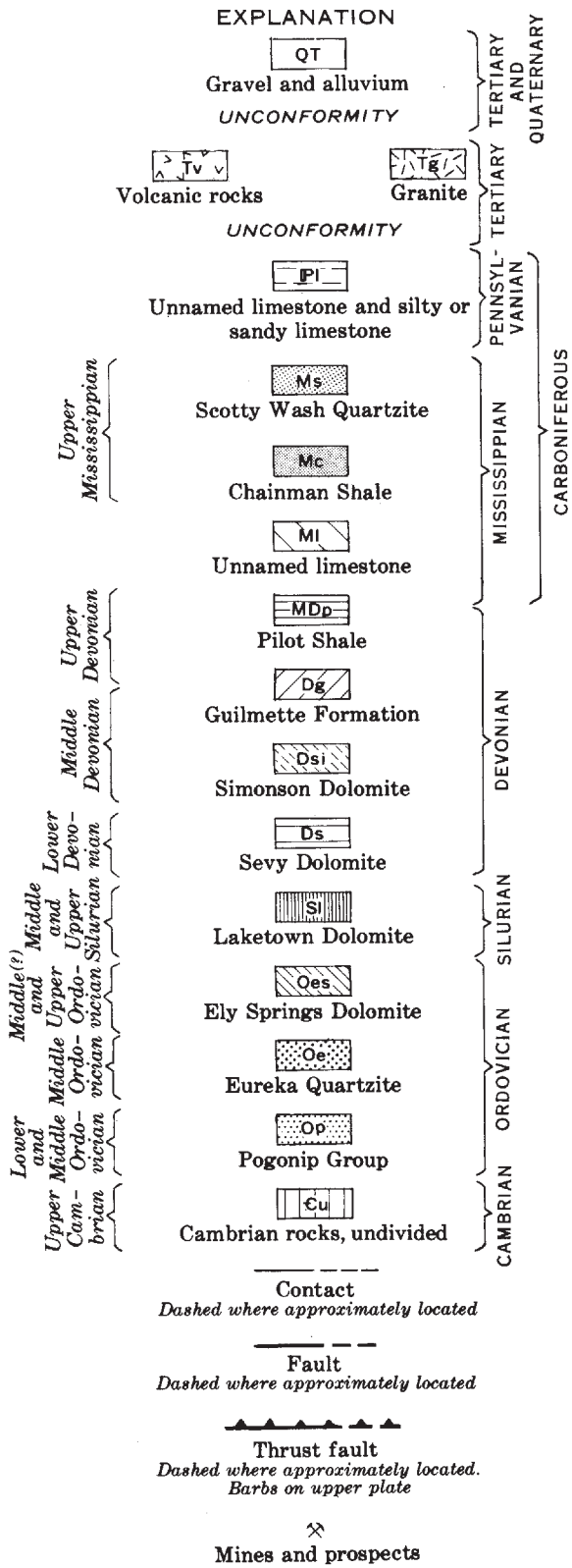
Geology

The part of the Timpahute Range included in the Tem Piute district is composed of steeply east-dipping Paleozoic sedimentary rocks, which include all the formations between the Pogonip Group and the Pennsylvanian limestones, as shown in the geologic map of the range (fig. 25). Permian rocks probably are present on the east side of the district. The Mississippian rocks near the north end of the ranges are intruded by two small granite stocks, each less than a mile in diameter. The dip of the bedding steepens northward along the west side of these stocks until the rocks are overturned. D. G. Wyant and D. M. Lemmon of the U.S. Geological Survey (written communication, 1947) believe the overturning results from pregranite thrust faulting. Conceivably, the Devonian and older rocks in the main part of the range are thrust over the Chainman Shale and higher rocks, because thrust plates rest on Upper Mississippian or Pennsylvanian rocks both south and north of the stocks in the southern foothills, and north of the Tem Piute road. In both places the thrust plates include Upper Cambrian, Ordovician, and Devonian limestones.

The thrust plate of Upper Cambrian and Ordovician limestones east of Tem Piute dips steeply east, as do the plates of these rocks in the Pahranagat and Spotted Ranges. Perhaps all these plates are part of a regional thrust plate as shown by a line pattern in plate 3.

In the southern foothills the Devonian rocks make up the upper plate, whereas north of Tem Piute they make up the lower plate. These rocks are probably equivalent to the West Range Limestone of Late Devonian Age. On the west side of the range, Middle Pennsylvanian rocks are either thrust on Ordovician rocks or moved into contact with them by right-lateral faulting. The affect of these major structures on the origin and downward extension of the ore deposits is unknown.

The tungsten deposits occur in or near thick bodies of tactite, which form three elongated bands parallel to the bedding of the Devonian and Mississippian limestone along the west side of the south stock (pl. 6). Low-grade, scheelite-bearing tactite bodies and richer calcite-fluorite-sphalerite-scheelite rock have been mined. The south stock is conspicuously more altered and less resistant to weathering than the north stock. The granite and the tactite are partly concordant with the limestone. Limestone is irregularly bleached and recrystallized as far as 700 feet from the granite contact; tactite is irregularly developed as far away as 450 feet; and silicated limestone is found even farther from the contact (D. G. Wyant and D. M. Lemmon, written communication,



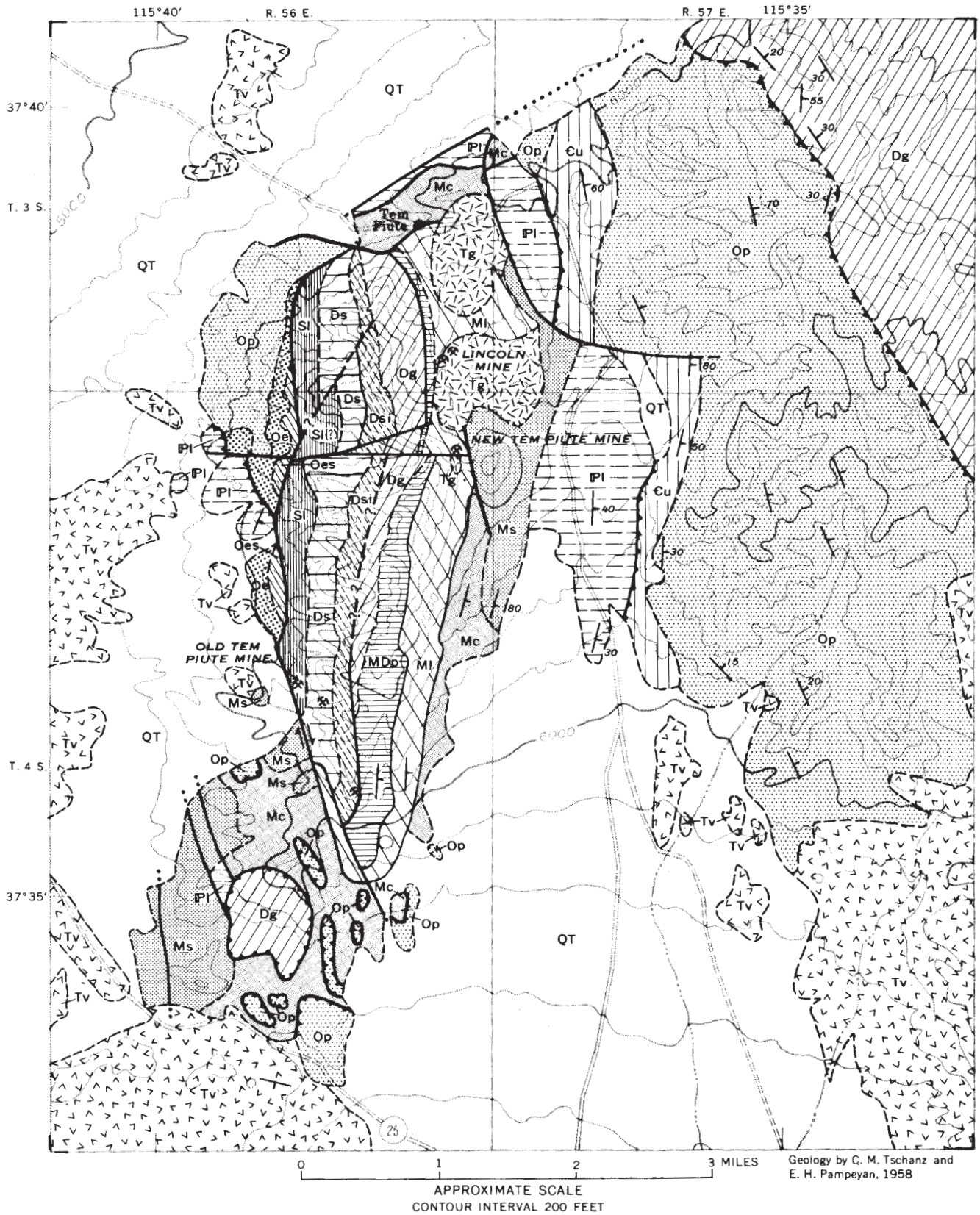


FIGURE 25. Geologic map of the Tem Piute district.

Table 15. Production of the Tem Piute district, 1869-1958.

(e, estimate; — —, no data)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value Au-Ag-Cu-Pb-Zn	WO_3 (units)	Tungsten value	Total value
1958	— —	— —	— —	— —	— —	$ — —	0	$ 0	$ 43,000
1957	— —	558	— —	— —	— —	500	35,707	1,116,800	1,117,300
1956	— —	— —	— —	— —	— —	— —	58,102	3,323,600	3,323,600
1955	— —	— —	— —	— —	— —	— —	62,453	3,847,100	3,847,100
1954	— —	— —	— —	— —	— —	— —	48,903	3,065,200	3,065,200
1953	— —	— —	— —	— —	— —	— —	16,352	1,022,800	1,022,800
1952	— —	— —	— —	— —	— —	57,600	17,102	1,091,100	1,148,700
1951	— —	— —	— —	— —	— —	— —	2,727	100,900	100,900
1950	— —	— —	— —	— —	— —	— —	0	0	— —
1949	— —	170	300	400	43,200	5,600	681	14,300	19,900
1948	— —	— —	— —	— —	— —	— —	0	0	— —
1947	— —	— —	— —	— —	— —	— —	5,175	125,500	125,500
1946	— —	— —	— —	— —	— —	— —	1,208	26,000	26,000
1945	— —	— —	— —	— —	— —	— —	2,752	64,500	64,500
1954	— —	— —	— —	— —	— —	— —	4,022	92,500	92,500
1953	— —	— —	— —	— —	— —	— —	3,479	89,800	89,800
1952	— —	— —	— —	— —	— —	— —	14,431	365,800	365,800
1941	— —	128	— —	2,000	— —	200	10,182	255,500	255,700
1940	3	1,225	100	8,700	— —	1,400	3,369	73,700	75,100
1939	— —	1,201	— —	700	— —	800	— —	1,800	2,600
1938	2	13,506	300	6,400	— —	9,100	18e	300e	9,400
1937	11	34,575	300	3,000	— —	27,300	175	3,200	30,500
1936	9	44,836	1,900	10,300	— —	35,700	— —	— —	35,700
1935	10	47,568	900	8,700	— —	35,000	— —	— —	35,000
1934	3	6,940	100	800	— —	4,600	— —	— —	4,600
1924-1932[1]	— —	15,469	— —	3,700	— —	9,400	— —	— —	9,400
1869-1883	— —	— —	— —	— —	— —	[2]11,400	— —	— —	11,400
Totals		166,176	3,900	44,700	43,200	$198,600	286,838	$14,680,200	$14,922,000

1. Nolan (in Hewett and others, 1936, p. 65).
2. Predominantly in silver values.

1945). A conspicuous unfossiliferous layer of hornfels 110 feet thick along the west side of both stocks is probably the sheared baked remnant of the Pilot Shale. Lenticular masses of tactite in this layer locally contain ore.

A contorted septum of Mississippian(?) limestone between 600 and 800 feet thick that is partly converted to tactite separates the two stocks. The bedding in this septum is nearly vertical, and it strikes nearly east-west at right angles to the regional strike. The generalized geologic relations are shown in figure 25. The detailed relations in the productive area are shown in the large-scale geologic map in plate 6.

Ore deposits

We did not examine the tungsten deposits, so the following description is entirely from the earlier work of other geologists of the U.S. Geological Survey. The description of the Lincoln mine is from the final report on the Defense Minerals Exploration Administration program at the Lincoln mine in 1957 (H. K. Stager and G. G. Gentry, written communication, 1957). This report and our district description draw heavily on the wartime work of D. G. Wyant and work done in 1945 by D. M. Lemmon. The following description is from the unpublished data of Wyant and Lemmon (written communication, 1945), which we revised and brought up to date.

Two types of tungsten deposits occur. One type consists of low-grade but very extensive garnet tactite bodies, which were not exploited until after 1948. Before 1948 most of the production came from a second type of deposit consisting of much smaller but richer masses of calcite-fluorite-sphalerite rock localized in marble remnants adjoining tactite. By-product fluorite and sphalerite concentrates were produced from these masses, in addition to scheelite.

Wyant and Lemmon (written communication, 1945) state:

> "Most of the tactite around the south stock contains some scheelite, but only part of it contains enough scheelite to be considered potential ore. The average grade of material that could be mined in large bodies is estimated at 0.2 to 0.4 percent of WO_3, determined from samples taken by the U.S. Bureau of Mines [Binyon, Holmes, and Johnson, 1950]. On the surface map [pl. 6] rock containing 0.5 percent WO_3 or more was distinguished from lower grade material on the basis of estimates made in ultraviolet light.
>
> "The tactite bodies exposed around the north stock are narrow and discontinuous, and contain too little scheelite to be economically significant; the largest body, on the northeast side of the stock, is composed of a series of lenses with a total length of 400 feet and average width of 1 to 2 feet."

No attempt was made to modify plate 6 to incorporate the later sampling of trenches and drill holes by the U.S. Bureau of Mines. These data and mine maps and sections are given in the report by Binyon and others (1950).

The two principal tactite zones are shown in plate 6. The No. 1, or Moody, zone that occurs along the west contact of the southern stock has produced most of the ore. This tactite zone extends for about 6,200 feet along the contact and is 15 to 110 feet thick, averaging about 40 feet thick in the Lincoln mine. The zone consists of bands of different kinds of tactite; for example, along the granite contact in the Lincoln mine is a pyrite-pyrrhotite-rich tactite 20 to 25 feet thick succeeded outward by a sulfide-poor garnet tactite that averages about 0.5 percent tungsten. The ore shoots concentrated on the limestone side of the Moody tactite consist of calcite-chlorite-fluorite rock that contains sphalerite and scheelite. This, the principal type ore mined to date, contains 0.5 to 2.5 percent tungsten and about 1.25 percent zinc.

The second principal tactite zone, the No. 4, or Grubstake, zone, is less continuous and less productive. This zone, which is about 2,000 feet long and averages 30 feet in thickness, is separated from the Moody zone by 100 to 200 feet of white platy hornfels (Pilot Shale?) and by two thin tactite layers, which together make up the No. 2 tactite zone. The Grubstake zone contained several high-grade ore bodies near the surface in the Lincoln mine, but these did not continue downward.

The tactite is relatively uniform in grade through a vertical range of 1,300 feet. The average grade of the garnet tactite outside the ore shoots is probably between 0.1 and 0.2 percent tungsten (Binyon and others, 1950, p. 11).

The silver deposits mined at old Tem Piute in the southwestern part of the range contained 13 to 81 ounces of silver per ton in carload lots. Most of the production in the 1930's is reported to have come from the Sterling claim, which produced 65 carloads of ore worth $65,600. These ores came from siliceous veins and replacement deposits along breccia zones in lower Paleozoic dolomites and in the Guilmette Formation. The ores are oxidized and contain no primary minerals or copper stain.

Lincoln mine. The following description of the Lincoln mine is quoted from the Defense Minerals Exploration Administration report by H. G. Stager and G. G. Gentry:

> "The [Lincoln] mine is developed by more than 20,000 feet of underground workings on six levels, the 100, 200, 300, 500, 700, and 900 levels, with adits

on the 100, 300, and 700 levels and an inclined shaft from the surface to the 900 level. Mining is by shrinkage stopes. The workings require little support and all were in good condition and accessible at the time mining was suspended in August 1957.

"The Lincoln mine has produced about 1,000,000 tons of ore that averaged about 0.45 percent WO_3. Most of this ore has come from the Moody ore zone. At the time operations were suspended the mill was operating at a rate of about 780 tons of ore per day that averaged about 0.4 percent WO_3, or a yield of about 5,000 units of WO_3 per month.

"*Ore deposits.*—The ore deposits are concentrations of scheelite, molybdenite, powellite, pyrite, pyrrhotite, sphalerite, and fluorite in parts of the two tactite deposits.

"Scheelite is the principal ore mineral and it is widespread in the surface and underground exposures of tactite but has been mined from only the Grubstake and Moody zones. Ore bodies within the Grubstake zone range from 80 to 300 feet long, from a few feet to 20 feet thick, and have been stoped for as much as 200 feet up the dip. Ore bodies within the Moody zone range from 60 to 300 feet long, from a few feet to 40 feet wide, and have been stoped for as much as 400 feet up the dip. These ore bodies range in grade from 0.3 percent to 2.5 percent WO_3 but average about 0.45 percent WO_3. The tactite between the bodies averages between 0.1 and 0.2 percent WO_3. Most of the scheelite in the ore occurs as small disseminated crystals scattered throughout the tactite groundmass, but rich seams of pure scheelite have been noted along fractures cutting the tactite and adjacent rocks.

"The other ore minerals, powellite, molybdenite, sphalerite, and fluorite, are less common although concentrates containing commercial quantities of molybdenum, zinc, and acid-grade fluorspar have been recovered from the ore. Pyrrhotite and pyrite are common and are the major gangue minerals of the Moody zone. The gangue minerals of the Grubstake zone, and to a lesser extent of the Moody zone, are garnet, epidote, calcite, and quartz.

"The DMEA drill holes cut scheelite-bearing tactite and silicated limestone near the north granite stock but the mineralized zones were too thin and too low in grade to warrant [development] * * *. This drilling indicates that the major mineralized zones are confined to the vicinity of the south granite stock.

"Exploration of the Moody ore zone on the 500 level * * * was almost entirely in dense pyrrhotite-tactite. This pyrrhotite-tactite is about 40 feet wide over most of the drift length but narrowed to 6 feet in the face. It contains numerous thin lenses, pods, and stringers of garnet-tactite. Scheelite is sparsely disseminated throughout the zone. The tactite averages about 0.1 percent WO_3 along the 300 feet of DMEA drift except in the area of the ore body where the grade ranges from 0.1 percent to 0.9 percent WO_3 and averages about 0.4 percent WO_3. The highest grade part of the ore body was about 7.6 feet wide, 28.5 feet long, and was stoped for about 20 feet up a nearly vertical dip. This high-grade part of the body averaged about 0.55 percent WO_3. The ore shoot containing this higher grade ore is about 65 feet long, 10 feet wide, and is inferred to extend 100 feet above and below the level. The ore shoot is mainly scheelite-bearing garnet tactite but disseminated scheelite of ore grade extends into dense pyrrhotite-tactite at each end and for several feet into the hanging wall."

D. G. Wyant and D. M. Lemmon (written communication, 1945) described the downward extent of the Moody ore as follows:

> "The deepest hole penetrated 4.6 feet of ore containing 0.92 percent of WO_3 at an altitude of 5,755 feet, 615 feet vertical distance beneath the outcrop. The average content of WO_3 is probably about 1.0 percent. The lower limit of the ore shoot is not known."

This ore body contains 3 to 4 percent zinc. The lower grade of the ore milled after 1944 was caused partly by the large-scale shrinkage stope method of mining and partly by depletion of the high-grade deposits.

The North Stope ore contains appreciable bismuth. Milling tests by the U.S. Bureau of Mines laboratory showed 0.92 percent bismuth in the tungsten concentrate and 0.74 percent in the combined zinc concentrates. The bismuth is probably associated with galena as bismuthinite (Binyon and others, 1950, p. 13).

North Tem Piute (Schofield) mine. The following description is chiefly from the unpublished data of D. G. Wyant and D. M. Lemmon (written communication, 1945) and a Defense Minerals Exploration Administration report by D. B. Tatlock and G. G. Gentry (written communication, 1956).

The southern half of the Moody ore zone near the south tip of the southern stock (pl. 6) is on the Schofield property. Four ore shoots, which plunge 45°-50° south, occur along the hanging wall of the Moody zone in a distance of 600 feet along the strike. These ore shoots are 16 to 200 feet long and 4 to 9 feet thick. They extend from the surface at least to the 200-foot level and probably to a

depth of 400 feet. The ore shoots occur in a single band of tactite 20 to 110 feet thick on the west contact of the granite. A narrower band of tactite occurs on the east contact. The ore in the Moody shoots contains 0.3 to 0.7 percent WO_3. The tactite between the ore shoots probably contains about 0.2 percent WO_3 and much of the tactite on the east side of the ore shoots contains 0.1 to 0.2 percent WO_3.

Highland District

(Lead, silver, gold, copper, manganese)

Location

The Highland district is in the Highland Range near its junction with the Bristol Range and between 4 and 8 miles west of Pioche. The district adjoins the Pioche district on the east, the Comet district on the southwest, the Ely Springs district on the west, and the Bristol district on the north. The boundaries are indefinite but the district is arbitrarily considered to include all of T. 1 N., R. 66 E. north of lat 37°55′ and the unsurveyed sections north to lat 38° N.

History and production

The history of the Highland district is inseparable from that of the Pioche district, with which the production figures have generally been included. The district was first explored during the initial mining boom at Pioche, but the first production followed erection of the smelter at Bristol Well, Bristol district, in 1872. This smelter treated ore from the Highland district, including iron ore from the contact zone of the Manhattan stock and oxidized lead-silver ore from the Mendha mine, for many years after 1872 (Westgate and Knopf, 1932, p. 6).

An accurate figure for the total production of the district cannot be given. The best estimate for the total gross production value is about $2,000,000. This figure, however, is much larger than the total production of mines known to be in the Highland district, as reported by Couch and Carpenter (1943, p. 87, 88) or Nolan (*in* Hewett and others, 1936, p. 63). More than a million dollars is reported to have been produced in 1891 from the Mendha mine, but according to records in the Lincoln County courthouse, reported by Couch and Carpenter, only 10,000 tons of ore worth $158,500 were produced from the Mendha mine between 1873 and 1924. Couch and Carpenter reported that 2,700 tons of ore worth $87,100 were produced between 1916 and 1924 from the Hamburg mine, the second most productive mine in the district. The Floral mill, which was presumably located in the Highland district at a place called Floral Spring, produced concentrates worth $25,400 between 1875 and 1885 (Couch and Carpenter, 1943, p. 87). Nolan (*in* Hewett and others, 1936, p. 63) gave the following incomplete production figures for the years 1908-1932: 824 ounces gold, 31,679 ounces silver, 2,141 pounds copper, and 813,331 pounds of lead with a total value of $79,813. These figures show only the relative importance of the principal metals, not the total amounts. In 1935, the district production was $7,100. Since then, the production has generally been included with that of the Pioche district.

Geology

The Highland district is underlain principally by Cambrian rocks which have been intruded by small stocks and dikes in the Blind Mountain area near the Manhattan Tunnel (pl. 7). Our map of the district was compiled from Westgate's field sheet (Westgate and Knopf, 1932), but with additions from later detailed maps of part of the district by Paul Gemmill and Harry Godbe of Combined Metals Reduction Co., and from our own observations. Detailed maps of the whole area are necessary to understand the structure, only the broad outlines of which are presented below.

The district consists of three principal structural elements. The lowest is a simple east-tilted block of Pioche Shale, Lyndon Limestone, Chisholm Shale, and limestone of the Highland Peak Formation which makes up the main part of the Highland and Bristol Ranges. These rocks are overridden by the second element, which consists of faulted and partly eroded thrust(?) plates largely composed of Upper Cambrian rocks, but also including most of the Highland Peak Formation and the Lyndon Limestone in the saddle between the Highland and Bristol Ranges. The rocks in the Highland Peak Formation are probably subsidiary thrust blocks dragged along beneath the main surface of movement of the Highland thrust plate. Upper Cambrian rocks appear locally to have overridden Tertiary volcanic rocks, perhaps because of landsliding; but the evidence is not conclusive. The Highland thrust plate exposed along the west side of the district (pl. 3) is thought to underlie Arizona Peak and to have overridden the Pioche Hills as well.

The third element is represented only by the small downfaulted remnant of the Bristol thrust sheet of Devonian rocks (dolomite facies of the Guilmette Formation) in the northwest corner of the district. This thrust plate covers a large area in the Bristol and West Ranges.

Detailed mapping of 17 units of the Highland Peak Formation by geologists of the Combined Metals Reduction Co. shows that the entire section in the Manhattan Gap area has been disrupted by differential movement between the incompetent shales below and the overthrust sheet of Mendha Formation above, forming a chaotic array of large and small fault blocks. This thrust megabreccia still retains a crude semblance of normal stratigraphic order. The relations are obscured by late normal faulting which offsets in several places the altered granite porphyry dike that intrudes both thrust plates.

Mineral deposits

The principal ore deposits of the Highland district are siliceous replacement veins in the thrust plate of Upper Cambrian rocks (Mendha Formation) on Arizona Peak, and the small bedded replacement deposits related to them. Lead, silver, and gold from the Mendha and Hamburg mines account for most of the production. Veins were mined in the Mendha, Hamburg, Highland Queen, National Group, Lucky Jim, and Last Chance mines.

The most productive veins strike nearly east-west, but northeasterly veins also occur. The so-called Manhattan fissure, a quartz vein as much as 6 feet wide which has produced a little lead-silver-gold ore, extends about 1,500 feet northeastward across the contact metamorphic aureole and the quartz monzonite plug. The Black Prince fissure, another northeast-trending vein which contains manganese, lead, silver, and zinc, can be traced 7,000 feet along the surface in the Mendha Formation and the upper part of the Highland Peak Formation near Highland Spring. The principal mines of the Highland district are briefly described in table 16.

Groom District
(Lead, silver)

Location

The Groom district is in the Groom mine 15-minute quadrangle near the south end of the Groom Range in T. 7 S., R. 55 E. (unsurveyed). It is 72 airline miles west-southwest of Caliente and 23 airline miles south-southwest of Tem Piute. The district is reached by about 25 miles of graded dirt road which connects with Nevada Highway 25 at the western flank of the Pahranagat Range. The following information, except for a few references to the regional geology, is from a report by Humphrey (1945) to which the reader is referred for additional information and detailed geologic maps.

History and production

The deposit at the Groom mine was discovered in 1864 and the district was organized in 1869. The mines were first worked for a 5-year period, during which they yielded a small but unrecorded amount. In 1885 the property was acquired by the Sheahan family, who still own it. The Groom mine produced steadily from 1915 through 1918, and sporadic shipments were made by lessees from 1918 to 1942. The property again produced steadily from 1942 to 1956. During most of this last period, the operator was International Mining Corp. in partnership with Dan Sheahan.

The Sheahans report the total production for the years 1915 to 1926 to be 6,145 tons of jig concentrates which contained 100,341 ounces of silver and 5,926,371 pounds of lead. The net smelter returns amounted to $338,393, which is only 63 percent of the gross value ($531,200) figured from the average yearly metal price. The total production from the district, nearly all of which came from the Groom mine, exceeds $1 million, as shown in table 17.

Geology

The Groom Range consists of a structurally simple homoclinal sequence of lower Paleozoic rocks that strike north and dip steeply eastward as shown on the geologic map (pl. 2). The Cambrian section exceeds 20,000 feet in thickness, and the total thickness of the continuously exposed Paleozoic rocks is about 26,000 feet. The Paleozoic rocks are covered on the east and north by Tertiary volcanic rocks.

The Groom district is in a 2,000-foot-wide, complexly faulted graben of Pioche Shale, Lyndon Limestone, Chisholm Shale, and Peasley Member of the Highland Peak faulted into the Prospect Mountain Quartzite. The graben is the major structural feature of the southern part of the Groom Range. Humphrey (1945, p. 29) calculates a vertical movement of over 3,000 feet on the Main fault — a fault which strikes north, dips west, and bounds the graben on the east. He also estimates that 3,000 feet of erosion have occurred since the displacement on the Main fault.

Most of the Prospect Mountain Quartzite in the graben area appears to be part of a minor thrust sheet that is older than the normal faults, which offset it in many places. This thrust fault, as shown in Humphrey's cross sections, dips west about 25° and must underlie the quartzite west of the graben. Both the thrust fault and the west-dipping faults are offset by east-dipping post-ore normal faults. Humphrey thought that the displacement on the principal thrust fault was between 1,000 and 2,000 feet and that the regional tilting to the present dip of 35°-40° preceded thrusting. Minor thrust faults in the Groom mine partly localize the ore bodies.

Mineral deposits

The only productive ore bodies are replacement deposits in limestone within the graben on the hanging wall of the Main fault. Irregular replacement and bedded replacement deposits are present. The bedded deposits are in three thin limestone beds in the upper part of the Pioche Shale. They contain a large tonnage that ranges between 4 and 5 percent lead, but economically they are marginal because of the high cost of production (about $8.50 per ton in 1951). The lower limestone beds in the Pioche Shale have not been explored below a depth of 390 feet despite the probable existence of deeper mineralization. The irregular replacement deposits are in the Lyndon Limestone along steep fissures that are related

to the Main fault. The limestone along the mineralized fissures is commonly silicified, and many minor east-west fissures contain galena. The Main fault is thought to be the principal feeder through the quartzite, although it is filled by 30 feet of impervious gouge in the Pioche Shale.

Argentiferous galena and subordinate sphalerite are the primary ore minerals, but cerussite and anglesite occur in the oxidized ore above the 50-foot level or deeper along open fissures. The lead content of the ore is relatively uniform, but the zinc content varies greatly from a trace to 22 percent. Lead is usually over 20 percent and silver consistently averages about one-third ounce per percent of lead. The gold content is negligible, and copper, as chalcopyrite or tetrahedrite(?), averages about 0.35 percent. A little pyrite is present.

The thin limestone bed containing all the bedded ore dips into the Main fault and is almost continuously exposed for about 2 miles from the Lane shaft (5,000 feet south of Groom shaft) and about 1.5 miles north of the Groom shaft, where it is covered by overthrust shale and quartzite.

The Groom mine is opened by a 210-foot shaft and two adits. The best ore is on or above the 100-foot level in a bow-shaped area about 250 feet long between the No. 3 thrust fault and the Groom fault. Most of the best ore is along north-south fissures in the hanging wall of a thrust that has offset the beds about 40 feet. Good ore is also found along closely spaced small east-west fractures. The ore bodies are as much as 30 feet wide.

The ore deposit in the Black Metal (Lane) mine contains 6 to 22 percent zinc and occurs in Lyndon(?) Limestone which may be overthrust. Some ore has been taken from a stope at the 110-foot level of an inclined shaft, the Lane shaft.

A few gold prospects occur along breccia zones in the quartzite in two places, one about 5 miles northwest of the Groom mine and another near the basalt cinder cone 12 miles north of the Groom mine.

Pahranagat (Hiko, Irish Mountain) District

(Manganese, silver, lead, copper)

Location

The Pahranagat (Hiko, Irish Mountain) district is on Mount Irish in the Pahranagat Range about 10 miles northwest of Hiko. The district is crossed by several graded dirt roads that connect with Nevada Highways 25 and 38.

History and production

This district has a long history (Stretch, 1867, p. 64-66; Browne, 1868, p. 339-340, 426-429). It was discovered in 1864 by an Indian of the Pahranagat tribe, who showed it to a party of prospectors in 1865. A thousand locations were made, and to accommodate the new district, Lincoln County was formed on February 26, 1866 from a part of Nye County. The county seat was first Crystal Springs and then Hiko before it was moved to Pioche in 1871. Production never met expectations, and it is doubtful if, until the last decade, the district ever produced as much as was spent on development.

In 1867 Messrs. Raymond and Ely erected an unsuccessful 5-stamp mill at Hiko, which in 1869 was moved to Pioche. This mill failed because the sulfide ore required roasting before milling. Later two more-successful mills were erected, a 5-stamp mill at the List mine and a 10-stamp mill at the Crescent mine. The ores processed in these mills were readily amalgamated after roasting. Several unsuccessful attempts were made to smelt the ores, and the stack of one of these smelters still stands in the vicinity of the Crescent mine.

Raymond (1869, p. 115) reports that $1,000,000 was spent in 1868, but only $20,000 in bullion had been shipped up to this time. The following year (1870, p. 201) he estimated the total production at no more than $80,000. The district was largely abandoned after the discovery of the rich ores at Pioche. Only a small sporadic production had been reported until 1951 (table 18), when the South Paw mine began shipping manganese to the government stockpile. The production from the South Paw, about $630,000, far exceeds the total for the rest of the district. The total production from the district is $801,400.

Geology

The geology east of Mount Irish is complex, but that of the mountain itself is simple. It is composed of lower Paleozoic rocks that dip gently westward. These rocks include the Pogonip Group, the Eureka Quartzite, and the Ely Springs and Laketown Dolomites. These rocks are inferred to be part of a major prevolcanic thrust plate that has overridden the complexly faulted upper Paleozoic rocks exposed on the east side. The overridden rocks range from the Guilmette Formation to the Scotty Wash Quartzite. A major zone of steep north-south faults complicates the thrust relationship and obscures a large overturned fold inferred to exist beneath the thrust. Post-thrust faulting may have rotated the beds so that the thrust is now steeper than originally. Mapping at a larger scale would be necessary to work out in detail the generalized relationships shown in plate 2.

Nearly all of the silver veins and the manganese deposits occur in the overthrust Ordovician rocks. Most of the silver veins are confined to limestones in the Pogonip Group, but the manganese deposits occur in the Ely Springs Dolomite.

Table 16. Principal mines of the Highland district and outlying areas.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Mendha	15	1 N.	66 E.	Pb, Ag, Au	Replacement fissure vein and related bedded replacement deposits in the Mendha Formation. Strikes N. 85° W., dips 75° N. and is 1 to 4 ft thick. Bedded replacement ore adjacent to vein is as much as 7 ft thick. Maximum values of 58 samples were as high as 0.7 oz Au, 87 oz Ag, and 36 percent Pb. Ore was limonite-stained jasper and lead carbonate. The vein was stoped to a depth of about 350 ft. The lower 130 ft of the shaft develop bedded ore.	Total production may be $1,158,500; it certainly exceeds $158,000. Developed by a 780-ft 30° inclined shaft, two vertical shafts, and 9 levels to a depth of about 600 ft. Westgate and Knopf (1932, p. 73-74).
Hamburg	15	1 N.	66 E.	Pb, Ag	Replacement fissure vein less than 1 ft thick in Mendha Formation strikes east and dips steeply north. Ore is chiefly limonite or red jasper and lead carbonate which locally replace wall rock. Vein cut by 5-ft dike of biotite dacite vitrophyre which has a microscopic texture typical of welded tuff.	Tunnel follows the vein. 2,671 tons of ore mined between 1916 and 1924 were worth $87,100. Couch and Carpenter (1943, p. 88); Westgate and Knopf (1932, p. 74-75).
Highland Queen	14	1 N.	66 E.	Ag, Au, Pb	Vein strikes N. 70° W.	Produced 992 tons of silver-gold ore in 1939 under lease by Walker and Bernard. Mining World (1940, v. 2, no. 2, p. 31).
Highland Mary	15	1 N.	66 E.		Vein in Mendha Formation.	
Lucky Jim	15, 14 22, 23	-------	-------	----------	do.	
National Group	15	1 N.	66 E.	----------	Three east-trending fissures in Mendha Formation.	
Last Chance	23	1 N.	66 E.	----------	Vein in Mendha Formation.	
Black Prince	26	1 N.	66 E.	Pb, Ag, Mn	Black Prince fissure can be traced 7,000 ft on surface in thrust plate of Mendha and Highland Peak Formations which rest on volcanic rocks. An altered granite porphyry dike parallels footwall of fissure. Dike and limestone on footwall are also mineralized. Values increase down shaft. Ore up to 35 ft thick. Siliceous manganese ore averages 13 percent Mn, 7 oz Ag, and 1 percent combined Pb-Zn. Maximum lead content is 5 percent.	Production reported to be 250 to 300 tons of silver(?) ore.
Blue Bell	9	1 N.	66 E.	----------	Geology unknown.	
Florence	5	1 N.	66 E.	----------	Vein in dolomite in Highland Peak Formation.	
Lucky Boy	9	1 N.	66 E.	----------	Vertical shaft cuts outer part of pyrometasomatic aureole of Manhattan quartz monzonite.	

Manhattan	8	1 N.	66 E.	Pb, Ag, Au	Elliptical area 2,700 by 3,900 ft of gossan of oxidized pyrite-garnet rock and tactite surrounds a small mass of sericitized quartz monzonite. Manhattan fissure strikes northeast and dips 70° SE. Fissure contains chalcopyrite and galena and is 3 to 5 ft wide in the adit.	Produced 248 tons of ore in 1939. Mining World, (1940, v. 2, no. 2, p. 31). Contact metamorphic rocks described by Gillson *in* Westgate and Knopf (1932, p. 41).
X-ray adit	16	1 N.	66 E.		Vein in Highland Peak Formation.	
Mountain Lion	17	1 N.	66 E.	Pb, Ag	In overthrust plate of Mendha Formation or Burrows Member (unit B) of Highland Peak Formation. Shaft 370 ft deep crosses thrust and enters Pioche Shale at 310 ft. Some ore mined on 200-ft level.	One car of ore shipped in 1930 and smaller amounts in 1928 and 1929 (Mineral Resources, 1928 and 1929).
Gypsy	— Location unknown —			Ag	----------	One car of silver ore shipped in 1921.
Yankee Boy	— Location unknown —			Ag(?)	----------	Several lots of ore shipped in 1921.
Forlorn Hope	29	1 N.	66 E.	------	----------	600-ft vertical shaft.
Outlying mines						
Dave Mathews lead	24	1 N.	65 E.	Pb	Lead in Mendha Formation.	Near Irmine and Postum mine; exact location unknown.
Irmine and Postum (Irvine and Bauers)	24	1 N.	65 E.	Au	Leaf gold deposited along planes of fracture and foliation in shale layer in the Mendha Formation. Gold ore in 50-ft inclined shaft is reported to be 12-18 in thick. A 10-ft limestone is replaced by iron and manganese oxides. Quartz-galena vein in limestone up to 1 ft wide strikes N. 65° W. and dips 65° N., is developed by 80-ft adit.	Two cars of gold ore were shipped. 35 tons were shipped to McGill smelter. Wheeler (1940, p. 13); W. T. Benson (written communication, 1945).

Table 17. Production of the Groom district, 1915-1956.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1956	1	764	400	66,300	— —	$ 11,300
1954	1	990	1,300	152,200	— —	22,200
1953	—	333	500	52,500	— —	7,300
1952	1	1,044	400	64,200	— —	11,400
1951	—	3,437	3,400	409,400	— —	74,800
1950	1	1,076	1,200	159,000	— —	22,700
1949	—	1,205	— —	175,600	— —	28,800
1948	2	3,484	1,700	318,600	— —	60,600
1947	—	6,109	4,600	397,000	28,000	67,100
1946	—	8,530	2,900	717,400	11,100	87,300
1945	5	8,304	4,000	636,000	— —	61,100
1944	3	6,040	— —	444,000	— —	39,900
1943	—	2,828	— —	203,500	— —	17,300
1942	—	5,549	1,800	382,600	— —	29,900
1938	—	80	— —	13,600	— —	700
1937	3	808	600	60,100	— —	4,300
1936	—	349	— —	28,345	— —	1,600
1933	6	1,573	268	81,342	— —	3,700
1928	—	— —	— —	— —	— —	[1]6,600
1927	—	— —	— —	— —	— —	[1]7,800
1926	—	— —	— —	— —	— —	[1]11,500
1925	13	4,700	1,274	307,245	— —	30,200
1924	—	3,326	— —	232,250	— —	[1]14,000
1923	—	— —	— —	— —	— —	[1]6,200
1918	—	— —	— —	— —	— —	[1]90,400
1917	—	— —	— —	— —	— —	[1]113,900
1916	—	— —	— —	— —	— —	[1]94,400
1915	—	— —	— —	— —	— —	[1]8,900
Totals[2]	36	60,529	24,342	4,901,182	39,100	$935,900

1. Couch and Carpenter (1943).
2. Humphrey (1945, p. 35) reports the 1915-1932 production equaled 16 oz Au, 93,957 oz Ag, 50,162 lb Cu, and 6,094,908 lb Pb with a total value of $531,200.

Mineral deposits

The most productive deposits are those of the manganese mined since 1950. They are gently dipping pyrolusite-rich replacement lenses in brecciated Ely Springs Dolomite along bedding-plane faults near the upper contact of the Eureka Quartzite. The ore bodies occur in an east-striking graben about 1,000 feet wide and several thousand feet long, which is broken by four east-west faults with minor displacements. The best ore is soft and is not exposed at the surface. Nearby jasperoid deposits contain too little manganese to be of economic value.

Manganese production began in November 1950, and by May 1, 1952, about 600 long dry tons of 37 percent ore worth $26,000 had been produced. Total production through 1956 was about 17,300 dry short tons of ore, containing between 32 and 43 percent manganese and averaging about 36 percent. The known deposits were then about exhausted, and a Defense Minerals Exploration Administration drilling project in 1958 did not find new ore. The total value at the railroad shipping point to the end of 1958 was $630,300, of which 80 percent was bought by the General Services Administration for stockpiling. The South Paw mine was mostly inactive between 1958 and 1960.

Little is known of either the silver veins or the location of most of the old mines. However, a few old mines were visited, but they were not carefully studied. The following descriptive matter is taken largely from the early reports of Raymond, Browne, and Stretch, all of which were written prior to 1871. Raymond (1870, p. 196) states in part:

> "* * * the principal ore deposits extend along the precipitous eastern slope of Mount Irish * * * There are numerous fissures, running apparently in every direction; but * * * there is but one master lode, generally called the Hyko lode, coursing nearly parallel with the crest of the range, dipping easterly and traced on the surface and by mining for a distance of five miles."

The Illinois (Lovell), Indiana, Soledad, Chimney, Cocomongo, and Yellow mines were on the Hyko lode. This vein is presumably along one of the faults shown on plate 2. According to Stretch (1867, p. 64-66), the veins are generally 2 to 15 feet wide and dip 70° or more. Transverse veins are numerous. The vein material was quartz and calcite and near the surface contained cerargyrite and argentiferous galena. Stetefeldite (mixed oxides of silver, copper, and antimony) and oxides of lead and iron were reported to occur. Copper carbonates are common on the outcrop and copper sulfides occur in the primary ore.

Table 18. Production of the Pahranagat district, 1867-1957.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead[1] (pounds)	Manganese ore tons (percent Mn)	Total value
1957	—	— —	— —	— —	787	
1956	—	— —	— —	— —	2,899 (35)	
1955	—	— —	— —	— —	3,736 (40)	
1954	—	— —	— —	— —	950 (30)	$630,300
1953	—	— —	— —	— —	— —	
1952	—	— —	— —	— —	1,421	
1951	—	— —	— —	— —	616	
1949	—	136	— —	500	— —	200
1948	—	1,107	1,400	7,300	— —	2,600
1947	1	4,479	7,000	17,000	— —	8,100
1945	—	419	— —	1,000	— —	400
1943	1	1,242	900	9,900	— —	1,800
1942	—	1,017	500	15,400	— —	1,800
1941	14	6,300	2,000	16,900	— —	6,200
1940	4	7,172	1,900	10,100	0	6,000
1939	2	5,430	2,100	9,700	0	4,400
1938	—	2,818	1,600	8,000	0	2,300
1937	2	3,200	700	13,000	0	3,400
1934	1	1,206	700	2,400	0	[2]1,000
1915-1932[3]	—	— —	— —	— —	0	[3]5,200
1912	—	— —	— —	— —	0	[2]4,000
1899	—	— —	— —	— —	0	[2]4,100
1898	—	— —	— —	— —	0	[2]1,400
1895	—	— —	— —	— —	0	[2]4,200
1885	—	— —	— —	— —	0	[2]2,900
1880-1883	—	— —	— —	— —	0	[2]9,900
1874-1875	—	— —	— —	— —	0	[2]1,200
1869-1870	—	— —	— —	— —	0	[4]80,000
1867-1868	—	— —	— —	— —	0	[4]20,000
Totals	25	34,526	18,800	111,200	10,409	801,400

1. Total recorded zinc production is 1,100 pounds.
2. Couch and Carpenter (1943, p. 85).
3. Nolan (in Hewett and others, 1936, p. 63).
4. Reported by Raymond (1869, p. 115; 1870, p. 201).

Fifty tons of ore from the Illinois mine yielded $112 a ton in silver. Browne (1868, p. 339-340) reports the surface ores contain between $50 and $500 in silver.

The vein at the property of Rosario Arcurio, on the south slope of Mount Irish, is a quartz vein 6 to 8 inches wide, which strikes N. 55° W. and dips about 70° NE. This vein has been explored for a length of 300 feet and a depth of 100 feet. The ore bodies are in limestones of the Pogonip Group; they are narrow and lenticular and contain limonite, cerussite, anglesite, and malachite. A shipment of 200 tons is reported to have averaged 2.4 percent copper, 5 percent lead, 32 ounces of silver, and 0.013 ounce of gold per ton.

Two fluorspar deposits have been reported in the Hiko district, but this report was not confirmed. One vein, supposedly from a fissure on the "highway" 12 miles west of Hiko, is reported to contain chlorite, calcite, and quartz.

The available information on the mines is summarized in table 19.

Comet District

(Silver, lead, zinc. manganese, tungsten, gold)

Location

The Comet district extends along the west side of the Highland Range and is considered to include the properties south of lat 37°55′ N. It adjoins the Highland district on the north and east and the Ely Springs district on the west. The district is about 10 miles west of Pioche. It is served by improved gravel roads to the Comet mine from the paved road at Caselton (Nevada Highway 83) and by unimproved roads along the range front.

History and production

The ores of the Comet district were discovered in 1882 (Lincoln, 1923, p. 119), but production prior to 1895 is unknown. Silver-lead ore containing small amounts of gold and copper was shipped intermittently from the district between 1895 and 1898 and between 1913 and 1920. Most of this early production came from the Schodde mine, which is reported to have produced about $125,000 during World War I.

The Comet mine was relocated in 1906, and, although additional claims were staked in 1913, production before 1924 is not recorded. Silver, lead, zinc, gold, and tungsten were produced from oxidized ore in the Comet mine between 1925 and 1950. Between 1945 and 1951, 13,700 tons of sulfide ore were mined.

Between 1947 and 1955 about 17,000 tons of low-grade manganese ore containing small amounts of silver, lead, and zinc from the Pan American were mined and milled for metallurgical testing.

The annual production of the Comet district is given in table 20. The total value of the metals produced from the district is $764,100.

Geology

The geology of the Comet district is simple (fig. 26). The west side of the Highland Range is composed of a homoclinal series of Cambrian rocks that strike north and dip gently east. The Cambrian rocks include the upper part of the Prospect Mountain Quartzite, the Pioche Shale, the Lyndon Limestone, and the lower part of the Highland Peak Formation. The lowest limestone in the Pioche Shale, the productive Combined Metals Member, is 80 to 100 feet thick, compared to about 50 feet at Pioche.

The following stratigraphic section from the mine sections of the Combined Metals Reduction Co. gives the approximate thicknesses of the Cambrian rocks that contain the ore deposits of the district.

	Thickness (feet)
Peasley (Davidson blue limestone) Member of Highland Peak Formation	150
Chisholm Shale	150
Lyndon Limestone	
White Prince limestone	190
Blue Prince limestone	190
Pioche Shale	
A shale	320
Sandstone	60
B shale	185
Susan Duster limestone	15
C shale	95
Combined Metals Member	80
D shale	230
Prospect Mountain Quartzite	

The mineral deposits occur in the Prospect Mountain Quartzite, Pioche Shale, and Lyndon Limestone below a major overthrust plate of Upper Cambrian rocks (Highland thrust plate, pl. 3) that is inferred to extend beneath the alluvium all along the west flank of the range. This thrust plate probably once extended over the entire district before erosion removed it.

Four veins, the largest of which is developed by the Comet mine (fig. 26), cut the Prospect Mountain Quartzite and the Pioche Shale in the Comet area. These veins, which strike about N. 60° E. and dip nearly vertically, are as wide as 13 feet in the quartzite but narrow to mere veinlets in the shale. The veins can be traced on the surface for about 1,400 feet (not shown on the geologic map). The fissures in the Lyndon Limestone at the Schodde mine have the same general strike and are parallel to several irregular lamprophyre dikes which contain some galena (Westgate and Knopf, 1932, p. 75).

Table 19. Principal mines of the Pahranagat district.
(u, unsurveyed)

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
South Paw (Steward-Bush)	20	3 S.	59 E.	Mn	Soft pyrolusite-rich lenses occur in graben in brecciated gently dipping Ely Springs Dolomite. Low-grade siliceous manganese ore crops out along four fissures at surface.	Production 1950 through 1956 totals 17,334 dry short tons containing 32 to 43 percent Mn and averaging about 36 percent. Total value was $630,300.
Gentry prospect	----	------	-------	Mn	Stringers of manganese oxides in limestone in area 50 by 100 ft. Maximum width of stringers is 6 ft. About one-fifth of width contains about 11 percent Mn.	Near South Paw mine; exact location unknown.
Ora Lovell (Illinois, Silver Prince)	29(?)	3 S.	59 E.	Ag, Pb	Quartz vein 3 to 6 ft thick strikes about N. 70° E. and dips 75° to 90° SW. Developed by two 100-ft vertical shafts about 225 ft apart with a connecting drift.	Illinois claim worked between 1868 and 1897. Silver Prince mine active prior to 1923. Total production unknown. In 1868, 50 tons mined from open cut yielded $112 per ton at mill, or $5,600. Four-ft chip sample by U.S. Bureau of Mines contained 0.005 oz Au and 10 oz Ag per ton, 4.4 percent Pb, and 0.2 percent Cu. R. R. Trengove (written communication, 1951).
Rosario Arcurio (Rosey)	1	4 S.	58 E., u.	Ag, Pb, Cu	Vein 6 to 8 in wide strikes N. 55° W. and dips 70° NE. Narrow lenticular ore bodies in limestone of the Pogonip Group along vein contain quartz, limonite, cerussite, anglesite, and malachite.	200-ton shipment averaged 2.4 percent Cu, 5 percent Pb, 32 oz Ag and 0.013 oz Au per ton.
Crescent	11, 12(?)	4 S.	58 E.,u.	Ag, Pb	Geology unknown.	Several tons at Crescent mill yielded $80 per ton in 1867. In 1868, 50 tons yielded $1,920 in silver. R. R. Trengove (written communication, 1951).

Table 20. Production of the Comet district, 1895-1952.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value
1952	—	— —	— —	— —	— —	$ 21,300
1951	20	3,472	18,700	88,800	248,100	68,900
1950	19	1,613	2,400	27,200	104,800	21,200
1949	104	17,226	9,000	99,100	497,900	98,400
1948	114	27,499	29,700	158,600	821,100	172,900
1947	105	16,157	200	99,000	207,200	57,700
1946	42	9,516	— —	70,900	455,900	72,500
1945	22	1,956	— —	20,000	70,600	12,000
1944	58	2,413	800	22,300	5,500	6,300
1942	7	191	— —	100	— —	400
1941	98	3,510	400	8,400	— —	6,500
1940	193	6,761	1,300	29,100	— —	13,200
1939	66	8,942	900	61,900	— —	11,400
1938	109	15,857	500	165,500	— —	21,700
1937	144	17,045	1,000	276,500	— —	34,700
1936	130.38	24,579	573	284,956	— —	36,800
1935	38.93	13,420	898	160,702	— —	17,500
1934	62.24	14,759	1,284	229,903	— —	20,300
1913-1932[1]	168	48,531	7,176	231,420	— —	64,900
1912	—	— —	— —	— —	— —	[2]600
1898	—	— —	— —	— —	— —	[2]800
1896	—	— —	— —	— —	— —	[2]2,200
1895	—	— —	— —	— —	— —	[2]1,900
Total						$764,100

1. Nolan (in Hewett and others, 1936, p. 62).
2. Couch and Carpenter (1943).

Mineral deposits

Quartz veins and bedded replacement deposits occur in the district. The primary ore in the quartz veins, principally the Comet vein, contains galena, sphalerite, pyrite, wolframite, scheelite (minor), argentite, and gold. The oxidized ore contains plumbojarosite, cerussite, and limonite. The Comet vein averages 6 feet in width and contains four ore shoots in the wider parts. A parallel fissure several hundred feet north of the Comet vein is reported to contain as much as 1.4 percent WO_3, but this vein has not been developed.

Bedded replacement deposits, 10 to 15 feet thick, occur in the lower part of the Combined Metals Member of the Pioche Shale at the Pan American mine and in or near the base of the Lyndon Limestone at the Schodde mine. Three diamond drill holes by the U.S. Bureau of Mines (Trengove, 1949) near the Schodde mine show that 12 to 15 feet of low-grade sulfide ore occur in the Combined Metals Member at depths between 590 and 1,250 feet. The grade is comparable to that in the Pan American mine and the mineralized ground may be continuous between the two mines. The average grade is about 1 ounce silver, 1 percent lead, 3 percent zinc, and 7 to 9 percent manganese. Drill hole 3 in Lyndon Gulch cut 10.5 feet of higher grade ore that contained as much as 4.6 ounces silver, 3.7 percent lead, and 7.8 percent zinc. An additional 5 feet in this hole had a metal content near the average figures. The primary ore contains pyrite, sphalerite, argentiferous galena, and manganosiderite similar to the bedded replacement ore in the Pioche district.

The available information on the principal mines in the Comet district is summarized in table 21.

Eagle Valley (Fay, Deer Lodge), Gold Springs, and Stateline Districts

(Gold, silver, uranium)

Location

The Eagle Valley (Fay, Deer Lodge), Gold Springs, and Stateline districts are contiguous areas near the Nevada-Utah State line between 14 and 21 miles from the railroad at Modena, Utah, and about 10 miles east of Eagle Valley. The Stateline district, most of which is in Utah, is about 14 miles north of the Eagle Valley and Gold Springs districts and about 16 miles west of Modena, Utah. As used in this report, the term Eagle Valley district, Nevada, includes the Deer Lodge district north of Deer Lodge Canyon, and the Fay district south of this canyon and north of Buck Mountain. The Fay district appears to have been named for a ghost camp in Deer Lodge Canyon west of the Hackett Ranch. The Gold Springs district is east of Buck Mountain and is mostly in Utah. The districts are reached by unimproved dirt roads.

History and production

The ore deposits in the Stateline and Deer Lodge districts were discovered about 1896 and were active for

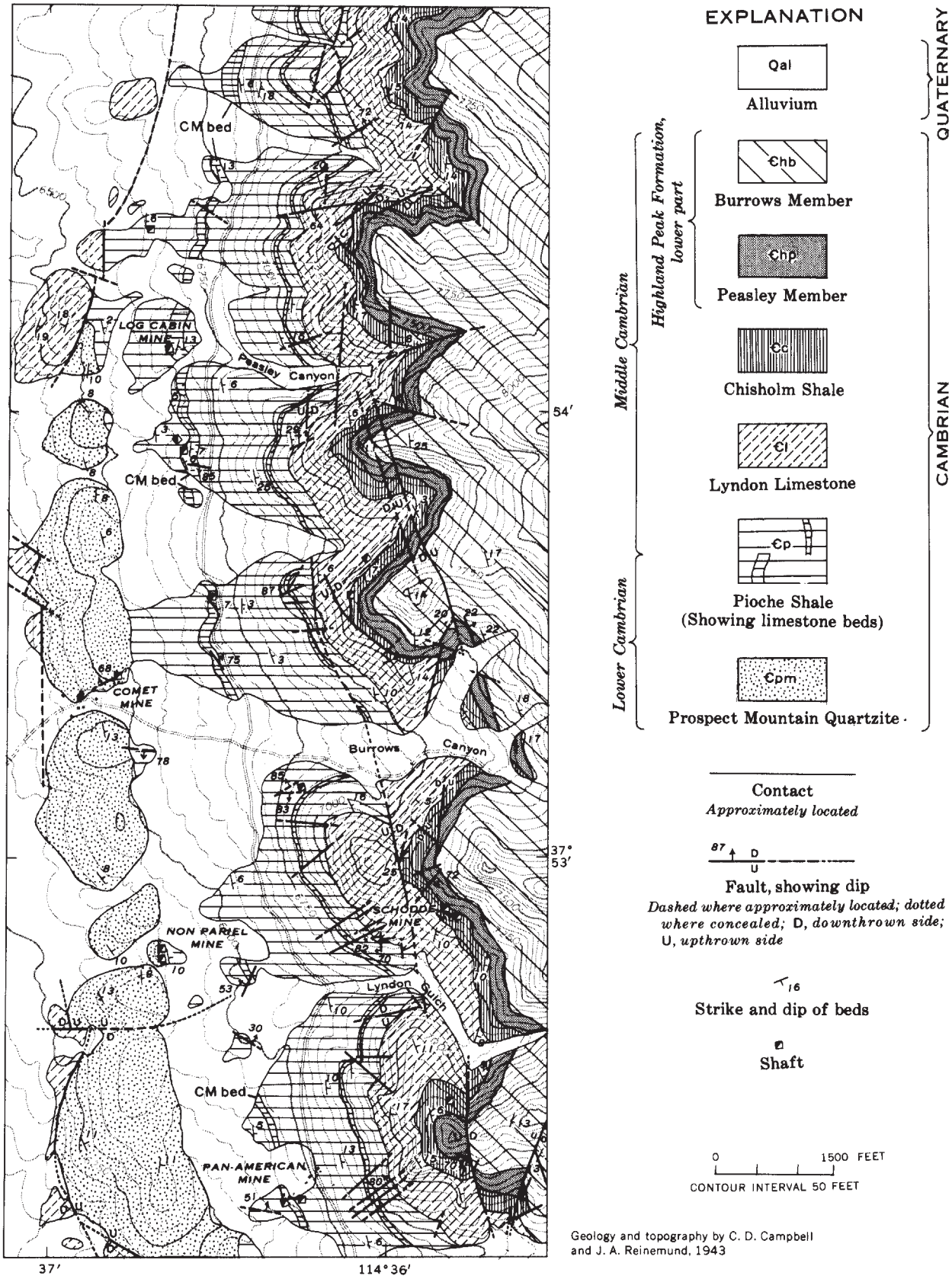


FIGURE 26. Geologic map of the Comet district.

Table 21. Principal mines of the Comet district.
(u, unsurveyed)

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Comet	5, 6	1 S.	66 E., u.	Pb, Zn, W	Four quartz veins which strike N. 50°-65° E. crop out discontinuously in the Pioche Shale for about 1,400 ft. The largest, the Comet vein, is 1-15 ft thick in the Prospect Mountain Quartzite and averages 6 ft where mined. The ore shoots are generally in the wider part of the vein and are localized by small changes in attitude of the vein where nearly horizontal movement has brecciated the quartz. The primary ore consists of chalcopyrite, sphalerite, galena, and some wolframite.	Total production has been 1,500 tons of oxidized ore, and 14,200 tons of sulfide ore, and 141 tons of concentrate. Total tungsten production value is probably in excess of $400,000. The sulfide ore averages 0.05-0.2 oz Au and 5-10 oz Ag per ton, 2-4 percent Pb, and 8-15 percent Zn. Westgate and Knopf (1932, p. 75).
Non Pareil	8	1 S.	66 E., u.	Au, Ag(?)	North-south(?) quartz vein near base of Pioche Shale.	Production unknown.
Pan American	9	1 S.	66 E., u.	Mn, Zn	Oxidized low-grade bedded replacement deposits in the Combined Metals Member of the Pioche Shale. Reserves containing 2 oz Ag per ton, 1 percent Pb, 2.5 percent Zn, and 9 percent Mn probably exceed a million tons. Mineralized limestone probably extends as far as the Schodde mine. Shaft follows Combined Metals Member and is low-grade oxidized ore to the end.	Between 1947-1955 about 17,000 tons containing about 1 oz Ag, 1 percent Pb, 2.5 percent Zn and 7 percent Mn per ton were mined and milled as a trial run. Operation under 1960 conditions was uneconomic. Production value estimated to exceed $170,000. Ore developed by a 2,300-ft 12° inclined shaft. Trengove (1949).
Log Cabin	31	1 N.	66 E.	Pb, Zn(?)	----------	800-ft inclined shaft.
Schodde (Lyndon)	9	1 S.	66 E., u.	Ag, Pb	Bedded replacement deposits occur in the Lyndon Limestone, and in the Combined Metals Member of the Pioche Shale. The production was from the upper 6-8 ft of Lyndon Limestone at its intersection with several vertical fissures that strike N. 70° E. near several small premineral lamprophyre dikes. Three diamond drill holes by the U.S. Bureau of Mines cut 12-15 ft of low-grade primary silver-lead-zinc manganese ore in the Combined Metals Member.	Reported to have produced about 1,000 tons of Ag-Pb ore worth $125,000 during World War I. Trengove (1949); Westgate and Knopf (1932, p. 75).

only a few years. Considerable production was recorded between 1900 and 1904. The Horseshoe mine in the Fay district produced 39,342 tons of ore worth $269,000 between 1900 and 1902.

The Gold Springs district was discovered about 1897, but active development did not begin until several years later. By 1908 the town of Gold Springs had a population of 250. The two most productive properties in the Gold Springs district were the Jennie mine in Utah, which produced about $52,900, and the Snowflake group on the east side of Buck Mountain in Nevada, which is estimated to have produced at least $31,000 prior to 1903. The Gold Springs district was undergoing active development in 1908 (Higgins, 1908) and considerable production was reported between 1907 and 1911.

The mines in Nevada were inactive between 1911 and 1930, but a small production was recorded during the 1930's and 1940's. The total recorded production in the Nevada part of the districts was about $423,000, as shown in table 22. As far as is known, all of the producing mines in the Stateline district were in Utah. There were mills at the Horseshoe mine in the Fay district, the Jennie mine in the Gold Springs district, and the Ophir and Johnny mines in the Stateline district, Utah. The Johnny mine produced $30,000 between 1900 and 1902 (Smith, 1902) and the Ophir produced at least as much. The Jennie mine produced 12,200 tons of ore containing $48,100 in gold and 8,441 ounces of silver, with a total value of $52,900 (Butler and others, 1920, p. 563). The Statz mine in the Stateline(?) district, Utah, shipped a considerable amount of uranium ore in 1956 and later.

Geology

We visited briefly but did not study the ore deposits of the Stateline, Deer Lodge, Fay, and Gold Springs districts. Most of the following description is from Butler and others (1920, p. 563-567), Smith (1902, 1908) and Higgins (1908). The geology of the entire area is discussed as a unit, but the veins in each district are individually described.

All the known mineral deposits are in volcanic rocks, which cover the entire area except for a ridge of the Highland Peak(?) Formation west of the Stateline district. The oldest volcanic rocks are andesitic and latitic flows, tuffs, and breccias, which are overlain by light-colored platy rhyolite that caps the higher hills. The structure is generally simple and the volcanic rocks are nearly horizontal.

The volcanic rocks are cut by many north-south veins, and the rocks near the veins, especially the older volcanic rocks, are altered in most places. The mafic minerals in the latitic rocks are generally chloritized, and the wall rocks along the veins are commonly bleached or silicified. The gold-bearing veins in the Stateline district are in silicified and iron-stained altered rhyolite, or rarely, in andesite.

Mineral deposits

Both north-south and east-west vein systems exist in the Stateline district, Utah. The principal north-south veins in this district, according to the map by Smith (1908, p. 16), are, from east to west, the Blackbird, Gold Eagle, Grand Central, Hard Times, Jumbo, Aggie D, Gold Belt-Utica, Willowvale, Free Coinage-Crown Point, Big 14, Sulphate, Hope, High Line-Venus, Burro, and Little Giant. The last five veins have a high silver-to-gold ratio. These veins generally dip 50°-70° W. All the other veins are characterized by gold with little silver.

The two most productive mines, however, were on a big discontinuously exposed east-trending vein. The ore from the Ophir mine on the west end of this vein is characterized by a high silver and a low gold content, but the Johnny mine on the east end and the Margaret mine between are characterized by equal parts of gold and silver. Much of the gold occurs as telluride. The ore shoots in the Ophir-Margaret-Johnny vein, which dips 65° N., occur at or near intersections with the north-south fissures and rake northwestward about 45°.

There are three northeast-striking veins and one northwest-striking vein besides those already named. The veins are generally between 3 and 6 feet wide but in the ore shoots locally widen to 10 feet. The vein filling is

Table 22. Production of the Eagle Valley district, 1900-1951.

(e, estimate)

Year	Gold (ounces)	Silver (ounces)	Total value
1951	1	1,344	$ 1,300
1949	1	634	600
1948	2	1,077	1,000
1943	7	49	300
1942	101	578	3,900
1941	44	270	1,700
1939	150	701	5,700
1938	42	206	1,600
1937	344	11,505	[1]21,200
1936	93	16,883	[1]16,300
1935	154	2,068	7,000
1934	58	4,978	5,600
1933	146	392	3,200
1932	5	118	100
1931	——	——	500
1910	159e	3,968	8,700
1909	149e	118e	3,200
1904	——	——	[2]15,500
1903-1932[3]	3,693	12,795	[3]84,600
1902	——	——	[2]23,900
1901	——	——	[2]155,500
1900	——	——	[2]89,600
Total			$423,000

1. From Bluebird and Helen mines.
2. Couch and Carpenter (1943, p. 84).
3. Nolan (in Hewett and others, 1936, p. 62).

fine-grained quartz, brecciated quartz, and volcanic rock. The veins contain considerable fluorite and manganese oxides.

Carbonate is less abundant and pyrite more abundant in the Stateline district than at Fay or Gold Springs. The ore generally had a value between $5 and $20 per ton (old price) but some ore worth $60 a ton was shipped and several hundred tons from the Ophir mine had a value of $100 per ton.

The principal veins in the Gold Springs district, from east to west, are the Jumbo, Independence, Jennie, Talisman, and Snowflake, but only the Snowflake is in Nevada (Butler and others, 1920, p. 367). Most of these strike north and dip steeply east. The Jennie vein can be traced for 2,200 feet and generally is 6 to 10 feet wide, but some stopes are as wide as 19 feet (Higgins, 1908, p. 16). There are eight other distinct veins on the Jennie property.

The Independence vein is 15 to 20 feet wide, and the ore had a value of $10 to $12 per ton. The Snowflake vein extends more than 6,000 feet along the east side of Buck Mountain and reaches a maximum width of nearly 100 feet. A shipment from a shaft near its south end on the Snowflake No. 5 claim assayed $660 per ton. Farther north 2,550 tons of $10 to $15 ore were mined from an open cut on the Snowflake claim. Still farther north on the Buck claim, the vein is developed by two shafts, one 135 feet deep and the other 150 feet deep. Several lots of ore from the Buck claim brought about $60 per ton. A smaller vein on the Charley Ross claim, in the Mountain View group of claims, has been developed by a 175-foot shaft on a "body of talc ore forty feet wide." This body is good milling ore, containing streaks assaying as high as $3,000 per ton. Shipments have given returns as high as $2,900. This rich ore is reported to contain gold telluride and sylvanite (Higgins, 1908, p. 15-18).

The principal veins in the Fay and Deer Lodge districts are the Horseshoe, Homestake, Iris, and Deer Lodge. The most productive mine was the Horseshoe, which produced more than 39,300 tons of ore worth $269,000 between 1900 and 1902. Some of these veins, like those in the Gold Springs district, extend into the rhyolite, but most of the production has come from veins in the latite. The prominent vein north of Deer Lodge Canyon, which is developed by the Helen, White Horse (Silver Star) and Gypsy claims, strikes N. 30° E., dips 40° SE., and can be traced for 3 miles.

The veins in all these districts are crustified fissure fillings that consist of chalcedonic and comb quartz, yellowish adularia, lamellar carbonate, fluorite, pyrite, copper carbonates, and free-milling gold. Native mercury is reported from several mines and was recovered by panning at the Homestake mine. Cerargyrite occurs in a prominent vein northwest of Deer Lodge on the White Horse (Silver Star) claim and molybdite occurs in the Jumbo lode in the Gold Springs district. The veins in the Stateline district contain much pyrite and some tellurides (Butler and others, 1920). Autunite occurs in a prospect near the summit of the high peak at the head of Deer Lodge Creek. A sample from here contained 0.14 percent uranium.

The information on the mines in these districts is summarized in table 23.

Viola (Pittsburg, Cherokee) District

(Silver, copper, lead, zinc, mercury)

Location

The Viola (Pittsburg, Cherokee) district lies northwest of the Tule Desert and 8 to 11 miles east of Meadow Valley Wash, along the south edge of the Clover Mountains. The district is north of the graded Carp and Bunker Peak road, and is crossed by a dirt road.

History and production

Little is known about the history of this district, for apparently no records were kept, but there was some activity at least as early as the 1880's when the Cherokee vein was discovered by a Cherokee Indian. Since that time, however, there has been only sporadic or intermittent activity in the district. According to a local rancher, Paul Henrie (oral communication, 1956), one carload of ore containing 1,400 ounces of silver per ton was shipped from a property (Viola shaft?) east of the Cherokee mine in the early days. The total production from the district is unknown but it is probably less than $400,000, most of which came from the Wells Cargo fluorspar mine, which was opened in 1958 (table 24).

Geology

All the known mineral deposits occur in three isolated areas of pre-Tertiary rocks surrounded by Tertiary volcanic rocks. The western area, called the Cherokee area, is composed of Permian and Triassic rocks that strike northwest and dip northeast. These rocks strike at right angles to Mississippian and Pennsylvanian limestones in the second or Pittsburg area; a major prevolcanic fault zone must separate the two areas. The limestones in the Pittsburg area strike northeast and dip steeply northwest. Limestone beds of Mississippian and Pennsylvanian(?) Age in the third or Wells Cargo area have about the same attitude as those in the Pittsburg area.

Mineral deposits

Nearly all the mineral deposits in the Pittsburg area occur in Mississippian limestone, usually near the base of the overlying altered volcanic rocks. Large masses of jasperoid, which cap many of the hills, are believed to

Table 23. Principal mines of the Eagle Valley and Gold Springs districts.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
					Eagle Valley District	
Horseshoe	30	1 N.	71 E.	Au, Ag	Crustified epithermal quartz vein in latite.	Total production considerably exceeds the 39,300 tons of ore worth $296,000 produced between 1900 and 1902. Had a 90-ton cyanide plant in 1902; 120-ton plant in 1908. Tailings shipped in 1931. Small mill in 1941-1942. Couch and Carpenter (1943, p. 87); Lincoln (1923, p. 119).
Homestake	30(?)	1 N.	71 E.	Au, Ag	do.	----------
Iris	30(?)	1 N.	71 E.	Au, Ag	do.	30-ton amalgamation and cyanide plant in 1907. 30-ton arrastra in 1908. Lincoln (1923, p. 119).
Gypsy and Helen groups (Interocean, Bluebird, Silver Star, and White Horse claims)	18(?)	1 N.	71 E.	Ag, Au	Prominent vein strikes N. 30° E., dips 40° SE. Can be traced 3 miles.	Shipment (17 carloads?) worth $36,760 made in 1936-1937. Three carloads shipped from Gypsy and Helen in 1941. Two carloads shipped from Silver Star in 1947.
					Gold Springs District	
Snowflake group (Big Buck and Little Buck claims)	32(?)	1 N.	71 E.	Au, Ag	Snowflake vein strikes north for more than 6,000 ft. Maximum width 100 ft. Developed by at least 3 shafts.	Estimated to have produced at least $31,000. 2,550 tons of $10-$15 ore mined from open pit. Shipment from shaft assayed $660 per ton.
Mountain View group	32	1 N.	71 E.	Au, Ag	Vein developed by 175-ft shaft contained milling ore with very high-grade telluride-rich streaks.	Higgins (1908, p. 15-18).

Table 24. Combined production of the Viola and Pennsylvania districts, 1915-1959.
(e, estimate)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Fluorspar (tons)	Fluorspar value	Total value
1959	—	—	—	—	11,050	$363,000e	$363,000e
1953	39	320	—	—	0	0	1,700
1950	—	152	600	—	0	0	300
1949	2	310	1,200	300	0	0	600
1942	78	1,014	300	300	0	0	3,507
1941	163	2,025	1,400	—	0	0	7,310
1940	77	952	400	100	0	0	3,422
1939	—	167	—	—	0	0	113
1937	—	86	200	800	0	0	138
1935	0.04	41	—	—	0	0	31
1934	—	92	—	—	0	0	59
1915-1932[1]	—	—	—	—	0	0	5,000e
Totals	359.04	5,159	4,100	1,500	11,050	$363,000	$385,180

1. Nolan (in Hewett and others, 1936, p. 65) states, "Recorded production (Viola), 1915-1932, 100 tons of ore containing silver, copper, zinc, and lead, valued at less than $5,000."

have formed beneath the altered volcanic rocks. The limestone near some of the deposits is recrystallized or altered. The deposits in the Pittsburg area, except for a quicksilver deposit, are argentiferous lead-zinc-copper deposits. Some deposits contain appreciable amounts of cadmium, antimony, and molybdenum, according to semiquantitative spectrographic analyses.

The Cherokee vein and the principal normal faults in the Cherokee area are roughly parallel to the strike of the sedimentary rocks. The vein and the other metalliferous deposits, all argentiferous copper deposits, occur in the Kaibab Limestone. Although the upper part of the Permian red-bed section has been prospected for gypsum, none has been mined.

The Wells Cargo area contains manganese and fluorspar deposits. The manganese deposit (Culverwell mine) is in a fault zone that separates limestone and volcanic rock. It has been known for many years, but the Wells Cargo fluorspar deposits were not discovered until about 1957, after we had mapped the area. The fluorite occurs as replacement bodies in silicified limestone, but little is known of the geology of the important deposits.

The available information on the mines in the Viola district is summarized in table 25.

Atlanta and Silver Park (Silver Springs) Districts

(Silver, gold, uranium)

Location

The Atlanta and Silver Park (Silver Springs) districts, in the northern Wilson Creek Range near the junction with the White Rock Mountains, are about 50 miles by road northeast of Pioche and about 20 miles by graded dirt road northeast of U.S. Highway 93 at Pony Springs. The old Silver Park district is about a mile west of the Atlanta district proper but these districts are usually considered as one.

History and production

The ore deposits in the Silver Park district were discovered in 1869, and the first recorded production was in 1871. By 1872 two mines were in operation. Some very rich ore was hauled from Atlanta to Pioche for milling, but the ores were exhausted by 1878. The recorded production prior to 1878 was only about $31,500. The Atlanta district was largely inactive until after World War II except for brief flurries of activity in 1917, 1935, 1938, and 1939. In 1948 100 tons of siliceous low-grade gold ore from the Atlanta mine was shipped to the McGill smelter for use as a flux, and between 1953 and 1955 16,000 tons of fluxing ore was shipped which contained $6 to $12 in gold per ton and about 0.05 percent U_3O_8. The total value of this fluxing ore was $181,200. Two carloads of uraninite ore, which averaged slightly more than 0.30 percent U_3O_8, about 1 ounce of silver, and 0.03 ounce gold per ton, were shipped from the Blue Bird mine between 1954 and 1956. The total value of the silver, gold, and uranium produced in the district is estimated to be about $270,300, as shown in table 26.

Geology

Ordovician, Silurian, and Devonian sedimentary rocks crop out in the Atlanta district from beneath the volcanic rocks that cover most of the surrounding area. Limestones of the Pogonip Group and the Ely Springs and Laketown Dolomites are extensively replaced by jasperoid in certain zones. These zones are partly related to intersecting sets of faults and partly to brecciated areas, although the jasperoid is not entirely confined to such zones. All the ore mined came from the jasperoid zones, and most of them are anomalously radioactive.

Hill (1916, p. 114-120) described the district and published a sketch map. A reconnaissance geologic map of the Atlanta area made by Sharp and Myerson (1956) of the U.S. Atomic Energy Commission was included as

part of a brief report on the Blue Bird mine. These maps are not in close agreement because the structure is complex and without fossils the similar dolomites cannot be readily distinguished.

Mineral deposits

The ores in the Atlanta, Bradshaw, and Solo Joker mines occur in silicified breccia zones along faults. Hill (1916, p. 117) states:

> "At the Bradshaw the rich silver minerals occur in fractures in a dense, very hard, red jasper. The ore zones at the Atlanta and Solo Joker are more open breccias, consisting of fragments of limestone, rhyolite tuff, quartzite, chert, and jasper, partly cemented by quartz, and containing much limonite and some pyrolusite. Some of the ore from these properties has the cellular platy structure commonly developed in veins of the late Tertiary period of mineralization. In this kind of ore the quartz is seen to be replacing barite."

Silver is economically important in all the ore, but in the Atlanta ore free-milling gold predominates and carnotite is also found (Hewett, 1923). The unoxidized ore at the Blue Bird mine is fine-grained pyrite and uraninite. Hill (1916) states that the ores of the Silver Park district contain oxidized silver, lead, and copper minerals and occur as replacement veins in dolomite.

An interesting vein of tungstenian psilomelane less than 2 feet thick occurs in the volcanic rocks on Rosencrans Peak about 4 miles due south of the Atlanta mine. The manganese oxides have an unusually high barium and tungsten content and contain appreciable thallium (Hewett and others, 1963, p. 21).

The available information on the principal mines is summarized in table 27.

Chief (Caliente) District

(Gold, silver, lead)

Location

The Chief (Caliente) district covers about 1 square mile on the east slope of the Chief Range in T. 3 S., R. 67 E. (unsurveyed). It is 3 miles by unimproved road west of U.S. Highway 93 and 5 miles due north of Caliente. Most of the following information, except that on the regional geology, is from the brief geologic report of the Chief district by Callaghan (1936).

History and production

The ore deposits in the Chief district were probably discovered about 1868 shortly after the initial discoveries near Pioche. The district was organized in 1870 (Lincoln, 1923, p. 118), and the Black Hawk ledge was worked by Raymond and Co. in 1871 and 1872 (Whitehill, 1873). The district was inactive in 1875 and 1876, but 293 tons of ore were shipped to Bullionville near Panaca in 1896. The production of the district between 1870 and 1896 probably did not exceed $25,000 (Nolan, *in* Hewett and others, 1936, p. 61). The next recorded activity was in 1907, and intermittent small-scale operations have continued to the present. The last recorded production was in 1953. The total production from the district is only about $88,000, as shown in table 28.

Geology

The Chief Range is composed largely of Prospect Mountain Quartzite which strikes a little west of north and dips about 25° NE. The Pioche Shale, Lyndon Limestone, and Chisholm Shale are faulted out by major thrust(?) faulting in the Chief district where an unfossiliferous limestone and dolomite unit, tentatively identified as Upper Cambrian, rests in fault contact on the quartzite. The limestone and dolomite unit is partly metamorphosed by the intrusion of dikes, sills, and plugs of diorite porphyry, but we consider that it may represent downfaulted remnants of the Highland thrust sheet consisting of limestone of Upper Cambrian or, possibly, Highland Peak Formation. Wollastonite and minor garnet, diopside(?), and pumpellyite(?) are developed near the diorite contacts.

Breccia zones are present between the inferred thrust(?) plate of limestone and the quartzite; they range from 10 to 40 feet thick and are generally cemented by mylonitic material and iron oxides or by quartz and other vein minerals. Ore bodies occur in these breccia zones or in the quartzite as veins that generally have an average strike of N. 15°-20° W. Callaghan's geologic map of the district is given in figure 27 to show the mine locations.

Mineral deposits

The mineral deposits are in fissure veins in the quartzite or in the breccia zones between quartzite and the overthrust carbonate rock. Some replacement of the quartzite and limestone and dolomite wallrocks has occurred along the fissures. The following description is from Callaghan (1936).

The principal metals are gold, silver, and lead. All the ore is oxidized, and galena is the only residual sulfide. Three types of veins, distinguished by their constituents, exist in this district.

The type of vein that has the highest content of gold and silver is the arsenian type, like the veins in the Advance, Old Democrat, and Lucky Hobo mines. The ore is a massive greenish to brownish vuggy aggregate of arsenopyrite replaced by scorodite, which is in turn re-

Table 25. Principal mines in the Viola district.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Cherokee	9	8 S.	68 E.	Ag, Cu	Quartz vein 10-40 ft thick in Kaibab(?) Limestone strikes N. 50° W. and dips 60°-70° NE.; can be traced for 2 miles. Copper carbonates, chrysocolla, and sulfides line fractures. High-grade streaks are 3-12 in wide but widths of 16-20 ft are mineralized.	Intermittently worked since 1880. Production probably less than 500 tons. High-grade silver ore near surface. Seven tons shipped in 1951 assayed 24 oz Ag and 5 percent Cu. Total gross value was $229. Cherokee shaft is 200 ft deep and has six levels totaling 412 ft. Viola shaft is 168 ft deep and has three levels totaling 163 ft. 1951 shipment came from the 134-ft south level of Cherokee shaft. G. G. Gentry (written communication, 1951).
Prospect	—Exact location unknown—				Prospect on edge of 30- to 90-ft porphyry dike that strikes N. 20° W. Nearby prospects contain white quartz with copper stain.	
Johnnie	27	8 S.	68 E.	Au(?)	Twelve-ft quartz vein that strikes about N. 50° W., dips steeply SW., and forms prominent ridge in volcanic rocks. No mineral showing; vein apparently barren.	90-ft vertical shaft on quartz vein.
Pittsburg	30	8 S.	69 E.	Ag, Cu	Vein in Mississippian (Monte Cristo) limestone near volcanic contact.	Production unknown.
Unnamed	24	8 S.	69 E.	Zn, Pb	Thirty-ft inclined shaft in white recrystallized limestone. Ore on dump contains galena or silver sulfides in calcite gangue. Jasperoid caps nearby hills.	Semiquantitative spectrographic analysis of one sample, in percent, shows over 10 Zn, 7 Pb, 0.7 Cu, 0.15 Cd, and 0.007 Ag.
Crystal (Larson?) mercury	18	8 S.	69 E.	Hg	Streaks and clusters of cinnabar crystals occur in altered talcy Mississippian limestone. Cinnabar ore shoot was 12 ft long, 6 in wide, and 15 ft deep. Ore is near faulted contact of white rhyolite which also contains cinnabar.	Developed by 15-ft shaft and several pits. Production unknown. Claim staked in 1939. Ore(?) reported to contain 25-26 pounds of mercury per ton. W. T. Benson (written communication, 1946).
Unnamed	18	8 S.	69 E.	Pb, Zn, Cu, Ag	Vein of jasperoid along fault near flat zebra-striped jasperoid adjacent to contact of punky altered rhyolite and limestone.	Semiquantitative spectrographic analysis of one sample, in percent, shows over 10 Pb and Zn, 1.5 Cu, 0.7 Sb, 0.15 Mo, 0.07 Cd, and 0.03 Ag. Property is a quarter of a mile SE. of mercury mine. Production unknown.
Lucky prospect	-------	8 S.	68 E.	Pb, Zn, Cu	Two vein systems, one north-south and one east-west, cut interbedded limestone and thin quartzite layers that strike northeast and dip 20° NW. East-west veins rarely exceed 2-4 ft in thickness; they contain galena, cerussite and copper carbonates. North-south vein is much thicker; it contains zincite and hydrozincite, with small amounts of lead carbonate, in calcite and quartz. Ore shoot 12-18 in wide and 30 ft long extends from surface to 20-ft depth and then narrows and disappears at bottom of a 60-ft 35° inclined shaft.	Exact location unknown. May be same property as above.

Wells Cargo	32	8 S.	69 E.	Fluorspar	Large replacement bodies of fluorspar in dark Carboniferous limestone. The fluorite is dark and difficult to distinguish from limestone, but some purple- and green-banded fluorspar is present.	Ore mined in small open pits and shipped as metallurgical grade fluorspar after crushing and screening. 11,500 tons of 70 percent CaF_2 produced in 1958. Estimated total value about $363,000.
Smith and Dobbins		24 miles east of Vigo		Mn	Nodules of wad and pyrolusite in gouge on footwall of fault that separates limestone and rhyolite tuff. Ore is 2 ft wide and extends to depth of at least 70 ft.	Not visited; exact location unknown. Nodules contain 40-44 percent Mn and 15-20 percent SiO_2.
Culverwell		19 miles NE of Carp		Mn	Pyrolusite, psilomelane, and some braunite in interstices of brecciated gangue containing two distinct types of complex iron silicates.	No recorded production. Not visited; exact location unknown. Ten-ft shaft entirely in manganese. Ore reported to contain 28 percent Mn, 6 percent Fe, 23 percent SiO_2, and 26 percent insoluble residue.

Table 26. Production of the Atlanta and Silver Park districts, 1871-1958.

(e, estimate)

Year	Gold (ounces)	Silver (ounces)	Total value
1958	26	362	$ 1,200
1956	— —	— —	3,400
1955	— —	— —	82,300
1954	1,974	7,595	76,000
1953	499	2,248	19,500
1939	— —	740	500
1938	— —	477	300
1935	2	2,759	2,100
1913-1920[1]	— —	— —	10,000e
1878	— —	— —	[2]2,300
1877	— —	— —	[2]2,100
1876	— —	— —	[2]23,600
1875	— —	— —	[2]600
1871	— —	— —	[2]2,900
Production prior to 1906[1]			75,000e
Totals	2,501	14,181	$301,800

1. Nolan (in Hewett and others, 1936, p. 61).
2. Couch and Carpenter (1943, p. 83).

placed by a brown micaceous mineral (arseniosiderite? or carphosiderite). Jarosite, descloizite, cerussite, mimetite, and beudantite were also present.

The second and most productive type of vein is the nonarsenian type that occurs in the Gold Chief mine in thrust(?) breccia. The vein filling is a network of tabular barite crystals and scattered grains of galena. Colloform chalcedonic quartz replaces and veins the barite. Quartz, hemimorphite, mimetite, and manganese and iron oxides fill the interstices between the barite crystals in the ore. The gold and silver content of this type of vein is low.

The third type of vein forms the principal lead deposits. These veins include a pipelike ore body in the Republic mine and an irregular cerussite body in the Lucky Chief mine. The ore from the Lucky Chief consists of grains and nodules of cerussite, powdery opal, plumbojarosite, and lumps of iron and manganese oxides in fine-grained quartz.

The available information on the principal mines, largely from Callaghan (1936), is summarized in table 29.

Patterson (Geyser, Cave Valley) District

(Tungsten, silver, zinc, copper)

Location

The Patterson (Geyser, Cave Valley) district is in the southern Schell Creek Range near Patterson Pass. The south end of the district is crossed by a graded gravel road that leaves U.S. Highway 93 about 45 miles north of Pioche and crosses Patterson Pass into Cave Valley. Steep truck trails cross the range crest in the central part of the district.

Table 27. Principal mines of the Atlanta and Silver Park districts.
(u, unsurveyed)

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Atlanta	15	7 N.	68 E.,u.	Au, Ag	Main ore body is part of a silicified breccia zone that is about 100 ft wide and crops out for about 3,000 ft along a N. 30° W. fault which dips 40° SW. A shaft cuts the ore zone at a vertical depth of between 90 and 215 ft. The ore zone extends at least 300 ft south of the shaft on the 200-ft level.	Meyers (1915) states a width of 55 ft on the 200-ft level contained between $3.50 and $4.50 per ton in Au, and a width of 25 to 30 ft on the 100-ft level averaged $5.50 to $7.00 per ton in Au. About $181,000 worth of low-grade fluxing ore was mined from an open pit south of the main shaft between 1952 and 1956. The early production is unknown. Hill (1916); Minerals Yearbooks (1953-1958).
Bradshaw	26(?)	7 N.	68 E.,u.	Ag, Au	Ore in two zones of red jasperoid that strike N. 45° W. and dip 50° NE. Western zone is 500 ft long and 150 ft wide. Eastern zone is smaller. Narrow N. 60° W. stringers and crevices carry oxidized silver minerals.	Large open pit and an inclined shaft developed the western jasperoid zone. Production unknown. Mine known in 1871. Hill (1916).
Silver Park (Jesse Knight)	16	7 N.	68 E.,u.	Ag	Siliceous replacement veins striking northeast and north are mineralized. Ore contains calcite, lead, and copper carbonates and cerargyrite.	Most of early production of the district probably was from this mine. Recorded production in 1876 was 373 tons worth $23,200. In 1913 a carload that carried 100 oz Ag per ton was shipped. Main shaft, formerly 300 ft deep, is caved 50 ft down. Hill (1916, p. 119-120); W. T. Benson (written communication, 1946). Semiquantitative spectrographic analysis of a sample by J. C. Hamilton, U.S.G.S., shows 0.7 percent Cu, 0.3 percent Ba, 0.15 percent each of Ag and Sb, and 0.03 percent each of Pb and Zn.
Solo Joker	16	7 N.	68 E.,u.	Ag, Au	Ore body is in a silicified breccia of rhyolite tuff, limestone, and jasper 10-15 ft thick. Zone strikes N. 60° E. and then N. 35° W.	Mine is on north side of gulley about half a mile south of the Silver Park mine.
Hulse (Blue Bird)	22	7 N.	68 E., u.	U	Pods of pyrite-uraninite ore occur in tabular jasperoid zones along flatly dipping faults which contain silicified gouge 1-4 ft thick. Mineralization appears to be controlled by an intrusive breccia zone or pipe which was later cut by many minor N. 35°-55° W. faults. Pyrite alters to carphosiderite.	Workings in 1956 totaled 275 ft. Two carloads averaging about 0.30 percent U_3O_8 shipped. Chemical analysis of two samples showed 0.11 percent and 0.67 percent U, and 0.1 percent and 0.3 percent As. Sharp and Myerson (1956).
Easter	17	6 N.	68 E.	Pb	Three nearly vertical veins strike N. 45° W. in altered rhyolite porphyry. Middle and west veins are 6 in to 1 ft wide and contain no metallic minerals except pyrite. The east vein can be traced for 400 ft and rarely exceeds 5 in in width.	East vein contains 5-23 percent Pb as galena and cerussite and 5 oz Ag per ton. No recorded production. Data from W. T. Benson (written communication, 1946).
Democracy (Hulse, Rosencrans) manganese	2, 11	6 N.	68 E.	Mn, W	Two- to three-ft vein of manganese oxides in pink Tertiary rhyolite tuff.	Ore reported to contain about 44 percent Mn. Ore is entirely dense botryoidal psilomelane which contains about 7 percent Ba, 3 percent W, 0.7 percent Sr, and 0.15 percent Tl, according to a semiquantitative spectrographic analysis by J. C. Hamilton, U.S.G.S. No known production. Hewett and others (1963, p. 21).

Table 28. Production of the Chief district, 1870-1953.
(e, estimate)

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Total value
1953	54	66	— —	200	$2,000
1948	— —	51	— —	2,700	500
1947	1	3	— —	— —	40
1946	25	177	— —	— —	1,000
1941	85	1,080	— —	1,100	3,800
1940	79	935	300	4,700	3,700
1939	169	1,502	600	1,900	7,100
1938	68	702	— —	1,100	2,900
1937	110	937	300	400	4,600
1936	— —	— —	— —	— —	[1]3,900
1935	160	1,808	— —	— —	6,900
1934	— —	— —	— —	— —	[1]1,800
1933	147	2,071	720	621	3,800
1932[2]	18	130	122	298	400
1928	25	164	— —	505	600
1926	— —	95	— —	10,399	900
1925	7	267	29	15,188	1,600
1914	750	238	— —	— —	15.600
1913	291	472	— —	208	6,300
1911	29	6	— —	— —	600
1909	11	77	326	— —	300
1907	3	76	5,430	— —	400
Production prior to 1900	— —	— —	— —	— —	25,000e
Totals	2,032	10,857	2,071	45,075	$93,740

1. Couch and Carpenter (1943, p. 84).
2. Nolan (in Hewett and others, 1936, p. 61) states, "Recorded production, 1907-32, 6,690 tons of ore yielding 1,410.46 oz. Au, 5,883 oz. Ag, 6,129 lbs. Cu, 65,283 lbs. Pb, valued in all at $39,406."

History and production

Rich silver ores were found in Patterson Pass about 1869, and more than 200 claims were located north of the pass soon afterward. Hill (1916, p. 123) states:

> "The ores were rich oxidized material carrying $212 to $520 in silver and $22 in gold a ton. White [1871, p. 93] reported that lead, antimony, copper, and iron were present in the ore. Apparently the activity of this camp was short lived, and there does not seem to have been any deep mining on any of the claims. There are few records of production from the district, either in the early days or in the last decade."

Schrader (1931, p. 7) reports that the Lake Valley Mining Co. shipped some siliceous silver ore in 1920 and 1921 and built a 50-ton cyanide plant which produced some silver bullion between 1922 and 1925. Siliceous silver ore was shipped in 1921, 1922, and 1923, and lead-silver ore was shipped in 1925. The exact source of this ore is unknown.

Some work was done in Cave Valley between 1920 and 1930 (Schrader, 1931, p. 7). In 1941 Owen Walker staked the Cinch and Pip mines, and 1,000 tons of tungsten ore, with an estimated value of about $19,000, were shipped during World War II. Since World War II, except for intermittent prospecting, the district was idle until 1956, when development of the Jerry group of claims began. The only recorded production figures for this district are listed in table 30.

Geology

The geology of the part of the Schell Creek Range that contains all the known mineral deposits is comparatively simple. This part of the range consists entirely of beds of Prospect Mountain Quartzite, Pioche Shale, and Pole Canyon Limestone, which strike generally north and dip eastward. The dip increases eastward from about 15° near the summit to about 45° on the east flank of the range. The same formations are exposed in Cave Valley, but they strike obliquely into the range and must have been dropped by a major fault. According to drill-hole data reported by Paul Gemmill (oral communication, 1956), a complex ecoulement or slide plate of Cambrian and Silurian rocks extends along the east flank of the range and appears to rest in part on Tertiary volcanic rocks near the Cinch mine. A major nearly east-west fault zone through Patterson Pass probably has cut out several thousand feet of Cambrian rocks, and this zone forms the southern limit of the Patterson district. The bedding of the Pioche Shale bends westward against this fault zone, suggesting right-lateral displacement. A N. 30° W. fault with several hundred feet of displacement crosses the southern part of the district.

A nearly vertical dike of biotite quartz monzonite(?) 50 feet thick strikes N. 60° W. across the Pioche Shale near the range crest on the Jerry group. A sill of the same rock 7 feet thick intrudes the Pioche Shale at the top of the lowest limestone. These bodies are too small to show on the geologic map.

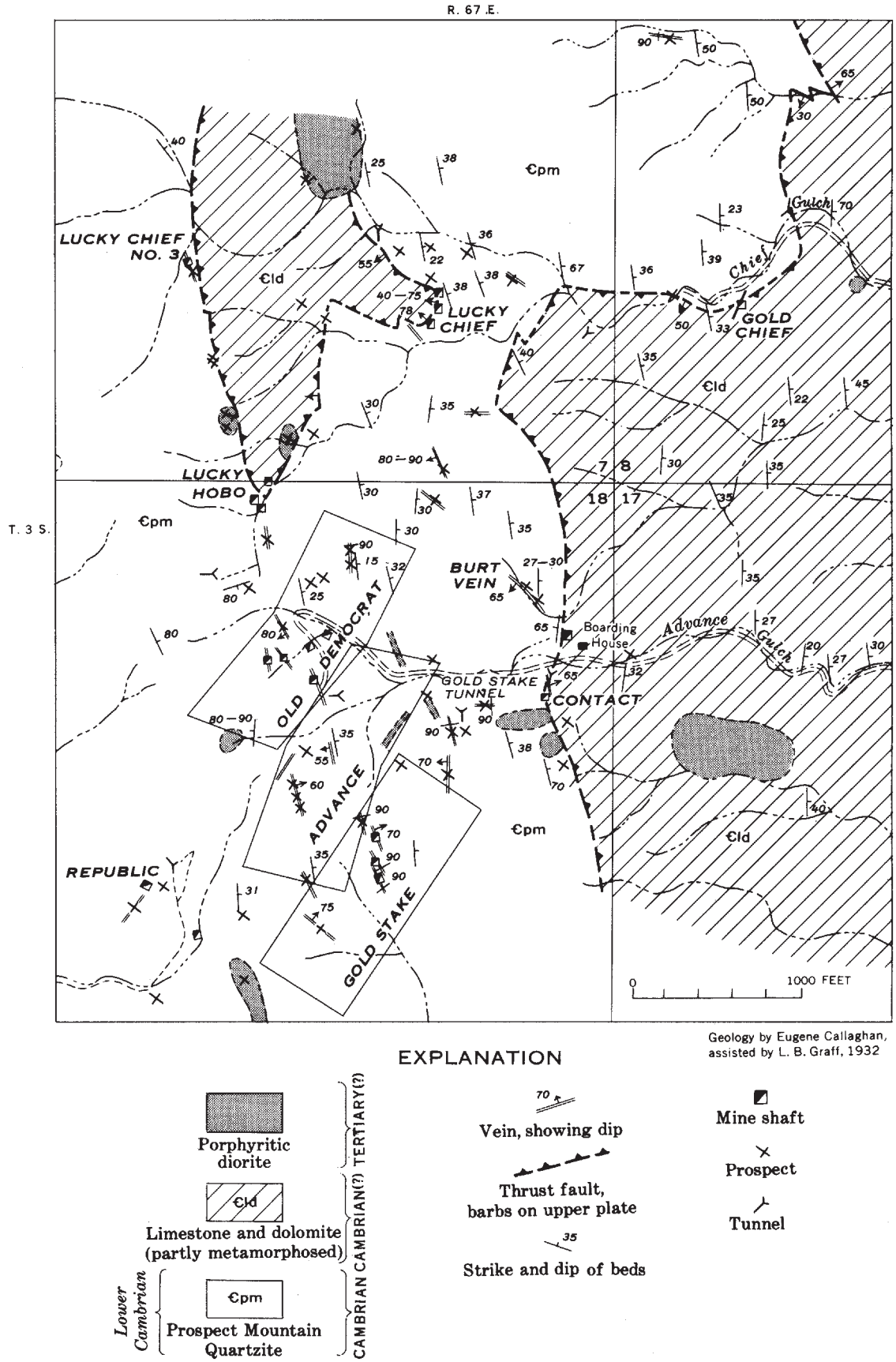


FIGURE 27. Geologic map of the Chief district.

Table 29. Principal mines of the Chief district.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Gold Chief (Chief)	8	3 S.	67 E.	Au, Ag, Pb	Ore is in thrust(?) breccia between limestone and quartzite which strikes N. 50° E. at the mine. Stopes trend N. 25°-30° E. Fissure flattens downward from 68° W. dip at surface to 36°. Ore contains barite, quartz, calcite, hemimorphite galena, and mimetite.	Production between 1911 and 1917 totaled $25,000. That between 1937 and 1940 totaled 189 tons with a value of $7,300. Total production exceeds $32,000. Ore assayed between 0.2 oz and 0.5 oz Au per ton. Inclined shaft was 430 ft deep. Callaghan (1936, p. 26-27); Couch and Carpenter (1940, p. 86).
Lucky Chief	7	3 S.	67 E.	Pb	Irregular lead carbonate ore body in thrust(?) breccia zone between isolated block of limestone and quartzite. Ore contained about 18 percent Pb and negligible Au and Ag.	In 1926, 24 tons of cerussite ore shipped. Callaghan (1936, p. 27-29).
Lucky Hobo	7, 18	3 S.	67 E.	Pb	Vein in breccia at limestone-quartzite contact near small bodies of diorite. Ore contains comb quartz, calcite, jarosite, and mimetite.	Shipment reported 1928. Callaghan (1936, p. 29).
Caliente Cobalt Mining Co.	-------	-------	-------	-------	---------- ---------- ---------- ----------	535 tons of ore worth $15,657 were produced between 1934-1940. Callaghan (1936, p. 18-26).
Advance	17	3 S.	67 E.	Au, Ag	Ore shoot in north-south vein in Prospect Mountain Quartzite at fracture intersection was 40 ft long and 3.5 ft wide. Several veins strike N. 30° W. to N. 30° E.	23 tons of ore assaying 1.08 oz Au and 6.6 oz Ag per ton were shipped in 1928. 293 tons assaying 1.078 oz Au per ton were shipped to Bullionville from Advance and Old Democrat in 1896. Callaghan (1936, p. 19-20).
Contact	18	3 S.	67 E.	Au	Contact vein strikes N. 7° W. along fault contact between Prospect Mountain Quartzite and carbonate rocks that contain lenses of iron oxide. Burt vein strikes N. 45° W., dips 65° SW. in quartzite.	Burt vein assays 0.41 oz Au per ton. Contact vein iron oxide contains 0.02 oz Au and 2 oz Ag per ton and 53 percent Fe. Callaghan (1936, p. 21).
Gold Stake	18	3 S.	67 E.	Au(?)	Gold Stake vein strikes S. 20° W. and follows an altered diorite dike. En echelon veins in quartzite.	Reportedly assays $3 to $27 (old price) for 70 feet. Callaghan (1936, p. 21, 23).
Old Democrat	18	3 S.	67 E.	Au, Ag	Irregular vein striking S. 10° W. is parallel to a lense of porphyritic diorite. Another vein strikes N. 30° E.	Production prior to 1907 unknown. In 1932, 28,700 pounds assaying 0.89 oz Au and 8 oz Ag per ton, and 1 percent Pb were shipped. Callaghan (1936, p. 23).
Republic	18	3 S.	67 E.	Pb, Ag, Au	Pipe of ore in altered quartzite on nearly vertical vein that strikes N. 5° W. Another ore shoot containing desclozite occurs at intersection of northeast- and northwest-trending fractures.	Small shipment in 1925. Ore reported to assay 0.08-0.39 oz Au and 1-8 oz Ag per ton, 11-17 percent Pb, and up to 2 percent Zn. Callaghan (1936, p. 25).

Table 30. Production of the Patterson district, 1904-1952.

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	WO_3 units	Total value
1952	—	80	—	—	—	$ 72
1951	—	232	100	2,300	—	632
1949	—	401	—	—	—	363
1942?	—	—	—	—	750	[1]18,900
1940	—	94	—	—	—	67
1904-1932[2]	40	25,925	490	5,499	—	25,000
pre-1904[3]	—	—	—	—	—	30,000
Total						$75,000

1. Estimated value of tungsten concentrates.
2. Nolan (in Hewett and others, 1936, p. 64).
3. Estimate not based on any reported production figures.

Mineral deposits

Near the Patterson Pass fault, silver was mined from some small replacement veins of white quartz and calcite that strike N. 10°-20° E. and are nearly vertical. These veins are in the Pole Canyon Limestone and strike at right angles to the major fault. Ore minerals are not abundant, but occasional thin yellow films of argentiferous lead carbonate and small pockets of argentiferous copper carbonates are present (Hill, 1916, p. 124).

The deposits near the crest of the range are low-grade bedded replacement deposits of copper and zinc in three limestone beds in the Pioche Shale or irregular tactite bodies that contain contact metamorphic minerals and scheelite and fluorite. The tactite may be related to a dike or sill.

Scheelite is present in the quartz in brecciated Pole Canyon(?) Limestone at the Cinch and Pip mines just north of the main road at the east base of the range. Other contact metamorphic minerals are absent. A quartz-wolframite vein cuts the Prospect Mountain Quartzite on the Eagle Rock group of claims near the alluvium on the west flank of the range. Another quartz vein near the top of the Prospect Mountain Quartzite contains wolframite, galena, cerussite, and bindheimite(?). These veins resemble the quartz-hübernite veins at the Geyser mine west of Geyser and at the Deer Trail property 2 miles farther north in White Pine County.

The ore deposits in Cave Valley are replacement veins and small replacement bodies in limestone. The veins generally strike north and dip steeply west. Replacement deposits formed where the veins cut a quartzite rib and limestone beds in the Pioche Shale. The veins contain pearceite (silver-arsenic sulfide), cerargyrite, cerussite, pyrite, and psittacinite (lead-zinc vanadinate). Small bedded replacement deposits in the Cave Valley mine contain lead, silver, and copper minerals in a silicified limestone (Schrader, 1931, p. 10-12).

On the Streator group of claims, 3 miles northwest of the Cave Valley deposits, ore occurs in the upper half of the Pioche Shale in replacement deposits in silicified limestone just above the 90-foot-thick quartzite. The ore bodies contain barite, argentiferous galena, an unidentified black mineral, pearceite, and psittacinite (Schrader, 1931, p. 14-16).

The available information on the principal mines is summarized briefly in table 31.

Pennsylvania District

(Copper, silver, gold)

Location

The Pennsylvania district is near the head of Pennsylvania Canyon, in T. 6 S., R. 67 E. (unsurveyed) about 3 miles south of Ella Mountain and about 7 miles northeast of the railroad at Elgin. The district is accessible from the Ella Mountain truck trail which goes between Eccles and Elgin.

History and production

The history of the Pennsylvania district is not recorded, but the Pennsylvania vein was discovered many years ago. Total production of the district is probably less than $50,000. The few available production figures have been combined with the production of the Viola district in table 23.

Geology

The pre-Tertiary geology is complex, but the Tertiary geology is simple (pl. 2). Fault blocks of Prospect Mountain Quartzite, Pioche Shale, and limestone of the Highland Peak Formation are exposed along Pennsylvania Canyon and on the south side of a Tertiary diorite stock(?). A thick series of Cretaceous(?) or lower Tertiary conglomerate and other clastic rocks rests on the faulted Cambrian rocks with marked unconformity. This conglomerate is overlain by andesitic volcanic rocks of Tertiary Age. All these rocks are overlain by the dominantly rhyolitic volcanic rocks that form the higher hills.

Table 31. Principal mines of the Patterson district.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Cinch	32	9 N.	65 E.	W	Thin seam (less than 6 in) of finely disseminated scheelite and powellite in brecciated quartz gangue on thrust fault. Ore crops out for several hundred feet in zone that strikes N. 58° W. and dips 10°-60° E. Mineralized thrust fault strikes north, dips west. Brecciated Cambrian limestone rests on Tertiary volcanic rocks.	Claims located in 1941. In 1942, 1,000 tons shipped had and average content of 0.75 percent WO_3. Total production 750 units worth approximately $19,000. S. W. Hobbs (written communication, 1943); Paul Gemmill (oral communication, 1952).
Pip	31 or 32	9 N.	65 E.	W, Ag	Scheelite in quartz gangue in Pole Canyon(?) Limestone.	Adjoins Cinch mine on west. No production; old silver pits.
Ad	25(?)	9 N.	64 E.	W(?)	Workings in dark calcareous quartzite. Limy shale and limestone 100 ft above tunnel ore altered to dark-green tactite which contains quartz, calcite, diopside, scheelite, fluorite, and some sphalerite and pyrite.	On summit of range at Swartz Canyon. Adit about 300 ft long. No recorded production. Hill (1916, p. 124).
Jerry	13, 24, 25	9 N.	64-E.	Cu, Zn	Large replacement deposits in three limestone beds in the Pioche Shale. They contain about 2.5 percent Zn and as much as 2.5 percent Cu. Replacement is progressively less in higher limestone beds. Ore conduits are closely spaced N. 65° E. vertical fissures. Five ft of oxidized ore, containing up to 3 percent Cu, occur for 30 ft near a N. 75° E. fissure, and in addition 50 ft contain up to 0.6 percent Cu. The lowest mineralized bed is a 20-ft limestone at the top of a 90-ft. quartzite in Pioche Shale.	No production to date. A 455-ft adit driven in 1957 on lowest mineralized bed shows 2.5 percent Zn ore throughout. D. B. Tatlock (written communication, 1958).
Geyser	7 or 8(?)	9 N.	65 E.	W, Ag	Wolframite and silver vein in Prospect Mountain Quartzite.	Ore assays up to 0.9 percent WO_3. Old stamp mill.
Eagle Rock	26	9 N.	65 E.	W, Cu	Two veins in Prospect Mountain Quartzite. One contains wolframite and sulfides; the other contains wolframite but no sulfides.	Semiquantitative analysis of a grab sample by J. C. Hamilton, U.S.G.S., shows about 1.5 percent Cu, 0.3 percent W, 0.15 percent Sb, Pb, Zn, and Bi, and a trace of Ag.
Cave Valley	16	9 N.	64 E.	Ag. Pb, Cu	Five north-striking fissures in Pioche Shale. Principal vein mined on 40-ft and 120-ft level from vertical shaft. The vein ranges in thickness from 1 in to 5 ft. The ore occurs in and near the lowest limestone bed in the Pioche Shale.	Total production probably about $5,000. Schrader (1931, p. 16). Two 5-ton shipments valued at $90 per ton.
Streator	5	9 N.	64 E.	Ag, Pb, Cu	Replacement deposits of Pb, Ag, and Cu ore in silicified limestone. Two and one-half ft of ore occur in lowest limestone bed in the Pioche Shale at intersection with a northwest-striking fissure.	Schrader (1931, p. 14-16).

Contact silicates are developed in the eastern part of the ridge of Cambrian(?) limestone that is faulted against Prospect Mountain Quartzite on the south side of the diorite. Samples from prospects in the silicated zone were checked with an ultraviolet lamp but no scheelite was found. The Pennsylvania vein parallels the eastern contact of the diorite stock with the overlying rhyolite.

Mineral deposits

The Pennsylvania quartz vein contains all the known ore deposits in this district (table 32). This vein strikes N. 20° W., dips an average of 20° E., and can be traced for 3,000 feet. The ore shoots in the Pennsylvania mine were mined for copper and silver, but the gold content was generally negligible. The ore shoot on the Culverwell-Johnson property, however, just east of the Pennsylvania mine was mined for both the gold and silver content. The gold ore was not sufficiently free-milling to permit the successful operation of a small mill.

Contact silicates, copper carbonates, and sulfides are present along shear zones in the eastern part of a limestone ridge south of the diorite stock. The mineralization is presumably related to the intrusion of the diorite.

Freiberg (Worthington) District

(Gold, silver, lead, zinc, tungsten)

Location

The Freiberg (Worthington) district is in the E½ of T. 1 N., R. 57 E. near the north end of the Worthington Mountains, about 20 miles north of Tem Piute. The district is served by graded dirt roads that connect with Nevada Highway 25 near Tem Piute and Nevada Highway 38 north of Hiko. The nearest railhead is Pioche, about 75 miles away.

History and production

The district is an old one, but production has been small to date. In 1865 an Indian showed the area to two prospectors, who then organized the Worthington district. In 1869 another party found good ore and reorganized the district under the name Freiberg. The earliest record of production from this district was made in 1919 when a little oxidized iron ore containing silver and lead was shipped from the Roadside property. In 1921 one lot of lead-silver ore was shipped from an unnamed property (Lincoln, 1923, p. 120). The total recorded production from the district, as shown by figures in table 33, is only $18,000. This value seems small consideraing that the remains of at least two mills were found in the district.

Geology

The geology in the Freiberg district consists of three structural elements, two of which are thrust sheets. The

Table 32. Principal mines of the Pennsylvania district.
(u, unsurveyed)

Name	Location Sec.	Location T.	Location R.	Commodities	Geologic setting	Production, remarks, and references
Culverwell (Johnson)	16(?)	6 S.	67 E., u.	Au, Ag	Flat quartz vein in diorite is probably the extension of the Pennsylvania vein. Also quartz along steep fault that does not cut vein. Many selected grab samples assay around 2 oz Au and between 14 and 25 oz Ag per ton. Maximum assay was about 3 oz Au per ton. Two channel samples 42 and 84 in wide contain 3 and 5 oz Ag, and 0.46 and 0.25 oz Au per ton, respectively.	About 16 carloads of gold ore reported shipped. Developed by shallow shafts and trenches. Could be mined by open pit. Small mill at Carson Springs was unsuccessful. Production estimated to be about $40,000.
Pennsylvania	16(?)	6 S.	67 E., u.	Cu, Ag, Au	Quartz vein strikes N. 20° W. and dips 12°-30° E. The vein is 3 to 15 ft thick. Widths greater than 2 ft contain between 2 and 29 oz Ag, as much as 0.24 oz Au, and 1 to 6 percent Cu. The vein is developed by two inclined shafts, several prospect pits, and by short drifts at vertical depths of 145 and 185 ft below the outcrop. The main ore shoot rakes northeast and was mined 450 ft down dip. The ore was as much as 40 ft wide but averaged about 4 ft. The remaining ore averages 1.61 percent Cu and 8 oz Ag per ton. The ore is very fine-grained quartz with disseminated bornite, chalcopyrite, covellite, and malachite. No ore was cut by a 530-ft drift north of the shaft on the deepest level.	Production was included with that of Chief and Delamar(?) districts. Total production estimated to be about $5,000. C. M. Tschanz and G. G. Gentry (unpublished data, 1953).

Table 33. Production of the Freiberg district, 1919-1948.

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)	Zinc (pounds)	Total value
1948	— —	32	1,500	— —	$ 300
1943	250	651	6,800	7,600	10,500
1938	2	1,499	— —	— —	1,000
1937	— —	145	4,300	— —	400
1935	13	14	— —	— —	500
1934	9	18	— —	— —	300
1919-1921[1]	— —	— —	— —	— —	5,000
Totals	274	2,359	12,600	7,600	$18,000

1. Nolan (in Hewett and others, 1936, p. 62-63).

highest plate consists of west-dipping Ordovician rocks along the west side of the range south of the mineralized area. This plate has moved eastward over all the formations from the Pogonip Group in the mineralized area to the Scotty Wash Quartzite at the south end of the range. At the north tip of the range the complexly faulted post-Pogonip rocks appear to be a remnant of a second thrust plate. The rocks beneath these plates, which contain the ore, constitute the third structural element. These rocks are intruded by two granite stocks and many granitic and lamprophyre dikes. Most of the limestone around the stocks has been converted to marble or tactite, or it has been silicified. The rocks surrounding the western stock are so altered that it is impossible to determine their age.

The eastern stock is a leucocratic granite which is cut by many small mafic dikes that strike generally northeast. Except for a tungsten prospect in the contact aureole of the western stock, all the mines and prospects are in limestones of the Pogonip Group near the eastern stock. The western stock is much more heterogeneous and basic. Around it the wallrocks are so altered and so intimately intruded by small igneous masses that it is difficult to distinguish the two.

Mineral deposits

The mineral deposits of the district are of two types: veinlike deposits of gold, silver, lead, and zinc; and scheelite deposits in tactite.

Nearly all the production has come from small irregular replacement lenses or veins along faults in limestone. Galena and pyrite are the only sulfides seen on the dumps. Most of the ore is oxidized and some deposits have a well-developed gossan which contains a green substance that resembles scorodite. These deposits include both gold veins and silver-lead veins. The grade of selected silver-lead ore is indicated by a 50-ton shipment from the Freiberg mine which contained 70.6 ounces of silver and 6.5 percent lead.

The scheelite deposits are near the western flank of the range on the west edge of the granite stock. Scheelite is disseminated through a light-green tactite which conains some wolframite(?). Inspection with an ultraviolet lamp showed that the tactite probably contains less than 0.4 percent WO_3. The deposit has been prospected by a short adit and shallow shaft; however, a considerable area of tactite favorable for scheelite deposits still remains to be explored.

Ely Springs (Lone Mountain) District (unorganized)

(Silver)

Location

The Ely Springs (Lone Mountain) district is on the west side of the Ely Springs Range about 13 miles due west of Pioche and about 4 miles west of the Comet district. The district is served by unimproved dirt roads.

History and production

Ore was discovered in the district before 1917, but the deposit at the principal mine, the Hedman (King Midas) mine was not discovered until 1943. The Irmine and Baurer gold mine, which is between the Ely Springs and Highland Ranges, is arbitrarily included in the Highland district. The total recorded production from the district, all of which was after 1949, is $8,400 as shown in table 34.

Geology

The Ely Springs Range, which is composed of complexly faulted Upper Cambrian and Ordovician rocks, is within the area of Westgate's geologic map (Westgate and Knopf, 1932). Most of the faults strike north and are steeply dipping normal faults.

Mineral deposits

The King Midas mine is in brecciated Upper Cambrian limestone on the hanging wall of a fault that strikes N. 15° W. and dips 45°-50° E. The ore along the fault occurs in silicified breccia which has been stoped to a depth of 30 or 40 feet. Ore minerals were not recognized on the dump, but a selected sample contained 50 ounces of silver per ton and 12 percent manganese, according to G. G. Gentry of the U.S. Bureau of Mines (oral communication, 1952).

Table 34. Production of the Ely Springs district, 1951-1955.

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)	Zinc (pounds)	Total value
1955	1	1,041	800	1,600	$1,300
1954	2	738	— —	— —	700
1953	5	5,209	— —	— —	4,900
1952	— —	184	— —	— —	200
1951	— —	— —	— —	— —	1,300
Total	8	7,172	800	1,600	$8,400

About 300 feet farther south, silicified manganese-stained rock occurs along a fault that strikes N. 80° E. The breccia along this fault contains fragments of shale, limestone, and Eureka Quartzite, but argentojarosite(?) was the only ore mineral. Several other prospects were seen near Ely Springs.

Don Dale District

(Lead, silver, gold, mercury)

Location

The Don Dale district is near the north end of the Groom Range north of Bald Mountain in T. 4 and 5 S., R. 55 and 56 E. As used in this report, the district includes the entire mineralized area on both sides of the range between Nevada Highway 25 and Bald Mountain. Prior to 1945, this area was probably considered part of the Tem Piute district, although it is about 10 miles to the southwest. The area is served by unimproved dirt roads.

History and production

The Don Dale district was organized about 1945, although some of the individual mines are much older. Production from the area is largely unknown, but it was undoubtedly small. The owners of the Don Dale mine reported that 200 tons of ore were shipped to Salt Lake. The Andies quicksilver property produced two flasks of quicksilver in 1955.

Geology

The northern end of the Groom Range is composed of Cambrian and Ordovician(?) rocks intruded by many granitic dikes and small stocks. On either flank of the range these rocks are largely covered by volcanic rocks, which are in turn cut by andesite porphyry dikes.

The granitic rocks are most abundant near the northern end of the outcrop of Prospect Mountain Quartzite and Pioche Shale, and on the periphery of the granitic stock on the summit the Pioche Shale shows contact metamorphism. The volcanic rocks on the west flank of the range are intruded(?) by masses of rhyolite that are now highly altered. These altered rocks are probably the same age as the intensely altered volcanic rocks on the east flank of the range near the quicksilver mine.

Mineral deposits

Mineral deposits are most numerous near the granitic stocks and dikes. Quartz veins in the quartzite are generally parallel to the dikes, suggesting that they both followed a pre-existing fracture pattern. Workings in the quartzite in secs. 27 and 34, T. 4 S., R. 55 E., probably explored gold and silver deposits, but virtually nothing is known about them.

The Don Dale mine is in shaly limestone and quartzite (Pioche Shale[?]) that is intruded by rhyolite and quartz monzonite. The workings follow a vein that trends N. 65° E. and contains oxidized lead, silver, and copper minerals in a quartz gangue. The ore minerals are confined to the vein and to a set of north-south cross fractures that dip 40°-60° E. An ore shoot at the intersection of the vein and a fracture was mined to a depth of 40 feet, and about 200 tons of ore were shipped. The last 10 feet of a 120-foot adit cut quartz monzonite porphyry that contains disseminated copper carbonates. The Don Dale mine was not visited during this study; the preceding information was obtained from W. T. Benson of the U.S. Bureau of Mines (written communication, 1945).

The Andies mine in sec. 4, T. 5 S., R. 56 E. is in argillized rhyolite(?). Cinnabar occurs as scattered crystals, thin veinlets, and coatings on fracture surfaces in the altered rhyolite. Gangue minerals are pyrite, limonite, jarosite, quartz, calcite, and gypsum. Drill holes put down through the overlying 5 to 40 feet of alluvium show the deposit to be a nearly flat-lying, low-grade blanket ranging from a few feet to as much as 45 feet thick, but averaging 15 feet. The average mercury content of the mineralized zone is about 3 pounds per ton, compared to a maximum content of 30 pounds. The preceding information is from a report by H. K. Stager and G. G. Gentry (written communication, 1959) prepared under the auspices of the Defense Minerals Exploration Administration.

Little Mountain District (unorganized)

(Copper)

Location

This district is in the Cedar Range about 12 miles southeast of Panaca and about 10 miles northeast of Ca-

liente. The area is crossed by a graded dirt road, the Caliente and Barclay road.

History and production

No information on the history or production of this district was found.

Geology

The Little Mountain district is in an area underlain by intrusive, extrusive, and a small amount of sedimentary rocks (pl. 2).

The oldest rocks are Cambrian(?) limestones, which are exposed at the north end of the district. They are unconformably overlain by andesitic volcanic rocks, and all are intruded by a Tertiary diorite or monzonite porphyry stock. The andesitic rocks and the diorite stock are themselves cut by a small granite stock and by several aplitic dikes as much as 80 feet thick. Rhyolitic volcanic rocks overlie the diorite, and the aplite dikes are probably the feeders for these rocks.

The texture of the diorite is variable, ranging from porphyritic to granitic. It contains biotite and hornblende and as much as 50 percent feldspar in the form of phenocrysts. Locally the diorite is sheared and readily crumbles where weathered. The more resistant parts of the stock contain many dark inclusions. The entire stock is probably chloritized, but alteration is more intense along shear zones. Here, the diorite is altered to clay minerals. It is also cut by silicified zones and by barren quartz veinlets. Epidote is developed locally along shears in the diorite and in the intruded andesites. Most of the shear zones strike northwest, but the dikes strike northeast and northwest.

Mineral deposits

All the mineral deposits occur in or near the stock, and many prospect pits showing a little copper stain but no visible sulfides are scattered along altered, often poorly defined shear zones through an area of about 2 square miles. John MacKenzie of Caliente (oral communication, 1956) states that copper stain and native copper have been found along Empy Wash (SE¼ T. 4 S., R. 68 E.) almost as far south as the railroad, a distance of about 5 miles.

Several prospects, including the Aztec (Dew, Charlie), are in the andesites at the diorite contact. A 60-foot shaft on the Don claim, a 30-foot shaft on the Aztec, and a 30-foot incline at the southeast end of the stock are the deepest workings. Nothing resembling a gossan is present in the pits.

A little malachite and chrysocolla are the only visible ore minerals in most prospects. The copper must occur chiefly as black chalcocite or tenorite, because rock with little copper stain or visible sulfides is reported to contain as much as 4 percent copper and averages around 1.5 or 2.0 percent. The highest reported silver content is 14 ounces per ton. One composite grab sample we collected from several prospects contained the following: 3 percent copper, 0.15 lead, 0.07 zinc, 0.03 bismuth, and 0.003 silver, according to semiquantitative spectrographic analyses.

The possibility of a large low-grade ore body is sufficiently great to warrant a small-scale sampling or geochemical prospecting program.

Silver King (Sunnyside?) District (unorganized)

(Lead, silver)

Location

The Silver King (Sunnyside?) district is on the north side of Silver King Mountain at the extreme southern end of Cave Valley, about 2 miles north of the Pioche and Sunnyside road in T. 5 N., R. 63 E., unsurveyed. Pioche, the nearest railhead, is about 46 miles away, 32 miles of which is graded dirt road.

History and production

The history of the area is virtually unkonwn. About 8 or 10 carloads of lead-silver ore were reported to have been produced from the Silver King mine, the only producer. About 62 tons of gold-silver-lead ore were shipped in 1939 (Mining World, 1940, p. 31).

Geology

The Silver King area is one of complex geology (pl. 2). A major north-trending normal fault separates low hills of Chainman Shale, Scotty Wash Quartzite, and Pennsylvanian limestone along the west side of the district, from the high ridge of Simonson Dolomite and Guilmette Formation in the southern Schell Creek Range to the east. The Carboniferous rocks are thought to be a downdropped remnant of the Silver King thrust plate (pl. 3).

A stock of quartz diorite about 2 miles long and as much as 1 mile wide is intruded along the north-trending post-thrust fault zone. A few quartz diorite porphyry and rhyolite dikes in the sedimentary rocks near the stock follow a set of north-trending fissures.

Mineral deposits

The ore bodies occur near the contact between the limestone of the Guilmette Formation and a small body of quartz diorite porphyry three-fourths of a mile northeast of the main stock. They occur in brecciated limestone where the dikes are cut by a set of east-west cross fractures. The ore occurs both as small replacement deposits and as veins. G. L. Thompson of the U.S. Bureau of Mines (written communication, 1942) reports that a 7-inch stringer of heavy lead-silver-arsenic sulfides was

exposed for 12 feet in the vein on the adit level of the Silver King property. There are three adits, at least one vertical shaft, and several prospects in the district. Underground workings total more than 500 feet.

Gourd Springs District (unorganized)

(Tungsten, barite, manganese)

Location

The Gourd Springs district is in T. 11 S., R. 69 E., on the east flank of the East Mormon Mountains, about 2 miles east of the Carp and Mormon Mesa road and 8 miles north of the Lincoln-Clark County line.

History and production

The only recorded production from this district was in 1929, when 60 tons of manganese ore worth $600 were shipped from the Amos Hunt property. In 1941 a large number of claims were located for tungsten, but no production was ever reported.

Geology and mineral deposits

The district is in an area of complex geology (pl. 2). A thrust plate of Pennsylvanian limestone, which makes up the main mass of the range, has overridden the Prospect Mountain Quartzite and Precambrian amphibolite, which is intruded by tourmaline granite pegmatite. A major normal fault hidden by alluvium is inferred to be along the east flank of the range (fig. 20). Tungsten and barite deposits occur in the Precambrian rocks, but the manganese deposits probably occur in Cambrian limestone. The available information on the mineral deposits in this district is listed in table 34; the table also includes data on other deposits in southeastern Lincoln County that are not included in organized districts.

Papoose District (unorganized)

(Gold, silver)

Location

The mineralized area is on the east side of the Papoose Range 8 miles south of Groom Lake and 13 miles south of the Groom mine. Access to this area is by the unimproved Frenchman Flat and Groom road.

History and production

No description of the history and geology of the area has been published. A small amount of gold-silver ore shipped in 1936-1937 from the Kelly mine was included with production of the Groom district. Total recorded production is 1,157 ounces of silver, 3 ounces of gold, and 44 pounds of lead.

Geology

The Papoose Range is composed of Prospect Mountain Quartzite, which appears to be complexly faulted. Tertiary volcanic rocks unconformably overlie the quartzite at the north end of the range and Cambrian carbonate rocks are present along the east side. A major north-trending fault east of the Kelly mine is inferred between the Prospect Mountain Quartzite and the low hills of Cambrian limestone and dolomite. In the adjacent part of the Nevada Test Site to the west, the lower Paleozoic rocks were inferred to be part of a major overthrust sheet (Johnson and Hibbard, 1957, p. 370) which rests on upper Paleozoic rocks, but the Prospect Mountain Quartzite in the Papoose Range is not part of this thrust plate.

Mineral deposits

The only known deposits are in the quartzite along breccia zones or narrow fissures. The deposits probably contain only gold and silver.

Fairview and Silverhorn Districts (unorganized)

(Silver, lead)

Location

The abandoned Silverhorn district is in the southern Fairview Range, 4 miles north of Bristol Pass. The Fairview district is an adjoining area on the southeast side of the range.

History and production

The ores of the Fairview district were discovered about 1882 but were not developed until 1922. The production in the following years is not known. The Silverhorn district was very active in 1921 after horn silver was discovered there, but the boom was ended by the failure to discover mineable ore.

Geology and mineral deposits

The geologic map of these districts made by Westgate (Westgate and Knopf, 1932) is incorporated in the county geologic map (pl. 2). The Paleozoic rocks are complexly faulted and some of the Devonian rocks may be part of the Bristol thrust sheet (pl. 3). However, detailed work is necessary before the structure can be fully understood.

Immense outcrops of jasperoid in the Mississippian limestone at Silverhorn contain thin films and seams of horn silver. The largest outcrops of jasperoid are hundreds of yards long and several hundred feet wide (Westgate and Knopf, 1932, p. 50). Descriptions of the mineral deposits are given in table 36.

Arrowhead (Southeastern) Mine

(Copper, lead, silver)

The Arrowhead (Southeastern) mine is at the north end of the Pintwater Range near its junction with the

Table 35. Principal mines of the Gourd Springs district.

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
Farnsworth-Jones (Amos, Amos Hunt)	20(?)	11 S.	69 E.	Mn	Mn oxides fill a strong N. 40° W. fissure that dips between 65° and 90° SW. Hanging wall is Cambrian dolomitic limestone. Footwall is altered "porphyry" which may be Precambrian.	Sixty tons of ore shipped in 1929 were worth $600. Not visited. Five samples contained 10-22 percent Mn, 4-14 percent Al_2O_3, and 25-54 percent SiO_2. Paul Gemmill (written communication, 1941).
Macbruson	32	11 S.	69 E.	W	Disseminated scheelite in amphibolite of Precambrian Age near large bodies of tourmaline-muscovite granite pegmatite.	Twenty-six claims located in 1941 by W. R. Cogart. Production unknown. Semiquantitative spectrographic analysis of one sample collected by us gave in percent: over 10 Si, Al, Co; 7 Fe; 1.5 Mg, Na, Ti; 0.4 W (chemical); 0.3 Mn, 0.15 Sr, Ba, Be, V, Zr; 0.007 Bi, Nb, Sr, Y. Composite sample by the U.S. Bureau of Mines contained 1.08 percent WO_3.
Barium prospect	29	11 S.	69 E.	Ba	Veins in Precambrian rock contain iron-stained barite and hematite(?). Veins are less than one ft thick.	
Bruce	15 miles southeast of Carp			Clay	Clay crops out in places for 1,000 ft "in district of intruded sediments."	Four-ft cut in open pit contains 0.6 percent Fe_2O_3 and 31.4 percent Al_2O_3. Maximum Al_2O_3 is 39 percent. One 55-ft vertical shaft. Not visited. Exact location unknown. Examined by U.S. Bureau of Mines in 1942.
Buckhorn	---	9 S.	69 E.	Kaolinite	Altered area in crushed limestone zone parallel to andesite dike that strikes N. 50° E. The altered area is 75 ft by 50 ft. It is bounded on the east by marble and on the west by the dike. An 80-ft shaft cut kaolinite only to a depth of 10 ft.	Not visited. Exact location unknown. W. T. Benson (written communication, 1945).

Table 36. Principal mines of the Fairview and Silverhorn districts.
(u, unsurveyed)

Name	Location Sec.	T.	R.	Commodities	Geologic setting	Production, remarks, and references
					Fairview district	
Fairview (Nevada)	36(?)	4 N.	65 E., u.	Pb	Northeasterly trending quartz vein in sheared and faulted Devonian(?) thrust(?) plate of dolomite and quartzite. Vein dips 25° W. Reported to have contained 20 percent Pb through a thickness of 14 ft near surface, but it is lean at depth.	Discovered about 1882. Development began in 1922. Developed by 52° inclined shaft and levels at 193 and 420 ft. Nearby vertical shafts are 50 and 75 ft deep. Westgate and Knopf (1932, p. 67).
					Silverhorn district	
Silver Horn	33, 34	4 N.	65 E., u.	Ag	Immense jasperoid outcrops and acidic dike in limestone of Mississippian Age, in part replacing fault breccia at contact of the limestone and the Chainman Shale. Seams with films of cerargyrite and argentite occur in the jasperoid. Jasperoid is 80 ft thick and extends to a depth of more than 200 ft.	No recorded production or significant potential production. Westgate and Knopf (1932, p. 51); Lincoln (1923, p. 128).
Silver Dale	4	3 N.	65 E., u.			

Desert Range, about 19 miles southeast of the Groom mine. It is an old mine, but its history and production are unknown.

The structure of this area is too complex to show at the scale of our map and it could not be satisfactorily mapped at a larger scale in the time we had available. The mine is in a silicified fault zone near the top of the Pogonip Group and copper-lead-silver(?) minerals crop out along this zone for 100 feet. A shaft, inclined 60°, follows the mineralized zone to a depth of at least 60 feet. It is likely that the deposit is just below a thrust sheet of Ordovician, Silurian, and Devonian dolomite.

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