Geology and Mineral Resources of the Ivanpah Quadrangle California and Nevada

GEOLOGICAL SURVEY PROFESSIONAL PAPER 275

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By D. F. HEWETT

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The geology of an area covering 3,900 square miles in the northeastern part of the Mojave Desert, including mountain ranges 6,000–7,000 feet in altitude

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GEOLOGY AND MINERAL RESOURCES OF THE IVANPAH QUADRANGLE, CALIFORNIA AND NEVADA

By D. F. Hewett

ABSTRACT

The Ivanpah quadrangle covers about 3,900 square miles in the northeastern part of the Mojave Desert of southeastern California and southern Nevada. It includes many mountain ranges 6,000 to 7,000 feet in altitude, and a single peak, Potosi Mountain, attains 8,504 feet. The ranges are separated by broad alluvial filled valleys and the lowest area, near the southwest corner, is about 1,000 feet above sea level.

The climate is typical of the southwestern desert regions. Rainfall in the valleys only rarely exceeds 5 inches a year, but it increases with altitude and may be more than twice that on the higher mountains. Only two small areas in the southeastern and northeastern corners drain outward to the sea; the remainder of the area drains to several enclosed basins. Temperatures occasionally rise to 120° F. in the lower valleys in summer, but fall below 20° F. only on the higher mountains in winter. The daily range is commonly 30° to 40°.

The exposed rocks include igneous, metamorphic and sedimentary varieties ranging from Lower pre-Cambrian rocks to the most recent unconsolidated alluvium. In many parts of the quadrangle, large areas of Lower pre-Cambrian metamorphic rocks are exposed. The most common type of rock is granite gneiss, largely with persistent lamination; some types show coarse augen of orthoclase. In a few places, the rocks mapped in this unit show little lamination; they may be parts of intrusive bodies of Mesozoic age. The highly foliated types of schist, quartz, mica, and hornblende are found in several areas but are not widespread.

In the northwestern quarter there is a broad belt of Upper pre-Cambrian sedimentary rocks, the Pahrump series, comprising three formations: the Crystal Spring formation, largely quartzite, argillite, and dolomite; the Beck Spring dolomite; and the Kingston Peak formation, largely sandstone and conglomerate. The total thickness on the north slope of Kingston Range is about 7,000 feet. These rocks are not known east of Kingston Range but they are reported westward in the ranges that border Death Valley.

The lowest sedimentary unit of Early Cambrian age, the Noonday dolomite, rests unconformably on the Pahrump series in the Kingston Range. It is 2,000 feet thick at the western border of the quadrangle but thins rapidly eastward and is not known east of Mesquite Valley. As the sedimentary rocks that overlie the Noonday dolomite and underlie the Goodsprings dolomite in the western half of the quadrangle are much thicker than similar sediments in the eastern half, western and eastern facies are recognized. The overlying sedimentary rocks of Paleozoic age maintain similar lithology and thickness throughout the quadrangle. Dolomite and limestone make up three fourths of the 6,000 to 7,000 feet; sandstone and shale form the remainder. Each system seems to be represented, but the only unconformity lies at the base of the Pennsylvanian series.

The sedimentary rocks of Mesozoic age are largely sandstone and shale and the units resemble those known in the Plateau province as much as 400 miles east and northeast. The greatest thickness is about 4,500 feet at the north border and they thin southward. Clastic rocks of volcanic types are exposed at a few places and surficial flowbreccias rest on the youngest sedimentary rocks of Mesozoic age in the southern half of the quadrangle.

In late Cretaceous time, all the earlier rocks were folded and faulted. Over most of the region, the folds were broad and open, but locally, in the thin-bedded limestones and quartzites, close folds were formed. Within the mapped area five great thrust faults and numerous minor thrust and reverse faults were formed. Along one, Mesquite thrust, the upper block rode eastward at least 8 miles. Late in the epoch of thrust faults, enormous bodies of quartz monzonite were intruded along one or more of the thrust faults. Then minor dikes and sills of monzonite porphyry, hornblende monzonite, aplite, and andesite were intruded. The many metalliferous deposits of gold, silver, copper, lead, zinc, and tungsten in this region are related to the belt of thrust faults and bodies of quartz monzonite and are found both in the intrusive rock and the sedimentary rocks which they intrude.

During early Tertiary time, the entire region was deeply eroded and most of the debris seems to have been carried out of the region. The precise age of the lowest Tertiary rocks is not known but from the evidence of nearby areas, they seem to be of Miocene age, probably late Miocene. Two basins of Tertiary sedimentary rocks are recognized. The smaller western basin is made up largely of fine debris derived from the nearby ranges and a little volcanic debris, mostly pumice. In the upper part, there are several lenses of breccia-conglomerate that contain some enormous blocks of dolomite of early Paleozoic age. The larger eastern basin was filled with volcanic material, breccias, and flows of rhyolite, latite, andesite, and basalt. Only the basal part is sorted and stratified land waste. A large plug of rhyolite and minor dikes and sills of rhyolite and basalt were intruded late in this epoch and in two districts, gold-bearing veins were formed in these rocks.

Late in Tertiary (middle Pliocene) time, all the earlier rocks were involved in a new epoch of deformation. The middle Tertiary sedimentary rocks and flows were warped into broad anticlines and then overridden by a great plate of diverse rocks that included pre-Cambrian gneiss and limestone and dolomite of early and late Paleozoic age. Remnants of this plate that still remain in the Shadow Mountains, Kingston Range and nearby ranges indicate that the dimension of the plate may have been 15 by 35 miles.

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After a period of erosion that removed much of the thrust plate and reduced much of the area to low relief, the Resting Springs formation (a succession of limy sandstone, conglomerate and pumice at least 1,000 feet thick) was deposited upon remnants of the thrust plate in a small area on the west side of Pahrump Valley. Again following a period of erosion, basalt flows were spread over an area of at least 300 square miles, southwest of Valley Wells. The older flows at the north end of the field are greatly eroded, but at the south end much younger flows that lie in modern valleys do not show much erosion. In the southern part of the field, the flows are surmounted by 26 cinder cones.

The highest range of the area, the Spring Mountains, is sustained by limestone of Paleozoic age and seems to have survived the early Tertiary period of great erosion. The thick sections of middle Tertiary sedimentary rocks and volcanic rocks of the eastern basin were deposited against its lower slopes. The nearby valleys, Mesquite on the west and Ivanpah on the east, however, appear to be due to downwarping (Mesquite) and faulting (Ivanpah) in recent time, in fact, after the basalt flows west of Valley Wells were poured out. Many small normal faults lie along the hills and ridges east and west of Ivanpah Valley. Such faults are also found in the ridges along the west border of the quadrangle, adjacent to the Death Valley depression. Even though erosion is carrying great quantities of waste into Mesquite and Ivanpah Valleys, their playas are nearly 1,500 feet below the upland that lies east and west of them.

The mineral resources include deposits of metals, the most important being zinc, lead, gold, and copper, and several nonmetals of which limestone, dolomite, and talc have been most important. Among those that have potential importance are deposits of the rare-earth metals and pumice.

There is a possibility that some gold deposits (Vanderbilt) were formed in Proterozoic time but most of the metal deposits are related to deformation and instrusion during late Cretaceous time. This study indicates that several factors determine their geologic distribution: their wall rocks, their original distribution in depth and their present areal distribution. The major factor in their distribution is the zone of thrust faults that trends generally north in the north half of the quadrangle. The zones of brecciation along minor rather than major thrust and reverse faults, several tear faults, and some early formed normal faults in the zone of thrusts have localized most of the metallic mineral deposits and all the important ones.

The type of igneous rocks that were intruded in the zone of thrust faults is secondary factor in the deposition of the metals. The largest bodies of intrusive rock, largely quartz monzonite but in part hornblende monzonite, lie in the southern half of the quadrangle, but the greater number and most productive metal deposits lie in the Goodsprings district in the northern part where there are many small sills and dikes rather than large intrusive bodies. Even though there are many metal deposits in and near the large bodies of quartz monzonite in the southern half of the quadrangle, only a few seem to be worthy of exploitation and none are as large as several in the Goodsprings district.

The position of host rocks in the geologic column is third factor in the kind and distribution of metal deposits. The most favored zone for deposition is in the massive limestone beds of the Monte Cristo limestone of Mississippian age. A few metal deposits are found in the overlying Bird Spring formation of Pennsylvanian age and in the underlying Sultan limestone Devonian and still fewer are in the Goodsprings dolomite (Upper Cambrian to Devonian). The reason for this stratigraphic distribution seems to lie in the probability that faults and breccia zones persist for greater distances, both horizontally and in depth, in the thick massive limestones than they do in the thinner bedded carbonate rocks, which contain thin layers of shale.

In the large bodies of intrusive quartz monzonite in the south half of the quadrangle, the metal deposits also show a zonal distribution downward from the upper contact with the intruded sedimentary rocks of Paleozoic age. Deposits of copper with minor amounts of silver are most common at or near the upper contact; successively downward in the intrusive, there are deposits of gold, tungsten, and molybdenum. Even though many such deposits have been found in the bodies of quartz monzonite, none have yet proved worthy of large plans for exploitation.

At two places, the Hart district (Castle Mountains) and Getchel district (Hackberry Mountain), thin veins that contain free gold have been found in the basal flows, largely rhyolite, of Tertiary age. These deposits are related to the late Tertiary period of mineralization. None have proved to be worthy of large plans for exploitation.

The Ivanpah quadrangle contains extensive beds of both limestone and dolomite, which are exploited where they are near transportation facilities to markets, and where the local beds are pure. The area could yield enormous quantities of both high-grade limestone and dolomite. The known deposits of talc occur at a definite horizon in the Crystal Springs formation (Pahrump series) where it has been intruded by sills of dark monzonite and diabase. Perlite has been mined in the flows of Tertiary age in the Castle Mountains; large quantities exist in other areas.

INTRODUCTION

LOCATION OF THE AREA

The Ivanpah quadrangle (fig. 1) lies between 115° and 116° west longitude, and between 35° and 36° north latitude.

The length of the eastern and western boundaries is about 69.0 miles and of the northern and southern boundaries, 56.2 and 56.8 miles respectively. The quadrangle contains therefore about 3,898 square miles of which 1,242 lie in Nevada and 2,656 in California. The southward course of the Colorado River, which separates Arizona from southern Nevada and southeastern California, lies 12 to 15 miles east of the eastern boundary of the quadrangle. The southern part of Death Valley trough which contains the sinks of the Mojave River (Soda Lake and Silver Lake) lies from 3 to 10 miles west of the western boundary. United States Highway No. 91, the main artery of travel from Las Vegas to Los Angeles, crosses the quadrangle diagonally from the northeast corner to near the southwest corner. Also the Union Pacific Railroad extends diagonally from the northeast corner to near the southwest corner. The settlement of Ivanpah on that railroad, and not far from the center of the quadrangle, is 517 miles by rail southwest of Salt Lake City and 267 miles northeast of Los Angeles.

The name Ivanpah is a Piute Indian word reported to mean "a small spring coming out from a white saline soil."

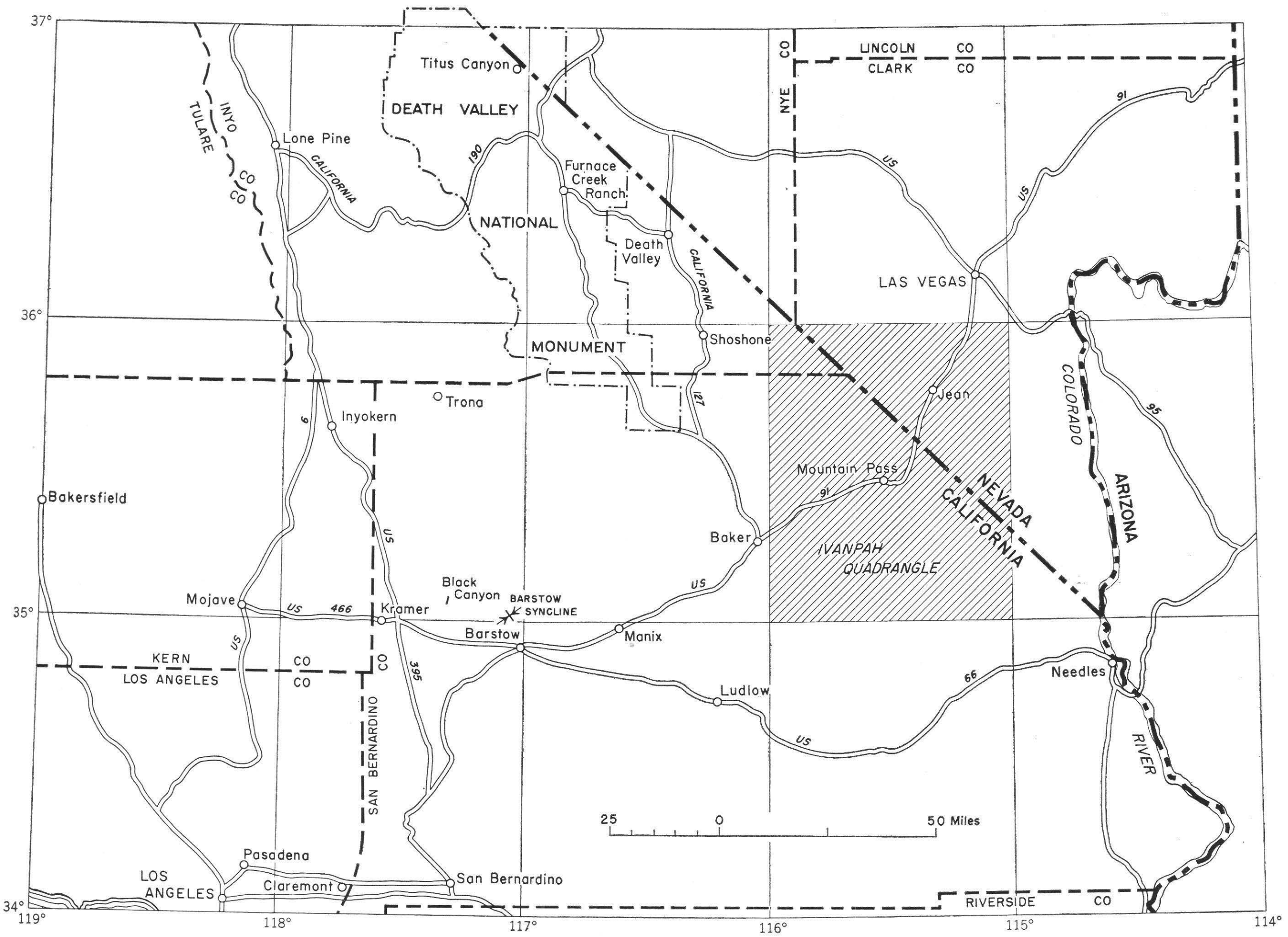

FIGURE 1.—Index map of southern Nevada and southeastern California showing location of Ivanpah quadrangle.

FIELDWORK AND ACKNOWLEDGEMENTS

Fieldwork by the writer in this region began October 15, 1921, and the succeeding 8 months were devoted to geologic mapping of the Goodsprings special quadrangle and the study of 72 mines included in it. Of the total area of that quadrangle, 224.5 square miles, all but 30.5 lie within the area of the Ivanpah quadrangle. Fieldwork in the remainder of the area covered three periods, September 10 to December 21, 1924; October 18, 1926 to February 24, 1927; and September 19 to October 20, 1929. Since 1929, many short visits to the area have been made.

The area under survey is large, about 3,900 square miles, and it is sparsely settled. The topographic map of the area is good. Necessarily, the methods of fieldwork took account of these elements. Even though many of the roads shown on the map have been abandoned, most of the critical areas lie within 6 miles of roads that could be travelled by a car. A light truck, carrying essential camp equipment, food, and water, was used, so that the party, including the geologist and assistant, was not dependent upon local accommodations. Commonly, settlements were used for living accommodations. In addition, the miners, prospectors, ranch owners and cattlemen of the region generously offered accommodations on many occasions. Generally, the day's work included a drive of 10 to 25 miles to a new area, a foot traverse of 5 to 15 miles up the ravines and along the ridges, and a return to base in the early evening. Locations were determined by topographic features or by compass sights on conspicuous objects. A simple calculation based upon the size of the area and the time devoted to field work, will show that an average of about 7 square miles of the bedrock surface was mapped every working day. In addition, about 100 mines and prospects outside the Goodsprings quadrangle were examined. Necessarily under this plan, attention to detail varied from place to place, depending upon its relative importance. For example, it seemed unwise to pursue the petrographic details of Lower pre-Cambrian rocks and minutae of the successive flows and tuffs of the Tertiary volcanic rocks. On the other hand, the attempt was made to record carefully the distribution of the pre-Cambrian rocks, and formations of Paleozoic and Mesozoic age, and their attitude in order that no essential structural features of the region would be overlooked. Doubtless, many details have been overlooked and some misinterpreted, but the author believes that in general the map and text portray accurately the principal features, insofar as stratigraphy and structure are concerned.

Many persons have contributed toward this study. G. L. McIntyre, a resident of the region, acted as field assistant during 1926, 1927, and 1929. By his intimate acquaintance with the region, knowledge of motor cars, unfailing energy, and cheerful spirit, he contributed greatly to make many difficult tasks pass smoothly. Frank Miller, of Goodsprings, served effectively as field assistant during September and October 1924. L. E. Williams, manager of the Yates cattle ranch at Valley Wells; John Woolf, manager of the Rock Springs Cattle Co. at Barnwell; and H. G. Gibson, of Cima, cheerfully extended generous hospitality many times. All the miners, prospectors and residents of the region aided in the progress of the work from time to time. Special mention should be made of Z. V. Farmer, of Lanfair; Jack Daly, of Horse Spring; William Hickey, of Kingston; James Birney, of Wheaton Springs; Charles Loomis, of the Beatrice mine; Richard Munzberg, John Fredrickson, Charles Beck, and Al E. Buys of Goodsprings, Nev.

HISTORY OF EXPLORATION

The Mojave and Colorado Deserts in southern California presented more obstacles to early exploration than any other area of similar size in the United States (Thompson, 1929, p. 9–23). Because of these obstacles, they were the last to yield to regular travel. It may be said that the Oregon Trail was established in the forties and the California Trail in the fifties, but wagon travel across the Mojave Desert did not begin until the sixties. Discoveries of valuable minerals in the region have followed the early explorations in successive waves, the earliest from about 1863 to 1885, the next 1890–1895, and the latest from 1905 to 1915.

If the early migrations of the aborigines are ignored, the earliest exploration by white men was a part of the effort to establish ties between the Spanish settlements of northern Mexico, the area that is now New Mexico, with those on the coast of southern California. Apparently the first white person to cross the Mojave Desert was Father Garces, a Spanish priest who had emigrated to Mexico and became a missionary among the Indians (Coues, 1901; Bolton, 1930). In 1774, Juan Bautista de Anza led an expedition from Tubac in southern Arizona to the site of San Francisco via the southern border of the Colorado Desert. In 1775, he, with Father Garces, set out from the same region to found a settlement at San Francisco, with a party of 240 persons, accompanied by 695 horses and 365 beeves. The main party, travelling by the southern route, arrived at San Gabriel Mission on January 4, 1776. Father Garces, after lingering at the Indian villages (rancherias) north of the present site of Yuma, followed the Colorado River northward, and, on March 1, 1776, arrived at the village of Santa Isabel, the present site of Needles, Calif. On March 3, with three other men he travelled 3 leagues to San Pedro de Los Jamajabs (Mojave), approximately opposite the site of old Fort Mohave. On March 4, he moved 2½ leagues westward to some wells, Pozos de San Geronimo (location obscure; possibly in the Dead Mountains), and on March 5, 8 leagues generally westward to some wells (probably Vontrigger Spring). On March 6, he moved 5 leagues westward "through level lands and grassy (Lanfair Valley). I arrived at a sierra that has pines though small ones and I named it Sierra de Santa Coleta (north end of Providence Mountain and nearby Mid Hills). In the afternoon (March 7), I passed the Sierra through a good gap (north of Columbia mine). Having travelled 4 leagues westward, I halted (Marl Spring)." On March 8, after travelling 6 leagues southwest, "I arrived at some very abundant wells which I named Posos de San Juan de Dios (obscure; probably springs on Indian Creek, but possibly wells on the eastern border of Soda Lake)." Thence he continued up the valley of Mojave River through Cajon Pass to San Gabriel Mission. Returning eastward, he followed Mojave River, and on May 20, 21, and 22, "I retraced the same road that I had come, as far as the Posos de San Juan de Dios (obscure)." On May 23, "Quitting the road of the coming, I directed my steps to the E. N. E. and having gone 2 leagues, I halted in the sandy plain (south of Valley Wells) where there was a Chemebet (Mojave) rancheria." There he remained a day, and on May 25, "I went 4½ leagues E. S. E. completing the crossing of the sandy plain and of the Sierra de Santa Coleta (Mid Hills)." On May 26, "I travelled 3 leagues E. N. E. with one turn to the south and halted nigh unto a poso, scant of water in consequence of its shallowness, which I named Pozo de San Felipe Neri (Rock Springs?)." On May 27, "I travelled 5 leagues E. N. E. (across Lanfair Valley?). The continuous sierras abound in grass and are clothed with a few trees." Finally, on May 28, "I went 1¼ leagues on a course N. E. and came to a good watering place that I named Aquage de la Trinidad (probably Piute Spring). Here I saw a Chemebets rancheria." From this point Father Garces returned to the villages on the Colorado River. After several years of missionary work throughout Arizona, he was killed at the mouth of the Gila River in 1781. This was a remarkable journey, especially if one considers the character of the country and the facilities available. Horses were used to carry their meager baggage, but the men travelled on foot and depended upon local Indians to guide them and furnish water and provisions. For many years thereafter, the Spanish made no attempt to colonize the region surrounding the Colorado River.

The Dominguez-Escalante party (Hill, 1921; Greer, 1928) attempted in 1776 also to go from Taos (New Mexico) to Monterey, California, via central Utah and southern Nevada and California. They reached the upper Virgin River before they abandoned the plan and returned to Taos (New Mexico) via northern Arizona.

In 1826, Jedediah Smith (Dale, 1918) a fur trader, went from the present site of Salt Lake City to San Gabriel Mission via Virgin River, the Mojave Desert, and Mojave River. After leaving the Colorado River he records (Dale, p. 190), "I travelled a west course fifteen days over a country of complete barrens, generally travelling from morning to night without water. I crossed a salt plain about 20 miles long and 8 wide (Soda Lake?); on the surface was a crust of beautiful white salt, quite thin." He then ascended the Mojave River to Cajon Pass and reached San Gabriel Mission, November 28, 1826. Dale thinks that Smith's route closely followed that of the present Santa Fe railroad. It is true that there are three salt lakes, Bristol, Danby, and Cadiz, along this route, but it lacks the numerous springs of the northern route across Lanfair Valley and Kelso Wash to Soda Lake, which is the logical route to the Mojave River. Smith made the same trip again in 1827, but lost 10 out of the party of 19 in a fight with the Indians at the Colorado River crossing (Warner, 1876, p. 181).

In 1829, the Antonio Armijo expedition (Hill, p. 464–465) composed of 60 Mexicans left Santa Fe, descended San Juan River, crossed the Colorado River at the Crossing of the Fathers, descended Virgin River, crossed the northern edge of the Mojave Desert, and ascended the Mojave River to Cajon Pass and San Gabriel Mission. This seems to have been the first expedition through this region for purposes of trade; they carried woolen blankets to exchange for mules, which they took back to Santa Fe. The same year, Ewing Young, with 17 men, including young Kit Carson (Sabin, p. 44–51) traveled from Taos through the Navajo and Zuni regions of Arizona to the western end of the Grand Canyon, then in three day's travel southwest, reached the Colorado River, crossed it, then came to "a dry river rising in the Coast Ranges (Mojave River?). This they followed several days before they came to water in it." Four days later they reached San Gabriel Mission. On the return trip to Taos he followed the route of Jedediah Smith down the Mojave River, across the desert to the Virgin River (Hill, p. 466; Warner, 1876).

Late in 1830, a party headed by William Wolfskill left Taos proceeded northwest and crossed the Colorado River at the present site of Moab, Utah, then crossed the Green River at the present site of Green River, Utah. He then proceeded southwest through Wasatch Pass to the Sevier River which he followed south to the source, then to the headwaters of the Virgin River and to the site of Las Vegas, Nevada. From there, he crossed the Mojave Desert to the Mojave River then followed it to Cajon Pass; he arrived at San Gabriel Mission in February, 1831. From this time onward, this general Route was followed by annual caravans from Taos to San Gabriel and became known as "the Spanish Trail."

The next incident in the history of the country was the exploration of Capt. J. C. Fremont (1845). Traveling south and southeast from San Francisco through the San Joaquin Valley, he entered Mojave Desert, and on April 21, 1845, reached the Mojave River near Victorville. From about the site of Daggett, he turned northeast across the desert, followed Amargosa River and crossed Mountain Springs Pass, May 1, enroute to Las Vegas and the Virgin River. There are numerous narratives of expeditions that followed the Spanish Trail after this time.

In 1848 G. D. Brewerton and Kit Carson with a party of 26 men made the trip from San Gabriel to Santa Fe via the Spanish Trail. On the way, they caught up with a caravan of Mexicans who were driving a herd of 1,000 horses and mules to New Mexico. Until 1848 the Mojave Desert was a part of the territory under the jurisdiction of Mexico that was ceded to the United States after the war with Mexico.

A new epoch in the history of the region began about 1853 with the initiation of surveys for railroad routes to the Pacific. Early in 1854 Lt. A. W. Whipple (1856, p. 29) crossed the Colorado River near Needles and followed closely the route of Father Garces to the Mojave River.

> About 40 miles above the junction of Rio Santa Maria, we left the Colorado at the mouth of a dry arroyo (Piute Wash) heretofore supposed to be the bed of Rio Mojave. Gradually ascending the barren slope of the hillside, 10 miles from the Colorado, we found several small springs of good water (Klinefelter). Twenty miles beyond, we encamped upon a pretty rivulet (Piute Creek) which watered a small valley that had been converted by the Mountain Pai-utes into a luxuriant garden. Passing the crest of a hill and leaving to our right the wide valley (Lanfair) supposed to belong to Mojave River, by a gradual ascent over wide prairies of rich grama grass, we reached

a rocky glen where were springs abounding in excellent water (Rock Springs). No timber was here although low cedars afforded plenty of fuel. From Rock Springs, 5 miles led us to the summit 50 miles beyond and 4,900 feet above Rio Colorado; the grades, however, by detours upon the ascending slopes, need not exceed 70 feet per mile. We then passed into a dry ravine (Kelso Wash) leading to Soda Lake.

On Whipple's map, the area between his route and the Spanish Trail, roughly that under investigation here, is marked "unexplored."

The same year, 1853, probably unknown to Whipple, Beale and Heap, working under Congressional authority to search for lands upon which to place some California Indians, made the journey from Westport, Kans., to Los Angeles via the Santa Fe and Spanish Trails (Beale and Heap, 1853, p. 101–109). They crossed the desert in August and experienced great hardship from the heat and lack of water and forage. Several years later, Beale used 30 camels as beasts of burden for a trip from Zuni to San Bernardino via the Colorado Desert (Beale, 1859; Exec. Doc. 43, 1857).

The first geological work in this region was done in 1853 by W. P. Blake, who was attached to the Williamson party, which was exploring for a railroad route across the Colorado Desert (Williamson, 1856). Blake prepared a colored geological map of the southern half of California. The exploration extended down Mojave River as far as Soda Lake and as far northeast as Agua Tio Meso (Garlic Spring). The map showed only granitic and metamorphic rocks and alluvium.

Fort Mohave, on the Colorado River, was built in 1858 and became the base from which subsequent explorations were conducted. In 1861, a ferry across the river was established here and the route to the Mojave River and Los Angeles came to be the most important in this part of the Southwest. Camp Cady was established in 1868 and for several years thereafter the Government maintained army posts at Piute Spring, Government Holes, and Marl Spring. The only specific reference to this region during this decade that has been found by the writer is contained in a report by J. R. N. Owen to the Commission of the United States and California Boundary Survey, dated April 15, 1861 (Whitney, p. 469–474). Whitney also presents notes (p. 463–469) made by a Dr. Cooper, who, in the winter of 1860–61, made the trip from Fort Mohave, on the Colorado River, to San Bernardino via Piute Spring, Rock Springs, and Marl Spring.

The explorations under the United States Army before 1869 were largely concerned with routes available for travel, but from then on the purpose was broadened to include preparation of maps and investigations of the resources of the region. The surveys under Lieut. G. M. Wheeler from 1869 to 1884, to which G. K. Gilbert was attached as geologist, yielded an atlas of maps on the scale of 4 miles to the inch, and seven volumes were printed concerning the character of the region, geologic features and mineral resources, climate, and plant and animal life.

On account of the steadily increasing importance of the mineral resources of the region, with which this investigation is chiefly concerned, subsequent events are recorded chronologically in the light of their bearing upon the development of the resources.

1854. Potosi mine discovered by party of Mormons.

1857. First mining at Eldorado Canyon. District organized 1861.

1861. First discoveries in New York Mountains.

1863. Work begun at Techaticup mine, Eldorado Canyon.

1865. First discoveries of Ivanpah mines, Clark Mining district organized July 18, 1865. The district was very active and productive until 1884.

1868. Stampede to White Pine followed by widespread prospecting in southern Nevada.

1869. First shipments of copper ore from Copper World mine, Clark Mountain.

1882–86. Sporadic work on gold-copper mines of Goodsprings region, the Keystone, Boss, Columbia, Double Up mines.

1883. Southern Pacific Co. built branch eastward from Mojave to Needles, where it joined the Atlantic and Pacific Railroad (present Atchison, Topeka and Santa Fe Railway Co). In 1884, Santa Fe Lines acquired the branch line and began to operate it.

1886. General decline of mining in Ivanpah district and increase in Goodsprings district.

1890. Crossman (1890–91) wrote a descriptive summary of mines of Clark Mountain, Providence and other districts.

1893. Railroad from Goffs to Vanderbilt (New York Mountains) constructed by A. Blake.

1893–96. Discovery and extensive development of gold mines at Vanderbilt, Calif.

1894. Turquoise found near Crescent, Nev., south end McCullough Range.

1897. Turquoise found in Riggs Wash, Calif., southwest of Shadow Mts. First work on Lucy Grey mine, Nev., in hills west of McCullough Range. First discoveries in Searchlight, Nev.

1903. F. L. Ransome examined mines of Searchlight and Crescent districts, Nev. Railroad from Barnwell, Calif. to Searchlight, Nev., completed; it was abandoned in 1923.

1904. Tractor road from Amargosa Valley through Mesquite Valley and State Line Pass to Roach, Nev., Los Angeles and Salt Lake Railroad.

1905. Los Angeles and Salt Lake Railroad (the present Union Pacific Railroad) completed. Vigorous prospecting throughout entire region; continued until 1910.

1915–18. Widespread exploration for zinc, copper, and lead ores in entire region during the war.

PIONEERS

It is appropriate at this place to refer briefly to those men who, by pioneering in this region, made important contributions to its history between 1865 and 1900. Joseph Yount was probably the first white settler in this region. He had been a member of Doniphan's Expedition (Hughes, 1848) in Texas and drove a herd of cattle into Pahrump Valley in 1865, finally settling at Manse ranch in Pahrump Valley in 1876. He and his two sons, Samuel E. Yount and John B. Yount, played an important part in the discovery of a number of mines in the region, particularly Keystone (1882), Columbia, Boss (1886), and Double Up. John Yount was still living on his ranch in Pahrump Valley in 1936. John Moss was one of the organizers of the Clark mining district, July 18, 1865, which then included the mines near the Colosseum, Copper World, and Mohawk, on the slopes of Clark Mountain. In 1868 he discovered one of the silver mines of Ivanpah (Crossman, v. 61, p. 363). Joe Good, also a cattleman, went into the region with John Moss and was the first owner of the spring around which Goodsprings was built. J. A. Bidwell went into the Clark district in 1866, and, as owner of the Lizzie Bulloch mine and mill, played an important role in the development of old Ivanpah. The McFarland brothers owned the Ivanpah Consolidated Mill & Mining Co., which operated the Beatrice mine. Charles Loomis, who was living at the Beatrice mine in 1929, went to the Ivanpah district in 1875 and worked there until 1882. A. E. Buys went to Ivanpah in 1881 and was active in mining near Goodsprings until his death there in 1925. A. G. Campbell went into Goodsprings in 1886 and located many mines in that district. Jonas Taylor relocated the Keystone mine in 1888, but gold was first produced in 1892.

Several of the springs of this region still bear the names of early settlers—Joe Good, Yates and Dan Kessler, cattlemen; Vontrigger and Whitfield, prospectors; Halloran, an Army officer.

SETTLEMENTS

The distribution and size of the settlements of this quadrangle are determined by four industries—mining, transportation, cattle raising, and agriculture. The state of these industries has varied from time to time since 1855, and the population has reflected the cycles of their rise and decline.

Although the first residents were attracted by mines (Potosi, 1854), the first permanent settlers (1865) sought grazing lands. Even though confined to four centers only, cattle raising is the oldest permanent industry. It was first started in Pahrump Valley (Manse and J. B. Yount ranches) but still continues at Valley Wells (Yates ranch), Barnwell (Rock Springs Cattle Co.) and McClanahan Spring (Smith's ranch). At times, after several wet seasons, the number of cattle has probably risen to eight or ten thousand, but, after several dry seasons, such as 1927–29, it has shrunk to several hundred. Watered from troughs at wells or springs, the cattle graze over the plains and hills as far away as 6 or 8 miles.

When this investigation was in progress most of the residents were engaged in mining and prospecting, but the total number has varied greatly since 1870, depending upon the rising or declining fortunes of the industry. About 1875, according to local report, there were about 500 persons in and near old Ivanpah on the east slope of Clark Mountain; most of these had left by 1885, and, in 1926, a few low adobe walls were all that remained of the town. Subsequently interest has chiefly centered around Goodsprings and Sloan, Nev., but Vanderbilt, Calif., (1892–98), Crescent, Nev., (1895), Cima, Calif., (1905–15), and Hart, Calif., (1907–10) have temporarily attracted considerable numbers. The population of the Goodsprings district rose to about 800 in 1917, declined to 50 in 1922, rose to 200 in 1925, and has declined to about 100 recently.

The settlement of Sloan is dependent upon the quarry and lime plant of the Nevada Lime & Rock Co., and, as these are continuously operated, the population remains fairly constant.

As the rainfall in the valleys of this region is uniformly less than 10 inches a year, it seems doubtful that forage crops or orchards can be raised without irrigation. From time to time, however, a number of persons have taken homesteads in several valleys and attempted to raise crops, in places by irrigation, using groundwater raised by pumping, and, in places, depending solely upon rainfall. Several attempts have been made to colonize Mesquite Valley, where water underlies a large area, 5 to 60 feet below the surface. The latest attempt, 1922 to 1925, brought 12 families and led to the establishment of a post office (Kingston, Calif.) and a school. In 1929, only two families remained, and in 1954, it was abandoned. A similar attempt was made to colonize Lanfair Valley between 1912 and 1918. In 1917, there were 130 voters registered in the valley, and there were two schools, and several post offices. In 1926, only three families, including nine persons, remained; in 1938, the town was abandoned. If mining is revived and a local demand is created, there are several areas where permanent agricultural industries may be developed.

The most permanent settlements of the region depend on the railroad that crosses it. In addition to the numerous small settlements required to maintain the tracks and bridges, Kelso contains a roundhouse and a hotel for railroad employees. Nipton is the point of departure of a regular stage service to Searchlight. The completion of a graded automobile highway across this region (U. S. Highway 91, Arrowhead Trail) in 1925 has led to the establishment of many roadside camps, equipped to take care of travelers and to dispense automobile supplies. Most of these may be considered permanent.

From what is known concerning the resources and climate, as well as the history, this region probably will never support permanently more than a few thousand persons. The following estimate of the population during 1924–26, was made by the writer:

Approximate Population, 1924–26

	Population
Black Mountains	None
McCullough Range	2
Crescent district	4
Vanderbilt district	8
Barnwell district	6
New York Mountains	2
Pinto Valley	6
Providence Mountains	12
Vontrigger district	8
Lanfair Valley	6
Sloan	150
Erie	12
Juan	11
Roach	10
Calada	10
Desert and nearby mines	30
Nipton	16
Ivanpah	10
Cima	20
Dawes (Ames)	8
Kelso	65
Sands	3
Goodsprings town and nearby mines	75
Mesquite Valley	10
Clark Mountain mines	8
Valley Wells	6
Shadow Mountain	2
Kingston Range	1
Total	500

GEOGRAPHY

SURFACE FEATURES

The area under survey lies near the southern border of the Great Basin, the major subdivision of the Basin and Range province as defined by Nolan (1943, p. 142). The term "Great Basin" was first used by Fremont, who recognized it as that large area east of the Sierra Nevada from which no streams drained outward to the sea; he prepared no map showing its limits. Obviously, any limits must be drawn according to drainage basins. In recent years, the term "Basin and Range province" has been used to include a larger area within which the outstanding surface features were linear mountain ranges and ridges separated by broad linear valleys. South of the Great Basin and limited southward by the San Andreas fault which almost coincides with several mountain ranges (San Gabriel and San Bernardino), is the Mojave Desert. Unlike the Great Basin, its surface is characterized by isolated mountains and ridges of various forms and arrangements that are separated by great sandy wastes of irregular shape and diverse extent. The western part of the Mojave Desert is sharply separable from the southwestern part of the Great Basin by a valley (Leach trough), which trends generally eastward and closely coincides with the Garlock fault.

The northeastern half of the Ivanpah quadrangle includes several linear mountain ranges separated by linear valleys and therefore shares the characteristic features of the Great Basin. The southwestern half, however, has several isolated mountains and ridges of diverse form but mostly very irregular. It therefore shares the features regarded as characteristic of the Mojave Desert. A line drawn from the northwest corner of the quadrangle map to the southeast corner roughly separates those regions. This line or zone coincides roughly with the Ivanpah fault and related flexures; the fault, however, does not seem to be related to the Garlock fault. These statements reveal the difficulty in defining and in drawing the limits of physiographic provinces in general, as well as the meagre state of knowledge of the geology of southern Nevada and southeastern California.

The dominating feature of southern Nevada is the Spring Mountains, an arcuate range that culminates in Charleston Peak (11,910 feet), 15 miles north of the Ivanpah quadrangle. This range may be regarded as continuing southward to Clark Mountain and Ivanpah Mountain in California but these mountains have more complex forms and the range name is not applied south of State Line Pass. The highest altitude in the quadrangle, Potosi Mountain (8,504 feet), lies on the axis of Spring Mountains. The geologic features of Clark Mountain and Ivanpah Mountain, stratigraphic and structural, have much in common with those of the Spring Mountains.

McCullough Range, which culminates in McCullough Mountain (6,996 feet), is a simple linear ridge for 15 miles, and it merges northward with a rugged ridge that culminates in Black Mountain (5,043 feet). As the two ridges are underlain by rocks that are utterly unlike, only fortuitous circumstances of erosion have given them continuity.

The group of ridges about 70 miles long, which includes New York Mountains, Mid Hills, and Providence Mountains, have linear continuity but they are interrupted by many small valleys. New York Mountains culminate in a peak (7,445 feet), but the highest point in the Providence Mountains (6,800 feet) lies south of this quadrangle. East of this chain of ridges there are many isolated small ridges and hills of irregular shape, the hills near Highland Spring, Castle Mountains, Piute Range, Hackberry Mountain, Table Mountain, and others. A wide variety of rocks underlie these ridges.

West of the chain formed by the Spring Mountains and Ivanpah Mountain lie numerous mountains and hills isolated by broad alluvial valleys. The Kingston Range which culminates in Kingston Peak (7,320 feet) is nearly circular and about 10 miles in diameter; it is a rugged area from which narrow valleys radiate. Old Dad Mountain (4,275 feet) is the culminating point of a prominent ridge, 15 miles long. The area between Kingston Range and Old Dad Mountain includes many rugged hills and ridges that have diverse sizes and forms.

Only a small part of the lowlands of the quadrangle drains outward to the surrounding region, and a still smaller part drains to streams that flow into the sea. More than half the quadrangle drains to lowlands in the quadrangle that have no outlet—Ivanpah, Mesquite, and Pahrump Valleys, whose low points have about the same altitude, 2,595, 2,550, and 2,550 feet, respectively. A small part of the northeast corner of the quadrangle drains to Las Vegas valley and thence to the Colorado River. The basin that lies east of Black Mountain and northeast of McCullough Range has no surface outlet to the Colorado River. The basin east of Crescent Peak drains to Piute Wash and thence to Colorado River at Needles. Most of Lanfair Valley drains south to an enclosed basin near Goffs. Kelso Wash and the small basins as far north as Highway No. 91 drain to Soda Lake, a sink of the Mojave River. Kingston Wash drains to Silver Lake, probably once a sink of the Mojave River.

The western half and southeastern quarter of the quadrangle contain extensive remnants of a nearly flat upland surface that range in elevation from about 3,500 to about 4,500 feet and are more conspicuous on the ground than on the topographic map. Parts of this surface can be considered as pediments of the nearby mountains, for they are smooth and gently rolling, are cut upon hard rocks of diverse varieties and show sporadic patches of debris of local origin. As this upland surface is an important datum in the recent history of the region, it seems appropriate to give it a name, the Ivanpah upland. Clearly, it was formed during a cycle of erosion that began in late Pliocene time; since it was formed, there have been profund movements on several faults, (see p. 105) and the drainage pattern has been greatly changed.

The Ivanpah upland is well shown in the basin east of Crescent Peak which drains southeast to Piute Valley and to Piute Wash where it is cut on middle Tertiary volcanic rocks. Most of Lanfair Valley is a part of the Ivanpah upland which is trenched by the few arroyos that drain southeast and south. The higher parts of Lanfair Valley are cut on monzonite; the hills that rise above the alluvium of the lower parts are wholly middle Tertiary volcanic rocks. The upland surface is represented by the smooth divide near Cima that lies between Ivanpah Valley and Kelso Wash.

The Ivanpah upland is also shown in the broad basin near Valley Wells cut largely on monzonite but in part, sedimentary rock of Paleozoic age. Erosion, northwestward down Kingston Wash to Silver Lake and westward to Soda Lake, is rapidly destroying the surface.

The upland is not widespread in the northwest quarter of the quadrangle but patches may be discerned in the hilly country between Clark Mountain and Kingston Peak, Calif. It is suggested by broad flat surfaces southeast and west of Potosi Mountain in Spring Mountains, Nev.

Even on the topographic map it may be noticed that the slopes of the mountains and ridges are gentle toward the Ivanpah upland surface; this is more impressive when they are viewed on the ground. In striking contrast, the slopes of the mountains and ridges toward the Mesquite, Pahrump, Ivanpah Valleys and Soda Lake are much steeper and more rugged. The floors of these valleys lie 1,000 feet or more below the upland and the intermittent streams are rapidly pouring large quantities of waste into them.

The Cima Dome, first recognized and described by Lawson (1915; Davis, 1933) is a nearly circular dome about 10 miles in diameter that rises about 1,000 feet above the Ivanpah upland. Several hills rise abruptly several hundred feet above the smooth surface of the dome. Only one of these hills, Teutonia Peak, is made up of the underlying monzonite; the others are remnants of ancient crystalline rocks or recent basalt cinder cones. It seems clear that Cima dome was formed when the Ivanpah upland was developed and that it has been only slightly affected by erosion since that upland was formed.

The processes and steps by which the outstanding surface features were developed are discussed on pages 101–106.

CLIMATE

The Ivanpah quadrangle lies within a larger region in which the annual rainfall is low and the annual as well as daily range in temperature is uncommonly high. Within the quadrangle, there are no stations for which observations have been made continuously for many years. Records of rainfall and daily temperature have been made almost continuously at Las Vegas since 1896 and at Searchlight since 1914 by the U. S. Weather Bureau. Within the quadrangle, records have been kept as follows (Waring): At Jean, from 1907 to 1915; at Pahrump Ranch, from 1914 to 1916; at Kingston, a post office and store in Mesquite Valley, from 1924 to 1942; at Yucca Grove on Highway 91, from 1932 to 1945; and at Lanfair, from 1912 to 1915 (Thompson, 1929). In recent years, 1941–45, records have been kept at Silver Lake Weather Bureau which lies in the Death Valley trough, 8 miles north of Baker on Highway 91.

Rainfall, in inches, at stations in and near the Ivanpah quadrangle

[Asterisks indicate that the record is incomplete]

Year	Nevada				California		
	Las Vegas (2,033 ft.)	Jean (2,864 ft)	Searchlight (3,445 ft.)	Pahrump (2,607 ft)	Kingston (2,475 ft.)	Yucca Grove (3,900 ft.)	Silver Lake (918 ft.)
1896	3.24	-------	-------	-------	-------	-------	-------
1897	5.35	-------	-------	-------	-------	-------	-------
1898	1.64	-------	-------	-------	-------	-------	-------
1899	2.03	-------	-------	-------	-------	-------	-------
1900	-------	-------	-------	-------	-------	-------	-------
1901	-------	-------	-------	-------	-------	-------	-------
1902	-------	-------	-------	-------	-------	-------	-------
1903	-------	-------	-------	-------	-------	-------	-------
1904	-------	-------	-------	-------	-------	-------	-------
1905	-------	-------	-------	-------	-------	-------	-------
1906	-------	-------	-------	-------	-------	-------	-------
1907	-------	*2.42	-------	-------	-------	-------	-------
1908	4.73	5.47	-------	-------	-------	-------	-------
1909	7.05	*6.15	-------	-------	-------	-------	-------
1910	4.11	*5.08	-------	-------	-------	-------	-------
1911	-------	*2.19	-------	-------	-------	-------	-------
1912	-------	*1.33	-------	-------	-------	-------	-------
1913	4.96	2.95	-------	-------	-------	-------	-------
1914	4.98	*3.48	10.18	*1.01	-------	-------	-------
1915	8.41	*2.74	8.67	*2.80	-------	-------	-------
1916	8.11	-------	6.79	*.58	-------	-------	-------
1917	4.33	-------	6.32	-------	-------	-------	-------
1918	8.68	-------	11.82	-------	-------	-------	-------
1919	4.95	-------	9.49	-------	-------	-------	-------
1920	4.74	-------	9.51	-------	-------	-------	-------
1921	5.47	-------	15.22	-------	-------	-------	-------
1922	5.81	-------	11.90	-------	-------	-------	-------
1923	4.50	-------	8.83	-------	-------	-------	-------
1924	2.49	-------	2.71	-------	-------	-------	-------
1925	5.27	-------	4.84	-------	*1.25	-------	-------
1926	3.58	-------	8.06	-------	1.38	-------	-------
1927	4.49	-------	8.35	-------	5.57	-------	-------
1928	1.75	-------	1.70	-------	1.74	-------	-------
1929	2.77	-------	3.50	-------	2.02	-------	-------
1930	3.97	-------	4.00	-------	4.84	-------	-------
1931	8.58	-------	13.23	-------	9.48	-------	-------
1932	7.75	-------	5.76	-------	4.83	4.03	-------
1933	2.94	-------	5.26	-------	3.05	4.61	-------
1934	3.34	-------	6.51	-------	2.70	3.93	-------
1935	4.38	-------	9.22	-------	4.11	7.81	-------
1936	5.84	-------	11.38	-------	3.30	10.17	-------
1937	3.13	-------	5.08	-------	3.19	*5.42	-------
1938	5.84	-------	9.45	-------	4.60	11.70	-------
1939	7.67	-------	17.44	-------	5.49	10.08	-------
1940	4.93	-------	8.69	-------	5.45	9.58	-------
1941	8.40	-------	18.34	-------	7.98	*13.14	8.15
1942	1.45	-------	2.10	-------	*2.15	-------	3.35
1943	5.66	-------	*3.76	-------	-------	-------	3.50
1944	1.91	-------	*1.85	-------	-------	6.80	3.45
1945	4.34	-------	9.79	-------	-------	11.00	5.30

Generally, most of the rainfall results from cyclonic storms during the months from December to March; the remainder results from violent local thunder storms during July, August, or September. As in many other regions, the rainfall increases with increase in altitude. For example, the rainfall at Yucca Grove (altitude 3,900 feet) is nearly twice that at Silver Lake (altitude 918 feet), 18 miles due west, and that at Kingston (altitude 2,475 feet), 30 miles northeast. Also, rainfall at Searchlight (altitude 3,445 feet) is generally 50 percent higher than that at Las Vegas (altitude 2,033 feet) about 48 miles north. From observations of snowfall in the mountains, there seems to be a tendency for increasing amount with higher altitudes. Although the rainfall during winter storms is higher, they do not cause as much erosion as the summer thundershowers. The great erosion indicated during several Tertiary and Quaternary periods when arid conditions undoubtedly existed, doubtless indicates the prevalence of violent storms throughout these periods.

Daily temperatures frequently rise to 105° to 110° F. during summer months and frequently fall 30° to 45° F. at night. Freezing is uncommon during the winter months at altitudes of 2,000 feet or less. With higher altitudes, the daily and seasonal minimum temperatures fall. Without doubt, the great daily and seasonal range in temperature are important factors in breaking up the rocks so that when storms come, the rock waste is quickly removed to the valleys and basins.

WATER SUPPLY

SPRINGS

In contrast with much of the surrounding desert region, the Ivanpah quadrangle contains many springs, and water may be obtained from shallow wells in several valleys. From time to time, as the result of several investigations (Waring, 1920), 68 springs have been examined in the quadrangle. Some are only small seeps that do not persist through the dry summer, but most of them flow perennially. There are many more springs that issue from the ground above an elevation of 5,500 feet than issue below it but not all of the higher mountains contain springs. Springs are common in Kingston Range, Spring Mountains, Ivanpah Mountain, and the New York Mountains. On the other hand, they are sparse in McCullough Range, on Black Mountain, and Shadow Mountain. In a broad way, springs are most abundant in the higher mountains that are underlain by granular rocks, such as quartz monzonite. The areas of crystalline gneisses such as underlie McCullough Range and several other mountains, contain only a few springs. The largest springs of the region, Goodsprings and Cottonwood

Springs (north of the northern border), rise in stratified rock, such as thin-bedded dolomite, warped into favorable structural forms; a few of the larger springs, Potosi, Ninety Nine, and others, rise along faults in the stratified rocks.

The accompanying table 1 records the general location, improvements, and approximate flow of most of the springs and a few of the wells known in this quadrangle. The list includes only a few of the wells for abundant data concerning these has been collected and presented by G. A. Waring (1920) and D. G. Thompson (1929).

Flow from these springs differs, and for springs that rise in coarse granitic rocks (quartz monzonite), generally ranges from 1 to 3 gallons a minute or from 60 to 180 gallons an hour. To many acquainted only with well-watered regions, springs of this size seem inconsequential, but many of them play an important role in the life and industries of this region.

WELLS

About 100 wells have been dug or drilled in the four alluvial valleys of the quadrangle. They are distributed as follows: Mesquite Valley (Waring, p. 77–78) 38 wells of which the deepest is 1,083 feet; Goodsprings Valley (Hewett, 1931, p. 7), 35 wells of which the deepest is 115 feet; Ivanpah Valley, 14 wells, of which the deepest is 687 feet; and Lanfair Valley, (Thompson, 1920, p. 672–673) 13 wells, of which the deepest is 879 feet. Although water in some of the wells rises nearly to the surface, it has never risen and flowed freely above the surface at any well. From the inadequate data available from these wells, it seems that the shallow groundwater tables of Mesquite and Ivanpah Valleys have very low gradients toward the lowest part of the present surface of the basin (Waring, p. 69). In places, however, (Mesquite Valley), the data indicate that the entire body of alluvium below the shallow water table is not saturated with water but contains saturated layers or lenses in the midst of material that is practically dry. The water in such lenses is under sufficient pressure to cause it to rise in the well, but not to the surface of the ground. There is rather meager information available concerning the character of the material which yields the water in the wells (see p. 108). This investigation adds little to that already in print concerning the location and depth of the wells in these basins or the quantity and character of the water which has been found.

CHARACTER OF GROUND WATER

All published analyses of the water from springs and wells of the quadrangle are contained in the following table. In considering these analyses it should be borne in mind that the samples from the deeper wells, (more than 100 feet deep), are probably drawn from several zones and there are probable variations in composition of water from these zones.

The waters from four of the springs (Nos. 16, 93, 111, 113) are drawn from surficial granitic alluvium and they have much in common. They are dominantly

TABLE 1.—*Record of springs and wells of Ivanpah quadrangle*

Location	Name or Owner of spring or well	Depth of well in feet	Depth to water 1926–7 feet	Remarks—geology, improvements, and observer
		Northwest quarter		
Kingston Range	Crystal Spring			Spring rises in rocky ravine on a fault. Piped 150 ft to box, then 300 ft to 4-ft tank, then 400 ft to barrel. Flow, 2 gpm.
Kingston Range	Beck Spring			Spring rises in talus opposite ravine. Improved by 10-ft tunnel; pipe to 6-ft tank. Flow, 4 gpm.
Kingston Range	Horse Spring			Spring rises in talus in ravine. Improved by pipe 400 ft to barrel. Used to water small garden. Flow, about 5 gpm; could be increased to 10–15 gal.
Kingston Wash	Coyote Holes			Rises in valley wash. Piped to trough, submerged by recent flood. Flow several gallons a minute.
Sec. 32, T. 23 S., R. 56 E.	J. B. Yount well	145	105	Drilled to 145 ft with 6-in. drill. Water rose 40 ft. Equipped with windmill; recently destroyed.
Kingston Wash	Kingston Spring			Not visited.
Clark Mountain	Pachalka Spring			Spring is an open pool in talus. One pipe, leading 40 ft to tank flows 3 gpm; another leading to a trough near Valley Wells flows 10 to 12 gpm.
Clark Mountain	Whitfield Spring			Not visited.
Clark Mountain	Greens mine	250±	104	New shaft of Mojave tungsten mine equipped with windmill and pump. Water intermittently pumped to trough for cattle.
Clark Mountain	Ivanpah Spring			Spring rises in granite talus on east end of ridge. Water piped 500 ft to tank on north side of ridge. Flow 22 gal per hr.
Clark Mountain	McIntyres Spring			Waring's (1920) Spring No. 91. Improved by a tunnel and water piped 5 miles north to Carbonate King mine.

TABLE 1.—*Record of springs and wells of Ivanpah quadrangle*—Continued

Location	Name or Owner of spring or well	Depth of well in feet	Depth to water 1926-7 feet	Remarks—geology, improvements, and observer
Southwest quarter				
Sec. 7, T. 16 N., R. 11 E.	Francis Spring			Spring rises in volcanic alluvium. Water is piped 150 ft to well equipped with pump, then 100 ft to trough. Flow estimated at 2 gpm.
Sec. 7, T. 15 N., R. 10 E.	Hytens well	125+	125	Inclined mineshaft equipped with bucket and windlass.
Sec. 14, T. 15 N., R. 10 E.	Halloran Spring			Spring rises in granitic alluvium near Halloran Wash. Improved by a tunnel. Water is piped 100 ft to a trough; flow estimated at several gallons a minute.
Sec. 9, T. 14 N., R. 11 E.	Granite Spring			Spring rises in granitic alluvium. Improved by a 5-ft pit in which water stands. No flow.
Sec. 10, T. 13 N., R. 11 E.	Indian Spring			Not visited.
Sec. 36, T. 13 N., R. 12 E.	Marl Spring			Spring rises in granitic alluvium. Improved by a tunnel. Water is piped 150 ft to trough. Flow estimated at several gallons a minute. Larger spring rises 600 ft south.
Sec. 20, T. 11 N., R. 10 E.	Railroad wells at Sands.	246	196	Two drilled wells, 11–13 in. in diameter. Water comes from alluvium lying on granitic rock. Yields 125 gpm.
Sec. 24, T. 11 N., R. 12 E.	Railroad wells at Kelso.	882	450	Three drilled wells, 9–13 in. in diameter. Water derived from alluvium. Yield, 3,500 gal per hr from 2 wells.
Mescal Range	Mescal Spring			Spring rises in gneissic rock, near contact with overlying dolomite. Improved by a well and tunnel. Water is piped 250 ft north to series of four troughs. Flow, about 1 gpm.
Ivanpah Mountain	Mexican well	5	2	Well sunk in granitic alluvium. Equipped with hand pump. G. A. W.
Ivanpah Mountain	Roseberry Spring			Spring rises in granitic alluvium. Estimated flow 20 gal per hr. G. A. W.
Ivanpah Mountain	Wheaton Spring			Spring rises in granitic wash, 1,500 ft south of camp. Piped to camp and to cattle trough. Flow, about 3 gpm.
Ivanpah Mountain	Mineral Spring			Not visited.
Ivanpah Mountain	Kessler Spring			Spring rises in granitic alluvium west of road. Piped to trough in corral. Estimated flow 2 gpm.
Cima	Gibsons well	200	None	Dug well near store. Dry.
Sec. 11, T. 14 N., R. 13 E.	Teutonia mine	200	70	Mine shaft equipped with pump. Water used locally.
Sec. 20, T. 14 N., R. 13 E.	Deer Spring			Not visited.
Sec. 23, T. 14 N., R. 13 E.	Cut Spring			Flow estimated at 100 gal per hr. G. A. W.
Sec. 36, T. 14 N., R. 13 E.	White Rock Spring			Flow estimated at 80 gal per hr. G. A. W.
Northeast quarter				
Bird Spring Range	Bird Spring			Spring issues from alluvium near thrust fault. Improved by tunnel and pipe 250 ft to trough. Flow, 2 gpm.
McCullough Range, sec. 8, T. 26 S., R. 61 E.	McClanahan Spring	25	20	Upper well equipped with hand pump and pipe to house. Lower well is 1,500 ft west.
Sec. 23, T. 26 S., R. 61 E.	McCullough Spring			Not visited.
Sec. 5, T. 25 S., R. 62 E.	Oro Hanna Spring			Not visited.
Sec. 16, T. 27 S., R. 62 E.	Highland Spring			Cement tank 4 x 4 x 10 ft built over natural tank in gulch. Water piped 250 ft to tank, then 2,500 ft to two troughs used by cattle. Flow, 2 to 3 gpm.
Ivanpah Valley, sec. 24, T. 26 S., R. 59 E.	Yates well	200±	180	Dug well in alluvium. Equipped with windmill and auxillary gasoline pump. Used for stock.
Ivanpah Valley	Yates well	91	81	Dug well equipped with gasoline pump and trough.
Sec. 8, T. 28 S., R. 61 E.	Wells at Crescent, Nev.	30		Wells dug in granitic alluvium. G. A. W.
Southeast quarter				
Castle Mountains	Lewis Holes	35	30	Dug well in granitic alluvium. Equipped with windmill, tank, and trough for cattle.
Castle Mountains	Quail Spring			Sought but not found.
New York Mountains	Malpais Spring			Spring rises from volcanic breccia. Water piped to trough. Estimated flow 2 gpm.
New York Mountains	Indian Spring			Sought but not found.
New York Mountains	Dove Spring			Spring rises in volcanic breccia. Estimated flow 2 gpm. G. A. W.
New York Mountains	Willow Spring			Spring rises in volcanic breccia. Estimated flow 2 gpm. Improved by shaft; piped 1,000 ft to trough. G. A. W.

TABLE 1.—*Record of springs and wells of Ivanpah quadrangle*—Continued

Location	Name or Owner of spring or well	Depth of well in feet	Depth to water 1926-7 feet	Remarks—geology, improvements, and observer
Southeast quarter—Continued				
New York Mountains	Bulloch Spring			Piped 300 ft north and northwest to two troughs.
New York Mountains	Spring			Spring issues from volcanic breccia 1,000 ft north of benchmark 4,572. Piped 50 ft southwest to trough. Estimated flow 30 gal per hr.
New York Mountains	Slaughterhouse Spring.			Spring rises in wash near Clark Mountain fault. Improved by a tunnel. Water piped 200 ft to trough. Estimated flow 3–4 gpm.
New York Mountains	Mexican Spring	30	20	Original spring abandoned. Present source is well dug in granitic alluvium.
Mid Hills	Springs in Cedar Canyon.			Seeps from granitic alluvium north of road. Not perennial.
Providence Mountains	Summit Spring			Not visited. Water piped 8 miles to Kelso.
New York Mountains	Granite well	20	15	Two wells 300 ft apart dug in decomposed granitic rock. One equipped with hand pump.
Providence Mountains	Gold Valley Spring	?	25	Spring improved by a well equipped by a hand pump.
Mid Hills	Government Holes	32	15	Dug well in granitic alluvium equipped with gasoline pump.
New York Mountains	Rock Springs			Spring rises in alluvium in ravine carved in granitic rock. Estimated flow several gallons a minute.
Hackberry Mountain	Hackberry Spring			Not visited.
Hackberry Mountain	Vontrigger Spring			Spring rises in volcanic breccia. Piped 1 mile to small garden. Estimated flow, 5 gpm.
Table Mountain	Spring			Spring rises in granitic alluvium 2 miles southeast of Table Mountain. Improved by tunnel; piped 200 ft to 10-ft tank. Estimated flow, 15 gal per hr.
Piute Mountain	Piute Spring			Spring rises in volcanic breccia near fault. Estimated maximum flow on surface, for half a mile, 40–50 gpm.

Analyses and classification of ground waters of Ivanpah quadrangle

[Well numbers according to Waring (W) or Thompson (T)]

Name of spring or well location	Well No.	Determined Constituents (parts per million)									Computed Quantities					Classification		
																Quality for—		
		SiO_2	Fe	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	Total solids	Total hardness $CaCO_3$	Scale-forming constituents	Alkali coefficients	Chemical character	Boilers	Domestic use	Irrigations
GEOLOGIC ENVIRONMENT—ALLUVIUM IN BASINS																		
Mesquite Valley																		
J. B. Yount well	45 W	13	0.45	58	30	20	266	58	24	0	338	268	230	81	Ca-CO_3	Fair	Fair	Good.
C. Heidecke well	58 W	23	Tr.	57	42	16	217	136	20	2.0	403	315	260	97	Mg-CO_3	do	Poor	Do.
W. A. Tritt well	64 W	26	.20	76	84	66	278	334	73	Tr.	823	534	390	26	Mg-SO_3	Bad	do	Do.
J. B. Yount well	72 W	53	Tr.	35	40	140	307	156	108	0	694	262	220	16	Na-CO_3	do	Fair	Fair.
Sandy Mill well	74 W	24	.16	80	45	30	273	189	20	1.80	542	384	340	81	Ca-CO_3	Poor	Poor	Good.
J. B. Cryor well	76 W	18	.20	61	41	26	256	122	29	Tr.	435	321	270	65	Ca-CO_3	Fair	do	Do.
Bullocks well	86 W	35	Tr.	69	37	406	224	207	251	Tr.	1,445	324	300	3.6	Na-Cl	Very bad.	do	Poor.
Ivanpah Valley																		
Old Borax Team well.	89 W	23	0.20	480	441	8,927	844	3,921	12,489	0	27,501	3,010	2,200	0.5	Na-Cl	Unfit	Unfit	Bad.
S. E. Yates well	96 W	30	Tr.	201	158	2,416	402	429	3,984	0	7,702	1,150	880	.5	Na-Cl	do	do	Do.
Desert well	97 W	17	------	26	19	107	154	49	139	--------	433	143	120	14	Na-Cl	Bad	Good	Fair.
Buckner well	103 W	41	1.4	15	5	101	171	31	61	0	372	58	94	9.9	Na-CO_3	Fair	do	Do.
Murphy well	106 W	59	.33	28	20	55	211	51	30	2.8	355	152	180	28	Na-CO_3	do	do	Good.
Ivanpah well	108 W	17	.30	26	4.1	49	73	73	35	5.0	240	82	100	47	Na-SO_4	Good	do	Do.
Lanfair Valley																		
Jacoby well	9 T	32	29	35	7	35	173	23	19	.08	229	116	150	35	Ca-CO_3	Fair	Good	Good.
GEOLOGIC ENVIRONMENT—SURFICIAL ROCK MANTLE																		
Ivanpah Mountain																		
Mexican well	93 W	45	0.27	79	48	96	342	189	88	2.4	746	394	360	20	Na-CO_3	Poor	Poor	Good.
Kessler spring	110 W	36	Tr.	67	17	35	178	58	71	9.0	406	237	260	29	Ca-CO_3	Fair	Fair	Do.
Cut spring	111 W	45	.66	67	18	44	236	61	57	.05	433	241	270	34	Ca-CO_3	Poor	do	Do.

Analyses and classification of ground waters of Ivanpah quadrangle—Continued

[Well numbers according to Waring (W) or Thompson (T)]

Name of spring or well location	Well No.	Determined Constituents (parts per million)									Computed Quantities					Classification		
																Quality for—		
		SiO_2	Fe	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	Total solids	Total hardness $CaCO_3$	Scale-forming constituents	Alkali coefficients	Chemical character	Boilers	Domestic use	Irrigations
GEOLOGIC ENVIRONMENT—SURFICIAL ROCK MANTLE—Continued																		
New York Mountains																		
Barnwell well	2 T	14	------	134	50	71	382	208	117	--------	782	540	490	17	$Ca-CO_3$	Bad	Poor	Fair.
Lecyr well	3 T	32	0.59	308	74	172	186	1,006	175	0.08	1,992	1,070	1,100	11	$Ca-SO_4$	Unfit	Bad	Do.
Moore well	16 T	36	.19	86	33	126	422	152	84	.31	731	350	340	19	$Na-CO_3$	Poor	Poor	Good.

carbonate waters with soda and lime greatly exceeding other bases. Total solids range from 406 to 746 parts per million. Water in the Barnwell well is drawn from andesitic breccia and water of the Lecyr well from local waste. Total solids in both waters are high and the Lecyr water is uncommonly high in sulfates and chlorides, considering the size of the collecting basin.

Areal distribution of the wells as well as their depths should be considered for waters from the wells in the alluvial basins. The shallow waters from the low areas of the basins are very high in sulfates and chlorides (Bullock, Borax Team and Yates wells). This seems to indicate that there is a steady drift of the more soluble salines in the shallow zones from the borders toward the central low areas. The waters from the shallow border (higher) wells closely resemble those from the springs in the high ridges, for they are the carbonate type, and total solids range from 355 to 823 parts per million. Further, the water from the deep zones of wells that lie midway between the central saline areas and the borders of the basins (Desert, Buchner, Murphy, Ivanpah, Jacoby wells) have about the same amount of total solids (229 to 433 parts per million) as the springs and are the same type (soda and lime carbonate). It is not known whether these deep waters (400 to 1,000 feet below the surface) are essentially static or not; probably they are more nearly static than the water in the surficial zones. When such zones are tapped by drilling and the waters are removed by pumping, it is probable that the zones are recharged by waters moving laterally from the outcropping intake belts.

DEPTH TO WATER IN MINES

The following table summarizes the data concerning depth to water in mines that have been collected during this investigation. These data supplement those given above concerning water in springs and wells.

Depth to water in mines

Mine No.	Name	Approximate altitude at surface, feet	Depth to water, feet	Country Rock
Spring Mountains				
27	Potosi	6,300	175	Yellowpine limestone member.
35	Keystone	4,757	100	Granite porphyry.
33	Alice	5,050	230	Bird Spring formation.
------	Lavina	4,275	125	Granite porphyry.
------	Valentine	4,200	170	Anchor limestone member.
Clark Mountain				
65	Mojave	5,100	105	Granite gneiss.
14	Huytens	3,250	125	Teutonia quartz monzonite.
Ivanpah Mountain				
94	Teutonia	5,400	70	Teutonia quartz monzonite.
91	Sunnyside	4,700	90	Granite gneiss.
New York Mountains				
102	Gold Bar-Vanderbilt	4,200	200	Granite gneiss.
97	Contact	5,400	50	Dolomite contact zone.
111	Barnett	5,150	55	Teutonia quartz monzonite.
109	Sagamore	5,900	80	Quartzite.
97	Big Hunch	6,300	100	Teutonia quartz monzonite.
Providence Mountains				
115	Columbia	4,700	90	Granite gneiss.
114	Francis	4,600	100	Do.
Hackberry Mountain				
134	California	3,560	160	Granite gneiss.
138	Lord and Irish	3,400	80	Teutonia quartz monzonite.
141	Leiser Ray	3,200	450	Do.

Kingston Range.—The mines of the Kingston Range area, largely tunnels that attain depths below the mean surface of 200 to 300 feet, are quite dry.

Spring Mountains.—Water was found in only five mines in the Spring Mountains area, but many tunnels that attain depths below the overlying surface of 200 to 700 feet are entirely dry. For example, no water accumulates on the lowest level of the Keystone mine about 500 feet, or the Yellow Pine, about 700 feet vertically below the overlying surface.

Clark Mountain.—All the mines nearby the Clark Mountains are dry (Calarivada, 285 feet; Wade mine, 95 feet; Benson mine, 250 feet; Sulphide Queen mine, 365 feet, vertically), except the Mojave mine (old shaft 350 feet, new shaft 250 feet vertically) in which water now stands at about 105 feet and which is equipped with a windmill and pump.

Ivanpah Mountain.—Except for a vertical shaft, 700 feet northwest of the Sunnyside mine, where water stands at 90 feet below the surface, all of the mines in Ivanpah Mountain are dry. (New Trail, 185 feet; Standard Mine No. 2, about 200 feet).

Halloran Wash.—Huyten's well, 125 feet deep, contains water but the mines near Halloran Wash are dry (Telegraph Mine, 125 feet).

McCullough Range.—Water is not found in any of the mine shafts of the McCullough Range and nearby mountains. (Lucy Grey mine, 260 feet; Lucky Dutchman mine, 335 feet; Nippeno mine, 350 feet, vertically.)

New York Mountains.—The Gold Bar (Vanderbilt), Sagamore and Big Hunch mines struck water that required pumping, but all of the other mines in the New York Mountains are dry. (Baldwin shaft, Vanderbilt, 300 feet; Midnight mine, 150 feet; Trio mine, 600 feet; Prospect No. 110, 250 feet vertically).

Mid Hills–Providence Mountains.—Water was struck in the Barnett (60 feet), Francis and Columbia mines but the others in the Mid Hills and Providence Mountains are dry (Death Valley mine, 310 feet; Gold King mine, 130 feet, vertically).

Vontrigger area.—All of the mines more than 125 feet deep in the Vontrigger Springs area and several that were shallower reached water.

Several conclusions may be drawn from this data concerning water in mines. Almost regardless of altitude in the region, mines in limestone and dolomite rarely contain water, even at depths as great as 700 feet. Where mines in these rocks reach water at lesser depths, it is sporadic and seems to depend upon the presence of porphyry dikes. Lava flows of Tertiary age (Hart and Hackberry Mountain districts) do not contain water at shallow depths.

Mines in gneissic rocks rarely retain water, even at depths of 200 to 300 feet below the surface. Not only do mines in the McCullough Range and nearby mountains show no water to 200 or 300 feet, but the areas are uncommonly deficient in springs.

Most mines that extend more than 200 feet in Teutonia quartz monzonite reach water but the quantity is not large. Similarly, springs are more common in this rock but their yield is small. In a broad way, the higher the surface, the greater the depth to water and conversely, the lower the surface the shallower the water table.

GEOLOGY

The following table shows the sedimentary and igneous rock units that have been recognized and mapped in this quadrangle and the kinds of deformation and erosion that have taken place. Ordinarily, geologic columns take account only of the successive units of rocks that have been laid down or intruded into the surface zone but do not take into account that geologic processes are continuous. Every part of the earth's crust is either receiving sediment or undergoing erosion, and is either quiet or being deformed or intruded by igneous rocks. The table attempts to present in brief form the recognized episodes that form parts of this continuous record.

Sedimentation, igneous activity, deformation, and erosion in the Ivanpah quadrangle

	Geologic system or epoch	Sedimentation	Igneous and related activity	Deformation	Erosion
QUATERNARY	Recent	Valley fans and local alluvium	Late flows of basalt and cinder cones.		Local internal.
	Pleistocene(?)	Older alluvium			External.
	Pleistocene(?)			Warping in Mesquite Valley. Large faults in Ivanpah Valley and Kelso Valley.	
	Pleistocene(?)		Early flows of basalt in Halloran Wash.		
	Pleistocene(?)	Resting Springs formation fresh-water limestone and gravel in Mesquite Valley.	Pumice in Mesquite Valley.		Local, internal.

about 500 feet, or the Yellow Pine, about 700 feet vertically below the overlying surface.

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	Pleistocene(?)			Warping in Mesquite Valley. Large faults in Ivanpah Valley and Kelso Valley.	
	Pleistocene(?)		Early flows of basalt in Halloran Wash.		
	Pleistocene(?)	Resting Springs formation fresh-water limestone and gravel in Mesquite Valley.	Pumice in Mesquite Valley.		Local, internal.

Sedimentation, igneous activity, deformation, and erosion in the Ivanpah quadrangle—Continued

TERTIARY

Geologic system or epoch	Sedimentation	Igneous and related activity	Deformation	Erosion
Pliocene, late				Widespread, profound, external, in Ivanpah upland.
Pliocene, middle(?)		Gold deposits in the Hart district Hackberry Mountain.	Kingston thrust, Northwest quarter. Playground thrust, Southwest quarter. Warping.	Local, internal.
Pliocene, early Miocene, late.	Conglomerate, sand and clay dominant in Western Basin. Present in Eastern Basin.	Rhyolite, latite andesite, and basalt flows dominant in Eastern Basin; pumice, ash and bentonite present in Western Basin.	Warping.	
	—Widespread unconformity—			
Miocene early, Oligocene, Eocene.				Widespread, profound, external.
Upper Cretaceous to lower Tertiary (Laramide).		Ore deposits, mixed sulfides widespread.	Normal faults.	
		Dikes of monzonite porphyry, aplite, Kingston Range quartz monzonite intrustions. Teutonia quartz monzonite.	Normal faults, thrust faults, open and closed folds.	
Jurassic(?)	Aztec sandstone	Sands granite, Dacite flow breccia.		
Triassic	Chinle formation, Shinarump conglomerate, Moenkopi formation.	Andesite tuff.		
	—Widespread unconformity, uplift, and warping—			
Permian	Undifferentiated Paleozoic< Kaibab limestone. Supai formation.			
Permian Pennsylvanian.	Bird Spring formation.			
	—Local unconformity—			
Mississippian	Monte Cristo limestone.			
Devonian	Sultan limestone.			
Devonian, Silurian, Ordovician, Upper Cambrian.	Goodsprings dolomite.			
Cambrian	Bright Angel shale, Tapeats sandstone } Eastern facies. Pioche shale, Prospect Mountain qtzite, Noonday dolomite } Western facies.			
	—Widespread unconformity—			
Pre-Cambrian	Pahrump series, Kingston Peak formation, Beck Spring dolomite, Crystal Spring formation.	Syenite sills.		
	—Widespread unconformity—			
Pre-Cambrian	Granite-gneiss, schist, pegmatite.			

OROGENIC EPOCHS

The geologic features of this region indicate that it has undergone profound disturbances during at least four periods in its geologic history. Disturbances occurred after deposition of Lower pre-Cambrian rocks, upper pre-Cambrian rocks, and also during the Laramide revolution and late Tertiary period (Pliocene). Each of these disturbances deformed the pre-existing rocks and was accompanied by or quickly followed by, intrusion or extrusion of igneous rocks. After each disturbance, the region underwent great erosion, followed, except for the last, by the deposition of one or more sheets of sediments, mostly of great areal extent. The several unconformities in the sedimentary rocks record minor disturbances.

The structural features of this region are so numerous and diverse and some have such magnitude that considerable attention has been given not only to their location, character, and extent, but to determining their ages, insofar as that is possible (pl. 2). It seems appropriate, therefore, to state briefly some of the criteria that were used to determine their age and their correlation. Some confidence is attached to the determination of the age of most of the major features; obviously, the needed evidence was not obtainable for many minor features, and for them the assigned age is little more than a guess.

The age of the rocks is the first criterion of major importance in determining the age of deformation. In a few places, minor features of deformation, minor faults in some sedimentary rocks, may develop when sedimentary rocks are in process of deposition. In general, most major features of deformation are formed after the sediments have become hard and coherent; they are therefore younger than the youngest involved rocks. In some regions, superimposed younger rocks do not have the characteristics found in the underlying rocks; it may be sofely stated, therefore, that the deformation took place between the time of formation of the youngest involved rocks and that of the oldest, unaffected rocks.

Angular unconformities or those that indicate considerable erosion, suggest that the area changed from one of deposition to one of erosion, and indicate deformation in this and nearby areas. The unconformities at the base of the Pennsylvanian system, (Bird Spring formation), and Triassic system, (Moenkopi forma tion), in this region indicate minor deformations before the over-lying beds were deposited.

Extrusive layered igneous rocks have some of the relations of sedimentary rocks and the same criteria may be used in determining their age. The best criteria of the age of intrusive igneous rocks are the age of the structural features which determine their location and form and have affected them since they were intruded.

Structural features are the second criterion of age of deformation. The kind, pattern, and sequence of structural features established for one area or region are apt to be found in nearby areas or regions. Until more specific evidence is available locally, it is assumed that the relations of the features in the unproved area are the same as in the proved area.

Rock alteration and ore deposits are other criteria of major importance. The intrusion of bodies of igneous rocks commonly is accompanied by circulation of water, either surficial or deep seated. This water deposits ores of the metallic minerals and causes alteration of the intruded rock and in some places, of the intruding rock also. The limestone was dolomitized widely in this region by the intrusion of the Teutonia quartz monzonite and to a lesser degree by some of the middle Tertiary intrusives such as Devil Peak. If faults contain ore deposits, as in the Clark Mountain fault, it is clear that the fault was formed before the process of ore deposition. In many mining districts, it is possible to recognize faults formed both before and after mineralization.

Surface forms and structural features are a fourth criterion of age of deformation. The diverse varieties of rocks, carbonate, sandy, shaly, igneous, and metamorphic, respond at different rates to weathering and erosion under different climatic condition. Under the arid conditions that have largely prevailed in this area during late Tertiary, Pleistocene, and Recent times, carbonate rocks are the most resistant and metamorphic and crystalline igneous rocks are the least resistant to erosion. Where they are unaffected by great faults, areas underlain by carbonate rocks form ridges and mountains, and those underlain by metamorphic and crystalline igneous rocks form lowlands. Where, on the other hand in arid regions the lowlands are underlain by carbonate rocks and the ridges, hills and mountains are underlain by metamorphic and crystalline rocks, consideration should be given to the possibility that such high areas have uplifted recently with respect to the lowlands.

PRE-CAMBRIAN ERA

CRYSTALLINE ROCKS

GENERAL FEATURES

The rocks of the Ivanpah quadrangle include many varieties of gneiss and schist, as well as some igneous rocks that have been only slightly metamorphosed. In some places, the rocks are assuredly older than sedimentary rocks of the Pahrump series (upper pre-

Cambrian), and in other places, older than Cambrian sedimentary rocks, but in still other places, the age of the rocks is inferred from the degree of metamorphism they present rather than from the rocks with which they are in contact. Although this report records the distribution of these rocks in many parts of the quadrangle, lack of detailed study and mapping of their distribution permits only general statements concerning the pre-Paleozoic history of the region. Some of the rocks included as pre-Cambrian are so slightly sheared or recrystallized that it is debatable whether they are pre-Cambrian or perhaps, of Mesozoic age. Those who have worked in nearby regions in the Mojave Desert, and especially those with prior experience in the Sierra Nevada in California, have assigned large units of rocks to the Mesozoic era that are less metamorphosed than those clearly demonstrable to be pre-Cambrian rocks. There are places in this quadrangle, for example, the northern and central parts of Old Dad Mountain, where basal Cambrian sedimentary rocks (Tapeats sandstone) rest upon crystalline rocks that lack many features of foliation and recrystallization characteristic of some proven pre-Cambrian rocks in southeastern California. The symbol on the geologic map therefore indicates that Mesozoic rocks may be included. The McCullough Range and its southward extension, New York Mountains, presents the largest continuous area of these rocks, but includes only a few of the many lithologic varieties known elsewhere. Extensive exposures lie along the east slope of Clark Mountain and Ivanpah Mountain and the northwest slope of Providence Mountains, but there are many small exposures widely distributed in the southern two-thirds of the quadrangle. For the most part, the rocks are resistant to decay and are rugged in the mountainous areas, even more rugged than the Teutonia quartz monzonite of Late Cretaceous to early Tertiary age, which commonly crops out nearby.

The pre-Cambrian crystalline rocks seem to fall into three age groups: the oldest group of sedimentary rocks which show a wide range of alteration to types of schist and marble; the next younger group of intrusive coarse-grained rocks, mostly granite and syenite; the youngest group of intrusive rocks of a wide range in composition and texture, but largely and most widely, aplite and pegmatites.

The schistose sedimentary rocks of the first group are widespread but they seem to form local, narrow belts rather than extensive bodies. Rocks that were once sandstones are now quartzites, most showing several degrees of feldspathization; those that were shale are now foliated mica schist, some garnetiferous and, rarely, with considerable sillimanite; the limestone and dolomite are now marble. Only in a few places do these rocks show folds and plication, so it seems that the original rocks have been altered but not greatly deformed. Probably the flow breccias of Old Dad Mountain are a part of this group.

The second group is the most widespread, and the several varieties underlie large areas. Coarse-grained granites with large crystals of feldspar, in places 2 to 3 inches long, are most common, but syenite and diorite are present. These rocks intrude and alter the earlier group of sedimentary rocks, but they also have been deformed by mashing, as they show lamination and local brecciation (mylonitization).

The third group includes a wide variety of rock types, but mostly they form thin dikes that lie parallel to the foliation of the older rocks and do not show the effects of deformation as do the earlier rocks. Fine-grained alaskite and coarser pegmatite are the most common types; dacite porphyry occurs near the Whitney mine and diorite near Vanderbilt. Dark ferruginous dikes are common. None of the rocks in the younger formations show at any place the degrees of alteration (change in mineral composition) and internal deformation that the pre-Cambrian crystalline rocks show.

These crystalline rocks are clearly the oldest rocks know in this area because they underlie unconformably the Pahrump series of sedimentary rocks and these underlie unconformably the lowest rocks of Paleozoic age of the area.

In the Piute Mountains and Old Woman Mountains that lie 20 miles south and 40 miles southwest respectively of the southeastern corner of the Ivanpah quadrangle, Hazzard and Dosch (Hazzard and Dosch, 1937, p. 308) recognized three groups of pre-Cambrian crystalline rocks which they called the Essex series, Fenner gneiss, and Kilbeck gneiss. The two oldest show general resemblance to the two oldest units of crystalline rocks in this quadrangle. To a similar assemblage of rocks that appears in the mountains west of Needles, Miller (1944, p. 113–129; 1946, p. 457–552; 1938, p. 417–446) has given the name "Needles Complex". He also records similar rocks in the Old Woman Mountains and Piute Mountains and Amboy-Cadiz area.

In the Panamint Range, which lies about 50 miles west of the northwest corner of the Ivanpah quadrangle, Murphy (p. 329–355) has studied and mapped the Panamint metamorphic complex. It contains crystalline rocks that resemble the two older groups here recognized.

McCULLOUGH RANGE

The McCullough Range presents the largest body of metamorphic rocks in the quadrangle. Only the northern and southern parts and eastern borders of the range have been closely examined.

The most abundant rock in the ridge wouthwest of McClanahan Spring is gray gneissic granite in which, over large areas, the foliation persistently trends N. 20°–40° E. and dips 30°–60°N. W. The most abundant mineral is pale-reddish microcline which forms twinned crystals one-fourth to half an inch long in a fine gray matrix. In the order of abundance, the matrix contains quartz, biotite, orthoclase, apatite, and titanite. This rock includes a few dikes of white pegmatite, largely microcline and quartz. Some of these dikes cut across the foliation of the gneiss but others are nearly parallel to it. There are no quartz veins. In the ridges east of McClanahan fault, contorted biotite schist, locally injected by granite, is common. The schist contains many pegmatite dikes that rarely exceed 10 feet in width. East and north of McClanahan Spring, there are belts of biotite and hornblende schist injected by gray granite; the schist is cut also by dikelike bodies of course red granite.

In the region east of McCullough Mountain, the oldest rock is a dark-gray quartz-mica schist, which typically contains quartz, 70 percent; biotite, 20 percent; oligoclase, 5 percent; orthoclase, 2 percent; and apatite and accessories, 3 percent. No hornblende or garnet are present. It forms narrow belts, lenses, and angular blocks, either enclosed in or invaded by gray granite. The foliation trends generally northeast and dips at low angles to the northwest. Locally, it is contorted into folds that trend northeast. The invading granite contains orthoclase, microcline, quartz, and biotite but no plagioclase. A specimen of the injected schist shows abundant microcline with biotite, quartz, albite, and zircon. The borders of the belts of schist adjacent to the granite show considerable almandite garnet. Both the granite and the belts of injected schist contain white dikes of pegmatite which are largely microcline and quartz.

The area along the southern end of the range, exposed within several miles north and south of the road from Crescent to Searchlight, shows sparse patches of schistose rocks but is largely one variety of gneissic granite, which shows several degrees of lamination. On the east side of the range, near the Peyton mine (no. 124, pl. 2), the prevailing rock is greenish-gray granite, that contains orthoclase, quartz, and hornblende with traces of oligoclase and shows only faint lamination. It is intruded here and there by small bodies of gray granite. Near such bodies and in the shear zones, the greenish granite locally shows much epidote. In the succeeding westward belts, the granite is progressively more gneissic. Near the Nippeno mine (no. 125, pl. 2) the granite contains microcline, quartz, oligoclase, and chloritized biotite. The feldspar deposit that has been opened north of Crescent (p. 163) is regarded as a pegmatite which has intruded the gneissic granite. In the southwestern part of McCullough Range, northwest of Crescent, gray gneissic granite like that east of Crescent, but more highly foliated is intruded by lenses of course pinkish granite. These bodies parallel the limination, which here trends north to N. 20° E. and dips 40° to 50° N. W. Near the Double Standard mine (no. 122, pl. 2) and southward, the gneiss is cut by narrow dikes of dark rock that trend generally eastward and are therefore parallel to some of the quartz veins.

Southward from the Crescent–Searchlight road as far as the region around Malpais Spring, the prevailing rock of the west slope of the range is the gray gneissic granite that is common to the north. In places near the crest, south of Crescent Peak, there are small masses of granite that seem to intrude the gneissic granite. As these resemble the Teutonia quartz monzonite near Teutonia Peak, they may be much younger than the gneisses which they intrude. From Malpais Spring, southwest to Vanderbilt, the gneissic granite contains more and more layers and lenses of thinly laminated quartz-biotite schist and diorite as well as dikes of white and pale-red alaskite. Half a mile north of Vanderbilt, a lens of white crystalline limestone about 150 feet wide crops out along the old railroad grade and has been explored by prospects. This and another at the south end of the Old Dad Mountain are the only occurrences of carbonate rock interlayered with the foliated crystalline rocks observed in this region. These occurrences throw light on the nature of the sedimentary rocks which were injected by the pre-Cambrian granitic rocks. Near Vanderbilt and southward to the Clark Mountain fault, against which the pre-Cambrian crystalline rocks abut, dikes of fine-grained diorite are increasingly common. A typical specimen collected from a prospect west of Barnwell shows alternating lenses of coarsely and finely crystalline rock. A thin section of the finer material contains hornblende and biotite in interlocking grains 0.2 to 0.4 millimeter in diameter, in a matrix of andesine (An_{40}), each in about equal proportions. A little pyrite is present, but there is no quartz, orthoclase, and apatite. Examination of a thin section of highly altered quartz-mica schist collected from a shaft near Slaughterhouse Spring, shows predominant quartz in interlocking grains and about equal minor porportions of bitote, chlorite, and muscovite. There are no feldspars. From this point southeastward, the foliation trends north to N. 30° W. and dips 40°–80°.

LUCY GREY RANGE

The most abundant rock in the latitude of the Lucy Grey mine (no. 121, pl. 2) is a gray gneissic granite much like that on the east side of the McCullough Range. The foliation trends persistently N. 30° E. to N. 45° E. and dips 80° NW. About 6 miles north, where a deep valley nearly crosses the range, is a similar gneissic granite of coarser texture. Fully 75 percent of the rock is simple flat crystals of orthoclase, 1 to 2 inches long, that are roughly aligned parallel to the foliation, which here trends N. 30° E. and dips 60° NW. The matrix is largely biotite. The granite contains sporadic, subangular, fragments of dark schist and is cut by a few widely spaced pegmatite dikes. On the northwestern end of the range a belt of crumpled biotite schist is intruded by coarse-textured reddish granite.

The two isolated hills at the south end of Sheep Mountain approximately sec. 5, T. 26 S., R. 60 E., are made up of gray gneissic granite that contains abundant crystals of orthoclase as much as 3 inches long in a matrix of biotite and quartz.

CASTLE MOUNTAINS

The flat area east of Hart Peak in the Castle Mountains coincides with the outcrop of fine-grained gray gneissic granite like that on the west slope of McCullough Range. The eastern portion contains masses of intruded white granite, and the southwestern portion contains granite characterized by coarse reddish orthoclase crystals. The foliation of the gneissic rocks trends generally north to northeast.

VONTRIGGER SPRINGS AND EASTWARD

Gneissic granite is the commonest pre-Cambrian crystalline rock in the southeast corner of the quadrangle. The hill east of the Leiser Ray mine (no. 141, pl. 2) is a body of sheared granite which is intruded by the underlying Teutonia quartz monzonite (see p. 63) and overlain by a cap of basalt of Tertiary age (see p. 82). The granite is largely made up of coarse orthoclase crystals (1 to 1½ inches long) in a sheared matrix of biotite and quartz. It therefore resembles the common rock at the north end of Lucy Grey range and southeast of Sheep Mountain.

Most of the large area of crystalline rocks that lies northeast of Vontrigger Spring is foliated gneissic granite but the area near the California mine (no. 134, pl. 2) has several varieties of sheared granite and dikes of alaskite. The granite includes abundant fine-grained and, less commonly, coarse-grained mixtures of orthoclase, microcline, and quartz with biotite and almandite garnet present both as sparse grains and as segregated lenses. These rocks are intruded by dikes of diorite and coarse-grained alaskite (p. 142). The garnet lenses probably were formed as a result of the intrusion of the alaskite. The foliation of the rocks strikes north to N. 20° W. and dips 60° W.

East of Blackburn, gneissic granite is the most abundant rock but it is intruded by granite porphry which has been mashed (mylonitized), so that it now shows sparse round crystals of white orthoclase as much as half an inch in diameter embedded in a matrix of minute angular fragments of quartz, orthoclase, biotite, and sericite. The schistosity of the porphry as well as the foliation of the gneiss strike northwest and dip steeply southwest. This body of gneissic rocks is probably underlain by the Teutonia quartz monzonite that crops out south of Blackburn.

On the southeast slope of Hackberry Mountain, the workings of the Crater mine (no. 133, pl. 2) reveal alaskite under the rhyolite flows in which the vein is found. Angular blocks of alaskite as well as rhyolite occur in the lowest rhyolite flow. It seems quite clear that the flows of Tertiary age lie upon an erosion surface cut on gneissic rocks.

MID HILLS

The large body of Teutonia quartz monzonite that underlies the New York Mountains and Mid Hills is locally overlain near Cedar Canyon by a block of pre-Cambrian gneissic rocks. This block is cut off from the quartz monzonite to the south by the Cedar Canyon fault which may be traced 8 miles northeastward. The most abundant rock north of the fault is foliated gneissic granite that contains lenses of hornblende mica schist and diorite. The schist resembles that of the McCullough Range, but it contains considerable hornblende. The estimated mineral composition of a specimen from Cedar Canyon follows: hornblende, 40 percent; quartz, 25 percent; andesine, (An_{40}), 25 percent; biotite, 10 percent; orthoclase, apatite, and zircon, accessory. It is not clear whether this rock was originally an intrusive rock or a sedimentary rock. Probably it was an intrusive rock since a lens of coarse quartz diorite nearby showed: andesine (An_{40}) 40 percent; hornblende, 20 percent; quartz, 15 percent; biotite, 15 percent; orthoclase, 5 percent. The foliation of these rocks trends generally northward and dips steeply west.

The prevailing rocks near Black Canyon are gneissic diorite and similar rocks rich in hornblende; there is no gneissic granite. The contact with the underlying quartz monzonite is well shown along the southwest border.

East of Table Mountain a reef of gneissic granite and granite schist nearly 2,000 feet wide may be traced 4 miles northward to the Barnett mine (no. 111, pl. 2) where it is cut off by a northwest-trending fault. The schist contains numerous aplite dikes. This is a curious belt of rocks because the planes of schistosity trend due north and, unlike most of the other blocks of such rock that are intruded by the Teutonia quartz monzonite, the base is nowhere revealed. A similar belt of gneiss and schist is shown in the monzonite, 8 miles southwest of Valley Wells and north of Halloran Spring (p. 22).

PROVIDENCE MOUNTAINS

The area of crystalline rocks on the northwest slope of Providence Mountains does not have much lithologic variety. The commonest rock is foliated fine-grained gneiss granite but there is some fine-grained dark diorite. The general trend of the foliation is northeast and the dip steeply southeast. Where metal-bearing veins have been explored (Columbia, Francis, Silver Fox, pl. 2, no. 114, 115, 113), the rocks are locally sheared and schistose. East of the Bonanza King mine, just south of the border of the quadrangle, the dolomite of early Paleozoic age in which the mine lies is separated from crystalline rocks by an extensive thrust fault. Here the commonest rock is greenish fine-grained diorite, highly sheared near the fault. In each of these areas, the gneiss is cut by reddish alaskite dikes. There are also sporadic andesite dikes, probably of Tertiary age.

At the north end of the Providence Mountains mass, where gneiss is intruded by monzonite, it is locally silicified and impregnated with pyrite. The contact of the two rocks is a surprisingly simple, smooth surface that has been traced several miles.

CLARK MOUNTAIN AND IVANPAH MOUNTAIN

A belt of crystalline rocks extends from Mesquite Pass southwest along the east front of Clark Mountain and Ivanpah Mountain, a distance of about 18 miles. This belt is limited on the northeast by the Ivanpah fault and on the southwest by the Clark Mountain fault, on the southwest side of which are quartzites and dolomites near the base of the section of Paleozoic age. Foliated gneissic granite is the most common rock throughout this belt. It has been formed by the injection (lit-par-lit) of a thinly laminated biotite-bearing rock by granitic magma (microcline and quartz). For the entire belt, the foliation trends northwest; generally it is N. 30° W. except in the area north of the Colosseum (no. 63, pl. 2) where it forms broad arcs that finally merge with the limiting Ivanpah fault. Contorted foliation is rare. There are local zones of mashed or mylonitized gneiss, but schists occur only sporadically; mostly they lie along the eastern border, especially northwest and southeast of Wheaton Spring. Fine-grained quartz mica schist, locally garnetiferous, was noted locally in these areas and in the hills near the Colosseum mine.

At the latter locality such a rock showed dark laminae made up of biotite, sillimanite, andalusite, and garnet. These were injected by layers and lenses of pink microcline and quartz. West of the Colosseum mine, the prevailing rock is a reddish gneissic granite which merges with broad zones of biotite and hornblende schist into which thin dikes of pinkish alaskite (coarse pink orthoclase and quartz) are intruded.

The gneiss and schists have been intruded by several varieties of dikes of pre-Cambrian rocks. They largely follow the foliation or planes of schistosity. The commonest dike rock is reddish alaskite but a white alaskite (oligoclase An_{25} and quartz) and white pegmatite were also observed. Dark dikes, rich in hornblende, are uncommon. A dark-gray dike rock from the hill in Ivanpah Valley, 6 miles west of Calada, contains coarse and fine hornblende crystals in a matrix of labradorite (An_{75}).

In addition to these dikes, two other varieties are interpreted as much younger, probably early Tertiary in age. The Colosseum mine explores an explosion pipe within which the gneissic granite is intruded by fine grained, drab-colored rhyolite (p. 125). Dikes of a similar rock lie several thousand feet north of the mine and a sill intrudes the Cambrian rocks just west of Clark Mountain fault.

Gneissic crystalline rocks appear in two areas along the east front of Ivanpah Mountain. The northern area forms part of a lone hill in sec. 22, T. 15 N., R. 14 E., in the vicinity of the New Trail copper mine (no. 88, pl. 2). Thin-bedded brown quartzite that strikes northeast and dips 70° northwest forms a crescentic area around the northwest end of the hill. Granite gneiss and a variety of actinolite-chlorite schist form the core of the eastern end of the hill. As the nearby surrounding hills are dolomite beds of the Goodsprings dolomite, which dip away from the lone hill, it seems clear that the crystalline rocks form the core of an anticline.

The second area extends 2 miles northwest from the Kewanee mine. The rocks are largely gneissic granite and the foliation trends northwest and dips southwest. The northeast or lower limit of the gneiss has been explored in the Morning Star mine (no. 92, pl. 2) where it trends northwest and dips 34° southwest (p. 126). The Sunnyside mine (no. 91, pl. 2), as well as the Kewanee, explores veins that lie within it (p. 141). The precise form and trend of the southwest or upper surface of the gneiss are not clearly shown.

SOUTHWEST QUARTER

In the southwest quarter of the quadrangle there are many isolated masses of gneissic rocks, remnants of a large plate of such rocks that once overlay the great intrusive body of Teutonia quartz monzonite. Field exposures of many of these remnants show clearly that they are limited downward by a simple surface and that they rest upon the monzonite. In a few areas the masses of such gneissic rocks are overlain by basal sedimentary rocks of Cambrian age, at the northwest end of Old Dad Mountain, in the hills northwest of Kelso, and at the northeast end of Providence Mountains. In a broad way, all these exposures fit in with the interpretation that the monzonite body was intruded along a great fracture in the crust which extended downward through the section of Paleozoic age into the pre-Cambrian crystalline rocks. The fracture has some aspects of a thrust fault along which the upper block has moved eastward upon the lower block. At the northwest end of this belt, especially in the neighborhood of the turquoise mines near Riggs Wash, and at the head of Halloran Wash the surface of contact between the quartz monzonite and the overlying gneissic granite is sharply defined and is broadly smooth and curving. It coincides with the local foliation of the gneiss, which trends generally eastward and dips steeply south.

The rocks included within the block bounded by the underlying monzonite on the north and Highway No. 91 on the south include several varieties of gneiss and schist. Near the Himalaya turquoise mine (p. 165) the base of the block is a broad belt of foliated gneissic granite that is succeeded southward by a gray granite without conspicuous gneissic structure. This in turn is succeeded southward in the area west of Halloran Wash by a broad belt of foliated gneissic granite which contains local belts of schist. A foliated gneiss from this area contains orthoclase and microcline, about 50 percent; quartz, 30 percent; and biotite and hornblende, 10 percent. This rock contains belts of dark gray schist that is made up of andesine (An_{30}), about 40 percent, quartz, 40 percent; and sillimanite, 20 percent. This rock undoubtedly represents sedimentary materials that have been thoroughly injected with granitic material.

The isolated hill, a mile in diameter, that lies east of the mouth of Halloran Wash presents a curiously banded appearance. It is made up of gray biotite granite, much like that which prevails westward, and is cut by innumerable dikes of white aplite and some small quartz veins.

Near the Stonehammer turquoise mine, a quartz vein in a block of limestone is explored by a shaft. About 100 feet below the surface, the shaft passes into granitic schist.

In order to account for the abrupt southward limit to this block of granite gneiss and schist, it is necessary to assume the presence of a fault which trends N. 60° E. and almost follows Highway No. 91 to Baker. The age of such a fault is obscure; it could have been formed at the time of the intrusion of the monzonite or somewhat later. The general distribution of the basalt flows of this part of the region indicates that those which lie north of Highway No. 91 have dropped several hundred feet lower than those south of the highway.

Southward from Highway No. 91 as far as Old Dad Mountain the remnants of pre-Cambrian rocks have not been examined closely. The hill near the Paymaster (Whitney) mine (No. 19) that forms the northern end of Old Dad Mountain is made up of granite, schist, and quartzite. The foliation of the schist and bedding of the quartzite strike north and dip at low angles eastward. The quartzite is feldspathized in part and is cut by many quartz veins; undoubtedly the schist represents an injected sedimentary rock. These rocks are intruded by syenite dikes and southward are overlain by sediments of Cambrian age.

Kelso Peak and a large part of the hills southeastward toward Kelso are underlain by gneissic granite. The attitude and distribution of several blocks of the overlying Cambrian sedimentary rock indicate complicated local faulting. A specimen of gneiss which underlies the basal Cambrian quartzite in this area contains about 60 percent orthoclase and microcline and 30 percent quartz. The southwest group of hills contains considerable areas of dark schists; the 4,200-foot hill is largely contorted dark schist made up of sillimanite, quartz, and biotite.

The rugged hill east of Marl Spring is a block of coarse-grained gneissic granite that rests upon the monzonite intrusive. The ridges 2 miles west of Marl Spring are made up of foliated gneissic granite with included lenses of hornblende schist.

The two isolated hills (4,643 feet) that lie 4 miles northwest of Teutonia Peak are made up of gray gneissic granite and biotite schist that is locally plicated. These rocks are intruded by dikes of gray quartz monzonite similar to that which surrounds them. Farther north, the cluster of low hills that lies 10 miles northwest of Teutonia Peak and 4 miles south of Valley Wells is also made up of many large blocks of gneissic granite and hornblende schist embedded in quartz monzonite of the Teutonia type.

On the north side of the canyon that cuts through the southern part of Old Dad Mountain, limestones containing fossils of Pennsylvanian age and having steep dips (p. 100) rest upon varieties of crystalline rocks that are not known elsewhere in the quadrangle. The contact marks the Playground thrust fault which, along the north side of the canyon, strikes nearly east and dips 20°–30° N. The most abundant rock is a reddish-brown flow breccia of dacitic type. Angular fragments, largely less than 1 inch but in part as much as 2 inches in diameter, show euhedral crystals of sodic andesine in a fine-grained, but wholly crystalline, matrix of quartz and mica with many small and a few large grains of epidote. No dark minerals are present. These fragments appear to be a recrystallized slightly porphyritic flow. The matrix of the fragments shows considerable coarse quartz and orthoclase and small percentage of sodic plagioclase in a finer matrix that contains much sericite. As a whole, the rock shows many fractures but no foliation. Except for the lighter color, the rock resembles the dacite flow breccia that rests upon the Aztec sandstone south of Mexican Well in Wheaton Wash (p. 49).

There might be considerable uncertainty concerning the age of this rock if it were not for some varieties of rock associated with similar flow breccia that forms the south wall of the canyon in Old Dad Mountain. Here, the angular fragments are more abundant in the matrix than in the rock that forms the north wall, and both rocks contain more and coarser crystals of quartz and feldspar. A clue to the age of these flow breccias is given by several reefs of white dolomite, in part crystalline, that limit the breccias at the east end of the canyon; they strike southeast and dip 70° NE. The dolomite is sporadically altered to pale-yellow serpentine. Both the unaltered and altered types of dolomite are more common in formations of pre-Cambrian rocks than in any formations of Paleozoic or Mesozoic age.

The hills south of the canyon are wholly flow breccia as far as the intrusive body of Sands granite. There is no cap of limestone of late Paleozoic age south of the canyon; the strike and dip of the Playground thrust, if projected southward would carry it over these hills.

In the central part of Old Dad Mountain where a local canyon cuts below the plate of rocks of Paleozoic age, dark green hornblendic gneiss is exposed. The Lucky Mine (no. 21, pl. 2) explores a shear zone in this rock.

NORTHWEST QUARTER

The exposures of pre-Cambrian crystalline rocks in the northwest quarter of the quadrangle fall into two structural groups. Two areas that lie in the general northwest extension of Clark Mountain, west of Mesquite Valley, are part of the basement over which a composite block (Kingston Range) has been thrust in late Tertiary (Pliocene epoch?) time. Shadow Mountain and parts of the Shadow Mountains are remnants of the overriding block.

The large area of crystalline rocks that lies northwest of Winters Pass as far as the road to Horse Spring (benchmark 3,143) includes only a few lithologic varieties. The most abundant rock is a pale-greenish-gray variety of gneissic granite that shows varying degrees of mashing or shearing. Some shear zones of this rock are so narrow and persistent on the surface that they are regarded as fault zones. Such a zone extends northeast toward Winters Pass (see p. 60). The gneissic granite is intruded by numerous lenticular dikes of fine-grained pale-pinkish pegmatite, especially in the northwestern part of the area. This area seems to lack the intrusions of dark basic rocks that are found southwest in the Shadow Mountain region. Throughout most of this area of pre-Cambrian gneiss, the schistosity strikes N. 10° E.–N. 45° E. and dips at low angles, 15°–45° NW. In the hills southeast of 3,143, the granite contains sporadic lenses of greenish manganese carbonate which largely replaces granite breccia.

Some of the blocks of sedimentary rock that rest upon this granite are autocthonous, that is, they now rest where they were deposited. Other blocks, such as those of Goodsprings dolomite around the southwest border, were not deposited where they are now found but have been thrust to their present positions. Not only is there no normal succession of beds, but their bedding is not parallel to the surface of contact (see p. 98).

In the small basin known locally as Copperfield, which lies 5 miles northeast of Horse Spring, mashed gneissic granite crops out over an area of about a square mile. The surrounding sedimentary rocks, however, are not those which are known to rest in normal succession upon the granite nearby, and their bedding is not parallel to the surface of contact. It seems clear that the area of gneissic granite is a fenster revealed by the erosion of a block of sedimentary rock that has been thrust over the granite. Many small patches of copper-stained granite have been explored for copper, but its source has not been determined. The granite contains much chlorite probably representing altered biotite.

Gneissic granite crops out in the gulch that drains westward along the northern edge of the Kingston Range. The local geologic features are described for the Beck iron deposit on page 158. A lenticular area of the gneissic granite is exposed for more than a mile along the north side of the gulch. It contains coarse white orthoclase, quartz, muscovite, and chlorite. On the north border, the granite is overlain by a lens of greenish rock, amphibolite, which is clearly an altered igneous rock intrusive in the Pahrump series. It is now largely actinolite, orthoclase, epidote, and chlorite. Explorations with core drills have shown that this amphibolite rock, as well as the vertical beds of limestone that contain the iron oxide bodies, end abruptly downward and are underlain by gneissic granite. When due account of the local relations is taken, it seems clear that the gneissic granite is part of the basement rock over which the surrounding rocks have been thrust. The contact of the granite with the Kingston Range monzonite porphyry that makes up the core of the Kingston Range is not exposed.

The remaining exposures of crystalline rocks in the northwest quarter of the quadrangle are remnants of the dissected thrust plate. As the plate contained a wide assortment of rocks and has been broken by several normal faults, the remnants contain a similar assortment, seemingly in great disorder. Most of the blocks of crystalline rocks lie in the Shadow Mountains (p. 95–98).

The largest block of crystalline rocks in this region is that which makes up Shadow Mountain. The most abundant rock is light-gray, thinly laminated gneissic granite largely made up of orthoclase and quartz grains mostly 1 to 2 millimeters in diameter; grains of albite and magnetite are present. The lamination is marked by thin layers of biotite spaced from 2 to 5 millimeters apart which trend northwest and dip 40°–60° NE. This rock is intruded by sills of dark gneissic syenite several hundred feet wide that lie parallel to the lamination of the granite. The syenite contains abundant orthoclase and hornblende; apatite is a common accessory mineral, and a little quartz is sparsely distributed in the interstices between the other minerals. The granite weathers to flat slabs and wedges whereas the syenite weathers to angular blocks. Both rocks are cut by sparse dikes of alaskite. Some quartz veins of the area lie along the contact of the syenite and granite. Along the western edge of Shadow Mountain, erosion has revealed a small area of unconsolidated light-gray clay and sands similar to beds that lie 6 miles west in the Shadow Mountain. Although the contact with the granite gneiss of Shadow Mountain is not exposed, the areal relations and absence of granitic debris in the nearby sands indicate that the granite gneiss rests upon the unconsolidated clays and has been thrust upon them.

For a distance of 5 miles, the hills that form the main ridge of the Shadow Mountains are blocks of gneissic granite and syenite, of the same varieties that are displayed in Shadow Mountain. The relative abundance of these rocks varies from one block to the next, however, and at the northern end the dark hornblendic rocks prevail. The lamination of the gneiss trends N. 40°–60° W. and dips 45° NE. Here and there the crest and northeast flank of the gneiss ridge contains caps of Cambrian sedimentary rocks, some folded in a fantastic manner (fig. 2). At several places along the west and north slope of this ridge, the base of the gneiss is clearly shown to rest on beds of pale-gray and yellowish shale, volcanic ash, and bentonite of middle Tertiary

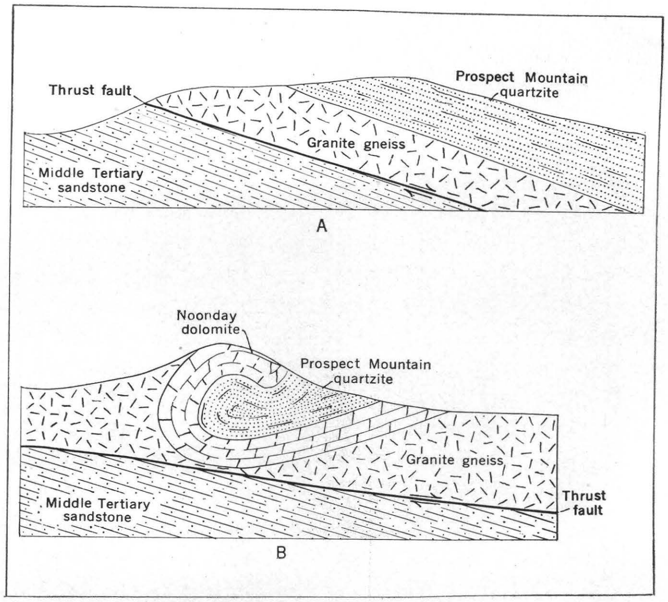

FIGURE 2.—Sections about N. 65° E. across the Shadow Mountains, Calif.

age. In a broad way, the bases of these blocks of gneiss are simple plane surfaces that trend northwest nearly parallel to the bedding of the underlying shale but dip slightly less steeply (p. 96).

Several other blocks of gneissic rocks form a chain of hills along the western border of the Shadow Mountains. In this area gneissic granite is the prevailing rock; one block shows a cap of Noonday dolomite. The small hill (3,218 feet) which lies near the north end of this range of hills shows a cap of gneissic granite and dark diorite about 200 feet thick which rests on feebly consolidated middle Tertiary gray sandy clays (see fig. 3). These strike northwest and dip 35° NE., but

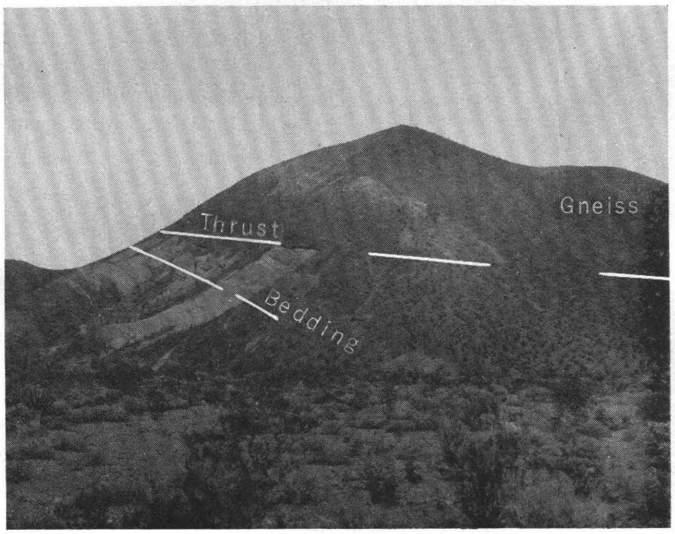

FIGURE 3.—View north to hill (3,218 feet) east of Evening Star Wash, showing block pre-Cambrian gneiss resting on clay of mid-Tertiary section, California.

the base of the gneissic rock is a flatter surface that trends northwest and dips several degrees northeast.

INTRUSIVE ROCKS, SHONKINITE AND SYENITE DIKES

Shonkinite and syenite form both simple and complex bodies in the vicinity of Mountain Pass north and south of Highway No. 91. The largest bodies of shonkinite crop out in the vicinity of the Birthday mine (p. 164) 2 miles north of the highway and at least three other large bodies of syenite and shonkinite crop out in a belt 3 miles long that extends southward from the highway nearly to Kokoweep Peak. Numerous veins that contain noteworthy amounts of bastnaesite, a fluocarbonate of the cerium group of rare earths, have been found both in and near the bodies of shonkinite.

South of Highway No. 91, three dikes of syenite intrude the local granite gneiss, but the bodies of shonkinite are small and inconspicuous. Of the three dikes of syenite, the southwestern dike is about 600 feet in diameter; the middle dike is about 300 feet wide and extends N. 45° W. about 3,000 feet; the third dike lies about 1,000 feet northeast of the middle dike and is about 500 feet long and 100 feet wide. Each dike underlies conspicuous knobs and ridges that rise above the surface of the nearby gneiss.

A specimen of the northeast dike rock is reddish brown and is composed almost entirely of coarse crystals of orthoclase and microcline from 15 to 35 millimeters long; it contains traces of hornblende, biotite, quartz, and magnetite. The rock of the other two dikes is similar but contains about 15 percent hornblende and traces of biotite.

Recent work by Sharp and Pray (1952) in the area of the Birthday mine shows that a body of shonkinite at least 1,500 feet wide and 7,000 feet long intrudes the local granite gneiss. The rock is dark, coarsely crystalline, and shows conspicuous biotite and feldspar. Thin sections show that the average composition is about 40 percent microcline, 30 percent biotite, and 25 percent clinopyroxene; minor accessory minerals include plagioclase, apatite, iron oxides, titanite, and zircon. Locally, the rock shows alteration to riebeckite and aegirite.

In the Birthday mine area, narrow dikes of coarse-grained syenite intrude the shonkinite. They are not conspicuous on the surface, but many have been found in the mine workings. Under the microscope the rock shows about 80 percent microcline, some biotite, amphibole, and pyroxene. South of Highway No. 91 the bodies of syenite are much larger.

Within a mile of the Birthday mine, the bodies of shonkinite and syenite are cut by many dikes and irregular bodies of micrograníte and lamprophyre. The composition of the microgranite is about 50 percent microcline, 30 percent quartz, 10 percent albite, and small amounts of biotite and amphibole. The lamprophyre is about half potash feldspar, and less biotite, amphibole, and clinopyroxene. It seems therefore to be related to the shonkinite.

In this area, the intrusive rocks are older than the veins and other bodies of barite-carbonate rock that contain bastnaesite and monazite (Birthday and Sulphide Queen Mines nos. 75 and 76, pl. 2). By the use of the Larson method, based upon the emanation of alpha particles and determining the lead content, the age of the monazite in the ore has been calculated as 925 million years. The intrusive rocks that are associated with the deposit are assuredly pre-Cambrian.

The other area is the hill that lies north of the Paymaster (Whitney) mine, on sec. 23, T. 13, N., R. 10 E. Here, the foliated gneiss is intruded by large dikes of pale greenish syenite, a rock that is largely orthoclase with minor microcline, biotite and quartz.

In several localities on the north and west slopes of Kingston Range in this quadrangle and in numerous localities 10 to 25 miles west of Kingston Range, dark-green sills intrude the Crystal Spring formation at approximately the same horizon and produce an alteration typified by abundance of white talc. At several localities the horizon is the base of the lowest limestone bed, that containing the magnetite lenses at the Beck iron deposit near Beck Spring. At the iron deposit, the rock is dark green, fairly coarsely crystalline, and has numerous veins of amphibole asbestos. These sections show orthoclase in a matrix of chlorite and actinolite.

Three miles northeast of Horse Spring, however, a similar dark-green sill underlies a bed of dolomitic limestone that contains a large lens of pure white talc. Recently it has been extensively developed at the Excelsior mine (p. 164). In nearby areas, the limestone is a dense white rock, thoroughly impregnated with minute grains of silica, probably the first stage in the alteration of dolomite to talc.

SEDIMENTARY ROCKS—PAHRUMP SERIES

The name, Pahrump series, is applied to a conformable assemblage of sedimentary rocks that unconformably overlies crystalline gneisses and unconformably underlies rocks of Paleozoic age on the north and east slopes of the Kingston Range. The name is derived from the valley that borders the Kingston Range on the north. (Hewett, 1940, p. 239–240.) In this region a maximum thickness of 7,000 feet of sedimentary rocks was measured.

FORMATIONS

The Pahrump series has been divided into three mappable units or formations as follows: Crystal Spring formation at the base of the series, Beck Spring dolomite in the middle, and the Kingston Peak formation at the top.

CRYSTAL SPRING FORMATION

The name, Crystal Spring formation, is derived from a well-known spring of that name (table 1) that lies on the north side of the prominent valley draining westward out of the Kingston Range. In this quadrangle, the formation is limited to a belt about 10 miles long, but the base is observed at only one locality, about 2 miles east of Horse Spring. The following section was measured on the south slope of the high ridge north of Beck Spring:

Section of Crystal Spring formation measured on south slope of ridge north of Beck Spring

	Feet
Top of section is base of Beck Spring dolomite.	
Crystal Spring Formation:	
Shale, sandy, pale-olive	200
Shale, brown, silicified, almost hornstone	60
Dolomite, massive, buff	40
Dolomite, shaly, buff with sparse blue chert	200
Shale, sandy, reddish-purple, contains several beds of buff dolomite, also sporadic zones of quartz pebbles, as much as ½ in. in diameter	250
Shale, sandy, red	30
Dolomite, gray; not persistent	20
Shale, slaty, green and purple, fractured	200
Dolomite, gray	20
Shale, green and brown	20
Dolomite, sandy, gray	6
Shale, green and black; locally slaty; quartzite layers near top	250
Shale, green	10
Limestone, white, crystalline; much fractured and cut by veins of ferruginous chert which merge with lenses of magnetite and hematite; lenses of green amphibole-magnetite rock at top	100
Shale, dense, green	10
Igneous rock, dense, dark-green; probably a sill	200
Base not exposed.	
Total	1, 616+

At the northwest corner of Kingston Range, 3 miles west of this section, about 1,000 feet of dark-brown quartzite is in fault contact with the Kingston Range monzonite porphyry that forms the main mass of the Range. Here, as near Beck Spring, the base is not exposed. As the combined thickness of beds of these two sections is more than 2,200 feet, the maximum total thickness of the Crystal Spring formation cannot be less than this figure.

The following section of the Crystal Spring formation was measured on the ridge 2 miles northeast of Horse Spring and 5 miles east of Beck Spring:

Section of Crystal Spring formation measured on ridge 2 miles northeast of Horse Spring and 5 miles east of Beck Spring

	Feet
Top of section is the base of Beck Spring dolomite.	
Crystal Spring Formation:	
Diorite sill, green	100
Chert, reddish-brown	100
Dolomite, brownish-red; containing wavy layers of chert	200
Dolomite, white, recrystallized and silicified; probably the bed which contains the Beck iron deposit	100
Diorite sill	300
Quartzite, black, dense cherty	50
Sandstone, fine-grained white, crossbedded	200
Grit, arkosic	300
Diorite, green, medium-grained	75
Quartzite, conglomeratic; largest pebbles well-rounded, as large as 5 in. in diameter near base; most pebbles ⅛ to ½ in. Some zones of arkose. Whole is cut by many quartz veins ¼ to 2 in. wide	500
Base of section is granite gneiss.	
Total	1, 925

These sections reveal the variable character of the material that make up the formation as well as the variable thickness.

BECK SPRING DOLOMITE

In contrast to the units immediately above and below it, the Beck Spring dolomite has uncommonly uniform characteristics and thickness throughout this region. Above Beck Spring, where the dolomite is about 1,100 feet thick, it is made up largely of beds of light-blue-gray dolomite, 2 to 4 feet thick. In the upper 200 feet, the beds are somewhat thinner, and they are separated by thin layers of shale. The top of the formation is abruptly succeeded by pale olive shaly sandstone of the Kingston Peak formation. On the east slope of Kingston Range the thickness ranges from 1,100 to 1,200 feet, and the top is considered to be the uppermost bed of dolomite, which underlies conglomeratic material characteristic of the Kingston Peak formation. The following section was measured 3 miles southeast of Horse Spring:

Section of Beck Spring dolomite measured 3 miles southeast of Horse Spring

	Feet
Top of section is base of Kingston Peak formation.	
Beck Spring dolomite:	
Dolomite and limy shale	50
Dolomite, blue-gray	2
Shale, limy	20
Dolomite, blue-gray	25
Sandstone, shaly, green	40
Dolomite, main mass of the formation	1, 000
Total	1, 137

Throughout the region, there are persistent beds of oolite several feet thick in the lower 200 feet of the formation. The oolites range from one-eighth to one-fourth of an inch in diameter.

KINGSTON PEAK FORMATION

Some lithologic units of the Kingston Peak formation persist throughout the region, but the thickness shows a considerable range from 2,000 feet on the north slope to 1,000 feet on the east slope of Kingston Range. In a broad way, the lowest and uppermost thirds of the unit are shaly sandstone with sporadic pebble zones; the middle third is almost wholly coarse conglomerate, of which the pebbles are largely quartzite and dolomite.

The following section was measured on the mountain northeast of Beck Spring:

Section of Kingston Peak formation measured northeast of Beck Spring

Top of section is base of Noonday dolomite.	
Kingston Peak Formation:	*Feet*
Sandstone, conglomeratic, pale-olive; pebbles largely 1 to 3 in., sporadic in sandstone rather than continuous layers. Pebbles of dolomite greatly exceed those of quartzite	600
Conglomerate, largely subangular cobbles in minimum matrix. Cobbles, largely quartzite near base, but of limestone increasingly in upper part; largely range from 4 in. to 12 in. but a few are 24 in. in diameter	600
Sandstone, conglomeratic, pale-olive; chert, limestone, and quartzite, pebbles are sporadic in limy matrix in lower 300 ft. and few are as much as 2 in. in diameter	500
Sandstone, pale-olive, shaly, thin-bedded	300
Total	2, 000

Section of Kingston Peak formation measured about 2 miles northeast of Horse Spring

Kingston Peak Formation:	*Feet*
Sandstone with sparse pebbles	200
Sandstone, conglomeratic, with only a few pebbles more than 3 inches in diameter	500
Sandstone, conglomeratic, with many cobbles as much as 2 feet in diameter. Quartz cobbles as much as 10 inches in diameter and well rounded	1, 000
Sandstone, with sparse pebbles	200
Total	1, 900

Section of Kingston Peak formation measured about 2 miles southeast of Horse Spring

Kingston Peak Formation:	*Feet*
Dolomite, blue-gray; no pebbles	200
Quartzite, red, shaly	100
Sandstone, dolomitic with subangular dolomite pebbles in lower part, mingling upward with material containing both quartzite and dolomite cobbles as much as 10 inches in diameter and well rounded	300
Shale, green, sandy at base, then green sandstone, greenish quartzite and green shale	400
Total	1, 000

At the southeast corner of Kingston Range the situation is puzzling. From the position and attitude of two blocks of Noonday dolomite it is clear that they are separated by at least one northwest-trending normal fault. West of the western block of Noonday dolomite, the beds of Kingston Peak formation trend northwest and dip uniformly northeast at 60° to 75°. If there were no faults in the area of the Kingston Peak formation, the thickness would be over 4,000 feet, surprisingly thicker than it is 2 miles northeast. Even though no fault has been recognized in this area, one is assumed to be present.

The conditions of deposition of this formation appear paradoxical therefore, their interpretation presents an interesting problem. As most of the quartzite and chert pebbles and cobbles are well rounded, it would appear that they have been moved a great distance from their source to the present site of deposition. By contrast, the cobbles of limestone and dolomite are uniformly subangular, and as these materials are relatively soft, they do not seem to have been moved far from their source. Apparently several sources, near and remote, contributed the coarse material. The general appearance of the material near the base and near the top, where many round pebbles occur sporadically and isolated in sandy and limy matrix, suggest a tillite. Of many pebbles and cobbles broken from their matrix, none was distinctly faceted or showed striae.

The aspect of most of the material in the middle part of the unit—the lenses of closely packed pebbles and cobbles in the minimum of sandy matrix, in part limy—resemble the fanglomerate material now being deposited in the alluvial fans near the mountains of this region. Conditions may have varied from the beginning to the end of deposition of the unit, but probably the formation represents alluvial fan material deposited under arid conditions. Hazzard (1939) has described briefly material near the Gunsight mine, about 15 miles west of Beck Spring, which underlies unconformably the lowest formation of Paleozoic age, and seems to correlate with that in the Kingston Peak formation. As the pebbles are faceted and show striations, he has interpreted it as the product of glaciation.

AGE AND CORRELATION

The only material that may be organic (algal) that has been collected from the Beck Spring dolomite does not aid in determining its age. It can only be stated that this conformable succession of sedimentary rocks nearly 7,000 feet thick unconformably overlies the crystalline gneisses of the region and unconformably underlies a great thickness of sedimentary rock that is assuredly Paleozoic in age. The degree of induration and alteration of these rocks is much less than is commonly found in rocks as old as these. The limestones of the Crystal Spring formation are largely crystalline and some of the zones of shale are now hornstone. They are only slightly more indurated than the sedimentary rocks of early Paleozoic age of this region. The Beck Spring dolomite, however, has the color, texture and degree of induration of part of the Goodspring dolomite.

In making structural studies of the Virgin Spring area, 50 miles northwest of Kingston Range, Noble (1941) recognized the formations of the Pahrump series, but he did not map them. In the northern end of the Inyo Mountains, 160 miles northwest, Kirk and Knopf (1918, p. 130) in 1912 recognized two formations, Deep Spring formation and Reed dolomite, apparently unconformably underlying the Campito sandstone which they considered to represent the lowest Cambrian formation in this region. Later Maxson (1935), reviewing the same region, recognized two additional formations unconformably underlying the Reed dolomite and separated by an unconformity, the Wyman formation of Maxson, 3,700 feet thick and the Roberts formation of Maxson, 2,500 feet thick. Any attempt to correlate the pre-Cambrian sedimentary rocks of the Inyo Range and Kingston Range is hazardous because the only fossils in either section are questionable algal remains of no diagnostic value, and the intervening distance is great. The only criteria available concern the general lithologic character of the units and the unconformities that have been recognized. Unconformities have been noted between each of the succeeding units in the Inyo Range—Roberts formation and Wyman formation of Maxson and the Reed dolomite and Deep Spring formation—but none has been noted between the three units of the Pahrump series in the Kingston Range region. It is obvious that there is no close similarity in the general succession of these sedimentary units that would permit confident correlation with those nearby. The Reed dolomite is the only distinctive carbonate unit in the Inyo Range and it does not seem to resemble the Beck Spring dolomite of the Kingston Range. Both in lithology and thickness, the Reed dolomite more nearly resembles the Noonday dolomite, the basal formation of Cambrian rocks in the Ivanpah region. Following this assumption, the two formations (Deep Spring and Campito sandstone combined) seem to resemble the Prospect Mountain quartzite (p. 29). There is some lithologic similarity between the Wyman and Roberts formations of Maxson and the Pahrump series, but the Inyo Range section lacks the distinctive sedimentary rocks of the Kingston Peak formation. It will probably serve little purpose with the meagre knowledge available to make any further attempt toward correlation of these pre-Cambrian sedimentary rocks.

PALEOZOIC ERA

CAMBRIAN SYSTEM

WESTERN FACIES

There are so many differences in thickness and lithology in the Cambrian sedimentary rocks, older than the Goodsprings dolomite (Upper Cambrian series to Devonian system), in the western and eastern parts of this quadrangle that two facies, western and eastern, are recognized. The sections that are exposed in the ranges and hills west of Spring Mountains have distinct affiliations with well-known sections west, northwest, and north for as much as 100 miles. Also, the sections exposed in and east of Spring Mountains resemble those well known as far east in Arizona as the Grand Canyon, or about 150 miles. The Mesquite thrust fault, traced from Ivanpah Mountain on the south through Clark Mountain to Mesquite Valley, a distance of about 25 miles, is considered a good boundary between the two facies. The great decrease in the thickness of the units below the Goodsprings dolomite in passing from the overriding block along the Mesquite thrust to the overridden block seems to indicate that the horizontal movement along it is much greater than along the other four major thrust faults. The formations that make up the section under the Goodsprings dolomite west of Mesquite thrust will be considered as the western facies and those east of the thrust, the eastern facies. The western facies includes the Noonday dolomite, the Prospect Mountain quartzite, and the Pioche shale. The eastern facies includes the Tapeats sandstone and the Bright Angel shale.

NOONDAY DOLOMITE

Areal distribution.—The Noonday dolomite is a distinctive unit that crops out widely on the north and east slopes of Kingston Range and in the hills as far east as the Winters Pass road to Valley Wells. The name "Noonday dolomite" was first applied by Hazzard (1937c, p. 300–301) to the unit 1,500 feet thick in the vicinity of the Noonday and Gunsight mines, about 14 miles west of Beck Spring in the Kingston Range. From the local relations, Hazzard concluded that it formed the base of the section of Paleozoic age.

In the Ivanpah quadrangle, the thickness of the Noonday dolomite ranges from nearly 2,000 feet near the Chambers mine on the west to 125 feet at the easternmost outcrop near Winters Pass, 17 miles southeastward. Throughout this distance, its properties are uncommonly uniform and distinctive. It is not known east of the Mesquite thrust.

In the intervening region the unit is well exposed and the thickness is intermediate between these extremes, being 500 to 600 feet on the high ridge west of benchmark 3,583 on the road to Kingston Wash and 600 feet where it forms the crest of the ridge, 3 miles northeast of Horse Springs. As the base and overlying conformable beds are well exposed at many localities, it is clear that the formation gradually thickens from the minimum of 125 feet at Winters Pass, westward to 2,000 feet at the border of the quadrangle. At the Mammoth copper mine (No. 62, pl. 2) in the foothills northwest of Clark Mountain, the crushed dolomite that underlies thin-bedded quartzite (fig. 18) is probably Noonday dolomite. At the south end of the Shadow Mountain, a block of old rocks that is thrust upon middle Tertiary sedimentary rock contains a stratum of dolomite about 100 feet thick between granite gneiss below and quartzite above; it is probably Noonday dolomite (section *E–E′*, also fig. 2).

The formation is almost wholly pure, fine-grained dolomite. The color is pale cream and fresh exposures are slightly mottled because of minor recrystallization. Lamination that might be interpreted as bedding is extremely uncommon in small outcrops, but it is noticeable in large masses. The beds that form the base of the formation at Winters Pass, under the layer of dolomite, consist of several feet of shaly sandstone containing thin layers of pebbles that range from one-eighth to half an inch in diameter. This zone of detrital material is surprisingly thin if one considers the profound unconformity which underlies it.

From Winters Pass to the hills east of benchmark 3,143, a distance of 8 miles, the Noonday dolomite rests on crystalline rocks—medium-grained granitic augen gneiss containing pink pegmatite in the Winters Pass area and chloritic pink feldspar gneiss and mica schist east of the benchmark. The surface of the contact is locally smooth and flat, even though it has been warped into a broad anticline. In the region around the north and east slopes of Kingston Range, therefore west and south of benchmark 3,143, the Noonday dolomite rests in places on several members of the Pahrump series. Within that part of the belt which lies west of Horse Spring, the dolomite seems to be nearly conformable on the Kingston Peak formation, but northeast, east, and southeast of Horse Spring, the surface of contact cuts across the strike and dip of members of the Pahrump series, and the surface has considerable relief.

The broad structural relations of the rocks that form Kingston Range and surrounding hills must be known (p. 95–99) to understand why the Noonday dolomite rests upon crystalline rocks in the eastern part of the belt and upon another younger group of rocks (pre-Cambrian, Pahrump series) in the western part of the belt. All the rocks of the western part of the belt are part of a great thrust plate, now deeply dissected, that has been moved eastward many miles so that the rocks are not only a few miles distant from masses of Noonday dolomite that rest on crystalline rocks.

Much of the Noonday dolomite contains small bodies of lead minerals throughout this region. At the western end of the belt, the Chambers mine (p. 143) has shipped several hundred tons of lead ore. The Blackwater mine, half a mile north of Horse Spring, and Sunrise mine, 3 miles northeast of Horse Spring, explore small bodies of lead ore in the Noonday dolomite. Also, the layer of Noonday dolomite that forms the high ridge northwest of benchmark 3,583 contains many prospects that show lead minerals.

Age and correlation.—Thus far, the Noonday dolomite has yielded no organic remains and it is known only that is it the lowest unit of the conformable section of early Paleozoic age, probably Lower Cambrian series.

Eastward from Mesquite Valley for several hundred miles, no rocks are known that may be correlated with the Noonday dolomite. Westward and northwestward from Mesquite Valley for several hundred miles, at least as far as the Inyo Mountains, rocks that bear some resemblance to the Noonday dolomite and occupy a similar position in the stratigraphic section are known. According to Noble, (written communication), the Noonday dolomite is present along the east slope of the southern part of the Panamint Range, about 75 miles west of Kingston Range.

PROSPECT MOUNTAIN QUARTZITE

The Prospect Mountain quartzite (Hague, 1892, p. 419) is well exposed and underlies large areas in a broad belt that extends from Clark Mountain 30 miles northwest to the hills that lie 10 miles north of Kingston Range. For much of this distance, the outcrops of the formation are only a few miles distant from exposures of similar quartzite below the Mesquite thrust fault, but the thickness is much greater, ranging from about 3,000 to 5,000 feet. The prevailing sandy character of the quartzite persists westward, but the beds present much diversity in detail.

CLARK MOUNTAIN AREA

The most southerly exposure in the Clark Mountain area lies in the two hills 2 miles west of Standard mine No. 1 (No. 84, pl. 2), (T. 15 N., R. 14 E.) where the upper part of the sandstone, Pioche shale, and lower part of the Goodsprings dolomite are overturned at the Mesquite thrust. The beds appear again on the ridge

3 miles west of Kokoweef Peak where they form the crest of an anticline that plunges northwest. They next appear on the north slope of Clark Mountain but they are too greatly folded to permit an accurate measurement of thickness; at least 1,500 feet are exposed (see figs. 4, 6, 14). West of Mesquite Pass the sandstone forms a ridge 2 miles long, and even though conditions for measurement are poor, the thickness of the beds is estimated to be between 3,000 and 4,000 feet. They form a broad syncline that pitches west.

WINTERS PASS AREA

The easternmost locality where the entire formation from the underlying Noonday dolomite to the Pioche shale is well exposed is on the long ridge that extends northwestward, west of the road through Winters Pass. Here a thickness of 4,200 feet was measured. Dense cherty quartzites predominate in the lower 1,000 feet, but near the base there are crossbedded conglomeratic beds, 5 to 10 feet thick, in which the coarsest pebbles are vein quartz, 1 by 1 by 2 inches. There are also a few beds of dolomite, rarely more than 10 feet thick, and red shale. Some of the dolomite beds, even though 80 percent or more carbonate, contain layers of well-rounded quartz grains about the size and shape of grains of wheat. The dolomite beds are less common in the second 1,000 feet but they alternate abruptly with the layers of quartzite.

About 1,500 feet above the base, there are a few beds of oölite, 10 feet thick, that weather brown. They seem to be part of a sequence that recurs at many areas in this region: gray sandy shale (base), oölite, gray sandy shale, red sandy shale, quartzite (top).

The upper 2,000 feet of the formation seems to be almost wholly thin-bedded, fine-grained quartzite that weathers pale rusty brown.

Two uncommon varieties of carbonate rocks that warrant detailed description are found in the formation in this area. The first is dark-gray fine-grained dolomite that uniformly weathers dark chocolate brown. It forms persistent beds less than 10 feet thick between red shale and brown quartzite. Two specimens were collected for analysis. (See table below.) The first (no. 5) collected from the 4,400-foot hill east of the Resting Springs road, 5 miles north of Horse Spring, occurs about 3,000 feet above the base of the formation; the second (no. 60) collected from the 3,800-foot hill in the northwest corner of T. 18 N., R. 12 E., west of the Winters Pass road; its position in the section is obscure, but probably it is about 1,000 feet above the base.

The uncommon feature of these analyses is the high content of manganese and iron. Such rocks, with even higher manganese and iron, are known in the pre-Cambrian sedimentary rocks of the Lake Superior region but they are uncommon in sedimentary rocks of Paleozoic age.

Analyses of dolomite from Prospect Mountain quartzite

[Analyst, J. Fairchild, U. S. Geological Survey]

Analysis		Calculated constitution	
No. 5			
CaO	28.44	$CaCO_3$	50.80
MgO	17.18	$MgCO_3$	35.93
FeO	3.25	$FeCO_3$	5.24
MnO	1.03	$MnCO_3$	1.67
Fe_2O_3	.28		
Insol	6.27		
CO_2	40.74		
Total	97.19		93.64
No. 60			
CaO	15.55	$CaCO_3$	27.76
MgO	6.86	$MgCO_3$	14.35
FeO	.72	$FeCO_3$	1.16
MnO	.18	$MnCO_3$	.29
Fe_2O_3	.64		
Insol	54.92		
CO_2	20.25		
Total	99.12		43.56

The second uncommon carbonate rock is that which contains noteworthy amounts of well-rounded quartz pebbles. No chemical analyses have been made but it is estimated that in some beds the dolomite matrix is 50 to 70 percent, and that the pebbles range from 30 to 50 percent. The matrix is fine-grained, dark-gray carbonate and the quartz grains and pebbles largely range from one-twentieth to half an inch in diameter. Most are distributed in well-defined but nonpersistent layers. The manner of deposition of such a rock is puzzling.

Four miles northwest of the Winters Pass area, beds 3,700 feet thick were measured from the top of the Noonday dolomite, but the section is probably incomplete as the overlying Pioche shale is not exposed.

The area of pre-Cambrian gneiss that extends northwest from Winters Pass to benchmark 3,143 on the road to Coyote Holes, roughly 8 miles long by 4 miles, is overlain along the southwest border by a thin layer of siliceous sedimentary rocks that is regarded as the basal section of the Prospect Mountain quartzite. The nearly horizontal contact of the base on the underlying granite gneiss is well exposed on the south border of the hills west of Winters Pass. There seems to be no doubt that this is a depositional contact even though no Noonday dolomite rests upon the gneiss as it does 2 miles north of Winters Pass. Throughout this layer of Prospect Mountain quartzite west of Winters Pass, the degree of induration of the sedimentary rocks, quartzite, and shales is much greater than that of the same zone that overlies the Noonday dolomite north of Winters Pass.

The total thickness of the layer of the Prospect Mountain quartzite in this border belt probably does not exceed 500 feet. The most common material is white granular quartzite but dense blue-gray vitreous layers are present. There are thin layers of ferruginous dolomite such as that found north of Winters Pass and conglomeratic material in which the coarsest pebbles are only a quarter of an inch in diameter. In places, for example west of the largest block of Goodsprings dolomite in the hills west of Winters Pass, the sedimentary rocks contain coarse grains of feldspar and are so highly indurated that they resemble the granite gneiss which underlies them. Farther northwest, south of benchmark 3,143, much of the sedimentary layer is indurated shale. South of benchmark 3,143, the contact between quartzite above and below appears to be depositional, even though there is no intervening Noonday dolomite.

In a broad way, the belt of Prospect Mountain quartzite seems to be part of a shallow syncline that trends northeast. In the eastern part of the belt, the beds strike northeast and dip 5° or less northwest; in the western part of the belt, the beds strike generally east and dip 5° or less north. The fact that this layer of sedimentary rocks is autochthonous on the underlying granite gneiss and that there is no Noonday dolomite, has bearing upon the interpretation that the local blocks of Goodsprings dolomite are parts of the Kingston thrust plate. In this area, at least 4,000 feet of beds under the Goodsprings dolomite are absent, even though the complete section is shown on the ridge north of Winters Pass (p. 32).

The entire Prospect Mountain quartzite is exposed in a belt nearly 3 miles wide, whose base is at the top of the Noonday dolomite that underlies the 5,200 foot hill 3 miles northeast of Horse Spring. Except for the lower thousand feet, the beds are too poorly exposed and present dips too diverse to permit a good measurement of thickness. The lowest 75 feet is red shaly sandstone, which is overlain by 100 feet of thin gray dolomite that weathers chocolate brown. The succeeding 500 feet are largely fine-grained quartzite, containing numerous pebble beds, 5 to 20 feet thick, in which the pebbles are well rounded but flat, rarely more than three quarters of an inch in diameter. They are wholly vein quartz and black chert. About 700 to 800 feet above the base there are several beds of oölitic dolomite 4 to 5 feet thick, each underlain and overlain by a bed of red shale. About 1,000 feet above the base there are several beds of pebbly gray dolomite in which the pebbles are vein quartz as much as half an inch in largest diameter.

On the ridge that extends northeast from Horse Spring, 4,700 feet of sandstone beds have been measured upward from the top of the Noonday dolomite to the point where the formation is cut off by a fault. This figure is therefore less than the total thickness. The lower 1,000 feet are well exposed and closely resemble the same part of the section on the ridge 2 miles east.

In the northwest part of the Kingston Range the Prospect Mountain quartzite forms the ridge that trends north, west of the Resting Springs road. The total thickness from the top of the Noonday dolomite to the end of the ridge is 3,970 feet, but it contains a sill of reddish-brown orthoclase porphyry, 400 feet thick, so that the actual thickness is only 3,570 feet.

OLD DAD MOUNTAIN AREA

On the northwest part of Old Dad Mountain, a large area of beds, here correlated with the Prospect Mountain quartzite, is separable into two parts by the Old Dad fault (p. 100). Northeast of the fault, the basal beds are exposed southeast of the Paymaster (Whitney) mine, where they uniformly strike east and dip 60° South; from here southward, the dip steadily decreases to 35° where the beds are concealed by recent alluvium. Southwest of Old Dad fault, the beds uniformly strike northwest, generally N. 30°–40° W. and dip 35°–50° NE. In both blocks the predominating rock is thin-bedded brown quartzite that contains zones of greenish shale and thin beds of dolomite that weathers brown. The entire section, at least 2,500 feet thick, seems to be made up of the three succeeding units, repeated six or eight times; gray dolomite, 3 to 5 feet thick; brown quartzite, 50 to 100 feet thick, made up of many layers 3 to 10 inches thick separated by thin layers of shale; brown quartzite and green shale, 50 to 100 feet thick, made up of alternating thin layers of each. Compared with sections exposed along the northeast slopes of Kingston Range, this section contains more shale, and the quartzite units are thinner. Compared with the section recorded by Nolan (1929) near Johnnie it resembles the Wood Canyon formation more than the underlying Stirling quartzite and Johnnie formation.

PIOCHE SHALE

Pioche shale crops out in extensive areas that form a belt nearly 30 miles long, which extends from the hills west of Standard mine No. 1 on the south to the foothills west of the north end of Mesquite Valley. In the type section at Pioche, Nev., the name Pioche shale was applied by Walcott (1908) to about 970 feet of green shale that overlies the Prospect Mountain quartzite.

At only one locality, however, is all of the formation well exposed in an unfolded and unfaulted belt; that locality lies west of the road that extends from Mesquite Valley through Winters Pass to Valley Wells.

The following section was measured:

Section of Pioche shale, measured at Winters Pass

	Feet
Goodsprings dolomite.	
Pioche shale:	
Dolomite, mottled, thin-bedded, weathers brown	50
Limestone, cherty, weathers brown; locally chert exceeds limestone	70
Shale, green below, reddish above	50
Limestone, mottled, dark-gray and brown	20
Quartzite, brown	2
Shale, green	12
Limestone, greenish-gray, sandy, crossbedded	5
Shale, green, sandy below; red, sandy above	45
Limestone, brown	2
Shale, brown, limy	10
Limestone, brown	12
Shale	2
Limestone and brownish sand, single ledge	10
Shale, green at bottom merging upward with green and brown sandy shale containing thin quartzite layers; several beds of mottled dark-gray and brown limestone, 1–3 ft thick in upper one-third	280
Shale, gray and greenish; several thin beds of mottled gray and brown limestone near top	90
Limestone, mottled, gray and brown; beds 1–4 ft thick	40
Limestone, brown shaly	8
Limestone, mottled, dark-gray and brown; single ledge	18
Shale, green, sandy, some quartzite and several beds of mottled limestone 1–3 ft thick	42
Shale, green, and thin limestone	20
Shale, green, and brown limestone. In lower 90 ft, shale greatly exceeds limestone which forms beds 3–6 in. thick; in upper 30 ft, llmestone beds 1–2 ft thick exceed shale	120
Shale, mottled green and brown, limy	10
Limestone, mottled, dark-gray	12
Shale, gray, limy	3
Limestone, mottled, dark-gray	1
Shale, green, containing many lenses of mottled brown limestone 1–12 in. thick	32
Shale, green sandy, containing few layers of brown quartzite 1–2 in. thick	38
Total	1, 004
Prospect Mountain quartzite.	

On the ridge 2 miles southwest of benchmark 2,846, at the northwest end of Mesquite Valley, the following section was measured below the Goodsprings dolomite:

Section of Pioche shale measured on ridge 2 miles southwest of benchmark 2,846 at northwest end of Mesquite Valley

	Feet
Goodsprings dolomite.	
Pioche shale:	
Dolomite, brown, thin-bedded, sandy	40
Shale, green	10
Dolomite, bluish-gray, thin-bedded	5
Shale, red	10
Dolomite, brown, thin-bedded	20
Dolomite, blue-gray, beds 2–3 ft thick	10
Dolomite, greenish, sandy, crossbedded	30
Shale, red, containing several 6-in. beds of brown dolomite	50
Shale, green sandy, local quartzite mottled	500
Dolomite, brown and gray	20
Total	695

There are extensive exposures on the west and northwest slope of Clark Mountain and the western slopes of Mescal Range, but the beds are folded and are not susceptible to detailed measurement and examination. North of Pachalka Spring the following section was measured below the base of the Goodsprings dolomite;

Section of Pioche shale measured north of Pachalka Spring

	Feet
Goodsprings dolomite.	
Pioche shale:	
Dolomite, brown, in beds 1–4 ft thick alternating with green shale	250
Shale, hard, nearly black, locally sandy	100
Shale, gray-green, with local thin brown and greenish quartzite	400
Total	750

EASTERN FACIES

TAPEATS SANDSTONE

Tapeats sandstone was first applied as a name to a sandstone unit about 285 feet thick which forms the basal unit of the section of Paleozoic age in the Bright Angel area of the northern part of Arizona (Noble, 1914, p. 100). The formation has been traced westward in the canyon of the Colorado River by Noble and others, and the similarities in character and thickness have led others to apply the name to sections in southern Nevada (Wheeler, 1943, p. 1796–1797). Throughout this large area, relatively few fossils have been found in the formation and these indicate that the age is Lower Cambrian.

The Tapeats sandstone, as well as the overlying Bright Angel shale, is widely distributed throughout the eastern half of the quadrangle. The thickness of exposures along the eastern limits, measured in a general north-south direction, ranges within rather narrow limits from 130 to 600 feet (fig. 4).

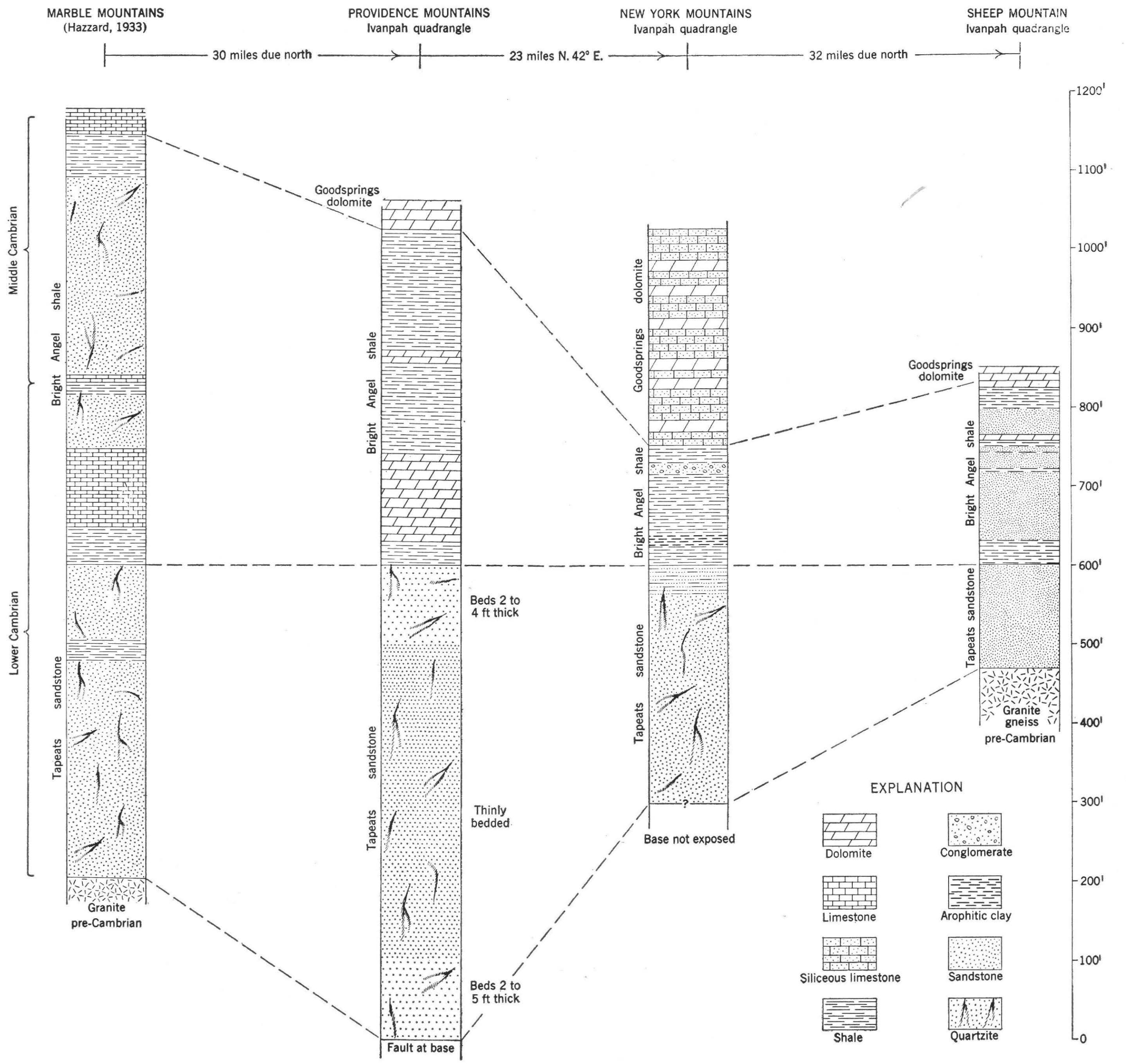

FIGURE 4.—Correlation of Cambrian sections from Marble Mountains, Calif., to Sheep Mountain, Nev.

In the Ivanpah quadrangle, the formation is not uniformly indurated sufficiently to warrant being called a quartzite, although where it is highly folded, it is properly so called. On weathering it commonly breaks down to thin, flat slabs and chips and to sand; outcrops rarely present rugged cliffs and escarpments. The color of the fresh sandstone is uniformly pale gray, but it weathers to pale rusty shades.

Sheep Mountain area.—The following section was measured a mile southeast of the southeast end of Sheep Mountain, near Jean, Nev.

Section of Tapeats sandstone measured 1 miles southeast of the southeast end of Sheep Mountain near Jean, Nev.

Top of the section is base of the Bright Angel shale.

	Feet
Tapeats sandstone:	
Sandstone, gray and brown, layers 1–3 in. thick; ripple marked; annelid burrows and trails in top layer	36
Sandstone, dark-brown, layers ½–2 in.; a layer of brown dolomite 4 in. thick at base	90
Sandstone, dark-brown, layers ¼–½ in. thick; contained orthoid brachiopods	3
Total	129

New York Mountain area.—Sections of Tapeats sandstone, Bright Angel shale, and Goodsprings dolomite are exposed in the New York Mountains, 2 miles south of Barnwell. The Tapeats sandstone is thin bedded, pale greenish, and shaly near the top; it lacks the pebbles characteristic of the exposures west and southwest of the Ivanpah Valley. About 300 feet are exposed near the Sagamore mine but as the unit rests on the intrusive body of quartz monzonite, the entire section of sandstone may not be present.

Providence Mountains.—The Tapeats sandstone and Bright Angel shale are well exposed on the north slope of a ridge that extends west from the main ridge of Providence Mountains, about 5 miles southeast of Hayden. The lithology and thicknesses are amazingly similar to those measured by Hazzard in the Marble Mountains, 25 miles south (figs. 4, 5).

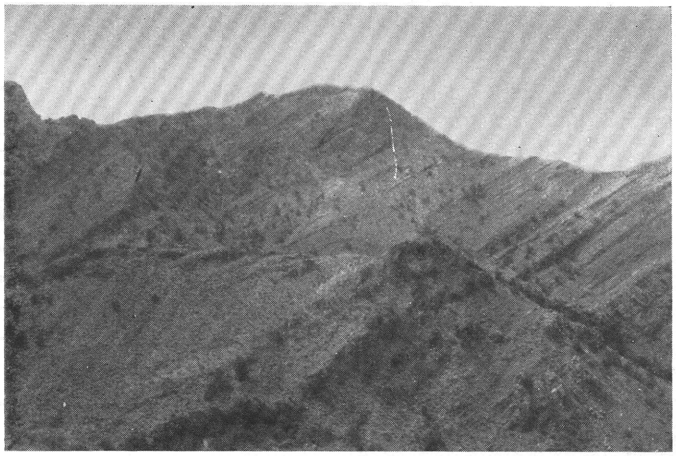

FIGURE 5.—View S. 70° W. toward the ridges on the west slope of Providence Mountains, Calif.

Section of Tapeats sandstone measured 5 miles east of Hayden

Top of the section is the base of the Bright Angel shale.

Tapeats sandstone:

	Feet
Shale, blue-gray when fresh; weathers gray; layers are micaceous	30
Quartzite, beds 2 to 4 feet thick, massive; shows local crossbedding with parallel layers, zones of pebbles, half an inch in diameter	100
Quartzite, largely beds 6 inches to 2 feet thick, with numerous black shale partings	400
Quartzite, beds 2 to 5 feet thick	100
Total	630

Mesquite Pass area.—The southeast-trending ravine that lies east of the road through Mesquite Pass closely follows the contact of quartzite on granite gneiss, warped into a local anticline. About 400 feet of reddish quartzite in beds 1 to 5 feet thick, which include several beds of red shaly sandstone 4 to 6 feet thick, rest upon the granite gneiss. The quartzite is locally crossbedded and in places there are quartz pebble zones in which the largest pebbles are 2 inches in diameter. Here and there, the section is separated from the gneiss by a thin diabase sill such as those that occur in the Pahrump series near Beck Spring.

Between this quartzite section and the Goodsprings dolomite above is 390 feet of rocks of which 140 feet are correlated with the Bright Angel shale; the remainder is a sill of rhyolite.

Colosseum mine area.—About 1,000 feet southwest of the Colosseum mine, the lowest beds of the section of Paleozoic age are of quartzite, 60 to 75 feet thick, which are separated from the underlying gneiss by a zone of sheared rock that coincides with the Clark Mountain fault. About 2,000 feet southwest of this point, the quartzite is 200 feet thick, and it contains sporadic pebble zones as much as 12 inches thick in which the pebbles are largely vein quartz. From the top of this quartzite to the base of the Goodsprings dolomite there is about 800 feet of quartzite, shale, and dolomite beds; these should include the Bright Angel shale.

As the entire section of Tapeats sandstone and Bright Angel shale is cut out by the Clark Mountain fault for the next 6 miles south of this area, it may be that here some of the basal beds of the Tapeats sandstone are cut out.

It should be noted that the two sections briefly described above, where the combined thicknesses of the Tapeats sandstone and Bright Angel shale range from 775 to 1,000 feet, are separated from nearby areas to the west where the combined thicknesses are much greater by the Mesquite thrust fault, along which the western block overrode the eastern block a great distance—certainly 10 miles or more.

In the hills 4 miles northwest of Kelso, between 500 and 600 feet of dark, locally crossbedded, quartzite rest on dense pinkish granite gneiss that is part of the pre-Cambrian complex of this region. The quartsite is overlain by the lower 400 feet of the Bright Angel shale section. The beds are broken by more faults than can be shown on the map. There are numerous faults that trend N. 25° E. and dip southeast that successively drop the eastward blocks of quartzite that trend east and dip steeply south. A later group of faults, along which the north side has dropped, trend N. 70° W. and dip northeast.

BRIGHT ANGEL SHALE

As the shale unit (Bright Angel shale and Pioche shale) that overlies the Tapeats sandstone and Prospect Mountain quartzite is much thicker above and west of the Mesquite thrust than it is east of the thrust, the same procedure in nomenclature that was used for the lower quartzite unit (Tapeats sandstone and Prospect Mountain quartzite) is adopted for the overlying shale. The name Bright Angel shale, applied by Noble (1914, p. 100) to about 348 feet of greenish sandy shale near the Bright Angel Trail, is here applied to the similar formation as far west as the Mesquite thrust. To the shale unit above and west of the Mesquite thrust, the name Pioche shale is applied.

The distribution of the Bright Angel shale is almost coextensive with that of the underlying Tapeats sandstone. It is sporadically exposed in the eastern half of the quadrangle east of the Mesquite thrust fault, where it attains a maximum thickness of about 420 feet (fig. 4). In the western half of the quadrangle above the Mesquite thrust, the Pioche shale is 1,000 to 1,600 feet thick (fig. 6).

In a broad way, the composition of the unit is rather simple where it is thin, consisting of green shale and thin sandstone layers. The composition becomes more diverse, however, as the unit thickens in a general westward direction (fig. 6). The details are presented below:

Section of Bright Angel shale measured in the Sheep Mountain area

	Feet
Goodsprings dolomite.	
Bright Angel shale:	
Covered, (shale?)	5
Dolomite, gray, with brown mottling	4
Shale, greenish	26
Sandstone, reddish-brown, layers ¼–1 in. thick	35
Dolomite, gray, weathers brown; thin layers in upper part	5
Shale, green micaceous; splits in thin layers	14
Sandstone, brown, thin-bedded	7
Shale, green, micaceous	4
Sandstone, brown, thin-bedded	9
Sandstone, dark-reddish-brown, layers ½–2 in. thick	6
Sandstone, medium-brown	3
Shale, brown	4
Sandstone, dark-reddish-brown layers, most of them ½–2 in. thick; some 2–3 in. thick; ripple-marked	55
Sandstone, medium-brown, micaceous, beds ½–1 in. thick	8
Sandstone, pale-brown; layers largely ¼–½ in. thick, shaly near base	25
Shale, greenish, micaceous; thin, sandy layers; contains fucoid impressions	7
Sandstone, dark-greenish; thin layers	5
Shale, dark-gray, sandy, micaceous	16
Total	238

Sagamore mine area.—Above the 300 feet of Tapeats sandstone exposed in the Sagamore mine area, there are 100 to 150 feet of beds that are largely gray to black shale and greenish shaly quartzite. In the lower 50 feet there are 2 layers of black clay, 3 to 6 inches thick, that sufficiently resemble coal to have caused prospecting by several short tunnels. In the upper 30 feet there is a bed of conglomeratic shale 10 to 15 feet thick. The pebbles largely range from 1 to 3 inches in largest diameter, are well rounded but elongate rather than spherical, and are wholly quartzite. The matrix is soft shale rather than sand and the pebbles readily separate from it. Nothing resembling this conglomeratic shale has been found elsewhere in the quadrangle.

The hill (5,700 feet) that lies about 2 miles west of Barnwell shows about 1,200 feet of beds that range from the base of the Tapeats sandstone to the lower part of the Goodsprings dolomite and they dip about 55° NE. There is no outcrop of the 150-feet shale unit near the Sagamore mine, 4 miles south. Instead, between the quartzite beds and the Goodsprings dolomite the outcropping beds are greenish hornstone; it is assumed that the hornstone unit represents the Bright Angel shale, altered by the underlying intrusive quartz monzonite.

Providence Mountains area.—The following section above the Tapeats sandstone was measured on the west slope of Providence Mountains:

Section of Bright Angel shale measured on west slope of Providence Mountains

	Feet
Goodsprings dolomite.	
Bright Angel shale:	
Shale, green and some reddish-brown, and some reddish-brown fine sandstone	150
Dolomite, 2 beds, gray; mottled with iron	15
Shale, olive-green, micaceous	100
Shale, weathers brown	15
Dolomite, dark-gray, beds 2–5 ft thick, shows many algal markings	110
Shale, blue-gray when fresh; weathers olive-gray; micaceous layers	30
Total	420

As shown in figure 2, the lithologic units and their thicknesses measured in this locality closely resemble those measured by Hazzard (1933, p. 67–70), at Marble Mountain, about 30 miles south of Providence Mountains.

Mesquite Pass area.—The following section, measured in the low hills north of Mesquite Pass (about sec. 31, T. 18 N., R. 13 E.) is the most westerly exposure of the Tapeats sandstone and Bright Angel shale. At this point, the rocks form part of the basement over which rocks of early Paleozoic age were thrust along the Mesquite thrust fault.

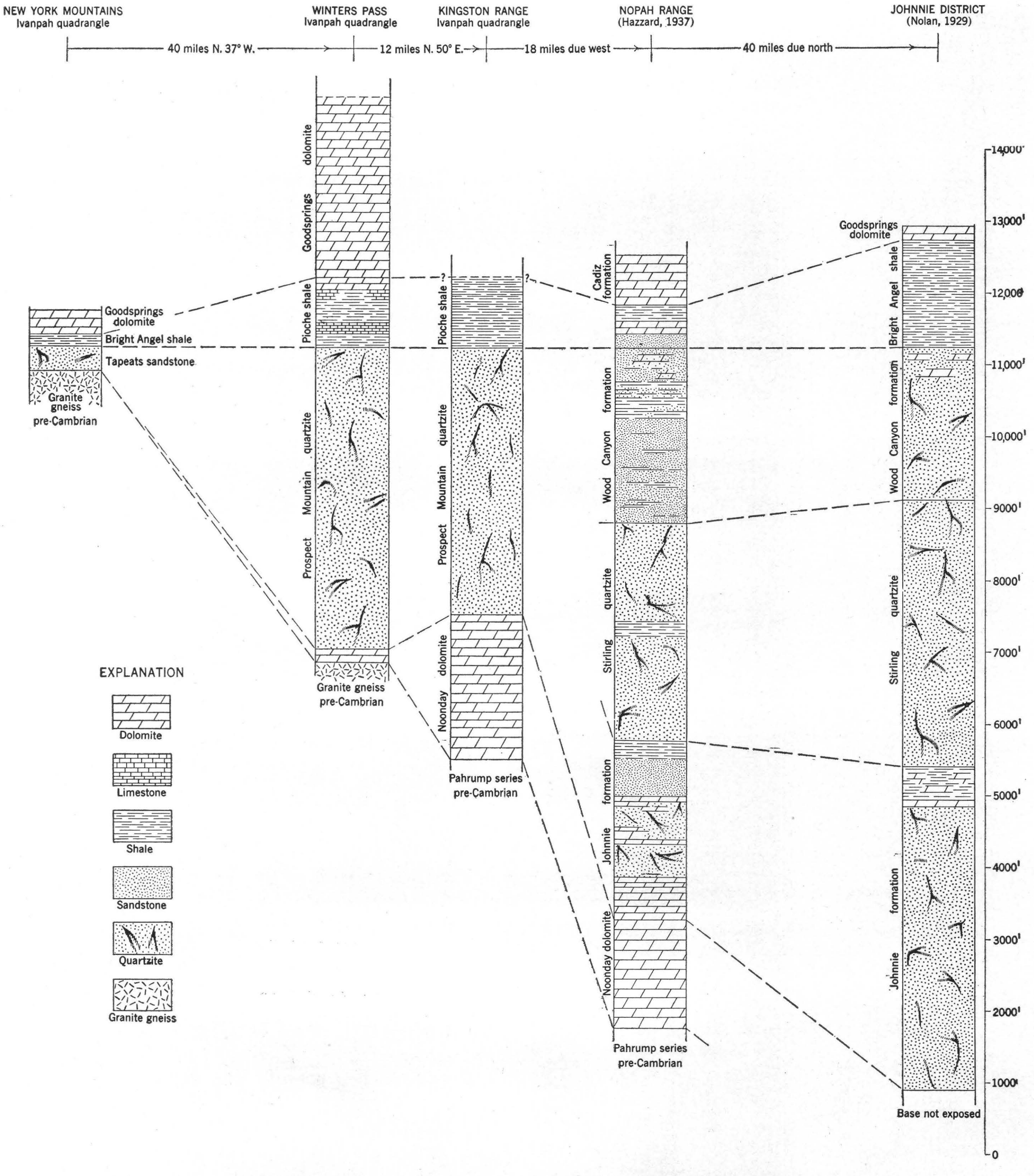

FIGURE 6.—Correlation of Cambrian sections from New York Mountains, Calif., to Johnnie district, Nev.

Section measured north of Mesquite Pass, sec. 31, T. 18 N., R. 13 E.

	Feet
Top of section.	
Goodsprings dolomite:	
Dolomite, black, mottled, weathers to beds 1–2 ft thick	100
Dolomite, weathers brown, thinly bedded; contains sand and chert layers	40
Dolomite, medium-gray, thinly bedded	40
Dolomite, dary-gray, mottled	15
Dolomite, mottled brown and gray	20
Limstone, blue-gray, mottled; considerable chert and veins of calcite	60
Total	275
Bright Angel shale:	
Quartzite, brown, thinly bedded with layers of red sandy shale	40
Sill, fine-grained, white (rhyolite?)	250
Quartzite, brown, thinly bedded with layers of brown and green shale	100
	390
Tapeats sandstone	400±

Colosseum mine area.—Near the Colosseum mine a belt of rocks crop out that attains a maximum thickness of 1,000 feet between the Clark Mountain fault on the east and the Goodsprings dolomite on the west. The belt contains the full thickness of the Bright Angel shale and variable thickness of the Tapeats sandstone. At the base of the Bright Angel shale section, 100 feet of thin-bedded dolomite and shale is overlain by 20 feet of white crystalline dolomite that locally is altered to chert. Overlying this is about 400 feet of alternating green shale and thin-bedded dolomite that weathers brown.

Kelso hills area.—In the low ridges about 3 miles northwest of Kelso, the following section was measured:

Section of Bright Angel shale measured 3 miles northwest of Kelso

	Feet
Top of section is Goodsprings dolomite.	
Bright Angel shale:	
Shale and thin sandstone, greenish	250
Dolomite, gray	110
Shale, greenish (source of collection 90)	200
Tapeats sandstone: Quartzite, thin-bedded	600
Total	1, 160

Both in lithology and thickness, this section resembles that measured on the north slope of Providence Mountains, 8 miles east (fig. 4). As there are several small faults that trend northeast and two larger faults that trend northwest and offset the small faults, the thicknesses shown are approximate.

The beds of this area are of interest because they are the most southwestern that show the lithology and thickness of the eastern facies, Tapeats sandstone, and Bright Angel shale. The Mesquite thrust is known to extend only to the hills west of the Standard No. 1 mine, which is 25 miles northeast of the Kelso area. As the Mesquite thrust lies above the great body of Teutonia quartz monzonite, it has been removed by erosion in the Kelso area.

FOSSILS

After diligent search in many localities, only a few fossils were found in the Tapeats sandstone and Bright Angel shale formations, and it seems probable that they are rather uncommon. The identifications of two collections are recorded below:

Collection nos. 2a, b, c, d. Collected in the middle part of the Bright Angel shale and Tapeats sandstone exposed in sec. 32, T. 25 S., R. 60 E., at the south end of Sheep Mountain, near Jean, Nev. Identifications by Edwin Kirk.

Collection 2a, from basal sandstone; orthoid brachiopods, trilobite fragments. Collection 2b; Annelid burrows and trails. Collection 2c; Fucoids. Collection 2d; probably inorganic.

Collection no. 90. Collected in the shale zone, overlying 600 feet of quartzite in sec. 14, T. 11 N., R. 12 E., about 2 miles northwest of Kelso. Report by C. E. Resser.[1]

The fossils are not well preserved but indicate the following species:

Olenellus fremonti (Walcott)
Paedumias nevadensis (Walcott)
Olenellus cf. *O. insolens* (Resser)
Olenellus n. sp. near *O. bristolensis* (Resser)

This fauna is therefore Lower Cambrian and appears to be the same as that at Bristol Mountain, near Cadiz.

Wheeler (1943) examined stratigraphic sections and collected fossils from Cambrian sedimentary rocks in southern Nevada with the view to precise correlation of the units. As the section at Pioche, Nev., has long been well known and closely studied, and is recognized as typical of that part of southern Nevada, Wheeler applied the formation names to units of the Cambrian system as far south as the Virgin Mountains, in Nevada and western Arizona. The work of Wheeler northeast of Ivanpah quadrangle, that of Hazzard and Crickmay (1933) in the Marble Mountains and Providence Mountains to the south, and that of Hazzard (1937c) in the Nopah Range to the northwest, considered with the two collections described above, indicate that the Tapeats sandstone of this area is Early Cambrian age, and that the Bright Angel shale is Middle Cambrian.

Thus far the Noonday dolomite has yielded no organic remains, and it is known only that it is the

[1] The generic assignments made by Mr. Resser have been changed by A. R. Palmer in 1951 to conform with modifications in nomenclature since the original assignments were made.

lowest unit of the conformable section of early Paleozoic age, probably Lower Cambrian series.

West of the Mesquite thrust, no fossils have been found in the Prospect Mountain quartzite or Pioche shale. According to Wheeler (1943) the upper part of the quartzite is of Early Cambrian age but the lower part is pre-Cambrian; also, the Pioche shale includes elements of Early and Late Cambrian age. Until these formations in this quadrangle can be studied more closely and more fossils collected, some uncertainty in their age will remain.

AGE AND CORRELATION

Any attempt to correlate the Cambrian formations of the Ivanpah quadrangle must be based upon existing knowledge of the thickness, distribution and fossil content of the units that have been recognized in the southern part of the Great Basin and adjacent parts of Utah and Arizona. It has long been recognized that there existed in central Nevada a trough that contained a great thickness of sediments of Paleozoic age in which each of the systems is represented. This trough has been known as the Cordilleran geosyncline (Schuchert, 1923; Ver Wiebe, 1932), and the axis appears to trend about N. 30° E. across eastern Nevada, even though at times during the Paleozoic era it migrated from this position. If projected southwest, the trough would pass west of the Ivanpah quadrangle. As shown by Nolan (1943, p. 141–196), available evidence indicates that the recognized formations of early Paleozoic age tend to maintain uniform thicknesses in a northeast direction but to increase abruptly in a northwest direction toward the trough of the Cordilleran geosyncline. This observation indicates the significance of the rock sections of early Paleozoic age in the Ivanpah quadrangle. As shown in figure 4, sections below the Goodsprings dolomite in the eastern half of the quadrangle below the Mesquite thrust show fairly uniform thicknesses and lithology in a northeast direction (parallel to the trough of the Cordilleran geosyncline), but in the western part of the quadrangle the thicknesses of the conspicuous lithologic units increase abruptly in a northwest direction toward the trough of the Cordilleran geosyncline (fig. 6). It seems therefore, that correlations of the lithologic units (Tapeats sandstone, Bright Angel shale) may be made confidently in a northeast direction, but the steady great increase in thickness of recognized lithologic units, and appearance of a unit (Noonday dolomite) below the shale and quartzite units, indicates the need for caution in making correlations in a northwest direction. As the most abrupt increase in thickness of the shale and quartzite units coincides with the Mesquite thrust, it seems appropriate to use the names (Pioche shale and Prospect Mountain quartzite) which have been applied to units of similar thickness in regions northeast of the Kingston Range region. No unit of carbonate rocks resembling, in character and thickness, the Noonday dolomite is known northeast of the Ivanpah quadrangle.

In his work near Johnnie, Nev., Nolan (1929) recognized three formations below the Bright Angel shale (Pioche shale?) as follows: Wood Canyon formation, Stirling quartzite and Johnnie formation; also in the Nopah Range, Hazzard (1937c) recognized the same formations. As Hazzard also recognized the Noonday dolomite below the Johnnie formation, it would appear that the Prospect Mountain quartzite, as defined in this report, is equivalent to the three units, Wood Canyon formation, Stirling quartzite and Johnnie formation. To this writer, who has not examined these three formations in the Johnnie area, it seems that characteristic elements of both the Wood Canyon formation and Stirling formation are present in the Prospect Mountain quartzite. However, those of the Johnnie formation are not readily apparent. Precise correlation must await more detailed work in both regions.

UPPER CAMBRIAN TO DEVONIAN ROCKS

GOODSPRINGS DOLOMITE

The Goodsprings dolomite is widely distributed in this quadrangle, probably more widely than any other stratigraphic unit. Even though it underlies large areas in the Spring Mountains, Kingston Range, Ivanpah Mountain, New York Mountains, Providence Mountains, and Old Dad Mountain, only in the northern part of the Spring Mountains and nearby ridges included within the Ivanpah quadrangle is the almost complete thickness exposed. In most of the other areas either the uppermost beds are removed by erosion or, as found more widely, the lower limit of the section is a thrust fault. In the region affected by Laramide thrust faulting (Spring Mountains), the lower limit of the overriding block is commonly a flat thrust fault that cuts across the Goodsprings dolomite several hundred feet above its base. On the other hand, in the broad belt around the Kingston Range where thrust faults of late Tertiary age appear, some klippen are large blocks of Goodsprings dolomite resting in diverse attitudes on pre-Cambrian crystalline rocks.

The formation was mapped over a large area in the Goodsprings quadrangle where the name was first applied (Hewett, 1931). In contrast to the underlying Cambrian formations the thickness and lithology of the Goodsprings dolomite are almost constant throughout the quadrangle.

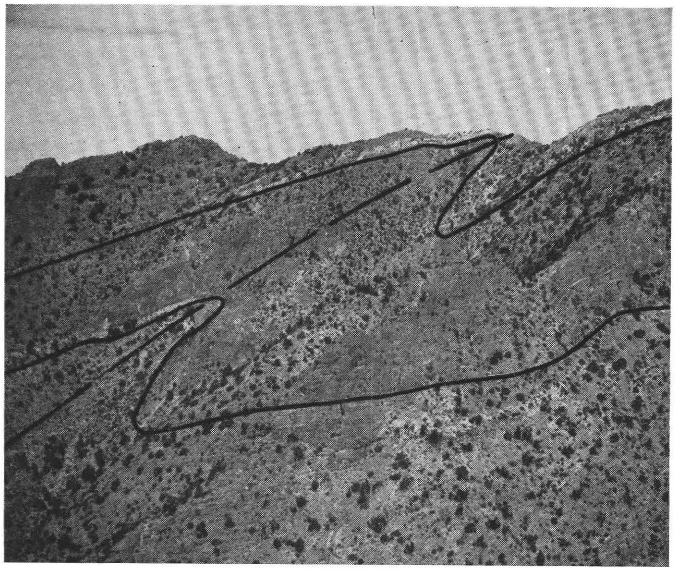

FIGURE 7.—View N. 10° E. toward close fold in Goodsprings dolomite, Clark Mountain, Calif.

The complete unfaulted formation is shown at only one locality, Sheep Mountain east of Jean, where the thickness is about 2,500 feet. Almost complete sections are shown on the west slope of Clark Mountain and the low ridges east of State Line Pass; in the first locality the presence of overturned folds prevents accurate measurement. The ridges that surround Mesquite Valley reveal only the upper 1,000 to 1,500 feet and most of the areas show folds and thrust faults (fig. 7). The formation is largely thick-bedded blue-gray dolomite, but thin shale beds are found in the lower part and thin beds of shale and sandstone in the upper part. Commonly, the dolomite has a mottled appearance in which light-gray dolomite largely surrounds irregular areas of dark dolomitic limestone (fig. 8). In other localities, the relations of dolomite and limestone are reversed. This mottling of light and dark-gray rocks is characteristic of some beds but is entirely absent in nearby overlying and underlying beds. For this reason, it is assumed that the local distribution of dolomite and limestone was determined during or soon after deposition and burial.

FIGURE 8.—Photograph of a specimen of Goodsprings dolomite, Inyo County, Calif.

The dolomitization of the limestones of the Sultan limestone, Monte Cristo limestone, and Bird Spring formation that is seen so widely in this region is revealed by several features but these are largely lacking in the Goodspring dolomite. In a few areas, notably in the Spring Mountains and south of the Bird Spring Range, the normally fine grained carbonate rocks of the Goodsprings dolomite are altered to more coarsely crystalline dolomite, uniformly light gray and without the mottling described above. Such rocks are interpreted as the dolomitized recrystallized Goodsprings dolomite.

Chert is relatively uncommon in the Goodsprings dolomite. In the Sheep Mountain section there is very little chert in the upper and lower zones, each 1,000 feet thick. Here and there in the central 500-foot zone, beds of dolomite 1 to 3 feet thick contain round concretions 5 by 5 by 10 inches.

The following section of the upper 400 feet was measured along the east slope of Spring Mountains.

Section of Goodsprings dolomite measured along east slope of Spring Mountains, sec. 29, 30, T. 26 S., R. 59 E.

	Feet
Sultan limestone.	
Goodsprings dolomite:	
Dolomite, gray, thin-bedded, may be some thin shale layers	30
Dolomite, buff-weathering, coarsely crystalline, persistent	5
Dolomite, cream and gray, thin-bedded	20
Dolomite, cream, coarsely crystalline, beds 4–10 ft thick; forms persistent ledge	80
Dolomite, gray, thin-bedded, some red shale	20
Dolomite, cream-colored; beds largely 5–10 ft thick; forms persistent ledge	90
Dolomite, buff, thin-bedded, shaly	60
Dolomite, light-buff, beds 1–2 ft thick	20
Dolomite, buff, shaly; several sandstone layers, 1–6 in	25
Dolomite, cream, coarse; beds 1–4 ft thick	40
Total	390

During folding, the Goodsprings dolomite, Sultan limestone, and Monte Cristo limestone, appear to have acted as a competent unit and to have determined the broader features of the folds. The underlying formations—Tapeats sandstone and Bright Angel shale, Prospect Mountain quartzite and Pioche shale—and the overlying formations of Paleozoic age—Bird Spring formation, Supai formation, and Kaibab limestone—are relatively incompetent and by minor folds and faults adjust themselves to the forms assumed by the competent unit.

The report on the Goodspring district (Hewett, 1931, p. 13) records only four collections of fossils from the Goodsprings dolomite: a brachipod, *Billingsella coloradoensis* (Shumard) of probable late Cambrian age, a primitive type of gastropod suggesting an Early Ordovician age; a new species of sponge that is probably of Silurian age, and some brachipods that are probably Devonian in age. These fossils indicate, therefore, that the Goodsprings dolomite includes rocks ranging from Upper Cambrian to Devonian. No other collections of fossils were found in the dolomite throughout the Ivanpah quadrangle.

Since work in this quadrangle was completed in 1929, Hazzard and Crickmay 1933) and Hazzard and Mason (1936a, b), working in the Providence and Marble Mountains to the south; Hazzard (1937c), working in the Nopah Range to the Northwest, and Wheeler (1943, 1948), working in ranges north and northeast, have made numerous collections of fossils. They with others have also attempted to correlate faunal zones found in the beds equivalent to the Goodsprings dolomite (Hazzard and Mason, 1936a; Hazzard, 1937a; Mason, Longwell, and Hazzard, 1937), and as a result they have given formation names to the following units: Cadiz formation of Hazzard about 700 feet thick, probably Middle Cambrian series; Bonanza King formation of Hazzard, about 1,500 feet thick in the Nopah Range, Middle Cambrian series; Cornfield Springs formation of Hazzard, about 3,000 feet thick in the Nopah Range, Middle Cambrian series; and the Nopah formation, 1,740 feet thick in the Nopah Range, Upper Cambrian series. On the basis of fossils collected in the Nopah Range, Hazzard also recognizes units equivalent to the Pogonip limestone, Lower Ordovician series; Eureka quartzite, Middle Ordovician series; Ely Springs dolomite, Upper Ordovician series; and an unnamed unit of Silurian age. As the thickness of the beds that lie between the top of the Pioche shale and the base of the Sultan limestone of Devonian age, total about 9,360 feet, it is quite apparent that the Middle and Upper Cambrian, Ordovician and Silurian rock units thicken westward rapidly much as the Lower Cambrian rock units thicken in the same direction.

It will serve little purpose to discuss further at this place the validity and significance of these faunal zones.

DEVONIAN SYSTEM

SULTAN LIMESTONE

The Sultan limestone crops out in many parts of the Spring Mountains, Bird Spring Range, Sheep Mountain, and near Kokoweef Peak in Ivanpah Mountain. It is also present in the high part of Providence Mountains, near the Bonanza King mine beyond the southern boundary of the quadrangle, and in the thrust plate that forms the high part of Old Dad Mountain. It is not known west of Mesquite Valley and in the region west of Winters Pass where the youngest unit of Paleozoic age is the Goodsprings dolomite. Also, it is not known in the McCullough Range and New York Mountains, east of Ivanpah Valley. Each of the three members of the Sultan limestone recognized in the Goodsprings quadrangle (Hewett, 1931, p. 13–16), Ironside dolomite member, Valentine limestone member, and Crystal Pass limestone member, appears to be present throughout the region in which the formation is recognized. The following table shows the thicknesses of these units, at places in the Goodsprings quadrangle and elsewhere:

Thickness of the units of the Sultan limestone in feet

Formations	Goodsprings quadrangle			Green Monster mine	Sloan, Bird Spring Ridge	Sheep Mountain	State Line Pass, sec. 30, T. 26S., R. 59E.	Koko-weef Peak	Standard No. 1 mine
	Sec. 11, T. 25., R. 58E.	Sec. 31, T. 24S., R. 58S.	Sec. 3, T. 24S., R. 57E.						
Crystal Pass limestone member	260	150	150	[1]	150	80	[1]	--------	[1]
Valentine limestone member	280	75	125	[1]	--------	[1 2]	[1 3]	--------	[1]
Ironsides dolomite member	100	80	60	[1]	--------	200	[4] 133	--------	--------
Total feet thickness	640	305	335	600	--------	400	603	300	250
Dip of beds	10°	85°	45°	50°	--------	10°	20°	--------	--------

[1] Present but not measured. [2] Fossil collection 11 (see p. 41). [3] Fossil collection C 22 b. [4] Fossil collection C 22 a.

In a broad way, the greater thicknesses of the Sultan limestone are found in the Spring Mountains; it is thinnest in the vicinity of Kokoweef Peak. As in the Goodsprings quadrangle, most of areas where the beds are very thick have a low dip; the thin beds tend to have steep dip. This relation suggests that under pressure the beds, largely limestone where undolomitized, deform by flowage.

The following section was measured at State Line Pass in sec. 30, T. 26 S., R. 59 E., where Spring Mountains present an escarpment toward Ivanpah Valley. It is not fully representative as the beds are widely dolomitized.

Section measured at State Line Pass, sec. 30, T. 26S., R. 59E.

	Feet
Monte Cristo limestone.	
Sultan limestone:	
Crystal Pass limestone member, largely thin plates one fourth to one half inch thick; massive near top. Sporadically dolomitized	250
Valentine limestone:	
Valentine limestone member, light-gray, and buff dolomite in beds 4–10 ft thick; sparse chert in round masses and in thin layers	220
Ironside dolomite member:	
Ironside dolomite member, sandstone, sporadic lenses, crossbedded	3
Dolomite, buff	60
Dolomite, dark-smoky-gray, with concentric concretions (bryozoa?); persistently laminated but layers do not weather in relief; many lenses of coarse dolomite	70
Total	603

Throughout most of this quadrangle, the lithologic characteristics of the three units are essentially the same as those recognized in the Goodsprings quadrangle. The Ironside dolomite is made up of dark, smoky gray, fine-grained dolomite in beds that commonly range from 2 to 8 feet thick. Chert is uncommon and fossils, largely corals, are scarce. In most places the Valentine limestone member is largely gray limestone in beds, 2 to 5 feet thick, but a few beds of dolomite are present. Nodules and layers of chert are rather common. In most localities, several zones of the Valentine limestone member contain numerous fossils, largely brachiopods, corals, and gastropods. The unit commonly shows partial or complete alteration to dolomite (section measured at State Line Pass). The Crystal Pass limestone member is a distinctive unit; more commonly than the underlying units it forms a conspicuous escarpment which, under weathering, shows thin layers ¼ to 1 inch thick but it is nearly pure limestone throughout. This is the limestone, 150 feet thick, that is mined as a source of lime at Sloan. At Sloan several hundred feet of the overlying beds (Monte Cristo limestone) and underlying beds (Valentine limestone member) are completely altered to dolomite.

In the southern part of Spring Mountains, sections of the Sultan limestone commonly show a single bed of sandstone or quartzite 3 to 10 feet thick. The position of the sandstone layer is different in the several sections, however. In the valley hills 2 miles northwest of Borax (sec. 27, 28, T. 25 S., R. 59 E.), a bed of sandstone 10 feet thick occurs in the lower part of the Valentine limestone member; 6 miles southwest, (sec. 30, T. 26 S., R. 59 E.) a bed of sandstone 3 feet thick lies at the top of the Ironside dolomite member (section above). Farther south, a bed of sandstone 5 to 8 feet thick lies at the top of the Crystal Pass limestone member. The sand grains are chert rather than quartz.

A few varieties of fossils, mostly corals, are common in the Ironside dolomite member, but they are more common in the Valentine limestone member; none have been found in the Crystal Pass limestone member. The following table presents the list of fossils collected during the survey of this quadrangle; it does not include those collected in the Goodsprings quadrangle.

Fossils from the Sultan limestone

[Determinations by Edwin Kirk]

	C11	C21	C22a	C22b
Hydrocoralline:				
Stromatopora sp		×		
Corals:				
Alveolites sp		×	×	
Cladopora sp			×	
Cyathophyllum sp	×		×	×
Brachiopods:				
Stropheodonta sp		×		
Atrypa reticularis (Linné)		×		
Tenticospirifer n. sp. near *T. norwoodi* (Meek)	×			×
Mucrospirifer cf. *M. argentarius* (Meek)		×		
Gastropod:				
Straparolus sp				×

Author's field nos.:
C11 (USNM 1991). Sec 7, T. 24 S., R. 57 E., Low Hills one mile southeast of Green Monster mine.
C21 (USNM 1994). Ironside dolomite member; unsurveyed ground; 1 mile northeast of 5,008 foot-peak, north of Mesquite Pass.
C22a (USNM 1992). Approximately sec. 3, T. 17 N., R. 13 E. Hills east of Mesquite Pass.
C22b (USNM 1993). 200 feet above base; same location as 22a.

According to Edwin Kirk, the age of these fossils is Middle Devonian. In the Goodsprings quadrangle, the age of a similar but larger assemblage from the Sultan limestone was late Middle or early Late Devonian. In his report on the rocks of Paleozoic age of the Nopah and Resting Springs Mountains, Hazzard (1939, p. 47–48) concludes that the fossils "collected [by Hewett] from the Valentine limestone member of the formation suggest a Mississippian rather than Devonian age." Hazzard believes "that further study will show the validity of the Mississippian age here suggested for the upper portion of the original Sultan limestone." As no fossils have been found in the Crystal Pass limestone member throughout this region and there are no conspicuous unconformities under or over this limestone, its age must be open to debate. On the other hand, the Valentine limestone member in the Ivanpah quadrangle yields a greater number of brachiopods of the genera and species determined to be of Devonian age (by Edwin Kirk) than the underlying Ironside dolomite member whose Devonian age is admitted.

MISSISSIPPIAN SYSTEM

MONTE CRISTO LIMESTONE

The areal distribution of the Monte Cristo limestone coincides closely with the underlying Sultan limestone. The five members that were recognized in the Goodsprings quadrangle, Dawn limestone member, Anchor limestone member, Bullion dolomite member, Arrowhead limestone member, and Yellowpine limestone member, persist throughout much of the northern half of the quadrangle, are present on Old Dad Mountain and maintain the characteristics that distinguish them in the Goodsprings quadrangle. The total thickness of all of the five members of the Monte Cristo limestone ranges from 400 to 800 feet in the Goodsprings area, and the range in the Ivanpah quadrangle is from 700 feet south of Devil Peak, where the beds dip 5° or less, to 350 feet near the Standard No. 1 mine, where the dip is 30°.

The name is derived from the Monte Cristo mine, Goodsprings quadrangle.

The Dawn limestone member is largely made up of beds of blue-gray to dark-gray limestone, 2 to 10 feet thick, but it is widely altered to dolomite. It was not found in the hills east of Bard but is present on Sloan Hill, in the Bird Spring Range, Sheep Mountain, along the southern extension of the Spring Mountains where they turn westward around Mesquite Valley and in the hills west of the Standard No. 1 mine.

The Anchor limestone member is generally several thick massive layers of light-bluish-gray limestone that contain a number of layers of chert nodules. Over wide areas it resists alteration to dolomite but on Sloan Hill and near Standard mine it is completely altered.

The Bullion dolomite member, like the underlying Anchor limestone member, has several thick layers so that the two commonly form a single cliff in escarpments such as those which face Ivanpah Valley south of Devil Peak and Clark Mountain. Throughout most of the region it is nearly pure dolomite but in a few places, such as Sloan Hill and near the Standard No. 1 mine where most of the limestones of the section of Late Paleozoic age are altered to dolomite, it is more coarsely crystalline than usual.

The Arrowhead limestone member is made up of alternating layers of fine limestone several inches thick and thin shale and rarely exceeds 10 feet in thickness. Near the Green Monster mine it is 7 to 8 feet thick; on Clark Mountain it is 10 feet thick. It was not found on Sheep Mountain nor near the Standard No. 1 mine.

The Yellowpine limestone member, a massive unit about 120 feet thick throughout the Goodsprings quadrangle, is generally thinner westward and southward. At the Green Monster mine it is 75 feet of pure limestone; on Clark Mountain it is 100 feet of dolomite.

The brachiopod faunas of the Anchor and Arrowhead limestone members are abundant and are found widely; fossils are uncommon in the Bullion dolomite member and Yellowpine limestone member. According to George H. Girty, who made the determinations, the age of the Monte Cristo limestone is early Mississippian. Only a few collections were made in the region outside the limits of the Goodsprings quadrangle.

Fossils from the Monte Cristo limestone

[Identifications by George H. Girty in 1928]

	C14	C17	C89
Corals:			
Triplophyllum sp	×	--------	×
Campophyllum? sp	--------	--------	×
Acervularia? sp	--------	--------	×
Syringopora surcularia Girty	×	--------	--------
sp. A	--------	--------	×
sp. B	--------	--------	×
Echinoderms: Crinoidal fragments	--------	×	--------
Bryozoans: *Fenestella*, several sp	--------	×	--------
Brachiopods:			
Rhipidomella aff. *R. burlingtonensis* (Hall)	×	×	--------
Schizophoria aff. *S. poststriatula* Weller	--------	×	--------
Leptaena analoga (Phillips)	--------	×	--------
Schuchertella aff. *S. rubra* (Weller)	--------	×	--------
Chonetes aff. *C. illinoisensis* Worthen	--------	×	--------
Productus aff. *P. setiger* Hall	--------	×	--------
Pustula aff. *P. concentrica* (Hall)	--------	×	--------
aff. *P. blairi* (Miller)	--------	×	--------
sp.	--------	×	--------
Camarophoris bisinuata (Rowley)	--------	×	--------
Leiorhynchus? sp	--------	×	--------
Camarotoechia aff. *C. louisianensis* (Weller)	--------	×	--------
Cranaena globosa Weller?	--------	×	--------
Spirifer centronatus var. (Winchell)	--------	×	--------
aff. *S. increbescens* Hall	×	--------	--------
Reticularia n. sp. ?	--------	×	--------
Syringothyris sp	--------	×	--------
Spiriferina solidirostris (White)	--------	×	--------
Cleiothyridina obmaxima (McChensey)	--------	×	--------
Pelecypods:			
Parallelodon? sp	--------	×	--------
Cypricardinia sp	--------	×	--------
Schizodus sp	--------	×	--------
Gastropods: *Pleurotomaria* sp	--------	×	--------
Cephalopods:			
Orthoceras sp	--------	×	--------
Goniatites? sp	--------	×	--------
Trilobites: *Proetus* n. sp	--------	×	--------
Ostracodes: *Bairdia* sp	--------	×	--------

Author's field nos.:
C14 (USGS locality 5746) sec. 1, T. 24 N., R. 56E; 500 feet north of Green Monster mine; Anchor limestone member.
C17 (USGS locality 5737) sec. 12, T. 17 N., R. 13 E.; 4,000 feet northwest of benchmark 5236; Anchor limestone member.
C89 (USGS locality 6386) sec. 8, T. 24 N., R. 56E.; crest of Valley Ridge, northwest end Mesquite Valley.

PENNSYLVANIAN SYSTEM

BIRD SPRING FORMATION

The Bird Spring formation is widely exposed in the Spring Mountains and the adjacent mountains both east and west in the northern third of the quadrangle; it is well exposed in a large area west of Sloan and Erie. Isolated outcrops are found west of Kokoweef Peak and the Standard No. 1 mine. In the southern third of the quadrangle, it is found on the top and west slope of Old Dad Mountain and near the Bonanza King mine on the southeast end of Providence Mountains, beyond the southern limit of this quadrangle. Two isolated

Fossils from the Bird Spring formation

[Identifications made by George H. Girty in 1928]

	3	3a	5	7	8	12	13	18	19	23	83a	83b	6	10
Corals:														
Triplophyllum sp											×			
Chaetetes milleporaceous Milne Edwards and Haime	×													
Bryozoans:														
Fistulipora aff. *F. excellens* Ulrich													×	
sp						×								
Fenestella sp						×		×						
Polypora sp						×					×			
Cystodictya aff. *C. pustulosa* Ulrich						×								
Brachiopods:														
Lingulidiscina aff. *L. missouriensis* (Shumard)										×			×	
Spirifer increbescens Hall var		×												
aff *S. increbescens* Hall			×	×	×				×	×			×	
cameratus Morton?														×
Cleiothyridina sublamellosa (Hall)											×			
aff. *C. sublamellosa* (Hall)				×				×	×	×				
Composita aff. *C. subquadrata* (Hall)				×					×	×			×	
subtilita (Hall)														×
aff. *C. subtilita* (Hall)						×								
Orthotetes sp									×				×	
? sp		×												
Derbyia? sp	×													
Chonetes aff. *C. laevis* Keyes									×					
aff. *C. leavis* Keyes?										×				
sp							×							
Productus aff. *P. inflatus* McChesney					×									
ovatus Hall									×					
ovatus var. *minor* Snider?									×	×				
Pustula aff. *P. pustulosa* (Phillips)														×
Avonia arkansana (Girty)?									×	×				
Marginifera aff. *M. muricata* (Norwood and Pratten)							×	×		×	×			
splendens (Norwood and Pratten)?														×
Schizophoria n. sp				×										
Schizophoria? sp												×		
Rhynchopora aff. *R. beecheri* Greger										×				
Spiriferina aff. *S. spinosa* (Norwood and Pratten)				×				×		×			×	
sp														×
Hustedia aff. *H. mormoni* (Marcou)										×			×	
n. sp						×								
n. sp.?										×				
sp									×					
Dielasma aff. *D. fernglenensis* Weller									×					
sp								×					×	
Pelecypods:														
Edmondia sp														×
Parallelodon? sp														×
Myalina aff. *M. perniformis* Cox													×	
aff. *M. swallowi* McChesney													×	
Schizodus sp							×							
Aviculopecten sp										×				
Gastropods:														
Bellerophon sp							×		×					
Euomphalus sp														×
Bulimorpha aff. *B. chrysalis* (Meak and Worthen)													×	
Cephalopods:														
Orthoceras sp													×	
Trilobites:														
Griffithides aff. *G. ornatus* Vogdes										×				
Griffithides sp								×	×				×	
Ostracodes:														
Paraparchites sp										×				

Author's field no.:
3 (USGS locality 5743). Sec. 9, T. 24 N., R. 59 E., crest of Bird Spring Range.
3a (USGS locality 5743a). Sec. 9, T. 24 N., R. 59 E., crest of Bird Spring Range.
5 (USGS locality 5442a). Sec. 8, T. 24 N., R. 59 E., crest of Biro Spring Range.
6 (USGS locality 5442). Sec. 8, T. 24 N., R. 59 E., crest of Bird Spring Range.
7 (USGS locality 5739). Sec. 13, T. 23 S., R. 60 E., west side of Sloan fault.
8 (USGS locality 5742). Sec. 29, T. 23 S., R. 59 E., Bird Spring Range.
10 (USGS locality 5741). Sec. 34, T. 23 S., R. 60 E., 3 miles north of Erie.
12 (USGS locality 5744). Sec. 31, T. 23 S., R. 57 E., 1 mile north of Green Monster mine.
13 (USGS locality 5740). Sec. 32, T. 25 S., R. 59 E., east of Devil Canyon mine.
18 (USGS locality 5738). Sec. 1, T. 17 N., R. 13 E., north of Dewitts camp.
19 (USGS locality 5736). Sec. 21, T. 18 N., R. 14 E., State Line Pass.
23 (USGS locality 5734). Sec. 25, T. 26 S., R. 58 E., east of State Line Pass.
83a (USGS locality 6385). Sec. 18, T. 15 N., R. 14 E., Standard mine area.
83b (USGS locality 6385a). Sec. 18, T. 15 N., R. 14 E., Standard mine area.

exposures lie in Lanfair Valley, in secs. 1 and 11, T. 12 N., R. 15 E.

In spite of its widespread distribution, good measurements of the total thickness can be made at only a few localities because it is generally intricately folded. On the west slope of Bird Spring Range it is about 2,500 feet thick, but on the west slope of Kokoweef Peak it is only about 1,200 feet thick. The name is derived from the Bird Spring Range.

The Bird Spring formation is largely beds of limestone less than 20 feet thick, alternating with thinner beds of shale, sandstone, and dolomite. In the Spring Mountains, it is probably 70 percent limestone, 10 percent sandstone, 15 percent dolomite, and 5 percent shale. The exposures west of Sloan and Erie are much more sandy. An estimate indicated that only 10 percent is pure blue-gray limestone, 60 percent is brown-weathering sandy limestone, and 30 percent is calcareous sandstone. These sandy beds are prevailingly cross-bedded and the lenses largely dip south as they do in the overlying Supai formation and Aztec sandstone. A collection of brachiopods from these beds (No. 10) 2 miles north of Erie contains varieties not found in the Spring Mountains.

Chert occurs sporadically in the form of flat concretions several inches thick, distributed in layers through some of the limestone beds. Some larger concretions, as much as 2 to 3 feet in diameter, are silicified colonies of the coral *Chaetetes*.

The sandstone, locally conglomeratic, that forms the basal unit along the east slope of Spring Mountains, especially near the Yellow Pine mine, is seen at a few places west and south of the mountains. At the Green Monster mine, it is 25 feet thick; near Dewitts camp, 5 miles south of Devil Peak, the basal unit is 20 feet of calcareous sandstone. Farther south, near Kokoweef Peak and the Standard No. 1 mine, there is no sandstone; the base of the formation is not exposed on Old Dad Mountain. The sporadic occurrence of this sandstone and the absence of the uppermost members of the Monte Cristo limestone (Arrowhead and Yellow Pine limestone members) at several localities indicates that there is an unconformity at the base of the Bird Spring formation.

In addition to beds of dolomite that form an important part of the formation, the limestone beds are partly or wholly altered to dolomite in large areas. The circumstances that control the distribution of the areas of dolomitized limestone are obscure; it is only known that the process is related to the deformation of the region (Laramide revolution) and intrusion of the masses of quartz monzonite and related porphyries. There is such an area at the south end of Spring Mountains that extends from Devil Peak to and beyond Dewitts camp. At the south end of the 5,300-foot ridge, the following section was measured:

Section of Bird Spring formation measured at south end of Spring Mountains

	Feet
Dolomite, light-smoky-gray, thin-bedded; largely 1–4 ft thick	150
Dolomite, smoky-gray, massive	30
Domolite, smoky-gray as above; one bed 12 ft thick	50
Dolomite, brown, sandy; weathers yellowish brown	20
Dolomite, gray	3
Dolomite, weathers brown	10
Dolomite, light-smoky-gray, thin-bedded	150
Dolomite, gray, massive	10
Dolomite, light-smoky-gray, thin-bedded	150
Total	573

According to G. H. Girty the fauna collected from the Bird Spring formation in the Ivanpah quadrangle is of Pennsylvanian age, and the fossil assemblages listed in this report suggest those characteristic of the lower half of the Pennsylvanian system. In the Goodsprings area faunas of both early and late Pennsylvanian age have been recognized; and in the much thicker section in the Las Vegas quadrangle, zones ranging in age from late Mississippian to Permian have been identified. Most of the collections from the Ivanpah quadrangle shown in the accompanying faunal chart are comparable to those recorded from the lower 450 feet of the formation in the Goodsprings area. Girty interpreted this fauna to be of early Pennsylvanian (Pottsville) age. A few of the assemblages listed in the chart contain fossils that are characteristic of the post-Pottsville rocks.

In the Las Vegas quadrangle to the north, more than 5,000 feet of rocks has been assigned to the Bird Spring formation. In this area the lower 700 feet of the formation has been called the Indian Springs member of Longwell and Dunbar (1936b). In an unpublished report on the faunas of late Paleozoic age of the Las Vegas quadrangle prepared in 1935, Girty interpreted the fossils from the lower beds to be of late Mississippian age though he recognized that most of the collections not only "lack the more diagnostic types of Chester fossils" but that they contain some "forms which if not distinctly Pennsylvanian are at least suggestive of that age." The upper part of the thick section in the Las Vegas quadrangle contains a fauna that is younger than any fauna so far identified from the Bird Spring formation in the Ivanpah quadrangle. Girty found it suggestive of the Hueco limestone of Texas (Permian(?) of present U. S. Geological Survey usage). Studies of the fusulinids from the Spring Mountains northwest of Las Vegas have provided supporting evidence that the formation in this area contains equivalents of the Hueco limestone and possibly some even younger rocks. Longwell and Dunbar (1936a, b) assigned the upper 2,900 feet of the Bird Spring formation to the Permian system, correlating the lower part of this sequence with the Wolfcamp formation of Permian(?) age and suggested that the upper beds may be of Leonard age. These findings confirm Girty's observations regarding the Hueco aspect of the larger invertebrate fossils collected from the upper part of the formation because the Hueco limestone, in general terms, is correlated with the Wolfcamp formation.

In the Nopah Range, Hazzard (1937c) referred 780 feet of limestone to the Bird Springs (sic) (?) formation. According to his report neither the base nor top of the formation were found. Two collections from the upper part of this sequence contained a fauna that Mason interpreted to be of Des Moines age and compared with the fossils known from the post-Pottsville part (between 450 ft. and the top) of the Bird Spring formation in the Goodsprings quadrangle. This correlation cannot be very precise, however, because in some collections from this part of the formation in the Goodsprings area Girty identified *Triticites*, that is *Fusulina secalica*, which would imply that the upper part of the Bird Spring formation in the type area is younger than the Des Moines group. Hazzard (1937c) also reported that,

"In the Providence Mountains, California, both Pennsylvanian and Permian are known to be present within a series of beds both lithologically and stratigraphically comparable with the Bird Springs formation of the Goodsprings area."

Beds that contain Permian(?) fusulinids and that are thought to be equivalent to part of the Bird Spring formation have been recognized by the writer on the west slopes of a high ridge about 9 miles northwest of Baker. No rocks of this age have been found in the region as much as 50 miles southwest of Baker.

PENNSYLVANIAN AND PERMIAN SYSTEMS

SUPAI FORMATION

Exposures of the Supai formation are confined to the Spring Mountains, the ridges north of the Ivanpah fault, and to the mountains east of Spring Mountains near the northern border of the quadrangle. Even though the overlying and underlying formations are present west of Kokoweef Peak, beds of the Supai formation have not been identified. The maximum thickness in the quadrangle is about 1,150 feet, measured in sec. 13, T. 23 S., R. 58 E. A section measured in secs. 13 and 24, T. 24 S., R. 59 E., is 800 feet thick. West of Dewitts Camp, in the southeastern corner of T. 18 N., R. 13 E., an estimate of its thickness is 700 feet.

The name was applied by Darton to a unit below the Coconino sandstone and Kaibab limestone in northern Arizona, and by its lithology and relations it has been traced intermittently through northwestern Arizona and southwestern Utah into southwestern Nevada,

In contrast to the great thickness of limestone underlying it (Bird Spring Formation?), the Supai formation is largely red sandstone and shale with a few sporadic beds of gypsum. As the overlying Kaibab limestone sustains ridges and steep cliffs, the beds of the Supai formation crop out on the lower debris-covered slopes and complete sections are not exposed. The following partial section was measured in sec. 6, T. 23 S., R. 60 E.:

Section of Supai formation measured in sec. 6, T. 23 S., R. 60 E.

	Feet
Top, not exposed.	
Sandstone, shaly, brick-red; local beds of gypsum	120
Sandstone, pale-reddish, locally mottled; made up of crossbedded layers 3–12 in. thick	115
Sandstone, cream, persistent	2
Sandstone, red, thin-bedded	2
Sandstone, cream to pale-red, single-ledge	3
Sandstone, pale-red and cream; persistent crossbedding	32
Sandstone, pale-red, crossbedded	24
Sandstone, cream, single-ledge	4
Sandstone, pale-red, crossbedded	14
Sandstone, pale-red	18
Sandstone, brick-red, thin-bedded	8
Sandstone, pale-red, mottled, crossbedded	11
Sandstone, brick-red, single-ledge	8
Sandstone, light-red, crossbedded; weathers to smooth ledges 5–10 ft thick	80
Base not exposed.	
Total	441

In secs. 13 and 24, T. 23 S., R. 59 E., the complete section, about 800 feet thick, is fairly well exposed. The lower 600 feet is alternating buff and red sandstone; the buff sandstone consists of beds 5 to 10 feet thick; the red variety is thin bedded. The upper 200 feet is red shaly sandstone which includes several beds of gypsum. In the northwest corner of T. 23 S., R. 60 E., the upper part of the Supai formation contains many veins of gypsum 6 to 12 inches thick. No beds of gypsum crop out, but such veins indicate their presence in the section. There has been some prospecting along the gypsum beds of the upper part of the Supai formation but no bed worthy of exploitation has been found. The most southwestern exposures of beds of the Supai formation in this quadrangle, in secs 5 and 6, T. 17 N., R. 14 E., do not yield details of the section.

PERMIAN SYSTEM

KAIBAB LIMESTONE

The Kaibab limestone, Permian in age, crops out in large areas in the northeastern part of the quadrangle, particularly in the Bird Spring Range. The southernmost outcrop in the quadrangle and probably the southwesternmost in the United States, lies west of Kokoweef Peak. The range in thickness in the Goodsprings quadrangle is 410 to 555 feet. West of Dewitts Camp the estimated thickness is 500 feet; at Kokoweef Peak, it is 400 feet. The name was applied by Darton to a unit of similar thickness in north-central Arizona and it has been recognized over large areas in northern Arizona, southern Utah, and eastern Nevada.

As in the Goodsprings area, the Kaibab limestone is made up typically of three members: a limestone, 200 to 250 feet thick at the base; a sandstone, 30 to 100 feet thick, generally containing a bed of gypsum; and a limestone, 200 to 250 feet thick at the top. Some sections show thin beds of dolomite but most of the formation is rather pure limestone. Chert nodules are uncommon in the lower members; they are common in the upper, which also yields most of the fossils.

The following section was measured in sec. 6, T. 24 S., R. 60 E., on a minor ridge east of Bird Springs Range:

Section of Kaibab limestone measured on Bird Spring Range, sec. 6, T. 24 S., R. 60 E.

	Feet
Top of upper member is eroded.	
Limestone, pale-gray; mostly beds 4–8 ft thick; considerable chert as spongy masses rather than solid nodules; increase toward top; numerous fossils	110+
Limestone, gray, thin-bedded; sparse chert layers and nodules; many crinoid stems	32
Sandstone, red, shaly; weathers to sand	36
Limestone, pale-gray; beds 6–12 in. thick, sandy near top	14
Limestone, pale-gray; several massive beds; sparse layers of spongy chert; few fossils	50
Limestone, pale-gray; massive with traces of bedding 5–10 ft; sparse chert layers and nodules; few fossils	70
Limestone, pale-gray, beds 2–4 ft thick	36
Limestone, pale-gray, massive, few chert concretions; numerous fossils	12
Limestone, gray, platy	2
Limestone, pale-gray; no chert, few fossils	6
Dolomite, cream, sandy, weathers cavernous	10
Total	378
Base is red shaly sandstone (Supai formation).	

The distinctive lithologic features of the Kaibab limestone, as well as those of the overlying Moenkopi formation and underlying Supai and Bird Spring formations, permit dependable interpretations of some complicated structural features where these beds are present. These are discussed in the chapter on structural features (p. 50).

Even though fossils are rather common in this formation, no attempt was made to make large collections, such as were collected in the Goodsprings area. Where a dependable determination of the formation was needed in a local structural problem, a few collections were made but they did not add new species to those already recorded. It is well known that the productid brachiopods from the Kaibab formation are large and roughly hemispherical and where they weather on exposures of the beds in their normal order, they rest on the flat side and present the round surface upward. In several places, the attitude of the fossils on weathered surfaces confirmed other evidence that the beds are overturned.

UNDIFFERENTIATED ROCKS OF PALEOZOIC(?) AGE

Near the western border of the quadrangle in the area bounded by Riggs Wash on the south, the Shadow Mountains in the east, and Kingston Wash on the north, there is a group of five hills made up of limestone and dolomite which cannot be correlated with confidence with any of the rocks of Paleozoic or pre-Paleozoic age in the quadrangle. The rocks of the four western hills have several characteristics in common and more closely resemble beds of late Paleozoic age than any other. The rocks of the eastern hill (4,880 feet) are more crystallized and resemble those of the Crystal Spring formation in the Kingston Range. For present purposes, they are designated "undifferentiated Paleozoic(?)." A hasty reconnaissance indicates that similar rocks form the summit of the Silurian Hills, west of this quadrangle, and several of the hills that lie between.

The easternmost hill (4,880 feet) of the group, is largely marble in which the grains average about 1 millimeter in diameter. The marble is white on fresh fracture but weathers pale brown. In places, it contains small plates of black mica (phlogopite). Bedding is inconspicuous, and even though it appears to average N. 45° W. and to dip 20° to 40° SW., there are wide departures from the average. Several thousand feet of beds must be present on this hill. The marble is cut by a few thin dikes of fine-grained biotite granite unlike other types that are present in the area. The rock also contains many thin veinlets of brown silica and a reddish carbonate.

The nearest counterpart to this marble is that which forms lenses near the base of the Crystal Spring formation in the Kingston Range and contains the magnetite beds of the Beck iron deposit. There, however, the marble contains considerable wollastonite; none is noted on hill 4,880. The Teutonia quartz monzonite crops out at many places in the low ground near the hill but the contact cannot be seen.

The eastern part of the hill is overlain by a sheet of dark dolomite breccia that strikes northwest and dips gently to the northeast. This breccia is similar to that which forms extensive lenses in the middle Tertiary sedimentary rocks in the Shadow Mountains that lie several miles north.

The 4,000-foot hill that lies 2 miles north of Riggs Wash well and 2 miles west of the 4,880-foot hill is made up of thin-bedded sandy limestone and dolomite. Bedding is conspicuous and the hill coincides with crest of an anticline that strikes N. 60° W. The dark-gray limestone has been altered sporadically to light-gray dolomite. Chert is present in thin layers. Silicate minerals characteristic of intrusive contact zones were not observed. A single dike of aplite was found in the saddle. The rock is not as much altered as that on the 4,880-foot hill.

Several hundred feet south and southeast of this hill, quartz monzonite crops out and at the southwest end of the hill, limestone seems to rest upon a small outcrop of greenish gneiss and schist.

The 3,800-foot hill that lies half a mile northeast of this hill is made up of limestone and surrounded by outcrops of tuffs, sands, and clays, common in the beds of middle Tertiary age nearby to the north.

Close search failed to reveal any fossils in the limestone, dolomite, or marble that make up these hills so that the only guide to their identity is the lithologic features. These most closely resemble parts of the formations of late Paleozoic age, Sultan, Monte Cristo, and Bird Spring; however, the marble that makes up the 4,880-foot hill is more altered and recrystallized than any other known beds of Paleozoic age. It seems best, therefore, to designate them as "undifferentiated Paleozoic(?)."

Two explanations may be offered to account for the existence of the group of five hills of limestone and marble on the border of a large area underlain by quartz monzonite. They may be remnants of the roof of the monzonite or roof pendants and their alteration is related to the intrusion. They may be remnants of a plate of rocks of Paleozoic age thrust eastward in late Tertiary time somewhat like the numerous remnants of pre-Cambrian rocks that were thrust over middle Tertiary sedimentary rocks in the Shadow Mountains (p. 96). The fact that two of the hills have local patches of middle Tertiary sedimentary rocks seems to eliminate this possibility. For the present, the five hills are regarded as remnants of the roof of the quartz monzonite intrusion

MESOZOIC ERA

TRIASSIC SYSTEM

MOENKOPI FORMATION

Outcrops of parts of the Moenkopi formation are widely distributed but the total area of outcrop is small. Most of the exposures are found on the east slope of the Spring Mountains and nearby ridges, but they occur sporadically southwest of State Line Pass. The southernmost exposures lie west of Kokoweef Peak where the total thickness is between 400 and 500 feet. The best measurements of the total thickness were made in the Goodsprings quadrangle where the range is from 750 to 950 feet. In most places, only several hundred feet of beds can be examined.

The name "Moenkopi" was applied by Ward to a formation in northern Arizona consisting largely of red and brown shale and sandstone. It has been traced westward and northwestward across northern Arizona and southern Utah, and Longwell (1928, p. 152) has recognized the unit in the Muddy Mountains in Nevada.

Longwell (1925) has described an unconformity at the base of the Moenkopi in the region east of Charleston Peak, Spring Mountains (Las Vegas quadrangle). There is a similar unconformity east of Goodsprings but it has not been seen farther south.

In the northeastern part of the quadrangle, the formation shows the lithologic features recorded in the Goodsprings quadrangle: a lower member of conglomeratic sandstone and red shale, a middle member of thin-bedded buff limestone and dolomite with thin zones of gray shale, and an upper member of red shale. The outcrops south of State Line Pass resemble the middle and upper members but west of Kokoweef Peak the outcropping beds are light-blue-gray limestone containing very little shale. The thin belt of Moenkopi limestone which underlies the Mesquite thrust for several miles southwest of State Line Pass has been helpful in determining the position of that thrust.

About two and one half miles west of Goodsprings, there are two small outcrops of tuffaceous rocks and conglomerate made up of igneous rocks that appear to have been laid down in the upper shaly member of the Moenkopi formation. The pebbles are trachytic; tuffs are probably andesitic. The material, like the enclosing Moenkopi sedimentary rocks, was indurated and deformed by the folding of the Laramide revolution in this region. No rocks resembling those have been found in the Moenkopi formation elsewhere in the Ivanpah quadrangle.

In submitting the determinations of the fossils, G. H. Girty comments: "Lots 75a and 75b have turned up a somewhat novel phase of the lower Triassic fauna; novel that is, in this area. The geologic age as Triassic is unquestionable, however."

Moenkopi formation is widely exposed in the Muddy Mountains, about 40 miles northeast of Las Vegas, where Longwell (1925) records thicknesses that range from 1,221 to 1,634 feet. In this region he collected many fossils characteristic of the formation in northern

Fossils from the Moenkopi formation

[Determinations by George H. Girty in 1928]

	Good-springs quad.	16	75a	75b
Aviculpecten parvulus		×		×
n. sp				×
sp				×
Bakewellia n. sp	×			×
Holopea? sp				×
Monotis? *Boutwelli*				×
n. sp				×
sp				×
Myalina post-carbonica				×
sp	×			×
Myophoria ambilineata	×			×
sp	×			×
sp				×
Pleurophorus? sp	×			×
Plicatula? n. sp				×
Pseudomonotis? n. sp	×	×		
Pteria n. sp				×
Terebratula thaynesiana			×	
Small gastropods		×		

Author's field nos.:
16 (USGS locality 7886). Sec. 6 T. 17 N., R. 14 E., west of Dewitts Camp.
75a (USGS locality 7897). Unsurveyed ground; 1 mile northwest of Kokowee Peak.
75b (USGS locality 7897a). Unsurveyed ground; 1 mile northwest of Kokowe Peak.

Arizona and did not recognize an unconformity at the base. In the Spring Mountains west of Las Vegas, however, Longwell recognized a noteworthy unconformity, and the writer has observed a similar unconformity east of Goodsprings, Nev.

In the central part of Providence Mountains east of Kelso, Hazzard (1937c, p. 329) measured 997 feet of sandstone, shale and limestone that yielded fossils much like those in lot 75b from Kokoweef Peak; they were considered by S. E. Muller to be late Early Triassic in age. An unconformity was observed at the top of the section but not at the base.

In the region south and southwest of Providence Mountains, typical Moenkopi rocks and diagnostic fossils are not known but altered flows, tuffs, and breccias are considered to be of Triassic age because they are intruded by granite (Hazzard, Gardner, and Mason, 1938).

SHINARUMP CONGLOMERATE AND CHINLE FORMATION

The name Shinarump conglomerate was applied to several outcrops of an unusual conglomerate that lie 2 miles west of the town of Goodsprings (Hewett, 1931, p. 34). The stratigraphic position of the conglomerate justified correlating it with a conglomerate of that name in southern Utah and eastern Nevada. It was not seen northeast of Goodsprings, but the overlying Chinle formation crops out widely in the northeast quarter of the Goodsprings quadrangle. Elsewhere in the Ivanpah quadrangle, the Shinarump conglomerate is not known and the Chinle formation is found at only one place, about 2 miles northwest of Kokoweef Peak. Exposures of the beds in this area, between the Aztec sandstone above and the Moenkopi formation below, are very poor and add little to what is known of them near Goodsprings, 27 miles distant. For several miles north of Goodsprings, the Chinle formation is largely red shaly sandstone; red, brown, and green shale; and thin zones of chert and limestone conglomerate and is about 1,000 feet thick. The formation is about 800 feet thick west of Kokoweef Peak.

Both the Shinarump conglomerate and Chinle formation have been traced from western New Mexico, across northern Arizona to the Muddy Mountains in Nevada (Longwell, 1928, p. 152). The general characteristics persist over this area, but thicknesses vary considerably, and beyond fragments of fossil wood, no fossils have yet been found in the western part of the belt. It has been considered to be Late Triassic in age.

JURASSIC(?) SYSTEM

AZTEC SANDSTONE

The name "Aztec sandstone," adopted from the name of a small copper mine north of Goodsprings, was first applied by Hewett in 1931 to a sandstone unit that overlies the Chinle formation and crops out as an impressive escarpment along the east slope of the Spring Mountains for many miles, north of Goodsprings. It has a thickness of 2,100 feet at the northern edge of Goodsprings quadrangle but its original thickness may have been greater, for it is limited upward by thrust faults. Field work in the Ivanpah quadrangle adds another area of definitely identified Aztec sandstone, that which lies 2 miles west of Kokoweef Peak. Here, overlying the Chinle formation, there is about 800 feet of red sandstone which has the peculiar crossbedding that is characteristic of the Aztec sandstone along the front of the Spring Mountains and the Navajo sandstone, probably the equivalent of the Aztec in eastern Nevada and southern Utah. The Aztec almost lacks bedding planes parallel to the lower and upper limits of the formation, but is made up of enormous lenses of sand, mostly 10 to 25 feet thick. Each of these lenses, however, is made up of many laminae, ½ to 2 inches thick, that have parallel strike and dip within the lenses. It has been considered that this feature has been produced by deposition of windblown sand.

On the east end of the Mescal Range, west of Kokoweef Peak, the Aztec sandstone is overlain by 50 feet of limestone and dolomite in beds 1 to 3 feet thick, and these are overlain by 80 feet of buff thin-bedded sandstone. In mapping, these beds were included in the Aztec sandstone. Then follow 600 feet of reddish-brown flow breccia (below), separated from the overlying Goodsprings dolomite by the Mescal thrust fault.

UPPER JURASSIC(?) SYSTEM—EXTRUSIVE ROCKS

In two separate areas in the south half of the quadrangle, flow breccias crop out; in one of the areas, at the east end of Mescal Range, the rocks are definitely older than the Laramide thrust faults as they are overlain at the Mescal thrust by the Goodsprings dolomite. At the other area, north of Sands on the Union Pacific Railroad, the flow breccias are intruded by small bodies of granitic rocks. In composition and texture, they are similar enough to be regarded as of the same age.

The ridge that forms the east end of Mescal Range, 2 miles northwest of Kokoweef Peak and south of Wheaton Wash, is made up of about 600 feet of reddish-brown dacite flow breccias and flows. The flows conformably overlie sandstone beds at the top of the Aztec sandstone and with them strike generally south and dip 15°–20° W. The Aztec sandstone crops out continuously from the north side around the east side to the south side of the ridge. On the north side of the ridge, between the massive light-brown sandstone and the gneiss that lies north of the Clark Mountain fault, there are prominent outcrops of light-gray dolomite that strike northwest and dip steeply southwest. Although no fossils could be found, these beds of dolomite are interpreted as those that lie near the base of the Moenkopi formation, and, as beds similar to the Shinarump conglomerate and Chinle formation are absent, the dolomite beds of the Moenkopi formation must have been dragged upward several thousand feet along the Clark Mountain fault.

No attempt has been made to measure and study closely the flows and flow breccias that rest on the Aztec sandstone in the Mescal Range and that crop out near Sands. Both are dark-reddish brown except for patches that are greenish, owing to the presence of fine grains of epidote. Weathered surfaces show numerous angular fragments of dark-red flow as much as 2 inches long in a glassy groundmass that weathers lighter in color. Thin sections of the fragments show angular and corroded grains of quartz, 10–15 percent; plagioclase (An_{20}), 5 percent; orthoclase, 3 percent; and no dark minerals. The matrix shows wavy and curved layers of microlites in glass. The feldspars show slight alteration to sericite (fig. 9).

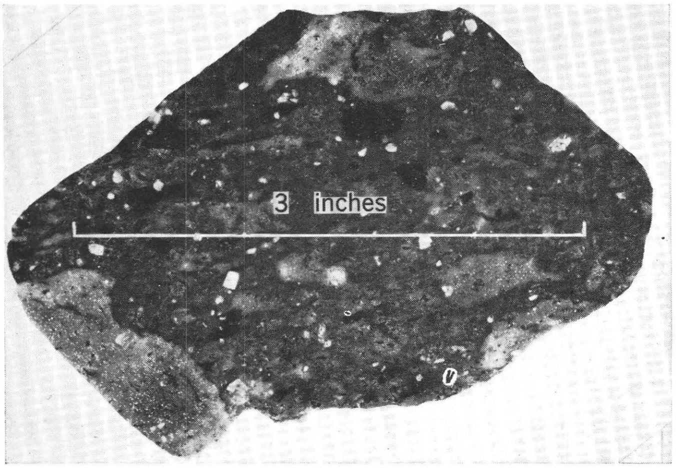

FIGURE 9.—Photograph of a specimen of dacite flow-breccia from Mescal Range, Calif.

Flow breccia that resembles the rock of the Mescal Range but differs in mineralogic detail is found widely in the Devils Playground, in secs. 6, 7, 8, 17, T. 11 N., R. 10 E. Here the flow breccia is broken by several faults and is intruded by bodies of Sands granite and dacite dikes. In the low hills, in an area about 2 by 3 miles that lies 5 to 10 miles north of Sands station, the flow breccia is a dark rock in which fragments of dense dark rock as much as 3 inches long are embedded in a darker, finer grained rock almost glassy in texture. Neither fragments nor the matrix show conspicuous phenocrysts; fragments form about 25 percent of the rock but they only show plainly on weathered surfaces.

In the nearby higher hills, 6 to 8 miles north of Sands, flow breccia forms a belt about 1,000 feet wide and 8,000 feet long. The rocks have the color and texture of those in the area 3 miles south, but they show sporadic alteration to epidote. The rocks are overlain by sandstone and flows regarded as Tertiary in age.

POST-CAMBRIAN AND PRE-TERTIARY INTRUSIVE ROCKS

In this report, pre-Tertiary intrusive rocks are grouped as those that are definitely associated with a late or Laramide orogeny and are widespread in the western half and southeast corner of the quadrangle and those that are not assuredly associated with the Laramide orogeny and may be Jurassic or associated with Nevadan orogeny. The latter rocks are confined to several townships in the southwest corner of the quadrangle, south, north, and east of Sands on the Union Pacific railroad and to the belt about 5 miles long near Mountain Pass on Highway No. 91.

SANDS GRANITE

Except for a few dikes, the intrusive rock north, east, and south of Sands is a granite whose appearance and properties are nearly uniform throughout the area; it is here designated the Sands granite. On fresh fracture, it is a light-gray holocrystalline rock, made up of feldspar, quartz, and minor biotite. It weathers to rounded knobs whose size and distribution are determined by persistent joint systems. The weathered surface is distinctly brownish, owing to a thin coating of desert varnish. Two specimens have been examined in thin section; one (176), from the hill in sec. 24, T. 11 N., R. 11 E., is representative of most of the area; the other (175), from near the contact with the flow breccia in sec. 17, T. 11 N., R. 10 E., is lighter in color than the average rock. Both are equigranular, holocrystalline rocks; the grains in the first specimen range from one eighth to one fourth inch in diameter; those in the second are slightly smaller. The mineral composition of the first specimen was estimated as follows: orthoclase, 60 percent; albite (An_{10}), 10 percent; quartz, 25 percent; muscovite, 2 percent; biotite, 2 percent; titanite, trace. The composition of the second specimen was estimated as follows: orthoclase, 65 percent; oligoclase, 3 percent; quartz, 30 percent; muscovite, 2 percent; and no dark minerals. The contact surfaces of the second rock with the flow breccia are faults and there is no evidence of corrosion of the invaded rock. Near the contact the grains of the granite are distinctly smaller than average and the intrusive relations of the granite are definite. The fragments of the flow breccia are sporadically altered to epidote.

Dikes intrusive in the granite were observed in both areas; one from the eastern locality is a pale brown porphyritic rock. It has phenocrysts of orthoclase and sparse quartz in a dense pale brown groundmass. At the western locality a dike of dacite porphyry that filled a northwest fracture was observed.

The study and mapping of the northern Bristol Mountains, adjacent to the southwest corner of the Ivanpah quadrangle, Gardner (1940, p. 272) recognized a "pink granite" intrusive in diorite and diorite gneiss. Large bodies of similar rock were identified at the northwest end of Newberry Mountain. The composition was estimated as follows: orthoclase, 40 to 45 percent; acid plagioclase, 10 to 25 percent; quartz, 25 to 35 percent; biotite, 0 to 4 percent; apatite, titanite and magnetite, small amounts. These rocks seem to resemble closely the Sands granite. Gardner assumed that they were intruded in Jurassic time.

LARAMIDE OROGENY

STRUCTURAL FEATURES

GENERAL DESCRIPTION

Rocks of pre-Paleozoic and Mesozoic age of this region have been greatly deformed by folding and faulting, notably by thrust faulting. This deformation took place after the youngest rocks of Mesozoic age of the area were deposited and before sediments and volcanic rocks, here designated middle Tertiary in age were laid down. These deformations are interpreted as episodes in that period of orogeny called Laramide.

The name Laramie was first applied to a group of sedimentary rocks in the upper Missouri River basin of Montana and for some years there was great discussion as to whether the contained fossil plants and invertebrates indicated their age to be Late Cretaceous or Tertiary. At that time, it was widely assumed that a single persistent unconformity separated Upper Cretaceous from Tertiary sedimentary rocks and the deformation that preceded the deposition of the younger beds was called Laramide. It is now known that in many parts of the Rocky Mountains and Wasatch Range, deformation of Mesozoic sedimentary rocks indicated by unconformities, took place at several, rather than in a single episode, and that these marked noteworthy epochs of deformation.

In applying the term "Laramide orogeny" to the folding thrust faulting, and, in places, normal faulting in southeastern California and southern Nevada, the writer is following the usage of Spieker (1946): "It would seem more appropriate to restrict the term 'Laramide' to the group of movements that occurred in the latter part of the upper Cretaceous and early part of the Tertiary, certainly not going beyond Eocene time."

The structural features presented in the rocks of the region affected by the Laramide orogeny indicate the following conclusions:

The belt of Laramide thrust faults is limited below (eastward) by a region that shows broad arching and normal faulting and above by a belt of simple structure with minor folds. The belt of thrusts cannot be traced south of Kelso, Wash; southward, the Providence Mountains are underlain by a relatively unfolded block of formations of Paleozoic age.

Throughout the region, the competent beds of Paleozoic and Mesozoic age largely show open folds. Near thrust faults, they have close, overturned folds shown in the Kaibab limestone and higher formations under the Bird Spring thrust and in formations of Paleozoic age under the Keystone thrust. Near each of the major thrusts, incompetent beds (lower part of Goodsprings dolomite, Bird Spring formation, and Moenkopi formation) show close, locally overturned folds. The region therefore, had open folds when thrust faults began to form and local close folds formed both above and below the thrusts as they developed.

The more eastern and lower thrust faults seem to have formed first and they were followed by the next western or higher; the Contact thrust passes under and is therefore older than the next higher Keystone thrust.

Assuming the present surface at about 4,000 feet elevation as a datum, the successively western or higher thrusts brought progressively older (lower) formations up to this datum. Pre-Cambrian rocks first appear westward at this datum in the Mesquite block, on the west slope of Clark Mountain; in the Winters block, pre-Cambrian crystalline rocks are thrust upon formations of early Paleozoic age.

From this, it follows that one net effect of the five major thrust faults was the building of a great arch of rocks which had its greatest thickness over the present positions of the Mesquite and Winters blocks. The known thickness of the sections of Paleozoic and Mesozoic age in the eastern half of the quadrangle is about 13,000 feet, but west of the Ivanpah fault it is thicker, attaining about 20,000 feet in the region east of Kingston Range and more than 30,000 feet in the Nopah Range, 30 miles northwest. As the thickness of the sedimentary section doubtless was increased further by thrust faults, probably the section was 30,000 feet thick or more over the Spring Mountain and Clark Mountain regions. Where, in the central part of the belt of thrusts, crystalline rocks are now exposed at the surface, it seems certain that at least 30,000 feet of rocks have been removed by erosion. Figure 10 has been prepared to show the effect of thrust faulting upon the distribution of rocks of Paleozoic and Mesozoic age.

AGE OF OROGENY

The region under survey does not yield dependable evidence of the time when deformation in this region began and when it ended. The reconnaissance work of Spurr and Rowe in 1900 (1903, p. 229) yielded a record of the stratigraphy of the Spring Mountains but did not recognize the thrust faults that are such an important feature of the area. Longwell (1921, p. 55–58) first recognized in 1919 the impressive thrust faults in the Muddy Mountains and worked in the intervening region (Las Vegas quadrangle) north of the Ivanpah quadrangle intermittently from 1922 to 1941. He demonstrated (1926) that one of the major thrust faults (Keystone) of the Ivanpah quadrangle may be traced as far as the Muddy Mountains and Glendale on Muddy Creek. It is now clear that the belt of thrust faults recognized and mapped from Kelso Wash on the south to Muddy Creek on the north, more than 100 miles, is the outstanding structural feature of this region. Mapping by Hazzard (Hazzard and Crickmay, 1933) in the Providence and nearby ranges, south of the 35th parallel did not record any thrust faults and the region north of Muddy Creek, has not been studied.

The work in the Ivanpah quadrangle shows only that the lowest and oldest thrust fault is younger than the latest rocks of Mesozoic age, the Aztec sandstone and dacite flow breccia (Jurassic? system) and older than the middle Tertiary sedimentary rocks and volcanic rocks. Light is thrown on the age of this orogeny by recent work in the northern Muddy Mountains, by studies of the batholith of southern California, south of the San Gabriel Mountains, and by the present state of knowledge of the orogeny and intrusion in the Sierra Nevada.

On the basis of recent work in the lower Muddy Valley, Nev., (Longwell, 1929; Read and Brown, 1937), Longwell concludes that the Muddy Mountain thrust was formed earlier than the Willow Tank formation of Longwell, (Bear River, Upper Cretaceous series) and that it was "either late in the Jurassic or during the Cretaceous before Bear River Time." Another thrust fault, Glendale, represented by several plates, seems to be younger than the Willow Tank formation of Longwell, and therefore younger than the Muddy Mountains thrust.

Extensive exposures of several varieties of intrusive rocks, called the batholith of southern California by Larsen (1948, p. 182), are interpreted as early Late Cretaceous in age. This determination is based upon observations by Woodford, Harris, and others in northern Lower California where granitic rocks intrude fossil-bearing sedimentary rocks of early Late Cretaceous age and are overlain by rocks of the upper section of the Upper Cretaceous series.

It is the consensus among geologists who have worked

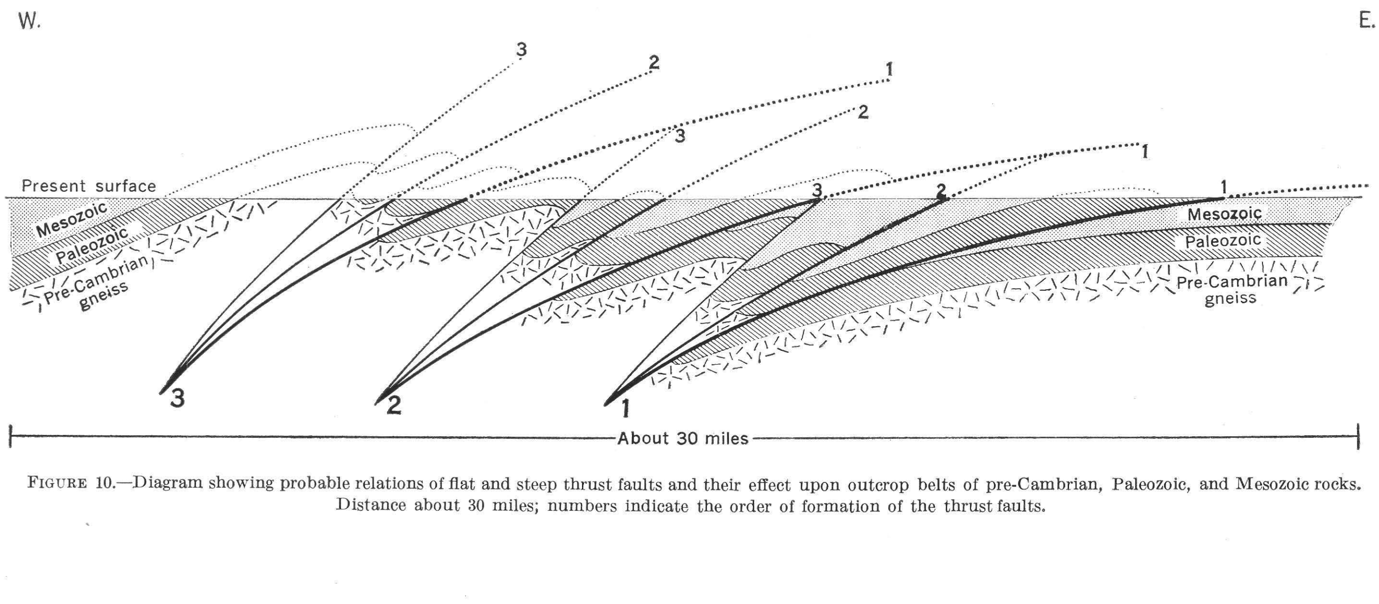

FIGURE 10.—Diagram showing probable relations of flat and steep thrust faults and their effect upon outcrop belts of pre-Cambrian, Paleozoic, and Mesozoic rocks. Distance about 30 miles; numbers indicate the order of formation of the thrust faults.

in the southern Sierra Nevada, the southern end of which lies about 200 miles west of the belt of thrust faults, that the orogeny and succeeding intrusion of granitic rocks began in Late Jurassic time, that is post-Mariposa time, and intrusion may have continued into Early Cretaceous time.

At least one dependable conclusion can be drawn from the available evidence in southern California in a region about 500 miles in diameter, the orogeny and intrusion of the western portion (Sierra Nevada) is distinctly earlier than that of the eastern portion. The intrusions of southernmost California are more closely dated (lower Upper Cretaceous series) than the orogeny of southern Nevada (pre-Bear River).

An attractive hypothesis is that both the earlier deformation and later granitic intrusions appeared first in the southern Sierra Nevada region on the west and moved progressively eastward so that by middle to Late Cretaceous time, they had reached the Spring Mountains. It is too early to affirm that has happened however.

CHRONOLOGY OF EVENTS

Work in the Ivanpah quadrangle confirms the interpretation of the succession of structural and related events in the Goodsprings quadrangle (Hewett, 1931, p. 54). They are summarized below, with the addition of the events recorded in the larger area.

1. Initial folding of the region.
2. Bird Spring overthrust involving minor normal faults.
3. Contact overthrust, followed by Potosi thrust, and Wilson thrust.
4. Keystone overthrust, involving minor folding, followed by Ironside tear fault, and Puelz thrust.
5. Sultan overthrust, followed by Milford thrust. involving minor folding, and Tam O'Shanter tear fault.
6. Mescal thrust.
7. Clark Mountain normal fault.
8. Mesquite overthrust involving minor close folding and minor normal faults.
9. Winters overthrust, involving minor close folding and thrust faulting.
10. Intrusion of Teutonia quartz monzonite and Kingston Range monzonite prophyry.
11. Early normal faults.
12. Dolomitization and other alterations of limestones.
13. Mineralization yielding ore deposits.

DESCRIPTIONS OF FAULT BLOCKS

Obviously, there is much conjecture involved in setting up such a comprehensive interpretation of structural events. There is some conjecture in interpreting the succession of thrust faults from east to west. From a mechanical standpoint, a thrust fault offers a means by which internal compressive stress in rocks is relieved by piling up rocks over the area under stress. At any cross section of such an area, there seems to be a relation between the distance that one block moves over another block and the extent to which the local mass of rock is lifted. If less work is involved in overcoming friction on the fault than in lifting the block by internal deformation or by forming new steeper thrust faults, the upper block will move forward and upward on the older, lower thrust. If, however, the upper block has moved forward to the point where friction absorbs more energy than lifting the block, it will rise. By this method of reasoning, it would appear that in a belt of major thrust fault, the lowest fault is the oldest and the successively higher thrusts are relatively younger.

It is not simple to interpret the age of the Clark Mountain fault. The relations of the rocks in the two sides indicate that it is a normal fault. Undoubtedly it is older than the Mesquite thrust, but it seems to be younger than the Mescal thrust. It can be fairly stated that it preceded the intrusion of the monzonite, for it limits that rock near Barnwell and throughout its course it contains minor ore deposits.

The precise position of the intrusion of the Teutonia quartz monzonite in the chronology of events is uncertain. In the Mescal Range and Ivanpah Mountain area, the monzonite intrudes the Mescal thrust which seems to be a minor rather than a major fault. This, considered with the distribution of metalliferous deposits which lie in and near it, indicates that it was intruded late in the period of thrust faulting, certainly later than the Mesquite thrust and probably later than the Winters thrust. The evidence near the Yellow Pine mine (Hewett, 1931, p. 131–137) indicates that the main sill follows a bedding plane but later minor dikes fill crosscutting fractures (tear faults).

The work in the Ivanpah quadrangle shows that the rocks of Paleozoic and Mesozoic age are folded as far south as Cima and Lanfair Valley and as far west as Shadow Mountains. The degree of folding varies greatly; east of the Bird Spring Range, the beds of late Paleozoic age form a broad anticline, but progressively westward to the hills on the west side of Mesquite Valley and Shadow Mountains, rocks of early Paleozoic age are more complexly folded. By contrast, the rocks of the Paleozoic era of the Providence Mountains are tilted and faulted but not greatly folded. Mapping south and west of the Goodsprings quadrangle shows the presence of at least two more major, and several minor, thrust faults.

For descriptive purposes the region is recognized as made up of a succession of blocks separated by the major thrust faults.

The following table summarizes the outstanding features of the eight blocks separated by thrust faults:

Summary of the features of the blocks bounded by thrust faults

Block	Age of beds at surface	Folding	Faulting
Sloan	Late Paleozoic, early Mesozoic	Broad arch	Few normal.
Bird Spring	Paleozoic and Mesozoic	Slight folds	Several normal.
Contact	Paleozoic and early Mesozoic	Open folds	Minor thrust, many normal.
Keystone	Paleozoic and early Mesozoic	Open folds. Few close overturned folds.	Minor thrust, many normal.
Mesquite northeast of Ivanpah fault.	Paleozoic	Largely homocline	Several normal.
Clark	Paleozoic and Mesozoic	Largely monocline	Several normal.
Mesquite southwest of Ivanpah fault.	Early Paleozoic and Proterozoic	Open and close folds	Minor thrust, several normal.
Winters	Early Paleozoic and Proterozoic	Many close folds, some overturned.	Major thrust, several normal.

SLOAN BLOCK

The Sloan block includes the area that lies northeast of the Bird Spring thrust as far as the mountain northeast of Sloan. On the southeast, it is limited by the overlapping, middle Tertiary volcanic rocks which are not affected by any of the deformation described below.

This area is an elongate dome, shown by the outcrops of rocks of late Paleozoic age, and it is broken by several normal faults, two of which limit a dropped block or graben (section *M–M'*). The dip slip on the southwestern fault is about 1,000 feet and that on the northeastern fault is about 1,800 feet. The northeastern fault passes through the low ground southwest of the limestone quarry at Sloan, where it separates beds near the base of the Sultan limestone on the northeast from beds several hundred feet above the base of the Bird Spring formation on the southwest. All exposed beds of the Sultan and Monte Cristo limestones, except the Crystal Pass limestone member, are completely altered to dolomite northeast of the fault. By contrast, there is little if any dolomitization of the limestones of the Bird Spring formation southwest of the fault.

BIRD SPRING BLOCK

As stated in the Goodsprings report (p. 44), the base of the Bird Spring block is the Bird Spring thrust along the east front of the Bird Spring Range, and the upper surface is the Contact thrust which crops out in the low hills east of Spring Mountains.

The Bird Spring thrust crops out conspicuously at several localities both north and southwest of Bird Spring, where it separates red sandstones of the Supai formation below from the Monte Cristo limestone and Bird Spring formation above. It appears to dip about 25° to the west. About 4 miles north of Bird Spring, it passes under the wash that drains northeast to Las Vegas Valley. It does not crop out south of Bird Spring, but its existence under the wash is indicated by the nearby outcropping rocks. The oldest beds exposed on the southern part of the east escarpment of Bird Spring Range are thinbedded dolomites of the Goodsprings dolomite, that are sharply folded along northwest-trending axes. The ridge a mile east is made up of the lower member of the Kaibab limestone that dips 3° W. The relations require the assumption that a fault exists under the wash. It is not clear whether the Bird Spring thrust extends as far south as Sheep Mountain, for the mapping southwest of Sheep Mountain does not require or even permit the assumption that a thrust fault of any magnitude is present.

The long ridge 2 miles northwest of Bird Spring is made up of the overturned lower member of the Kaibab limestone which strikes N. 20° E. and dips 35° NW. A mile north of this ridge the Bird Spring thrust crops out, separating westward-dipping beds of the Supai formation below from vertical limestones of the Bird Spring formation above (see section *M–M'*). The areal relations indicate, therefore, that the section including the Supai formation, Kaibab limestone, Moenkopi formation, and Chinle formation is folded into an overturned syncline under the Bird Spring thrust; the syncline roughly coincides with the broad valley east of the Bird Spring Range. The beds of the overriding block of Bird Spring formation are also overturned at the thrust. Most of the high part of the Range is underlain by nearly horizontal beds of the Bird Spring formation, but along the west escarpment these beds dip gently from 15° to 20° under Goodsprings Valley. The outcrops surrounding Goodsprings Valley do not require the presence of a normal fault of noteworthy displacement under the wash.

The fault pattern in the south half of Bird Spring Range is complex. The most extensive, the Cottonwood fault, traced from the mountains 10 miles northwest, can be traced through the range but does not coincide with a depression or valley. The mapping in the vicinity of Borax, Nev., in Ivanpah Valley 10 miles southeast, indicates the presence of a normal fault that may be correlated with the Cottonwood fault. Throughout its known extent the fault dips steeply west, but the displacement differs from place to place. Throughout the Bird Spring Range the displacement is normal, with the west side having dropped 500 to 1,000 feet. In the Spring Mountains, however, near Mountain Springs Pass north of latitude 36°, displacement of the Keystone thrust on the Cottonwood fault is normal, but below the thrust where beds of the Sultan limestone abut against Aztec sandstone the displacement is reversed. From these relations it would appear that the Cottonwood fault was once a reverse fault (formed before the Keystone thrust was formed) along which new movement in the opposite direction has taken place in relatively recent time, perhaps in Pleistocene time.

The Cottonwood fault is one of the four extensive normal faults that actually extend across the present crest of Spring Mountains; the others are a small fault in Devil Canyon, State Line fault, and Ivanpah fault. Most of the other normal faults, of which there are many, lie along the eastern slope of Spring Mountains and the north end of McCullough Range, and in general, the displacements increase toward Ivanpah Valley. They show evidence of recent movement, certainly since Miocene time.

Dolomitization of limestone is noteworthy along the Cottonwood fault and the Bird Spring thrust. Much of the limestone of the Bird Spring formation north of Cottonwood fault is dolomitized.

At least three north-trending normal faults in the southern half of the Bird Spring Range are offset and are thus later than both the northwest-trending normal faults and the Bird Spring thrust.

CONTACT BLOCK

The Contact block is limited below by the Contact thrust which is well exposed along the east slope of Spring Mountains and above by the Keystone thrust which was traced for many miles in the Goodsprings quadrangle, first, at the north, along the east slope of Spring Mountain, then south of Mountain Springs Pass along the west slope, and finally south of Columbia Pass, along the east slope again, a total distance of about 25 miles. According to Longwell (written communication), the Keystone fault has been traced northward to Las Vegas Wash. As the Contact thrust is not known north of Cottonwood fault where the Keystone thrust is exposed and its southern extension is overridden by the Keystone thrust near Columbia Pass, it seems to be definitely older than the Keystone thrust.

For 1 mile north of Cottonwood Pass and 3 miles south of it, the Contact thrust is well exposed where beds of the Monte Cristo limestone and Bird Spring formation are thrust upon the Aztec sandstone. For much of this distance the overlying beds are folded into pronounced anticlines but for the most part the Aztec sandstone dips gently under the thrust. The thrust dips from 10° to 30° westward and between the Ninetynine and Contact mines it is broken by normal faults that trend northwest.

Where it crosses the Spring Mountains, the Keystone thrust is readily traced, but in the low hills on the west slope the trace is covered with wash.

Within the area of the Contact block, there are two extensive thrust faults, Potosi and Wilson, and several minor thrusts. For its areal extent this block contains more folds than any other thrust block of this region. The anticlines are assymmetrical and the axial planes dip uniformly west and southwest. The folds are open rather than closely appressed and only rarely are the beds on the steep eastern limbs overturned.

Normal faults are confined to small areas at the northern and southern ends of the block. Only the Cottonwood and Ninetynine faults have noteworthy displacements.

KEYSTONE BLOCK

The Keystone block is limited below by the Keystone thrust and above by the Mesquite thrust. There seems to be no uncertainty in correlating the several outcropping parts of the Keystone thrust from Mountain Springs Pass in the Las Vegas quadrangle as far south as the mouth of the Devil Canyon, or about 25 miles. By contrast, the correlation of the major thrust faults south of the State Line Pass with those north of it involves considerable conjecture. There are only two major thrust faults southwest of Mesquite Valley—the Winters thrust which follows the valley to Winters Pass and the Mesquite thrust which extends southeast through Mesquite Pass about 20 miles to the Standard No. 1 mine. The latter is correlated with the thrust fault which separates a block of rocks of early Paleozoic age above the Moenkopi formation and Kiabab limestone below, in the hills at the south end of Mesquite Valley. Under this interpretation, the Keystone thrust dies out under the wash of the northern part of Ivanpah Valley. As the Winters thrust separates two blocks of rocks of early Paleozoic age, it may not be as extensive as the Mesquite thrust.

In the northern part of the Goodsprings quadrangle for a distance of 3 miles, the Keystone thrust separates highly folded Goodsprings dolomite above from Aztec sandstone, below. The differences in strike and dip of the Keystone thrust and of the underlying Aztec sandstone are so slight that the upper block must have been pushed eastward over an erosion surface cut on that sandstone. Traced southwest and south as far as Keystone Wash, about 13 miles, the Keystone thrust lies within a belt of Goodsprings dolomite that has the features of an overturned anticline. East of the Ironside fault, a tear fault, the Keystone thrust separates Goodsprings dolomite above from the Bird Spring and Moenkopi formations below for about 9 miles, or until it disappears under the Wash east of the Lincoln mine (section *K–K′*). A possible segment of this thrust crops out for a mile at the mouth of Devil Canyon. In the area north of Mountain Springs Pass (Las Vegas quadrangle), the thrust dips about 8° W.; then it gradually steepens to nearly vertical on the west side of the range; finally, east of Keystone Wash, the dip flattens until in the hills east of Crystal Pass it is only 20°. As it has been traced by Longwell northward to Las Vegas Wash, its known strike length is about 45 miles, greater than any other fault in this region.

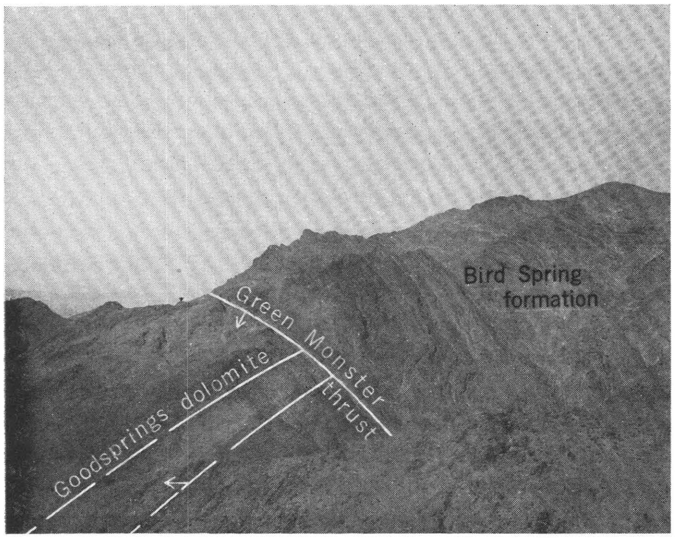

FIGURE 11.—View northwest toward Green Monster thrust fault, near Green Monster mine, Nevada.

Within the Keystone block, as thus defined, there are many less extensive thrust faults. The Green Monster (fig. 11) thrust lies in a lobe that extends westward from Spring Mountains between Potosi and Keystone Washes; it may extend northwest under the wash of Pahrump Valley but it does not extend southeast beyond the Ironside fault. For most of its course the Green Monster thrust separates beds of the Bird Spring formation thrown into an overturned syncline below, from steeply dipping beds of the Goodsprings dolomite above (section *J–J′*, fig. 12). It dips steeply, S. 68°–70° W. and for much of its course is marked by a zone of breccia that locally is as much as 150 feet thick. The limestones of the Bird Spring formation are altered sporadically to dolomite nearby. At several places in this area, detailed structural features in the thin limestones of the Bird Spring formation reveal the manner by which the beds are deformed and thickened near minor thrust faults (figs. 11, 13, 14).

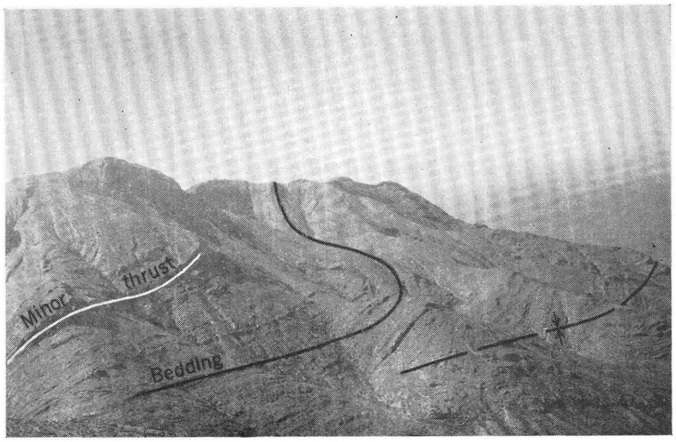

FIGURE 12.—View N. 80° W. toward hills north of Green Monster mine, Nevada. All beds shown are part of Bird Spring formation.

The Sultan and Milford thrusts are minor faults like the Green Monster and, like it, they end southeast against tear faults (section *K–K′*). Further southeast, the present displacement of the State Line fault indicates a normal fault but the local features suggest that

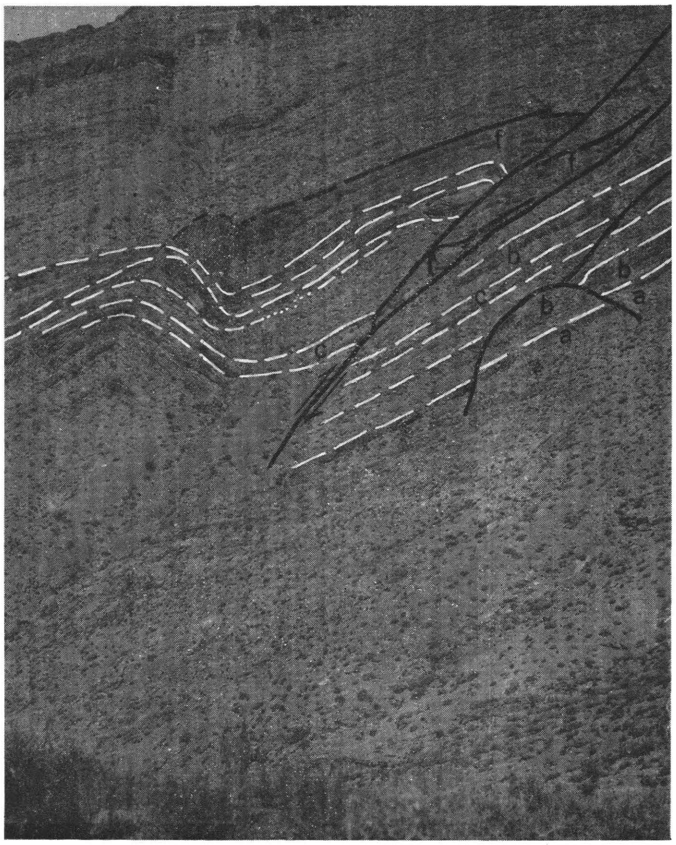

FIGURE 13.—Ridge in sec. 5, T. 24 S., R. 57 E., showing open folds and minor thrust faults in Bird Spring formation, Nevada.

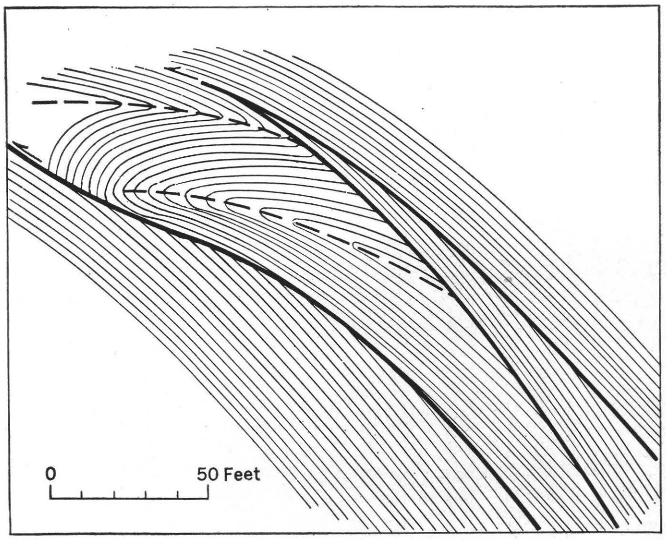

FIGURE 14.—Detailed structural features in limestones of the Bird Spring formation, sec. 9, T. 24 S., R. 57 E., Nevada.

it was originally a steep thrust fault along which later movement in the reverse direction has exceeded the original displacement (fig. 15). In State Line Pass, the fault strikes N. 55° W. and dips about 70° SW (section *L–L′*). It is marked by 20 to 30 feet of breccia and sporadic dolomitization of the nearby limestones. On the southwest side, beds of the Bird Spring formation which farther south strike northeast and dip 25° NW., are turned abruptly downward so as to strike northwest and dip 80° NE. toward the fault. On the northeast side of the fault, almost the entire Monte Cristo limestone overlain by several hundred feet of Bird Spring formation is exposed along the escarpment under the fault; these beds strike northwest and dip gently northeast. In spite of the present displacement, the attitude of the beds south of the fault and the presence of dolomitization indicate that it was originally a thrust fault.

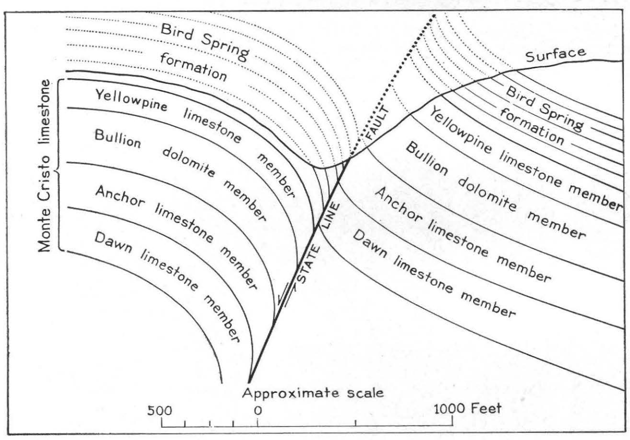

FIGURE 15.—Diagrammatic section N. 45° E. through State Line Pass, showing recent normal movement on earlier steep thrust fault.

The fault next southwest of the State Line fault is a steep thrust that strikes N. 35° W. and dips 70° SW (section *L–L′*). On the southwest side, the high ridge (4,900 feet) is capped by 300 feet of the Sultan limestone which strikes N. 10°–20° W. and dips 5° W. Near the fault, these beds turn down and dip abruptly toward the fault. On the northeast side of the fault, the ridge (4,500 feet) is capped by several hundred feet of limestone of the Bird Spring formation below which, on the southeast end of the ridge, the entire Monte Cristo limestone crops out (fig. 16). The Anchor limestone member shows sporadic dolomitization. The dip displacement along this fault appears to be about 1,200 feet. If there was later displacement in the opposite direction here, as at the State Line fault, it cannot be determined.

The next large fault southwest of that just described strikes N. 30° W. and dips about 60° SW.; the breccia zone is about 50 feet thick. The beds at the surface on the southwest side are undolomitized limestones of the upper part of the Bird Spring formation which strike N. 35° W. and dip 35° SW.; the dip is reversed close to the fault. As these beds abut against the upper beds of the Goodsprings dolomite, the dip displacement must be 2,500 feet or more. The lack of dolomitization of the limestones of the Bird Spring formation throws some doubt upon the possibility that the fault was once a thrust along which there has been later normal displacement.

Within the Keystone block, normal faults are localized in a few areas rather than distributed widely. There are a few in the hills west of Wilson Pass that are made up of Goodsprings dolomite. They lie in the angle between the Potosi thrust and the Ironside tear fault, and do not seem to have much regional significance.

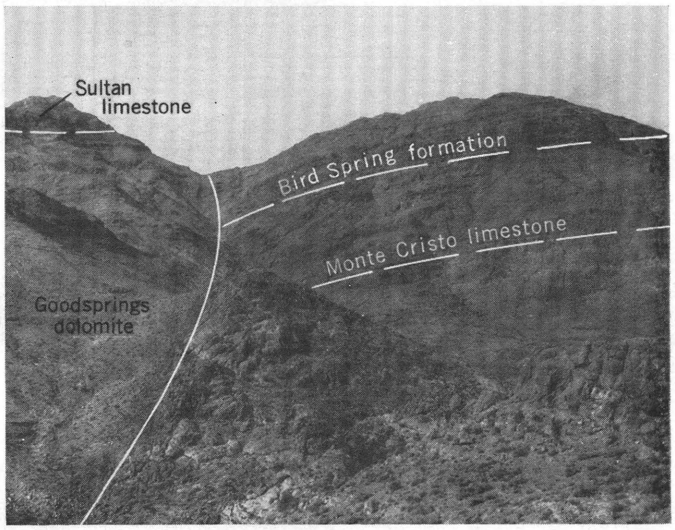

FIGURE 16.—View N. 35° W. toward gap in ridge 1 mile south of State Line Pass, showing steep thrust fault.

The greatest concentration of normal faults in the entire region lies along the east slope of Spring Mountains, between Porter Wash and Devil Canyon. They were shown in detail in fig. 17 of the Goodsprings report (Hewett, 1931, p. 50). In this area, there are several normal faults of northwest strike and southwest dip that contain zinc deposits (Star mine) and are therefore premineral (section *K–K′*). These are displaced by numerous faults of the same strike but northeast dip that are post-mineral. As none of them displace the flows of Table Mountain, it is assumed that they are pre-Miocene and probably were formed late in Laramide orogeny.

There are three normal faults whose displacements are less than 200 feet in the high part of Spring Mountain several miles south of Devil Peak.

Viewed broadly, the Keystone block contains only a few areas of highly folded beds and they are sporadically distributed. At the north, in the vicinity of Mountain Springs Pass, the Goodsprings dolomite contains several asymmetric open anticlines near the Keystone thrust. Farther south, the only recumbent fold in the entire block is found in beds of Bird Spring formation under the Green Monster thrust (fig. 12). Eastward from the Ironside fault, the beds from the Monte Cristo limestone to the lower part of the Goodsprings dolomite are folded into a single asymmetric anticline and syncline that extend eastward beyond Columbia Pass.

Except for a few short folds largely north of Devil Peak and near Bonanza Wash, the entire block of the Spring Mountains from Columbia Pass to, and slightly beyond State Line Pass, is almost a simple homocline, broken, however, by a few thrust and normal faults. Close folds and recumbent folds, except as stated above, are conspicuously absent.

MESQUITE BLOCK NORTHEAST OF IVANPAH FAULT

Mesquite block northeast of Ivanpah fault is limited below by the Mesquite thrust which may be readily traced around the hills about 5 miles southwest of State Line Pass. As there is some uncertainty about the correlation of the thrust faults north and south of Ivanpah fault, and the most dependable correlation beyond the fault is that of the parts of the Mesquite thrust, new names will be applied to the blocks below it, southwest of Ivanpah fault. The upper limit of the Mesquite block is the Winters thrust which follows Winters Pass.

Mesquite thrust is readily traced for most of its course north of Ivanpah fault. On the north side of the hills at the south end of Mesquite Valley, the thrust separates beds of the Moenkopi formation below, from beds that range from the Goodsprings dolomite to the Bird Spring formation above (section *L–L′*). On the north side of the hills the beds of the Moenkopi formation, thin brownish limestones and reddish and greenish shales, strike N. 30° W. and dip 15°–25° SW. In these hills the beds of the overlying block, even though broken by at least 5 mappable normal faults, strike generally north to northwest and dip 30°–40° NW. The beds above the Mesquite thrust are thoroughly brecciated as much as 500 feet above it, and none of the faults in the overlying block break the Mesquite thrust; they must have been formed before the block reached its present position.

On the west side of these hills, the Mesquite thrust separates Kaibab limestone below from Goodsprings dolomite that strikes east and dips 30°–40° N. above. There are outcrops of Moenkopi formation low on the east front of the hills and several miles southeast a low ridge of Moenkopi limestone rises above the wash. No measurement could be made, but it is clear that the Mesquite thrust dips about 45° NE. under the hills. Broadly, both the Mesquite thrust and the overlying beds of Paleozoic age are warped into a trough that plunges northwest under Mesquite Valley. The cause of this warping is apparent when the features a short distance west and northwest of the outcrop of Kaibab limestone are considered.

Beds of Kaibab limestone form a narrow ridge several thousand feet long and as much as 300 feet wide that lies between the limestones of early Paleozoic age on the northeast and sheared granite gneiss on the southwest. The ridge is bounded on the southwest by a well-defined shear zone that strikes N. 43° W. and dips 60° NE.; this is the Ivanpah fault that is readily traced from the Mesquite Pass road southeast for 5 miles until it passes into the wash of Ivanpah Valley. Clearly, it is younger than the Mesquite thrust and the displacement is normal.

CLARK MOUNTAIN BLOCK

Clark Mountain block southwest of Ivanpah fault is limited by the Clark Mountain normal fault below and the Mesquite thrust above. The Clark Mountain fault can be traced by intermittent but good exposures from the road through Mesquite Pass on the north, southward past the Colosseum mine and east front of Clark Mountain and Kokoweef Peak to Ivanpah Valley, a distance of about 20 miles. It is correlated with a fault near Barnwell on the southeast end of Ivanpah Valley but it is not identified beyond Cedar Canyon fault which undoubtedly displaces it.

At the north end, the Clark Mountain fault is identified on the east side of a northward draining ravine in sec. 5, T. 27S., R. 13 E., where it is marked by 10 feet of sheared gneissic granite, slightly iron stained, that strikes about N. 20° W. and dips 35° SW. (sections

H–H', *I–I'*, *L–L'*). This sheared granite merges downward with the normal gray gneissic granite of the area. The sheared granite is overlain by: 1 foot of brecciated dolomite; 5 feet of gray dolomite; 2 to 3 feet of sheared cherty limestone; 10 feet of chert containing lenses of limestones; 100+ feet of brecciated dolomite cemented by fine-grained silica. Within the next mile north, this dolomitic material is underlain by several hundred feet of quartzite like the normal Prospect Mountain quartzite of this region.

The fault is well exposed in ravines as much as a mile north and a mile south of the Colosseum mine, but its presence is indicated only by the zone of sheared granite at the base of the section of Cambrian age. The variable thickness of gravelly quartzite, shale, and thin beds of dolomite under the main body of Goodsprings dolomite indicate that in plan the fault weaves through a stratigraphic range of 1,200 feet below the base of the Goodsprings dolomite. About 2,000 feet south of the Colosseum mine the shear zone is overlain by 200 feet of gravelly quartzite and 1,000 feet of thin-bedded quartzite, shale, and thin dolomite. The strike is N. 30° W. and the dip 35° SW. A sill of fine-grained rhyolite extends for about 2,500 feet in the quartzite section near the fault. This rock closely resembles that explored by the workings of the Colosseum mine. Both this mine and a number of other prospects explore deposits of gold-bearing material not far from the Clark Mountain fault. The sill and mineralization indicate that the fault was formed before the mineralization.

Southeast of Clark Mountain, the fault is well exposed on the east slopes of three hills at the east end of Mohawk Hill (sections *H–H'*, *I–I'*). Here, the fault is a simple smooth surface that, in plan, weaves throughout a stratigraphic range of several hundred feet in the lower part of the Goodsprings dolomite. The strike is N. 10° W. and the dip 60° W. None of the quartzite, shale, and thin dolomite beds near the Colosseum mine is present here.

For a mile northwest and a mile southeast of Kokoweef Peak, the fault separates sheared granite gneiss on the northeast from the Goodspring dolomite on the southwest. The strike is N. 27° W. and the dip 60° SW. Within this distance several prospects both in the sheared granite and dolomite explore sporadic copper minerals.

On the southeast side of Ivanpah Valley near Barnwell, a fault separates the pre-Cambrian gneiss on the northeast from Teutonia quartz monzonite that intrudes the section of Cambrian age. About 500 feet southeast of Slaughterhouse Spring, a fault that strikes N. 55° W. and dips 65° SW. separates the gneissic granite and diorite on the northeast from altered limestone on the southwest. Several shallow shafts (Copper King No. 2) explore sporadic copper minerals in the fault zone.

Finally, about a mile west of Barnwell, several shafts explore a shear zone that separates contorted diorite gneiss on the northeast from altered limestone on the southwest (section *Q–Q'*). The shear zone strikes N. 15° W. and dips 52° SW. Projected southeastward, the fault would meet the Cedar Canyon fault under the wash of Lanfair Valley. Like the Clark Mountain fault northwest of Ivanpah Valley, this fault zone shows sporadic mineralization and is therefore premineral.

The Clark Mountain fault appears to be normal but it cuts off and is therefore younger than the Mescal thrust; on the other hand at the south end of Mesquite Valley it appears to be overlain by the Mesquite thrust and is therefore older than it. As it is mineralized at many places, it is probably one of the features of the Laramide orogeny.

Within the Clark Mountain block, the beds dip relatively uniformly at low angles westward and are broken by only a few persistent faults. At the northwest end of the block there are four faults that strike northeast and dip steeply southeast; all are normal and each displaces the Mesquite thrust a few hundred feet. It should be noted that the traces of these faults are broad arcs, concave southeastward. This accords with the broad trend of the beds in this area, as well as with the trend of the Clark Mountain fault and Mesquite thrust. The same is true of the trace of the Winters thrust. The curvature of these normal faults, beds, and thrust faults indicates that the present depression of Mesquite Valley coincides with a recent downwarp. The downwarp is also indicated by the form of the Mesquite thrust northeast of the Ivanpah fault.

Within this block lies the old mining district of Ivanpah (p. 129), in which an impressive record of production was made by four mines between 1875 and 1885. Throughout the district, the country rock is the Goodsprings dolomite, which strikes northwest and dips 25° to 40° SW. Most of the explored veins strike northwest and dip steeply northeast. They appear to be faults along which the northeast sides dropped a short distance.

The Mescal thrust is well exposed on the east end of Mescal Range, 2 miles south of Mountain Pass. For nearly 2 miles, beds in the lower part of the Goodsprings dolomite rest upon the flow-breccia of late Mesozoic age, which in turn rests upon the Aztec sandstone (p. 48). It is along the southern part of this thrust that the wedge of Teutonia quartz monzonite is intruded. The distribution of the formation units north and south of the wash that drains west from Kokoweef

Peak seems to require the assumption that the Mescal thrust is either cut off by or merges with the Mesquite thrust. On the other hand, there seems to be no doubt that the Mescal thrust terminates northward against the Clark Mountain normal fault and is therefore older than that fault. The place of the Clark Mountain fault in the middle of the epoch of Laramide thrust faults seems to be established.

MESQUITE BLOCK SOUTHWEST OF IVANPAH FAULT

Mesquite block, southwest of the Ivanpah fault is limited by the Mesquite thrust fault below and by the Winters thrust above. The Mesquite thrust is indicated by the relations of the beds along the west slope of the hills that lie north of Mesquite Pass. For several miles north of the pass, beds of Prospect Mountain quartzite that trend northeast to north (hill 5008 feet) end abruptly eastward against the Monte Cristo limestone, and the Bird Spring formation, which strike north and dip as much as 30° west. The indicated fault strikes generally north and dips about 35° W., but traced northward it extends across the main ridge a mile north of hill 4,960 feet. Along the east front of the main ridge, facing Mesquite Valley, there are four low spurs (only two shown on the topographic map) which are made up of Goodsprings dolomite that strikes northeast to east and dips 30° northwest to north. Westward, these beds of the Goodsprings dolomite abut abruptly against beds of the Bird Spring formation. The indicated fault dips northeast and appears to be the extension of the Mesquite thrust. Where next seen in the low hills northeast of Ivanpah fault it separates the Kaibab limestone on the southwest from the Monte Cristo limestone on the northeast.

This interpretation indicates that the Ivanpah fault does not extend far north of the road through Mesquite Pass. Northwest of the road, the normal fault is replaced by the warp in the Mesquite thrust.

On the high parts of the north and south slopes of Clark Mountain the Mesquite thrust has not been traced but its existence is indicated by the local areal geology (section *H–H′*). Older beds on the west—Prospect Mountain quartzite, Pioche shale, and Goodsprings dolomite—are thrust upon formations of late Paleozoic age as high as the Bird Springs formation that form the summit of Clark Mountain.

The Mesquite thrust can be identified on Mohawk Hill, near the center of which Goodsprings dolomite, which strikes northwest and dips 35° SW., is thrust upon the Valentine limestone member of the Sultan limestone, which strikes northeast and dips 15° NW. The same conditions are found in the hills north of Mescal Range. On this range, however, the outcrops reveal that the overthrust plate is warped into a pronounced anticline.

Where last found southward, in the ridge west of Standard No. 1 mine, the fault separates the westward-dipping overturned section of Cambrian sedimentary rocks on the west from westward-dipping limestones 500 feet above the base of the Bird Spring formation on the east. The Goodsprings dolomite above the fault is much broken and is cemented by white calcite. The beds under the thrust are broken and dolomitized.

As stated earlier (p. 28) the thickness of the beds under the Goodsprings dolomite, Prospect Mountain quartzite, and Pioche shale is much greater in the Mesquite block than in the blocks which underlie it. This great difference in thickness of the quartzite-shale units probably indicates the great horizontal distance that the block above the Mesquite thrust has moved eastward with reference to the block below it. There is no way of estimating this distance but it must be more than 5 miles and may be 10 miles or more. Likewise, the beds of the Mesquite block, the Prospect Mountain quartzite, and Pioche shale, are more intricately folded than they are farther east. These folds are well shown on the north slope of Clark Mountain and hills to the west. In unsurveyed sec. 17, T. 17 N., R. 13 E., the beds near the base of the Prospect Mountain quartzite show complicated close folds (fig. 17). Near the Mammoth copper mine (p. 136, fig. 18 no. 62), in sec. 14, T. 17 N., R. 12 E., granite gneiss is thrust upon Noonday dolomite (not mapped on pl. 1) and Prospect Mountain quartzite which show complicated folding (fig. 18, p. 60). Farther south along the west slope of Clark Mountain in about unsurveyed sec. 29, T. 17 N., R. 13 E., beds in the middle of the

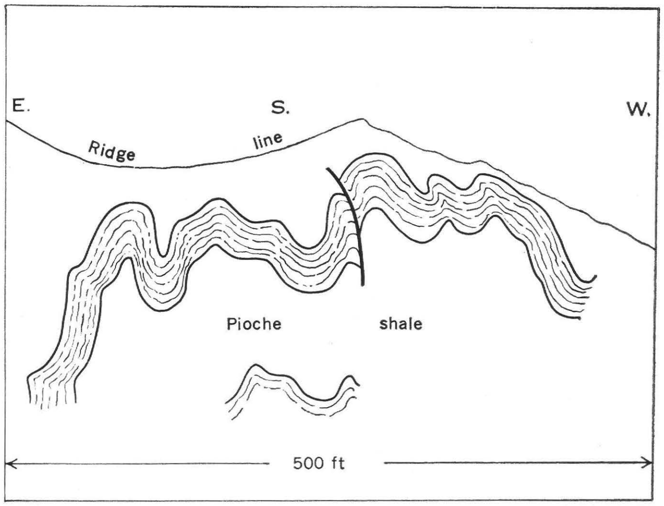

FIGURE 17.—Folds in uppermost beds of Prospect Mountain quartzite on the north slope of Clark Mountain, Calif.

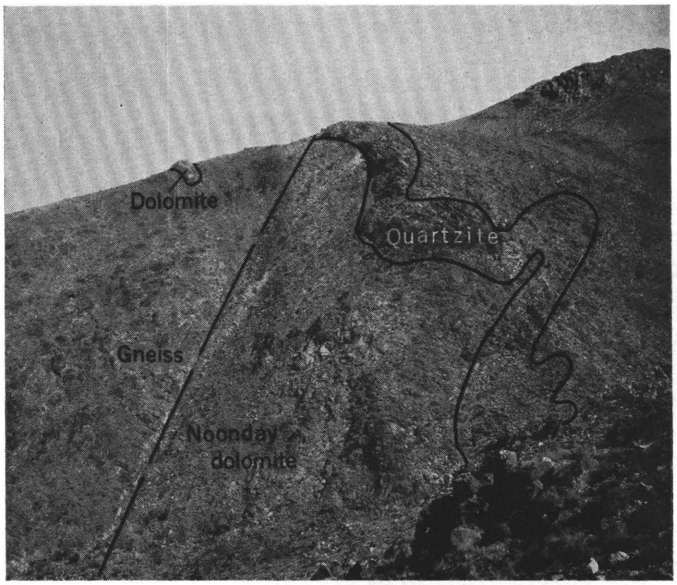

FIGURE 18.—View N. 45° E. toward thrust fault and folds on northwest slope of Clark Mountain, Calif.

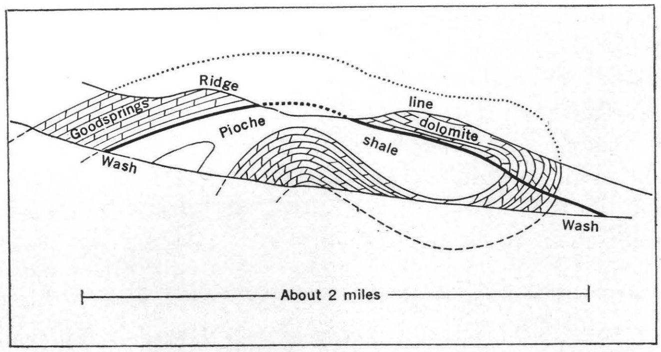

FIGURE 19.—Sketch from photograph showing recumbent fold in Goodsprings dolomite, east of Winters Pass, southwest of Mesquite Valley.

Goodsprings dolomite have small overturned folds; in these, the beds on the steep limb are much thicker than they are on the flat limb (fig. 7).

At the north end of the Mesquite block there are complicated folds and minor thrust faults that cannot be accurately shown on the geologic map. The mapping shows that the hills east of the Winters thrust are underlain by a large plate of Goodsprings dolomite warped into a plunging anticline. Actually, exposures in a small park, probably in secs. 11 and 14, T. 18 N., R. 12 E., indicate that this plate is the upper limb of a recumbent anticline (fig. 19). Local exposures indicate that the upper limb has moved forward along a minor thrust, over the lower limb (fig. 20). The Mesquite block is practically unaffected by normal faults.

WINTERS BLOCK

Winters block is limited by the Winters thrust below, and as no Laramie thrust faults of great extent have been identified in the region that lies northwest of the Winters thrust, it includes all of that area of pre-Tertiary rocks which lies west and northwest of Winters Pass. There is good evidence at many localities in this area that the late Tertiary thrust blocks contained large masses of sedimentary rocks of early Paleozoic and pre-Paleozoic age which were folded and faulted during the Laramide deformation.

The Winters thrust is not exposed but must be assumed because of the attitude and distribution of the rocks on both sides of the ravine leading to Winters Pass (section *G–G′*). For a distance of at least 4 miles, this ravine separates a block on the northwest containing granite gneiss overlain by nearly 7,000 feet of sedimentary rocks of early Paleozoic age that strike generally northwest and dip northeast, from a block on the southeast side that is largely Goodsprings dolomite that strikes northeast and east and dips northwest and north. As the ravine follows a curved course, concave southeast, it is probable that the trace of the thrust is curved and that it conforms to the attitude of the Mesquite thrust and normal faults a few miles southeast and, therefore, has been warped during the recent sinking of Mesquite Valley. Some of the faults in the eastern foothills of the Kingston Range precede the intrusion of the Kingstone Range monzonite porphyry and therefore probably belong to the Laramide orogeny. The age of others is less apparent. Some seem to be related to the orogeny of late Tertiary age.

Of the four prominent spurs that lie along the southwest side of Mesquite Valley, northeast of Winters thrust, three have complicated folds and faults. Section *G–G′* (pl. 1) is drawn along a line N. 49° E. that passes through the first spur north of Winters Pass. The lowest four formations of Paleozoic age (Noonday dolomite, Prospect Mountain quartzite,

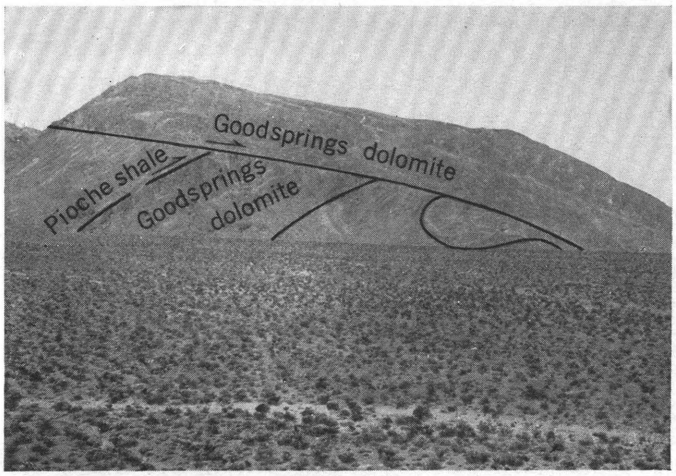

FIGURE 20.—View N. 50° W. toward ridge west of Mesquite Valley, showing block of Goodsprings dolomite thrust across folded Goodsprings dolomite and Pioche shale, Nevada.

Pioche shale, and Goodsprings dolomite) rest on pre-Cambrian gneiss and dip conformably northeast as far as the last saddle in the ridge west of Cub Lee Spring. Abruptly at the saddle, the beds of Goodsprings dolomite dipping northeast, rest upon similar beds dipping southwest. On the ridge east of the low saddle similar beds dip northeast again forming an anticline under the thrust fault.

The second spur, south of the road from Ripley to Horse Spring, is a simple homocline of Noonday dolomite and Prospect Mountain quartzite, which strike northwest and dip northeast at 30° to 35°.

The third spur, west of benchmark 2,682, has complicated folds and thrust faults (section *C–C′*, pl. 1). Beginning at the hill (5,200 feet) a mile north of the Horse Spring road, the ridge that extends northeast to Mesquite Valley exposes beds of early Paleozoic age from the base of the Noonday dolomite through

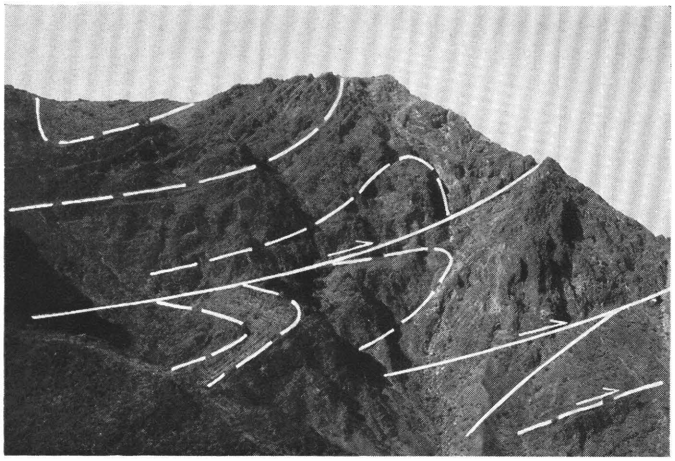

FIGURE 21.—View S. 65° W. toward low hill west of Mesquite Valley, showing folds and flat thrust faults in Goodsprings dolomite.

the Prospect Mountain quartzite and Pioche shale to the Goodsprings dolomite, which forms the high point on the spur (4,300) adjacent to Mesquite Valley. This entire section, however, has been thrust upon an anticline in Goodsprings dolomite. There is a resemblance, therefore, to the structural situation on the first spur north of Winters Pass. The details of some of the complicated structural features in this spur are well shown in figure 21, which shows the south side of the minor spur 2 miles due west of benchmark 2,682. All beds shown are parts of the Goodsprings dolomite. Two minor thrust faults are visible, one separating close folds in dolomite from a recumbent fold.

The fourth spur of the group, 2 miles southeast of benchmark 2,846, shows two asymmetric anticlines separated by a close syncline; the axes trend northwest and the axial planes dip steeply southwest.

KINGSTON RANGE AND SHADOW MOUNTAINS

Except in the large area that lies north and northeast of Kingston Range, formations of Paleozoic age are represented by isolated blocks of the Kingston thrust plate. Some are as much as 4 miles long and 2 miles wide (Shadow Mountain and the Shadow Mountains). With several exceptions, the structure of these blocks is simple. Within the Kingston Range area, itself a part of the Kingston thrust plate, the beds of the Pahrump series and formations of early Paleozoic age dip uniformly north and northeast away from the intrusive mass of Kingston Range monzonite porphyry (section *A–A′*). Similarly, in the smaller blocks of the Kingston thrust plate, the beds, largely belonging to the Goodsprings formation, dip gently northeast. Some blocks show the evidence of deformation; generally they are brecciated and show gliding surfaces near the base. One block culminating in the 4,500 foot hill, 4 miles southwest of Winters Pass and 4 miles east of benchmark 3,318, is made up of two plates of Goodsprings dolomite. One of the exceptions to the pattern of structural simplicity in this area is found in the 3,900 foot hill at the south end of Shadow Mountains, through which a cross section is presented in section B, fig. 2. Here, the Noonday dolomite and overlying lower part of the Prospect Mountain quartzite are folded into an overturned closely appressed syncline. The feature is too small to show on sec. *E–E′*, pl. 1.

INTRUSIVE ROCKS

TEUTONIA QUARTZ MONZONITE

The name Teutonia quartz monzonite is proposed for several large bodies of intrusive rock that crop out in a broad belt extending across the south half of the quadrangle and exceeding 250 square miles in area. If the thin cover of alluvium and Recent basalt flows were removed, the area of outcrop would probably exceed 500 square miles. It is named for Teutonia Peak where it is typical. Within the mapped area, several types of quartz monzonite are recognized but there is one type that persists widely, and the others do not depart greatly from it in mineralogy, texture, and chemical composition. In a few places, the boundaries of the types may be identified and traced locally and conclusions drawn concerning relative ages of the bodies. No features of the outcropping bodies have been recognized, however, which throw doubt on the idea that the period of intrusion was brief, and that in the process of intrusion the several bodies behaved as one single mass. The several types of quartz monzonite are treated as a single unit called Teutonia quartz monzonite, and are referred to in this report as quartz monzonite for simplicity.

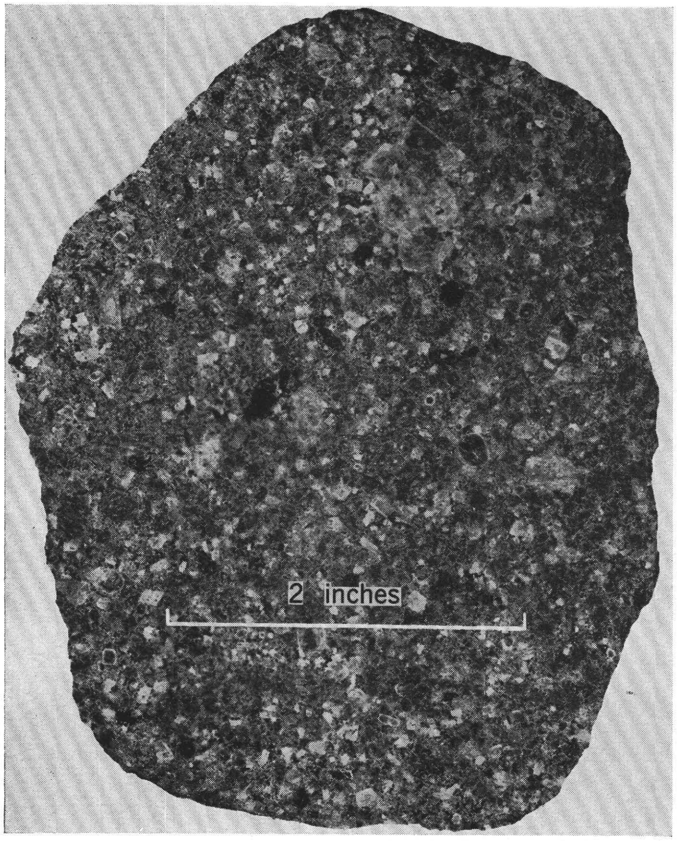

FIGURE 22.—Photograph of a specimen of Kingston monzonite porphyry, Kingston Range, Calif.

A porphyritic variety of the typical monzonite forms the core of the Kingston Range (specimen 14, fig. 22), and the sill near the Yellow Pine mine near Goodsprings (Hewett, 1931, p. 36–38) closely resembles it. In addition, the large bodies of monzonite contain dikes of several varieties of monzonite porphyry and aplite.

Over most of the area of outcrop, the monzonite weathers to smooth surfaces. The broad dome, about 10 miles in diameter, that lies northwest of Cima, has attracted attention for many years and the name "Cima dome" has been applied to it (Lawson, 1915; Davis, 1933). The circumstances under which it was formed are discussed on page 9. The rugged westward escarpments of the Mid Hills and that of the New York Mountains appear to have resulted from the rapid erosion that has taken place recently by the sinking of Soda Lake to the west and Ivanpah Valley on the north. Under the arid conditions that prevail, the rock disintegrates into its mineral constituents but these do not readily decompose.

FORM OF THE QUARTZ MONZONITE BODY

With the exception of the dikes and sills near the Yellow Pine, Lavina, Columbia and nearby mines, and the monzonite porphyry mass of the Kingston Range, the outcrops of quartz monzonite lie southwest of the Clark Mountain fault. What appears to be the southeastern extension of this fault in the New York Mountains, southeast of Ivanpah Valley, forms the northeastern boundary of the monzonite body that underlies a large part of those mountains.

At many places in the Mescal Range and Ivanpah Mountain, the surfaces that limit the monzonite body, both on the west and east, can be closely traced on the surface and the dips can be determined in mine workings. Near the tip of the wedge on the south slope of Mescal Range, the western boundary is a surface that dips west nearly parallel to the nearby inclined shaft of the Jackrabbit mine. Traced northward, to the north slope of Mescal Range, this surface coincides with the Mescal thrust along which the dolomites near the base of the Goodspring formation have been thrust upon the dacite flow breccia that rests upon the Aztec sandstone. Traced northward, the Mescal thrust is cut off by the Clark Mountain normal fault. Even though it is not known north of the Clark Mountain fault, the Mescal thrust is one of the major thrusts of the region.

South of the Mescal Range, the contact of the dolomite and monzonite lies less than 100 feet east of the Standard No. 1 mine shaft and the dip is obscure. Near the Standard No. 2 mine, the contact surface is nearly a plane that dips 78° W.; farther south at the Copper King shaft, it dips 60° W. From the Mescal Range to the Copper King shaft, the contact surface cuts obliquely across the bedding of the overlying limestone and dolomite of Paleozoic age. In the hills west of Standard No. 1 mine, a spur from the Mescal thrust must turn westward and merge with the Mesquite thrust. The distribution and attitude of the formations of Paleozoic age west of Kokoweef Peak and near Standard No. 1 mine, however, do not require that the northernmost part of the monzonite body lies in a thrust of great magnitude. The formations of Paleozoic age above and below the monzonite body seem to have been merely pushed apart along a minor fault.

The eastern limit of the Ivanpah Mountain monzonite body is a simple surface that strikes northwest and dips 35° SW. near the New Trail mine (No. 89, and p. 139) and 50° SW. near the Allured mine (No. 90, and p. 141). In horizontal plan, therefore, the monzonite body of this area is a wedge about ten miles long which comes to a point on the east end of Mescal Range, a short distance east of the Jackrabbit mine (No. 79, and p. 146). That those surfaces are intrusion contacts rather than post intrusion faults is shown by the zone of alteration in the adjacent limestone and dolomite. If these limiting surfaces are projected downward, however, they will meet and pinch out the monzonite body several thousand feet below the present erosion surface.

In the region southwest and west of Ivanpah Mountain the rocks that limit the quartz monzonite westward are crystalline gneisses and schists. From Cima northwest to Riggs Wash, about 25 miles, there is a belt in which blocks of crystalline rocks rest upon the quartz monzonite; the contact trends northwest and dips gently southwest. The contact can be traced clearly in the Mid Hills, southeast of Kelso Wash; it strikes west and dips 45° S. near the summit (5,665 feet) north of the Columbia mine. The base of the great mass of monzonite that underlies Mid Hills and New York Mountains is not exposed. Similarly, in the region east of Blackburn and the Leiser Ray mine, the monzonite is overlain by blocks of pre-Cambrian rocks, but nothing is known of the rock which underlies it.

When all the features of the monzonite mass are considered—the nature and distribution of roof pendents on Cima dome, the wedge in Ivanpah Mountain, and the blocks of crystalline rocks northwest and southeast of Cima and near Leiser Ray mine—it seems that in its broader aspects, the mass has intruded the surficial zone of rocks along the Mescal thrust, pushing aside the rocks on either side. This fracture extended from the crystalline basement rocks upward into the rocks of Paleozoic and Mesozoic age as high as the Aztec sandstone (Jurassic (?) system). There is nothing about the relations of the monzonite to the limiting rocks in any part of the region to indicate that any large part of it is a crosscutting stocklike mass.

MEGASCOPIC P PERTIES

The most widespread variety of quartz monzonite, that which forms Cima Dome and is most common in the low hills as far northwest as Riggs Wash (25 miles), is a holocrystalline rock that is light gray where fresh and pale-reddish brown on weathered outcrops (specimen 94, fig. 23). The rock is composed mostly of grains of feldspar and quartz that range from 5 to 15 mm in diameter with sparse plates of biotite that commonly have no definite distribution but in a few places have linear arrangement. The remainder of the rock is coarse crystals of pale-reddish or pink orthoclase from 20 to 40 mm in diameter. Many of these crystals are Carlsbad twins. In the New York Mountains, Mid Hills and hills near the Leiser Ray mine, coarse crystals of orthoclase in a feldspar-quartz groundmass are common but they are white rather than pink (specimen 126, fig. 24, specimen 130, fig. 25). In the flat area, north of Teutonia Peak, crystals of white orthoclase as much as 3 inches (75 mm) long are common, and, as they are

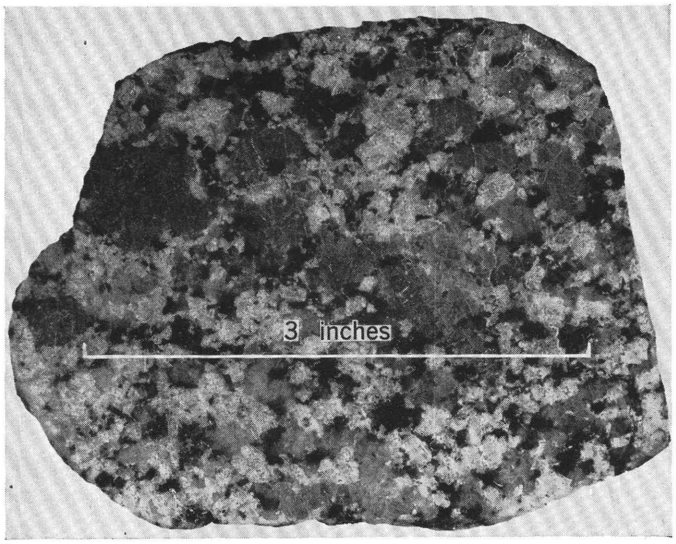

FIGURE 23.—Photograph of a specimen of Teutonia quartz-monzonite, Francis Spring area, California.

set free by disintegration, they are strewn along the dry washes. An uncommon feature of these coarse crystals of orthoclase is the presence of zones of biotite flakes parallel to prism and pinacoid faces of the crystals. Similar varieties containing simple orthoclase crystals as much as 3 inches long were observed in Cedar Canyon, in the Mid Hills, in the park 4 miles southeast of Elora, and near the Leiser Ray mine, north of Goffs. Hornblende and other dark minerals are very rare in the typical monzonite, but local areas of some varieties contain as much as 5 percent.

The most common variety that departs from the typical Teutonia quartz monzonite is slightly finer in grain and lacks the coase orthoclase crystals. It occurs on the west slopes of Cima Dome and is common on the northwest slope of New York Mountains near Mexican Spring and Slaughterhouse Springs. Of the

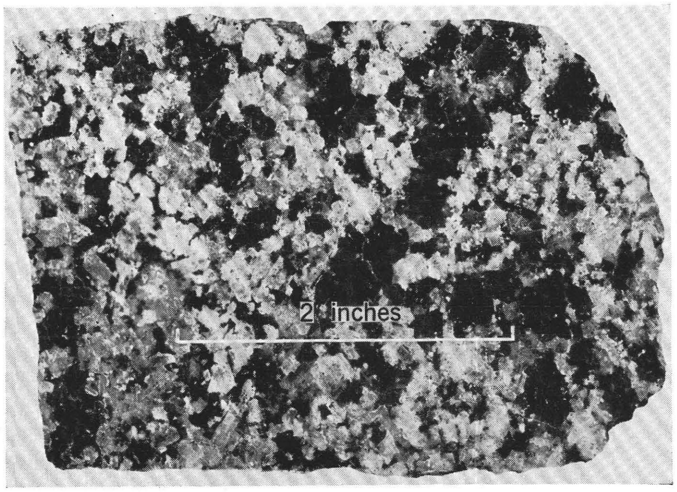

FIGURE 24.—Photograph of a specimen of Teutonia quartz-monzonite, Gold Valley area, California.

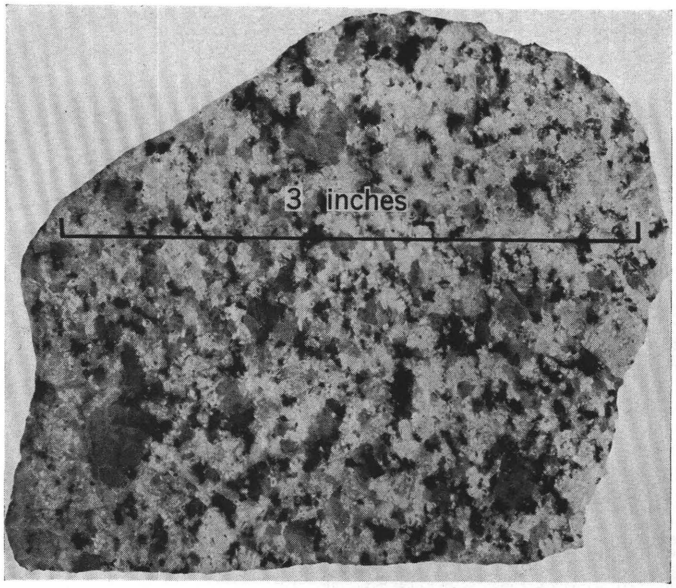

FIGURE 25.—Photograph of a specimen of Teutonia quartz-monzonite, near Leiser Ray mine, California.

three specimens selected for analyses, specimen 117 from Columbia mine well and specimen 130 from Leiser Ray mine were chosen because the rocks were quite unweathered and in texture and mineralogy were similar to the typical Teutonia quartz monzonite.

MICROSCOPIC FEATURES

In Specimen 117, from the Columbia mine well, the rock is holocrystalline and most of the grains of orthoclase, microcline, andesine, and quartz range from 1 to 4 mm in maximum diameter; quartz is largely interstitial with respect to the feldspars. The dark minerals, biotite, magnetite, titanite, and zircon, form sporadic clusters. The last two are uniformly terminated crystals. Biotite is slightly altered to chlorite; otherwise the rock is quite fresh.

Specimen 126 (fig. 24) from the Gold Valley mine is holocrystalline rock and most of the grains of orthoclase, anedesine, and quartz range from 2 to 5 mm in maximum diameter; quartz is largely interstitial. Dark minerals tend to be widely dispersed; biotite shows alteration to chlorite; grains of sericite are liberally dispersed through orthoclase; andesine is almost unaltered.

Specimen 130 (fig. 25) from the Leiser Ray mine is holocrystalline rock; most of the grains are of orthoclase, oligoclase, and quartz and range from 1 to 4 mm in diameter. Some quartz is interstitial. Dark minerals are dispersed; biotite is quite fresh. There is sparse alteration of orthoclase to sericite.

INCLUSIONS

Both angular fragments of igneous and large blocks of sedimentary rocks are included within the Teutonia quartz monzonite. The evidence indicates that these blocks were engulfed in the intrusive mass and have been revealed at the present surface by erosion. They may be contrasted with much larger blocks of sedimentary rocks and gneiss that rest on nearly flat horizontal surfaces of monzonite and are disposed in such a manner as to indicate that they are remnants of pendents of the cover into which the monzonite was intruded.

The blocks of igneous rocks include several varieties of hornblende granite, gneiss, and schist but the latter is most widespread. Commonly, the blocks

Estimated mineral composition—quartz monzonite

Minerals	14 [a]	112	94	87	117 [a]	150	126 [a]	130 [a]
Orthoclase	40	15	Present	Present	25	50	30	30
Microcline	—	—	—	—	Present	—	Present	—
Plagioclase:								
Oligoclase	25	—			—	20	—	30
Andesine	—	60	Present	Present	50	—	40	—
Quartz	30	20	do	do	15	20	15	30
Hornblende	—	—	—	—	—	—	3	—
Biotite	Tr	5	Present	Present	3	3	3	1
Muscovite	—	—	—	—	—	—	Present	3
Sericite	—	—			—	—	Much	—
Titanite	1	—	—	—	3	—	1	None
Apatite	—	—	—	—	1	Tr	Tr	None
Magnetite	Tr	—	—	—	1	Tr	1	—
Zircon	Tr	—	—	Present	1	Tr	—	—

[a] Thin section examined.

14. Kingston Range monzonite porphyry, 2 miles south of Horse Spring.
112. Riggs Wash, sec. 17, T. 16 N., R. 10 E.
94. Francis Spring, sec. 24, T. 16 N., R. 10 E.
87. Copper King mine, sec. 25, T. 15 S., R. 13 E.
117. Columbia mine, sec. 4, T. 11 S., R. 14 E.
150. New York Mountains, sec. 3, T. 13 S., R. 14½ E.
126. Gold Valley mine, sec. 31, T. 12 S., R. 14½ E.
130. Leiser Ray mine, sec. 23, T. 11 N., R. 17 E.

Analyses of Teutonia quartz monzonite

[Analyzed by J. G. Fairchild]

	14	117	130
SiO_2	71. 50	67. 04	71. 77
Al_2O_3		15. 37	14. 60
Fe_2O_3		1. 06	. 77
FeO	1	2. 52	1. 77
MgO		1. 33	. 20
CaO	1. 00	3. 64	1. 95
Na_2O	4. 17	3. 10	3. 85
K_2O	5. 91	4. 61	4. 31
H_2O-		. 12	0
H_2O+		. 40	. 53
TiO_2		. 45	. 20
Total		99. 64	99. 95

14. Kingston Range monzonite porphyry, 2 miles south of Horse Spring.
117. Columbia mine, sec. 3, T. 11 N., R. 14 E.
130. Leiser Ray mine, sec. 23, T. 11 N., R. 17 E.

are angular without evidence of corrosion. The range in size is from a few inches to as much as several hundred feet in maximum dimension; the largest are found near the well in Riggs Wash. Smaller blocks are common west of Marl Spring, near Death Valley mine and in the northwest slope of Mid Hills, 4 miles southeast of Joshua (Hanlon). A specimen of this rock is about 60 percent feldspars, largely andesine (An_{40}) with minor orthoclase; minor quartz; and about 40 percent is aggregates of hornblende, biotite, and titanite. There is considerable apatite in the andesine grains. The rock is holocrystalline and the grain size ranges from ½ to 2 mm. The mineral composition resembles that of the sills of the Copper World mine (p. 136).

The regional evidence indicates that these blocks were frozen in the intrusive monzonite within several thousand feet of the roof, from which they probably were detached. Fragments of fine-grained, pale-reddish monzonite were observed in the normal Teutonia quartz monzonite near Granite Spring.

The Sunnyside (p. 141) and Morning Star (p. 126) mines near the Kewanee mine (p. 126) on the east slope of Ivanpah Mountain explore a wedge-shaped block of gneissic granite that is wholly enclosed in quartz monzonite. The Sunnyside shaft, sunk at an inclination of 35° westward to a depth of 300 feet, is wholly in gneissic granite, which is overlain by quartz monzonite several hundred feet west. The Morning Star tunnel, 2,000 feet east of the Sunnyside extends 600 feet northwest along the contact of granite gneiss (above) and quartz monzonite (below); the contact strikes nearly north and dips 35° W. The block of gneiss is therefore a flat wedge inclined westward, but wholly surrounded by monzonite.

Blocks of dolomite and limestone several hundred feet long, obviously once wholly surrounded by monzonite, are found at a few places. The southern part of a small park eroded in monzonite, 4 miles southeast of Joshua (Hanlon), exposes several blocks of white crystalline dolomite, the largest of which is 1,200 feet long on the Cottonwood claim (p. 156) that covers the block; a shaft has been sunk 100 feet in the contact zone several feet thick, within which the limestone has been altered largely to garnet, epidote, hornblende, and quartz. It is locally reported that this contact rock contains scheelite, but this has not been confirmed.

The hill north of the Kewanee mine camp exposes two parallel tabular blocks of dolomite that are wholly surrounded by monzonite; they trend N. 35° W. and dip 35° SW. The large wedge of granite gneiss (above) similarly enclosed in monzonite, lies along the strike extension of these blocks of dolomite.

On the northwest slope of New York Mountains, about 1,000 feet southwest of Slaughterhouse Spring, a quarry (Piehls) has been opened on a block of coarse white marble that is surrounded by monzonite. The marble is cut by veins of brown garnet (grossularite?) and quartz. The contact of limestone near the base of the section of Cambrian age on monzonite lies several thousand feet east.

A block of gray limestone crops out south of a copper prospect (p. 135) 1,500 feet southeast of the Stone Hammer turquoise mine (p. 165) that lies about 4 miles northeast of Halloran Spring. The limestone is in gneissic granite that lies above the nearby monzonite.

In two places in the quadrangle there are tabular masses of gneissic and schistose granite in the monzonite that forms the local country rock. The eastern tabular body extends from Rock Springs east of Government Holes, due south about 5 miles. The local rock is a granite rather than quartz monzonite such as that which adjoins it on the east and west, so that it is not a sheared form of the local monzonite which closely resembles the typical Teutonia quartz monzonite. It seems to be a tabular block of pre-Cambrian gneiss enclosed in the intruding granite and monsonite.

The western tabular block extends generally eastward from Riggs Wash 10 miles to Halloran Wash, north of Highway No. 91. It separates unlike intrusive rocks, the normal Teutonia quartz monzonite on the north and a finer-grained gray granite on the south. The block is from 2,000 to 3,500 feet thick and the dip is steep to the south. The rock resembles some of the pre-Cambrian gneissic granites more than any phase of the intrusive monzonite. The contact of the gray monzonite with typical gneisses lies 2 to 3 miles south of the block. Like that south of Rock Springs, it is pre-Cambrian gneiss and schist.

ALTERATION OF THE BORDERING ROCKS

In general the rocks adjacent to the monzonite are neither extensively nor greatly altered. The kind and degree of alteration seem to depend upon the character of the adjacent rocks; the location with reference to the main body of the monzonite; and whether the adjacent rock was part of an extensive body, as for example, the roof, or whether it was a block largely or wholly enclosed in the intrusive.

Carbonate rocks are much more widely and thoroughly altered than such siliceous rocks as the assemblage of igneous rocks that characterize the pre-Cambrian crystalline basement. The monzonite is in contact with carbonate rocks in only a few localities. Both the top and bottom of the wedge that extends from Copper King mine northward to Mescal Range persistently show several types of alteration. The limestones of late Paleozoic age that form the hill north of Standard mine No. 1 are bleached and altered to dolomite but this type of alteration is not widespread along the upper contact and is absent along the lower contact with the monzonite. Much more persistently along both upper and lower contacts, the carbonate rocks are altered to an assemblage of silicate minerals of which garnet (grossularite?), and diopside are most abundant. This type of alteration is best revealed in mine workings, such as those which extend from Standard mine No. 1 to Copper King mine on the upper contact and from the Allured mine to the New Trail (Johnson) mine on the lower contact. The zone of alteration is persistent but not extensive, for the thickness is commonly measured in tens of feet. It is about as extensive on the lower contact under the intrusive wedge as it is on the upper contact. The Standard mine No. 1 (p. 139) explores a northwest-trending fracture in the bleached and altered Goodsprings dolomite near the monzonite contact. A 10-foot zone of garnet, epidote, and quartz lies against the monzonite but cross fractures (northeast) in the bleached dolomite show lenses of magnetite as much as 3 feet wide in the midst of contact rock. A specimen of mottled green and brown contact rock contains considerable hedenbergite and garnet. The shaft of the Standard No. 2 mine, 250 feet deep, is wholly in bleached and altered dolomite a few feet above the monzonite contact. Farther south the Copper King shaft, inclined 70° W., follows the contact of the Goodsprings dolomite and monzonite; the zone of silicate rock is about 8 feet thick. It contains magnetite in a garnet-epidote matrix; above it in the bleached dolomite are sporadic patches of serpentine and diopside. In 1943 scheelite-bearing rock was being mined in the contact zone. Half a mile north of the Copper King shaft, a shaft (name unknown) which extends west at an inclination of 64° to a depth of 200 feet, is wholly in biotitized monzonite underlying bleached dolomite that shows sparse silicate minerals and magnetite.

At the New Trail (Johnson) mine, (p. 139, and pl. 2, no. 89), a shaft 185 feet deep explores a northeast-trending fracture in the Goodsprings dolomite, about 500 feet stratigraphically below its contact with the monzonite which here strikes N. 30° W. and dips 35° SW. The zone of contact rock that follows the fracture contains considerable brown garnet (grossularite?), diopside, vesuvianite, and dark-green mica (phlogopite?). The nearby dolomite is bleached and shows sparse patches of yellow serpentine.

Two miles south, the Allured mine (pl. 2, No. 90), includes 3 shafts, 100, 150, and 150 feet deep respectively, all in bleached and altered Goodsprings dolomite below the monzonite contact. The actual contact is marked by a zone of iron gossan, undoubtedly derived from pyrite, and most of the silicate minerals lie along fractures in the dolomite. Garnet (grossularite?), diopside, and vesuvianite were observed.

In that part of New York Mountains which lies between Ivanpah and Barnwell, especially the little basin in which Slaughterhouse Spring is situated, carbonate rocks near the base of the Goodsprings dolomite overlie the monzonite. The surface of contact is a broad dome rather than a plane. On the east side of the divide, the Trio mine shaft, 600 feet deep is located near Clark Mountain fault which separates a block of Goodsprings dolomite on the southwest from the pre-Cambrian gneiss on the northeast. For a distance of 20 to 50 feet above the contact, the dolomite is altered to silicate rock, white tremolite rock near Slaughterhouse Spring, and garnet-epidote rock near the Trio mine. Examined in thin section, a specimen of white marble collected a few feet above the contact near Slaughterhouse Spring shows crystals of calcite that average 1 millimeter in diameter, about 90 percent; sheaves of wollastonite, about 8 percent; and clusters of diopside grains, 2 percent. Another specimen nearby is almost wholly blades of wollastonite and a few patches of diopside and orthoclase; it contains no garnet. About 1,000 feet west of Slaughterhouse Spring, a low hill capped by a block of limestone has been explored by a quarry as a source of limestone. The white marble is cut by veins of brown garnet, 3 to 10 inches wide, and shows sporadic coarse crystalline masses of magnesite. On the ridge 2 miles west of the Trio mine, the Live Oak mine (No. 106, pl. 2) explores a vein of fluorite that lies in Goodsprings dolomite and is parallel to and 20 to 30 feet distant from the contact with the monzonite. At the Queen mine (No. 107, pl. 2), 2,500 feet south of the Live Oak, two tunnels explore a vein of fluorite that follows the contact of the Goodsprings dolomite and the monzonite.

The roof pendents of limestone that are enclosed in quartz monzonite show the same kind of alteration as the bodies that are in contact with the intrusive in the Ivanpah Mountains. On and near the Columbia claim in the small park 4 miles southeast of Joshua (Hanlon) numerous angular blocks of white crystalline dolomite crop out, that probably once were wholly closed in the monzonite. The largest of these is 1,200 feet long but others range from 100 to 300 feet long (p. 156). The border zones of these blocks several feet wide are completely altered to mixtures of silicate minerals which locally contain several sulfides, magnetite, and quartz. The most abundant silicates are garnet and epidote but diopside, chondrodite, and hornblende are present.

The rocks near or adjacent to the Kingston Range monzonite porphyry have been altered in much the same way as those near the Teutonia quartz monzonite but to a less degree. The carbonate rocks show sporadic alteration to brown garnet, diopside, and tremolite. Southeast of Horse Spring, shale in the Crystal Spring formation has been altered to a striped green and gray hornstone made up of layers of fine-grained quartz with minor diopside. About a mile west of Horse Spring, a prospect explores a 3-foot lens of magnetite that is enveloped in garnet, epidote, and horneblende formed by the alteration of dolomite. The prospect lies 75 feet west of a large fault that separates monzonite on the east from the sediments on the west (p. 158).

On a western spur from Kingston Range, a mile or more west of the western boundary of the quadrangle, the monzonite porphyry has irregularly intruded pre-Cambrian gneiss, and the overlying quartzite at the base of Crystal Spring formation is much broken by faults. The quartzite of the area is locally granitized by the addition of considerable feldspar; this type of alteration was not found elsewhere.

DOLOMITIZATION

Dolomitization of limestone has taken place widely in the Goodsprings quadrangle and the process has been fully described in the report on that district (Hewett, 1931, p. 57–67). There it was shown to be related to the thrust faults, early normal faults, and intrusives of the epoch of Laramide orogeny.

In the larger area of the Ivanpah quadrangle, the dolomitized rocks were noted in many places, but in some of these places there are no outcropping bodies of intrusive rock and the relations are not clear. In the hills north and west of Sloan, the entire Sultan and Monte Cristo limestones, except the Crystal Pass limestone member, are completely converted to dolomite (p. 162). Similarly, in the hills south of Devil Peak as far as State Line Pass, the Sultan limestone, the Crystal Pass limestone member of the Monte Cristo limestone, and parts of the Bird Spring formation are widely altered to dolomite. In neither of these areas were outcrops of intrusive monzonite observed. South and west of Spring Mountains limestones of late Paleozoic age are widespread but the alteration to dolomite is sporadic. For example, the limestone section of late Paleozoic age northwest of Standard No. 1 mine which lies at the contact of the monzonite and the limestones, is largely converted to dolomite, but several miles north little alteration is to be found.

KINGSTON RANGE MONZONITE PORPHYRY

The Kingston Range monzonite porphyry is a name here proposed for the mass of intrusive rock that forms the central part of the Kingston Range, surrounded on the west, north, and east by pre-Cambrian sedimentary rocks and rocks of early Paleozoic age. The term "monzonite porphyry" will be used in this report to refer to the Kingston Range monzonite porphyry or to bodies of rock which have the same lithology and texture. It is exceptionally homogeneous in mineralogy and texture throughout. Only the borders adjacent to the surrounding sedimentary rocks show slightly finer texture. On fresh fractures, the rock is pale brownish, but weathered surfaces show a darker film of desert varnish. Phenocrysts of white orthoclase, commonly 3 to 8 millimeters long are found, but in the central core they are as much as 25 to 30 millimeters long. They are imbedded in a brownish dense matrix whose minerals are only revealed in thin section. Biotite flakes several millimeters in diameter are uniformly distributed through the matrix (specimen 14, fig. 22). In thin section, the matrix is shown to be grains of quartz and crystals of oligoclase (An_{20}). In addition to biotite, the accessory minerals are titantite, magnetite, and zircon; there is no hornblende. A partial analysis of the rock is given in the table on page 65.

The mineralogy and analysis show the close similarity of the Kingston Range monzonite porphyry to the Teutonia quartz monzonite and it seems probable that the rocks were intruded in the same epoch.

The sedimentary rocks that surround the Kingston Range monzonite porphyry dip steeply outward and show alterations that indicate its intrusive character. There are several faults of the intrusive epoch that radiate outward from the central core.

The ravine that drains westward from Beck Spring to the Amargosa Valley reveals a flat surface carved in pre-Cambrian gneiss, about 7,000 feet long by 2,000 feet wide. Evidence on the surface and from drill cores on the Beck iron deposit (p. 158) shows clearly that the pre-Cambrian sedimentary rocks, dipping 80° N., end downward against the gneiss and have been thrust upon it, probably in post-Miocene time. The relations of the Kingston Range monzonite porphyry to the gneiss are not clear but it seems probable that it had already been intruded into the pre-Cambrian sedimentary rocks when the entire Kingston Range was thrust to its present position.

The rocks near or adjacent to the Kingston Range monzonite porphyry have been altered similarly to those near the Teutonia quartz monzonite but to a lesser degree. The carbonate rocks show sporadic alteration to brown garnet, diopside, and tremolite. Southeast of Horse Spring, shale in the Crystal Spring formation has been altered to a striped green and gray hornstone made up of layers of fine-grained quartz with minor amounts of orthoclase that alternate with layers that are largely fine-grained diopside. About a mile west of Horse Spring, a prospect explores a 3-foot lens of magnetite that is enveloped in garnet, epidote, and hornblende formed by the alteration of dolomite. The prospect lies 75 feet west of a large fault that separates monzonite on the east from the sediments on the west.

On a western spur from Kingston Range, a mile or more west of the western boundary of the quadrangle, the monzonite porphyry has irregularly intruded pre-Cambrian gneiss, and the overlying quartzite at the base of Crystal Spring formation is broken in many places by faults. The quartzite of the area is granitized locally by the addition of considerable feldspar; this type of alteration was not found elsewhere.

DIKES AND SILLS

Within the monzonite bodies three varieties of dike rocks are recorded: aplite, monzonite porphyry, and hornblende porphyry. In the great expanse of Teutonia quartz monzonite in this region, however, few pegmatite dikes were found.

Thin dikes of aplite are rather widespread and abundant in parts of the quartz monzonite, but they are not uniformly distributed throughout; they are uncommon in the Kingston Range monzonite porphyry. The dikes range from 2 to 10 inches thick and fill a complex system of intersecting fractures; under weathering, fragments are strewn about the surface. Aplite dikes are abundant in the hills south of Highway No. 91 near Granite Spring and Squaw Tit and on the west slopes of the Mid Hills and north slopes of New York Mountains, especially southeast of Joshua (Hanlon) and near Table Mountain (south of Government Holes). The aplite has not been studied closely; the texture is microgranular and it seems to be wholly feldspars and quartz. No dark minerals are present.

Dikes of monzonite porphyry are common in several parts of the quartz monzonite and they are conspicuous because under weathering they sustain prominent ridges, even though most are less than 50 feet thick. The most conspicuous group form ridges near Lopez camp, 4 miles southeast of Elora. Four dikes, ranging from 25 to 50 feet wide, sustain prominent ridges that strike N. 60° E. on the east side of the small park in which Lopez camp is situated. The rock is uniformly pale brown and contains terminated crystals of quartz and orthoclase 2 to 4 millimeters in diameter in a fine-grained matrix of feldspars, quartz, and biotite. The feldspars are orthoclase and andesine. There is close resemblance to the Kingston Range monzonite porphyry except that this latter has coarser grains. Dikes of similar rocks are found on the north slope of New York Mountains and southeast of Brant, where they occupy fractures that trend northeast and dip at low angles southeast. They were also noted near Lecyr well and the Leiser Ray mine.

About a mile west of Mexican Spring, south of Ivanpah in the New York Mountains, the 4,400 foot northward-trending ridge is sustained by a tabular body of dense biotite monzonite that strikes due north and dips 50° E. Both the ridge and the coarse monzonite of the area are cut by quartz veins that trend west and wouthwest and dip north. About 2 miles southeast, a dike of monzonite porphyry, like those east of Elora, extends about 2,000 feet, N. 55° W. from the Lecyr well. A quarry south of Crescent Peak exposes a large body of quartz, feldspar, and mica.

Another variety of dike rock, present in the quartz monzonite, is characterized by the presence of hornblende phenocrysts, with or without conspicuous feldspar, in a dense greenish or brown groundmass; quartz is inconspicuous or absent. Such rocks are found in the Copper-World (No. 71, pl. 2) and Dewey (No. 72, pl. 2) mines (p. 136), in the hills west of Marl Spring, and near the Leiser Ray mine.

Many dikes and sills of dark-gray, fine-grained igneous rocks occur on Clark Mountain and the nearby hills, but they are very uncommon elsewhere in the quadrangle. Three sills of these rocks were found in the Copper World mine (p. 136) and others were observed in faults on the northwest slope of Clark Mountain. None of the outcrops are large enough to show on the geologic map. Most are dark, equigranular holocrystalline rocks whose mineral composition resembles that of the Teutonia quartz monzonite except that hornblende is abundant; others are olive green and finer grained. The most abundant rock at the Copper World mine contains orthoclase, 25 to 35 percent, somewhat altered to sericite; andesine (An_{30}), 5 to

10 percent; quartz, 15 to 20 percent; hornblende, 20 to 25 percent; apatite, 1 to 3 percent; and no biotite. A similar sill was found in the workings of the Dewey mine, 1,000 feet south of the Copper World mine. Another underground sill is olive green and much finer in grain. It is largely oligoclase (An_{15}) with minor quartz, considerable epidote and chlorite (probably derived from hornblende), and no orthoclase or fresh hornblende.

About 2 miles north of the Copper World, a 10-foot dike in a minor thrust fault is a light-gray, fine-grained rock. It contains sparse phenocrysts of orthoclase as large as 1 mm. in diameter in a fine-grained mass composed of spherulites of orthoclase, all much altered to sericite. It contains no dark minerals. Near the Jackrabbit mine, on Mescal Range 8 miles southeast of Clark Mountain, there are small dikes of rock that resemble the Copper World sills.

In two areas of the quadrangle, there are dikes and sills of dense rhyolite which seem to be related to veins of gold ore and therefore to Laramide structural features. Within the first area, about a mile in diameter surrounding the Colosseum mine, sills and irregular dikes were examined at three localities. The Colosseum mine (p. 125) now includes several tunnels, one of which extends from the north side of a ridge about 1,000 feet to the south side, and a shaft about 200 feet deep. In 1927, the tunnel was 560 feet long, with several drifts, but subsequently, according to R. T. Walker, it was extended through the ridge. At several places in these workings as well as on the nearby surface there are irregular dikes of a very dense, drab-colored rock which shows sparse small crystals of orthoclase, quartz, and biotite in a matrix of equigranular orthoclase and quartz that largely range from 0.01 to 0.03 mm in diameter. The country rock near the Colosseum mine is schistose granite with much biotite and hornblende locally. Along the contact of the dikes and granite as well as shear zones, there are pyritized zones as much as 50 feet thick. Work by Walker (1928, p. 895–898, 939–942, 976–984), subsequent to 1926, indicates that the Colosseum mine workings explore a breccia pipe.

As the rhyolite of this area resembles that which forms the plug at Devil Peak, 12 miles north, the question arises whether these rhyolite dikes may also be of late Tertiary age as the Devil Peak intrusive is thought to be. The most significant clue is the widespread association of gold-bearing pyrite veins with the rhyolite dikes near the Colosseum mine. None are known near the Devil Peak intrusive.

The workings of the Green, Turner, and Malet mine (No. 64, pl. 2), about 1,000 feet northeast of the main Colosseum tunnel, cut several dikes of very dense gray rhyolite. In the dense groundmass there are sparse phenocrysts of plagioclase, quartz, and biotite as much as 0.5 mm in diameter. The groundmass is largely interlocking grains of orthoclase and quartz, 0.01 to 0.02 mm in diameter. Local relations indicate that the pyritic mineralization near this and the Colosseum mine is related to the intrusion of the rhyolite dikes.

About 2,000 feet southwest of the Colosseum shaft, a sill of very dense rhyolite from 5 to 10 feet thick, lies along the bedding of the Cambrian quartzite about 100 feet above the base; it may be traced readily for 2,500 feet. The groundmass is equigranular orthoclase and quartz grains 0.01 to 0.02 mm in diameter, and there are sparse crystals of orthoclase, partly altered to sericite, apatite, and zircon.

The second area lies in sec. 12, T. 18 N., R. 11 E., west of the Mesquite Pass road. Here a dike of dense gray rhyolite cuts Cambrian quartzites that form part of a block thrust upon pre-Cambrian gneiss. The dense groundmass is made up of interlocking grains of orthoclase and quartz through which there are grains of orthoclase, oligoclase, and quartz as much as 1 mm in diameter. The ground mass and coarse grains of feldspar are dusted with flakes of sericite.

ALTERATION OF BORDERING ROCKS

Except in the Dewey mine (No. 72, pl. 2), the hornblende monzonite dikes have produced little alteration of the country rock. At the north end of that mine, the beds of Goodsprings dolomite have been altered to a group of anhydrous and hydrous silicates of lime and magnesia as well as brucite (hydrous oxide of magnesia) and spinel (magnesium aluminum oxide).

MINERALOGY OF THE CONTACT ZONE AT THE DEWEY MINE

By Jewell J. Glass

The Dewey mine is located in Cambrian dolomite that has been intruded by fine-grained hornblende monzonite sills. The intrusion of the monzonite has altered the dolomite, by causing the formation of several varieties of magnesium silicates and a few other rare minerals. The rock nearest to the intrusive sills shows the greatest alteration and as the distance from the contact increases, the amount of silicates decreases and the amount of carbonates in turn increases. Masses of calcium carbonate and magnesium carbonate occur in intimate intergrowth, cut by veinlets of later secondary calcite, and merge into the unaltered dolomite.

DESCRIPTION OF THE SPECIMENS

Seven specimens were collected, beginning at a point near the wall of the dike and continuing in a numbered sequence outward to the unaltered dolomite, thus representing a cross section of the metamorphosed dolomite. The specimens vary in color from pale greenish yellow near the igneous contact to greenish and grayish brown, then light brown fading to nearly pure white, and finally the white grades into the light-gray dolomite.

Zone I.—The groundmass of specimen no. 1 is pale greenish yellow streaked with a network of white veins. The texture is finely granular; the white veins are composed of a compact fibrous material resembling satin spar, and vary in width from 1 to 5 millimeters.

In hand specimen the yellowish mineral appears to predominate. In order to determine more accurately the amounts of each of the two minerals that seem to make up the rock, a 17 gram sample of the specimen was crushed and separated by heavy solutions into gravity portions. The heavier fraction, though less in volume, was composed of the greenish-yellow (chalcedony-yellow) mineral which, when examined under the microscope was found to be monticellite, and the white "float" or light material was thaumasite. The weight in grams of the two portions (8.5 grams and 8.4 grams respectively) were nearly equal; however, the proportion of thaumasite by mass was greater than that of the monticellite. A thin section of the specimen also shows a greater amount of thaumasite than of monticellite.

The satiny, fibrous veins of thaumasite cut sharply across the older, massive thaumasite and the monticellite; the thaumasite appears to occur in two distinct forms and in two distinct generations.

The most important and the most interesting feature of the thaumasite-monticellite rock is its mode of occurrence. A thin section of this specimen indicates that the monticellite was formed before the thaumasite. The monticellite has been replaced by the earlier, massive (microscopically granular) thaumasite. The veins do not appear to fill fractures; patches and fingers of the fibrous thaumasite can be seen in the older thaumasite as though the older material is being replaced. A small amount of colorless diopside was found in the crushed sample, but none was observed in the thin section; therefore, the relationship of the diopside is not known.

The genesis of the thaumasite is not clear. No evidence of other sulfates has been observed in any of the samples. At Crestmore, Calif., as cited by W. F. Foshag (1920, p. 80), thaumasite was derived from spurrite by the action of sulphate-bearing water. No spurrite was found in the Dewey mine, however. The association of the thaumasite with monticellite, however, is similar to that at Crestmore. The association and origin of thaumasite seems to be different in each of its several occurrences.

Zone II.—Specimen no. 2 is a grayish-green to brownish-green, fine-grained silicate rock composed of two varieties of pyroxene: the common variety of diopside, which occurs sparingly; and a variety with high index of refraction and other optical properties that correspond to fassaite (a type of augite described as an alteration product of monticellite), which is more abundant. A thin section of this specimen does not indicate the origin of the pyroxenes.

Zone III.—Specimen no. 3 is a pale-brown silicate rock composed of diopside, serpentine, and altered monticellite.

Zone IV.—Specimen no. 4 is pale-gray, nearly white, and is composed mostly of calcite with scattered grains of dolomite, aggregates of colorless diopside, islets of cherty quartz, and fibers of serpentine. This specimen represents the results of the process of dedolomitization.

Zone V.—A white specimen (no. 5) is composed of altered and replaced quartz. The quartz may have been a remnant of quartzite that was interbedded with the original dolomite. The cracks and fissures are filled with fibrous serpentine that has altered to deweylite in some places.

The groundmass of specimen no. 6 is pure white, sugary calcite with inclusions of lenses or aggregates of minerals consisting of pale-green fassaite, colorless diopside, yellow monticellite altering to a brown fibrous mineral, and a brown amorphous mineral that resembles serpentine and is not suitable for optical study.

Specimen no. 7 is fine-grained serpentinized dolomitic limestone, containing white calcite veins. The rock mass is largely carbonates grading into the unaltered dolomite.

DESCRIPTION OF THE MINERALS

Deweylite.—The deweylite is amorphous, gumlike in appearance, and is yellowish brown. It has variable indices of refraction $n=1.530$ to 1.550. Deweylite occurs as an alteration product of serpentine and by some authorities is classified as a serpentine.

Diopside.—The diopside is white or colorless with properties that coincide with the type of pyroxene that commonly occurs in limestone. The optical properties of this mineral are recorded in table 2.

Fassaite.—Fassaite is a variety of augite that contains alumina. It occurs in two specimens. In one it is greenish gray to pale brown; in the other one it is pistachio green. The optical properties are the same in both (see table 2). A qualitative chemical test on this mineral shows an appreciable amount of alumina. This variety of augite is reported to be derived from the alteration of monticellite.

Grossularite.—Garnet was observed only in the thaumasite-monticellite rock. Here it occurs as minute granules, very rarely. It is brownish yellow and has

TABLE 2.—*Properties and associations of minerals that occur in representative samples taken at intervals across a contact metamorphic zone at the Dewey Mine, San Bernardino County, Calif.*

Mineral name and composition	Color	Indices	Axial angle (2*V*)	Dispersion	Sign	Orientation	Crystallization and habit	Occurrence	Remarks
Deweylite, $4MgO \cdot 3SiO_2 \cdot 6H_2O$.	Yellowish brown	Var. $n=1.530-1.550$					Amorphous, gumlike, microscopically fibrous.	Alteration of fibrous serpentine.	Decomposed by hot HCl.
Diopside, $CaO \cdot MgO \cdot 2SiO_2$.	White	$\alpha=1.670$ $\beta=1.680$ $\gamma=1.698$	60°	r>v	+	$Z \wedge c$ 37°	Monoclinic; prismatic cleavage.	Grains and small aggregates in monticellite and with calcite in dolomite.	Pyroxene group. Typical colorless varieties found in limestone and dolomite.
Fassaite, $CaO \cdot MgO \cdot 2SiO_2$.	Pistachio green to gray.	$\alpha=1.685$ $\beta=1.690$ $\gamma=1.710$	60°	r>v	+	$Z \wedge c$ 42°	Monoclinic; prismatic cleavage.	Associated with diopside in monticellite, and in masses between the monticellite-thaumasite zone and the diopside-serpentine-monticellite zone.	A variety of augite, commonly an alteration product of monticellite. May contain aluminum.
Grossularite, $3CaO \cdot Al_2O_3 \cdot 3SiO_2$.	Brownish yellow	$n=1.753$					Minute, rounded, crystals dodecahedral.	Associated with thaumasite in monticellite.	Garnet, probably intermediate in composition between grossularite and pyrope. May also contain Mg.
Monticellite, $CaO \cdot MgO \cdot SiO_2$.	Chalcedony yellow	$\alpha=1.640$ $\beta=1.647$ $\gamma=1.653$	85°	r>v	−		Orthorhombic; cleavage poor; massive to granular.	Intergrown with thaumasite in contact zone adjacent to igneous intrusion in dolomite.	Olivine group. Gelatinizes in hot HCl. Op. property indicate iron-free variety.
Serpentine, $3MgO \cdot 2SiO_2 \cdot 2H_2O$.	Grayish green, yellow brown.	Mean=1.550 $\alpha=1.510$ $\beta=1.512$ $\gamma=1.523$.	35°		+		Amorphous to chalcedonic. Orthorhombic (?). Fibrous.	Amorphous variety associated with fibrous serpentine in dolomite, and with calcite and quartz.	Common, fibrous. Decomposed by hot HCl.
Thaumasite, $CaSiO_3 \cdot CaSO_4 \cdot CaCO_3 \cdot 15H_2O$.	White	$\epsilon=1.468$ $\omega=1.507$			−		Hexagonal; massive to fibrous.	Associated with monticellite in close contact with diorite dike intruded into dolomite.	Decomposed by hot HCl.

an index of $n=1.753$, which is higher than that for the grossularite ($n=1.736$) described by doctor W. T. Schaller (1935) from the same area, illustrating the variability of garnet in contact metamorphic zones.

Monticellite.—The clean grains of monticellite are chalcedony yellow. The cleavage is distinct.

The indices of refraction for this monticellite are lower than those recorded for the mineral from other localities. The indices correspond closely to those determined by Schaller, Ross, and Glass, reported by W. T. Schaller (1935) in his description of monticellite from this same locality. The indices of refraction on this specimen of monticellite are $\alpha=1.640$ $\beta=1.647$, $\gamma=1.653$, $B=0.013$, and are near those for the pure (artificial) $MgO.CaO.SiO_2$ usually given as $\alpha=1.639$, $\beta=1.646$,$\gamma=1.653$, $B=0.014$. The optical axial angle is large, 85° (estimated), which establishes another point of agreement with the properties of pure monticellite, seldom found in nature.

Serpentine.—Serpentine occurs in two forms, the common amorphous type and the fibrous variety; both are common in dolomite contact zones.

Thaumasite.—Thaumasite was described under the section on rocks in a previous paragraph, together with the theory of its origin. The indices of refraction, $\epsilon=1.468$, $\omega=1.507$, are essentially the same as the values recorded for homogeneous thaumasite from other localities.

CENOZOIC ERA

EARLY TERTIARY EROSION

From the end of the Laramide orogeny until the deposition of the earliest middle Tertiary sediments (upper Miocene series), this region seems to have been under active erosion. The nearest known Eocene deposits are the marine limestone on Rock Creek near Valyermo, about 100 miles southwest and the Homestake limestone member of the Carmel formation, of the Iron Springs district in southwestern Utah, about 160 miles northeast. The general absence of Eocene and Oligocene deposits in southern Nevada and southeastern California indicates that the drainage of this region was outward to the sea and all of the products of erosion were removed.

FEATURES OF THE UNDERLYING SURFACE

In the western third of the quadrangle, even though the Middle Tertiary rocks are well exposed in several townships north of Riggs Wash, only along the southern border of the basin is the underlying contact revealed. Here, these rocks rest upon a surface of low relief carved on quartz monzonite. That surface, like the sedimentary rocks and flows which rest upon it, is broken by a few faults, and the sedimentary rocks have been warped, probably at the time of faulting. The evidence of the faulting is found in the distribution and attitude of the remnants of the thrust plate which rests upon the sedimentary rocks.

In the eastern half of the quadrangle, the contact is exposed at places for a distance of 35 miles, from near Sloan and Erie on the north; along the hills north and east of McClanahan Spring; on the east slope of the Lucy Grey Range and east slope of McCullough Range; on the east slope of New York Mountains; and in the central valley of Castle Mountains. It is exposed also in the low hills east of Blackburn in the southeast corner of the quadrangle.

In general, as one considers the features of the former surface at several parts of the belt from north to south, several conclusions are indicated.

The local relief of the surface was greatest in several areas along the westernmost parts of this belt: southeast of Sloan, south of Erie, along the east slope of the northern parts of the New York and Providence Mountains. In these areas the relief seems to have been several hundred feet to the mile. At the first two areas, the underlying rocks are limestone; at the third, the rock is pre-Cambrian gneiss.

The local relief of the surface was lowest, several tens of feet to the mile, in the following areas; northeast of McClanahan Spring, along the east slope of the Lucy Grey Range, along the east slope of McCullough Range, in the Castle Mountains, in the hills east of Blackburn. In all of these areas the underlying rocks are pre-Cambrian gneiss or quartz monzonite. In appraising the significance of these features, allowance must be made for the well-known fact that in arid regions carbonate rocks resist erosion much better than igneous rocks and siliceous sedimentary rocks.

In considering the broad features of the surface on which the middle Tertiary rocks were laid, attention must be given to the known distribution of great thicknesses of the Tertiary rocks, the general succession of diverse rock types, and the kind and extent of deformation of the middle-Tertiary rocks in the several areas

The greatest thicknesses of these rocks are found in three areas along the eastern border of the quadrangle. Along the eastern escarpment of Black Mountain, about 3,200 feet of tuffs, breccias, and flows is exposed, and the total to the basement of pre-Tertiary rocks is greater, although there is no evidence to indicate how much greater. The estimated thickness of flows and tuffs that crop out on the west slope of Highland Spring region is about 1,800 feet. If there are no faults in the valley that separates this range from the McCullogh Range to the west, and there is no evidence of any, the total thickness to the underlying pre-Cambrian rocks of the basement is about 4,500 feet. Only 950 feet of flows and tuffs is exposed along the west slope of Piute Range; the total thickness is probably at least 2,000 feet. The masses of latite and rhyolite that make up the hills east of Erie, Castle Mountains, and Hackberry Mountain appear to represent residues of volcanic piles that were only partly covered with later flows, rather than remnants of once extensive flows and breccias.

The general succession of igneous rocks is as follows: The rhyolites and latites that form the volcanic piles of Hackberry and Castle Mountains and hills east of Erie appear to be oldest.

The andesites that form the lower part of the Black Mountain section; possibly those of the Highland Spring Range and those at the north end of New York Mountains.

The basalts that form the upper 1,200 feet of the Black Mountain section, that overlap the andesites of the Castle Mountains, that cap the Piute Range, that rest upon several hundred feet of latite and andesite flows and tuffs that form the ridges north of McClanahan Spring, and that form the low hills east of Blackburn, are youngest. The basalt flows that form bills west of Lanfair (4,705-foot hill, p. 105) are much younger, however.

It is probably significant that the most western exposures of the volcanic rocks in the region north of McClanahan Spring, where water-laid tuffs and breccias predominate, contain latite and rhyolite flows at or near the base, andesite flows in the middle, and basalt flows at the top.

Even though it is recognized that with the exception of the cone west of Hackberry Mountain, major sources of these volcanic rocks have not been identified and that, unlike marine sedimentary rocks, individual volcanic flows and tuffs probably do not extend great distances from their source, say several tens of miles, several conclusions concerning regional relations may be advanced:

1. The only cone that has been recognized, that west of Hackberry Mountain, was the source of a single variety of rock, rhyolite; there is nothing to suggest that it was the source of the basalt flows a few miles east. If there is a local source (vent) of the latite flows east of Erie, which is possible, there is no evidence that it yielded more than one variety of rock; the thin cover of basalt flows appears to be the western fringe of the Black Mountain field. It seems, therefore, that each of the several rock types was derived from a separate source or vent. It is interesting that throughout the entire region a definite succession of rock types appears.

2. The great thicknesses of flows, tuffs and breccias of Black Mountain area, Highland Spring area and Piute Range accumulated in great depressions, several thousand feet deep, which were bounded westward by higher hills of low relief. As the depressions were filled up, streams carried the finer material westward where it was deposited against the hills. Some flows of each of the three major units reached westward to the low hills.

3. The ridges that now form Spring Mountains and Ivanpah Mountain, underlain by limestones, sandstones, and shale of Paleozoic and Mesozoic age, probably coincide with the position of rugged ridges and even mountains that existed when the volcanic rocks were poured out.

4. The region west of Spring Mountains and Ivanpah Mountain was a piedmont of low relief. Upon this piedmont area the volcanic rocks and sediments south of Kingston Wash were deposited.

MIDDLE TERTIARY ROCKS

GENERAL FEATURES

The rocks that are here considered to be middle Tertiary in age include a wide variety of sediments, gravels, sandstones, and clays; pumice and bentonitic materials that are probably derived from tuffs; a wide variety of igneous flows, tuffs, and breccias; and a few intrusive bodies. The most extensive bodies of these rocks appear to have been deposited in two separate basins which, in middle Tertiary time as now, were separated by the Spring Mountains and other ranges—Clark Mountain, New York Mountains, and Providence Mountains. The largest western basin seems to have been roughly circular, about 12 by 15 miles, and the center was near the present Shadow Mountains. The eastern basin was much more extensive for the Ivanpah quadrangle includes only the western border. It extended from the Black Mountain Range on the north, covered McCullough Range and the eastern slopes of New York Mountains and Providence Range.

In the western basin, most of the material is the waste from the nearby surrounding mountains of middle Tertiary time, but a small part is volcanic pumice, tuffs, and flows. In the Spring Mountains, almost all of the material is volcanic tuffs, breccias, and flows (Table Mountain and the intrusive plug of Devil Peak). In the eastern basin, most of the material is volcanic flows which are locally more than 5,000 feet thick (Black Mountain) but near the base there is a zone of gravels, sand, and clay derived from the nearby older rocks. The local features of the rocks will be presented under these three areal units: (1) the eastern basin, (2) the Spring Mountains, (3) the western basin.

Even though no fossils except a few ostracods have been found in these rocks in this quadrangle, they are considered to be units of the middle Tertiary system for the following reasons:

The basal sedimentary rocks of the western basin lie upon a surface of low relief largely carved on Teutonia quartz monzonite. These relations indicate that a period of profound erosion intervened between the Laramide orogeny and the deposition of the sedimentary rocks of the basin. Over most of the eastern basin, the basal sedimentary rocks largely rest upon a surface of low relief carved upon pre-Cambrian crystalline gneiss.

The sedimentary rocks largely resemble those known within several hundred miles that have been considered from paleontologic evidence to be of Miocene or early Pliocene age. No sedimentary rocks of proven Eocene age are known in the northern part of the Mojave Desert or the southern part of the Basin and Range Province (Woodring, 1931). The nearest rocks determined (from fossils) to be Oligocene are those in Titus Canyon in the Grapevine Range, about 100 miles northwest of Kingston Peak (Stock and Bode, 1935).

Considering structural relations, these rocks were deposited after the Laramide orogeny and a long period of erosion and before a second orogeny that is represented in the western basin by an extensive thrust fault, the Kingston thrust, along which a wide range of rocks, pre-Cambrian crystalline gneisses, pre-Cambrian sedimentary rocks and sedimentary rocks of early Paleozoic age, were thrust upon sedimentary rocks of the western basin. This epoch of thrust faulting is considered to be of middle Pliocene (?) age as it involves rocks determined to be lower Pliocene series in the Avawatz Mountains (Henshaw, 1939).

Another group of sedimentary rocks and volcanic tuffs and flows (Resting Springs formation) appears in the extreme northwestern part of the quadrangle but they rest upon a mature surface carved upon rocks of Paleozoic age that in part are involved in the Kingston Peak thrust faulting. These sedimentary rocks are considered to be early Pleistocene in age (p.102).

VOLCANIC ROCK TYPES

There are many varieties of volcanic rocks of the middle Tertiary series ranging from nearly pure white (rhyolite of Devil Peak) to nearly black (basalts), the color depending on the chemical composition, the state of aggregation, and kind and degree of weathering. The rocks that are low in iron have light colors—gray, brown, and even white; as the iron content increases, the color becomes darker. Fragmental or minutely granular rocks are largely light colored unless the iron content is very high. However, the glassy varieties of most igneous rocks are dark, the most siliceous (obsidian) as well as basaltic glasses.

The fresh volcanic rocks of this area are largely light colored, even though they seem to have been erupted from several centers. They are various shades of light reddish brown, light gray, and nearly white over large areas in the northeast corner (Erie, McClanahan Spring), east central region (Castle Mountains), southeast corner (Hackberry Mountain). Dark to black rocks predominate in several areas (Black Mountain, Piute Range, Halloran Spring). Under the influence of weathering in the desert climate, all varieties of rocks tend to become covered with a thin black film, known as "desert varnish."

Even though the volcanic rocks present a wide variety of colors and textures, only a few rock names are used in this report. These names were largely adopted and used in the field but for many specimens of several varieties, thin sections were studied in the office and some revisions of field terms were made. In addition, several partial and complete analyses were made. (To facilitate an understanding of the volcanic rock problem, the following definitions of the common names applied to these rocks are stated.)

Rhyolite is applied to rocks that contain crystals of sanidine (potash feldspar) and grains of quartz in a five-grained stony or glassy matrix; most varieties are light-reddish brown or nearly white. Dark minerals (biotite, augite, or hornblende) are rare or lacking.

Latite is applied to rocks that contain crystals of striated feldspar (lime-soda), but no quartz, in a fine-grained or glassy matrix; most varieties are light-reddish brown. Some contain sparse plates of biotite mica, but no augite and hornblende.

Quartz-latite is applied to rocks that contain meagre crystals of striated feldspar (lime-soda) and some crystals of quartz in a fine-grained or glassy matrix; the colors are generally light brown or gray.

Andesite is applied to rocks that contain abundant crystals of striated feldspar (lime-soda), meagre dark minerals (biotite, augite, hornblende), and no quartz or sanidine in a stony matrix. The colors commonly range from light to dark gray or green.

Basalt is applied to rocks that contain sparse crystals of striated feldspar, augite, and olivine, in a fine stony or glassy matrix; these rocks are generally dark colored or nearly black.

In most of the areas described below, light-colored rocks that would be called rhyolite or latite predominate; in only a few areas do andesites and basalts predominate. In parts of several areas (Erie, Castle Mountains, Hackberry Mountain), it has been difficult to distinguish confidently at every place in the field between rhyolites and latites. After study of many thin sections of these rocks with several chemical analyses available, it is clear that over large areas the rocks lie in the transition zone between rhyolites and latites. The quartz content of the rhyolites is rarely high, and in places only careful search of what appears to be latite reveals the presence of quartz (or tridymite). As noted elsewhere, latites of Tertiary age in the West, even though the potash content is uniformly higher than the soda content, it is not revealed by the presence of sanidine but seems to be largely if not wholly in the glassy matrix.

EASTERN BASINS

GENERAL FEATURES

Extrusive volcanic rocks and some sedimentary materials underlie large areas in the eastern half of the quadrangle. These areas form an almost continuous belt from the northern boundary along the eastern boundary to the southern boundary of the quadrangle. The hills east of Erie and Black Mountain are wholly made up of volcanic rocks; they form a narrow fringe along the east slope of McCullough Range; they also form the high parts of the Castle Mountains, Piute Range, and Hackberry Mountain and are sporadically distributed in the intervening hills. There are a few patches on the western slopes of McCullough Range and the hills near Crescent; none are found on the western slopes of the New York Mountains, Mid Hills, and Providence Mountains.

The contact of the volcanic rocks and the underlying basement rocks may be observed for many miles along the northern part of the western border of the belt. From Crescent southward the contact is largely concealed by local alluvium; it is exposed for several miles near Vanderbilt, near Gold Valley, the east slope of Providence Mountains, and east of Vontrigger in the southeast corner of the quadrangle. At the northern limit of the belt, the basement is sedimentary rocks of Paleozoic age; in the McCullough Range and Castle Mountains, it is pre-Cambrian gneisses; and near Hackberry Mountain and the low hills to the east, it is quartz monzonite with local areas of pre-Cambrian gneisses. The surface on which the volcanic rocks rest is one of low relief.

Even though they present a wide variety of colors and textures, the volcanic rocks fall readily into a few lithologic groups, which present approximately the same succession in the several areas in the quadrangle. For purposes of description, the following areas are recognized:

Black Mountain area and southern extension as far as McClanahan Spring at the north end of McCullough Range.

Hills east of Erie that merge eastward with the southern extension of Black Mountain Range.

McCullough Range and Lucy Grey Range to the west.

Highland Spring area, east of McCullough Range.

Northern half of New York Mountains and nearby hills east and west of Crescent Peak.

Castle Mountains.

Piute Range.

The hills east of Hackberry Mountain as far as the Leiser Ray mine.

Hackberry Mountain and hills as far west as Providence Mountains.

BLACK MOUNTAIN AREA

Black Mountain presents a rugged escarpment 2,000 to 3,000 feet high toward the valley that lies east of it. Along this escarpment there are good exposures of about 3,000 feet of flows, tuffs, and breccias. By contrast, the west side of the mountain slopes gently westward and merges with remnants of a flat terrace that encircles the south end of Las Vegas Valley. The section along the eastern escarpment is separable into two members, of which the lower is about 2,000 feet thick under Black Mountain and made up largely of reddish-brown andesite breccia. The upper member, 1,200 feet thick under Black Mountain, consists wholly of basalt flows and breccia (fig. 26). The breccia blocks

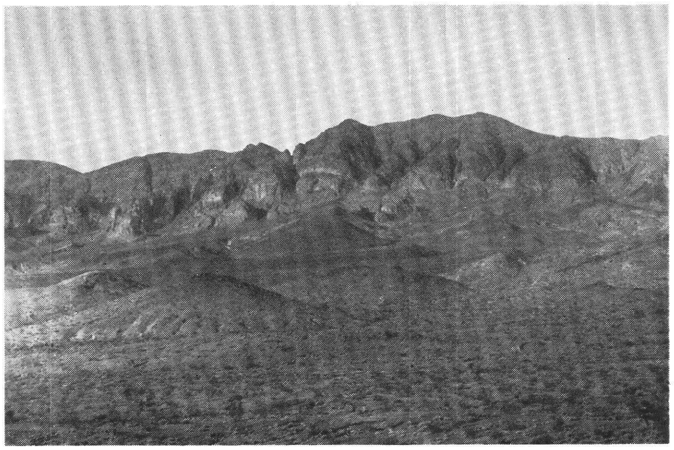

FIGURE 26.—View S. 60° W. toward east face of Black Mountain in T. 23 S., R. 61 E., Nevada.

of the lower member are dark-brown augite-andesite, angular in form, and range from several inches in diameter to 4 by 4 by 5 feet. They are embedded in fine matrix of similar material that is lighter in color. The breccia is indurated so that only the large blocks weather free from the matrix; the present surfaces cut across the smaller blocks. These breccias weather to round forms, and south of Black Mountain they form rugged pinnacles.

The lowest exposed part of the section, 2 miles south of Black Mountain, contains flows of dark-brown dense latite (no. 22, table 5), but this rock appears to be uncommon or lacking in the upper 2,000 feet. Its presence here conforms with the general succession noted throughout the quadrangle, the latites underlie and are earlier than the andesites, which are overlain by the basalts which are younger.

The upper member, 1,200 feet thick under Black Mountain but only 500 feet thick 5 miles north, is an alternating succession of black basalt flows (largely 2 to 5 feet thick though locally 10 feet) and zones of reddish-brown breccia, 5 to 20 feet thick. In section, the flows are lenticular and few are more than several hundred feet long. Viewed from a distance, the section appears to be wholly flows, but they are less than one-third of the thickness. In a specimen (No. 20, table 8) collected 2 miles north of Black Mountain, and therefore near the middle of the member, about half the volume is blades of labradorite and grains of augite and olivine; the other half is a matrix of glass and needles of feldspar.

Traced southward into T. 24 S., R. 62 E., and the northern half of T. 24 S., R. 61 E., the basalt flows of the upper member become thinner and form the flat upper surface of the high part of the range at an elevation of 3,600 to 4,200 feet. In the northern half of T. 25 S., R. 61 E., the basalt flows are only several hundred feet thick and overlie nearly a thousand feet of evenly stratified light-colored tuffs; these replace the lower member of andesite breccias on the east slope of Black Mountain.

The 3,900-foot hill in SE¼ sec. 16, T. 25 S., R. 61 E., shows the following section:

Section measured in SE¼ sec. 16, T. 25 S., R. 61 E.

	Feet
Basalt flows and breccias (upper member)	200
Breccia and cream-colored tuff	400
Dacite flow, weathers brown	100
Breccia, purplish-gray, andesitic	400
Total	1, 100

The following four sections were measured along the southward and westward facing escarpment in the southwest quarter of T. 25 S., R. 61 E.; the fifth was measured on a hill a mile east of the escarpment.

Specimen 29 (table 5) is latite, a dark-brown rock that shows alternate layers of black glass and brown stony material. It contains about 35 percent of crystals of orthoclase, andesine, biotite, and augite as much as 2 mm long. The matrix is glass containing minute microliths. It is latite.

Specimen 28 (table 5) is latite, a brown rock which shows about 15 percent of crystals of orthoclase, oligoclase, and sparse quartz in a brown matrix of glass and sparse minute microliths. Titanite and biotite are present but inconspicuous. In mineral composition, it closely resembles specimen no. 29, below it. It is considered a latite.

Specimen 27, latite tuff, is a light cream-colored fragmental rock without coarse grains or lamination.

Correlation of stratigraphic sections of basal middle Tertiary sedimentary rocks and flows in T. 25 S., R. 61 E

[Thickness of section units is given in feet]

1	2	3	4	5
Basalt				Basalt flow,[1] 60. Basalt brown, 50.
Andesite, platy	Andesite, 100+ platy		White tuffs, 50+ Gray breccia, 50. Dacite flow, 40.	Tuff and breccia, 400.
Rhyolite tuff breccia, 300	White tuffs, 200 Rhyolite flow breccia, 100	White tuffs, 200 Rhyolite flow breccia, 100	White tuffs, 200 Gray breccia, 100. Brown breccia, 75.	Tuff,[2] Breccia.[3]
	Andesite breccia, 50	Tuff, breccia, bentonite, 75.		
			Latite flow, 50	Latite flow.[4]
Total 300+	450	425	565	510.
Base				
Gneiss	Gneiss	Gneiss	?	?

[1] Specimen 26. [2] Specimen 27. [3] Specimen 28. [4] Specimen 29.

1. 3,900-foot hill, sec. 18, T. 25 S., R. 61 E.
2. 4,100-foot hill, sec. 17, T. 25 S., R. 61 E.
3. 4,350-foot hill, SE¼ sec. 20, T. 25 S., R. 61 E.
4. 4,350-foot hill, SE¼ sec. 28, T. 25 S., R. 61 E.
5. 3,700-foot hill, sec. 22, T. 25 S., R. 61 E.

Under the microscope, it is seen to contain 90 percent or more glass fragments with a few percent each of orthoclase, plagioclase and microcline(?).

Specimen 26 (table 8) is basalt, a highly vesicular black rock containing sparse small crystals of feldspar and olivine. Thin sections show labradorite, augite, and olivine in a fine matrix of feldspar and augite.

Structurally, the main Black Mountain Range appears to be the western half of a large anticline. At the north end, the basalt flows strike N. 70° E. and dip 12° N. Southward, the strike of the basalt flows turns first to due south, dipping 12° W. at the crest of Black Mountain and then turns to S. 20° E., dipping 12° SW. at the south end in T. 24 S., R. 62 E. From here south to the ridge that culminates eastward in the 3,900-foot hill, the strike of the basalt flows is about N. 80° W.; the dip is 3° N. This ridge culminates in a south-facing escarpment that marks the location of a 400-foot fault (fig. 27). South of this fault as far as McClanahan Spring, the area is broken by several northward-trending faults, and the flows and tuffs dip northeast to east at 10° to 15°. This dip is flatter, however, than the gneiss surface on which the flows and tuffs rest. On the ridge northeast of McClanahan Spring, the basal tuffs and gravels have the same strike and dip as the surface of the gneiss; strike N. 30° W. and dip 55° NE. (fig. 28). From here northward along the west-facing escarpment, the surface of the gneiss is smooth but shows a relief of about 100 feet in a mile.

From the preceding description of the rocks that underlie Black Mountain Range, their lithologic features and attitude, it is clear that a thick section of breccias and flows, only poorly stratified and with-

FIGURE 27.—View N. 20° W. toward south end of Black Mountain in T. 25 S., R. 61 E., Nevada.

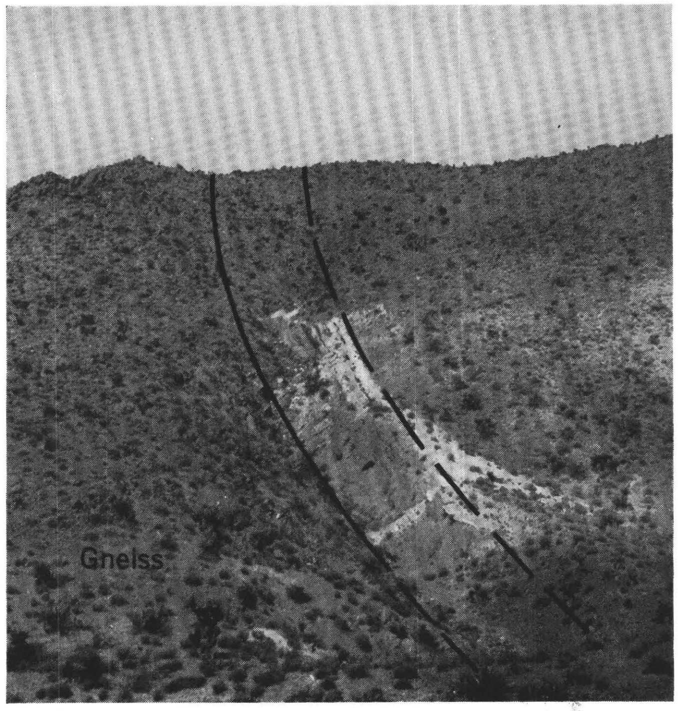

FIGURE 28.—View N. 30° W. toward low rdge in sec. 8, T. 26 S., R. 61 E., showing basal sediments of middle Tertiary section resting on pre-Cambrian gneiss. Nevada.

out any definitely waterlaid varieties under Black Mountain, is replaced southward and probably westward by a few flows in the midst of waterlaid tuffs and gravels that rest upon the pre-Cambrian gneiss surface. The source of these volcanic materials is not known; it can hardly lie in this quadrangle and probably lies in the region to the east. As described below (p. 78), the hills east of Erie and south of Las Vegas Valley are made up of latite flows, unlike any in the Black Mountain section except a single flow at the base. Furthermore the basalt flows near the top of the Black Mountain section overlap the latite flows that lie to the west.

The most plausible interpretation of the regional relations of these rocks, is that the andesite breccias and basalt flows, over 3,000 feet thick, that underlie Black Mountain Range were derived from sources east of the area under study and filled up a great depression that extended generally northward. The tuffs northeast, north, and northwest of McClanahan Spring were laid down by streams in intermittent layers against the low hills of gneiss that formed the western border of the depression. Only a few of the basalt flows of the Black Mountain section extended westward to the hills that bounded the depression on the west.

HILLS EAST OF ERIE

The group of hills east of Erie that form a semicircular ridge, culminating in the 4,014-foot hill on the west and the 3,830-foot hill on the east, are made up largely of latite flows. By contrast, the hills to the south, which nearly surround the 3,000-foot depression, are made up of light-colored tuffs and breccias capped by basalt flows which are the western extension of the rocks that underlie Black Mountain. The 3,830-foot hill is capped by basalt flows that overlap the latite flows to the north and thus determine their relative ages.

Four specimens of the latite flows (37, 39, 42, 43, table 5) have been examined under the microscope; a complete analysis of one (no. 37, p. 92) and a partial analysis of another (no. 43) have been made (p. 92). The most common rock is pale gray or pale-reddish brown and shows conspicuous blades of biotite and sparse feldspar in a fine-grained groundmass (fig. 29).

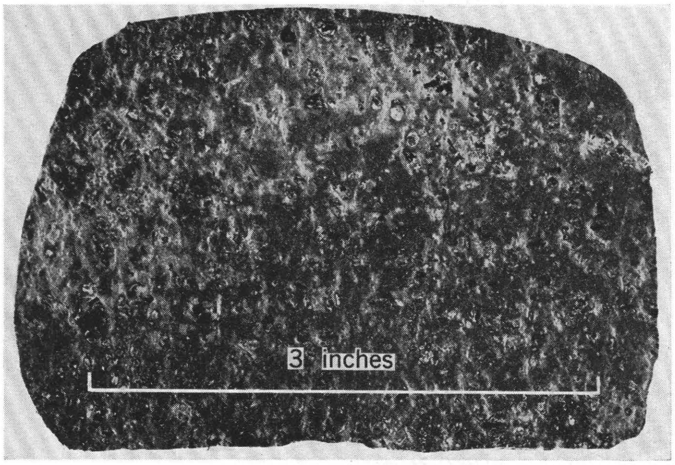

FIGURE 29.—Photograph of a specimen of latite, hills east of Erie, Nev.

Other varieties show darker colors, but biotite is persistently present and feldspar is only locally conspicuous. The mineral composition of the four specimens is shown in table 5. Through differences in color individual flows may be identified and traced locally. By the attitude of the flows, three domal areas may be identified: that which culminates in the flat-topped hill (3,900 feet) a mile southwest of the 4,014-foot hill; the group of hills (about 3,900 feet) in sec. 6, T. 24 S., R. 61 E; that which culminates in secs. 2 and 3, T. 24 S., R. 61 E. The flow that is horizontal on the crest of the first dome dips as much as 40° south on the south slopes of the hill and nearly as steeply on the west and east limbs. On the second dome, the flows dip 20° W. on the west slope and 20° SE. on the south slope. The crest of the third dome coincides with a depression carved in tuffs and breccias under a latite flow that dips 10° N. on the north limb and as mnch as 15° E. on the east limb. A satisfactory explanation of these domes cannot be offered; neither is the explanation of the circular valley surrounded by the three domes apparent. A few normal faults are recorded in the domal areas to the north and others in the hills to the south, but they do not appear to have any close relation to the present valley.

The rocks that underlie the latite flows are exposed in only one area, sec. 29, T. 23 S., R. 61 E., where several members of the Monte Cristo limestone crop out, having a northwest strike and northeast dip.

In two areas between Sloan and Jean, flows that crop out inconspicuously are shown clearly in railroad cuts. The most extensive flow, which crops out irregularly for 2 miles south of Sutor, is latite, but it is unlike the other bodies of latite that lie about 4 miles northeast (no. 39, table 5). This latite is a mottled light-brown rock that contains conspicuous crystals of orthoclase and fragments of a darker but similar rock. Thin sections show about 20 percent of phenocrysts (orthoclase, oligoclase, and biotite) in a groundmass of glass and minute lithophysae. The thickness of the flow cannot be great, as hills of limestone of Paleozoic age crop out nearby to the north, west, and south. The source of the flow is unknown.

The second area lies a mile north of Erie, and it, too, must be thin, as hills of limestone of Paleozoic age crop out nearby. In sec. 2, T. 24 S., R. 60 E., a railroad cut exposes light-colored tuffs and breccias. The fine tuff contains sporadic fragments of red and brown vesicular flow as much as 1 inch in diameter. The tuff contains sparse grains of quartz and biotite; it is probably rhyolite.

Other small areas of flows lie along the railroad about 4 miles north of Erie and a mile east of Sloan. The first is a thin flow of vesicular basalt and the second, dense basalt that overlies brown biotite-bearing latite much like that south of Sutor. Most of the second flow lies northeast of the extension of the Sloan fault.

The sources of the latite are probably the same as those that yielded the flows east of Erie, but they are not known. The source of the basalt is probably local, but it is unknown.

McCULLOUGH RANGE AND LUCY GREY RANGE

For a distance of 12 miles the lower east slopes of McCullough Range are underlain with a sheet of gravels, sand, tuff, and flows, and the contact with the underlying gneiss may be observed most of this distance The basal 500 feet or more of beds of the Tertiary system, exposed east and northeast of McCullough Range, closely resembles the basal sections exposed from McClanahan Spring north and west for 6 miles (p. 76), but the succeeding 3,000 feet or more, most of which is exposed in the Highland Spring Range, is unlike the Black Mountain section (p. 75).

The section in sec. 23, T. 27 S,. R. 61 E., is shown in the following table as well as those at the northeast end of the Lucy Grey Range and near McClanahan Spring.

The andesite flow which caps the ridge in the McCullough Range (specimen 16) is a dark gray slightly vesicular rock with conspicuous augite crystals and sparse feldspar. An estimate of its mineral composition is given in table 7.

The strike and dip of the beds along the east slope of McCullough Range indicates an anticline that plunges gently 70° E. and is shown in the Highland Springs Range. For the entire distance from the low ridges east of McCullough Range northeast 12 miles to McClanahan Spring, the dip of the tuffs and gravels as well as their contact with the underlying granite gneiss does not depart much from 35°. This is a measure of the deformation of the middle Tertiary rocks of the area.

The Lucy Grey Range lies about 6 miles west of the McCullough Range and, like it, trends nearly due north. Two areas of gravels, tuffs, breccias, and flows are exposed along the east slope; the southern area, about 4 miles long, lies east of the Lucy Grey mine; the northern, about 3 miles long, lies east of the 5,613-foot hill. Several hundred feet of basal sand, gravels, breccia, and flow is exposed in the northern area resting on granite gneiss (Lucy Grey Range, table 3). In this area, the strike of the beds and flows is S. 10°–25° E. and the dip is 35° E., parallel to the contact with the underlying granite gneiss. The gneiss surface is almost a plane and the rock shows a shallow zone of weathering. The rocks that make up this section, their attitude, and the character of underlying surface in this area closely resemble the features of the section on the east slope of McCullough Range about 8 miles east and form the basis for the assumption of an extensive normal fault with about 20,000 feet dip displacement between the two ranges.

A mile south of the ridge where this section was measured, due east of the 5,613-foot hill, the same rocks occur, except that a flow of latite (p. 91, specimen 36) intervenes between the andesite flow above and the sand and gravel that rest on the granite gneiss. The andesite flow at the top of the section (specimen 167) is a dark-gray rock, not visibly vesicular; the mineral composition is shown in table 7 on page 93. It resembles andesite 6 miles north (specimen 35); near the McClanahan Spring (p. 93, specimen 30) and east of McCullough Range (table 7, p. 93, specimen 16).

East of the Lucy Grey mine conditions are different. From hill 5,020 south, the rocks are largely andesite flows, breccias, and tuffs that strike generally northeast and dip south but they are in fault contact with the granite gneiss to the west. The base of the section is not revealed in this area. The following section was measured on the hill south of the 5,020-foot hill.

Section measured on hill in T. 27 S., R. 60 E.

	Feet
Andesite flow, dark-gray (specimen 167)	50+
Andesite, augite, flow Gravel, thin bedded, largely gneiss Andesite, augite, flow Tuffs, light-colored, thin-bedded Andesite, augite, flow Breccia, green and reddish	500
Total	550+

Obviously the structural situation in this area is complex. The blocks of flows are not only dropped against the granite gneiss on the west, but the strike of the flows lies across rather than parallel to the length of the blocks and the range. In their broader aspects,

TABLE 3.—*Correlation of stratigraphic sections of basal middle Tertiary sediments and flows*

a	b	c
Andesite flow,[1] 40 ft	Andesite flow, caps ridge [2]	Andesite flow, pale-reddish, 25 ft.
Breccia, andesitic, evenly stratified but not well sorted; coarsest material 5 in. in diameter, 80 ft	Breccia, andesitic, largely vesicular andesite, fragments as large as 2 x 3 x 4 ft, 100 ft	
	Tuff, white, fine, well-stratified, coarsest material about 2 in. in diameter, 100 ft	Tuff, white, fine, 6 ft.
Sand and gravel, arkosic at base; gravel zones are arkose, limestone, and schist up to 2 in. in diameter, 20 ft	Breccia, andesitic, gray, and reddish; coarsest material about 6 in. in diameter, 80 ft	Gravels arkosic thin layers of pebbles, limestone, and dolomite as large as 6 in. in diameter, 15 ft.
Total, 140	280	46.
Base		
Gneiss	Gneiss	Gneiss.

[1] Specimen 35.
[2] Specimen 16.
a. Lucy Grey Range, sec. 4, T. 27 S., R. 60 E.
b. McCullough Range, sec. 23, T. 27 S., R. 61 E.
c. McClanahan Spring, sec. 9, T. 26 S., R. 61 E.

these areas of flows on the east slope of Lucy Grey Range and those on the east slope of McCullough Range indicate the presence of an enormous fault in the valley between these two ranges. A cross section (*0–0′*) through these ranges indicates that the Lucy Grey Range has dropped about 20,000 feet with respect to the McCullough Range.

This 550-foot section of breccias and flows resembles parts of the section in the Highland Spring Range (below) more than any other in this region.

HIGHLAND SPRING AREA

The range in which Highland Spring is located is made up wholly of volcanic rocks. The basement upon which they are laid is not revealed, but, as there is no reason for suspecting the presence of a fault in the valley west of the range, it is assumed that the section is continuous downward with that exposed on the east slope of McCullough Range. The following section was measured on the west slope of hill 4,895, in sections 17, 16, 9, 10, T. 27 S., R. 62 E.:

Section of the Highland Spring region (hill 4,895)

	Feet
Crest of hill 4,895	
Andesite flow, gray; weathers brown	200
Andesite tuffs, greenish, thin-bedded	200
Andesite flow, gray; weathers brown	80
Andesite tuffs	250+
Andesite flow, greenish-gray	250
Andesite flow, purplish-brown; red scoria at top	70
Tuffs and breccias, yellowish	100
Andesite, gray, weathers reddish, forms ridge	150
Breccias, reddish	150–200
Andesite, augite (minor hornblende, biotite); has few cavities near top ½ to 2 in. in diameter, lined with quartz crystals; lower half is much jointed, and weathers to round pebble-like fragments; weathers gray; forms cliff under 4,900-ft hill	350
Total	1, 800–1, 850+

The flows and tuffs strike north and northeast and dip east and southeast at 10° to 15°. Locally, southeast of Highland Spring, their attitude confirms the extension southeastward of the anticline that was recorded east of McCullough Range (p. 94). The southwestern part of the range is covered with a great sheet of coarse alluvium.

NEW YORK MOUNTAINS AND CRESCENT PEAK

An area on the east slope of the New York Mountains from Malpais Spring southwest 7 miles to Vanderbilt, in underlain by andesitic breccias and minor flows that in turn rest upon pre-Cambrian gneiss and schist. Sporadically in this area there are small lenses of sand and gravel made up of granitic debris that lie between the gneiss and the volcanic material above. In places, these lenses are as much as 25 feet thick, and are composed of fairly well stratified sand and gravel, the pebbles ranging in size from less than 4 inches in diameter to as much as 10 inches. Clearly, it is material of local origin that fills channels in the gneiss surface.

The material that underlies the 5,700-foot hill west of Malpais Spring is typical of a large area. The hill is capped by 150 feet of rudely stratified dark reddish-brown to black andesite breccia, most of the fragments of which are less than 1 foot in diameter but some are 4 by 5 by 6 feet. A typical specimen is a dark-gray slightly vesicular rock containing sparse blades of feldspar; the mineral composition is given in table 7, no. 155. East of Malpais Spring a thin flow of light-brown latite (rhyolite?) was observed, but light-colored tuffs such as occur north of McCullough Mountain are not present. The strike of the breccias is generally northeast and the dips are low to the southeast, attaining a maximum of 20°. Observations in this area indicate that the relief of the underlying surface of erosion ranges from 400 to 600 feet to the mile along the northeast strike of the belt.

About 2½ and 4 miles southeast of Nipton there are two ridges that are partly underlain by volcanic rocks. On both ridges the rocks are rudely stratified andesitic breccias and flows, dark reddish brown and greenish and vesicular. The layering strikes northeast and dips 10° to 15° SE. The character of the rocks and their attitude are similar to those observed on the east slope of the Lucy Grey Range. The distribution of the areas of volcanic rocks and the attitude of the underlying gneiss surface indicate the presence of normal faults along most of which the west side has dropped 100 feet or more.

CASTLE MOUNTAINS

Like the Highland Spring Range region 15 miles north, the Castle Mountains form a topographic unit and are made up largely of rocks that are unlike those which form the nearby mountains. The Castle Mountains area is largely rhyolite, a flow and breccia near the base, overlain by a single flow of andesite; rhyolite flows form the crests of ridges and peaks. These rocks rest on a flat surface carved on granite gneiss that is well exposed in a triangular area 3 miles long, in the northeast part of the mountains. As fragments of gneiss lie on the dump of the Oro Belle shaft, reported to be 600 to 700 feet deep, at the southwest end of the mountains, this rock probably underlies the entire mountain mass at shallow depth. Where it may be examined in the northeast part of the area, the granite gneiss surface has a relief of several hundred feet to the mile.

West of Lewis Holes, the lowest unit of the section is a pale-reddish flow of rhyolite, 10 to 25 feet thick, overlain by 300 feet of reddish to dark-brown scoriaceous andesite flow that is overlain by 200 feet of pale-yellowish, thin-bedded tuff and a pale-brown rhyolite flow 200 to 300 feet thick (specimen 162, table 4, fig. 30), which forms a cap under Hart Peak (5,515 feet). In the area northwest of the outcrop of granite gneiss, all these flows and tuffs strike generally northeast and dip 15° to 25° NW. Southeast of Lewis Holes, the four units mentioned above strike generally northeast and east but the dip averages 50° SE. and locally attains 60° (sec. *P–P′*). The rhyolite flow (unit 4) is overlain, however, by 1,000 to 1,500 feet of reddish and brown breccias (unit 5) and tuffs; and this, by basalt flows that extend southward and form the flat top of the northern part of Piute Range. Specimen 163, table 8, shows the mineral character of this rock.

The attitude of the rocks in the Castle Mountains area, indicate an asymmetric anticline that strikes about S. 45° W. and plunges southwest about 250 feet to the mile. The folding has involved both the surface flows and the basement granite gneiss, much the same as recorded above on the east slope of McCullough Range. Minor faults appear north of Heart Peak and near the town of Hart.

The basalt flows of the northern 4 miles of Piute Range are nearly horizontal as far as the southeast slopes of the Castle Mountains, where the dip abruptly increases to 25° SE. The relations indicate that the folding which produced the Castle Mountains anticline began after the deposition of the rhyolite tuffs and flows on a nearly horizontal surface of granite gneiss and probably late in the period of the deposition of the basalt flows of Piute Range. There is no evidence however of a great unconformity between the early rhyolites, andesites and late basalts of this region.

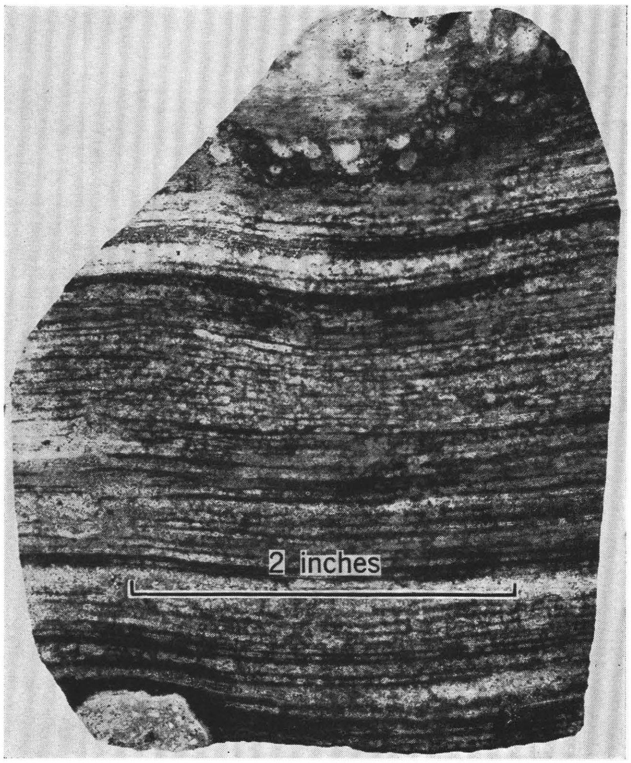

FIGURE 30.—Photograph of a specimen of rhyolite, Hart Peak, Calif.

The mine workings near the abandoned town of Hart, several thousands of feet of tunnels, shafts and drifts, are wholly in rhyolite flows, breccias, and tuffs, somewhat altered near the veins that were explored (p. 161–162).

PIUTE RANGE

Piute Range is a simple monoclinal block about 14 miles long and scarcely 2 miles wide. On the north it merges with the Castle Mountains. The southern terminus may be regarded as the ravine through which the old road to Fort Mohave passes. Piute Spring, the largest in the region, lies in this ravine a short distance east of the quadrangle.

Piute Range is made up of nearly horizontal flows and breccias that range from latites at the base to basalt at the top. The following section was measured in secs 13 and 14, T. 13 N., R. 18 E.:

Top.	*Feet*
1. Olivine basalt flows, columnar jointing. Four distinct flows, each with scoriaceous top; some bombs (specimen 138f, table 7)	300
2. Breccia, with thin zones of sand and gravel	50
3. Latite flow, brown, like unit 6	150
4. Breccia at base, with stratified gravels of granite, aplite, quartz, limestone, and older flows; maximum pebbles 4 to 5 in	100
5. Obsidian, gray, (specimen 138b, c, table 7)	50
6. Latite flows, platy (specimen 338a, table 6)	200
7. Breccia, stratified, largely obsidian	100
Total	950

Observations along the north end of the range indicate that most of this section lies above the andesitic breccias (unit 5) of the Castle Mountains section, southeast of Lewis Holes.

These flows are essentially parallel and, for at least 8 miles, the strike is slightly west of north and the dip several degrees east, so that along the west-facing escarpment the outcrops of the flows gradually rise southward. Two faults with northeast strike cross the range; along them the southeast block drops about 250 feet.

At the south end of the range, the two ravines north and south of the 3,789-foot hill mark zones of faults that trend west of north and dip 45° W. Along each the southwest side has dropped several hundred feet.

South of the ravine through which the road passes the hills are wholly basalt flows that strike about N. 70° E. and dip about 5° NW. (specimen 136, table 8).

The four isolated hills near the center of Lanfair Valley are wholly made up of brown latite flow. The mineral composition is shown in table 6, specimen 137.

HILLS EAST OF HACKBERRY MOUNTAIN

The two groups of hills, each about 5 miles in diameter, that rise above the plain east of Hackberry Mountain have similar geologic features. Upon a surface of low relief carved on a basement of quartz monzonite and pre-Cambrian gneiss there are sporadic caps of basalt generally without much if any waterlaid sand, gravel, or tuff intervening (section *S–S′*). Only two specimens have been examined closely (specimens 131, 156, table 8) but as the rocks have similar color and texture throughout the two areas, they are probably much alike and derived from similar nearby sources if not the same source. All are dense black flows with only sparse scoriaceous phases. They contain small sporadic feldspars (labradorite (An_{60})) in a dense black groundmass. The mineral composition is shown in table 8.

In the hills, 1 mile northwest and 2 miles northeast of benchmark 3,355 (near Leiser Ray mine), basalt flows rest upon a surface of low relief carved on quartz monzonite with only sporadic arkosic sands intervening. These flows appear to dip gently south and, with the basalt-capped hills farther northeast, indicate a low anticline that strikes about N. 60° E. Specimen 131 (table 8) appears to be typical of the basalts of these hills. The hill that lies about 2 miles southeast of benchmark 3,355 is also capped with basalt flow and scoria that rest upon a surface carved on granite gneiss and dip 10° N.

The hill (4,300 feet) in sec. 36, T. 12 N., R. 17 E., about 3 miles east of Blackburn is capped with the following section:

Top	*Feet*
Basalt flow (no. 156, table 8)	150–200
Obsidian, gray	5– 10
Tuff, white, mostly without bedding; contains several thinly bedded layers	60
Sand, arkosic	1– 2
Total	216–272

Base: Granite gneiss.

This hill is limited on the northwest by a fault, strike N. 45° E., along which on the northwest side, the base of the section (given above) is offset 500 feet southwest. On the hill, the outcrops of the basalt flow form a broad arc; the strike on the west end is N. 50° W. and the dip is 25° NE.; on the east end of the hill, the strike of the flow is N. 30° E. and the dip is 15° NW.

The two hills that lie east and west of Vontrigger Spring (secs. 10 and 11, T. 11 N., R. 17 E.) are formed of rudely stratified tuffs and breccias of rhyolitic composition and appear to be related to the volcanic field that lies west of Hackberry Mountain (below). These rocks are nearly horizontal and younger than the basalt flows that cap the hills several miles northeast and east (above).

HACKBERRY MOUNTAIN AND HILLS EAST OF PROVIDENCE MOUNTAINS

These hills, within an area roughly 5 by 18 miles, contain the most extensive outcrops of a few varieties of volcanic rocks known in the Tertiary system of this quadrangle. As similar rocks underlie Pinto Mountain and Table Mountain, it seems probable that these rocks were once much more extensive, probably covering an area about 15 by 20 miles and maybe even more. A reconnaissance south of the quadrangle indicates that similar rocks extend at least 20 miles farther in this direction.

The name "Pinto Mountain" is applied locally to the flat-topped hill (6,000 feet) at the head of Cedar Canyon in the Mid Hills, about 2 miles north of Government Holes. It rises about 800 feet above the surrounding flat surface that is eroded on quartz monzonite. The following section was measured at the southwest end of the mountain:

Pinto Mountain section

	Feet
Rhyolite, massive flow	10
Rhyolite, platy, columnar flow	25
Rhyolite, platy, merges upward	15
Rhyolite tuff, welded, pale-brown, columnar (specimen no. 125a)	15
Tuff, rhyolite, creamy gray, sparse bedding, coarsest fragment 1 in	95
Rhyolite, flow, resembles the 75-ft flow at base of section but more vesicular	75
Tuff, rhyolite, unstratified	170
Tuff, stratified, crossbedded	20
Tuff, cream; sparse unsorted fragments of rhyolite up to 2 in	150
Limestone, pale brown, dense, mottled with white calcite (specimen no. 125b)	32
Limestone, cream, dense, faintly laminated (specimen no. 125c)	12
Concealed, probably tuff	15
Rhyolite flow, pale-reddish, weathers dark brown; slightly vesicular at base, more so higher	75
Tuff, rhyolitic	50
Total	759

Base of section.

Viewed in thin section, specimen 125–a is rhyolitic welded tuff showing sparse orthoclase in a glassy base; it contains sparse fragments of a similar rock. Specimen 125–b is completely soluble in cold dilute hydrochloric acid and leaves no residue. Specimen 125–c, likewise, is completely soluble in cold dilute acid and leaves no residue. These two specimens are therefore rather pure limestone.

Table Mountain (6,100 feet) about 5 miles south of Pinto Mountain, is underlain by 60 feet of columnar rhyolite flow which is much like that which forms the top of Pinto Mountain. Under the flow is 200± feet of well-stratified white tuff that lies on a flat surface cut on quartz monzonite. Clearly, the 260 feet of volcanic material rests upon a hill of monzonite that was about 500 feet higher than the base of the Pinto Mountain section. This gives an idea of the local relief of the monzonite surface when the volcanic rocks were extruded.

Hackberry Mountain as well as the group of hills that lie west of it as far as the eastern slope of Providence Mountains are underlain by rhyolite flows, breccias and tuffs that closely resemble the rocks that form the Castle Mountains mass. Curiously, these rhyolitic rocks have no counterpart in the hills that lie east of Blackburn and Vontrigger. The basement upon which these rhyolitic rocks rest is exposed at only one place, in and near an open cut at the Getchel (Crater) mine, 2 miles west of Vontrigger (p. 162). Here, a rhyolite flow breccia rests upon granite gneiss and schist intruded by alaskite dikes. It appears that the entire mass of Hackberry Mountain north and west of Blackburn rests upon similar pre-Cambrian gneiss and possibly some intrusive quartz monzonite. Here, the surface of contact has low relief.

Only three varieties of rock appear in the area between Hackberry Mountains and Providence Mountains; rhyolite flow breccia which contains the veins at Getchel mine, welded rhyolite tuff and rhyolite flows. Where exposed on the east slope of Hackberry Mountain, the flow breccia is light brown, and contains conspicuous phenocrysts of orthoclase and many small angular light-brown fragments disposed in wavy zones; no quartz was observed. The flow breccia appears to have formed a mound several hundred feet thick upon which the other rocks were laid; it does not crop out on the north, west, and south slopes of the mountain. The flow breccia is overlain by 250 to 300 feet of nearly white, well-laminated rhyolite tuff and this is overlain by several hundred feet of light-reddish brown welded rhyolite tuffs that form the surface of much of the north, west, and south slope of the mountain. On Hackberry Mountain these flows and tuffs strike uniformly east and dip gently north on the north side and south on the south side of the mountain, so that the mountain reveals an anticline much like that in the Castle Mountains. On the top of the mountain, the tuffs dip 5° N., and farther north they dip successively 10°, then 15° along the north base. In the low hills that extend south from the mountain to the border of the quadrangle, the tuffs depart slightly from the simple pattern and strike generally north and dip 5°–10° E.

An area about a mile in diameter on the east slope of Hackberry Mountain contains many small gold-bearing chalcedonic veins (Getchel Camp) similar to those on the south end of Castle Mountains (Hart district, p. 161).

The cluster of hills about 3 by 4 miles that lies west of Hackberry Mountain is made up of the same rocks but their local distribution and attitude indicate that the central 4,700-foot hill is a volcanic neck that probably was the source of the surrounding flows and tuffs. The highest breccias crop out in a circular belt and dip inward. The flows and breccias outside the circular belt dip consistently away from the central area. The prevailing flow is a light-brown rhyolite whose features are shown in table 4 (no. 141 b); they are very similar to those of no. 162 (table 4) in Castle Mountain (fig. 28). These hills suggest that the anticline in Hackberry Mountain extends westward.

One flow (no. 141–a, table 4) that crops out on the highest hills displays some uncommon and interesting features. More than half the rock is gray spherical lithophysae, ranging from ¼ to 1 inch in diameter, embedded in a brown matrix of minute lithophysae. A few phenocrysts of orthoclase are scattered through the brown matrix and a few are embedded in the gray lithophysae, which appear to have grown at the expense of the matrix. Each gray sphere is covered with a layer of small white lithophysae (fig. 31).

The flat-topped hills that lie west of the cluster of hills just described, as far as the east slope of Providence Mountains or about 10 miles, are underlain by well stratified rhyolite tuffs and flows that are the western extension of those that cap the west and north slope of Hackberry Mountain. The northward- and eastward-facing escarpments that limit these flat-topped hills show alternating layers of light and dark rocks, which, from a distance, appear to be volcanic flows. On close examination, as shown by the following section, the layered rocks are almost wholly tuffs and tuff-breccias that show several degrees of hardness; only the two top layers of the 1,000 foot section are flows. The dark layers are welded tuffs that resist erosion and form cliffs; the light layers are only weakly cemented and therefore weather to smooth slopes (section *R–R′*).

The following section was measured by Ward C.

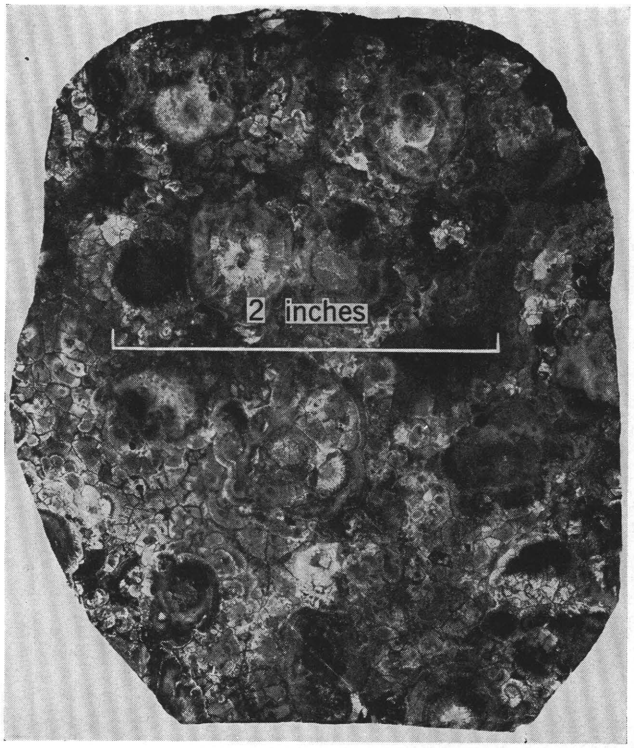

FIGURE 31.—Photograph of a specimen of sperulitic rhyolite, Hackberry Mountain area, California.

Smith on the northwest slope of the ridge that lies 2 miles southeast of Gold Valley Spring:

Section on ridge 2 miles southeast of Gold Valley Spring

Top of hill	*Feet*
Rhyolite flow, thinly laminated (no. 191–14)	75
Obsidian, black; forms cliff	25
Pumice, white	25
Rhyolitic tuff, light-brown, forms cliff	150
Rhyolitic, welded tuff, dark-brown (no. 191–9)	65
Rhyolitic welded tuff, columnar jointing	25
Rhyolitic tuff, cavernous	15
Pumice, white with sporadic pebbles of metamorphic rock	50
Rhyolitic welded tuff, dark-brown; forms cliff	125
Rhyolitic welded tuff, reddish-brown (no. 191–2)	140
Rhyolitic welded tuff, obsidian grains	50
Total	745
Base of hill.	

Brief examination indicates that the higher layers of tuffs and flows are roughly the equivalent of those which underlie the flat ridge on the north and west slopes of Hackberry Mountain and the cluster of hills that lie west of them. Similarly, they closely resemble the tuffs and flows that make up the sections at Pinto Mountain and Table Mountain. However, the Pinto Mountain section, 8 miles north, contains two beds of nearly pure limestone that were not observed elsewhere in the region.

It seems certain that the depression in the high part of the hills 3 miles west of Hackberry Mountain marks the source of a large part of the tuffaceous material found as much as 8 miles west and north, and it may have been the principal source of such material in this entire area. The material spread outward as far as the ancestral Providence Mountains, Mid Hills and New York Mountains. It is surprising that remnants of such tuffaceous materials are not found in any of the hills east of Vontrigger Spring. The white tuffs under the basalt flows in the area 6 by 8 miles square east of Vontrigger Spring resemble the rhyolite tuffs to the west, but the thickness is much less and they are conformably overlain by basalt flows not known west of Vontrigger Spring.

If, as it appears, the crater west of Hackberry Mountain was the source of a large part of the layered tuffs and flows in this area, they must have had initial dips outward from the source. The recorded dips, however, depart from such a simple pattern. The eastern half of the area reveals a pronounced anticline and the western half shows persistent southeastward dips at low angles. These departures from simple pattern must indicate the deformation that the beds have undergone since they were laid down.

SPRING MOUNTAINS AND NEARBY HILLS

Volcanic rocks have been recognized in the following areas that are in or near the Spring Mountains: the Valley Ridge at the north end of Mesquite Valley, 3 miles west of the Green Monster mine; Table Mountain southwest of Goodsprings, Nev.; the Sultan mine area; and the Devil Peak area.

VALLEY RIDGE

Sedimentary rocks of volcanic origin are shown at one locality on the northeast side of Mesquite Valley but are not known on the southwest side of the valley. The best exposures are on the lower slopes of a prominent ridge (Valley Ridge) in secs. 5 and 6, T. 24 S., R. 56 E.; it lies 3 miles west of the Green Monster mine. The high part of this ridge, about 2 miles long, is a canoe-shaped block of Monte Cristo limestone about 8,000 feet long and 900 feet thick; strike of the bedding is N. 70° W., dip 60° NE.

The sedimentary rocks that underlie this block of Monte Cristo limestone are thinly laminated tuffs, exposed in a number of ravines on the south slope and at places in the north slope of the ridge. Viewed in thin section under the microscope, the rock shows angular grains of orthoclase, 30 percent; plagioclase, 5 percent; quartz, 10 percent; biotite, 5 percent; volcanic glass, 20 percent; grains of calcium carbonate, 30 percent. The rock is latitic ash and grains of carbonate cemented by carbonate. The low western extension of this ridge has many outcrops of tuff, calcareous tuff, magnesite, and a pale-brown latite flow; they strike N. 60°–80° W., and dip 45°–60° N.

The contact of the limestone with the tuffs is shown in many ravines on the south side of the ridge and at places on the other sides. The surface on the south side is nearly a plane which, for several thousand feet, strikes N. 70° W. and dips 65° NE.; the surface has shallow grooves and striae that pitch 30° SE. (fig. 32). At a few places irregular small blocks of limestone have been plucked out of the main block and the recesses are now filled with crumpled tuff similar to that under the main block. On the east end of the ridge, the contact is not exposed fully at many places, but prospect tunnels (probably made in search of borates) have been driven in the steeply dipping tuff under the limestone. Exposures of tuff on the north side of the ridge and west end, show clearly that the block of limestone is canoe shaped and rests upon steeply dipping tuff. The nearest outcropping belt of Monte Cristo limestone extends along the ridge near the Green Monster mine 3 miles east.

TABLE MOUNTAIN

Table Mountain lies about 3 miles southwest of Goodsprings. It is essentially a flat-topped plateau at an altitude of about 5,000 feet, even though it is dissected by several deep ravines (Hewett, 1931, p. 40). It is underlain by a single flow of dark-gray vesicular andesite that overlies sporadic sheets and lenses of andesite breccia and tuff. As these lenses dip inward toward the central area, both breccias and flow are assumed to be derived from a vent under the mountain. The rock is a common variety of andesite with sparse small phenocrysts of oligoclase and hornblende in a glass matrix. If, as indicated, these rocks had a local source, it is surprising that other bodies of similar rocks are not found nearby. The flow that forms the top of Table Mountain does not appear to have been disturbed since it was laid down.

A dike of basalt was found in sec. 30, T. 24 S., R. 58 E., about 4 miles west of Goodsprings, Nev. From the alterations shown in the adjacent rocks, it is probably related to the Laramide intrusions, however.

SULTAN MINE AREA

In a valley on the west slope of Spring Mountains, only a mile southwest of Table Mountain, an area of about 200 acres is underlain by several hundred feet of latite flows, tuff, and breccia that appear to have been derived from a local vent in the hills to the southwest. These flows and tuffs lie on a surface of low relief carved in limestone of Paleozoic age, and they dip consistently northeast toward Table Mountain at 22°–30°; whatever may have been their initial dip, they have probably been tilted northeast since deposition.

In appearance and mineral composition the uppermost flow (Hewett, 1931, p. 40) is almost identical with that which lies southeast of Devil Peak (p. 86), and east of Erie (no. 42, table 5), and closely resembles the rhyolite flows of Castle Mountains and Hackberry Mountain (nos. 62 and 141b, table 4).

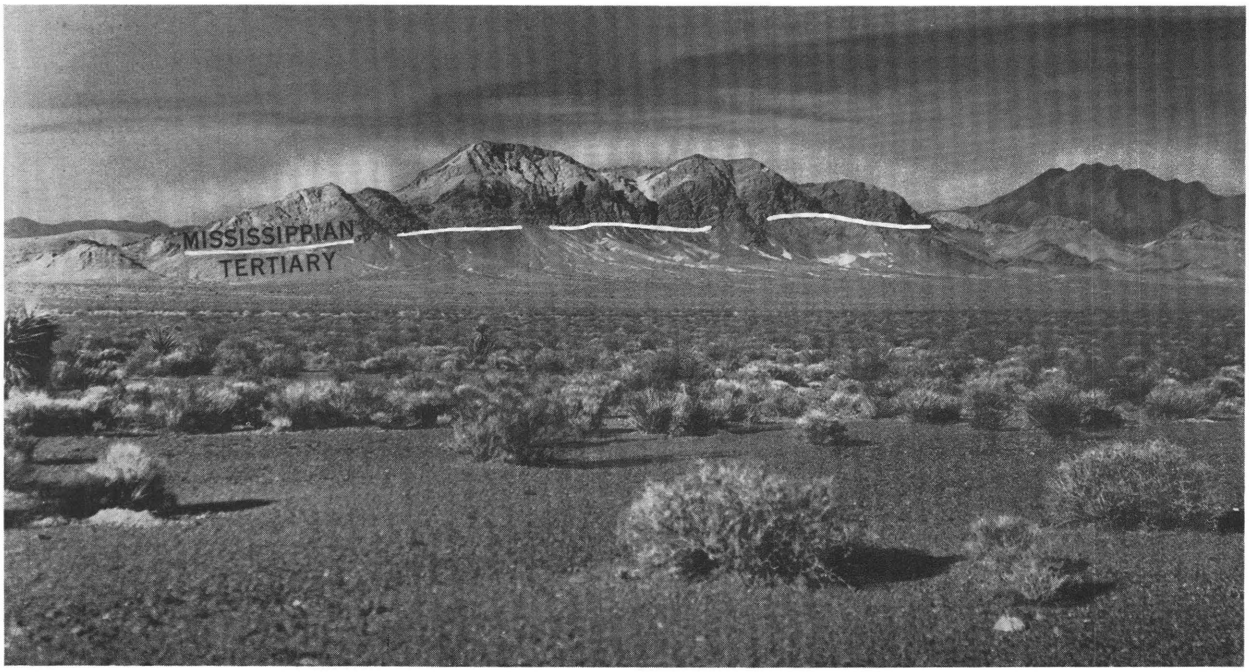

FIGURE 32.—View N. 30° W. toward ridge at north end of Mesquite Valley, showing block of limestone of Mississippian age thrust upon sediments of middle Tertiary section, Nevada. (Photograph by Eliot Blackwelder.)

DEVIL PEAK AREA

Devil Peak (5,865 feet) coincides with the center of a rhyolite plug, roughly elliptical in outline, about 7,000 by 11,000 feet. Most of the mass is a dense light-gray stony rhyolite, parts of which show wavy lenticular vesicles. Hand specimens show no identifiable minerals; under the microscope, the texture is microgranular and grains range from 0.02 to 0.06 mm. in diameter. The principal mineral is orthoclase but there are sparse grains of sodic plagioclase, biotite, and quartz. According to partial analysis by J. G. Fairchild of the Geological Survey, the rock contains silica, 73.58 percent; CaO, 0.05 percent; Na_2O, 2.99 percent, K_2O, 5.52 percent.

The northern border of this intrusive body is in contact with beds that range from the Goodsprings dolomite to the upper part of the Bird Spring formation. These rocks are bleached and altered to dolomite for a distance of about 100 feet from the contact. By contrast, between the stony rhyolite and the beds of the Bird Spring formation which limit the rock on the south, there are zones of stratified tuffs and obsidian, both dipping inward toward the neck. Next to the limestones of the Bird Spring formation, there is a zone of white tuff-breccia about 30 feet thick and next to this a zone of black rhyolite obsidian 10 to 50 feet thick, which merges with an irregular zone of reddish flow breccia. These flows, breccias, and tuffs dip inward toward the center of the plug at angles that range from 30° to 50°. From these rocks and their relations, it would appear that there was first an explosive crater in nearly horizontal limestones of Paleozoic age and it was later filled by the stony rhyolite. On the south border, the rhyolite is not in contact with beds of Paleozoic age and they show no alteration.

This plug may have been the source of the flows and tuffs that lie 2 miles southeast, described below.

In sec. 18, T. 26S., R. 59 E., 2 miles southeast of Devil Peak, a ridge about 1,000 feet long and 500 feet wide rises about 125 feet above the surrounding wash. The following section is exposed on the southwest slope:

Section measured 2 miles southeast of Devils Peak in sec. 18, T. 26S., R. 59 E.

	Feet
Latite flow, pale-reddish; laminated; layers locally much contorted (40 c)	30
Latite flow, gray, splintery, glass, containing round masses of black glass (40 b)	10
Latite flow, gray to reddish, with lenses of gray glass	10
Latite breccia, light reddish; laminated fragments largely 2 to 6 in. in diameter	25
Latite tuff, pale-reddish; alternating zones of fine laminated and coarse fragments; some limestone cobbles as much as 10 in. in diameter	65
Total	140

The rock which forms the uppermost flow shows alternating layers of stony and glassy material. Both show sparse grains of orthoclase as large as 0.20 mm and cristobalite but no quartz (40 c). The gray glassy flow (40 b) is a curious rock which finds a counterpart in places on Hackberry Mountain and the Castle Mountains. Most of the rock is highly fractured gray glass; when it is heated before a blowpipe, it first boils furiously as if it were giving off much gas (water?) and then fuses quietly. About 20 percent of the mass is round kernels of black glass which show no fractures. When the solid rock is tapped gently with a hammer, it breaks into many splinters of gray glass and hard black pebbles; the rock is obviously in a state of strain because of cooling.

These flows and tuffs strike N. 45° W., and dip 30° NE., and therefore accord with the attitude of similar rocks in the Sultan area, 7 miles northwest. It would be a simple and attractive concept to assume that the flows and tuffs of both areas were laid down horizontally, and that their present attitude measures the degree to which they have been tilted since deposition. Even though there are faults in the rocks of Paleozoic age adjacent to or near these areas, the faults are not the type that would aid this concept. If a single fault formed the northeast boundary of both areas of flows, along which the southwest side dropped, it would indicate that the present attitude of the flows was due largely to the tilting of a large block which crossed the present axis of Spring Mountains. As the flows seem to be derived from a local source, it seems that the similarity in attitude is coincidental.

WESTERN BASINS

In the western third of the quadrangle sediments and related volcanic tuffs and flows are found in three areas: the Shadow Mountains basin, the Halloran Spring area, and the Devils Playground area. The wide variety of coarse and fine detrital materials in the three areas have some resemblance in lithology and degree of induration. As most of the sediments are still relatively unconsolidated, they are readily eroded to smooth slopes that are heavily cloaked with coarse debris and thick sections cannot be examined closely. Only in a few places, such as the rugged hills east of Kingston Springs, are sections more than 100 feet thick fully revealed.

SHADOW MOUNTAINS AREA

The area known to be underlain by these sediments is about 12 by 15 miles, roughly from Riggs Wash on the south to Kingston Wash on the north and Shadow Mountain on the east (fig. 33). None of these sediments are known in the large area north of Kingston Wash, which includes the Kingston Range and other mountains

FIGURE 33.—View S. 20° E. from airplane to the Shadow Mountains, south of Kingston Wash, Calif. (Courtesy of Spence Photos, Los Angeles.)

east as far as Mesquite Valley. Only along the southern border near Riggs Wash, however, are the basal beds to be seen resting upon the older rocks, here the Teutonia quartz monzonite. In the descriptions that follow, the distinction between the Shadow Mountains, a rugged chain about 8 miles long, and Shadow Mountain, an isolated hill 7 miles to the east, should be noted.

The basal sediments of this basin can be examined only in the washes that drain south to Riggs Wash and those that drain north to Kingston Wash, exposed near the Metropolitan power line that extends from Hoover Dam to Los Angeles. The sediments include coarse and fine arkosic sands and gravels, minor amounts of yellowish clays, and consolidated and unconsolidated layers of pumice and volcanic ash. On the ridge of three hills, a mile west of the 4,880-foot hill near Francis Spring that is the southernmost remnant of the basin, 100 feet of arkosic sandstone, yellow clay, and indurated pumice is overlain by 30 to 75 feet of cemented dark dolomite breccia. The hills east of the 4,880-foot hill (west and south of Francis Spring) have similar sections. In each of these areas, the sediments rest upon a surface of low relief carved on Teutonia quartz monzonite. Near Francis Spring, the sediments locally rest upon the east slope of the 4,880-foot hill that is made up of crystalline limestone, here considered as undifferentiated rocks of Paleozoic age (p. 46).

The thickest exposed section of the sedimentary rocks of the western basin was measured in the principal wash that drains westward from the Shadow Mountains, that which lies a mile south of Kingston Springs.

Section measured in wash 1 mile south of Kingston Springs

Top of section	Feet
Dolomite breccia-conglomerate, dark-gray. This bed thickens to 100 feet, 1500 feet north where it sustains a prominent ridge; it thins and disappears southward	20
Shale and sandstone, drab and pale-olive-green	150
Sandstone, conglomeratic, pale-brownish	25
Shale and sandstone, drab and pale-olive	100
Dolomite breccia-conglomerate, dark-gray; this bed sustains the main ridge south of the ravine for several miles	100
Sandstone, drab, thin-bedded; local conglomerate zones	200
Sandstone, conglomeratic, 10 ft of sandstone at top, 10 ft of coarse conglomerate, 10 ft of sandstone at base, persistent	30
Sandstone, drab, thin-bedded	300
Conglomerate, coarse, pebbles as large as 10 in. in diameter	40
Sandstone drab, thin-bedded	500
Total	1, 465

Several features of the conglomerate beds are worthy of detailed description. The 100-foot breccia-conglomerate near the top of the section and the thinner 20-foot bed at the top are made up of both angular and slightly rounded fragments of dark-gray dolomite such as is characteristic of the Goodsprings dolomite. No limestone fragments were noted in these two higher beds of conglomerate. The fragments show a wide range in size; some are 6 to 12 inches in diameter but most are less than 4 inches. The conglomerate is highly indurated so that surfaces of erosion are smooth and cut across the fragments. Many fractures also cut across the fragments.

By contrast, the lower beds of conglomerate contain a wide assortment of all of the materials of Paleozoic and pre-Paleozoic age—dolomite, fossil-bearing limestone, granite gneiss, and quartzite. Also, the lower beds do not show the same degree of induration as the higher beds; fragments of the several rock types weather free from the matrix.

With the exception of the dolomite breccia-conglomerates that form persistent beds in several parts of the basin, the clastic materials in the section above are similar to those which are known widely in the sections of the Tertiary system and modern basins of the arid regions of the west. Several varieties of uncommon sedimentary rocks crop out from place to place in the basin. Along the Western Star Wash that drains north on the western border of the Shadow Mountains, beds of white fine-grained dolomite, 4 to 5 feet thick, crop out.

The chain of low hills that trend eastward, about 3 miles north of Shadow Mountain (secs. 31, 32, T. 18 N., R. 11 E.), shows outcrops of a lens of breccia-conglomerate that overlies tuff, calcareous clays, and rhyolite flows that strike N. 60° E. and dip 40° SE. In these hills good exposures of layers of brown opaline silica are several feet thick. The rock contains sparse grains of quartz but no feldspars or glass. It appears to be a variety of tuff, silicified soon after the sediments were deposited.

Borate minerals which are known and exploited at many places in Miocene and later rocks of the Mojave Desert, have been sought by prospectors in several localities but have not been found. Within 1 mile along the upper part of Evening Star Wash in the Shadow Mountains, beds of nearly white pumice more than 20 feet thick have been explored by prospect pits.

Beds of dolomite breccia-conglomerate appear at several horizons in the section of middle Tertiary age of the western basin. As they have uncommon features that indicate significant episodes in the history of the region, detailed features of several will be described. Figure 34 shows the principal outcropping beds in an area 5 by 8 miles. In major plan, these beds are large lenses; the largest is that which forms the crest of the ridge west of Evening Star Wash for a distance of more

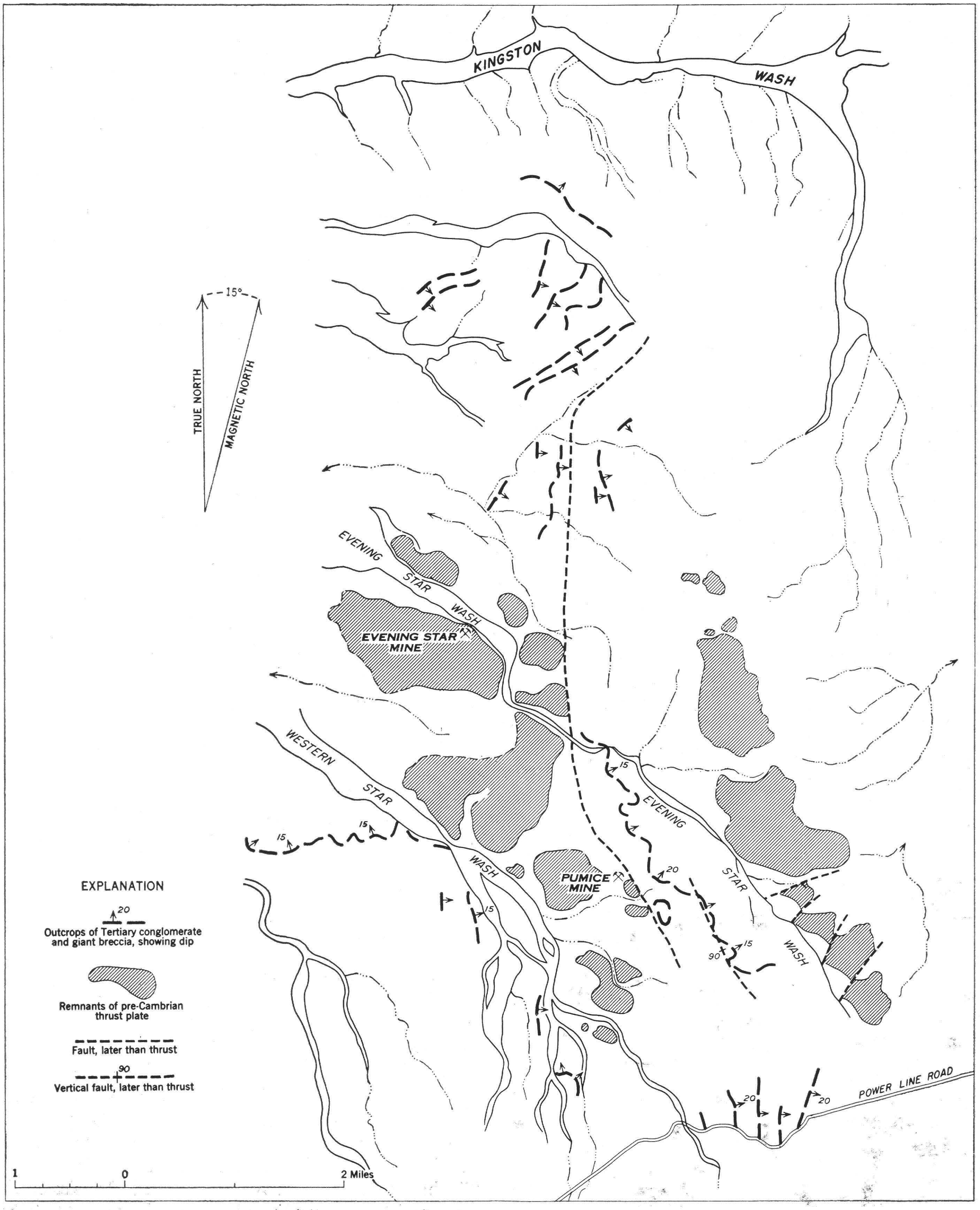

FIGURE 34.—Map of Shadow Mountains area showing remnants of plate of pre-Cambrian gneiss on mid-Tertiary sediments.

than 3 miles. In the central part, the thickness is about 800 feet but near the ends of the lens, the thickness is less than 200 feet. In the southern part of the basin, there are at least four lenses in the section and the thicknesses range from 50 to 200 feet.

These lenses are made up wholly of fragments of dark-gray dolomite, all apparently derived from the Goodsprings dolomite. No fragments of fossil-bearing limestones, shale, or sandstone that might have come from formations of middle or upper Paleozoic age have been recognized. In most exposures of the lenses, the fragments are largely subangular to angular and range from 1 to 6 inches in diameter. The fragments are closely packed in a fine matrix and highly indurated.

In a general way, the thicker the lens the larger the fragments that may be found. The longest lens, that which lies west of Evening Star Wash, contains many angular blocks 10 to 25 feet in diameter and one block of dolomite near the central part is about 1,000 feet long and 300 feet thick. A mile north, there is another block that is 300 by 600 feet. Both blocks show persistent bedding that departs from the strike and dip of the lens. Obviously extraordinary processes have contributed to deposit lenses of such material in the midst of ordinary clastic sedimentary rock, largely clay, sandstone, and conglomerate.

These lenses have other features that are difficult to understand. The lenses of breccia-conglomerate are broken by many fractures, but only a few crosscutting faults have been observed in the field (fig. 34). In Evening Star canyon near the northern end of the thickest lens, curved fractures show grooves that plunge down the dip of the lens indicating differential horizontal movement. Also, wherever the base of this lens of indurated dolomite is exposed, striations and small furrows on it trend down the dip. There can be little doubt that this longest, thickest lens shows internal fractures and has moved on its base after it was indurated. So impressive is this evidence of movement of this lens that early in the study of the area, the possibility was considered that it was part of a thrust plate somehow related to the plates of pre-Cambrian gneiss that are present in the area.

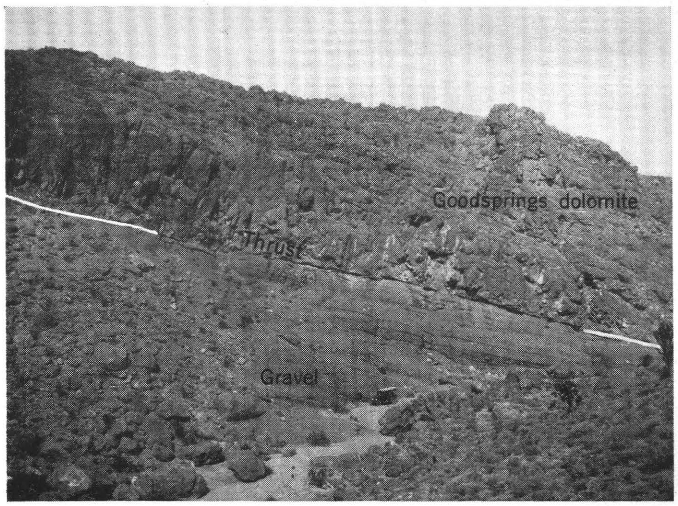

FIGURE 35.—View toward north wall of Evening Star Wash, showing layer of dolomite breccia-conglomerate resting on gravel of middle Tertiary section, California.

An uncommon variety of clay-carbonate sediment is exposed in the ravines that drain the northwestern border of Shadow Mountain, 6 miles east of the Shadow Mountains. The upper part of the mountain is made up of vertically foliated gneissic rocks of several varieties (p. 24). The ravines on the northwestern border have cut down into unconsolidated sediments of three varieties: cream to buff clays containing thin calcareous layers; pale-reddish clays, well stratified sand and gravel. The beds strike N. 20° E. and dip 5° to 8° E. They crop out within 500 feet of the gneiss, but the contact cannot be seen. In the laboratory, a specimen of buff clay was examined closely for volcanic ash but none was found. The clay disintegrates slowly in water and when dilute hydrochloric acid is added there is vigorous evolution of carbon dioxide. The undissolved sediment contains angular grains of quartz, orthoclase, and a little plagioclase but no pumice.

The degree to which the sediments of the western basin are deformed is discussed on pages 95–98. As shown on figure 34, the sediments in the eastern half of the basin strike generally north in the southern part and northeast in northern part; they dip generally east at angles that range from 10° to 20°. In the western part of the basin, they strike generally west and dip about 15° N. The basal beds are known only in the southern border. The thickest measured section (p. 88) is only about 1,500 feet but it seems probable that the maximum thickness is more than 2,500 feet. Shadow Mountain rises above a plain covered by recent alluvium that conceals the eastern portion of the basin. If the prevailing eastward dip is not reversed under this cover, the eastern limit of the basin may be a fault.

HALLORAN SPRINGS AREA

In the western third of the quadrangle, there are two other outcropping areas of sedimentary rocks that seem to be correlated with those of the Shadow Mountains basin. In an area about 1 by 2 miles near Halloran Spring, there are 1,200 feet of reddish conglomeratic arkoses, more indurated than similar material in the Shadow Mountains. The material is largely feldspar and quartz, typical of the nearby quartz monzonite. The beds strike uniformly N. 20° W. and dip 50° NE. The base of the section overlaps the hill of gneiss on the west, and the eastern limit is a normal fault that strikes west of north. The degree of induration raises the

TABLE 4.—*Mineral composition of rhyolites*

[All specimens are light brown]

	162	141-a	141-b	191-2	191-9	191-14
Phenocrysts						
Orthoclase	Trace	Moderate	5 percent	Sparse	Common	Sparse.
Andesine						
Labradorite						
Biotite	None	None	None	None	None	None.
Quartz	Trace		Trace	Trace	None	None.
Matrix						
Orthoclase	Abundant	Abundant	Abundant	Trace	Few grains	Abundant.
Plagioclase		None	None			
Glass	None	Trace	Trace	Abundant	Abundant	Abundant.
Quartz	Abundant	Trace	Trace	Trace	(Tridymite)	None.
Spherulites	Abundant	Abundant	Abundant			
Biotite	None	None	None			
Cristobalite	?	?	Present			

162. Hart Peak area, Castle Mountain, sec. 5, T. 30 S., R. 62 E., Nevada.
141-a. Hackberry Mountain, sec. 17, T. 11 N., R. 16 E.
141-b. Hackberry Mountai,n sec. 17, T. 11 N., R. 16 E.
191-2. Gold Valley Spring area, sec. 3, T. 11 N., R. 14½ E.
191-9. Gold Valley Spring area, sec. 3, T. 11 N., R. 14½ E.
191-4. Gold Valley Spring area, sec. 3, T. 11 N., R. 14½ E.

TABLE 5.—*Mineral composition of latites*

	22	43	42	37	39	28	29	36
Phenocrysts						15 percent	35 percent	
Orthoclase	3 percent	None	None	?		8 percent	50 percent	8 percent.
Oligoclase						An_{20} 3 percent		An_{20}. 2 percent.
Andesine	AN_{30} 2 percent	AN_{40} 5 percent		AN_{40} ?	AN_{40} 5 percent		AN_{35} 25 percent	An_{20}. 2 percent.
Labradorite			AN_{50} 5 percent; AN_{60} 1 percent					
Biotite	Trace	1 percent	1 percent	1 percent	1 percent	1 percent	1 percent	1 percent.
Quartz	None	None	None	None	Trace	2 percent	?	None.
Augite		None	Trace			None	Trace	Do.
Matrix								
Orthoclase	15 percent	25 percent (orthoclase and plagioclase)			60 percent (orthoclase and plagioclase)	15 percent	20 percent	30 percent.
Plagioclase	An_{20}		50 percent	?				
Glass	Abundant	75 percent	50 percent	Abundant	40 percent	80 percent	80 percent	70 percent.
Apatite			Present					
Biotite	Trace					Trace	Trace	Trace.
Titanite						Trace		
Color								
	Dark brown.	Light brown.	Light brown.	Light brown.	Light brown.	Brown	Dark brown.	Light brown.

22. Black Mountain, sec. 36, T. 23 S., R. 62 E., Nev.
43. Erie area, sec. 31, T. 23 S., R. 61 E., Nev.
42. Erie area, sec. 2, T. 24 S., R. 61 E., Nev.
37. Erie area, sec. 24, T. 24 S., R. 60 E., Nev.
39. Erie area, sec. 25, T. 24 S., R. 60 E., Nev.
28. McCullough Range, sec. 34, T. 25 S., R. 61 E., Nev.
29. McCullough Range, sec. 34, T. 25 S., R. 61 E., Nev.
36. Lucy Grey Range, sec. 36, T. 26 S., R. 60 E., Nev.

question whether the arkose may be older than the material in the Shadow Mountains.

DEVILS PLAYGROUND AREA

The group of hills, about 2 by 3 miles, that lies from 6 to 9 miles north of Sands contain the only rocks in the southwest quarter of the quadrangle considered to be of Tertiary age. This group of hills is separated by faults into three areas of which the northern contains rocks of Paleozoic age alone. The other two areas, south of the northeast-trending fault, consist of a belt of rocks about 3,000 feet wide by about 3 miles long that appear to be slightly unconformable on the flow breccia of Mesozoic age. The basal sedimentary unit is 10 to 15 feet of blue-gray cherty limestone without traces of fossils. This is succeeded by 500 to 700 feet of sandstone, largely buff in color but locally reddish; the thickness increases southward. The sandstone is largely thin bedded but massive locally in the middle. The unit is fine sand without any gravel. It is slightly more indurated than the Tertiary sandstone of the Shadow Mountains section. The uppermost layers are greenish as though they contain tuffaceous material.

This sandstone is conformably overlain by 4 or 5 volcanic flows that aggregate 800 to 1,000 feet thick. The flows are dense with only sparse phenocrysts of feldspar. Except for one flow, which is dark greenish gray, they are dark reddish brown. The uppermost reddish flow shows persistent platy parting; the others are massive. Only the greenish flow has been examined in thin section. It shows sparse square crystals of oligoclase in a matrix of laths of oligoclase (An_{15}) and fine chloritic material; there are sparse grains of quartz. Both the greenish and reddish rocks are here considered to be andesites.

TABLE 6.—*Mineral composition of latites*

	138a	157	137
Phenocrysts			
Orthoclase		None	None.
Andesine	An_{40}, 5 percent	An_{40}, 40 percent	An_{25}.
Biotite	1 percent	None	None.
Quartz	None	None	Trace.
Augite	None	None	None.
Matrix			
Plagioclase	An_{40}, 80 percent	An_{40}	AN_{25}.
Glass		Fair	Abundant.
Biotite	Trace	None	Trace.
Color			
	Brown	Light brown	Brown.

138a. Piute Range, sec. 13, T. 13 N., R. 17 E., Calif.
157. Lanfair Valley, sec. 32, T. 13 N., R. 16 E., Calif.
137. Lanfair Valley, sec. 3, T. 12 N., R. 16 E., Calif.

Analyses of latite

[Analyses by J. G. Fairchild]

	37	43	138a
SiO_2	66. 81	68. 53	69. 01
Al_2O_3	16. 16		
Fe_2O_3	2. 01		
FeO	1. 25		
MgO	. 72		
CaO	2. 62	. 51	2. 31
Na_2O	3. 42	3. 48	3. 91
K_2O	5. 66	6. 19	4. 76
TiO_2	. 35		
H_2O-	. 10		
H_2O+	. 48		
	99. 58		

37. Erie Crater area, sec. 24, T. 24 S., R. 60 E., Nev.
43. Erie, Nevada, sec. 31, T. 23 S., R. 61 E., Nev.
138a. Piute Range, sec. 14, T. 13 N., R. 17 E.

For most of the belt, the sandstone and flows strike S. 20° E. and dip about 45° NE.; locally the flows attain 60°, a rather high dip for the middle Tertiary rocks.

LATE TERTIARY (MIDDLE PLIOCENE?) OROGENY

GENERAL FEATURES OF THE DEFORMATION

Following their deposition, the middle Tertiary sedimentary and volcanic rocks were warped broadly and briefly subjected to erosion before extensive thrust faults developed in the northwestern and southwestern corners of the quadrangle. It will facilitate a better understanding of these disturbances if the evidence is presented for each of the three longitudinal belts in which the sediments and volcanic rocks were deposited. In general, the middle Tertiary rocks of the eastern third of the quadrangle, Black Mountain, the McCullough Range and nearby ranges, the New York Mountains and Mid Hills, have been warped and tilted eastward and they have been broken by a few large and many small normal faults. At three places, separated by intervals of 20 miles, east of McCullough Mountain, in the Castle Mountains, and near the Leiser Ray mine, the flows show local sharp anticlines. No thrust or reverse faults have been recognized in this belt. There are reasons (p. 105) for concluding that some of the largest faults, notably those which limit the great graben of Ivanpah Valley, developed much later than the warpings and anticlines, in fact after the Ivanpah upland which is regarded as of early Pleistocene age. As the anticlines reveal compressive stress, it is probable that they were developed during an earlier period when the Kingston thrust was formed (middle Pliocene?).

In the central belt, roughly coinciding with the Spring Mountains and Clark Mountain, the massive middle Tertiary intrusives (Devil Peak) and extrusives (Table Mountain) show no evidence of later deformation but the layered volcanic sedimentary rocks attain dips as high as 60° west of the Green Monster mine, 30° east of the Sultan mine and 30° east of Devil Peak. The high dip at the first locality seems to be related to the movement of the overlying plate of Monte Cristo limestone; in part, the dips at the other two localities are probably due to the slopes of the surfaces on which they were laid down.

It is within the western belt that profound disturbances are recorded in post-early Pliocene (?) time. Remnants of large plates that have been thrust into their present positions lie within two areas—one in the northwest corner including the Kingston Range and Shadow Mountains, roughly 16 by 35 miles, and the other including Old Dad Mountain in the southwest corner. The remnants of the plate rest upon

TABLE 7.—*Mineral composition of the andesites*

	21	35	30	167	16	155	138b	138c	138f
Phenocrysts	35 percent	20 percent	?		45 percent	Few	20 percent	70 percent	Sparse.
Orthoclase									Trace.
Andesine	An_{30}, 20 percent			Orthoclase	An_{30}, 40 percent	An_{40}	An_{40}, 5 percent	An_{40}	An_{40}.
Labradorite		An_{60}, 10 percent	An_{50}	Fair			An_{60}, 5 percent	An_{60}	
Augite	10 percent	5 percent	Sparse	Fair	5 percent	?	Coarse, 10 percent	Coarse	Sparse.
Hornblende		3 percent							
Olivine	5 percent	None	Sparse	Fair					
Apatite	None	None	Trace	Much					
Biotite					Rare	Sparse			
Matrix	65 percent	80 percent			50 percent	?	80 percent	30 percent	
Feldspars	Abundant	Abundant		Fair	Abundant	Abundant	Abundant, 60 percent	Abundant	?.
Augite			?				Abundant, 20 percent	Abundant	50 percent.
Hornblende									25 percent.
Glass	Abundant	Abundant	None		Abundant	Abundant	Abundant	Abundant	25 percent.
Color	Dark gray	Gray	Gray	Gray	Gray	Dark brown	Gray	Gray	Gray.
Vesicular	Yes	No	No	No	Yes	Yes	No	No	Sparse.

21. Black Mountain, sec. 15, T. 23 S., R. 62 E., Nev.
35. Lucy Grey Range, sec. 33, T. 26 S., R. 60 E., Nev.
30. McClanahan Spring, sec. 8, T. 26 S., R. 61 E., Nev.
167. Lucy Grey Range, sec. 3, T. 28 S., R. 60 E., Nev.
16. McCullough Range, sec. 14, T. 27 S., R. 61 E., Nev.
155. Malpais Spring unsurveyed area, Calif.
138b. Piute Range, sec. 13, T. 13 N., R. 17 E., Calif.
138c. Piute Range, sec. 13, T. 13 N., R. 17 E., Calif.
138f. Piute Range, sec. 13, T. 13 N., R. 17 E., Calif.

middle Tertiary sedimentary rocks in two areas only in the northwest corner—the ridge west of the Green Monster mine and the Shadow Mountains. In the Shadow Mountains, the surface that limits the plate below cuts across the more inclined beds below, indicating warping and erosion of the beds before the plate was thrust over them.

STRUCTURE OF THE ROCKS EAST OF IVANPAH VALLEY

The character and distribution of the middle Tertiary sediments and volcanic rocks of the eastern basin and nature of the surface upon which they were laid down have been described on p. 72–82. As the basal sediments of the section throughout this region are gravels, sands, and tuffs it seems probable that the intial dips were not more than several degrees at most, and that greater dips indicate the degree to which they have been tilted since deposition.

Except in the Black Mountain area in the northeast corner, the greatest dips of the middle Tertiary rocks are found near the western border of the belt where they rest upon diverse older rocks, and the dips are progressively lower in an eastward direction. In the northeast corner, the surface of contact may be seen at only a few localities—between Jean and Sutor, east and north of Erie, and in the low hills several miles southeast of Sloan. In each of these areas, volcanic flows rest upon a surface of limestones of Paleozoic age that shows appreciable local relief. Waterlaid material is not present under the volcanic rocks, which dip gently east and southeast.

Wherever the contact of the middle Tertiary rocks and underlying older rocks may be examined south of these areas, as far as the east slope of Providence Mountains, layers of fine sediments and gravel were first deposited on the older rocks before sheets of volcanic flows appear. From the chain of low hills east of Sheep Mountain, the surface of contact and dip of the middle Tertiary rocks may be observed southward for many miles. In the chain of low hills at the north end of the McCullough Range (T. 25 S., R. 61 E.), the basal beds dip 5° N. and are broken by three faults

TABLE 8.—*Mineral composition of the basalts*

	20	38	32	26	163	136	131	156
Phenocrysts					Sparse	Sparse	Sparse	Trace.
Labradorite	An_{60}, 35 percent	$Ab_{40}An_{60}$, 10 percent	$Ab_{30}An_{70}$, 15 percent	$Ab_{40}An_{60}$, 10 percent	An_{50}	An_{60}	An_{60}	An_{60}.
Olivine	5 percent			Trace	Trace	Trace	Moderate	None.
Augite	8 percent		5 percent	Trace		Trace	Moderate	None.
Hypersthene		3 percent						
Biotite		1 percent	None			Trace	Trace	None.
Matrix:								
Feldspars	50 percent	10 percent		Yes	Abundant	Abundant	Abundant	Abundant.
Olivine					Abundant			
Augite				Trace	None	Abundant	Abundant	
Glass	50 percent	75 percent	75 percent		None	None	None	Abundant.
Color	Black	Black	Black	Black	Black	Dark gray	Black	Black.
Vesicular	No	Yes	No	Yes	No	No	No	No.

20. Black Mountain, sec. 10, T. 23 S., R. 62 E., Nev.
38. Erie area, sec. 18, T. 24 S., R. 61 E., Nev.
32. East of Jean, sec. 18, T. 25 S., R. 61 E., Nev.
26. McClanahan Spring, sec. 27, T. 25 S., R. 61 E., Nev.
163. Quail Spring, sec. 3, T. 14 N., R. 17 E., Calif.
136. Piute Canyon, sec. 19, T. 12 N., R. 18 E., Calif.
131. Leiser Ray area, sec. 10, T. 11 N., R. 17 E., Calif.
156. Blackburn area, sec. 36, T. 12 N., R. 16 E., Calif.

that strike northeast. Along each of these faults the west side has dropped, at the first more than 500 feet, at the second and third about 150 feet each. South of the low divide near the third fault, the basal beds dip 10° E. on the first hill and 15° E. on the second hill. The valley that lies east of these hills coincides with a fault, whose displacement is low at the north end but increases to about 1,200 feet east of McClanahan Spring (Section *N–N′*, pl. 1). Along the hills east of this valley, the basal beds of the middle Tertiary system dip 15° E. at the north end, then 25° east of McClanahand Spring, then consistently about 35° for about 10 miles along the east border of McCullough Range (section *N–N′*). One of the three anticlines in the beds of the middle Tertiary system and flows of this region lies due east of McCullough Mountain. It is most conspicuous in the basal beds of the section (p. 79), but dies out southeastward on the east slope of the Highland Spring Range.

The approximate position of the contact of the section of the middle Tertiary system on pre-Cambrian gneiss is indicated by outcrops east of Crescent Peak. It is not exposed again southward until the hills near Malpais Spring and Castle Mountains are reached.

The Lucy Grey Range is divided into two equal parts by a deep east-west valley. Along the east slope of the northern part, east of Hill 5,613, the basal beds of the middle Tertiary system are exposed and rest upon pre-Cambrian gneiss (see section *a*, p. 79). For a distance of 4 miles, the beds strike north and dip 35° E. (section *0–0′*). The situation in the southern part of the range is different. The base of the section of middle Tertiary age is not exposed, but flows that appear to be from 500 to 1,000 feet above the base are in fault contact with gneiss for 5 miles. The flows strike northeast and dip 20° SE.

The character and attitude of the middle Tertiary rocks on the east slopes of the Lucy Grey and McCullough Ranges require the presence of a great normal fault in the longitudinal valley that separates them. If the beds on the east slope of McCullough Range are projected upward at 35° until they meet the projection of the assumed fault, the indicated dip displacement of the fault is about 20,000 feet, an enormous amount (section *0–0′*). If the middle Tertiary rocks showed many sharp folds, it might be assumed that a part of the indicated displacement was due to folding. Such is not the case, however, as only three short anticlinal folds were recognized in the entire area of these rocks. Several explanations may be offered of the manner by which such a displacement might be created, but of the existence of the displacement there seems no doubt. Furthermore, it seems to be matched by a similar displacement on the Ivanpah fault southwest of Ivanpah Valley.

In the valley at the northeast end of the Castle Mountains, several square miles of pre-Cambrian gneiss crop out and the contact with middle Tertiary rocks is exposed widely. The area coincides with the crest of a sharp anticline that plunges southwest. On the northwest limb the basal sedimentary rock of the section of middle Tertiary age dip from 20° to 25° N.W., but on the southeast limb near Lewis Holes and Quail Spring they dip 60° SE. No faults were observed in the Castle Mountains, but one small normal fault is indicated at the southwest end (section *P–P′*).

In the northern part of the New York Mountains, between Barnwell and Malpais Spring, the basal beds of the middle Tertiary rocks resting on pre-Cambrian gneiss crop out persistently. In the northern part of this area east of the north-trending fault, the beds strike northeast and dip 20° SE.; in the southern part, they strike about N. 70° E. and dip 10° S. The dip displacement along the fault is about 2,200 feet. What appears to be an extension of this fault is found in the low hills east of Nipton where it separates east-dipping middle Tertiary rocks on the west from granite gneiss on the east.

In a railroad cut a mile north of Barnwell a northwest-trending fault that dips 45° NE. separates andesite flow on the northeast from gneissic diorite on the southwest. Along this fault the horizontal offset of the base of the volcanic rocks is about 4,500 feet, and the dip displacement is about 1,500 feet. It is correlated with the Ivanpah fault (section *Q–Q′*).

The belt of middle Tertiary rocks that extends eastward along the southern border of the quadrangle from Providence Mountains to the eastern border has simple structural features. The structure of the volcanic mass that coincides with Hackberry Mountain is locally complicated.

The succession of tuffs and flows that covers a large area from Providence Mountains eastward to Hackberry Mountain dips gently southeast and south. Dips are highest near the northern limit of the rocks, ranging from 10° in the western part to 5° in the eastern part, and they are progressively lower farther south. No faults were recognized in this part of the area. East of Blackburn and Vontrigger, where the middle Tertiary rocks are represented by sporadic remnants of once-extensive layers of sand, tuff, and basalt flows, several small normal faults and an anticline are indicated (section *S–S′*). The anticline, which is indicated by the attitude of remnants of the middle Tertiary rocks, strikes and pitches southwest. Dips on the limbs are low, however, 5° or less. The faults were not observed but they are required by the distribution and attitude of the layered rocks.

KINGSTON THRUST FAULT

Kingston thrust fault is the name applied to the surface that limits, downward, many blocks made up of rocks that range from pre-Cambrian gneiss through a thick section of pre-Cambrian sedimentary rocks, the Pahrump series, to formations of Paleozoic age that are as high as the Monte Cristo formation of Mississippian age. These blocks are found in 4 distinct areas: the Kingston Range, about 10 miles in diameter; the Shadow Mountains and Shadow Mountain, about 10 by 12 miles; the hills west of Winters Pass about 3 miles in diameter; and the Valley Ridge, 2 miles long, that lies 3 miles west of the Green Monster mine. Of these four areas, the blocks in two, Shadow Mountains and Valley Ridge, rest on middle Tertiary sedimentary rocks; the blocks in the others rest discordantly on pre-Cambrian gneiss and the earliest sediments of Paleozoic age. It seems certain that the blocks in the first three areas are parts of one large plate, about 14 by 25 miles; there is a remote chance that the block in the Valley Ridge area is a separate plate.

In two localities in the Kingston Range there is evidence that the rocks that make up the high part of the range, above the 3,750 foot contour, rest with discordance on a basement of pre-Cambrian gneiss. Most of the high part of Kingston Range is Kingston Range monzonite porphyry, which intrudes the Pahrump series. The contact may be readily traced for 10 miles along the eastern part of the range and for 3 miles in the northwest part. Along the north slopes the Pahrump series attains its maximum thickness of 7,000 feet, and the dips range from vertical near the base to 40° in the uppermost beds. Farther north, the formations of early Paleozoic age, Noonday dolomite, and Prospect Mountain quartzite, nearly 8,000 feet thick, rest unconformably on the Pahrump series, and the dips range from 60° to 35°. In this regional setting, a flat area of pre-Cambrian gneiss 1,500 feet wide and 7,000 feet long, is exposed in the bottom of the main valley that drains westward in the northern part of Kingston Range. The contact of the vertical beds of the Pahrump series on the underlying gneiss is concealed by local wash but it seems to lie at the 3,750-foot contour. On the south border, the area of gneiss is limited by steep slopes of the intrusive monzonite porphyry. The areal mapping indicates that the great thickness of steeply dipping beds of the Pahrump series is cut off downward by the gneiss surface at the 3,750-foot contour; fortunately, 2 of the 14 holes drilled in 1924 on several lenses of magnetite passed abruptly from vertical beds of limestone in the Crystal Spring formation into gneiss at the 3,750-contour. The drill holes were inclined northward at 45° and cut the limestone-gneiss contact about 800 feet north of its position on the surface. Complete details of the lithology and attitude of the Crystal Spring formation, the lenses of iron ore, and the drill cores are presented in the report that deals with the iron ore deposits of the Kingston Range (Hewett, 1948). (See also section *A–A′*, this report.)

Similar conditions are revealed in the flat bottom of a broad valley, locally known as Copperfield, about 7 miles north of Kingston Peak and 5 miles northeast of Horse Spring. Here, granite gneiss crops out over an area 3,000 by 8,000 feet; the gneiss is made up largely of coarse crystals of orthoclase in a fine-grained matrix of chlorite and quartz. It shows a persistent foliation that strikes northeast and dips low to the northwest and southeast. In places the gneiss is heavily impregnated with limonite which may be related to an old soil. On the east, the flat area of gneiss is limited by low hills made up of light- and dark-brown quartzite with minor amounts of green shale of the Prospect Mountain quartzite that strike N. 40° W. and dip 40°–50° NE. Southward, these beds overlie the Noonday dolomite, which rests unconformably on the Pahrump series. The area of gneiss is limited on the west by Prospect Mountain quartzite that strikes northwest and dips 25° NE. but the contact is covered by local wash. The general distribution of the rocks around Copperfield basin require a northwest-trending fault that would separate the gneiss and quartzite. The elevation of this flat area of gneiss is about 3,750 feet.

The areal mapping in the vicinity of Copperfield indicates that several thousand feet of beds at the base of the section of Paleozoic age rest in great discordance on granite gneiss (section *B–B′*). Taken together, these two areas indicate that a plate made up of at least 15,000 feet of sedimentary rocks of Paleozoic and pre-Paleozoic age and the intrusive core of Kingston Range monzonite porphyry that form the higher part of the Kingston Range and nearby hills, above an elevation of about 3,750 feet, has been thrust over a basement of pre-Cambrian granite gneiss.

The Shadow Mountains region, about 10 by 12 miles, reveals many blocks of gneissic rocks with flat bases that rest upon middle Tertiary sedimentary rocks (Hewett, 1928). Figure 34 was prepared on a base of mosaic air photographs (approximate scale, 1 inch=2,000 feet). It shows 24 blocks of gneissic rocks, several of which show autochthonous patches of sedimentary rocks of early Paleozoic age, terminated below by flat smooth surfaces, that rest upon several varieties of middle Tertiary sedimentary rocks. The blocks range in size from about 500 feet in diameter and 100 feet thick to 5,000 by 9,000 feet and 700 feet thick. The foliation of the gneisses is everywhere highly inclined, the dip in the northwestern blocks being about 40° and in the southeastern, nearly vertical. Considered together, they appear to be remnants of a continuous plate of gneiss about 4 by 6 miles.

Shadow Mountains, a northward-trending ridge about 8 miles long, is bordered on the east by a prominent wash that drains north to Kingston Wash. The higher parts of this ridge, about 4 miles long, coincide with blocks of gneissic rocks. The slopes, both on the east and west, show extensive areas of middle Tertiary sedimentary rocks. A parallel but not continuous ridge lies west of Shadow Mountains, sustained by a persistent lens of dolomite breccia-conglomerate (p. 70). The intervening wash is locally known as "Evening Star Wash" from the mine that lies in the area (no. 9, pl. 2). It cuts through the ridge of conglomerate at the north end (fig. 35) to form a box canyon. A chain of 14 prominent hills about 5 miles long lies west of the ridge of conglomerate and each of the hills is sustained by a block of gneissic rocks. West of the chain of hills is a prominent wash that drains northwest to the Death Valley trough; it is here called the "Western Star Wash." Tributary drains from the east to Western Star Wash separate the several hills from what would otherwise be a continuous ridge. The group of blocks of gneiss that form the Shadow Mountains are here called the "eastern belt"; those that sustain the hills east of Western Star Wash will be called the "western belt."

The most northerly small blocks of the eastern belt are dark-greenish diorite gneiss terminated below by a flat surface. This surface cuts across beds of the underlying sandstone that strike N. 20° W. and dip about 10° east (section *D–D′*). The next 3 blocks southward are largely dark gneiss, and the surface of contact with the underlying sandstones is covered by hillside wash. The south half of the next hill, 7,000 feet long, shows the surface of contact of granite gneiss on thin-bedded red sandstone, which strikes N. 65° W. and dips 15° NE. In the saddle at the south end of this block the surface of contact of granite gneiss on white clays and pumice strikes west of north and dips 5° NE. Similar sedimentary rocks crop out for a mile along the east side of the hill. From this gap south the bases of the succeeding 4 blocks are surfaces that strike northwest and dip gently northeast, but they are offset in such a manner that small faults that trend northeast are indicated. The northern 3 blocks show granite gneiss overlain by plates of Noonday dolomite and Prospect Mountain quartzite (sections *A* and *B*, fig. 2, also section *E–E′*). The last hill southeast is wholly shattered Noonday dolomite. The underlying sedimentary rocks are sandstone, pumice, and yellow clays that strike N. 65° W. and dip 15°–20° NE. The beds of pumice have been explored recently by pits and trenches.

Summarizing, each of the higher hills that form the long ridge known as Shadow Mountains is a cap or block of gneissic rocks in part diorite and in part granite, which is terminated downward by a smooth flat surface which cuts across the bedding of the underlying middle Tertiary sedimentary rocks. The basal zones of the blocks of gneiss are fractured but not brecciated or greatly disturbed. Neither is the bedding of the underlying sedimentary rocks greatly disturbed.

The ridge that lies west of Evening Star Wash is sustained for nearly 3 miles by the lens of breccia-conglomerate interbedded in the middle Tertiary sedimentary rocks, described on page 90. West of this ridge and east of the Western Star Wash lie the western belt of hills that are sustained by blocks of gneiss, fourteen of which appear on figure 34.

The northernmost hill is underlain by the largest block of the Shadow Mountains region, about 5,000 by 9,000 feet. The underlying middle Tertiary sediments crop out at the northeast corner and the contact is explored by the workings of the Hillside (Evening Star) mine (no. 9, pl. 2). After passing through 40 feet of loosely-consolidated sandy clay and gravel, the tunnel passes into granite gneiss; the surface of contact strikes N. 75° E. and dips 80° S. This is much steeper than any other contact in the region. Yellowish clays crop out on the north side of this hill, about a mile west of the mine.

The 3,218-foot hill that lies east of the Evening Star mine shows feebly consolidated clay and sand from place to place on the south, east, and north lower slopes. The sediments strike N. 45° W. and dip 35° NE. The upper 200 feet of the hill is a block of granite gneiss and diorite gneiss whose foliation trends northwest and is nearly vertical (fig. 3). The lower 100 feet is fractured but not brecciated; there is no zone of breccia. Locally, along the southwest slopes of the hill, the surface of contact dips 15° to 20° but as it crops out at the same elevation on the northeast slope, it must approximate a plane.

The surfaces of contact of the gneiss blocks on the middle Tertiary sediments are shown at many places on the southern group of nine hills (fig. 34), especially on the slopes of the south half of the 4,500-foot hill, about 7,000 feet in diameter. The upper half of this hill is a block of granite gneiss, the foliation of which trends about N. 45° W. and dips 40° northeast. There are many dikes of alaskite, 1 to 5 feet wide which are intruded along the foliation (fig. 36). The surface

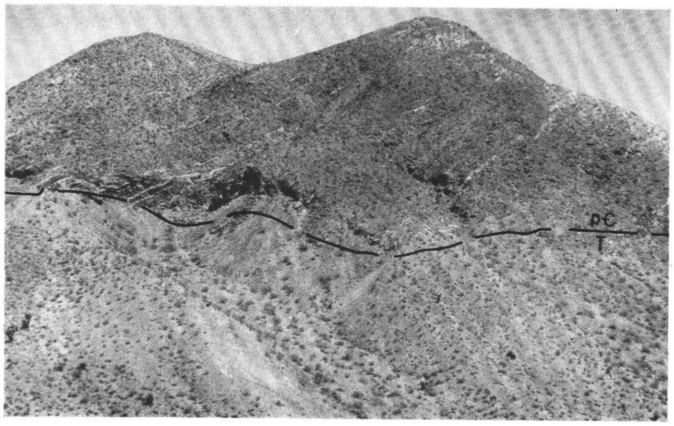

FIGURE 36.—View southeast toward hill (4,500 feet) east of Western Star Wash, showing block of pre-Cambrian gneiss resting on clay and sand of middle Tertiary section, California.

of contact of the gneiss with the underlying middle Tertiary clays is nearly a plane that strikes northeast and dips at low angles to the southeast.

On the next hill south, 4,600 feet high, about 3,500 feet in diameter, the contact of the old rocks on the middle Tertiary sediments is shown at many localities on the north, west, and south sides. Granite gneiss forms the south slopes of the upper block, but it is overlain by a sheet of Noonday dolomite several hundred feet thick, which strikes northeast and dips 25° NW. (fig. 37). On the north slopes of the block, the Noonday dolomite rests on the middle Tertiary sediments which strike northwest and dip 20° northeast (fig. 38). The surface of contact is nearly a plane that trends north and dips at a low angle to the east.

At the head of a ravine south of this 4,600-foot hill an attempt has been made to mine a thick bed of pumice by open cuts and inclined shafts. The pumice crops out on the west slope of a low hill which is capped by a block of granite and diorite gneiss, about 100 feet thick.

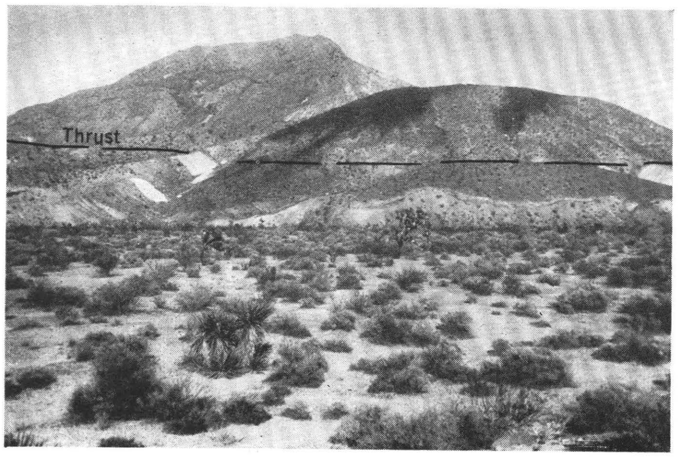

FIGURE 37.—View east toward hill (4,600 feet) east of Western Star Wash, showing block of gneiss and Noonday dolomite resting on clay and sand of middle Tertiary section, California.

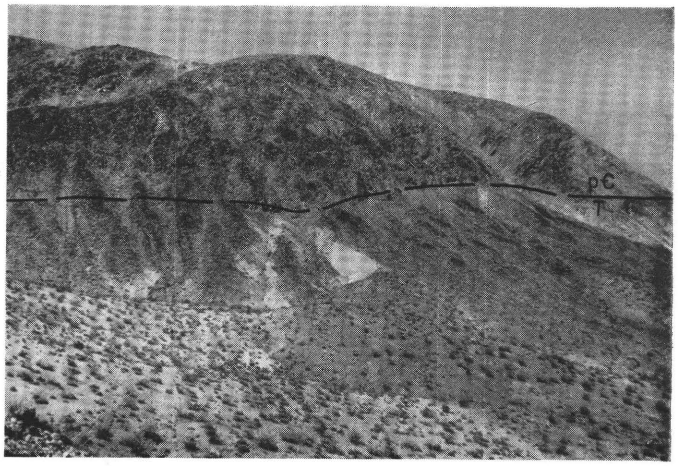

FIGURE 38.—View southeast toward hill (4,600 feet) east of Western Star Wash, showing block of gneiss and Noonday dolomite resting on clay and sand of middle Tertiary section, California.

On the east, the hill is limited by a fault, on the east side of which the middle Tertiary sediments crop out. Farther south, several other hills show blocks of gneiss resting on the middle Tertiary sediments.

In its larger aspects, this belt of hills east of Western Star Wash shows 14 remnants (Klippen) of a plate of gneissic rocks, locally overlain by an autochthonous sheet of Noonday dolomite, which rest upon sandstone and shale of the middle Tertiary system. Throughout the belt, these sedimentary rocks strike northwest and dip as much as 35° NE. The surface of contact, the Kingston thrust, is nearly a plane whose diverse low dips indicate several broad warps that strike generally east; these warps may indicate the shape of the base as the plate moved over the sedimentary rocks or may indicate warping after it was moved to its present position.

The fault shown in the ravine at the southern end of the belt of hills seems to explain the relation of the two belts of blocks east and west of Evening Star Wash, respectively. Along this fault, the western part of the original plate was dropped about 1,500 feet (secs. *D–D′*, *E–E′*).

Shadow Mountain is an isolated area of pre-Cambrian crystalline rocks about 2 by 3 miles, which lies about 6 miles east of the Shadow Mountains. Most of the mountain is granite gneiss, whose foliation strikes northwest and dips steeply northeast. Within the granite gneiss there are several broad layers of dark diorite gneiss; such a layer about 1,500 feet wide underlies the eastern higher part of the mountain. At the southwest end of the mountain, there is a small outcrop of quartzite which resembles that at the base of the Crystal Spring formation (Pahrump series). The ravines that drain the west slope of Shadow Mountain expose unconsolidated sediments that include reddish and cream-colored clays, sands, and thin layers of fine gravel. These strike N. 20° E. and dip 5°–8° E. toward Shadow Mountains. They may be traced eastward to within 500 feet of outcrops of granite gneiss but do not seem to be derived from the rocks of Shadow Mountain. These local observations would not arouse much concern if some drill holes in the low western part of the mountain had not passed from hard gneiss into light-colored clays (see Foster mine, no. 10, pl. 2, p. 135). In view of the mapping in the Shadow Mountains where numerous remnants of an extensive plate of pre-Cambrian gneiss and Noonday dolomite rest upon middle Tertiary sediments, there seems to be more than a possibility that the old rocks of Shadow Mountain are part of the plate.

The third area within which remnants of the Kingston thrust plate are shown, is about 3 by 4 miles and lies west of Winters Pass, northeast of the Shadow Mountains. Within this area, three of the five blocks of Goodsprings dolomite rest in discordance on a basement largely pre-Cambrian gneiss, but in the western part of the area two blocks rest on shale and quartzite of the Prospect Mountain quartzite. The most abundant basement rock in the northeastern two-thirds of the area is coarse granite augen gneiss well exposed along the road through Winters Pass and the shallow ravines that drain eastward to the ravine that the road follows. The foliation trends generally northeast and dips at low angles northwest. In the southern part of the area, the granite gneiss is overlain by a horizontal sheet of dense gray quartzite several hundred feet thick, but this seems to have been deposited where it lies (autochthonous Prospect Mountain quartzite). Similar material crops out in the ravines that drain the southwest part of the area where the strike is northwest and dip is 20°–30° SW. The five blocks of Goodsprings dolomite rest upon a smooth, nearly horizontal surface cut across both the granite gneiss and quartzite. There can be no doubt that the blocks of Goodsprings dolomite are not in place as nearly 3,000 feet of beds, most of the Prospect Mountain quartzite and all of the Pioche shale are missing although the complete section from the Noonday dolomite to the Goodsprings dolomite is present north of Winters Pass, a few miles northeast.

The largest of the blocks of Goodsprings dolomite, about 5,000 by 8,000 feet, may be considered as made up of two parts probably separated by a fault. The northeastern part, about a mile in diameter, is made up of two layers of Goodsprings dolomite both striking N. 45° W. and dipping 35°–45° NE. The two layers are shown in the southwestern escarpment about 500 feet high. The southwestern part of the block is also Goodsprings dolomite but the strike is N. 45° W. and the dip 45°–60° NE. In the ravine at the southwest base of the block, the discordance between the attitude of the overlying Goodsprings dolomite and the underlying Prospect Mountain quartzite is well shown.

In the low gap between the two parts of the block, a layer of middle Tertiary sedimentary rocks, volcanic ash, and shale at least 200 feet thick and 1,000 feet long crops out; the strike is northwest and the dip 20° NE. The local structural relations are obscure; the layer seems to be overlain by the northwestern part of the plate of Goodsprings dolomite. It is interpreted as part of the thrust plate; nothing like these sedimentary rocks is known northeast of Kingston Wash.

The next largest block of Goodsprings dolomite is about 800 by 4,000 feet and 400 feet thick; the strike of the beds is N. 25° W. and the dip is 25° NE. The surface of contact with the underlying granite gneiss is well exposed along the western part of the block. The remaining three blocks of Goodsprings dolomite are much smaller, only several hundred feet in diameter, but they present the same evidence of discordance with the underlying gneiss.

The fourth area within which there is evidence of thrust faulting of late Tertiary age includes a single isolated ridge (Valley Ridge) at the northwest end of Mesquite Valley in secs. 4, 5 and 6, T. 24 S., R. 56 E., Nevada. The ridge lies east of monument 117 on the Nevada-California boundary, rises about 800 feet above the floor of the valley, is about 8,000 feet long, and presents a bold escarpment to the south (fig. 32).

The high part of this ridge is a canoe-shaped block of Monte Cristo limestone about 8,000 feet long and 800 feet thick, within which the bedding strikes N. 70° W. and dips 60°–70° NE. The surface of contact of the limestone on the sedimentary rocks (fig. 32) is almost continuously exposed along the south slope of the ridge and from place to place on the north slope and east and west ends. On the south slope the surface of contact is nearly a plane for several thousand feet; it strikes N. 70° W. and dips 65° NE. (fig. 39). The surface shows shallow grooves and striae which pitch 30° SE. At a few places, there are irregular recesses in the surface where angular blocks of limestone have been plucked out; they are now filled with highly crumpled tuffaceous sedimentary rocks similar to those which underlie the large block. The actual surface of contact can be examined only in a few places on the other slopes but its approximate position is quite clear. It seems impossible to explain the existence of this block of limestone of Mississippian age, surrounded by a belt of tuffaceous sedimentary rocks upon which it locally rests, except as a remnant of a larger plate thrust to the position where it is now found.

In order to summarize the evidence of the existence of the Kingston thrust fault, the kind of evidence, the adequacy of detailed exposures, and their extent in the four areas will be briefly reviewed. Some consideration should also be given to kinds of rocks involved and the probability that a plate of the extent indicated could be so extensively eroded within a short period of geologic time.

The Shadow Mountains area presents at many places very convincing evidence of the existence of a plate of old rocks (pre-Cambrian gneiss) thrust upon very young rocks (middle Tertiary system). Within an area about 4 by 6 miles, 24 blocks of gneiss were mapped on figure 34, resting on a flat smooth surface that cuts across the bedding of relatively unconsolidated sediments considered to be of middle Tertiary age and having noteworthy dips. The original plate of gneiss is broken by a much younger normal fault.

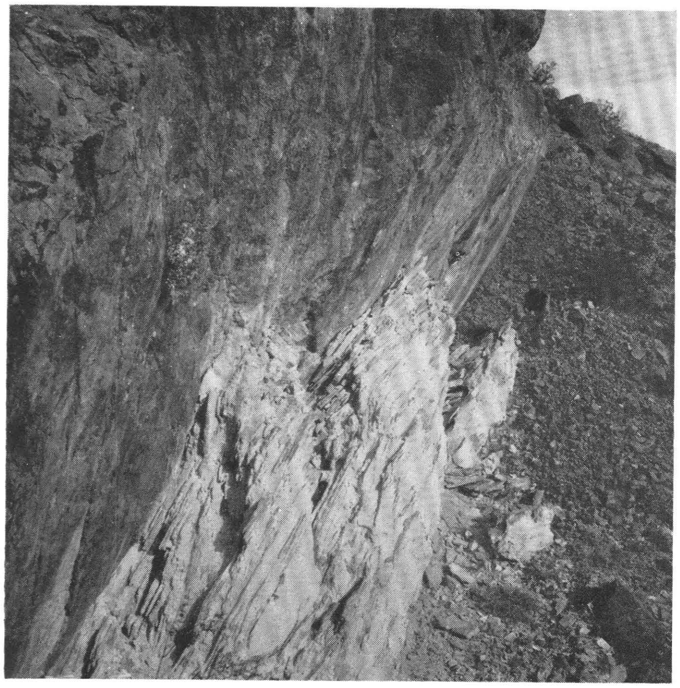

FIGURE 39.—View N. 70° E. along contact of Mississippian limestone on tuffs of middle Tertiary section, shown in figure 32. Nevada.

In the Kingston Range, two fensters of pre-Cambrian gneiss are revealed by erosion through a plate made up of Upper pre-Cambrian and Cambrian sedimentary rocks and intrusive rock of Late Cretaceous to early Tertiary age, highly unconformable on the gneiss. This interpretation is confirmed by cores of two drill holes on iron deposits. The areal limits of the plate are not exposed but it seems to be at least 12 by 15 miles.

In the hills west of Winters Pass, five blocks of Goodsprings dolomite and a small lens of Tertiary sedimentary rocks, rest with discordance on a basement that is largely pre-Cambrian gneiss and locally Prospect Mountain quartzite. The base of each of these blocks is exposed at many places; it seems certain that the five blocks are the remnants of a plate that was at least 3 miles in diameter.

The regional setting of these three plates indicates that they are parts of a once-continuous plate about 15 by 27 miles in extent. The plates in the Kingston Range and the hills of Winters Pass are largely made up of sedimentary rocks, and the basement in each is pre-Cambrian gneiss. By contrast, the plate in the Shadow Mountains is pre-Cambrian gneisses with sporadic patches of basal sedimentary rocks of Paleozoic age and the basement is middle Tertiary sediments which locally rest upon Laramide monzonite.

It is a plausible assumption that the plate of limestone of Mississippian age that rests upon middle Tertiary sedimentary rocks of Valley Ridge in Mesquite Valley is a part of the large plate described above, but this is not necessary; the plate may represent part of a local thrust plate whose roots are concealed under alluvium in Mesquite Valley.

It is also a plausible assumption that there is some relation between the coarse breccia-conglomerate in the upper part of the middle Tertiary system of the Shadow Mountains and this thrust plate. It will be recalled that the conglomerates in the lower part of the Tertiary system contain fossils characteristic of formations of late Paleozoic age and that the highest dolomite conglomerates seem to be made up wholly of material from the Goodsprings dolomite, near the base of the section of Paleozoic age. If it be assumed that a great plate of rocks made up of pre-Cambrian gneiss overlain by a conformable succession of sedimentary rocks of Paleozoic age were to move eastward, erosion would remove first the materials of late Paleozoic age and then the progressively lower and older rocks. Such materials could be deposited in a sedimentary basin that lay east of the plate and the plate could later move over its own waste in that basin. The large blocks of Goodsprings dolomite in the upper breccia-conglomerate could not have been transported by water to their resting place but may have been carried in a sheet of unconsolidated waste moving under the influence of gravity. Wherever observed, the bases of these lenses of breccia-conglomerate reveal movement after consolidation. The fatal weakness of this assumption is that there is widespread evidence that the middle Tertiary sedimentary rocks were tilted and eroded before the plate of pre-Cambrian gneiss moved over them.

A satisfactory explanation of the extent and source of the Kingston thrust plate must await careful study of the region to the west and northwest.

OLD DAD FAULT

The Old Dad Mountain area (T. 12 N., R. 10–11 E.) presents a group of complicated structural features; rocks that range in age from the oldest Proterozoic through the Paleozoic are involved. (This mountain should not be confused with that of the same name but more widely known, which lies about 20 miles south, in T. 8 N., R. 11 E.) The most persistent structural feature in this area is the Old Dad fault which crops out prominently on the east slope of the mountain for 5 miles with a strike of N. 33° W. and a dip of 70° NE. The hard rocks in place on the northeast side of the fault are largely gray granite gneiss containing white and pink orthoclase, quartz and meagre white mica; dikes of alaskite, containing white orthoclase and quartz without mica which intrude the granite gneiss; basic intrusive rock, greenish and chloritized. These rocks form a belt 2 miles long on the east side of Old Dad fault and an isolated hill east of the main ravine that cuts across Old Dad Mountain.

For about 2 miles north of this ravine, the rocks on the west side of Old Dad fault are limestones of the Bird Spring formation, which are thoroughly broken in a zone 200 feet wide adjacent to the fault. This crushed rock presents numerous triangular facets toward the fault. The dip of the Old Dad fault and the rocks that form the two walls indicate that the fault is a thrust. The possibility should be considered, however, that it is a normal fault which has been tilted southwest about 30° (section *F–F′*).

PLAYGROUND THRUST FAULT

The northern two-thirds of Old Dad Mountain shows a cap of rocks of Paleozoic age resting at the north upon pre-Cambrian crystalline rocks. An extremely simple flat thrust fault, here named the Playground thrust, separates the cap from the base of the mountain. Where it is exposed on the north side of the ravine that crosses Old Dad Mountain, the fault seems to strike N. 30°–40° E. and to dip about 20°–30° NW. (fig. 40). In the central third of Old Dad Mountain, the upper plate is made up of Goodsprings dolomite, Sultan limestone, Monte Cristo limestone and the Bird Spring formation, which are folded to a simple anticline that plunges southeast. Owing to the attitude of this anticline, successively older formations are brought to the surface northward, so that on the northern third of the mountain the cap consists only of Goodsprings dolomite.

The rocks that underlie the Bird Spring limestones at the Playground thrust are the pre-Cambrian flow breccias that have been described on page 22. At places on the north side of the canyon, the flow breccias appear to strike northwest and dip from 20° to 30° NE. On the south side of the canyon, the flow breccias are bleached and much broken by vertical joints so that their attitude is not apparent.

The west slope of Old Dad Mountain is broken by two sets of normal faults: an early group (represented by a single fault on the geologic map) that strikes N. 35° W. and dips steeply west; a later group that strikes N. 30° E. and dips steeply northwest. Along the second group the displacement increases southwestward and the faults die out northeastward on the mountain. In detail, too small to be shown on the map, the effect of the two systems of faults is to produce a checkerboard of outcrops. At the north end of the central third of Old Dad Mountain, a persistent fault with N. 30° E. strike and northwest dip drops a block of Monte Cristo limestone on the north side against the pre-Cambrian rocks on the south side. Even though it is not apparent from the local outcrops, this block of Monte Cristo limestone must be a part of the thrust plate that forms the high part of Old

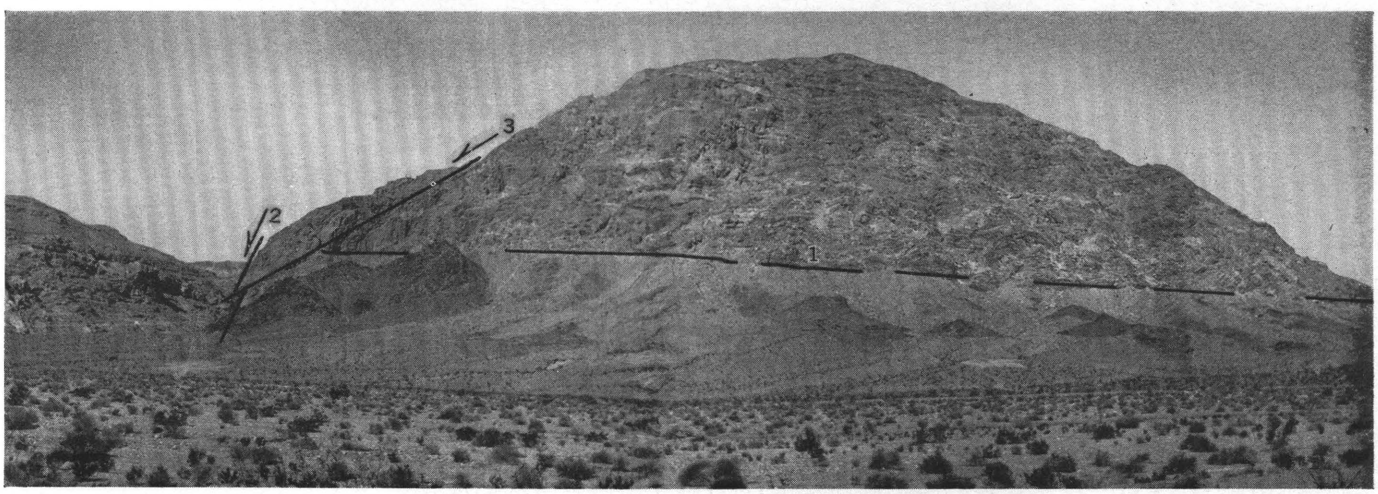

FIGURE 40.—View northwest across wash through Old Dad Mountain, showing block of Bird Spring formation resting upon pre-Cambrian gneiss and flow-breccia, California.

Dad Mountain. The dip displacement on this fault near the block of Monte Cristo limestone must be about 2,000 feet. The displacement farther east must be scarcely 500 feet, so that like the normal faults of similar strike farther south, the same sort of hinge movement is indicated.

The succession of faults on Old Dad Mountain is interpreted as follows:

1. Playground thrust
2. Old Dad fault, N. 33° W.
3. The N. 35° W. group along the west slope
4. The N. 30° E. group

As assured middle Tertiary rocks are lacking in this area, the age of these faults is a matter for speculation. The Playground thrust is a very simple surface, nearly a plane, that strikes northeast and dips at low angles northwest. Along it, folded rocks of Paleozoic age rest on pre-Cambrian dacite flow breccia. These features resemble those of parts of the Kingston thrust with which it is therefore correlated.

Is the Old Dad fault a thrust or a tilted normal fault? If it is the latter, it may have originally dipped steeply westward, and, with all the features on Old Dad Mountain, have been rotated about 30° westward. Actually, the Playground thrust plate appears to have been rotated eastward along a northeast axis, much like the plates in the Shadow Mountains. If this is true, then the Old Dad fault once had a lower eastward dip than it now has. It seems probable that the Old Dad fault was originally a thrust and that it broke the earlier Playground thrust. There are normal faults but no thrusts in the hills that lie along the west side of the Devils Playground.

AGE OF THE KINGSTON AND PLAYGROUND THRUSTS

At the present time, the evidence is not at hand with which to state the precise age of the several structural features described above, of the succeeding epochs of erosion, or of the deposition of sedimentary rocks. It can be stated with assurance only that the events followed others in a definite order. The basic assumption is that the rocks here called middle Tertiary in age may contain the equivalent of the Avawatz formation of Henshaw (1939) (lower Pliocene series) and that no younger beds are involved in the thrust faults exposed in the Ivanpah quadrangle. Until further study of this general region has been made and fossils have been found in the sedimentary rocks, only tentative statements can be made that the orogeny of which these great thrusts are a part, is post-early Pliocene(?) age.

EPISODES AND PROCESSES OF QUATERNARY AGE

Even in the early stages of fieldwork in this region, it was apparent that there were so many episodes of deformation, deposition of sediments, and extrusion of volcanic materials, and erosion since the orogeny of late Pliocene age, that it seemed difficult if not impossible for all of these events to have taken place within the geologic time available under existing orthodox concepts. Yet the evidence of the following episodes seems convincing.

1. Development of the Ivanpah upland.
2. Deposition of the Resting Springs formation.
3. Erosion of the Resting Springs formation.
4. Extrusion of the early basalt flows.
5. Development of Ivanpah Valley by faulting; of other normal faults and Mesquite Valley by warping.
6. Deposition of the older alluvium.
7. Deposition of the younger alluvium, and local lake beds near Valley Wells and in Lanfair Valley.
8. Extrusion of the later basalt flows.
9. Deposition of wind blown sand.

DEVELOPMENT OF THE IVANPAH UPLAND

The erosion that produced the Ivanpah upland may have begun in late Pliocene time, but even so the remaining episodes seem to require much more time than is commonly assigned to the Quaternary period.

An enormous volume of rock must have been removed by erosion during the development of the Ivanpah upland, whose outstanding features and extent have been described on page 19. There seems to be no way by which the thickness of the frontal zone of the Kingston thrust plate may be estimated closely. Within the area of 16 by 35 miles within which remnants still persist, it seems doubtful that the average thickness could have been less than 10,000 feet, and parts of it may have been 15,000 or even 20,000 feet. Except the Kingston Range block which is now about 3,000 feet thick, most of the remnants are from 200 to 500 feet thick. Most of the indicated erosion of the plate must have taken place before the Ivanpah upland was completed.

Most of the ranges (Spring, Clark, Ivanpah, New York, and Providence Mountains) that rise above the Ivanpah upland are composed of carbonate rocks. The only exceptions are the McCullough, Lucy Grey and Kingston Ranges which are made up of pre-Cambrian gneiss and monzonite porphyry, respectively. Even though comprehensive studies of the region surrounding Ivanpah quadrangle have not been made, so great is the volume of rock removed to establish the upland, that it seems fair to conclude that the streams of the region must have drained outward to the sea rather than to interior basins. Little is known of the depth of the filling in Soda Lake and Silver Lake basins; the deepest well, near Baker, about 450 feet deep, is wholly in unconsolidated alluvium.

DEPOSITION OF RESTING SPRINGS FORMATION

The hills southwest of Pahrump Valley in the northwest corner of the quadrangle show large areas of sedimentary and volcanic rocks that assuredly were deposited on hills of Goodsprings dolomite and appear to be younger than the thrust faulting of late Pliocene age; they are here regarded as younger than any other beds of Tertiary age and are designated the Resting Springs formation. Resting Springs lies on the old road (Spanish Trail) about 15 miles southwest of the largest of the hills west of the limit of this quadrangle. The hills that lie in the eastern half of T. 21 N., R. 9 E., show three principal units: the lowest including about 600 feet of sandy limestone with pebble zones, the middle consisting of water-laid light-colored tuffs, and the upper unit of flows of reddish latite and dacite.

The following section of the lower part of the lowest unit was measured in sec. 13, T. 21 N., R. 9 E., where the beds strike N. 30° W. and dip 30° NE.

Section of Resting Springs formation measured in sec. 13, T. 21 N., R. 9 E.

Top of section	*Feet*
Limestone, brick-red, fine-grained	6
Limestone, reddish-brown; with pebbles as much as 1 in. in diameter	3
Limestone, cream and red	2
Limestone, red	8
Limestone, reddish; pebbles as much as 1 in. in diameter	5
Limestone, red	10
Limestone, red and buff, persistent	3
Limestone, red	5
Pebble bed, maximum diameter of pebbles 1½ in	2
Limestone, red	2
Pebble bed, maximum diameter of pebbles half an inch	2
Limestone, red	3
Pebble bed, persistent	6
Limestone, red, sandy, contains some pebbles	20
Pebble bed, brown, maximum diameter of pebbles, 2 in	3
Limestone, red, thin-bedded	6
Pebble bed, brown, maximum diameter of pebbles, half an inch	1
Limestone, red	5
Limestone, tuffs	4
Limestone, red	5
Pebble bed, brown	1
Limestone, red	4
Pebble bed, dolomite and quartzite pebbles	4
Limestone, red with pebble zones	20
Sandstone, limey, pebbles as much as one-fourth inch in diameter	2
Limestone, red	7
Pebble bed, gray dolomite and quartzite pebbles as much as 2 in. in diameter; limey matrix, persistent	5
Limestone, buff, sandy, platy	50
Limestone, red, platy	50
Total	244

At the base is Goodsprings dolomite having the same strike and dip as the overlying limestones of the Resting Springs formation.

The red limestones in this section are an uncommon variety. When dissolved in weak hydrochloric acid, they leave an abundant spongy residue of partly devitrified glass shards, some orthoclase but no quartz. Such material suggests that volcanoes were active in this or nearby drainage basins. The dolomite and quartzite gravels were derived from rocks on the borders of the basins.

Farther southeast at two localities, 5 and 6 miles respectively northeast of Horse Springs, there are patches of mottled buff limestone about 1,000 feet in diameter and of unknown thickness which rest upon surfaces of low relief carved on Prospect Mountain quartzite. The rocks are nearly pure limestone, have a wavy layering, and resemble calcareous tufa. At the northern locality, just north of the Inyo County line, this material contains zones of quartzite pebbles as much as 6 inches in diameter. The layering trends generally north and dips 30° to 40° E., but this layering is probably not parallel to the surface on which the limestone was deposited.

Another patch of buff limestone caps the low hill north of benchmark 2,846, in the center of Pahrump Valley. Here the layering trends northwest and dips 20° NE., or broadly parallel to that at the localities described above, roughly 5 and 6 miles south.

At the south end of Mesquite Valley, half a mile east of the Mesquite Pass road, in sec. 5, T. 17 N., R. 13 E., there is an outcrop, too small to map, of latite tuff which probably belongs to this group of rocks. On the south site of a ravine 30 feet of white tuff is exposed resting on Prospect Mountain quartzite and overlain by recent local wash. This is overlain by cemented dolomite breccia. The tuff strikes north and dips 20° W., almost conformable with the attitude of the quartzite. Viewed under the microscope, the tuff is largely glass with some orthoclase, oligoclase, and biotite, but no quartz.

The outcrop lies only a few hundred feet west of the Clark Mountain fault along which the rocks of Paleozoic age on the west side have dropped with respect to the pre-Cambrian rocks on the east. The age of the Clark Mountain fault is discussed on pages 57–58. The attitude of the tuffs suggests late movement on the fault.

The interpretation of the age of the Resting Springs formation is based upon the assumption that the outcropping hills of Goodsprings dolomite against which it was deposited are themselves part of the plate which has been thrust eastward upon the Kingston thrust. The continuity of beds of the Prospect Mountain quartzite and Pioche shale in the hills northeast from Horse Spring indicates that they are part of the overthrust plate. Even though there are not continuous exposures, the continuity of the strike and dip of the quartzite as far northwest as the 3,800-foot hill in sec. 32, T. 21 N., R. 10 E., upon which there is a thin sheet of Resting Springs formation indicates that the whole area of Cambrian strata is a part of the plate that moved eastward along the Kingston thrust, and that it took place after the middle Tertiary sedimentary and volcanic rocks were deposited.

Reconnaissance examination of the region northwest of these hills indicates that the sedimentary rocks of the Resting Springs formation are part of a great sheet, as remnants extend at least 15 miles northwest along the east flank of the Nopah Range. The rocks are not known east of Pahrump and Mesquite Valleys. The known distribution of this sheet of sedimentary rocks in Pahrump Valley and their attitude suggests that this valley, like Mesquite Valley to the southeast, is coextensive with an area of recent downwarp; whether the northeast side of the valley marks a fault or a corresponding warp is not known.

The age of these beds is not known. However, their place in the cycle of sedimentation, deformation, and erosion during late Pliocene or Pleistocene time seems definite. Compared with the beds that occur at the base of the section of middle Tertiary sediments along the flanks of the Shadow Mountains, those of the Resting Springs formation contain less local sand and gravel, much more lime, and about the same amount and kind of volcanic glass. Even if their place in the cycles of sedimentation, deformation, and erosion during late Tertiary time was not known, the sedimentary rocks of the Resting Springs formation do not closely resemble those of the earlier formation.

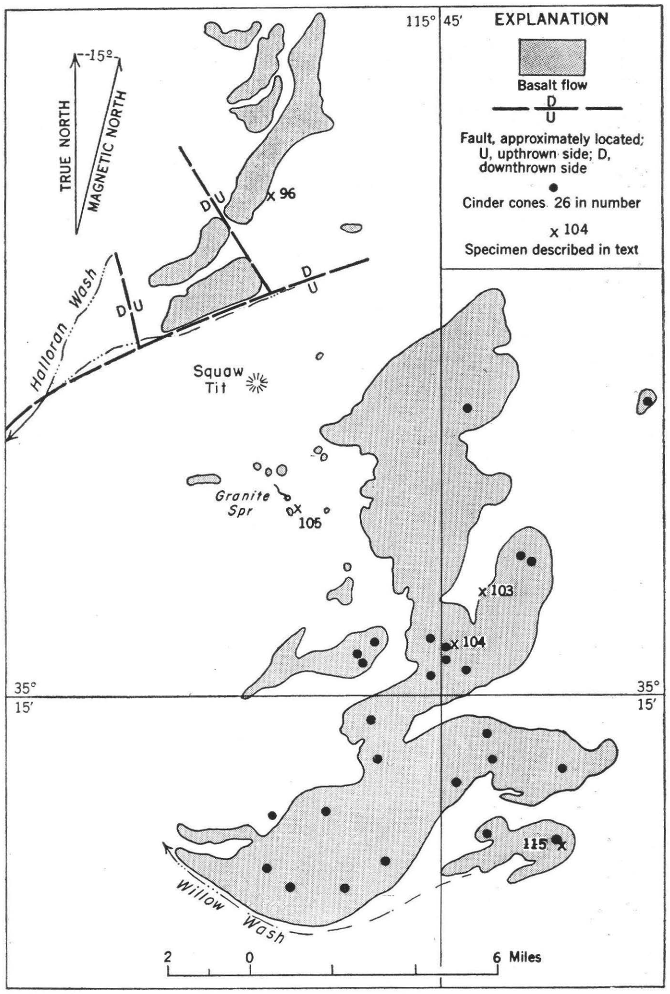

FIGURE 41.—Present distribution of remnants of older and younger basalt flows and cinder cones between Halloran and Willow Springs Washes.

EROSION OF THE RESTING SPRINGS FORMATION

The surface upon which the earliest basalt flows (Halloran Wash, fig. 41) were deposited seems almost to coincide with the Ivanpah upland, but the local sheet of sand that underlies the flow probably represents the filling of a local erosion channel. The sporadic distribution in the northwest corner of remnants of the Resting Springs formation indicates that once it was more widespread. The erosion of the formation probably began before the downwarp of Mesquite Valley and has continued to recent time.

EXTRUSION OF EARLY BASALT FLOWS

In the southwest quarter of the quadrangle basalt flows underlie about 75 square miles. In the southern half of the area the flows are surmounted by 26 cinder cones which mark the locations of craters that were the source of most, if not all, of the flows (fig. 41). Over most of the area, the flows appear to rest upon a surface cut on quartz monzonite, but in a few areas, such as that east of Granite Spring, a sheet of unconsolidated sand lies between the two rocks. Even though they are composed of the same kind of basalt, it is quite clear that considerable time elapsed between the extrusion of the older northern flows and the younger southern flows. The conclusion is reached that the most extensive group of flows, which once covered nearly 300 square miles, were laid on remnants of Ivanpah upland, a surface of moderate relief that has been recognized over a large area in the quadrangle. However, some of the flows in the south half of the lava field flowed southwest down the present valleys and have not been appreciably eroded.

Most of the cinder cones and the youngest flows lie in the southern half of the lava field; by contrast, there are only several cones in the northern half of the lava field where the flows are thicker. In fact, so far as this examination was carried, all of the present flows in the north half of the field appear to be remnants of a single extensive group of flows, once about 12 miles wide and 25 miles long. The great sheet that underlies about 20 square miles northeast, east, and southeast of Granite Spring attains a maximum thickness of about 400 feet east of Granite Spring and is thinner to the north and to the south. It presents an abrupt scarp to the west. Along this scarp a layer of sand 50 to 75 feet thick separates the flow from the underlying quartz monzonite. From the highest of these hills (benchmark 4,936) where the group of flows is about 400 feet thick, it slopes gently northeast, east, and southeast at a gradient of 150–200 feet to the mile. By contrast, to judge from the distribution of lava-capped hills north, west, and south of Granite Spring, it seems clear that the flow once extended at least 4 to 5 miles west of the present escarpment, and that before erosion it sloped gently west at a gradient of several hundred feet to the mile. In other words, before the flow in the region west of the escarpment was dissected, it had the form of a broad arch whose axis trended northwest.

In view of the great extent to which the flows west of the escarpment have been eroded, it is surprising to note that some of the flows at the southern half of the lava field are confined to present valleys and are not eroded. This can mean only that the great sheet east of Granite Spring is appreciably older than the small flows in the south. There is no way to estimate the age of these flows. From their appearance and lack of erosion, those at the southern part of the lava field may have been extruded in historic time. It is concluded that the entire group of flows may be assigned to Quaternary time.

All twenty-six of the cinder cones are built upon earlier flows; from several of the cones late flows broke through the sides. Most of the cones have a simple symmetrical form with a depression in the center. They are made up of coarse angular blocks of scoriaceous lava. Several large cones have one or more satellitic small cones nearby.

The rock of which the flows, older and younger, as well as the cones, are made, is uncommonly homogeneous throughout the field. The group of flows that forms the northern half of the field (specimens 96, 105 in the following table) is dense black rock that contains sporadic coarse grains of labradorite, brown hornblende, and black glass, mostly 1–3 millimeters in diameter. The groundmass is largely fine blades of labradorite and olivine with sparse iron oxide. The other three specimens (103, 104, 115, table 8), collected near cones in the south half of the field, are dark gray to black and more vesicular than the northern flow. Coarse grains of labradorite and olivine are less common in a finely crystalline groundmass of labradorite and olivine; in one specimen (104) there is considerable glass in the groundmass. The rock from the most southeastern cone contains irregular grains of clear cleavable andesine (An_{30}) as much as 1½ inches in diameter but the groundmass is largely fine blades of labradorite (An_{65}).

In general, the dense parts of the basalt flows are nearly black, but the more vesicular rock of the cinder cones is dark-reddish brown.

The only other flows in this quadrangle that have been poured out on the present surface, obviously much younger than the other volcanic flows, are found in the northeast corner of the quadrangle between Sutor and Sloan on the Union Pacific Railroad. These flows, however, are latite.

In appearance and mineral composition, the basalts of this area closely resemble those described by Gardner (1940), which are found in the lava field that extends from Lavic westward nearly to Newberry along the

Mineral composition of basalt flows

	96	195	103	104	105
Phenocrysts					
Andesine			An_{40}	An_{40}	An_{30}
Labradorite	An_{60}	An_{60}	An_{60}	An_{60}	An_{65}
Olivine	Present	Present	Present	Present	Present
Horneblende		Present			
Augite			Present	Trace	None
Black glass	Present	Present			
Matrix					
Plagioclase laths	Abundant	Abundant	Abundant	Present	Abundant
Olivine	Common	Common	Common		
Augite			Present		
Iron oxides		Present		Present	
Glass				Abundant	
Vesicles	Abundant	None	Common	Common	Common

96. Sec. 32, T. 16 N., R. 11 E.
195. Sec. 9, T. 14 N., R. 11 E.
103. Sec. 20, T. 14 N., R. 12 E.
104. Sec. 36, T. 14 N., R. 11 E.
105. Sec. 9, T 14 N., P. 11 E.

Mineral composition of the recent flows

	45	50
Phenocrysts	20 percent	Sparse
Orthoclase	15 percent	
Andesine	An_{30}; 5 percent	
Augite	1 percent	
Biotite	2 percent	
Olivine		Sparse
Matrix	80 percent	
Feldspars		Abundant
Augite		Abundant
Biotite		Sparse
Lithophysae	20 percent	
Glass	80 percent	
Color	Pale green	Black
Vesicles	Sparse	None

45. Latite from Sutor, sec. 28, T. 24 S., R. 60 E., Nev.
50. Basalt from Sloan, sec. 13, T. 23 S , R. 61 E., Nev.

Santa Fe railroad about 50 miles south of this area. The flows west of Lavic have been spread over recent surface features as they have in the Sutor-to-Sloan area.

At only one locality in the eastern half of the quadrangle is there a body of basalt flow which has the appearance of being relatively recent. The low hill (4,705 feet) nearly a mile in diameter in sec. 17, T. 12 N., R. 16 E., and a smaller hill 1,000 feet north, are underlain by black vesicular basalt that contains coarse grains of plagioclase, much like the material that forms the flows north of Willow Wash, in T. 13 N., Rs. 11 and 12 E. It rests upon a flat surface carved on quartz monzonite, a part of the Ivanpah upland.

In nearby regions both west and southwest, basalt flows that closely resemble the older and younger flows of this area have been recorded. At Black Mountain, 25 miles northwest of Barstow, Baker (1911) recognized a flow of basalt lying unconformably on beds of his Rosamond series (Miocene series). Hulin (1925, p. 148), near Randsburg, has mapped small patches of similar basalt to which he applied the same name, Black Mountain basalt. Gardner (1940) has mapped flows of basalt in the Lava Bed Mountains, 60 miles east of Barstow, which resemble and have the same relations as the flow at Black Mountain. Also, near Pisgah, 40 miles east of Barstow, Gardner has mapped a very recent flow of basalt that was derived from a recent crater (Mt. Pisgah).

There is always uncertainty in the correlation of volcanic rocks on the assumption that similar rock types in nearby regions appeared at the surface at the same time. The relations of the older basalt flow near Granite Spring (Ivanpah quadrangle) to both preceding as well as succeeding events, indicates that it may be correlated with the Black Mountain basalt to the west and southwest. The younger flows of this area and the related cinder cones seem to correlate with the Pisgah crater and flows.

FORMATION OF VALLEYS BY FAULTING AND WARPING

Plate 2 shows many normal faults which are interpreted as late Tertiary or Quaternary in age; some are small and others are impressively large. Most of the large normal faults lie around the borders of Ivanpah Valley and most of them are determined by displacements of Tertiary strata. Tertiary rocks are absent in the Bird Springs Range and Spring Mountains north of Table Mountain so that there is uncertainty about the age of the normal faults in that area.

The floors of both Ivanpah and Mesquite Valleys stand at an altitude of about 2,500 feet or about 1,500 feet below the surrounding uplands, Lanfair Valley to the east and the Valley Wells plain to the west. From the borders of both of these uplands, waste is being abundantly poured into the valleys. From these relations, it is apparent that the valleys have been formed relatively recently either by warping or faulting or both.

Ivanpah Valley is a closed basin whose floor lies about 1,500 feet below the Ivanpah upland and is essentially bounded by Ivanpah fault on the southwest and by McCullough fault on the east. The dip displacement on Ivanpah fault, based upon the offset of the Mesquite thrust where last exposed eastward, is about 8,000 feet and the displacement increases southeastward. On the basis of offset Tertiary sedimentary rocks, the dip displacement on McCullough fault is about 20,000 feet. Numerous small normal faults displace the Tertiary sedimentary rocks along the ends of McCullough Range and along each, the block nearest Ivanpah Valley has dropped. Along the State Line fault, the latest movement dropped the southwest side nearly 2,000 feet. Ivanpah Valley, therefore, roughly coincides with a block in the shape of an isosceles triangle hinged at the northwest base and pointing southeast, whose apex has dropped about 20,000 feet since the Ivanpah upland was developed. There seem to be two ways by which a depression such as Ivanpah Valley could be formed: by the dropping or down warping of a block roughly coinciding with the valley or by deflation or removal of debris by winds. When one has observed some of the dust storms that occur in this region in the spring, he is prepared to recognize that much material in the form of dust is removed from all or parts of the region. The records of the wells drilled for water in Ivanpah and other nearby valleys, however, indicate that they are areas of aggradation rather than degradation. Deflation is taking place in this region but it appears inadequate to account for selective erosion of the valleys. Ivanpah Valley contains some of the largest alluvial fans of the eastern Mojave Desert, and they are in process of aggradation by drainages that rise not only in front of but behind the surrounding high mountains.

The Cedar Canyon fault has uncommon features somewhat similar to those of the State Line fault, 35 miles north; the late movement on both faults reverses the early movement. In the lower part of Cedar Canyon, as indicated by the plate of pre-Cambrian rocks on the north side and its absence on the south side, the north side seems to have dropped. On the other hand the section of middle Tertiary sediments under Pinto Mountain, 900 feet thick south of the fault, and the flows farther east indicate that in later time the south side has dropped at least 900 feet. As wells drilled for water southeast of the fault at Kelso by the Union Pacific Railroad have penetrated as much as 1,950 feet of unconsolidated sediments, it would appear that the Cedar Canyon fault extends to Soda Lake and partly explains the depth of the fill in Kelso Valley.

Several normal faults displace the Playground thrust and along each, the block toward Soda Lake has dropped. Similarly, along the Eastern Star fault, in the Shadow Mountains, the western block toward the Death Valley trough has dropped about 1,500 feet. Along the Halloran fault that trends northeast, the northwest side has dropped only several hundred feet.

The great trough, of which Death Valley is a part, lies only a few miles west of Ivanpah quadrangle. The altitude of the floor of the valley ranges from about 1,000 feet at Soda Lake to 600 feet, 40 miles north. Some (Blackwelder, 1934) who have studied parts of this trough in recent years think that it drained southward to the sea near the Gulf of California in recent time. According to Noble (1941) the lowest part of the valley has formed through both local warping and local faulting. The number of recent normal faults along the western one-third of the Ivanpah quadrangle is small but the displacement along them is consistent with general subsidence along the Death Valley trough.

Mesquite Valley coincides with a downwarp; minor faults may limit parts of the valley, but it is thought that they have played only a small part in the depression of the valley. Evidence of the warping is shown in the present shape of the Mesquite thrust fault (pl. 2), and in the attitude of the Resting Springs formation. In the hills northeast of Clark Mountain and north of Ivanpah fault, the thrust surface is warped to a trough that plunges northwest toward Mesquite Valley. The latest movement on the State Line fault by which the southwest side dropped (fig. 17) may have coincided with the downwarping of Mesquite Valley. There are large alluvial fans on the northeast sides of Mesquite Valley and Pahrump Valley.

Briefly summarizing, there are only modest alluvial fans on the slopes above the Ivanpah upland; the large alluvial fans of the region lie on the slopes below the Ivanpah upland and are spread out toward the valleys that lie below it. The large valleys in this region have been formed by recent faults (Ivanpah Valley), recent warps (Mesquite Valley), or by warping, faulting, and erosion.

DEPOSITION OF ALLUVIUM

OLDER ALLUVIUM

In numerous localities in the quadrangle, of which five are worthy of note, there are extensive outcrops of unconsolidated sand and gravel that, from their composition and elevation with respect to the nearby country, appear to belong to an earlier cycle than the alluvium now in process of deposition. They are the low hills at the north end of Mesquite Valley, the northern part of the Shadow Mountains, the hills west of Kelso Peak, the low hills south of Barnwell, the hills near Highland Spring.

Along the Nevada-California line about 5 miles southeast of Stump Spring, two elongated hills form a ridge nearly 4 miles long that rises about 300 feet above the nearby wash. They are made up largely of light- and dark-brown quartzite, gravel, and boulders, subangular to angular, mostly 3 to 6 inches in diameter, with a few as large as 10 by 12 by 15 inches. These appear to have been derived from the Prospect Mountain quartzite, which does not crop out in the hills within 15 miles to the northeast. It does crop out however, in the hills on the southwest side of Mesquite Valley and near Johnnie, about 30 miles northwest. The gravels are deficient in limestone and dolomite of Paleozoic age, which form the nearby hills to the east. However, there are a few cobbles of Goodsprings dolomite, green shale (Pioche? shale) and red limestone, such as form the hills 10 miles west. The source of these gravels is apparently the hills to the west and northwest, rather than the nearby hills to the northeast.

Somewhat similar deposits of coarse gravels were observed in sec. 30, T. 23 S., R. 59 E. at the northern end of Goodsprings valley, east of Spring Mountains; they were described in detail in the Goodsprings report, (Hewett, 1931, p. 41). The conclusion was reached that the large boulders of quartzite that are present were derived from beds of quartzite in Cambrian formations near Johnnie, Nev., and they have been carried 40 miles southeast in a channel that crossed the mountains. The channel is now broken into three separated basins. This stream channel seems to have existed after Ivanpah valley was formed (fig. 42).

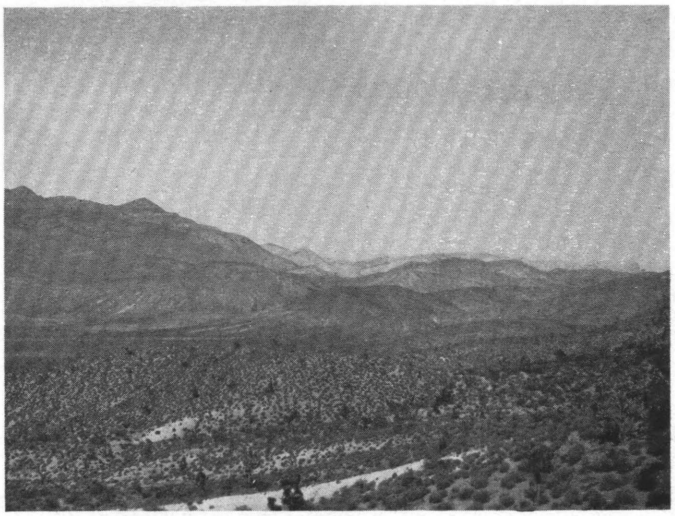

FIGURE 42.—View N. 35° W. from hill in sec. 30, T. 23 S., R. 59 E., Nevada along old stream channel to Charleston Peak, 40 miles distant.

Near the low hills that lie southwest of Pahrump Valley about two miles north of benchmark 3,466, there is a cluster of huge well-rounded boulders of Kingston Range monzonite porphyry. The largest of these, about 30 by 25 by 12 feet, is estimated to weigh about 800 tons. They lie on recent alluvium at an altitude of 3,100 feet or about 2,000 feet lower than the nearest outcrop of Kingston Range monzonite porphyry, 9 miles south. In many places in northern latitudes it would be assumed that such boulders were transported to their resting place by glaciers. From what is now known of the recent climate of this region, this interpretation seems impossible. A more plausible suggestion would be that the boulders, rounded by weathering, were transported by flows of mud and sand aided by torrential rains. Beyond this cluster no other boulders were found within 10 miles.

Unconsolidated sand and gravel form a group of three hills that lie between Shadow Mountain and the Shadow Mountains and rise from 300 to 700 feet above the surrounding wash. Another ridge lies south of Kingston Spring, on the west slope of the Shadow Mountains. The contained cobbles show a wide range of rock types—black basalt, red scoriaceous basalt, quartzite, dolomite and light-colored flows, appearing to have a local source. Most of them are more than 6 inches in diameter; the largest is 12 by 15 by 18 inches. They form a thick veneer on light-colored sand and tuffs. Near Coyote Holes, on the south side of Kingston Wash, a fault that trends N. 15° W. and dips 70° W., is shown in these gravels. Along the fault the west side has dropped 12 feet. This is the youngest fault that has been recognized in the quadrangle. It is roughly parallel to the fault that is exposed on the west slope of the Shadow Mountains.

The ridges that lie between Old Dad Mountain and Kelso Peak present the largest area and apparently the greatest thickness of old gravels. The area is about 16 square miles and the highest hill rises about 1,300 feet above the wash to the west. The entire assemblage of rocks that make up the section of early Paleozoic age of this region is represented. There is also considerable granite gneiss (pre-Cambrian rocks), some blocks of which are as much as 6 feet in largest diameter; these are considerably decomposed by weathering. The hills covered by these gravels rise to 4,200 and 4,300 feet, only 450 feet lower than Kelso Peak (4,746 feet), the highest hill in an area 25 miles in diameter. Only in a few places are the gravels exposed under the mantle of local debris. The 3,300-foot hill that lies 2 miles east of Old Dad Mountain is capped by cemented limestone and dolomite gravels. These overlie fairly well stratified sand, gravel, and fanglomerate.

The apparent source of this material is the region to the east, and it must have been deposited after the Ivanpah upland was established. It should be noted that the highest hills made up of this coarse alluvium rise to the average level of that upland.

The small valley that lies between two ridges about 2 miles west of Valley Wells contains coarse gravel in which all the nearby rocks are represented. The largest blocks are quartzite and the local monzonite, as much as 5 feet in largest diameter.

There are two large bodies of unconsolidated gravels near Barnwell, one 3 miles north and the other 2 miles south. The first of these, several hundred acres in extent, forms the crest of the New York Mountains at an elevation of 5,000 feet. It contains all the rocks that crop out in the nearby area—gray limestone, volcanic rocks, and granite gneiss, which is most abundant. Some of these boulders, as much as 2 feet in diameter, are well rounded.

The second body forms the flat-topped ridges that trend eastward from Lecyr well on the east slope of New York Mountains. The body seems to have been a continuous sheet but it is now dissected by several valleys, 100 to 125 feet deep. The blocks are largely dolomite of the varieties represented in the hills to the west.

The west slopes of the hills that extend southward from Highland Spring east of McCullough Range are heavily cloaked with coarse gravels in which granite gneiss predominates. Blocks as much as 4 by 4 by 6 feet are common. As the gneiss of the McCullough Range is the obvious source, they must have been laid down before the valley that separates the hills from the range was eroded.

In addition to the five areas described above, there are numerous smaller areas of coarse gravels; some lying within the Goodsprings quadrangle are described in the report on that area. Four small areas of coarse gravels that lie in this quadrangle, outside the limits of the Goodsprings quadrangle, are:

1. On a flat eastward spur, 3 miles southeast of Devil Peak, at an altitude of 4,100 feet and therefore about 1,200 feet above the nearby floor of Ivanpah Valley, there is a patch of coarse boulders about 100 feet in diameter, too small to show on the geologic map. The boulders are composed of limestone, dolomite, sandstone, and chert, largely 6 to 24 inches in largest diameter; a few are 2 by 2 by 3 feet. The source of the boulders is probably the rocks of Paleozoic age that form the higher part of Spring Mountains to the west.

2. About one mile north of Erie, Nev., in sec. 3, T. 24 N., R. 60 E., there is a patch of coarse boulders about 4,000 feet long and more than 100 feet thick that covers a ridge at an altitude of 3,000 feet. The boulders are largely dolomite of the Yellowpine limestone mem-

ber and quartzite. Some are as much as 4 feet in diameter. They are probably derived from the outcrops of the member that lie several miles west and northwest. The area is shown on the geologic map.

3. A mile north of Sloan, Nev., the hill that rises to 3,700 feet is strewn with sporadic boulders of Goodsprings dolomite as much as 15 inches in diameter. As the Goodsprings dolomite is now known to crop out within 5 miles west or northwest, the source of the boulders appears to be the higher parts of Spring Mountains. The area is not shown on the geologic map.

4. The flat top of the hill that rises to an elevation of 2,500 feet east of the Whitney (Paymaster) mine or about 500 feet above the surrounding alluvial plain in T. 13 N., R. 10 E., shows three patches of coarse boulders each about one hundred acres in extent. Boulders of granite gneiss that could have local origin and quartzite of remote origin, are as much as 6 feet in diameter. The areas appear on the geologic map.

The objectives of this study did not permit the close examination of each of these areas of coarse gravels and boulders that would be needed to determine their source and conditions of deposition. All of the areas lie 400 feet or more above the local valleys and several lie near the highest hills of the local areas. In several areas, most of the gravels and boulders are of local origin; the source of others is unknown but obviously, many miles distant. In each area, the material was deposited in an early cycle of aggradation and all are now in process of degradation. Among these areas, it seems quite certain that all were not deposited in one cycle of deposition.

YOUNGER ALLUVIUM

Only a glance at the geologic map of the quadrangle is needed to show that at least half of the area, probably 60 percent, is underlain by younger alluvium, the recent waste from the mountains that is either in process of movement from the slopes of the mountains to the valleys or has come to rest in the depressions such as Ivanpah and Mesquite Valleys (Waring, 1920, p. 54). Waring classified the land in these valleys as shown in the following table.

Area of land of different classes in Pahrump, Mesquite, and Ivanpah Valleys

	Lowlands		Alluvial slopes		Mountains		
	Area (square miles)	Percent of total	Area (square miles)	Percent of total	Area (square miles)	Percent of total	Total area of basin (square miles)
Pahrump basin	250	24	330	32	460	44	1,040
Mesquite basin	90	23	115	29	190	48	395
Ivanpah basin	85	11	375	49	310	40	770

The purposes of this investigation did not justify close study of the precise nature, distribution and depth of this alluvium.

In a region such as this—where rainfall is low and highly variable; where the daily range in temperature is high, 30 to even 50 degrees Fahrenheit; and the annual range is much higher, about 120 degrees—rocks of all kinds tend to break down by disintegration rather than decomposition. As a result, even the upper slopes of the highest mountains are covered with a thin veneer of rock fragments. Consequently, not only the cloudbursts that come in the summer, but every shower sweeps large volumes into the nearest ravine and valley. Every ravine that drains the hills and mountains is building up an alluvial fan of coarse material; some of the fine material quickly reaches the lowlands. Compared with those of nearby desert regions, the alluvial fans in the larger valleys are enormous; some are as much as 4 miles in radius. The manner of formation of the larger depressions such as Ivanpah Valley and Mesquite Valley seems apparent; for some of the smaller depressions, such as those east of Jean and Erie, the mode of origin is not evident.

The thickness of the fine sediments in the large depressions can only be conjectured. The deepest wells in the four principal depressions are as follows: Mesquite Valley, 1,083 feet; Ivanpah Valley, 687 feet; Lanfair Valley, 879 feet; Kelso Wash, 1,970 feet. The material through which these wells passed was fine and coarse alluvium brought from the nearby mountains. Obviously the total thickness of such material must be much greater, probably several thousand feet in the case of Mesquite, Pahrump and Kelso Valleys. As explained elsewhere, there is reason for thinking that the basement hard rocks under Ivanpah Valley must have dropped about 20,000 feet and that the unconsolidated fill may be nearly that thick.

Any review of the recent processes of erosion and deposition of sediments in this region will assuredly lead to the conclusion that the rates of both are much higher than is commonly considered to be the case in some other regions.

DEPOSITION IN LOCAL LAKES

Within an area about 2 by 3 miles just south of Valley Wells beds of light gray marl, largely unconsolidated and nearly horizontal, are exposed. Local badlands have been carved recently by the headward erosion of intermittent streams that drain northwest to Kingston Wash, revealing thicknesses as much as 30 feet, but the beds are probably much thicker. Tests indicate that the material is at least two-thirds calcium carbonate, though it appears to be clay.

Although the beds are now in process of erosion, they were evidently deposited in a closed basin on the Ivanpah upland. It is not evident how the basin was formed; probably drainage was dammed by coalescing alluvial fans on the upland.

In November, 1950, K. E. Lohman of the U. S. Geological Survey, accompanied by the writer, made a collection of small mollusca from the clays in the middle of the section exposed in the badlands about one mile southeast of the Yates ranch at Valley Wells. These were referred to Dwight W. Taylor who, accompanied by W. O. Gregg, made a larger collection on February 2, 1951, from the beds exposed along Highway 91 southeast of Valley Wells. The following identifications made by Messrs. Taylor and Gregg:

	Highway 91	*Badlands*
Pisidium sp. undet	×	-------
Lymnaea palustris nuttaliana Lea	×	-------
Lymnaea modicella Say	×	-------
Gyraulus circumstriatus Tryon	×	×
Deroceras cf. *laeve* (Muller)	×	-------
Succinea avara Say	×	×
Pupilla n. sp	×	×
Vertigo berryi Pilsbry	×	×
Vertigo sp. indet	×	-------
Vallonia cyclophorella Sterki	×	×

"Ten species are represented: a freshwater clam (*Pisidium*), three freshwater snails (*Lymnaea, Cyraulus*), a land slug (*Deroceras*), and five land snails. The occurrence of the slug is especially interesting since slug shells have never been found in Pleistocene deposits in Western North America and are known only rarely from the High Plains region.

"The species apparently lived in and on the mud bottom in the shallow borders of the lake and among the vegetation at its margin. The lake was probably perennial; moisture at least was permanent. The mean annual temperature was probably not much different from that of the present time, with summer extremes lower.

"Of the eight identified species, only three have been found in Pleistocene deposits in the area: *Succinea avara* and *Lymnaea modicella* in Las Vegas valley, and *Lymnaea palustris nuttaliana* in the deposits of Searles Lake. With the exception of the *Pupilla*, all are still living. The others are widely distributed in the western United States.

About one mile north of the rocky ravine that is followed by the old Fort Mohave road, in sec. 13, T. 12 N., R. 18 E., erosion has cut into lake beds that lie against the west slope of Piute Range. The beds are exposed in an area of badlands, several hundred acres in extent and about 250 feet deep. The beds are buff clay and sand without carbonate concretions, and with gravel only in the uppermost 25 feet, which also contain layers of caliche. It would appear that fine sediments accumulated in a basin on the west slope of Piute Range and they are revealed in a small valley after erosion cut the notch through Piute Range.

EXTRUSION OF THE LATER BASALT FLOWS

Flows shown in figure 41 include both early flows that lie on the Ivanpah upland and have been warped and greatly eroded locally and later flows that lie in the present valleys and show little evidence of erosion. In order to distinguish closely between the distribution and limits of both groups of flows, much more study will be needed than was given by the author. Some of the 26 cinder cones shown on figure 41 rest upon the early flows but most rest upon late flows. As none of the cones show much erosion, they were probably active at about the same time.

DEPOSITION OF WINDBLOWN SAND

Windblown sand is found throughout this region, from the valleys to the tops of the hills and mountains. The greatest accumulations are found in the lower valleys of the western half of the quadrangle, especially in Mesquite Valley and Devils Playground, and in these, there are large areas of sand dunes. On most of the nearby hills, especially the east slope of Old Dad Mountain, there are large areas of windblown sand. Even though dunes are not conspicuous on the valley floors of the Ivampah upland, fine windblown silt mixed with the fine alluvium washed from nearby slopes forms a mantle in these valleys. During the spring months, there are several severe wind storms, lasting 24 to nearly 36 hours, during which there is so much dust in the air that visibility is limited to several hundred feet. Obviously, during such wind storms, enormous quantities of fine sand are transported.

The following table presents the results of sizing and mineral determinations of a sample of dune sand, collected about 2 miles northwest of Sands on the Union Pacific Railroad.

Analysis of dune sand collected near Sands, Calif.

Screen size (mm)	Weight		Minerals (percent)
	Grams	Percent	
Larger than 0.25	18.0	12.6	Quartz, 60; orthoclase and microcline, 20; plagioclase, 10; hornblende, zircon, chert, 10.
Larger than 0.125	108.7	76.0	More hornblende than above; most grains, subangular.
Larger than 0.062	16.1	11.3	More hornblende and zircon than above.
Less than 0.062	.2	.1	Dark heavy minerals, 20.
Total	143.0	100.0	

The examination shows that even though the coarsest 12.6 percent of the grains are well rounded, the progressively finer grains are more angular. Also, there is a progressive increase in the heavier dark minerals in the finer sizes.

RELATIONS OF THE EPISODES OF CENOZOIC AGE TO THOSE OF NEARBY REGIONS

The following table presents an interpretation of the correlation of the principal events of Tertiary and Quaternary age in the Mojave Desert region. Obviously, much uncertainty is attached to the correlation of volcanic rocks, the sedimentary rocks of small continental basins, and surfaces of erosion. None of these episodes has the dependability of fossil-bearing zones. However, several episodes that probably have regional expression, such as the surface of erosion carved on the pre-Tertiary rocks upon which the earliest Tertiary sediments were laid down, seem to be dependable. In the eastern Mojave Desert region, where the underlying rocks are gneiss, granite, and monzonite, the surface had low relief, but by contrast, hills and even mountains of limestone and dolomite stood several thousand feet above the surface carved on the crystalline rocks. This surface of erosion seems to be the most dependable episode for correlation of rocks deposited during the Tertiary period.

There is some uncertainty about the correlation of the earliest Tertiary sedimentary rocks; sedimentation may not have begun at the same time in each basin. Because of the lack of fossils in the Tertiary sedimentary rocks of the Ivanpah quadrangle, at this time it seems

Correlation of Tertiary and Quaternary episodes, northeastern Mojave Desert

	Randsburg quadrangle (Hulin, 1925)					Newberry-Ord Mountains (Gardner, 1940)					Ivanpah quadrangle (This report)				
	Epoch	Deposition of sediments	Igneous intrusions extrusions	Deformation	Erosion	Epoch	Deposition of sediments	Igneous extrusions	Deformation	Erosion	Epoch	Deposition of sediments	Igneous intrusions extrusions	Deformation	Erosion
QUATERNARY	Recent	Alluvial fans, basin fill		Warping, minor faulting	Local internal	Recent	Alluvial fans, basin fill Daggett Ridge lake beds	Basalt flows, Pisgah basalt, Amboy basalt		Local internal	Recent	Alluvial fans, basin fill Lake beds in Valley Wells and Lanfair Valley	Cinder cones and basalt flows		Local internal
		Older alluvium										Older alluvium		Warping Mesquite Valley; faulting in Ivanpah Valley	Local internal
	Pleistocene		Black Mountain basalt	Warping	Local planation	Pleistocene	Gravels?	Black Mountain basalt		Local internal	Pleistocene	Resting Spring formation in Pahrump Valley	Early basalt flows Halloran wash		Local internal
TERTIARY	Upper Pliocene				Local										Ivanpah upland, profound, external
	Middle Pliocene Lower Pliocene		Red Mountain andesite		Local Local internal	Pliocene(?)		Red Mountain andesite			Pliocene Lower Pliocene		Andesite flows in Lanfair Valley	Kingston thrust Warping	Local, internal Local, internal
	Upper Miocene	Rosamond series, saline clay, arkose	Latite and rhyolite flows, tuffs and quartz porphyry dikes	Warping			Rosamond series (Barstow syncline)		Warping, faulting, forming basins		Lower Pliocene Upper Miocene	Clay sand gravels	Bentonite pumice basalt andesite latite rhyolite	Warping, faulting forming basins	Local
	Oligocene				Peneplanation, profound external					Peneplanation Erosion, external	Lower Miocene Oligocene				Mature upland
	Eocene		Dark and light dikes		Erosion, external			Dark and light dikes			Eocene				
											Laramide		Aplite dikes, monzonite porphyry, quartz monzonite	Thrust faults open and close folds	
	Cretaceous Jurassic?		Atolia quartz monzonite								Cretaceous Jurassic(?)	Aztec sandstone	Flow breccia		

best to assign them to the middle Tertiary system. The nearest fossil locality in upper Miocene rocks is the Barstow syncline (Barstow, Rosamond?) (Baker, 1911). The nearest fossil locality in lower Pliocene rocks is that which lies at the southeast end of Avawatz Mountains, about 7 miles northwest of Silver Lake (Henshaw, 1939). Here, a plate of intrusive granite of Mesozoic age seems to have been thrust upon the inclined and eroded beds of the lower Pliocene series. Further examination of the Ivanpah area may yield fossils in the beds of middle Tertiary age and permit precise correlation with sedimentary rocks of late Miocene or early Pliocene age.

At the present time, the second most dependable episode seems to be the orogeny (folding and thrust-faulting) in the post lower Pliocene series and it seems to be definitely determined at the south end of the Avawatz Mountains. Thrust faults of late Tertiary age, not very definitely dated, are known in the Virgin Springs area (Noble, 1941), the Tecopa quadrangle (Mason, 1948), and farther west, along the south slope of the Calico Mountains (Erwin and Gardner, 1940), and at Frazier Mountain, 175 miles southwest of the Shadow Mountains (Buwalda, Gazin, and Sutherland, 1930).

The third dependable episode for correlation purposes at present seems to be a second mature erosion surface, probably early Pleistocene or upper Pliocene in age, the Ivanpah upland. Most of those who have worked in the western and central Mojave Desert region (Baker, 1911), have recognized a mature erosion surface, upon which there rest from place to place extensive remnants of basalt flows, such as that at Black Mountain, 25 miles northwest of Barstow. In most places such flows show broad folds and normal faults and have been much eroded.

An equivalent of the Manix lake beds (Buwalda, 1914), and the Daggett lake beds (Gardner, 1940) has not been recognized in the Ivanpah quadrangle. The small areas of lake beds shown near Valley Wells and on the eastern border of Lanfair Valley seem to be much younger than the Manix lake beds.

MINERAL DEPOSITS

Deposits of useful minerals are widespread in this quadrangle. Almost all the deposits that have been exploited appear on plate 2. These fall readily into two groups: metallic deposits, which are numerous and widely distributed; nonmetallic deposits, of which some, such as limestone and dolomite, are widespread but are exploited in only a few places.

The report on the Goodsprings district described 72 productive mines, all within the bounds of the larger Ivanpah quadrangle, but there are many more prospects not listed. Of these mines in the Goodsprings area, only 30 are shown on plate 2; the remaining 42 are relatively small and their appearance on this plate would tend to produce confusion. Outside the Goodsprings area, locations of 102 metal mines and prospects appear on plate 2, almost all of those that have been found and examined in the area. Some prospects that have little or no record of production appear on the map. As their location is indicated, they contribute to the broad picture of the distribution of mineral deposits and, therefore, to an understanding of the causes that have led to their formation.

METAL DEPOSITS

Of the 141 mines and prospects shown on plate 2, 130 are deposits of metallic minerals. These include deposits explored primarily for gold, silver, copper, lead, zinc, iron, molybdenum, tungsten, antimony or tin. In a strict sense, only a few deposits in the region are explored for a single metal (examples; the iron deposits, the gold deposits of late Tertiary age). Most of the deposits contain noteworthy quantities of the minerals of several metals. Classification of a deposit as a gold, silver, or copper deposit depends largely upon the metal which was most valuable in the shipments. Thus, most of the deposits that contain noteworthy copper contain also some gold and silver.

During the period since the deposits were discovered, about 1870, the prices for the common metals have fluctuated widely; those for tungsten ores have probably fluctuated more widely than any others, from about $1.60 per unit in 1921 to $30.00 per unit in 1945. Several of the deposits explored from 1916 to 1918 for tungsten were first explored for gold. As the value of the tungsten minerals shipped exceeded that of the gold, the deposits are classified as "tungsten deposits." Obviously, such a system of classification is not strictly logical and cannot be considered rigid. Most of the mines of the region were inactive from 1924 to 1929 when they were examined and for some it was difficult to determine whether they had been explored primarily for gold, silver, or copper. As the records of production submitted by the owners of the mines to the U. S. Geological Survey and U. S. Bureau of Mines were available, these were used in assigning the mines to the several groups.

METALLOGENIC EPOCHS

On the basis of the areal geology, at least two epochs of ore deposition are recognized, Laramide (Late Cretaceous to early Tertiary) and late Tertiary (Pliocene?) in age. It is possible that some of the gold and copper deposits (for example, those in the McCullough Range) were formed in Proterozoic time, since they are remote from intrusive rocks of the Teutonia quartz monzonite type. Some, such as the copper deposits near Vanderbilt in the New York Mountains and the California (no. 135, plate 2) near Vontrigger Spring, even though near bodies of quartz monzonite, show mineralogic features unlike the majority of the copper deposits and may be pre-Cambrian in age. Most of the metalliferous deposits are so disposed with respect to the structural features of the Laramide orogeny (thrust and early normal faults) or the Teutonia quartz monzonite, as to leave little doubt that they were formed during that orogenic epoch. Even though very few ore deposits are in thrust fault breccias, there is an exceptional concentration of lead, zinc, and copper deposits in the zone of thrust faults in the Spring Mountains north of State Line Pass (Hewett, 1931, p. 77, fig. 14). Also, near Clark Mountain and Ivanpah Mountain, deposits of copper, lead, zinc, gold, and antimony are concentrated in the zone of thrust faults, especially near the wedge of monzonite at the northern limit of the Teutonia quartz monzonite mass.

Ore deposits are sporadic in the New York Mountains, but except for the gold deposits near Vanderbilt north of the post-mineral Ivanpah fault, they lie close to the contact of the Teutonia quartz monzonite and the overlying rocks of Paleozoic age; some of the deposits are in the intrusive rocks, and others are in the sedimentary rocks. Farther south, in the northern part of the Providence Mountains, gold, silver, and copper deposits are concentrated close to the contact of the Teutonia quartz monzonite and the overlying masses of pre-Cambrian gneiss. In the southeast corner of the quadrangle, gold, tungsten, and copper deposits are concentrated largely in the monzonite intrusive or the pre-Cambrian gneisses nearby, which are intruded by the monzonite.

Ore deposits are rather sparse in the southwest quarter of the quadrangle, largely an area of pre-Cambrian gneiss, probably underlain by the Teutonia quartz monzonite. Except for the gold and iron deposits on the west slope of Old Dad Mountain, most of the deposits are in the intrusive near its contact with the roof of pre-Cambrian gneisses. In the northwest quarter of the quadrangle the few deposits of lead and iron ore are in the sedimentary rocks of Proterozoic and early Paleozoic age, near the Kingston Range monzonite porphyry which intrudes them.

The silver deposits of old Ivanpah, north of Clark Mountain, probably belong to the Laramide epoch although they appear to contain but a single metallic mineral, stromeyerite (sulfide of silver and copper), in a gangue of dolomite and are unlike any of the other silver-bearing veins in the entire area. Even though narrow, the veins are very rich. They lie in northwest-trending fractures in the Goodsprings dolomite, just above the Clark Mountain normal fault.

The geologic elements that have probably determined the regional and local distribution of the Laramide metal deposits are discussed below.

A few gold deposits are found in rhyolite flows near the base of the middle Tertiary volcanic rocks where they rest upon pre-Cambrian gneiss in the Hart and Hackberry Mountain districts (p. 159). No metal deposits are known in the middle Tertiary rocks in the western part of the quadrangle.

REGIONAL CONTROLS OF THE LARAMIDE ORE DEPOSITS

Of the many and widely distributed ore deposits in the Ivanpah quadrangle, most are localized in areas that are from 5 to 15 miles in diameter. The geologic map indicates the causes of the localization of some deposits in which gold, silver, copper, lead, zinc, tungsten are the most valuable metals. It is noted that:

1. Deposits notable for the copper, lead, and zinc content in the Spring Mountains are concentrated in the belt of thrust faults, in or near which there are dikes or sills of granite porphyry (Hewett, 1931, fig. 14).

2. The group of gold, tungsten, and silver deposits on the north slope of Clark Mountain lie on the two sides of the Clark Mountain fault in an area where there are intrusions of rhyolite. West of the fault, the silver veins of old Ivanpah district are found in Goodsprings dolomite, but east of the fault the country rock is granite gneiss. The difference in environment may partly account for the different mineral content of the veins on the two sides of the fault. It is also possible that the veins of the Ivanpah district belong to an epoch of mineralization of late Tertiary age.

3. The group of metal deposits that lie in the Mescal Range and Ivanpah Mountain, from the Mescal mine on the north to the Teutonia on the south, lie either in the wedge of Teutonia quartz monzonite or in the overlying and underlying dolomites of early Paleozoic age, not more than a few thousand feet from the contact. Copper, lead, and zinc deposits predominate in the dolomite and gold and tungsten veins in the intrusive. Most of the copper deposits are of the contact type. It seems that the general distribution of metal deposits in this area is determined by the wedge of monzonite.

4. The small group of copper and lead deposits on the southwest slope of Clark Mountain, that extend from the Keiper mine on the north to the Mohawk on the south, seem to be related to the sills and dikes of hornblende monzonite that intrude the dolomites. The Evening Star tin deposit, 8 miles south, has similar associations.

5. The tungsten, gold and copper deposits in the New York Mountains lie either at the contact of sedimentary rocks of Paleozoic age with the Teutonia quartz monzonite or in the monzonite within a few thousand feet normal to the surface of contact. The Sagamore mine (no. 109) explores the only deposit entirely in the sedimentary rocks. As in the Ivanpah Mountain, the general distribution is determined by contact of the monzonite with the sedimentary rocks; the tungsten and gold veins are in the intrusive and the copper deposits are at the contact.

6. The group of copper, silver, and gold veins at the north end of the Providence Mountains lie either in pre-Cambrian crystalline rocks that form the roof of the Teutonia quartz monzonite or in the intrusive below the contact. The gold veins are wholly in the intrusive, the silver veins wholly in the crystalline rocks, and one copper vein is in each of these rocks. The Barnett (no. 111), and several smaller gold veins nearby are in the monzonite not far below the original position of the crystalline cover.

7. In the southeast corner of the quadrangle, east of Vontrigger Spring, two copper deposits (nos. 134, 135) and several gold veins occur in pre-Cambrian gneiss presumably underlain by monzonite, whereas several tungsten veins and one silver vein occur in the monzonite intrusive.

8. No explanation is offered for the localization of the gold veins of the Old Dad Mountains and Shadow Mountain. The first group may be related to the Sands granite.

9. The scattered gold and copper deposits that are found along the western border of the quadrangle from Riggs Wash on the north to Marl Spring on the south are in the monzonite intrusive not far from remnants of cover of crystalline rocks.

10. No explanation is offered for the localization of the gold, silver, and lead deposits in the pre-Cambrian rocks of the McCullough Range and nearby areas. The mineral assemblage resembles that in districts in or near monzonite intrusives bodies, but none is known in this area.

11. The gold veins of the Vanderbilt district are in pre-Cambrian gneiss about a mile from outcrops of monzonite, but the mineral assemblage suggests that they may have been formed earlier and deeper in the crust than the other veins of the New York Mountains, and may be pre-Cambrian in age.

Summarizing the evidence of the factors that seem to have controlled the general distribution of the Laramide metal deposits, it seems clear that the monzonite intrusive mass or masses have been the dominant element. The metal deposits thus far known seem to be concentrated in those areas where there are remnants of the rocks that formed the roof of the Teutonia quartz monzonite. In those areas, there are veins in the intrusive (largely gold and tungsten with minor amounts of silver, copper, and lead within several thousand feet of the cover); veins at the contact of the intrusive and the cover (largely copper deposits of the contact type); and veins in the rocks that form the cover, (largely silver, lead and zinc with minor amounts of copper, again largely within several thousand feet normal to the intrusive contact). The cover is composed either of sedimentary rocks of Paleozoic age or pre-Cambrian crystalline rocks.

The zone most favorable for the deposition of metals is that which includes the upper part of the monzonite intrusive, 5,000 or maybe 10,000 feet thick, and the lower part of the cover of rocks of Proterozoic and Paleozoic age, several thousand feet thick, but rarely exceeding 5,000 feet. No veins have been found that seemed worthy of exploration in those areas of Teutonia quartz monzonite where erosion has cut deepest below the original cover, for example, the area 10 miles in diameter that lies west of Cima. Similarly, a broad belt about 10 miles wide extends from Cima dome northwest to Riggs Wash and beyond, or about 25 miles, within which there are only a few gold mines and copper prospects. This belt lies east of the cover of sporadic blocks of pre-Cambrian rocks; recent basalt flows cover nearly one-fourth its area.

Within the rocks that form the cover of the monzonite intrusive, pre-Cambrian granite gneiss and carbonate rocks of Paleozoic age, there is a tendency toward zoning of the metal deposits viewed both horizontally on the present surface and vertically upward through the stratigraphic column. The bodies of iron minerals (magnetite in the Kingston Range and Old Dad Mountain) seem to have been deposited at the greatest depth below the surface after the rocks were folded and intruded; they are found in limestone of the Pahrump series (Kingston Range) and Cambrian dolomite (Old Dad Mountain). Above the copper deposits of the contact type, found where the monzonite is in contact with dolomites of early Paleozoic age, there are a few mixed sulfide deposits in the Tapeats sandstone (Sagamore mine, 109, lead); a few gold deposits in or near dikes of granite porphyry (Keystone mine, No. 35; Red Cloud mine, no. 31); a few copper deposits; and finally, in limestones of late Paleozic age and dolomites, many lead and zinc deposits.

In considering the effect of the different rock types upon the deposition of metallic sulfides, the fact that carbonate rocks favor or facilitate the deposition of lead and zinc sulfides is worth noting. Thus, lead sulfide deposits in the Kingston Range are restricted to the Noonday dolomite. In the Goodsprings district, all the lead and zinc deposits occur in carbonate rocks, largely in the Monte Cristo limestone about 1,000 feet thick.

SUPERGENE PROCESSES

Earlier in this report, under Water Supply, p. 14, the depths at which the mines encounter water have been set forth in detail. Most of the sulfide minerals have been oxidized above the present local water table and in most places they survive below the water table. In other words, nothing about the known distribution of sulfide minerals indicates that there have been great changes in the depth to water in recent time.

In this region galena resists alteration to sulfates and carbonates more readily than any other sulfide. In many places pyrite resists weathering 100 feet or more above water-level (Colosseum mine, no. 62, 63, Paymaster mine, no. 19). Chalcopyrite and sphalerite, however, are rarely found above the level of local water. Shipments of copper ore seem to have contained mostly malachite, azurite, and minor chrysocolla, but very little chalcopyrite (Copper World mine?).

In contrast with regions that have greater rainfall, there has been little supergene enrichment of the metals except possibly gold and zinc. In several gold mines there seems to have been noteworthy enrichment during oxidation (Keystone, Lucy Grey). Conversely, the veins of old Ivanpah district which appear to contain a single sulfide, stromeyerite, present no evidence of supergene enrichment.

In the Goodsprings report, the weathering and enrichment of zinc minerals has been considered fully. The sulfide, sphalerite, is rather uncommon in the mines of this entire region; the zinc in the shipped ores is largely in the form of hydrozincite, rarely smithsonite, and calamine. Under weathering, the zinc in sphalerite has generally migrated downward and in part laterally, with the result that the bodies of hydrozincite contain more zinc in a given volume of rock than the original bodies of sulfide. The same cannot be said with certainty of copper. The several sulfides of copper have been found in only a few mines, much more rarely, in fact, than the common carbonates of copper. Only rarely, however, do the carbonates form large compact masses. Secondary sulfides such as bornite are very uncommon (New Trail mine). The bodies of oxidized copper minerals seem to represent slight enrichment over the original sulfides.

Several varieties of supergene silica are widespread but rarely abundant. Both hypogene and supergene varieties of alunite have been found; the supergene variety is present at the Kirby mine, no. 39, and at each of the turquoise mines. Jarosite (and possibly the soda variety) is found in the weathered parts of many veins and it is probably as widespread as limonite.

OUTLOOK FOR MINING

Any attempt to appraise the outlook for mining in a region should take account of the geologic character and environment of the known mineral deposits and of the circumstances under which they have been discovered, developed, and exploited. These circumstances include the regional and local waves of migration and prospecting, the improvements in mining, metallurgy, and transportation, and the development of markets and prices. Forecasts of future trends must depend upon assumptions of the maintenance or change or technology, transportation, markets, and prices. Under history of exploration (p. 4), there are presented in chronologic order many episodes that reveal the causes that have contributed to the discovery, past production, and present state of development of the minerals.

DISCOVERY AND DEVELOPMENT OF MINERAL RESOURCES

The first period of discoveries of mineral resources began in 1854, when lead and zinc were discovered at the Potosi mine, and extended to 1865, when the silver mines of Ivanpah were discovered. Some of these discoveries were made by early Mormon settlers, others by the wave of eastward migration of miners and prospectors who were disappointed in the Comstock district, and some by men in the U. S. Army who were stationed at military camps along the old government road between 1860 and 1870. Until 1883, when the present Atchison, Topeka and Santa Fe Railway was completed to Mojave, it was necessary to transport supplies from San Bernardino, and any ore produced to that point, about 190 miles from Ivanpah. Most of the ore deposits of this region that have produced noteworthy quantities of gold, silver, and copper were discovered between 1865 and 1892. Some deposits of lead and zinc were found before 1892, but development lagged even in the Goodsprings district until 1892, when the branch of the Atchison, Topeka and Santa Fe Railway was completed from Goffs to Vanderbilt. The panic of 1893 and the decline in the price of silver brought quiescence until about 1905, when the Union Pacific Railroad from Salt Lake City to Barstow was completed.

The second epoch of extensive search and prospecting that began about 1905 continued through the war of 1917–18. It was caused in part by the completion of the Union Pacific Railroad in 1905, in part by the mining boom throughout the west that began with the discovery of gold at Tonopah in 1900 and was sustained for

Principal minerals of the ore deposits

[Explanation: a, abundant; c, common; u, uncommon; r, rare]

No.	Name	Country rock	Hypogene minerals																																			Supergene minerals																				
			Metallic															Gangue																																								
			Galena	Gold	Pyrargyrite	Stromeyerite	Chalcopyrite	Tetrahedrite	Sphalerite	Arsenopyrite	Pyrite	Molybdenite	Stibnite	Hematite	Magnetite	Cassiterite	Wolframite	Fluorite	Chert	Quartz	Spinel	Ankerite	Dolomite	Magnesite	Rhodochrosite	Diopside	Wollastonite	Tremolite	Actinolite	Garnet	Monticellite	Epidote	Chondrodite	Sericite	Phlogopite	Serpentine	Barite	Bornite	Chalcocite	Chert	Tenorite	Limonite	Manganese oxide	Aragonite	Cerussite	Malachite	Hydrozincite	Aurichalcite	Calamine	Chrysocolla	Anglesite	Jarosite	Plumbojarosite	Argentojarosite	Beaverite	Alunite	Pyromorphite	Vanadates
	GOLD DEPOSITS																																																										
12	Dan Henry	Granite gneiss																		a																						a								c									c
14	Huytens	do																		a																						a				c													
17	Telegraph	Teutonia monzonite									c									a																																							
19	Paymaster	Granite gneiss									c									a																																							
22	Prospect	Teutonia quartz monzonite									c									a																																							
31	Red Cloud	Granite porphyry		u							c								u																						c																
34	Chaquita	Goodsprings dolomite		?							c								c																						c																
35	Keystone	do		c							c								c	r																	u					a	c			u				u									
62, 63	Colosseum	Granite gneiss									c									c																																							
64	Greene	do	c								c									a																						c			c								c					
92	Morning Star	Teutonia monzonite									c									a																																							
102	Vanderbilt	Granite gneiss	c							c	a									a			c																																			
102	Midnight	do									c									a																																							
103	Boomerang	do																																																										
103	Gold Bronze	do	c							c	a									a																																							
116	Gold King	Teutonia monzonite									c									a														c																									
117	Lost Burro	do																		a																																							
121	Lucy Grey	Granite gneiss		?																a																						c	c																
123	Lucky Dutchman	do									c									a																						c																	
130	True Blue	do					c													r																																							
111	Barnett	Teutonia monzonite	c				c				c									a																																							
122	Double Standard	Granite gneiss	c		u		c	c												a																	c																						
125	Nippeno	do	c				c													a																	u																						
	SILVER DEPOSITS																																																										
59	Beatrice	Goodsprings dolomite				?																	a																																				
60	Allie	do				?																	a																																				
60	Lizzie Bulloch	do				?																	a																																				
61	Stonewall	do				c																	a																							u													
77	Mescal	do									r		c						a																																								
94	Teutonia	Teutonia monzonite																		a																				c																			
95	Death Valley	do	c						c		c									a														c																									
113	Silver Fox	Schist							c		c									a																																							
115	Columbia	Granite gneiss							c		c									a																																							
141	Leiser Ray	Teutonia monzonite					c	c						c						a																																							
	COPPER DEPOSITS																																																										
	Vein type																																																										
29	Ninety Nine	Dolomite fault																	c	u																			c			a	c			c				c									c
28	Doubleup	Yellowpine																	c	u																			u			a				c				u									
36	Ironside	Dolomite fault																	a																							a				u				u									
37	Boss	Monte Cristo fault		u			u													c																			u			a				c				c		c							
41	Columbia	Sultan limestone					u												u	u																		u	u			c				a				c									u
44	Lincoln	Goodsprings																	u	u																						u				u				c									
55	Prospect	Crystal Pass limestone																																								c				c													
10	Foster	Granite gneiss																		c																										c													
16	Prospect	Teutonia monzonite									c																																			c				c			c		c			c
57	McCuen	Gneiss dolomite																		c																						c				c				c						c		
58	Calarivada	Goodsprings																a		c														c			c																					
67	Benson	Granite gneiss									c																																															
91	Sunnyside	do					c																											c				c																					
120	Prospect	do																		c																										c													
101	Copper King #2	Gneiss dolomite									c															c	c																															
106	Live Oak	Dolomite monzonite																a		a														c												c													
107	Queen	do					c				c							a		a														c					c																				
108	Giant Ledge	Teutonia monzonite	c				c				c							c		a																																							
110	Prospect	Dolomite flows	c				c		c		c																																																
112	Copper Bell	Teutonia monzonite					c				c	c								a																		c			r					c													
114	Francis	Granite gneiss					c		c		c							c		a																																							
134	California	Gneiss					c				c									a																										c													
83	Prospect	Granite gneiss																																												c													c
	Contact type																																																										
71	Copper World	Dolomite diorite					c				c									c						c				c						c										c													
72	Dewey	do																			c					c				c	c				c	c																							
81	Standard No. 1	Contact rock													c					a						c				a																c				c									
86	Prospect	do																		a										a																				c									
87	Copper King	Goodsprings dolomite													c					a				c						a		a														c				c									
88	New Trail	do					c		c											c						c				a					c	a		c								c													
90	Allured	do																		c						a				a						a						a				c													
	LEAD DEPOSITS IN DOLOMITE																																																										
1	Chambers	Noonday	c																																												r	c	r	c						c	
39	Kirby	Goodsprings	c																c	u																						c			a				u				a			c	u	
53	Ingomar	Yellowpine	c																																							c					a		c									
54	Christmas	do	c																																												a		c		c							
56	Carbonate King	Bird Spring	c						c		c								c																							c			c		c		c		c	c						
65, 70	Birneys	Goodsprings	c															a																a												c													
69	Keiper	do	c				c		c																																																	
73, 74	Mohawk	do	u																																					c					c	c						c	c		c			
78	Buzzard	Sultan limestone																																								a											c					
79	Jackrabbit	Goodsprings																		c																						a			c													
105	Trio	do																									c			a		a														c				c									
106	Live Oak	do					c				c							c																c																									
9	Hillside	Granite gneiss	c																	c																																							
109	Sagamore	Tapeats sandstone	a				a	c	a		c									a					c																																		
124	Peyton	Teutonia quartz monzonite	c				c													c																																							
	ZINC DEPOSITS																																																										
26	Green Monster	Bullion	c																																												c												
27	Potosi	Yellowpine	c						a																																					u	a	u	c			u							
30	Contact	Bullion	u																																										u		a	u	c										c
32	Yellowpine	Yellowpine	a										u						u																							c			a	a	a	c	a	u	u	c	c				r	u
33	Alice	Bird Spring	u																																			r			c			u		a	c	c		u							u
38	Mobile	Anchor limestone	u																	u																								u	u		a		c		u							u
40	Bill Nye	Bird Spring	c																																										c		a		c									c
43	Mountain Top	do	a																c																										c	c	a		c	u								c
45	Monte Cristo	Anchor limestone	c																c																										c		a		a									
46	Bullion	Bullion	a																																										c		a		c		c							
47	Anchor	Anchor	a																																								u		c		a		c		u							u
48	Hoodoo	Monte Cristo	c																																							c			c				u									c
49	Root	do	c						r										u																							c			c		a		c	u	c							
50	Singer	Bullion	a																																										c		a		c	u							c	u
51	Sultan	Fault breccia	a																u																							c			c		a	u	c				u					
52	Milford	Bullion	a						u																																	c			c		a		c		u							
68	Clark Mountain	do																																													c											
80	Carbonate King	Yellowpine	u						u																																						a		a									
42	Argentena	Bird Spring Yellowpine	a																																										c	a			c									
	MOLYBDENUM, TUNGSTEN, AND TIN																																																										
97	Big Hunch	Teutonia quartz monzonite					c				c	c								a																										c													
66	Mojave	Granite gneiss															c			a																																							
96	Cottonwood	Dolomite-monzonite					c		c			c		c						a										c		c																											
99	Prospect	Teutonia quartz monzonite	c					c	c		a																u																																
100	Carbonate	do	c					c	c		a																u																																
138	Lord & Irish	do																		a							u																																
85	Evening Star	Goodsprings dolomite													c	c												c				c				c																							
70	Wades	Granite schist											a						c	a																	c																						
	IRON DEPOSITS																																																										
2	Beck	Crystal Spring												a	a												c	c								c																							
3	Prospect	do													a																																												
21	Old Dad	?					u				u			a	a					u																																							
24	Prospect	Goodsprings												a																																													

10 years or more by such discoveries as those at Goldfield in 1903, and in part by the high prices of copper, lead, and zinc from 1914 to 1918. There can be no doubt that many metal deposits in this region were considerably explored and yielded a modest production under the influence of these three factors.

A third epoch of exploration began with the depression of 1930 and most exploration of gold deposits since 1933 is due to the increase in the price of gold in that year. The discovery of the Telegraph mine in 1930 led to reopening of other gold mines nearby (Paymaster) and discovery of several new deposits (Brannigan, Oro Fino, no. 20, and Lucky, no. 21). The war in 1941–45 brought a decline in gold mining, but also renewed work that still continues in many lead and zinc deposits. The exploitation of the copper deposits did not increase with the increase in price, however, and this indicates that the deposits were largely exhausted during the war in 1917–18.

A major purpose of the geologic study of this region has been to examine the localization of the metal deposits and indicate areas worth development. Even though at least 200 metal deposits have been found and somewhat explored, only 3 districts have noteworthy production of the metals, Goodsprings (lead and zinc), Clark Mountain (Copper World and Mohawk mines) and Ivanpah (silver). The remainder of the region seems to contain many metal deposits of modest size and grade, whose distribution is related largely to the zone of contact of the Teutonia quartz monzonite and the rocks that it invades. Even though it has great size, the form of the monzonite body seems rather simple. Only in the vicinity of the Keystone mine are there bodies of this type of rock that have highly irregular form and that intricately intrude the host rocks. At no place in this entire region are there bodies of igneous rocks that can be regarded as stocks, with which so many metal mining districts of the west seem to be associated (Butler, 1915). When the great size of the monzonite mass is considered, it seems that the zone of alteration of the nearby or adjacent carbonate rocks is small, in fact it is generally confined to a few tens of feet. In several western mining districts, such as Clifton-Morenci, Ariz., where large quantities of copper have been and are being produced, the zones of alteration of the carbonate rock are much more extensive.

Other features of the monzonite that may have bearing upon the problem are its form and attitude and the nature of the fracture by which it invaded the older rocks. As explained earlier (p. 62) the northern part of the mass, near Mescal Range, is a wedge that is limited by nearly parallel inclined surfaces that dip 35° W. It seems to fill an inclined fracture that passes downward through the entire section of rocks of Paleozoic age into the crystalline basement; its source, therefore, seems to lie to the west. The fact that the present surface reveals numerous ore deposits of modest size in and near the wedge, indicates that any ore-bearing solutions given off by the intrusive body were dispersed widely rather than concentrated in a few areas. There seem to be no localized lithologic or structural features that would aid in concentrating ore-bearing solutions. In the present state of knowledge of the elements that lead to or control ore deposition, it seems hardly worth while to speculate further.

The record of production of silver of the old Ivanpah district on the north slope of Clark Mountain indicates that it is worthy of exploration, particularly in depth. The veins are small, but recent work on several shows that if explored cautiously with due regard to the attitude of the ore shoots and faults, they can still be worked at a profit. The recent success in exploring the veins on Mohawk Hill and the record of the Copper World and other nearby deposits, where the carbonate rocks are broken by many faults and intruded by sills and dikes of hornblende monzonite, indicate that the area is worthy of careful prospecting. The general outlook for the Goodsprings district has been discussed in the earlier report (Hewett, 1931, p. 73–75).

MINERALOGY

The following table has been prepared to show the principal minerals observed at each of the deposits that have been examined. Within the time available it was not possible to make this record exhaustive. The minerals are arranged according to their composition and recognized local association; even though the table is incomplete, it shows the assemblage that is characteristic of the several groups and indicates their relations. The list supplements but does not repeat the names of all of the minerals recorded in the Goodsprings report.

NATIVE METALS

Gold.—Native gold is undoubtedly present in the unweathered parts of many of the Laramide deposits of this region, but it has been recognized at only a few mines, for example, Barefoot, Keystone, and Chaquita. Many of the shallow shafts in parts of the southern half of the quadrangle were driven to explore veins that yielded some free gold in the oxidized portions, and work ceased when the veins passed into unoxidized material. Probably the free gold recovered from post-mineral faults in the Lucy Grey mine was supergene; gold in such material probably would not persist far below the lower limit of oxidation.

Silver.—Native silver was not observed in any deposits during this investigation. It may have been present in some silver-rich veins (Ivanpah, Teutonia, no. 94, Death Valley mines, no. 95) but local owners say that it was much less abundant in the oxidized parts of the veins than the chloride (cerargyrite). The presence of large amounts of salt (sodium chloride) in the ground waters of this desert region would favor the formation of silver chloride rather than native silver.

SULFIDES

Arsenopyrite.—Arsenopyrite was definitely identified in ore from the Gold Bronze mine (no. 103), Vanderbilt district, and tentatively recognized in similar ore from the Gold Bar shaft nearby. In the first mine, it forms clusters of coarse, well-formed crystals associated with pyrite and galena. As arsenopyrite is commonly found in deposits that show mesothermal or hypothermal associations, these gold-bearing veins in pre-Cambrian gneiss at Vanderbilt may have been formed before the Laramide mineralization, possibly in Proterozoic time.

Chalcopyrite.—Chalcopyrite is the most widespread and abundant of the copper-bearing sulfides, but the quantity is rarely very large except at a few deposits exploited primarily for copper (Copper World, no. 71). Small quantities are found in veins in pre-Cambrian crystalline rocks, the Teutonia quartz monzonite, and the intruded dolomites of Paleozoic age and also in veins worked primarily for gold, silver, lead, molybdenum, and tungsten.

Bornite.—A little bornite is present in the ore from several deposits worked for copper. It appears to have been formed by replacement of chalcopyrite.

Chalcocite.—Chalcocite was identified at one mine only, the Queen lower tunnel; it replaces chalcopyrite.

Galena.—Galena is the most abundant mineral at several lead mines, but small quantities are present in the ore of many deposits worked for gold, silver, copper, zinc, and tungsten. In the lead mines it forms coarse masses but terminated crystals have not been found; in the other deposits, it forms small grains both in quartz and other sulfides. It weathers readily to the carbonate and sulfate of lead.

Pyrite.—Pyrite is the most abundant sulfide mineral at most of the veins worked for gold and copper, and small quantities are widespread elsewhere. Most of the veins contain only a small percentage of pyrite, but in a few veins (Columbia, 115; Vanderbilt, 102), the percentage rises to 10 percent or more. Well-formed crystals are very rare.

Sphalerite.—Even though sphalerite is probably the primary zinc mineral in all of the zinc deposits in the dolomites of Paleozoic age, only rarely has it survived oxidation (Anchor mine, 47). On the other hand, a little sphalerite is present in numerous veins in the pre-Cambrian rocks and intrusive rocks in the southern part of the quadrangle, which are worked for silver, copper, and lead. Like galena, in these veins it forms small grains, generally mixed with other sulfides.

Stibnite.—In the only vein in the quadrangle worked for antimony (Wade, 70), stibnite forms coarse prismatic crystals in the gangue of chert and barite. It has survived oxidation at the present surface. However, at the Mescal mine (77), which was worked for silver, fine-grained stibnite occurs in a gangue of chert.

Molybdenite.—Molybdenite is the principal sulfide at the Big Hunch mine (97) where pyrite and chalcopyrite are also present. It forms thin films on the wavy sutures that limit grains of quartz. At the Copper Bell (112), worked for copper, it forms fine flakes scattered through the quartz gangue.

Tetrahedrite.—A little tetrahedrite, undoubtedly silver-bearing, is present in several quartz veins in the Teutonia quartz monzonite and in the Sagamore vein (109) in quartzite. It forms small grains largely associated with other sulfides.

Pyrargyrite (Ruby Silver).—Small crystals were noted in quartz lenses at the Double Standard mine (122), worked for silver.

Stromeyerite.—Stromeyerite is the only sulfide observed at the mines in the old Ivanpah district (59, 60, 61). It forms black metallic grains in the dolomite veins of the Stonewall mine (61). It is a relatively rare mineral in western silver deposits.

CHLORIDES AND FLUORIDES

Cerargyrite.—Cerargyrite was not identified but it is reported to have been the principal silver mineral in the oxidized zone of the veins of old Ivanpah.

Fluorite.—Pale-lilac, fine-grained fluorite is the most abundant gangue mineral in the veins of two areas. One area includes the Live Oak (106), Queen (107) and Giant Ledge (108). The first two mines contain considerable pale-yellowish sericite in veins at the contact of the Teutonia quartz monzonite and Goodsprings dolomite; the third, the Giant Ledge, is near the contact. The second area includes the Calarivada (58) and Birney's (65) veins. Even though in dolomite, the veins also contain considerable sericite. Fluorite is also present in the Francis copper vein (115).

OXIDES

Quartz.—Several varieties of quartz are found throughout the quadrangle. It is the most abundant mineral in most of the veins that are mined for gold, copper, and iron, and in several mined largely for silver, lead, zinc, molybdenum, and tungsten. Mostly, such quartz is massive even though it forms layers and lenses; comb quartz is very uncommon but it was noted in most of the veins mined for wolframite. Veins of quartz are the latest or nearly the latest formed mineral in the iron deposits (Beck) and contact copper deposits. Veins as much as 2 feet thick cut the mass of feldspar mined near Crescent Peak (126). Small terminated crystals of quartz of supergene origin are rather common in the region, especially in the Goodsprings district.

Chert.—This name is applied to many forms of fine-grained silica that are obviously none of the common forms of chalcedony, opal, hyalite, tridymite, or cristobalite. The hypogene forms (Hart and Getchell district, Mescal, no. 77, and Wade, no. 70 mines) are fine-grained and range from white to gray brown. Such material is common at the three turquoise deposits. The formation of large bodies of supergene chert is favored in carbonate rocks (Kirby mine). There is also local association of alunite and fine-grained chert (Kirby mine, no. 39; Mammoth prospect, no. 62; the turquoise deposits).

Spinel.—Small black octahedrons of spinel were found in the zone of contact rock nearest the monzonite sills in the Dewey mine (no. 72).

Tenorite.—Tenorite, the black oxide of copper was identified in the ore from the Copper Bell mine (no. 112).

Limonite.—Limonite, the hydrous oxide of iron, is widespread, as it forms from the oxidation of many iron-bearing minerals, sulfides, carbonates, and silicates. The commonest variety is dense fine grained and hard, and tests have shown that much of it is siliceous; it is a variety of ferruginous jasper. Earthy varieties are common, however. The mineral is conspicuous along the outcrops and surficial parts of almost all gold, copper, and lead veins and probably indicates the widespread occurrence of pyrite below the zone of oxidation. It is less abundant at zinc deposits in limestone but in a few (Piute mine, no. 82) large quantities are present. Some bodies of limonite do not indicate the presence of metals other than iron. About one mile southeast of Kokoweef Peak, a ridge several thousand feet long is sustained by a lens of hard siliceous limonite, 50 to 150 feet wide. The limonite contains many angular fragments of white and gray dolomite similar to the Goodsprings dolomite which encloses the limonite. Minor prospecting has not revealed any other metals of value. In many places, limonite, both dense and earthy, contains considerable jarosite from which it seems to have been derived.

Manganese.—Manganese oxides are relatively abundant in a few places. Noteworthy are the Ninetynine mine (no. 29); Birney's prospect (no. 65); Sagamore mine (no. 109); Lucy Grey mine (no. 121); and Double Standard (no. 122). In contrast with iron, manganese is very uncommon in the ore deposits of this region and is not restricted to deposits of a single metal.

CARBONATES

Calcite.—Calcite is a common mineral in several types of ore deposits, in lead and zinc deposits in dolomite, and in the contact type of copper deposit.

Dolomite.—The limestone beds near many lead and zinc deposits are altered to dolomite, and, with calcite, it forms the veins in these rocks that contain lead and zinc sulfides. Dolomite is the principal gangue mineral in the silver-bearing veins in the old Ivanpah district (nos. 59, 60, 61 on pl. 2).

Magnesite.—A vein of magnesite, 1 to 3 feet wide in the Goodsprings dolomite, has been explored near the New Trail copper mine (no. 59). It is reported that a trial shipment of 125 tons contained 98 percent $MgCO_3$. The vein is pure white; the texture is partly fibrous and partly porcelainlike.

Ankerite.—Near the Beck iron deposits (no. 2), the limestone is locally replaced by pale-brown ankerite; also, ankerite has been recognized at the bastnaesite-bearing veins near Mountain Pass.

Rhodochrosite.—This carbonate of manganese is reported in ore from the Sagamore mine (no. 109) but was not recognized during this investigation. It was observed in a vein on Mohawk Hill (p. 146).

Bastnaesite.—This mineral, the fluocarbonate of cerium, lanthanum, and other rare earths, was discovered in veins on the Birthday group of claims, 2 miles north of Mountain Pass in 1949. Prospecting soon showed its presence in many veins in a belt that extends 5 miles south. Also, large quantities are present in the body of barite carbonate rock at the Sulphide Queen mine a mile north of Mountain Pass.

Cerussite.—Cerussite is probably the most abundant lead mineral in the ores that have been shipped from the mines of the entire region. Most of it forms loosely coherent granular masses; good crystals are rare, but some have been found in the Monte Cristo mine (no. 45). In contrast with the sulfate, anglesite, which is the first product of oxidation of galena and remains close to that source, the carbonate occurs under circumstances indicating that commonly the lead has migrated many feet from the source, galena.

Malachite and azurite.—Some malachite was observed at every copper deposit in this region and a little is present at most gold and lead deposits. It is generally earthy, in a few places fibrous, and rarely botryoidal. As only a few copper deposits have been explored far below the zone of oxidation, it is the most abundant copper mineral in the ores shipped from the region. Azurite is sporadic; at a few places (Copper World, no. 71), it replaces dolomite to a noteworthy degree.

Aurichalcite.—Aurichalcite is rather common in the zinc deposits of the Goodsprings district but is uncommon elsewhere. It was observed at Mammoth mine (no. 57) and Calarivada (no. 58).

Hydrozincite.—Hydrozincite is the most abundant zinc mineral in the zinc deposits of the Goodsprings district and at the few zinc deposits in the remainder of this region, notably Carbonate King mine (no. 56) and Clark Mountain mine (no. 68). It was not observed and is probably uncommon in the vein deposits in igneous rocks.

SILICATES

Diopside.—Diopside was identified at three of the contact-type copper deposits (Dewey, no. 72; Allured, no. 90; Cottonwood, no. 96), and is probably present in most of these deposits. It is commonly associated with garnet and epidote. It is also sporadically present in carbonate rocks near the monzonite contact.

Hedenbergite.—The pyroxene, hedenbergite, associated with garnet, was observed in contact rock near the Standard No. 1 mine.

Wollastonite.—Blades of wollastonite, unaccompanied by other silicates, are present in the limestone in which the Beck iron deposits occur. In the vicinity of Slaughterhouse Spring (New York Mountains), the limestone near the base of the Goodsprings dolomite is altered to marble, garnet, and vesuvianite.

Actinolite.—Near the iron deposits of the Kingston Range, syenite sills are extensively altered to actionolite.

Tremolite.—Tremolite is exposed where dolomite is in contact with the Teutonia quartz monzonite in the Kingston Range (Beck mine, no. 2).

Garnet.—Pale-brown garnet (grossularite) is abundant at all of the contact-type copper deposits. In a few places (Cottonwood prospect, no. 96) it is dark enough to be the andradite (lime-iron) variety, but precise determinations have not been made. Associated with it are the common contact silicates, diopside, vesuvianite, and epidote as well as magnetite and quartz.

Monticellite.—Pale-gray granular masses of monticellite were found in the contact zone at the Dewey mine (no. 72).

Vesuvianite.—Columnar crystals of vesuvianite were found only at a few mines, New Trail (no. 88), Allured (no. 90) mines but undoubtedly it is much more common.

Sillimanite.—A dark schistose rock, rich in sillimanite was found in the pre-Cambrian schists in the hills 5 miles northwest of Kelso.

Epidote.—The typical green variety of epidote is present at all of the contact-type copper deposits. At the Cottonwood prospect (no. 96) it is formed later than brown garnet and earlier than quartz. It is the principal gangue mineral at the Evening Star tin deposit (no. 85).

Chondrodite (humite).—Pale-brown grains in dolomite at the Cottonwood prospect (no. 96) were determined by W. T. Schaller to be chondrodite. It was also found at the Dewey mine (no. 72).

Calamine.—Small quantities of calamine, a silicate of zinc, are present at most, if not all, of the zinc deposits in carbonate rocks in this region and at some lead and copper deposits (Chambers, no. 1, Calarivada, no. 58). It rarely forms an ore of zinc.

Sericite.—Fine-grained brownish masses as well as pale-yellow coarse crystals of sericite are closely associated with fluorite at several lead and copper deposits (Birney's, no. 65; Calarivada, no. 58; Live Oak, no. 106; Queen, no. 107).

Phlogopite.—Phlogopite, black mica, is abundant at several of the contact-type copper deposits (Copper King, no. 87; New Trail, no. 88).

Serpentine.—Serpentine is so common as to be a characteristic wall-rock mineral at the contact type of copper deposits in dolomite, the Beck iron deposit and the Evening Star tin deposit (no. 85). Other silicates of lime and magnesia with or without iron or alumina, such as diopside, tremolite, garnet, epidote, vesuvianite, and others, form close to the intrusive and early in the succession, but serpentine (and antigorite) replace the dolonite in an outer, more remote zone.

Sepiolite.—At the Chambers mine (no. 1) a white claylike gangue on fractures in the wall rock dolomite proved to be sepiolite.

Thaumasite.—Veinlets of white fibrous thaumasite as much as half an inch wide are abunadnt in the second zone from the diorite dike at the Dewey mine (p. 70).

Talc.—A pure white variety of talc has been mined from time to time at two localities in the quadrangle, near Beck Spring and the Excelsior mine near Horse Spring. It has formed by replacing dolomite in the Crystal Spring formation.

Chrysocolla.—A little chrysocolla is present at all of the copper deposits in the siliceous rocks of the western half of the quadrangle. At two deposits (Foster, no. 10; Prospect, no. 55) a little dioptase was observed. By contrast, it is rare and much less common than malachite in the contact type of deposit.

PHOSPHATES

Pyromorphite.—Pale-yellow masses of pyromorphite, a phosphate of lead, are common at the Chambers mine (no. 1), and it is probably present at most lead deposits.

Libethenite.—Olive-green coatings of phosphate of copper (libethenite) are present at several mines (Prospect, no. 16; Peyton, no. 124).

Turquoise.—Turquoise (see p. 165), has been extensively mined at three localities: near Riggs Wash (no. 13); near Valley Wells (no. 15); and near Crescent Peak (no. 127).

VANADATES

Tests by the use of hydrochloric acid have shown that at many places pale-yellow and brown films on ores from several silver, copper, and lead deposits indicate that they are vanadates. The varieties have not been determined. In the Goodsprings district, attempts have been made to mine material containing 1 or 2 percent vanadic oxide at several lead and zinc deposits.

Carnotite.—Thin films of a yellow mineral at several localities near Sloan and near Jean were determined to be carnotite.

SULFATES

Barite.—Barite is conspicuous in the gangue at the Wade antimony mine (no. 70) and at the Nippeno mine (no. 125). It is abundant in most of the veins near Mountain Pass that have recently been explored for bastnaesite.

Anglesite.—Even though anglesite was observed at two deposits only (Chambers, no. 1; Carbonate King, no. 56), it is probably present at all of the deposits that contain oxidation products of galena.

Brochantite.—Brochantite, a basic sulfate of copper, was observed at the California mine (no. 135).

Chalcanthite.—Chalcanthite was observed at the Colosseum mine (no. 62) and California mine (no. 135). It was surprising to find the mineral at the Colosseum mine, a gold mine where no copper sulfides were found.

Gypsum.—Beds of gypsum are found in the Supai formation (Goodsprings quadrangle) and in the sandstone bed between the two members of the Kaibab limestone. A prospect (no. 118) near the north border of the quadrangle explored the bed in the Kaibab limestone. Small crystals of gypsum are found in ores from the oxidized zones of many metal deposits.

Alunite.—In addition to the recorded occurrence in the Goodsprings district (Kirby mine, no. 39), alunite was found at the McCuen copper mine (no. 62), the Jackrabbit lead mine (no. 79), and the Toltec turquoise mine (no. 128). At each of these localities, it appears to be a supergene mineral.

Jarosite group.—Minerals of the jarosite group occur widely throughout this region, but at a few places only were the masses such as permitted easy determination of the species. Any pale-yellow earthy or finely crystalline material in this region may be suspected as belonging to the jarosite group, but analyses or microscopic tests of distinctive material are needed to determinet the species, jarosite, natrojarosite, plumbajarosite, argentojarosite, and beaverite. The jarosites are the normal product of the oxidation of iron-bearing sulfate solutions in a desert region, and survive a long time on the surface. Only rarely do the jarosites break down to iron oxides above water level.

LARAMIDE ORE DEPOSITS

GOLD DEPOSITS

The mineralogic features of the gold deposits of Late Cretaceous to early Tertiary age (Laramide) are surprisingly similar throughout; mostly they differ slightly in the amount of sulfides present. The gangue is quartz in all except two (Keystone no. 35; Chaquita no. 34), and these lie in the Goodsprings dolomite. Pyrite is a persistent sulfide; chalcopyrite and galena also are found in a few. Arsenopyrite was found only in the Gold Bronze; it is probably present in other veins of the Vanderbilt district. The mineral assemblage here suggests hypothermal conditions (deep-vein zone) and raises the question whether these veins may not be pre-Cambrian in age rather than Laramide. Furthermore, most of the quartz of the Vanderbilt veins is badly crushed and recemented by quartz and pyrite.

As for environment, 18 deposits are in pre-Cambrian crystalline rocks, largely granite gneiss; 8 are in Laramide intrusive rocks, largely Teutonia quartz monzonite or similar porphyries of the Goodsprings district (Red Cloud, no. 31). Some deposits in pre-Cambrian rocks are remote from outcropping bodies of Teutonia quartz monzonite (Paymaster, Brannigan, and Lucky near Old Dad Mountain and Lucy Grey, no. 121). Most of the other gold deposits, however, are in either quartz monzonite or granite gneiss, near the intrusive contact of these two rocks. The Gold King (no. 116) and Lost Burro (no. 117) are in quartz monzonite but scarcely 1,000 feet below the roof of gneiss which the quartz monzonite intrudes; the Barnett vein (no. 111) and the prospects west of Marl Spring (nos. 23 and 24), have the same relation. The Colosseum (no. 62 and 63) and other nearby gold deposits, though in gneissic rocks, seem to be related to a local irregular intrusive body of rhyolite. As for other metal deposits in this region, crystalline rock types do not appear to determine the location of deposits as much as the zone of contact of intrusive and intruded rock. The following table is an index to the 28 gold deposits of late Cretaceous to early Tertiary age shown on plate 2.

Gold deposits

No.	Name	Country rock	Year examined
11–12	Henry	Pre-Cambrian gneiss	1926
14	Huytens	Teutonia quartz monzonite	1926
17	Telegraph	do	
19	Paymaster	Pre-Cambrian gneiss	1929
20	Oro Fino	Quartzite	
21	Lucky	Pre-Cambrian diorite	1947
23, 24	Marl Spring prospects	Teutonia quartz monzonite	1927
31	Red Cloud	Granite porphyry	1922
34	Chaquita	Goodsprings dolomite	1922
35	Keystone	do	1924
62–63	Colosseum	Pre-Cambrian gneiss	1929
64	Green, Turner, and Mallet	do	1929
75	Sulphide Queen	do	1950
92	Morning Star	Gneiss-quartz monzonite	1927
93	Kewanee	Teutonia quartz monzonite	1927
102	Vanderbilt	Pre-Cambrian gneiss	1927
102	Midnight	do	1927
103	Gold Bronze	do	1927
111	Barnett	Teutonia quartz monzonite	1927
116	Gold King	do	1927
117	Lost Burro	do	1927
121	Lucy Grey	Pre-Cambrian gneiss	1929
122	Double Standard	do	1927
123	Lucky Dutchman	do	1927
125	Nipreno	do	1927
130	True Blue	do	1927

HENRY MINE

Several mines have been opened on the south slope of Shadow Mountain. At least one, the Henry mine, (no. 11–12, pl. 2) was opened as early as 1895 (Tucker and Sampson, 1943). The principal exploration, a tunnel about 750 feet long, lies in a ravine on the southeast slope but there are also three shallow shafts.

Two kinds of rock make up most of Shadow Mountain. The most abundant is a pale-gray granite gneiss which is largely orthoclase, quartz, and biotite. Intruded into this are belts of dark-greenish syenite gneiss, which is largely orthoclase with some hornblende and a little quartz, and dikes of aplite intruded into the gneiss. The lamination of the gneiss strikes north and dips 45° to 60° E. The Henry mine explores a quartz vein that lies between granite gneiss below and syenite gneiss above. The strike of the vein is N. 10° W. and the dip is 50° E. The vein has been stoped as much as 100 feet upward from the tunnel and along it for 300 feet. As the vein is not stoped where it is less than 8 inches wide, much of it must have been wider. In addition to quartz, the vein shows limonite, chrysocolla, and vanadates, but no sulfides. In recent years the mine has been an intermittent source of small shipments. From 1913 to 1919, there is record of production of 35 tons of ore that contained about 2.90 ounces of gold to the ton and a little silver, copper, and lead.

HUYTENS MINE

In the vicinity of Huyten's well, 5 miles northwest of Halloran Spring, several shafts have been sunk on a vein that outcrops conspicuously for several hundred feet. The main shaft (14, pl. 2) is 125 feet deep, and there are also three more that are shallower. The vein trends N. 40° E., dips 70° SE., and ranges from 2 to 4 feet wide. It is largely layered quartz but contains also considerable limonite and some copper minerals. Probably gold is the most valuable constituent as it is reported that some of the ore was crushed and treated nearby. The enclosing rock is gray monzonite.

TELEGRAPH MINE

Within an area of several square miles southeast of Halloran Spring (no. 17, pl. 2), there were several old shallow shafts and pits at the time of this examination, 1926–27 and 1929. About November 1930, high-grade gold ore was found by Ralph and H. H. Brown of Salina, Utah, and the Telegraph vein was located. This discovery and its early development led to a small boom as the result of which 20 other veins were located in the area and there was considerable development. When the writer visited the area in 1947, all the mines were closed down and most of the equipment had been removed.

According to Tucker and Sampson (1943, p. 462) the Telegraph vein, having a strike of N. 30° E., and dip of 30°–50° NW., cropped out for about 500 feet. Veins having similar strike were explored on the Telegraph Extension claim and on the South Telegraph. On the South Telegraph claim, the vein was explored to a depth of 125 feet and on that level for a distance of 465 feet. The width ranged from 4 to 8 feet. A shaft on the Telegraph claim was 100 feet deep and the width of the vein ranged from 6 to 8 feet. Apparently, the vein was largely quartz with minor calcite and mixed sulfides. The production is given in the table below.

Recorded production of the Telegraph mine (No. 17, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1932	65	116. 65	310	
1933	511	298. 00	1, 582	
1934	99	50. 30	327	
1935	44	16. 81	113	
1936	442	231. 65	832	
1937	285	29. 00	129	
1938	32	12. 00	114	
1939	199	286. 00	530	
1940	452	931. 00	793	
1941	119	188. 00	187	
1942	216	261. 00	244	
1946	155	74. 00	141	400
1947	117	47. 00	100	100
1948	13	18. 00	21	

PAYMASTER MINE

The Paymaster mine (Whitney) (no. 19, pl. 2) lies at the head of a ravine that drains westward from some low hills 7 miles north of Old Dad Mountain and 12 miles southeast of Baker. The vein was discovered about 1900 and most of the work shown in the accompanying sketch map (fig. 43) was done between 1910 and 1914. During this period the mine was equipped with a mill and is reported to have yielded between $50,000 and $100,000 worth of gold (Tucker and Sampson, 1943). Water for the mill was derived from Indian Spring, 5 miles northeast. As shown by the following table of production, the mine was operated by several owners from 1932 to 1944. The following description is based upon an examination in October 1929.

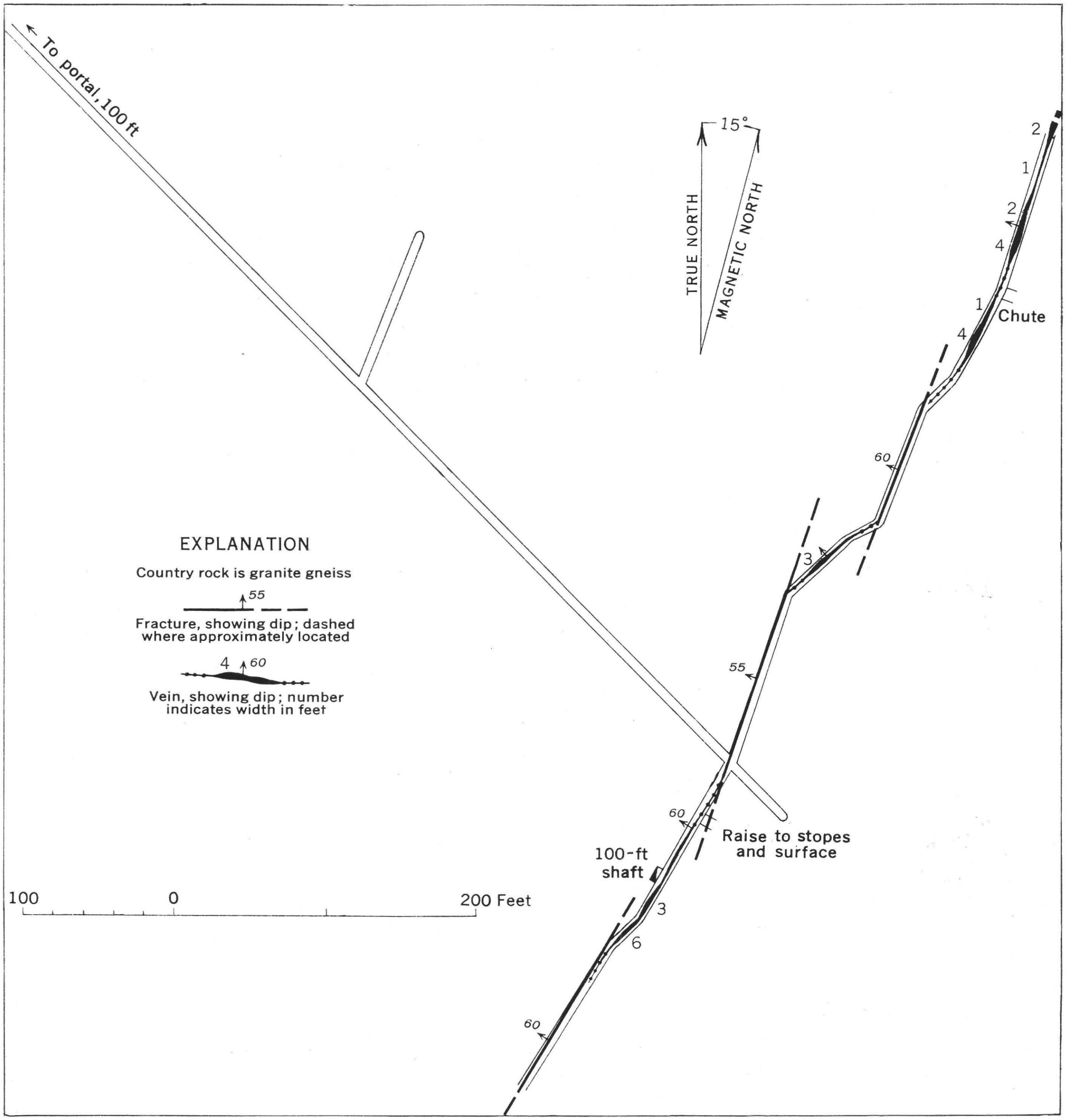

FIGURE 43.—Sketch map of tunnel level, Paymaster mine.

Recorded production of the Paymaster mine (no. 19, p. 2), Halloran Springs district

[Published by permission of U. S. Bureau of Mines]

Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)
1932	25	12.88	3
1933	15	6.28	1
1934	16	7.27	1
1935	30	13.28	2
1938	810	54.00	62
1939	10	4.00	5
1940	6	13.00	3
1941	82	165.00	29
1942	20	16.00	4
1944	9	24.00	7

The workings explore a simple type of massive quartz vein in granite gneiss. The foliation of the gneiss strikes north and dips east at a low angle; by contrast the principal vein strikes N. 20° E. and dips steeply west. One prominent group of joints in the gneiss strikes N. 70° W. and dips southwest. The vein is massive quartz without conspicuous structural features or druses. It contains sparse pyrite which, according to local report, yields high assays in gold. On the tunnel level, the pyrite is largely oxidized. A polished specimen of vein quartz containing pyrite shows that both pyrite and quartz are minutely crushed and recemented; gold lies in the cracks.

In 1929 the drifts for the vein had intersected two faults that strike about N. 15° E. and dip 55°–60° NW. These faults displace the vein and contain several inches of quartz breccia; as the faults were explored by stopes, it seems probably that the breccia contained supergene gold.

BRANNIGAN MINE

According to Tucker and Sampson (1943), the vein explored by the Brannigan mine (not on pl. 2) was discovered in 1930. It lies in low hills at the northwest end of Old Dad Mountain where the country rock is quartzite, shale, and dolomite of the Prospect Mountain quartzite. The beds trend generally north and dip at low angles east. The vein, 1 to 2 feet of quartz, trends N. 10° E. and dips 70° W.

During 1938, 1939, and 1940, it yielded 51 tons of ore containing 59 ounces of gold and 20 ounces of silver, which was milled nearby.

ORO FINO MINE

According to Tucker and Sampson (1943), the Oro Fino mine (no. 20, pl. 2) lies about 12 miles southeast of Baker or about 2 miles south of the Paymaster mine; it was not examined during this investigation.

It is reported that the mine explores a quartz vein 3 to 12 feet wide in limestone and quartzite (Prospect Mountain quartzite). The record of production follows.

Recorded production of the Oro Fino mine (no. 20, pl. 2)

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Year	Crude ore (tons)	Recoverable metals	
		Gold (ounces)	Silver (ounces)
1902	3	----------	20,460
1937	35	9	7
1938	139	90	26
1939	38	34	32
1940	162	91	32
1941	70	134	27
1948	81	42	10

LUCKY MINE

The Lucky mine (no. 21, pl. 2) lies on a southward spur from the northern part of Old Dad Mountain, about 17 miles southwest of Baker and 2 miles south of the Brannigan mine. The vein of quartz was discovered by E. C. Johnson about 1937. The country rock is pre-Cambrian diorite which underlies the plate of Goodsprings dolomite that forms the crest of Old Dad Mountain.

About 1,277 tons of ore mined during 1938, 1939, and 1940 yielded 512 ounces of gold and 489 ounces of silver.

MARL SPRING PROSPECTS

In the area of quartz monzonite which lies west and southwest of Marl Spring (no. 23–24, pl. 2), there are several shafts and tunnels that explore narrow quartz veins. There are traces of an arrastra at Marl Spring and it is locally reported that some of these openings were made as early as 1860 by soldiers employed in patrolling the stage road that passed Marl Spring (see p. 6). The monzonite of the area has a finer texture than that which occurs farther north but this is probably due to the proximity of masses of pre-Cambrian gneiss into which the monzonite was intruded. The principal opening is a 50-foot shaft which explores a quartz vein from 6 to 18 inches wide that lies 1½ miles west of Marl Spring. The quartz shows pyrite but no copper minerals.

RED CLOUD MINE

The state of explorations in 1924 and geologic features of the Red Cloud mine (no. 31. pl. 2) were described in the report on the Goodsprings district. As a result of exploration 36 tons of crude ore mined in 1934 yielded 56.09 ounces of gold and 4 ounces of silver, and 26 tons of crude ore mined in 1936 yielded 21 ounces of gold and 3 ounces of silver. The mine has not been examined since 1924.

Recorded production of the Red Cloud mine since 1930 (no. 31, pl. 2)

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Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)
1934	36	56. 09	4
1936	26	21. 00	3

ORO AMIGO MINE

The workings and geologic features of the Oro Amigo mine (not on pl. 2) which lies about 8,000 feet northwest of the Keystone mine, were described in the report on the Goodsprings district where it was classified as a copper mine. On the basis of a shipment of 22 tons of ore in 1936, which contained 22 ounces of gold and 69 ounces of silver and too little copper to be paid for, it should be considered a gold deposit. It has not been examined since 1924.

CHAQUITA MINE

On the basis of the state of explorations in 1924, the features of the Chaquita mine (no. 34, pl. 2) about 3,000 feet west of the Keystone mine were described in the report on the Goodsprings district. Early in the depression of 1929–33 when gold deposits were greatly sought, explorations at the Chaquita mine struck a shoot of good ore and the mine developed from the old inclined shaft to a depth of 640 feet (ninth level). As a result of explorations on the old Chaquita vein and other veins, the mine yielded gold valued at about one million dollars, thus exceeding the production of the Keystone mine.

In recent years, much of the equipment has been removed and most of the workings below the old tunnel level are inaccessible. Figure 44 is a vertical section through the shaft and shows the position of the veins that were explored. The production is shown in the following table.

Recorded production of the Chaquita Mine (no. 34, pl. 2)

Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1935	85	23. 66	12	----------	----------
1936	11, 402	2, 960. 61	244	7, 508	429
1937	27, 058	6, 667. 0	500	8, 500	700
1938	21, 789	8, 179. 0	526	2, 600	700
1939	31, 604	7, 025. 0	412	400	----------
1940	24, 327	4, 686. 0	362	----------	----------
1941	6, 582	1, 323. 0	85	100	100

KEYSTONE MINE

A description of the Keystone mine (no. 35, plate IV) with geologic maps of two levels appears in the report on the Goodsprings district. In 1931, a new campaign of exploration was begun and extended to 1941. The mine has not been examined since 1924.

The following table shows the production during this period of both the Keystone and the nearby Barefoot mine.

Recorded production of the Keystone-Barefoot Mines (no. 35, pl. 2)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1931	165	15. 58	1	----------	----------
1932	20	5. 42	2	----------	----------
1934	108	482. 71	84	1, 951	----------
1935	4, 100	1, 069. 88	168	575	----------
1936	397	482. 13	62	----------	----------
1937	501	668. 0	63	3, 000	----------
1938	2, 161	1, 966. 0	177	6, 400	----------
1939	7, 922	3, 264. 0	415	2, 700	3, 600
1940	9, 356	2, 511. 0	213	1, 800	----------
1941	500	286. 0	31	100	----------

GOLDEN CHARIOT MINE

The Golden Chariot (not on pl. 2) was only a prospect with modest record of production in 1924 and the features were briefly described in the Goodsprings report.

It was reopened in 1931 and was worked until 1942. It has not been examined since 1924. The record of production from 1931 to 1942 follows:

Recorded production of the Golden Chariot mine

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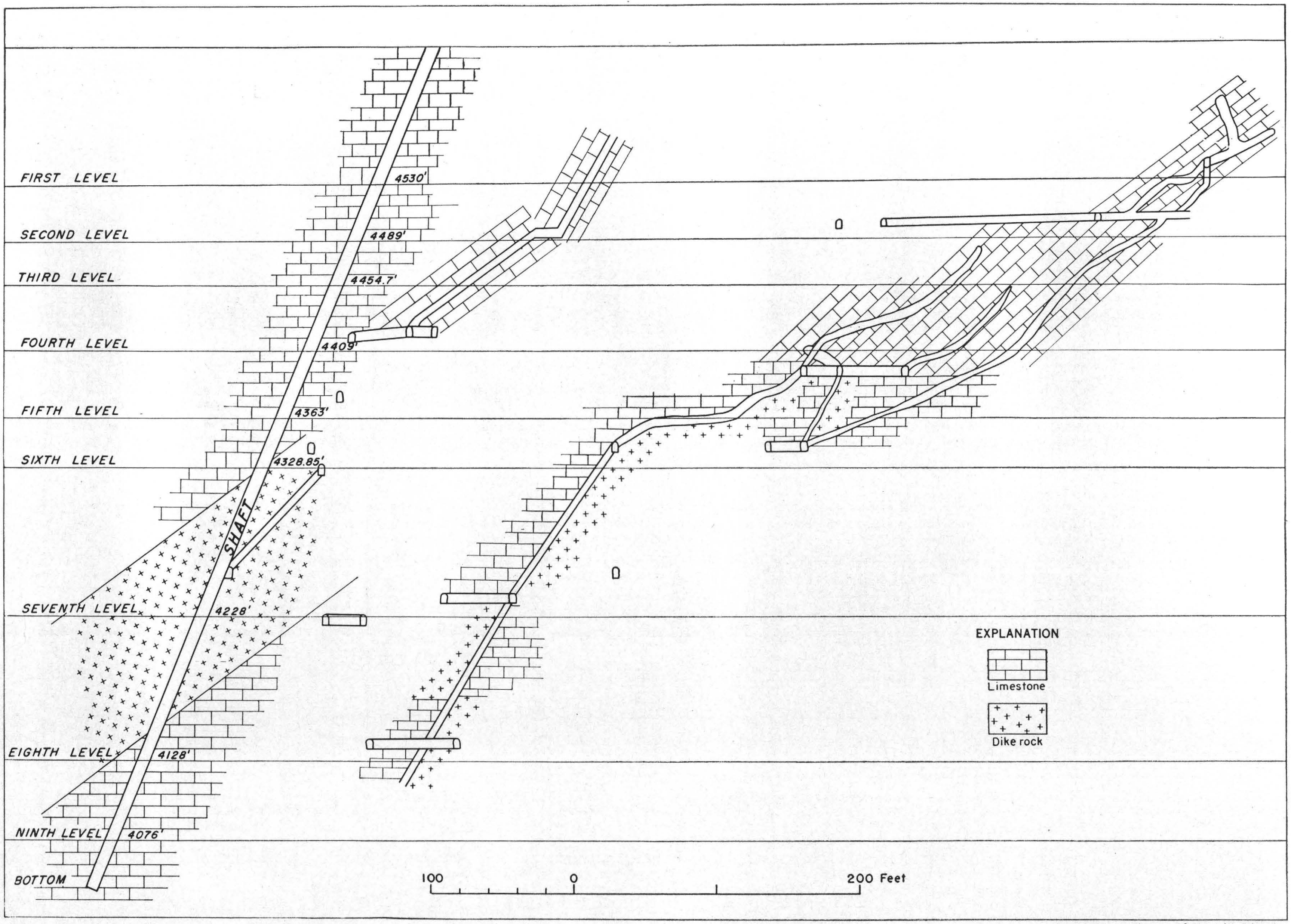
Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1931	31	43. 12	25	----------
1932	60	84. 76	10	----------
1933	172	140. 95	18	----------
1934	296	394. 12	105	2, 190
1935	231	807. 50	85	2, 320
1936	1, 549	759. 90	88	3, 557
1937	148	234. 00	32	600
1938	59	154. 00	30	2, 200
1939	42	77. 00	12	600
1940	5	62. 00	6	----------
1941	403	133. 00	17	700
1942	14	16. 00	6	----------

CLEMENTINA MINE

The Clementina mine (not on pl. 2) lies 3,000 feet southeast of the Keystone mine and includes a tunnel and several shallow shafts. Prior to 1924, 13 tons of material that yielded 10 ounces of gold, 8 ounces of silver, and 522 pounds of copper had been shipped from the mine. In 1924, 22 tons of ore was shipped containing 24 ounces of gold, 9 ounces of silver, and 300 pounds of copper. The mine has not been examined since 1924.

LAVINA MINE

The Lavina mine (not on pl. 2) which lies about 2½ miles west of Goodsprings, was described in the Good-



Geology by engineers of Chaquita Mine Co

FIGURE 44.—Vertical geologic cross section through the Chaquita mine workings.

springs report. After a long period of idleness, it was operated from 1934 to 1936 and it yielded the following production:

Lavina mine

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1934	26	15. 10	373	750	--------
1935	120	19. 00	294	520	458
1936	57	20. 00	433	--------	543

COLOSSEUM MINE

At the time of examination (1929) the Colosseum mine (nos. 62–63, pl. 2) included numerous explorations on the north and south slopes of a westward-trending ridge that lies 4 miles north of Clark Mountain. The principal exploration was a tunnel 560 feet long which extended southeast from the north side of the ridge. Near the face of this tunnel several hundred feet of drifts explored a mineralized breccia zone. On the south side of the ridge a 200-foot shaft, now inaccessible, explored another breccia zone.

As revealed in these workings, the country rock is gray biotite granite gneiss which, within an area about 1,000 feet in diameter, is fractured and intricately intruded by dikes of rhyolite. The rhyolite is a dense pale-gray rock which shows sparse small grains of orthoclase, quartz, and mica in a matrix of minute grains of feldspar and quartz. About 2,000 feet southwest of the mine, a similar rock forms a sill 5 to 10 feet thick about 100 feet above the base of the Cambrian system. The intrusive rock that forms the plug of Devil Peak, 12 miles northeast, closely resembles this rhyolite in appearance and composition (p. 86).

According to R. T. Walker, who examined the mine several years later after much more development, the area explored by the mine may be regarded as a breccia pipe (explosion crater) of rhyolite in the gneiss (Walker, 1928, p. 895–898, 939–942, 976–984).

As explorations stood in 1929, they revealed mineralized breccia zones along the major contact of the gneiss and intrusive rhyolite. Beginning about 1931 (Tucker and Sampson, 1943) further development was undertaken and a mill erected to treat the ore. The work included extending the tunnel from the south side of the ridge and driving a new tunnel 200 feet lower. From both of these tunnels, ore has been mined from bodies that lay along the contact of the rhyolite plug and the gneiss. As shown in the following table, ore was mined and milled almost continuously from 1931 to 1939. From 1938 to 1942 about 5,000 feet of diamond-drill holes were driven to search for and outline ore bodies.

Recorded production of the Colosseum Mine (nos. 62–63, pl. 2) Ivanpah district (Clark Mountain)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1929	66	36. 90	65	124	456
1931	100	25. 76	--------	--------	--------
1932	362	167. 99	51	155	--------
1933	17	22. 00	10	--------	--------
1935	59	58. 38	5	6	32
1936	47	44. 39	--------	--------	--------
1937	120	25. 00	--------	--------	--------
1938	2, 103	169. 00	24	--------	--------
1939	142	66. 00	--------	--------	--------

GREEN, TURNER AND MALLET MINE

On the north slope of the ridge on which the Colosseum mine lies, there are several tunnels as much as 100 feet long and shafts as much as 30 feet deep (no. 64, pl. 2). These explore quartz veins from 1 to 6 inches wide in the granite gneiss. They have diverse strike but dip steeply. The veins contain a little pyrite and galena, as well as their oxidation products, limonite, plumbojarosite, and cerussite. The principal value of the vein material, however, lies in the gold content. One of the owners reports that a recent shipment of 6 tons of quartz yielded $720 gross value.

Several dikes of rhyolite were observed near the explorations.

SULPHIDE QUEEN MINE

Gold was discovered and the Sulphide Queen mine (no. 75, pl. 2) was developed 2 miles northeast of Mountain Pass on Highway 91, about 1934–45, after field work by the writer in this region was completed. The following summary of the local features and the mine is abstracted from the report by Tucker and Sampson (1943).

The mine explores a vein in the pre-Cambrian gneissic granite that forms a broad zone east of the Clark Mountain fault. The principal working is an inclined shaft, 385 feet deep from which there are levels at 114, 213, and 315 feet. An adit connects with the shaft at 65 feet. Mine workings explore a vein of fine-grained quartz which strikes about N. 30° W. and dips 70° SW. One shoot is about 100 feet long and a maximum of 15 feet wide. A few percent of sulfide minerals is present; pyrite, arsenopyrite, and galena have been observed. The principal value lay in the gold content but as the gold was not free, calcining was necessary in order to recover it.

According to Fred B. Piehl, an owner, a 75-ton cyanide mill was operated from January 1 to May 28, 1941. From the 6,819 tons treated during these 5 months, 906.5 ounces of bullion was recovered that contained 511.5 ounces gold and 50.1 ounces of silver.

MORNING STAR MINE

Of the group of small mines that lie in a basin along the east slope of Ivanpah Mountain, about 9 miles north of Cima, the Morning Star (no. 92, pl. 2) has the most extensive explorations. The principal work is a tunnel that extends northwest about 600 feet, from which there are three drifts aggregating 400 feet. According to Tucker and Sampson, in 1943 two winzes had been sunk from two of the crosscuts, 240 feet and 400 feet respectively at 32° W.

The tunnel follows a zone of gouge that dips 34° W. and separates an overlying block of granite gneiss from an underlying intrusive quartz monzonite. Similar blocks of granite gneiss crop out and are explored by mine workings nearby. The granitic gouge contains a little galena, but the gneiss is cut by many quartz veins that carry pyrite and a little gold. This material, which is reported by the owners (Myton and Brown) to contain $3.00 to $5.50 worth of gold to the ton, was the basis for the explorations.

KEWANEE MINE

The Kewanee mine (no. 93, pl. 2) is the southernmost of the group that lies on the east side of Ivanpah Mountain, 9 miles north of Cima. A shaft 185 feet deep explores a quartz vein in quartz monzonite. The workings were not examined.

VANDERBILT MINES

Within an area of about one square mile in the hills of the middle part of the New York Mountains, there are several groups of gold mines, the most important being the Vanderbilt group (no. 102, pl. 2). According to Crossman (1890, p. 363), veins in the Vanderbilt district, formerly the New York district, were found in 1861 by prospectors exploring eastward from Death Valley, and a small mill was erected in 1862. It was visited by members of the party of Lt. G. M. Wheeler in 1871, but there was little development until about 1892 when a spur of the Atchison, Topeka and Santa Fe Railway was built from Goffs to Barnwell. Most of the veins of the area were found during the next few years. There was considerable development and some gold was produced. Probably more ore was mined in the area from 1934 to 1941, however, than in all previous years.

The most abundant rock in the workings is granite gneiss, but there are zones of mica schist that contain dikes of pink granite. The lamination ranges in strike from north to N. 30° W., and the dip ranges from 50° W. to vertical. As the vein strikes N. 70° W. and dips 60° NE., it cuts obliquely across the lamination.

The principal vein (Gold Bar) is explored by three shafts; the most western, Gold Bar, is 425 feet deep; the Ed, 400 feet deep and inaccessible, and the Baldwin, 230 feet deep (Tucker and Sampson, 1943). During the examination in 1929 most of the existing workings were accessible. As exposed on the 200-foot level, the Gold Bar vein is made up of numerous layers of quartz and gouge and the width between defined walls ranges from 3 to 12 feet. On the 200-foot level, the vein is offset 2 feet by a postmineral fault that trends north parallel to the lamination of the rocks. Throughout the workings, the vein shows brecciation to an uncommon degree. One specimen, examined closely after having been sawed and polished, is revealed as an aggregate of angular fragments of early-formed quartz containing a small percent of sulfide, pyrite, chalcopyrite, arsenopyrite, and galena, which have been cemented by marcasite and dolomite. Water level is about 200 feet below the surface.

The shipments from 1914 to 1941 are recorded in the following table:

Recorded production of the Vanderbilt mines (no. 102, pl. 2)

[Published by permission of U. S. Bureau of Mines. Items marked with asterisk (*) are pounds bullion]

Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1914	3.0	12.00	7.0	----------	----------
1915	4.0	17.40	57.0	----------	----------
1929	100.0	123.00	476.0	1,338	----------
1930	107.0	162.00	531.0	1,019	----------
1934	1,384.0	693.80	2,511.0	5,372	1,854
1935	1,355.0	435.30	1,174.0	2,321	2,699
1936	59.0	109.00	227.0	1,771	464
1938	111.4	47.50	241.7	2,590	----------
	*118.3	176.77	1,200.2	----------	----------
1939	54.0	24.46	169.1	1,309	----------
	*1,906.0	146.63	932.7	----------	----------
1940	*885.2	65.92	669.0	----------	----------
1941	36.5	28.61	87.2	207	----------
1942	48.2	27.71	61.1	170	----------
	Slag, precipitate, etc.				
1938	122.0	7.69	50.7	----------	----------
1939	569.0	1.60	48.0	21	----------
1940	1,681.0	13.63	639.0	51	----------

MIDNIGHT MINE

The Midnight (Darling) mine (no. 102, pl. 2) lies about 1,000 feet northwest of the Gold Bronze shaft. In 1929, the main shaft (Darling) was 300 feet deep on a vein that trends about N. 30° E. and dips 70° NW. It was not examined in detail. The vein was quartz with sparse pyrite.

There is record of the shipment of 3 tons containing 4 ounces of gold and 12 ounces of silver.

GOLD BRONZE MINE

The Gold Bronze mine (no. 103, pl. 2) is the easternmost of the group of mines near Vanderbilt. Mining in the area was most active between 1893 and 1895, when this mine is reported to have yielded about $50,000 worth of gold. The mine was operated intermittently between 1902 and 1913 and again between 1934 and 1940. Two shafts, the Gold Bronze and another 200 feet south, explored parallel veins to depths of 300 and and 200 feet respectively. In 1929 neither shaft was accessible. The prevailing rock near these shafts is a slightly laminated, dark fine-grained diorite.

The vein probably trends east and dips steeply north. The vein is quartz with considerable sulfide minerals, fine-grained masses of pyrite, coarse crystals or galena and coarse crystals of arsenopyrite.

BARNETT MINE

The Barnett mine (no. 111, pl. 2) lies along the west slope of a low ridge about 2 miles south of Rock Springs. The vein has been traced by shallow workings for nearly 2,000 feet. The principal exploration is an inclined shaft 320 feet deep. In 1926 water stood 60 feet below the surface, but it was locally reported that there are drifts at 100, 200, and 300 feet aggregating about 1,000 feet.

The shaft explores a vein that strikes N. 10° W. and dips 67° E. The enclosing rock is the gray quartz monzonite of the region. East of the mine, trending generally north, is a belt of schistose granite about 3,000 feet wide and at least 5 miles long. There are aplite dikes in both the monzonite and the schistose granite that are older than the veins of the area. As shown in the upper part of the shaft, the width of the vein between walls is about 4 feet. It contains several lenses of quartz 6 to 10 inches wide in the midst of sheared, sericitized monzonite. The quartz lenses contain a small percentage of sulfides, pyrite, galena, and chalcopyrite, in decreasing order of abundance. The quartz appears to have been shattered before the sulfides were introduced.

Some indication of the grade of the ore in the vein may be obtained from the composition of three cars of sorted ore shipped during 1913, 1914, and 1915.

Recorded production of the Barnett mine (no. 111, pl. 2)

[*Total recoverable metals, gold, silver in ounces; lead, copper in pounds]

Date	Weight wet (pounds)	Weight dry (pounds)	Gold (ounces per ton)	Silver (ounces per ton)	Lead (percent)	Copper (percent)	Insoluble (percent)	Iron (percent)	Sulfur (percent)	Gross value, per ton
1911	38, 000	--------	*18. 00	*58. 00	*1, 755. 0	*328	--------	--------	--------	--------
1912	60, 000	--------	*58. 92	*120. 00	*3, 000. 0	--------	--------	--------	--------	--------
1913 [1]	67, 940	66, 617	2. 635	7. 56	5. 3	1. 7	65. 8	10. 4	10. 4	$57. 07
1914 [2]	74, 800	74, 120	1. 92	5. 10	3. 6	1. 15	72. 4	8. 7	1. 1	39. 49
1915 [3]	50, 720	49, 792	2. 30	7. 90	9. 2	1. 9	62. 6	10. 3	12. 0	53. 41

[1] June. [2] March. [3] April.

GOLD KING MINE

The Gold King mine, also called the Gold Valley mine (no. 116, pl. 2) lies about 700 feet south of Gold Valley Spring, which is in some low hills northeast of Providence Mountains. At the time of examination (1927) a force was engaged in sinking an inclined shaft, then about 230 feet deep. There were several hundred feet of drifts on two levels, at 60 and 175 feet respectively.

These workings explore a simple type of gold-bearing quartz vein that lies in the typical quartz monzonite intrusive of the region. Fresh specimens collected underground show an equigranular groundmass of quartz, plagioclase, and biotite containing coarser crystals of pink orthoclase (see pl. 24). The vein trends northwest and dips 32° to 40° SW. The width between the walls is about 4 feet. Where opened by stopes on the upper level it contains one or two lenses of quartz 10 to 15 inches thick. The remaining material is pale-green and white sericite gouge representing an alteration of the monzonite.

Some ore was stoped above the upper level and treated in a mill at Gold Valley Spring, but there is no record of the result. According to local report, the vein material yielded about $10 to the ton. The quartz contains a little pyrite. One carload of 15 tons shipped in 1932 contained a total of 2.82 ounces of gold and 4 ounces of silver.

LOST BURRO MINE

The Lost Burro mine (no. 117, pl. 2) lies 2,000 feet east of the Gold King mine. A shaft about 125 feet deep explores a vein in quartz monzonite that trends north and dips 35° W. The vein, about 3 feet wide, contains lenses of quartz as much as 6 inches thick. There is no record of production.

LUCY GREY MINE

The Lucy Grey mine (no. 121, pl. 2) lies near the head of a basin that drains the west slope of the Lucy Grey Range west of McCullough Range. Although there are several prospects within a mile south and west, none have attained an advanced state of development or production. The mine includes a 300 foot vertical shaft with levels at 80, 200, and 250 feet that in 1929 aggregated about 1,100 feet (fig. 45). It was discovered in 1903 by T. L. Bright and most of the exploration was done between 1905 and 1918. It is equipped with a small cyanide plant.

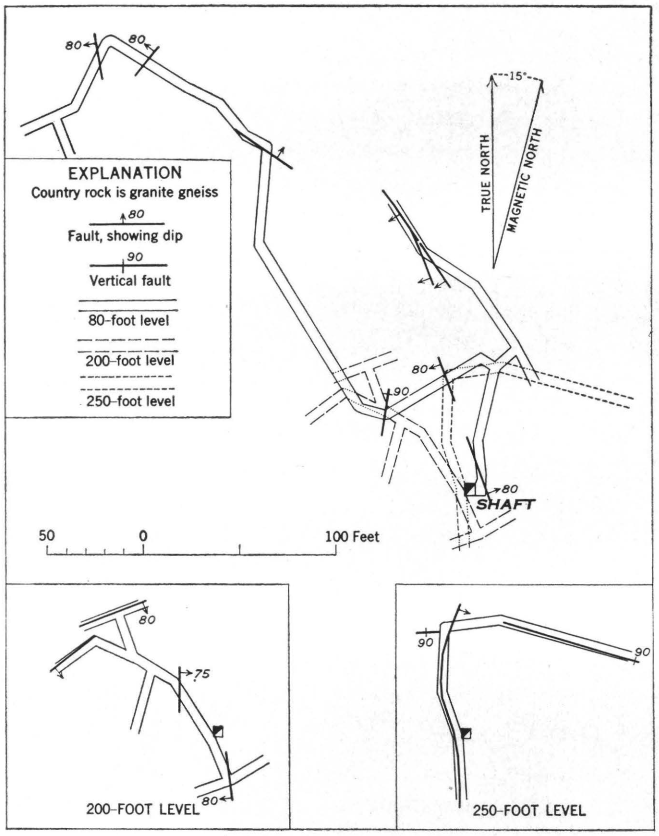

FIGURE 45.—Sketch map of workings, Lucy Grey mine.

The shaft is sunk at the southeast border of an elliptical breccia pipe in granite gneiss. The surface extent of the pipe is 150 by 200 feet and within it the gneiss is thoroughly broken into angular blocks, few exceeding 1 foot in diameter. These are cemented by veins of comb quartz, 1 to 2 inches thick. The transition zone from the highly broken gneiss to that which is undisturbed is scarcely 1 foot wide. The rock within the pipe shows stains of iron and manganese oxides, but the surrounding rock is free of stain. The gneissic bands trend N. 30°–45° E. and dip 80° NW., but the longer axis of the pipe trends northwest.

Within the area explored by the levels the cemented breccia is broken by many iron-stained fractures that cut across the quartz veins and are undoubtedly post-mineral. (See fig. 45.) The stopes are confined to these fractures. This fact, the oxidized character of the entire area, and the high grade of ore mined indicates that the gold along these fractures was supergene in origin and was derived from the small quartz veins that cement the breccia. The grade of the material mined has fluctuated widely. Forty tons treated from 1913 to 1916 yielded $68 worth of gold and $9.70 of silver per ton.

DOUBLE STANDARD MINE

The Double Standard mine (no. 122, pl. 2) lies on the southwest end of McCullough Range, about 3 miles northwest of Crescent. The workings include 4 shafts, 2 more than 100 feet deep, and 4 tunnels. These aggregate about 1,000 feet of work.

These workings explore a shear zone that trends nearly due east and dips vertically. The enclosing rock is pre-Cambrian granite gneiss in which the lamination strikes nearly due north and dips 40° W. The shear zone, 20 feet wide, contains 3 or 4 lenses of quartz, each 4 to 10 inches wide. The quartz contains a small percentage of sulfides, largely galena and tetrahedrite with traces of chalcopyrite. In places barite is an accessory gangue mineral. Apparently the vein was explored as a source of gold and silver.

The recorded production follows:

(Recorded production of the Double Standard mine, (no. 122, pl. 2) Crescent district (Clark County, Nevada)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1937	79	44	867	--------	--------
1939	150	81	267	--------	2, 000
1940	183	103	538	200	1, 600
1941	58	48	118	--------	600

LUCKY DUTCHMAN MINE

The Lucky Dutchman mine lies at the southwest corner of the McCullough Range, about 5 miles northeast of Nipton. The principal work is a vertical shaft about 300 feet deep, in 1927 completely dismantled and inaccessible. The country rock of this area is a gray gneissic granite which contains sparse red feldspar. Presumably the mine explored a ledge of quartz which strikes N. 80° E. and dips 35°–40° S. This ledge, 10 to 25 feet thick, crops out predominently east of the mine. Fragments on the dump show comb quartz with casts of pyrite. It was probably explored for the gold content.

NIPPENO MINE

The Nippeno mine (no. 125, pl. 2) lies in the low hills a mile north of Crescent Peak. It includes an inclined shaft, 500 feet deep, with levels that aggregate about 2,000 feet. These workings explore a quartz vein whose width rarely exceeds several inches. It trends N. 25° W. and dips 45° NE. The accessory minerals are galena, chalcopyrite, their products of oxidation, and a little barite. The mine was not examined in detail.

Recorded production of the Nippeno mine (no. 125, pl. 2)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1931	80	41. 12	34	1, 800	
1932	80	15. 91			
1933	234	138. 67	40		
1934	230	209. 36	82	155	679
1935	450	80. 40	135		
1936	3	5. 96	2		
1937	66	44. 00			
1939	25	3. 00	1		100

TRUE BLUE MINE

A number of shafts have been sunk in an area of several square miles covering the low hills east of the railroad to Barnwell and north of Vontrigger spring. Most of the work has been done in an area scarcely 200 feet in diameter in what is known as the True Blue mine (no. 130, pl. 2). Here there are three shafts, 80, 100, and 125 feet deep, which explore shear zones in the granitic gneiss. These zones contain disseminated chalcopyrite and its oxidation products.

The dominant rock of the area is granite gneiss, which is cut by dikes of coarse alaskite and aplite. South and east of the mine there are belts of sheared granite, diorite, and biotite schist. The strike of the foliation of these rocks is N. 50° W., and the dip is steeply southwest. The mineralized zones lie parallel to the foliation.

A mile east of the True Blue mine a 60-foot shaft (Dan Simmons, no. 131) explores a narrow quartz vein, and 2 miles farther east several shafts (Copperopolis, no. 132) are sunk on mineralized shear zones in schistose granite.

SILVER DEPOSITS

Deposits in which the value of the silver exceeds that of any other metal fall readily into three groups on the basis of mineralogy and rock environment. The first group includes the deposits of old Ivanpah district (Beatrice, no. 59; Allie, no. 60; Lizzie Bullock, no. 60; Stonewall, no. 61), all in Goodsprings dolomite. The only sulfide observed in the veins is stromeyerite; the only gangue mineral is dolomite.

The only deposit in the second group is the Mescal (no. 77), which contains stibnite, pyrite, and an obscure silver sulfide in a gangue of fine-grained quartz. This mineral assemblage resembles that at the Wade antimony deposit (no. 70), 3 miles northeast, but this deposit is in pre-Cambrian gneiss and the Mescal vein is in Goodsprings dolomite.

The third group of veins, four in number, has about the same assemblage of sulfide minerals, pyrite, galena, blende, and chalcopyrite, with sparse tetrahedrite and pyrargyrite; quartz is the principal gangue mineral. The Death Valley vein contains also considerable fine sericite. One of these veins is in pre-Cambrian gneiss or schist; the other three are in Teutonia quartz monzonite. Each of the four, however, lies near the contact of the monzonite and gneiss (or schist) into which it is intrusive. As noted above, most of the gold veins have similar distribution.

The assemblage of minerals in the third group of silver veins is scarcely diagnostic of definite physical conditions; they are known in deposits that are regarded to be either mesothermal or epithermal. On the other hand, the assemblage in the first and second groups suggest epithermal conditions.

Silver deposits

No.	Name	Country rock	Year examined
59	Beatrice	Goodsprings dolomite	1926
60	Lizzie Bulloch	do	1926
60	Allie	do	1926
61	Stonewall	do	1926
77	Mescal	do	1926
94	Teutonia	Teutonia quartz monzonite	1927
95	Death Valley	do	1927
115	Columbia	Pre-Cambrian gneiss	1927
141	Leiser Ray	Teutonia quartz monzonite	1927

BEATRICE MINE

The Beatrice mine (no. 59, pl. 2) lies on the west end of Ivanpah Hill, 3 miles north of Clark Mountain which contains most of the mines of old Ivanpah district. The deposit was discovered in 1870, and during the principal period of activity from 1870 to 1880 the mine was owned and operated successively by the McFarland brothers and the Ivanpah Consolidated Mill and Mining Co. The production of the Beatrice mine including that of the Monitor, which lies southeast, is estimated to have been about $3,500,000 in silver bullion (Crossman, 1890, p. 363).

In the vicinity of the mine, the strike of the beds of the Goodsprings dolomite turns from N. 45° W. on the east to N. 70° W. on the west; the dip is almost constant at 25° SW. As the vein trends northwest and dips northeast, the strike is parallel to the bedding but the dip is opposed. The same general relations are found

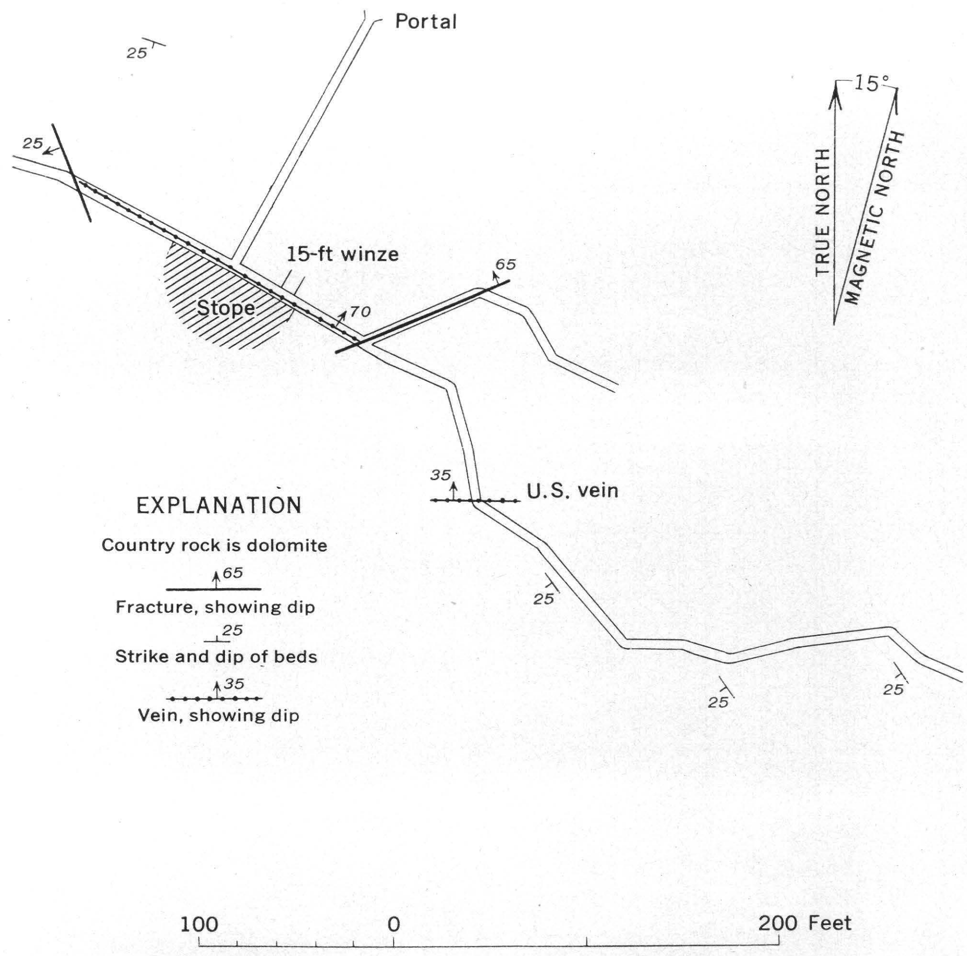

FIGURE 46.—Sketch map of tunnel level, Beatrice mine.

in the Stonewall mine, 1 mile east. The nearest outcropping intrusive igneous rock is the sill of rhyolite that lies half a mile east.

The principal workings of the mine are shown in figure 46. In the tunnel the vein is explored for 170 feet, but it is cut off by faults at both ends. On this level, the vein is 3 to 4 feet of crushed and bleached dolomite limited upward by a good wall that shows striae and deep furrows. No sulfide minerals were observed; thin films of copper and vanadium minerals are common. The U. S. vein lies in the footwall and the U. S. no. 2 lies in the hanging wall.

The fault which limits the Beatrice vein on the east in the tunnel is also shown in the surface workings 200 feet higher, where it clearly displaces the vein about 40 feet. The fault was undoubtedly formed after mineralization. The total stoped length of the vein in the surface workings is about 350 feet.

According to early reports, several tons of ore produced during the first year of operation yielded $1,096 worth of bullion per ton. Recent shipments of several tons contained from 120 to 180 ounces of silver per ton.

LIZZIE BULLOCK MINE

The Lizzie Bullock (no. 60, pl. 2) is among the mines on Ivanpah Hill that were discovered about 1870 and explored during the next decade. It lies in a gulch on the northeastern slope of the hill. When examined in 1934 with the owner Martin Kewiser, only one tunnel was open and in process of exploitation. The mine included a crosscut about 210 feet southwest to the vein along which drifts extended about 200 feet; two winzes extended to a level 100 feet below.

The vein includes several layers of dolomite and iron-stained dolomite breccia several inches wide that trend N. 50° W. and dip 80°–85° NE. The local bedding of the enclosing Goodsprings dolomite strikes northwest and dips at low angles southwest. There are small stopes above the tunnel level. The vein shows sparse stromeyerite and stains of copper carbonate.

Recently (1946) Kewiser shipped 37 tons of ore that contained 1 ounce of gold, 3,741 ounces of silver and 500 pounds of copper. The mine was one of the four principal mines of the district during the early days of the district.

ALLIE MINE

The Allie mine (no. 60, pl. 2) lies on the east side of a deep ravine that drains the north slope of Ivanpah Hill. It is one of the five mines that were discovered about 1870, and most of the existing workings were made between 1870 and 1880. Most of the output was derived from a group of short tunnels, now largely caved and inaccessible. However, a lower tunnel, which is connected with some of the stopes, remains accessible but it did not reveal any ore. It extends S. 40° E. for a distance of 600 feet, and there are many connecting short drifts. The accessible workings above the tunnel present a veritable maze in which men have been lost for several days.

These workings all lie within the Goodsprings dolomite which broadly trends N. 30°–40° W. and dips 40° SW. The zone explored by the workings, however, is badly broken. The ore was derived from a zone of pockets that trends southeast in the disturbed zone, rather than from simple veins such as occur in the Beatrice and Stonewall mines. These pockets occurred in veins of white dolomite that replace the gray dolomite. There are numerous post-mineral fractures that strike northeast and dip southeast, but there are also some flat and some highly curved fractures.

According to Crossman (1890, p. 363) the silver content of the ore ranged from 300 to 4,400 ounces per ton. It is reported to have paid $100,000 in dividends.

STONEWALL MINE

The Stonewall mine (no. 61, pl. 2) is the most eastern n the Ivanpah district. It was discovered about 1870, and most of the work was done prior to 1890. The mine includes several tunnels of which the lowest, about 700 feet long (fig. 47), was completely accessible in 1927. In 1926 and 1927 the mine was operated under lease by T. L. Bright, and in 1928 and 1929 by the owner, Martin Kewiser.

The mine is located in the gray dolomite beds of the Goodsprings dolomite several hundred feet above the base, where they trend N. 40° W. and dip 40° SW. The workings explore a narrow but well-defined vein that trends about N. 45° W. and dips 50° NE. The vein is commonly a single lens of cream-colored dolomiet from 1 to 4 inches wide, but in several places it includes 2 or 3 lenses and the total width is 12 to 15 inches. The vein follows a fracture zone in the dolomite along which there is some brecciation (fig. 47), but there is no distinct wall as at the Beatrice mine. The vein is broken by numerous fractures that trend northeast and dip uniformly northwest. Along most of these fractures the vein is displaced from 6 to 12 inches, or, in one extreme case, 5 feet. Some of these cross fractures are indicated by 2 to 6 inches of sheared dolomite; along others, water has dissolved the dolomite and left an open water course.

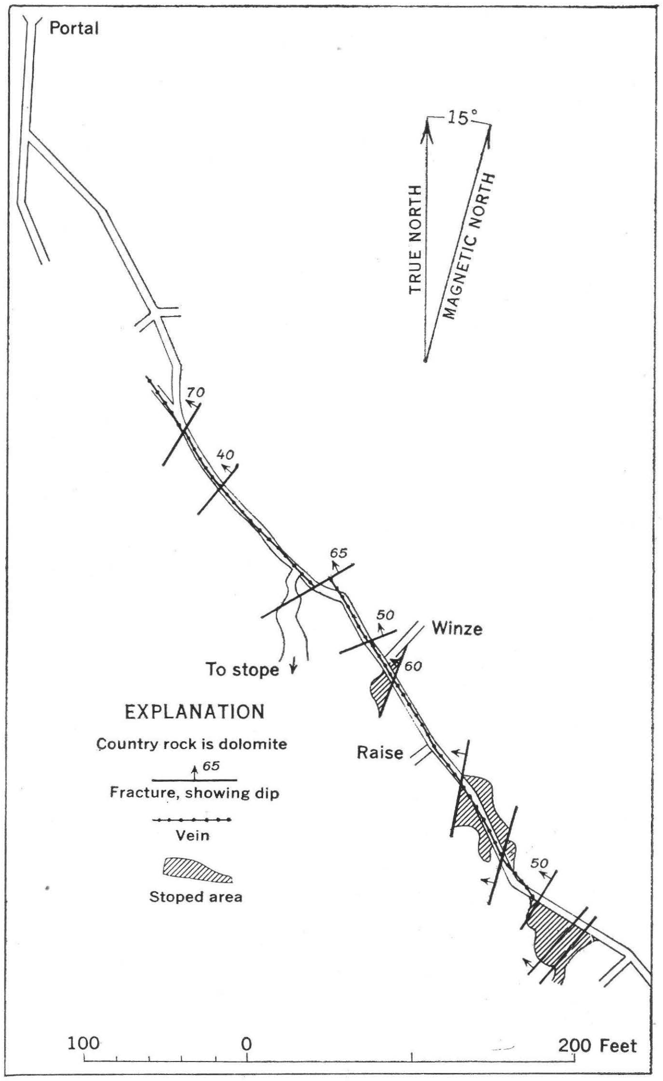

FIGURE 47.—Sketch map of tunnel level, Stonewall mine.

Other than the light dolomite which forms the gangue, only a few copper and silver minerals were observed. The only sulfide is stromeyerite (sulfide of silver and copper). Polished surfaces of high grade ore show stromeyerite in process of alteration to tenorite, azurite, and malachite; chloride of silver is reported. Smelter settlements record several percent of both lead and copper. Stromeyerite occurs as aggregates of small grains or as solid masses as much as several inches in diameter in the midst of the light dolomite. The intersections of cross fractures with ore-bearing vein material were not observed but the fact that several ore shoots abut against the southeast side of the cross fractures suggests a relationship, even though similar fractures in the Beatrice mine are postmineral.

Complete records of production are not available.

The output of 10 tons of selected ore in recent years has contained silver ranging from 500 to 750 ounces per ton.

MESCAL MINE

The mine (no. 77, pl. 2), variously known as Mescal, Mollusk, or Cambria, lies high on the northeast slope of Mescal Range, about a mile south of U. S. Highway 91 which descends Wheaton Wash. According to Charles Loomis, living at the Beatrice mine in 1927, it was located as the Cambria mine by Henry Morgan in 1881 and in 1882 was bought by McFarland and Loomis, who did considerable development work. It is briefly described by Crossman (1890, p. 363).

The state of the development in 1929 is shown in figure 48. The enclosing rock is thinly bedded dark-gray dolomite of the Goodsprings dolomite which here trends N. 10° W. and dips about 35° W. The contact of an underlying intrusive rhyolite sill is a bedding plane that lies about 250 feet stratigraphically below the zone of rocks explored by the mine. Near the mine, the contact is broken by two cross faults that trend N. 70° E. and dip 80°–82° N. In each case, the north block is dropped.

The mine explores a single shoot of ore from the surface to the bottom of a winze below the third level, or about 300 feet (fig. 48). The shoot follows a wall that lies nearly parallel to the bedding. On the tunnel level, the wall follows the bedding of the dolomite closely, but in the main winze it is clearly shown that it cuts across minor folds. This wall and the meager breccia that underlies it must have been formed during the epoch of compression and essentially mark the position of a minor thrust fault. The mine also reveals several minor faults that trend N. 70° E. and dip 70° S., along which the displacement is about one foot. The specific cause of the localization of the shoot in the thrust fault is obscure. From what is known of the region, it seems probable that it is determined by one or more minor cross fractures, possibly of the tear type.

The shoot was largely a body of fine-grained quartz that sporadically contained fine disseminated sulfides. The sketch (fig. 49) made at the bottom of the deepest winze shows the distribution of the quartz and the way in which it has replaced the dolomite. The width of the stopes ranges from 2 to 5 feet. The most abundant sulfide in the material on the dump is stibnite, which locally forms 10 to 20 percent of the weight. A carefully polished specimen shows a little pyrite. Since silver was the most valuable constituent, some silver-bearing sulfide must be present. These sulfides fill the pores of the spongelike mass of quartz that replaced the dolomite.

The records of production indicate that ore shipped contained from 50 to 100 ounces of silver and about $3.50 worth of gold to the ton.

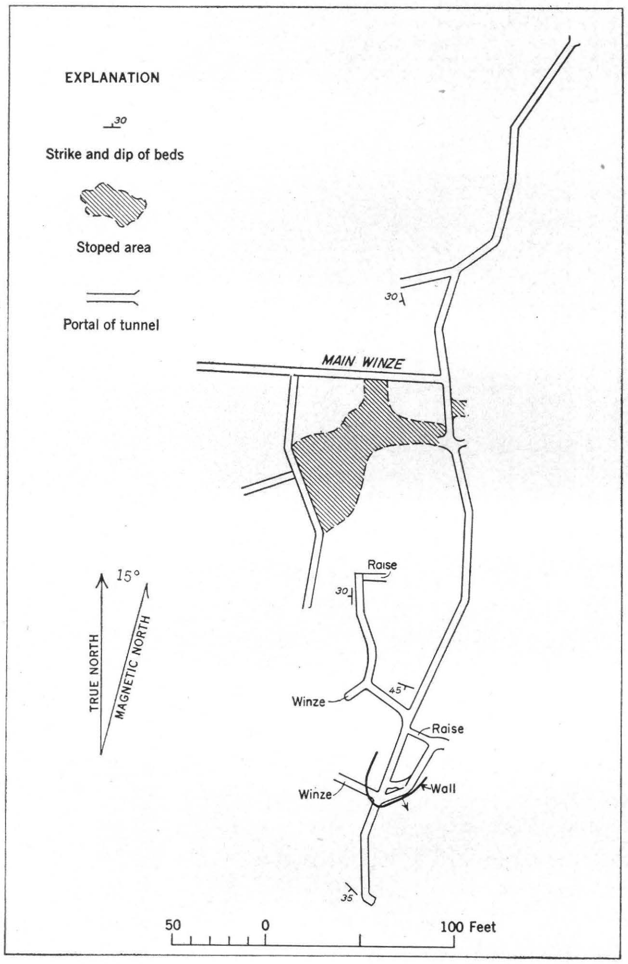

FIGURE 48.—Sketch map of workings, Mescal mine.

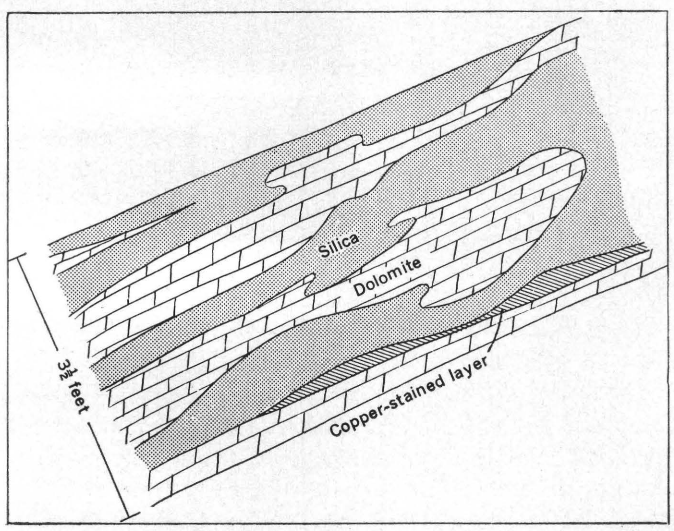

FIGURE 49.—Sketch of Mescal vein, winze below third level.

Recorded production of the Mescal mine, (no. 77, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1908	1		100			
1909	1		200			
1915	22	3.53	2,069			

TEUTONIA MINE

The Teutonia (Dutch Silver) mine (no. 94, pl. 2) is located on the northeast slope of Teutonia Peak in the typical Teutonia quartz monzonite of the region. The shaft is now caved, but it is equipped with a pump and is a local source of water. According to the owner, T. L. Gibson, the shaft is 200 feet deep on the vein which strikes N. 55° W. and dips 80° SW. The width of the vein along the outcrop ranges from 5 to 8 feet. The mineralogy is the same as that at the Death Valley mine, but there appears to be more quartz present here. In addition, the vein contains several varieties of dense chert which are probably supergene in origin.

About 112 tons of ore that contained from 100 to 150 ounces of silver to the ton and several percent of lead has been shipped.

DEATH VALLEY MINE

The Death Valley mine (also known as the Dolly Varden and Arcalvada, no. 95, pl. 2) lies in the flat area north of the Mid Hills, 3 miles southeast of Cima. It was discovered in July 1906 and was actively explored until 1915. No underground work has been done since 1920. After the mill burned in 1924, the main shaft caved and is inaccessible. This shaft was 430 feet deep at an inclination of 45° to 55°, and there were levels at 100, 150, 200, and 400 feet.

The vein explored in this mine strikes northeast and dips southeast. The outcrop lies in the typical coarse quartz monzonite of the region, but according to the owner, J. L. Strawn, the vein passes into fine-grained gray quartz monzonite with depth. Specimens of the vein material and wall rock show considerable alteration of the monzonite to green sericite. The fine gray monzonite contains sparse veinlets of epidote. The vein material on the dump shows blend, galena, and pyrite in a matrix of sericite and quartz. The principal value lies in the silver content. A parallel vein containing similar minerals lies about 150 feet above the main vein and has been explored from a crosscut on the 400-foot level.

Most of the output shown in the accompanying table was crude ore, but a part was concentrate made in the mill.

Recorded production of the Death Valley mine, (no. 95, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Lead (pounds)
1907	2,484	166.51	74,595	
1908	361	49.92	26,021	17,857
1910	20		1,800	
1911	41	3.00	1,907	2,222
1913	82	5.00	4,500	
1914	37	10.00	2,960	
1915	27	2.00	1,640	
1919	560	4.00	2,700	11,000
1920	920	20.00	6,612	13,061

COLUMBIA MINE

The Columbia mine (no. 115, pl. 2) lies at the head of a valley that drains northwest from the north end of Providence Mountains, 6 miles southwest of Dawes. The workings include a shaft 380 feet deep which is inclined 49°, from which there are drifts southwest at 100, 200, and 300 feet. These drifts explore the footwall vein. A crosscut from the south side of the ridge and connected drift explore the hanging-wall vein (fig. 50). A crosscut from this drift meets the shaft at the 100-foot level. Water stands in the shaft 120 feet below the surface.

These veins lie in fine-grained granite gneiss that is made up of layers of quartz and orthoclase separated by thin layers and films of chlorite. The general trend of the foliation of the gneiss is southwest and the dip southeast. The hanging-wall vein is a zone of sheared gneiss from 1 to 6 feet wide in which there are sporadic lenses of quartz as much as 2 feet wide. Unlike the white quartz that makes up the veins in the monzonite in the New York Mountains and eastward, the quartz

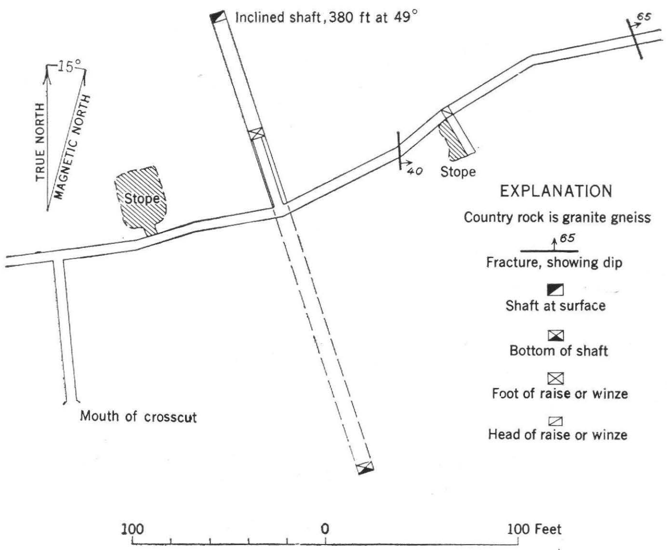

FIGURE 50.—Sketch map of workings, Columbia mine.

of this vein is dense and dark gray. Polishing and etching reveal that the quartz has replaced the enclosing rock and has been minutely brecciated and recemented several times. The only sulfide minerals observed were pyrite and blende, which also have been crushed.

The records of the early production, when the shaft was sunk and the levels run on the footwall vein, are not at hand. At that time, 1900–1905, there was a 5-stamp mill on the property. During recent years, 57 tons of selected ore that was mined and shipped yielded 0.28 ounce of gold and 35 ounces of silver to the ton.

On the Silver Fox prospect (no. 113, pl. 2), 2,500 feet north of the Columbia mine, a 40-foot vertical shaft explores a 4-foot vein of similar quartz, which contains 10 to 20 percent of pyrite and blende.

LEISER RAY MINE

The Leiser Ray mine (no. 141, pl. 2) lies on the south slope of the low hills in the southeast corner of the quadrangle, 8 miles northeast of Goffs on the Santa Fe railroad. The vein that has received the greatest amount of exploration was probably known prior to 1891 (Crossman, 1891, p. 18), but most of the existing workings were made between 1905 and 1915 (Cloudman, Huguein, and Merrill, 1917, p. 75–78). Several mills and much other equipment were installed in 1915; since then these have been dismantled and removed. The main vein is explored by two inclined shafts; the deepest, 200 feet on the incline, meets a vertical vein 90 feet below the surface.

Teutonia quartz monzonite underlies the area (fig. 25). It is a light-gray rock containing conspicuous biotite, quartz, and both fine and coarse orthoclase. A large area of this rock west of the mine workings is altered to a dense gray rock with numerous reddish patches. The gray portion is wholly fine sericite and quartz. The reddish patches contain fine-grained quartz and feldspar; the color is due to disseminated iron oxide, doubtless derived from pyrite. The rock presents, therefore, evidence of almost complete hypogene alteration (sericite and pyrite) as well as fine-grained silica (see p. 117) formed by supergene processes. There are at least four varieties of dikes that cut the monzonite. Three of the dikes—monzonite porphyry (much like that of the Kingston Range, see p. 67), aplite, and andesite—contain feldspar phenocrysts but no quartz and are premineral, but the fourth, probably lamprophyre, is postmineral. On the 200-foot inclined shaft, the vein is cut by five such dark dikes.

The principal vein crops out prominently along the crest of a ridge where the width ranges from 2 to 7 feet. The strike is nearly due east and the dip 45° N. A narrower parallel vein crops out 75 feet south. The vein is quartz with sparse druses but without layering. The only sulfides noted were sparse chalcopyrite and galena; traces of specular hematite are present. Among several oxidation products the vanadates, principally descolzite and cuprodescloizite (Schaller, 1911), are abundant as crusts and needles of diverse colors—yellow, brown, greenish and black. The latest mill erected in 1915 was designed primarily to recover the vanadates from the ore. There is record of production in 1916 and 1917 of 40 tons of material, probably concentrate, that contained an average of 17 percent copper, 1.2 percent lead, about 11 ounces of silver, and 0.15 ounce of gold per ton.

The 900-foot shaft north of the vein was sunk primarily for water, and at the time of examination water stood about 450 feet below the surface.

COPPER DEPOSITS

The 31 copper deposits listed in the accompanying table may be considered in two groups, depending upon the host rocks and the characteristic minerals. The first group are tabular veins of which 8 (those of the Goodsprings district) are in faults in carbonate rocks (nos. 28, 29, 36, 37, 41, 44, 55, and 58). The mined ore was largely oxidized copper minerals in a carbonate gangue. Several deposits contained a little chalcocite that was probably supergene and quartz that was hypogene. Also, 7 deposits are simple veins in pre-Cambrian granite gneiss (nos. 8, 10, 67, 91, 114, 120, and 134); 3 veins are in Teutonia quartz monzonite (nos. 16, 108, and 112); 4 veins are at the contact of two rocks, gneiss, carbonate rocks, or intrusive rocks (nos. 57, 83, 101, and 107).

Copper-mixed minor sulfides

No.	Mine or prospect	Country Rock	Year examined
8	Copperfield prospects.	Pre-Cambrian gneiss	1922
10	Foster	Pre-Cambrian granite gneiss	1926
16	Prospect	Teutonia quartz monzonite	1922
28	Double Up	Yellowpine limestone member	1922
29	Ninetynine	Bullion dolomite member	1922
36	Ironside	Valentine limestone member	1922
37	Boss	Monte Cristo limestone	1922
41	Columbia	Goodsprings dolomite	1922
44	Lincoln	do	1922
55	Prospect	Crystal Pass Limestone member	1926
57	Mammoth	Gneiss-dolomite contact	1926
58	Calarivada	Goodsprings dolomite	1926
69	Benson	Pre-Cambrian granite gneiss	1926
71	Copper World	Dolomite-diorite	1926
72	Dewey	Goodsprings dolomite	1926
81	Standard no. 1	Contact rock	1926
83	Prospect	Granite schist	1926
84	Standard No. 2	Contact rock	1926
86	Mine	do	1926
87	Copper King	do	1926
88	New Trail	Goodsprings dolomite	1929
90	Allured	do	1927
91	Sunnyside	Pre-Cambrian granite gneiss	1927
101	Copper King No. 2	Gneiss-dolomite	1927
107	Queen mine	Teutonia quartz monzonite	1927
108	Giant Ledge	do	1927
110	Prospect	Dolomite-flows	1927
112	Copper Bell	Teutonia quartz monzonite	1927
114	Francis	Pre-Cambrian granite gneiss	1927
120	Prospect	Pre-Cambrian gneiss	1927
134	California	do	1927

The second group of copper deposits belong to the contact type; they are irregular bodies of sulfides in the midst of carbonate rocks that have been altered to several silicates of lime, magnesia, and iron. They lie near bodies of igneous rocks: monzonite in the case of nos. 81, 85, 86, 87, 88, and 90; diorite in the case of nos. 71 and 72. The most productive copper deposit in the entire region, Copper World (no. 71) belongs to this type. Except at this mine, the oxidized copper minerals have been much more abundant than sulfide minerals.

COPPERFIELD PROSPECT

Within an area of several hundred acres that lies in a basin about 5 miles north of Horse Spring, once known as Copperfield (no. 8, pl. 2), a number of shallow prospect pits have been sunk on some showings of copper minerals. The principal rock of the area is gneissic granite, characterized by coarse feldspars in a matrix of chlorite. The planes of schistosity lie nearly horizontal. As stated elsewhere (p. 23), this rock is a variety of the pre-Cambrian granite gneisses. The only copper mineral noted was malachite, and, as it does not seem to be related to veins or lenses of quartz, the origin is obscure. The grade of the material is so low and the distribution so sporadic that it cannot be regarded as of much economic worth.

In the area of schistose granite gneiss that lies southeast of Kingston Range, at a point 2,000 feet north of a 4,500-foot hill, there are numerous quartz veinlets, 1 to 12 inches wide, that show sporadic patches of malachite and limonite. Farther east toward Winters Pass, there are many larger quartz veins, 1 to 3 feet wide, but they do not show any copper minerals.

FOSTER MINE

There has been some exploration for copper in the low hills (no. 10, pl. 2) that form the western part of Shadow Mountain (Riddell, G. S., and Foster, 1937). The explorations include a tunnel 250 feet long; 2 shafts, 60 and 80 feet deep; and some churn drill holes. Although quartz containing some copper stains has been found, the explorations do not reveal a persistent quartz vein. The country rock is the granite gneiss containing sparse alaskite dikes characteristic of the area (see p. 24).

Riddell and Foster record that drill holes, after passing through granite gneiss, entered a "clay sill." As the evidence along the west border of Shadow Mountain indicates that the crystalline rocks have been thrust over unconsolidated clay and sand of middle Tertiary age, it seems probable that the "clay sill" is these materials. In this event, copper minerals would be confined to the overlying hard rocks.

UNNAMED PROSPECT

A copper deposit (no. 16, pl. 2) has been explored by a 100-foot shaft on the north slope of a low hill 1,500 feet east of the Stone Hammer turquoise mine. Drifting on the 45-foot level is about 100 feet and that on the 100-foot level is about 200 feet. These workings explore the contact of the intrusive quartz monzonite with a belt of quartz schist and limestone, along which there are sporadic lenses of copper-bearing pyrite, now weathered to limonite. The principal minerals are chrysocolla, malachite, and several copper-bearing phosphates and vanadates. The rare copper-bearing plumbojarosite, beaverite, is rather common. Although a bed of limestone crops out prominently on the surface, it has not been struck in the workings. The contact of the quartz monzonite with quartz schist and limestone strikes N. 83° E. and dips 75° S. parallel to the schistosity of these rocks. They are undoubtedly roof pendants of pre-Cambrian rocks in the monzonite.

NINETY NINE MINE

In the report on the Goodsprings district, the geologic features of the Ninety Nine mine (no. 29, pl. 2) were described and a map of the tunnel level was presented. During 1944–46, exploration yielded the production recorded in the following table. The mine has not been examined since 1924.

Recorded production of the Ninety Nine mine since 1930 (no. 29, pl. 2)

Year	Crude ore (tons)	Recoverable metals		
		Silver (ounces)	Copper (pounds)	Lead (pounds)
1944	50	149	6, 800	----------
1945	144	356	18, 200	----------
1946	42	179	10, 000	100

BOSS MINE

The Boss mine (no. 37, pl. 2) was described in detail in the Goodsprings report. It was included in the group of copper mines even though the value of the included gold and palladium exceeded that of the copper. Development in the late years of the depression yielded the production recorded in the following table. It has not been examined since 1924.

Recorded production of the Boss mine since 1930 (no. 37, pl. 2)

Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1931	71	77. 40	145	2, 865
1935	55	39. 80	148	4, 007
1936	264	117. 76	425	14, 991
1937	1, 527	105. 00	113	4, 500
1938	80	35. 00	156	6, 000
1940	17	4. 00	23	2, 200

COPPER PROSPECT

In the zone along the east slope of Spring Mountain, from the Anchor mine on the north to the Carbonate King on the south, a distance of 12 miles, a single prospect was found (no. 55, pl. 2). It lies on the east side of the range in sec. 18, T. 26 S., R. 59 E. An open-cut has been driven in the uppermost beds of the Crystal Pass limestone member which here strikes N. 25° W. and dips 20° SW. From a lens of breccia that lies parallel to the bedding, half a ton of siliceous limonite containing about 10 percent copper has been removed. The lens is enveloped by an aureole of dolomitized limestone.

MAMMOTH MINE

The Mammoth mine (no. 57, pl. 2) lies at the head of a gulch that rises in a small mountain about 5 miles northwest of Clark Mountain. It was worked in a small way by the owner, W. D. McQuen, from 1906 to 1929. From 1916 to 1918, it yielded about 100 tons of ore that contained 22 to 25 percent copper. During the next 11 years it yielded 38 tons of ore that contained 16 to 28 percent copper. Both the gold and silver in these shipments were low. The mine includes three tunnels on the north and south sides of the gulch; the longest tunnel contains about 150 feet of drifts. The aggregate footage is about 400 feet.

The area is one of complicated structural detail. A tear fault, along which schistose granite gneiss is thrust over the basal section of the Cambrian system, trends northeast just north of the mine (fig. 18). The longest tunnel explores the contact of the Noonday dolomite on this gneiss.

The minerals in the ore and on the dump include malachite, azurite, chrysocolla, auricalcite, alunite, limonite, and quartz. Unweathered vein material has not yet been found; before weathering it probably contained largely pyrite, chalcopyrite, and quartz. Alunite and the copper minerals are products of weathering.

CALARIVADA MINE

The Calarivada mine (no. 58, pl. 2) lies in a small knob that rises above the wash about 2 miles north of Ivanpah Hill. Most of the work, which includes a shaft 285 feet deep and about 500 feet of drifts, was done in 1921–22. The shaft is now dismantled. The material on the dump is gray dolomite of the Goodsprings dolomite, in part considerably bleached but not recrystallized. Some of the material shows veins of quartz bordered by a zone in which the dolomite is replaced by coarse muscovite, fluorite, and a little barite. In places, where those minerals are intimately mixed, the fluorite is formed later than both barite and sericite. There is no record of production (Tucker and Sampson, 1931).

BENSON MINE

The Benson mine (no. 69, pl. 2) lies at the head of one of the ravines, low on the east face of Clark Mountain. When visited in 1926, work had been abandoned for some years and all equipment had been removed. A vertical shaft estimated to be 200 feet deep connects with about 500 feet of workings. To judge from material on the dump and surface pits, these workings explore a lens of copper-bearing pyrite that lies along a schistose zone in the granite gneiss. Several other prospects in the neighborhood explore similar deposits.

COPPER WORLD MINE

The most productive copper mine in this quadrangle is the Copper World (no. 71, pl. 2), located on the southeast slope of a westward spur from Clark Mountain, about 4 miles northeast of Valley Wells. Although the exact date of discovery of the Copper World mine is not recorded, it was one of the first mines of the region to be explored, and there is a record of shipments as early as 1869 (Crossman, 1890–91). After this early exploration, little was done until 1898 when a smelter was erected (Min. and Sci. Press, 1897, v. 74, p. 94; 1899, v. 78, p. 35). After a brief campaign of exploration which yielded copper worth about $750,000 (Calif. State Min. Bur., Bull. 50, 1908), it again lay idle until 1906. From that year to 1908, under the ownership of the Cocopah Copper Co., it was the source of 3,638 dry tons of ore that contained about 7 percent copper. The principal period of operation extended from 1916 to 1918 when about 1,735 of crude ore containing about 4 percent copper and 1,353 tons of matte containing 25–28 percent copper were shipped. The principal explorations include several thousand feet of tunnels and drifts and a shaft 100 feet deep, from the bottom of which there are several hundred feet of drifts (fig. 51).

These workings explore a block of the Goodsprings dolomite that has been intruded by several sill-like bodies of quartz monzonite. This rock is dark gray, fine grained, and holocrystalline, but it differs from the great body of quartz monzonite that lies a few miles southwest in that it is finer grained and contains abundant hornblende instead of biotite. Two sill-like bodies have been intersected in the tunnel and a third crops out on the surface. The lowest sill is 12 feet, the middle is about 50 feet, and the uppermost is 15 feet thick. The underground distribution of the sills is complicated by faults. From what may now be seen, it appears that the original copper minerals were associated with the bodies of silicate minerals that were

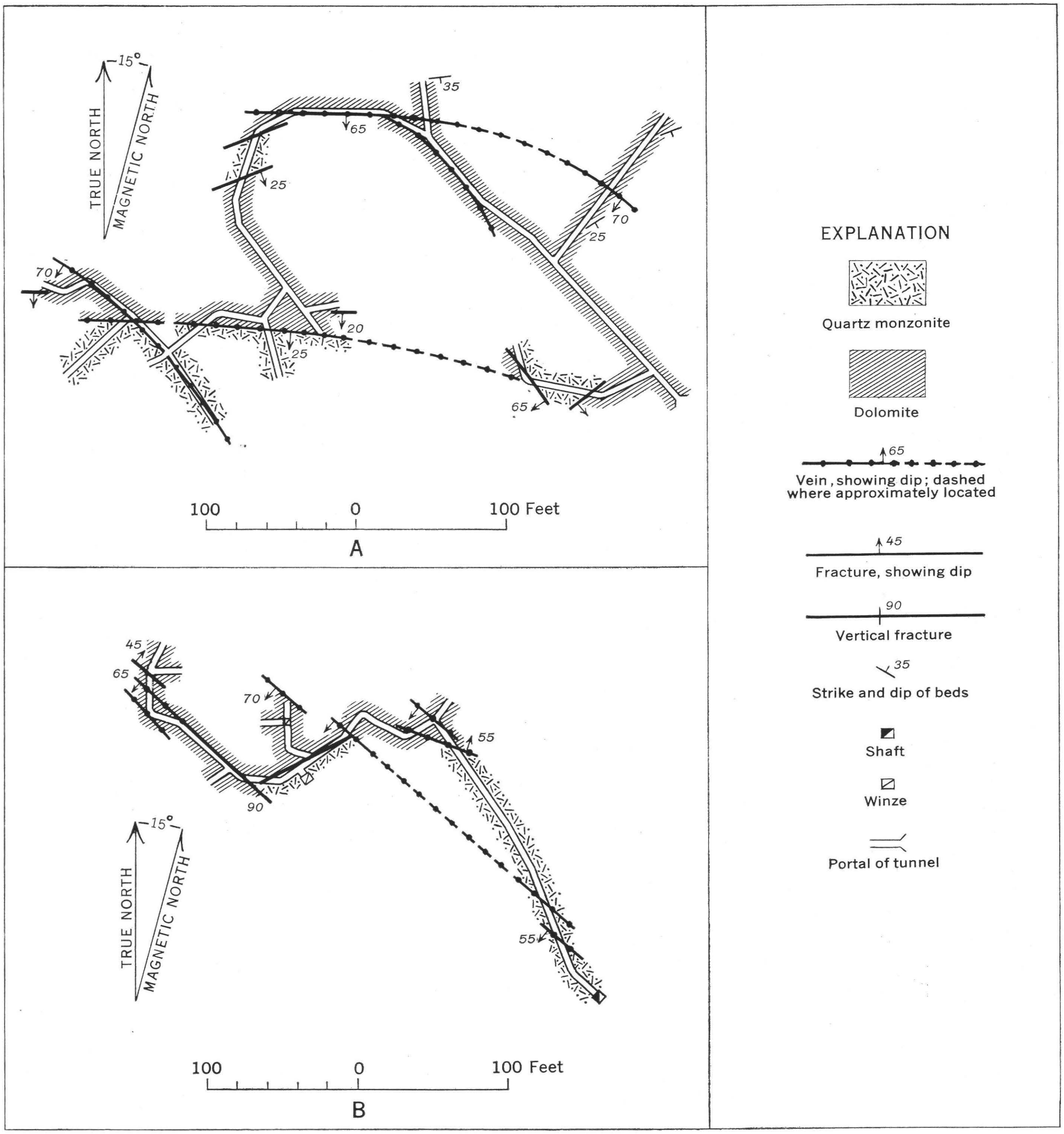

FIGURE 51.—Sketch maps of two levels, Copper World mine: *A*, tunnel level; *B*, 100-foot level.

formed in the carbonate rocks in contact with the intrusive monzonite. Only the oxidized copper minerals may now be seen and these are widely distributed, principally replacing the dolomite. Malachite and azurite are the most common, but doubtless other minerals were present in the ores.

The principal silicate mineral formed in the contact zone is diopside, but this mineral is now largely replaced by other minerals, such as brown serpentine. The silicate zone is only a few feet wide and beyond it the dolomite is bleached to pale shades of brown and cream. A thin section of this rock shows that it is largely made up of grains of carbonate 0.15 to 0.20 millimeter in diameter, but that it also contains 10 to 20 percent of small grains of brucite and serpentine uniformly distributed throughout. The great variety of minerals observed at the Dewey mine (p. 69) was not found here.

In spite of the complexity of the pattern by which the rocks are distributed underground, the sequence of events seems clear. The beds of dolomite strike about east and dip 25°–35° S. and the monzonite sills have been intruded along the bedding. The sills have been broken by fractures that strike northwest and dip 60°–80° S., and that contain veins of quartz several inches wide. These veins cut across the altered dolomite. Finally, the sills and quartz veins are broken by numerous minor post-mineral faults that strike northeast and dip northwest.

Recorded production of the Copper World mine (no. 71, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1906	310 dry			32,337.0
1907	3,291 dry		13,835	486,923.0
1908	37		515	1,682.0
			Ounces per ton	*Percent*
1916	339.9 dry		3±	11.0+
1917	1,395		4±	10.0±
	88.8 matte	0.04	25±	44.0±
1918				
	1,264 matte	.07	28±	44.0±
		Ounces	*Ounces*	*Pounds*
1943	3,743 old slag	21.00	2,226	286,000.0

DEWEY MINE

The Dewey mine (no. 72, pl. 2) is located on the southeast side of the same ridge as the Copper World and about 1,000 feet southeast. The workings include two tunnels, of which the lower and most extensive is shown in figure 52.

As at the Copper World mine, the bedding of the Goodsprings dolomite strikes nearly east and dips 25°–35° S. Also, the dolomite beds are intruded by several sills of fine-grained gray monzonite and are broken by faults that strike northeast. These later faults are offset by later faults that strike northeast.

The northernmost drift which ends in monzonite shows five distinct and separable zones of alteration of the gray dolomite within a distance of 50 feet. The minerals formed by this process of alteration are so well developed and uncommon that specimens were collected for detailed study. This has been done by Jewell J. Glass of the U. S. Geological Survey (p. 69). Along another contact zone in the mine the gray dolomite is altered to a dark rock that contains black mica (phlogopite) and spinel.

According to Dr. L. D. Godschall, 165 tons of copper

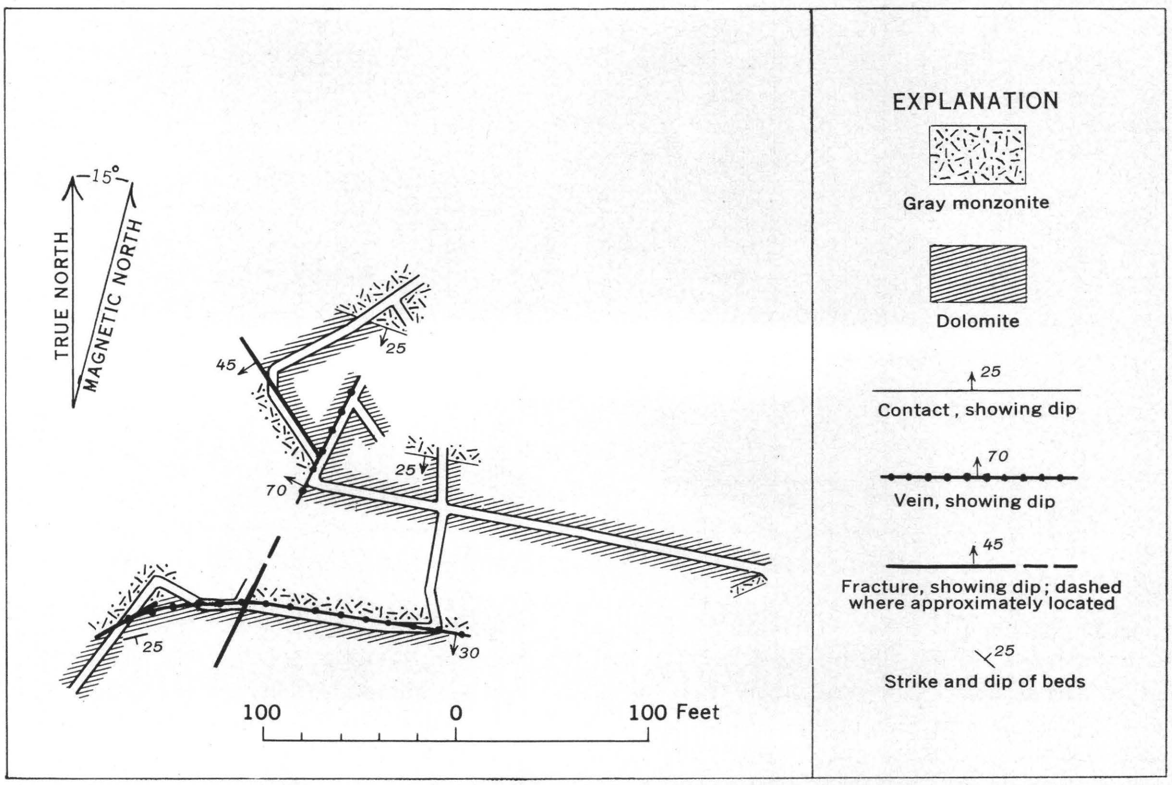

FIGURE 52.—Sketch map of tunnel, Dewey mine.

ore was mined from the south drift of this tunnel, 55 tons was added to Copper World ore and smelted, and the remaining 110 tons is on the dump at the smelter.

STANDARD NO. 1 MINE

The Standard mine (no. 81, pl. 2) lies on the north side of a small basin that drains the west slope of Ivanpah Mountain. The principal working, a vertical shaft reported to be 356 feet deep, is now dismantled and inaccessible below the 100-foot level. Apparently it contained more underground workings than any other in this part of the region. Like most of the others, it explores the zone of altered dolomite that overlies the quartz monzonite intrusion. In this area the contact is irregular, and most of the explorations lie along a fracture in the sedimentary rocks that trends northwest and dips steeply southwest. The monzonite that lies northeast of this fracture shows sporadic alteration to epidote along veinlets. The dolomite on the southwest side is altered to quartz-garnet rock for a distance of 10 feet, and beyond this it is bleached and recrystallized. In the altered zone, there are sporadic lenses of magnetite as much as 3 feet thick. Some greenish patches in the contact zone, identified in the field as serpentine, proved on careful examination to be a ferruginous diopside (hedenbergite) largely altered to a mixture of calcite and chlorite.

The only copper minerals noted were the carbonates, malachite and azurite, and the silicate, chrysocolla. The mine was discovered in 1904 and was operated continuously from 1906 to 1910. During this period, the output was about 4,000 tons of ore that contained 8 to 9 percent copper, 2 to 5 ounces of silver and 0.05 to 0.07 ounce of gold to the ton. It has been idle since 1918.

Recorded production of the Standard No. 1 mine, (no. 81, pl. 2)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1906	2, 713	135. 01	9, 354	454, 618	--------
1907	68	3. 19	151	11, 560	--------
1908	750	49. 58	7, 076	135, 000	--------
1909	362	19. 1	1, 612	66, 065	--------
1910	35	. 35	110	842	1, 545
1917	45	--------	650	14, 000	--------
1918	22	1. 98	344	5, 279	--------
1919	14	1. 11	56	2, 915	--------

COPPER PROSPECT

About a mile southeast of Kokoweef Peak a shaft (no. 83, pl. 2) about 100 feet deep has been sunk on a quartz lens in granite schist. The Clark Mountain fault lies about 200 feet south of the shaft. As malachite and azurite are the commonest metallic minerals, the deposit was probably exploited for its copper content. An olive vanadate is common. The total amount of workings is about 400 feet.

STANDARD NO. 2 MINE

The Standard No. 2 mine (no. 84, pl. 2) lies a mile south of the Standard mine and a mile northeast of the Copper King. The principal working is a shaft about 250 feet deep inclined westward at 78°. It explores the contact zone of the Goodsprings dolomite over the quartz monzonite intrusion. According to local report, about 4 cars of 22 percent copper ore were shipped about 1906. The mine has been active recently (1948).

About half a mile north of the Copper King mine, another shaft (no. 86, pl. 2) has been sunk about 300 feet at an inclination of 64° along the contact of the quartz monzonite and overlying dolomite of the Goodsprings dolomite. As at the Copper King mine, the zone of contact minerals is only about 10 feet thick and is overlain by a thicker zone of bleached dolomite. The monzonite near the contact is also much richer in biotite than the average of the region. The only copper mineral noted was chrysocolla.

COPPER KING MINE

The Copper King mine (no. 87, pl. 2) lies on the west slope of Ivanpah Mountain about 10 miles north of Cima. It includes an inclined shaft 100 feet deep with several hundred feet of drifts that explore the contact of the monzonite with the overlying dolomite of the Goodsprings dolomite. Along the nearby outcrop of the explored zone the dolomite is altered to a mixture of contact minerals of which epidote and magnetite are most conspicuous. The overlying dolomite is bleached and shows veinlets of serpentine. The underlying monzonite is much darker and finer grained within a few feet of the contact than farther away. This is due to a great increase in the percentage of biotite that makes up 5 to 10 percent of the rock. The other constituents in order of abundance are quartz, microcline, orthoclase, andesine, and zircon.

The mine has not been worked in recent years. A shipment of 8 tons in 1909 contained 13 percent copper and 15 ounces of silver and 0.1 ounce of gold per ton. The only copper minerals noted were malachite and chrysocolla.

NEW TRAIL MINE

The New Trail mine, also known as the Johnson or Anchor (no. 88, pl. 2) lies on the west side of a valley carved in the east side of Ivanpah Mountain, about 3 miles southeast of Kokoweef Peak. At the time of visit (September 1929), it was actively worked and there

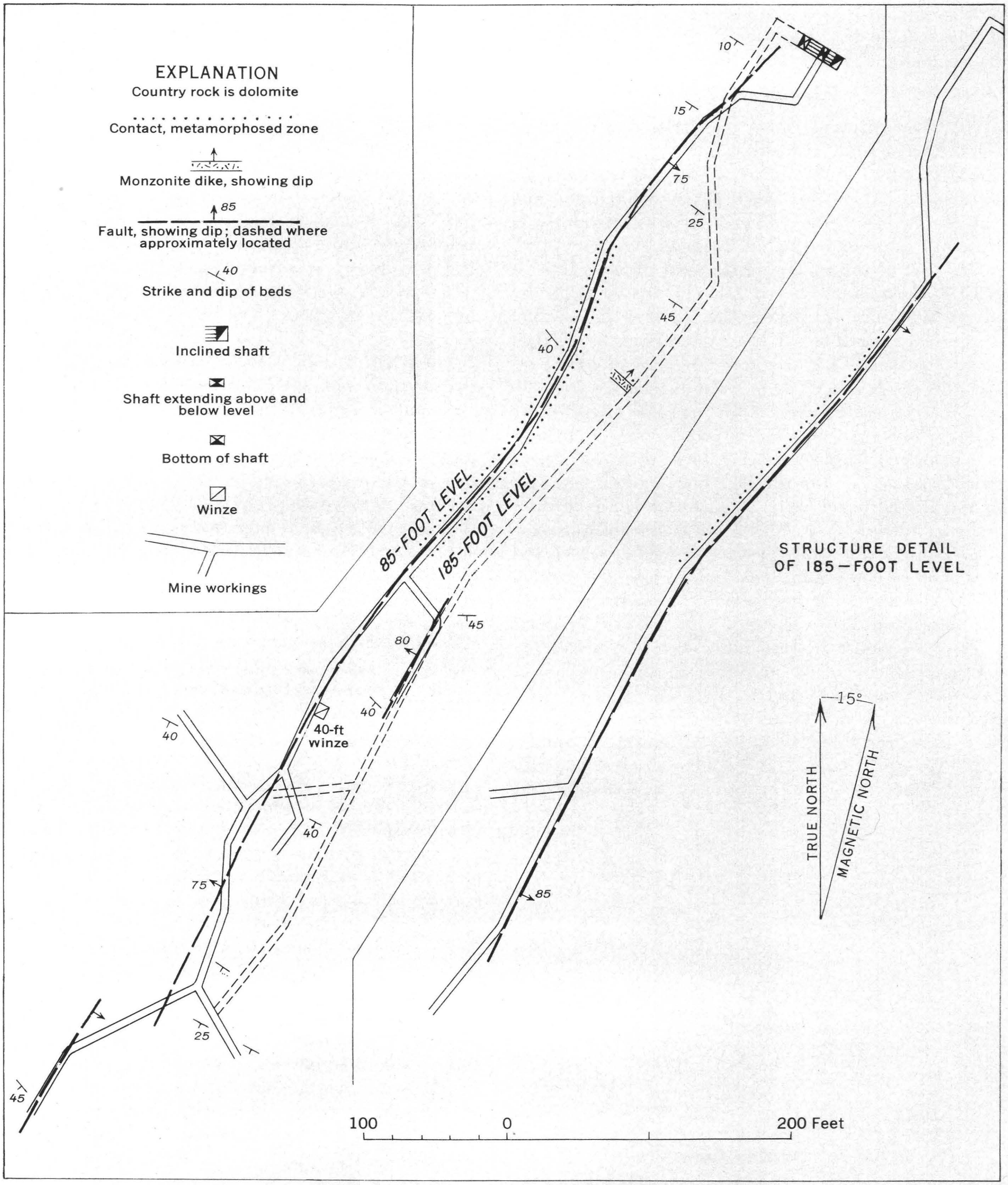

FIGURE 53.—Sketch map of workings, New Trail mine.

was a shaft 185 feet deep from which levels were turned off at 85 and 185 feet. The workings aggregated about 2,500 feet (fig. 53).

These workings explore a zone in the dolomite beds of the Goodsprings dolomite that lies about 500 feet stratigraphically below the contact with the overlying quartz monzonite. This part of the monzonite intrusion has the form of a sill about 7,000 feet thick (p. 62). The surface of contact trends northwest and dips about 35° SW. It cuts across the bedding of the Goodsprings dolomite, which strikes N. 40° W. to N. 70° W. and dips from 15° to 60° SW.

The unoxidized copper minerals that have been found, bornite and chalcopyrite, are largely parts of lenses that lie along a persistent fracture which is marked by a shear zone 2 to 10 inches wide. The fracture strikes N. 30° E. and dips steeply, in part northwest and in part southeast. Although the fracture trends almost normal to the monzonite contact above, it does not break or fault the contact. In addition to the copper minerals the shear zone contains blende and phlogopite, the magnesian mica. For most of the explored distance, the fracture cuts only gray dolomite, locally bleached white and in small part altered to pale-greenish serpentine. On both levels, however, the walls are pale-brownish garnet rock (largely grossularite and diopside) for a distance of 250 feet (fig. 53). Most of the garnet rock contains no copper minerals, but at one place on the 185 foot level a pocket of sulfides, 5 feet in diameter, lay above a crosscutting 4-foot dike of fine-grained monzonite. Apparently, the garnet rock replaces a definite bed of dolomite about 180 feet thick.

According to local report, about 2,000 tons of sorted ore from several nearby workings were shipped during 1917–18. Recently several carloads of ore containing about 14 percent copper and a little gold were shipped.

Recorded production of the New Trail (Johnson and Anchor) mine, (no. 88, pl. 2), Ivanpah (Cima) district

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Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1929	49	9.00	149	10,875
1930	64	10.00	200	15,495
1939	24	1.00	1,136	100
1945	272	47.00	806	22,800
1947	100	13.00	728	19,200
1949	98	27.00	429	17,800
1950	566	92.00	3,376	62,500

ALLURED MINE

The Allured mine (no. 90, pl. 2) includes several tunnels, shallow shafts, and pits in an area about 1,500 feet in diameter that lies 2 miles south of the Johnson mine. The principal exploration is a shaft about 150 feet deep that explores the altered dolomite beds of the Goodsprings dolomite below its contact with the quart monzonite intrusive. The actual contact is marked by a gossan of iron oxide, without magnetite so far as can be noted. As in the area near the Johnson mine, the contact trends northwest and dips 50° SW. Here, the nearby dolomite is altered to garnet, diopside, vesuvianite, and serpentine. Most of the workings are no longer accessible, but it appears that only small bodies of copper minerals were found. The dumps show only the common assortment of oxidized copper minerals.

SUNNYSIDE MINE

The Sunnyside mine (no. 91, pl. 2) lies half a mile west of the Morning Star mine. The workings include a shaft about 300 feet deep inclined westward at 35°, from which there are drifts at four levels. The shaft lies wholly within gneissic granite, which is undoubtedly a block in the intrusive monzonite. The upper part of the shaft follows a flat fracture, but with depth this is lost and a vertical fracture is explored. Along this fracture, the granite is thoroughly converted to greenish sericite which contains a little chalcopyrite.

About 900 feet southwest of the Sunnyside, a shaft is sunk in similar gneissic granite, but another shaft 700 feet west of it is wholly in the intrusive monzonite. It seems probable that the blocks of gneissic granite are pre-Cambrian rocks (see p. 65).

COPPER KING NO. 2 PROSPECT

The Copper King prospect (no. 101, pl. 2) is located in Slaughterhouse Gulch above the spring of that name, about 2 miles southeast of Ivanpah station on the Union Pacific Railroad. Even though no ore appears to have been shipped from this prospect, it reveals copper sulfides deposited in the shear zone that marks the Clark Mountain fault and proves that the fault was in existence before the Laramide mineralization took place. In this area the fault strikes N. 55° W. and dips 60° to 70° SW. It separates granite and diorite gneiss on the northeast wall from white crystalline limestone, which contains about 10 percent of wollastonite and diopside, on the southwest wall. The same relations of copper minerals to the Clark Mountain fault are found at the Trio mine, 2 miles southeast. The fault gouge contains pyrite and the common carbonates and silicates.

QUEEN MINE

The Queen mine (no. 107, pl. 2) lies at the head of the south fork of Keystone Canyon, 4 miles southwest of Barnwell. The workings include two tunnels driven generally southward 250 and 325 feet respectively to explore the contact of the Goodsprings dolomite with the quartz monzonite intrusive. Both tunnels start in quartz monzonite, and after passing through the contact strike a quartz-fluorite vein in the dolomite. The vein trends N. 45° E. and dips 35°–45° SE., and is therefore nearly parallel to the contact and only a few feet distant from it. The vein is made up largely of quartz and fluorite but it contains a little pyrite and chalcopyrite. In the upper tunnel it attains a width of 12 feet. The dolomite is not altered, but the adjacent monzonite is largely converted to a mixture of quartz and sericite and is cut by many small quartz veins. There is no record of production.

GIANT LEDGE MINE

The Giant Ledge mine (no. 108, pl. 2) lies at the head of a valley that drains southward from the south side of New York Mountains. It includes two tunnels, the lower extending 610 feet northwest to a caved area; another, 300 feet higher, includes 500 feet of drifts and crosscuts. The upper tunnel explores a quartz vein 10–15 feet wide that strikes N. 25° W. and dips steeply southwest. The lower tunnel cuts several quartz veins that strike N. 30°–50° W. and dip steeply southwest. The width of the veins ranges from 2 to 9 feet. Probably the widest vein in the lower tunnel is the same as that explored in the upper tunnel, but this has not been proven by underground work.

These veins are nearly pure quartz, but several contain small amounts of pyrite; traces of galena and fluorite were recognized in one vein. The enclosing rock is the intrusive quartz monzonite that underlies a large part of the New York Mountains. The quartz vein in the upper tunnel lies parallel to the contact of the monzonite and the Goodsprings dolomite, 600 feet east. Probably the veins were explored for their gold content, but the amount produced is not known.

Within an area 1,500 feet in diameter in the low hills that lie 2 miles west of benchmark 5118 near the southern edge of New York Mountains there are eight shafts and short tunnels (no. 110, pl. 2). The principal works is a shaft 250 feet deep with about 500 feet of drifts, which, to judge from the materials on the dump, explores the Cedar Canyon fault along which flows of Tertiary age on the south lie in contact with the Goodsprings dolomite and monzonite on the north. This shaft is dismantled but the dump yields blocks of nearly solid sulfides, largely pyrite with a little chalcopyrite, galena, and blende in a chloritic gangue.

Another shaft, 800 feet north, is about 200 feet deep. The dump shows quartz with sparse stains of copper and quartz schist. Nothing could be learned concerning the record of operations at these mines.

COPPER BELL PROSPECT

The Copper Bell prospect (no. 112, pl. 2) lies on the south side of a small park at the north end of Providence Mountains, 4 miles south of Elora. The explorations include a 30-foot inclined shaft and several pits in the monzonite of the area. The vein is a reef of massive white quartz 5 to 7 feet wide without comb structure or lamination and almost without druses. It contains sporadic grains of chalcopyrite and crystals of molybdenite.

FRANCIS MINE

The Francis mine (Tucker and Sampson, 1931) includes several shafts and tunnels that lie half a mile southwest of the Columbia mine (no. 114, pl. 2). Three shafts have been sunk along a vein within a distance of 600 feet to depths that range from 100 to 140 feet. A fourth shallower shaft lies 1,000 feet southwest. None is now accessible.

These shafts explore a quartz vein, 5 to 10 feet wide, that crops out conspicuously. The enclosing rock is biotite granite gneiss that contains many small irregular quartz veins. The vein is largely quartz with some fluorite, scheelite, and the sulfides blende, pyrite, and chalcopyrite. A small production—200 tons of crude ore that yielded 2,435 ounces of silver and 10,626 pounds of copper—is reported.

On the north slope of McCullough Mountain near the head of the ravine that drains north to McCullough Spring, a shaft (no. 120, pl. 2) has been sunk to a depth of 100 feet on a sheared basic dike in the granite gneiss that forms this range. The dike strikes north and dips 55° E. It has been much sheared and chloritized and contains sparse lenses of quartz. Near these there are stains of malachite that are probably derived from chalcopyrite, although none was seen.

CALIFORNIA MINE

The openings of the California mine (Crossman, 1890–91) are located on both sides of a small valley that lies 2 miles northeast of Vontrigger and 9 miles slightly west of north from Goffs (no. 134, pl. 2). The main opening is a shaft near the crest of the ridge on the east side of the valley. It is 317 feet deep, but water stands 160 feet below the surface. There are several hundred feet of work on the 100-foot level. The Medbury shaft lies on the west side of the valley and is inclined at 54° for the first 85 feet and then at 60° for 60 feet to the bottom.

The rocks exposed in the vicinity of these workings include several varieties of gneiss and their alteration products (see p. 20). The most common rock consists of fine grained orthoclase and quartz (alaskite), with variable amounts of biotite and almandite garnet, which is widely altered to chlorite. Although the rock is layered and some layers are rich in biotite, none of it is schist. Some layers contain only coarse-grained microline with a little quartz and garnet. The rock breaks along several systems of joints oblique to the layers that trend from north to N. 20° W. and dip from 55° to 80° W. No crosscutting dikes of pegmatite or aplite were noted. Reference to the geologic map indicates that the gneiss is underlain at shallow depth, perhaps 500 feet or less, by the quartz monzonite intrusive of the region.

The only sulfide minerals observed are chalcopyrite and pyrite. Oxidized copper minerals are abundant, especially malachite and azurite, with chalcanthite and brochantite as common efflorescences on the walls near water level. Most of the chalcopyrite is disseminated in the siliceous and feldspathic layers of the gneiss. Such material forms short lenses from 10 to 20 feet thick that lie almost parallel to the gneiss layers. In the Medbury shaft, one ore body is limited on the ends by crosscutting fractures. None of the lenses is limited laterally by defined walls.

During the latest period of operation by the Consolidated Gold and Copper Co., from 1926 to 1929, 3,917 tons of material was shipped to the Arizona copper smelters, much of it from the old dumps. The average yield was 4.7 percent copper, 0.075 ounce of gold and 0.75 ounce of silver per ton.

Recorded production of the California Gold and Copper Co., (no. 134, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Gold (ounces)	Silver (ounces)	Copper (pounds)
1907	29	2. 27	39	5, 353
1911	50			4, 000
1926	526	41. 01	348	45, 667
1927	1, 897	134. 90	1, 528	185, 991
1928	1, 004	61. 93	822	98, 027
1929	490	62. 21	352	40, 411
1940	61	3. 00	23	3, 600
1944	939	36. 00	488	52, 200
1945	224	12. 00	86	9, 200

LEAD DEPOSITS

With the exception of several in the Goodsprings district, the deposits in which lead is the most valuable metal are all tabular, veinlike bodies, but they occur in a variety of rocks. Of the 19 deposits listed in the acccompanying table, 14 occur in carbonate rocks that range from the Cambrian system (Noonday dolomite) to the Pennsylvanian system (Bird Spring formation). One (Sagamore, no. 109) occurs in the Tapeats sandstone, two (Hillside, no. 9, and Peyton, no. 124) in pre-Cambrian granite gneiss and granite. No vein with noteworthy lead minerals has been found in the Teutonia quartz monzonite.

The lead deposits of the Kingston Range (Chambers, no. 1 and others), even though in the Noonday dolomite, appear to be related to the Kingston Range monzonite porphyry. Two lead deposits (Blue Buzzard, no. 78, and Jackrabbit, no. 79) lie near the northern end of the wedge of monzonite, but those in the Goodsprings district are rather remote from large bodies of granite porphyry; small dikes and sills are nearby. Like the Copper World (no. 71) and Dewey (no. 72), the lead deposits at Keiper's mine (no. 69) and on Mohawk Hill may be related to the small dikes and sills of diorite.

Lead deposits

No.	Name	Country rock	Year examined
1	Chambers (Silver Rule)	Noonday dolomite	1926
4	Blackwater	do	1926
6	Sunrise	do	1926
9	Hillside (Evening Star)	Pre-Cambrian granite gneiss	1926
39	Kirby	Goodsprings dolomite	1924
	Shenandoah	Monte Cristo limestone	1922
54	Christmas	Yellowpine limestone member	1922
53	Ingomar	do	1924
	Hoosier	Bird Spring formation	1922
65	Birney's	Goodsprings dolomite	1926
69	Keiper's	do	
73	Mohawk	do	1926
74	Mohawk	do	1926
78	Blue Buzzard	Sultan limestone	1926
79	Jackrabbit	Goodsprings dolomite	1926
105	Trio	do	1926
106	Live Oak	do	1926
109	Sagamore	Tapeats sandstone	1927
124	Peyton	Monzonite	1927

CHAMBERS MINE

The Chambers (Silver Rule) mine (no. 1, pl. 2) is located on the north slope of a prominent ridge, which lies about 3 miles northwest of Beck Spring in the Kingston Range. Two tunnels, whose aggregate length is about 1,000 feet, are connected by an inclined winze 200 feet long. The mine was actively worked on a small scale almost continuously from 1900 to 1919. Records indicate that it has yielded about 600 tons of ore that contained from 19 to 52 percent lead, a little copper and zinc, a trace of gold, and from 4 to 21 ounces of silver per ton.

All the workings lie in the Noonday dolomite, which here trends due west and dips 45° N. From what may now be seen in the upper tunnel, it would appear that the ore body lay along a breccia zone that strikes N. 75° W. or nearly parallel to the bedding and dips 70° N., or somewhat more steeply than the bedding. Some dip faults were noted but they appear to have small displacement and to be postmineral. The principal minerals are fine-grained galena, anglesite, pyromorphite, auricalcite, and calamine. Material in a cross fracture that appeared to be white clay has been determined to be a variety of sepiolite (parasepiolite, a hydrous silicate of magnesia). The indices of refraction average about 1.505 and the birefringence is about 0.010; it gelatinizes in hydrochloric acid. Myriads of minute crystals of calcite are dispersed through the sepiolite to the extent of about 20 percent by weight. The origin is obscure but the material probably represents a hydrothermal alteration of dolomite.

BLACKWATER MINE

On the northeast side of a prominent hill one mile northeast of Horse Spring, a tunnel (the Blackwater water mine, no. 4, pl. 2) has been driven 720 feet generally southwest to explore small bodies of lead ore in the upper part of the Noonday dolomite. Most of the tunnel is in the overlying quartzite and no valuable minerals were observed. It is reported locally that several cars of lead ore were shipped from prospect pits 200 feet higher on the hill.

SUNRISE MINE

About 4 miles northeast of Horse Spring, a tunnel, the Sunrise (Blue Dick) mine (no. 6, pl. 2) has been driven southwest about 450 feet to explore the upper part of the Noonday dolomite. According to the owner, C. A. Beck, no ore was struck in the tunnle, but the 86 tons of lead ore was mined from shallow workings that lie above the tunnel. The beds of dolomite strike N. 45° W. and dip 40° NE.

HILLSIDE MINE

A small mine, the Hillside (Evening Star) mine (no. 9, pl. 2), that lies on the north edge of a lone hill west of Shadow Mountains reveals such an interesting structural situation that it is worthy of record. A tunnel that extends S. 10° W. for about 140 feet first passes through 40 feet of loosely consolidated sandy shale and gravel, which strikes N. 75° E. and dips 80° S, then meets a fault parallel to this bedding. Beyond the fault, the tunnel continues for 100 feet in granite gneiss, which contains the explored quartz vein. Probably the fault is in the nature of a tear fault and the gneiss has been pushed eastward so as to ride over the shale and gravels, since a similar block of gneiss rests on these beds 2,000 feet east. (See fig. 3.)

The vein strikes N. 20°–30° W. and dips 30° NE. The width ranges from 4 to 8 inches in the northwest portion from 1 to 2 feet in the southeast portion. The only sulfide observed in the vein is galena. Presumably this mine is the Hillside from which 10 tons were shipped in 1925. Total explorations are about 350 feet.

Ten tons of crude ore was shipped from the Hillside mine in 1925, yielding 7.80 ounces of gold, 241 ounces of silver, and 6,618 pounds of lead.

KIRBY MINE

The geologic features and maps of the Kirby mine (no. 39, pl. 2) were presented in the report on the Goodsprings district. After many years of idleness, it was reopened in 1945 and yielded a small production. It has not been examined since 1927.

Recorded production of the Kirby mine since 1930 (no. 39, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1945	175	1	264	200	22, 100	1, 100
1945	53	--------	68	200	5, 000	--------

SHENANDOAH MINE

The geologic features of the Shenandoah mine (not shown on pl 2) were presented in the report on the Goodsprings district. From 1934 to 1936, the mine was actively exploited for the content of lead molybdate, wulfenite, which is more abundant than in any other mine in the district. The mine has not been examined since 1927.

Recorded production of the Shenandoah mine since 1930

Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1930	22	0. 22	177	85	21, 476	--------
1931	18	. 17	170	--------	18, 407	--------
1934	4, 787	--------	315	--------	137, 955	28, 635
1935	5, 000	2. 90	932	368	125, 311	--------
1936	190	. 48	42	--------	6, 250	--------
1940	26	--------	193	--------	16, 300	--------

HOOSIER MINE

The geologic features of the Hoosier mine (not shown on pl. 2) as they were revealed by the workings in 1927 were described in the report on the Goodsprings district.

BIRNEY'S PROSPECT

The area of Goodsprings dolomite which lies south of the Old Ivanpah district contains several prospects that reveal galena and copper stains in shear zones. Some show streaks of fluorite as much as 2–3 inches thick and mixtures of fluorite and minutely fibrous sericite. More work has been done at the Birney prospect (no. 65, pl. 2) than at any other; none have yet yielded shipments. The minerals are similar to those of the Calarivada mine.

KEIPERS MINE

According to Tucker and Sampson (1931), Keipers mine (no. 69, pl. 2) lies about 7 miles northeast of Valley Wells on the west slope of Clark Mountain.

The area includes a small body of dark-gray monzonite that resembles the dikes in the Copper World and Dewey mines. The monzonite intrudes dolomite beds of the Goodsprings dolomite. Quartz veins containing galena, sphalerite, and chalcopyrite have been explored in the monzonite and the zone of altered dolomite. The longest tunnel is about 285 feet.

Recorded production of the Keipers mine (No. 69, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1926	29	--------	86	--------	14, 796	--------
1927	13	1. 09	88	74	9, 242	--------

MOHAWK MINE

There are several mines on Mohawk Hill, but most of the exploration has been done in two that are locally known as the Mohawk mine (nos. 73–74, pl. 2). In 1927 the principal exploration lay on the north side of the ridge (fig. 54) but about 500 feet of work were done on the south side of the ridge 1,500 feet southeast. The workings on the north side included a shaft inclined southwest at 32° for the first 80 feet and at 21° for the next 80 feet. There are stopes on levels extending outward from both sides of the shaft.

The enclosing rocks are the dark-gray dolomites of the Goodsprings dolomite but they are bleached nearly white near the ore body, much as they are in the Copper World and Dewey mines, 2 miles northwest. On the surface the beds trend northwest and dip southwest at 20°–30°, but underground they trend N. 70° W. in the eastern part of the mine and N. 25° W. in the western part, so that they form a local warp that plunges southwest. The ore body lies in a breccia zone that closely follows the bedding. The lower stopes abut against a persistent fault that carries from 6 to 12 inches of limonite. It seems probable that this fault was the source of the solutions which deposited the ore in the bedded breccia zone. Other fractures in the lower workings also contain limonite, but they appear to be postmineral.

The ore minerals noted on the dump and underground include plumbojarosite, jarosite, beaverite, cerussite, a copper arsenate, malachite, and chert. Traces of galena were found on the dump.

On the south side of Mohawk Hill, a tunnel (no. 79) has been driven generally northeast in beds of the Goodsprings dolomite which trend northeast and dip southeast. The workings explore the upper surface of a sill of quartz monzonite which resembles that found near the Copper World mine. The dolomite beds are bleached near the contact with the sill. There are also quartz veins, one (1 to 6 feet wide) nearly follows the

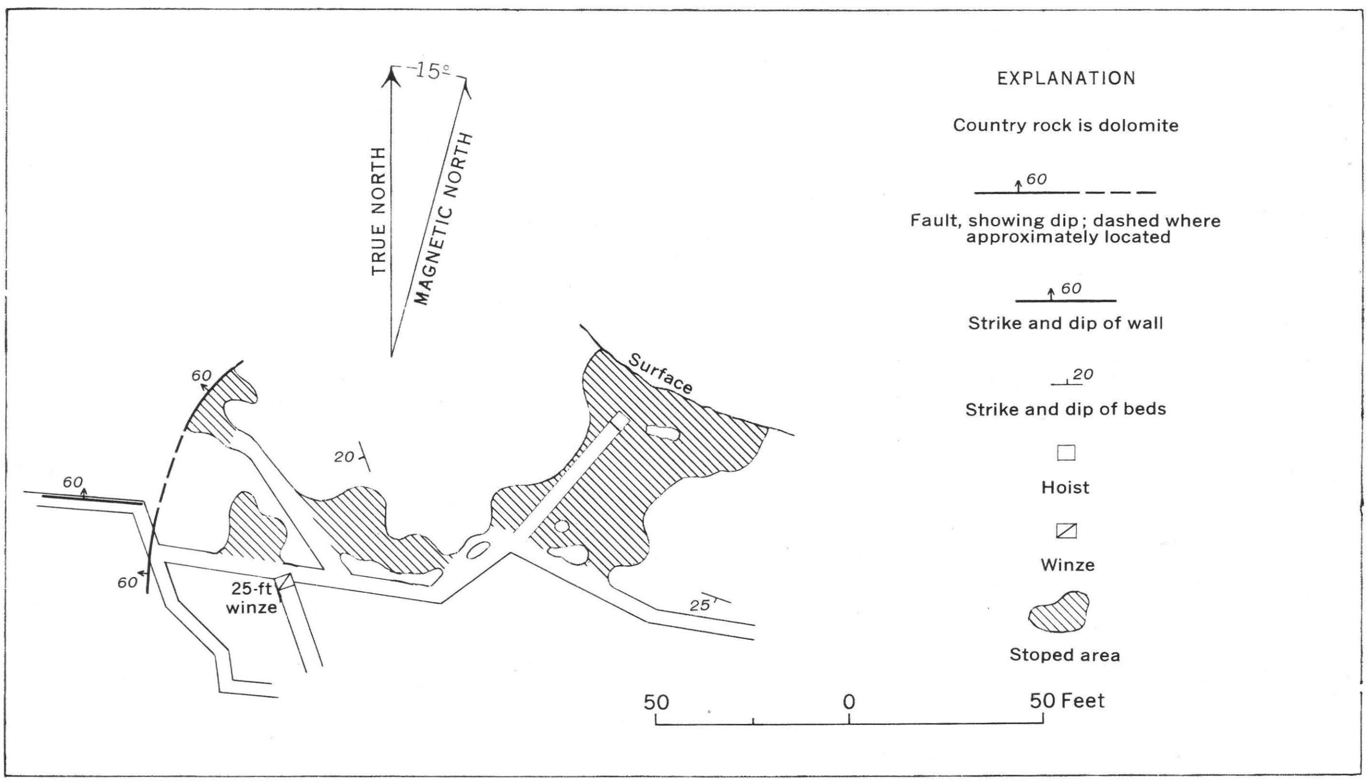

FIGURE 54.—Sketch map of north workings, Mohawk mine.

contact with the sill. No ore is exposed in place, but the product of the mine appears to have been an oxidized lead ore possibly containing a little copper.

On the north side of Mohawk Hill, 1,500 feet east of the workings on the north side, rhodochrosite was seen in a narrow quartz vein which fills a fault that displaces a small monzonite dike. This is one of two recorded occurrences of this mineral in Ivanpah quadrangle; the other is at the Sagamore mine (110).

Recorded production of the Mowhawk mine, (no. 73, 74, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1916	33	----------	----------	----------	----------	----------
1917	----------	----------	----------	----------	----------	----------
1918	270	4	----------	19,856	243,205	----------
1944	1,781	23	9,003	20,000	244,600	202,500
1945	5,473	42	27,199	57,800	705,500	550,600
1946	4,581	38	23,217	40,600	793,600	329,600
1947	822	10	7,366	12,600	229,400	12,100
1948	1,951	19	14,170	27,500	489,900	----------
1949	856	67	4,993	12,800	189,800	----------
1950	130	1	533	1,000	20,700	----------
1951	920	5	5,295	9,800	159,700	----------
1952	209	1	1,026	1,500	48,700	----------

BLUE BUZZARD MINE

The Blue Buzzard mine (no. 78, pl. 2) is located on the east end of the high ridge known as Mescal Range, nearly 1,000 feet above the nearby valley. The mine is an inclined shaft 60 feet deep, from the bottom of which a drift extends 55 feet northwest. Raises from this drift and from the shaft explore the ore shoot.

The thin-bedded limestone of the Sultan limestone and dolomite of the Goodsprings dolomite which underlie the east end of Mescal Range trend generally N. 10°–30° W. and dip 35° SW. Near the mine, these beds trend N. 35° W. and dip 60° SW., but half a mile south near the Jackrabbit mine, they again trend N. 30° W. The zone explored by the mine lies about 150 feet above the wedge of monzonite which is the northern extension of the enormous body that underlies many square miles in the south half of the quadrangle. A pale-greenish dike, much like those intrusive into the dolomite near the Mohawk and Copper World mines, lies in the hanging wall of the deposit. It is locally altered to serpentine.

Recorded production of the Blue Buzzard mine (no. 78, pl. 2)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1925	47	0.47	112	261	26,154
1940	23	----------	45	100	11,800
1947	29	----------	47	200	10,000
1948	44	----------	100	300	16,300

The mine explores two lenses of lead and iron minerals 6–15 inches wide separated by 3–5 feet of bleached dolomite in the midst of the normal dark-gray dolomite near the base of the Sultan limestone. Apparently plumbojarosite and iron oxides were the most abundant minerals.

JACKRABBIT MINE

The Jackrabbit or Iron Horse mine (no. 79, pl. 2) lies half a mile southeast of the Blue Buzzard mine on the southeast slope of Mescal Range, where it merges with the local plain. In 1927 the workings included a shaft about 187 feet deep at an average slope of 45° SW. There are short drifts at the bottom of the shaft and both northwest and southeast from a point 30 feet above the bottom.

The deposit is a series of lenses of siliceous lead-bearing limonite that replaces two beds of dolomite of the Goodsprings dolomite which here trends N. 30° W. and dips 35° SW. In the shaft, the lenses of ore from 2 to 3 feet thick are separated by 4 feet of light-colored dolomite. The same relations were observed in the Blue Buzzard mine. In addition to siliceous lead carbonate, plumbojarosite, and limonite, the lenses also contain some white quartz which is uncommon in such deposits. The southeast drift shows a badly decomposed dike rock. On the bottom level, the vein zone abuts against a slip that trends N. 30° W. and dips 80° NE.

TRIO MINE

The principal working of the Trio mine (no. 105, pl. 2) is a vertical shaft on the southeast slope of an isolated hill that is about 1½ miles southwest of Barnwell. The shaft marks the position of a mine opened about 1892 and known as the Copper Bullion, from which some copper ore was shipped soon after the railroad from Goffs was completed. According to local report, the shaft was once 600 feet deep, but it is now caved and inaccessible. Water must have been encountered as the pipe still remains in the shaft. Other shallow shafts and pits are located on the north and slopes of the hill.

The mine workings are wholly in highly altered carbonate rocks, which appear to be the lower beds of the Goodsprings dolomite that here form the northeast limb of a local anticline. On the northeast border of the hill, several hundred feet from the vertical shaft, the carbonate rocks are in contact with dark gneissic rocks (Proterozoic); this contact marks the position of the Clark Mountain fault. On the west and south border of the hill the carbonate rocks, with nearly vertical dip, rest upon quartz monzonite that crops out widely farther southwest. The local relations of the rocks indicate that the monzonite was intruded on a flat fault but that it was limited northeastward by the Clark Mountain fault; therefore it is younger than that fault.

Even though the workings could not be examined, it seems clear that lead and copper sulfides were confined to the zone of altered carbonate rocks that rest upon the monzonite intrusive. The dumps show blocks made up of brown garnet (grossularite), diopside, epidote, and wollastonite, the fractures of which are coated with malachite and chrysocolla.

The following table shows the production recorded in 1916–17:

Recorded production of the Trio mine (No. 105, pl. 2)

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Year	Crude ore (tons)	Recoverable metals			
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1916	210	38	50	37, 801	72, 710
1917	32	--------	74	4, 000	--------

LIVE OAK MINE

The Live Oak mine (no. 106, pl. 2) lies half a mile north of the Queen mine in the north fork of Keystone Canyon on the east slope of New York Mountains. A tunnel about 350 feet long extends generally northwest, and near the inner end explores a vein of fluorite which, like that in the Queen mine, lies in the Goodsprings dolomite and is parallel to and only 20–30 feet distant from the contact with the quartz monzonite intrusive. The vein, about 8 feet wide, trends northwest and dips northeast. The vein of fluorite contains a little sericite, pyrite, and chalcopyrite. The nearby dolomite is bleached and locally recrystallized but is not appreciably altered otherwise.

The only record of production is one ton that contained 10 percent lead and 24 ounces of silver.

SAGAMORE MINE

The Sagamore (New York) Mine (no. 109, pl. 2) lies near the head of one of the valleys that drains the eastern slope of New York Mountains, 4 miles southwest of Barnwell. It was one of the first mines found in this part of the region and was one of the factors that led to the construction of the railroad from Goffs to Barnwell (Calif. State Min. Bur., 1908, p. 327–328). The principal periods of activity extended from 1905 to 1910, from 1913 to 1917, and from 1942 to 1945. Most of the work has been done on one (no. 3) of four known veins. In 1927 it included two tunnels, aggregating about 1,200 feet, and a shaft (fig. 55). The mine is connected by tramway with a mill 2,500 feet east.

Recorded production of the Sagamore (New York) mine (no. 109, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1907	40	--------	600	2, 400	8, 000	--------
1908	368	--------	1, 629	10, 803	28, 810	--------
1913	90	217. 7	36	--------	--------	--------
1917	197	12. 0	5, 184	22, 000	109, 349	--------
1942	114	1. 0	682	3. 200	12, 200	--------
1943	68	2. 0	117	4, 700	22, 000	3, 000
1944	139	2. 0	1, 741	7, 800	39, 600	16. 000
1945	27	--------	108	600	2, 000	--------
1951	55	--------	730	3, 000	14, 700	3, 500

The mine explores a quartz vein that crops out conspicuously for 2,000 feet in quartzite of the Tapeats sandstone. The vein is inconspicuous in the overlying shales (Bright Angel shale) and dolomite (Goodsprings dolomite). Near the mine, the quartzite strikes N. 30° W. and dips 25° SW., but eastward the strike becomes due east. The average course of the vein is N. 70° E. and the dip 65°–80° NW. It therefore lies normal to the trend of the monzonite contact, which crops out 2,500 feet southwest of the mine. The vein is cut off by a dike of dacite porphyry that contains phenocrysts of orthoclase. The dike trends S. 85° W. and is 75 or so feet wide. As the vein seems to be offset, it is probably older than the dike.

The vein is largely white quartz that contains lenses and bunches of mixed sulfides to the extent of about 5 percent by weight. These include abundant sphalerite, chalcopyrite, and galena with subordinate pyrite. Wolframite and rhodochrosite are reported. The quartz is generally finely crushed and recemented by silica and sulfides. All of these minerals, with the possible exception of pyrite, were deposited in the quartz breccia, partly replacing it. The vein locally attains 15 feet in width, but for most of the lower tunnel, the range is from 1 to 3 feet.

PEYTON MINE

The Peyton mine (no. 124, pl. 2) lies on the northwestern border of Piute Valley, 2 miles northeast of Crescent Peak and half a mile south of the road between Nipton, Calif., and Searchlight, Nev. The principal exploration is a 100-foot inclined shaft with levels at 25, 50, and 100 feet. The enclosing rock is dark-greenish granite gneiss. The vein, which strikes north and dips 45° W., underlies a dike of fine-grained monzonite porphyry. It includes lenses of quartz with minor amounts of galena and chalcopyrite and attains a maximum width of 1 foot. The mine once was equipped with a mill and has probably been the source of a small production.

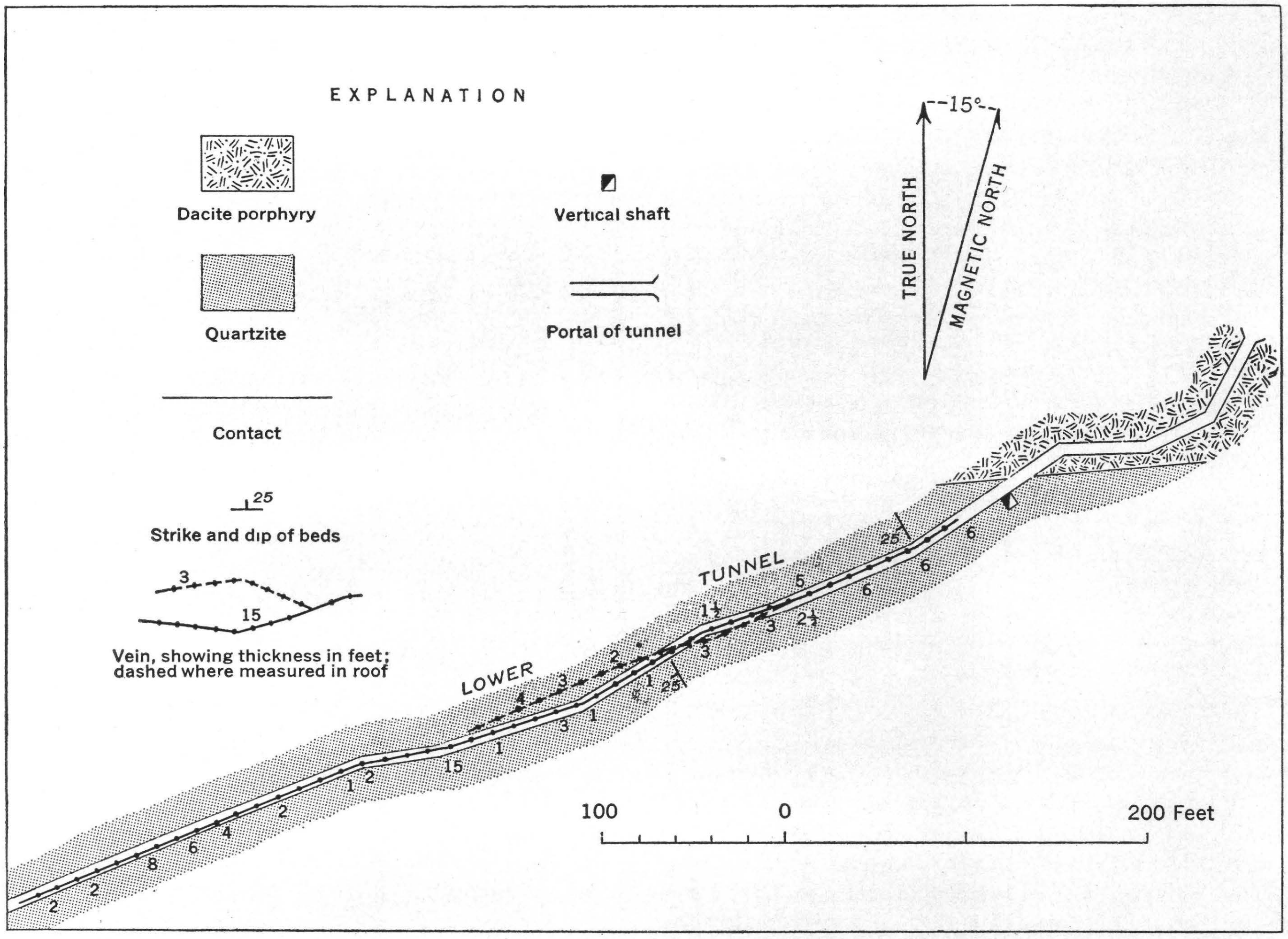

FIGURE 55.—Sketch map of tunnel, Sagamore mine.

ZINC DEPOSITS

Even though deposits explored primarily for zinc minerals are the most abundant in the Goodsprings district, they are conspicuously lacking in the southern half of the quadrangle, south of Kokoweef Peak. Of the 20 deposits listed in the accompanying table, only 3 small deposits lie south of Devil Peak. All are confined to carbonate rocks of Paleozoic age of which some were originally dolomite (Goodsprings dolomite); others were originally limestone and were altered to dolomite prior to deposition of zinc sulfides. Of the 20 deposits, 15 are in breccias in the upper units of Paleozoic age, Anchor limestone member, Bullion dolomite member, Yellowpine limestone member and Bird Spring formation; only 1 lies as low as the Goodsprings dolomite.

Even though a little sphalerite is present in veins in the gneissic granites and intrusive monzonite, it is nowhere abundant. It is most conspicuous in two deposits on the northwest slope of the Mid Hills (Silver Fox, no. 113; Columbia, no. 115), where the only other sulfide is pyrite.

Compared with deposits rich in gold, copper, and even lead, the zinc deposits are more remote from large bodies of intrusive monzonite, although the most productive deposit (Yellow Pine, no. 32) lies below a large sill. The next largest deposit (Potosi, no. 27) is at

Zinc deposits

No.	Name	Country rock	Year examined
26	Green Monster	Bullion dolomite member	1926
27	Potosi	Yellowpine limestone member	1922
30	Contact	Bullion dolomite member	1922
32	Yellow Pine	Yellowpine limestone member	1924
33	Alice	Bird Spring formation	1922
38	Mobile	Anchor limestone member	1922
40	Bill Nye	Bird Spring formation	1922
42	Argentena	Yellowpine limestone member	1926
43	Mountain Top	Bird Spring formation	1924
45	Monte Cristo	Anchor limestone member	1924
46	Bullion	Bullion dolomite member	1922
47	Anchor	Anchor limestone member	1922
48	Hoodoo	Monte Cristo limestone	1922
49	Root	Monte Cristo limestone	1922
50	Singer-Tiffin	Bullion dolomite member	1922
51	Sultan	Fault breccia	1922
52	Milford	Bullion dolomite member	1924
56	Carbonate King	Bird Spring formation	1924
68	Clark Mountain	do	1926
80	Carbonate King	Yellowpine limestone member	1944
82	Piute	Goodsprings dolomite	1926

least 7 miles from the nearest outcropping body of granite porphyry.

As sphalerite is readily susceptible to oxidation, the most abundant zinc mineral in the most fully explored deposits is hydrozincite; smithsonite and calamine are much less abundant.

GREEN MONSTER MINE

The Green Monster mine (no. 26, pl. 2) lies at the southwest end of a prominent ridge on the north border of Mesquite Valley. Like the Potosi mine about 8 miles northeast, it is several miles distant from the nearest mine or prospect. It was located about 1891 and about 1900 was sold to George Hearst and associates of San Francisco, who did most of the development work and shipped all the ore before 1920. The small production from 1942–44 was made by Roy Jacobson of Goodsprings, Nev.

The upper part of the Monte Cristo limestone is well exposed in the vicinity of the mine. The beds strike about N. 60° W. and dip 50°–55° SW. The ore zone explored by the mine is the upper 20 feet of the Bullion dolomite member, which is about 300 feet thick. The Arrowhead limestone member, which crops out and is exposed at many places in the mine, is from 7 to 8 feet thick. The Yellowpine limestone member is about 75 feet thick but in this area it is not visibly altered to dolomite. It is overlain by 25 feet of sandstone that marks the base of the Bird Spring formation. Several hundred feet south of the mine the higher thin limestone beds of that formation are much crumpled.

The mine workings (fig. 56) include two inclined shallow shafts that follow the ore and a vertical shaft about 250 feet deep that intersects the ore zone at 165 feet. Recent work followed the ore shoot to a depth of 400 feet below the outcrop. The ore is

Recorded production of the Green Monster mine (no. 26, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1915	969					589, 050
1916	1, 158		5, 152		72, 256	684, 250
1917	537		1, 570		21, 500	297, 500
1918	865		647		89, 397	423, 693
1919	99				15, 260	60, 061
1920	56	0. 23	256	416	23, 615	16, 092

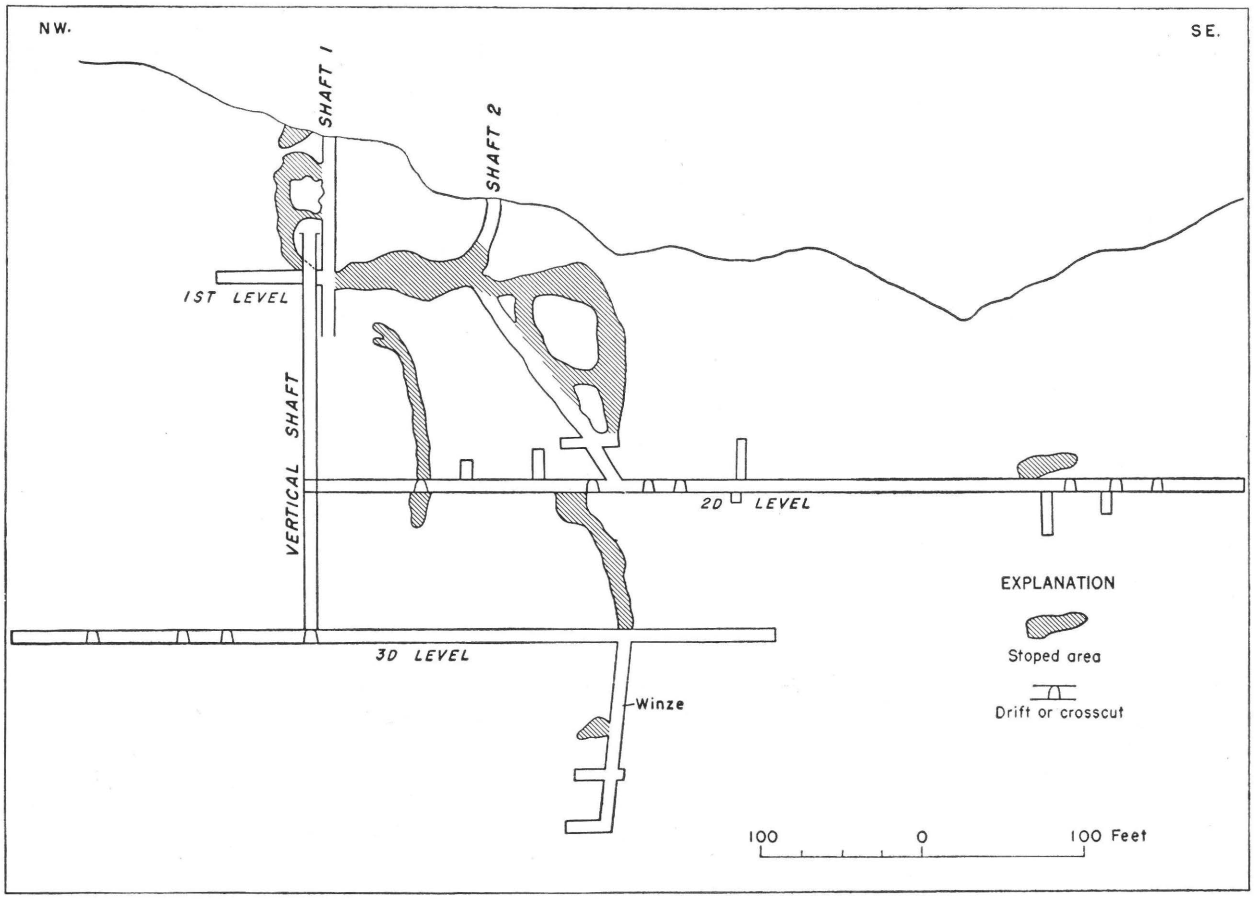

FIGURE 56.—Longitudinal section through workings of Green Monster mine.

largely hydrozincite with smaller amounts of the common lead minerals. These formed a fairly well defined shoot that pitched steeply southwest in the breccia of the Bullion dolomite member. About 1942, the uranium-bearing mineral rutherfordine was discovered in material on the dump but the quantity was not large (Albritton, Richards, Brokaw, and Reinemund, in press).

POTOSI MINE

The Potosi mine (no. 27, pl. 2) lies high on the west slope of a ridge a mile and one half west of Potosi Mountain, 11 miles northwest (airline) from Goodsprings. Commonly, it is reached from Arden on the Union Pacific Railroad, from which it is 21 miles southwest, It was the first mine in the district as some lead ore was mined and shipped to Las Vegas to be smelted in 1856. It was operated almost continuously from 1905, when the Union Pacific Railroad was completed, until 1927 but has closed most of the years since then. Most of the shipments were made by the Empire Zinc Co., but the mine is now owned by the International Smelting Co.

The ore bodies largely occurred in the Yellowpine limestone member but some ore was mined from the beds as much as 50 feet below it. Recent work (Albritton, Richards, Brokaw, and Reinemund, in press) indicates that there is a pronounced unconformity at the base of the overlying Bird Spring formation. The ore bodies lie near the trough of a minor syncline, but their local distribution is determined by many complicated faults. One conspicuous fault that forms the roof over all of the ore bodies has been variously interpreted as a normal and as a thrust fault; another conspicuous fault is a simple northward-trending normal fault. No postmineral faults have been recognized. The Potosi mine contains more sulfide of zinc than any other in the district and it is widely dispersed throughout the mine; sulfide of lead is more widespread but the quantity is less. On the other hand, in the ore shipped hydrozincite was the principal mineral; calamine and smithsonite were uncommon. During the period when most ore was mined, the oxidized zinc ore was calcined; the loss in weight was 20 to 25 percent and some zinc was volatilized. During its history, the mine produced 20 times as much zinc as lead. There is no record of production since 1927.

YELLOW PINE MINE

The Yellow Pine mine (no. 32, pl. 2), with the highest record of production among the mines of the quadrangle, lies 4 miles west of Goodsprings. For many years, a narrow gage railway connected the mine with Goodsprings and Jean but recently that has been replaced by a well-graded road, paved from Goodsprings to Jean. Several of the claims were located as early as 1892, and the Yellow Pine Mining Co. was organized in 1901. The mine produced every year from 1906 to 1930. After a period of idleness, 1931 to 1936, it has been operated almost every year to 1949. Since 1942, it has been owned by the Coronado Copper and Zinc Co. For more than 2 years during the recent war, June 1943 to September 1945, a party of geologists of the U. S. Geological Survey under C. C. Albritton made a detailed examination of this and nearby mines and a report is in process of publication (Albritton, Richards, Brokaw, and Reinemund, in press). During 1942 and 1943, the U. S. Bureau of Mines drilled about 5,000 feet of holes in search of ore.

The stratified rocks explored by the mine workings include the Bullion dolomite member, Arrowhead limestone member and Yellowpine limestone member of the Monte Cristo limestone, and the basal sandstone of the Bird Spring formation. The limestone beds are about 400 feet thick; of this, the Arrowhead limestone member is about 10 feet thick and the Yellowpine limestone member, which contains most of the ore bodies, 70 to 110 feet thick. The bed of sandstone is largely from 23 to 28 feet thick; in the adjacent Prairie Flower mine, it is represented by a bed of gravel and cobblestones, relatively uncemented.

In the southern part of the mine workings, these limestones strike N. 15°–25° E. and dip about 35° W., but in the northern part they strike N. 55°–65° E. and dip as much as 60° NW. This block of ground is the west limb of a much-faulted anticline.

In addition to the stratified rocks, a persistent sill of granite porphyry several hundred feet thick, lies over the basal sandstone of the Bird Spring formation. Also, in the northern part of the mine, there is a dike of similar rock, about 80 feet thick, that cuts across the limestones.

Most of the ore bodies and all of the larger ones are tabular but they are elongate parallel to the general strike of the enclosing limestones. Commonly the stoping thickness is 10 to 20 feet but several stopes were 30 to 40 feet thick. The ore bodies extended from 50 to as much as 300 feet down the dip and they were found for more than 2,000 feet along the strike. The most abundant mineral in most of the ore bodies was hydrozincite, but calamine, smithsonite and galena were widespread and cerussite and anglesite were abundant. Small amounts of other carbonates, sulfates, and silicates of zinc, lead, and copper were found widely. Throughout the mine, the wall rocks—Bullion dolomite member, Arrowhead limestone member and Yellowpine limestone member—were almost completely altered to dolomite. From what could be learned in recent years, it seems probable that the original sulfides of zinc, lead, and copper were deposited in dolomite breccia and that the host rocks were changed from limestone to dolomite before they were broken up. It seems clear also that these breccia zones were tabular but that they were not parallel to the bedding of the enclosing Yellowpine limestone member.

The present distribution of the oxidized ore bodies is much more complex than might be guessed from the preceding description of their content, form, and relations. Within the explored belt, about 4,000 feet long, there are at least 25 conspicuous faults that cross the belt and most of these interrupt the continuity of the ore bodies. The strike of these faults is largely from due west to northwest and they dip steeply either southwest or northeast.

There has been a wide divergence of opinion among observers as to whether these faults were formed before the sulfide minerals were deposited (premineral) or after the sulfide minerals (postmineral). Most observers agree that there has been some recent movement on the faults. The presence of unbroken crystals of galena in several of the faults indicates that some of the crosscutting faults are premineral and some observers think that most, if not all, faults are premineral and represent the channels along which zinc- and lead-bearing solutions rose to and spread out in the breccia zones in the Yellowpine limestone member. If this interpretation is correct, undiscovered ore bodies should be sought where crosscutting faults intersect the Yellowpine limestone member.

Other geologists, thinking that these faults are postmineral, conclude that the many ore shoots are parts of a long pipe and that new ore shoots should be sought along its extension northward. The problem is not simple because, under weathering of zinc sulfide, zinc migrates some tens of feet and in places it is hard to determine whether a given body of oxidized zinc minerals represents zinc sulfide weathered in place or whether the zinc has migrated into breccia formed after the deposition of the sulfide.

The ratio of zinc to lead has varied from one body to another. The product shipped has included some crude ore, some sorted to high-grade zinc or lead content, as well as some concentrate and the tailing from milling. The annual production since 1930 is given below.

Recorded production of the Yellow Pine mine since 1930 (no. 32, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1930	989	15	471	572	228,000	
	3,476				655,298	
					1,584,350	
1937	1,294				244,500	606,000
	943	15	5,914	143,600	203,400	
1938	1,445				345,900	653,200
1939	209	3	1,946	21,600	114,000	
	722				109,000	395,800
1940	1,381				125,700	718,100
1941	936				35,900	609,400
1942	202				19,700	91,600
1944	158		53		7,000	84,400
1945	1,227	8	3,125	3,100	241,600	481,700
1946	616	4	1,050	1,500	48,500	226,300

Recorded Production of the Yellow Pine mine (Rover Group) (no. 32, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1931	1,900				273,990	1,038,779
1932	283				55,536	151,431
1933	137	0.81	517		57,927	23,346

ARGENTENA MINE

The Argentena mine workings (no. 42, pl. 2) are located on the top of a flat-topped ridge, 3 miles southwest of Goodsprings. The mill lies at the foot of the east slope of the ridge. Most of the exploratory work is on the Galena claim located in 1887, but little work was done until the Argentena Mining Co. was organized in 1927.

The rocks that crop out near the mine include the lower 150 feet of the Bird Spring formation, the Yellowpine limestone member and Arrowhead limestone member of the Monte Cristo limestone. The Yellowpine limestone member is completely altered to dolomite in this area, but the limestones of the Bird Spring formation are only sporadically altered. The Fredrickson fault, which is a bedding-plane thrust west of the Fredrickson mine, becomes, southeast of that mine, a steep fault marked by several persistent large lenses of breccia along which the west side seems to have moved north with respect to the south side.

In the early study of the Argentena mine (1926), it appeared that zinc-lead ore bodies occurred in both the lower part of the Bird Spring formation and Yellowpine limestone member and that the Fredrickson fault and nearby fractures determined the localization of the ore (Hewett, 1931, p. 148–149). Recent work (1944) by Albritton and others (Albritton, Richards, Brokaw, and Reinemund) indicates that all the ore lies in the Yellowpine limestone member and that there are a few persistent faults and many minor fractures, all interpreted as a linked system of one epoch of deformation.

Most of the ore produced from 1926 to 1944 was derived from tabular, nearly horizontal breccia zones that lay nearly parallel with the bedding of the Yellowpine limestone member and 30 to 50 feet below the top. The principal ore shoot was such a body mined from the southern tunnel but another was mined from the northern tunnel, several hundred feet distant.

Only oxidized zinc minerals, calamine and hydrozincite, were found but galena and its oxidation products are widespread, both in the tabular breccias as well as the steep faults.

Recorded production of the Argentena mine (no. 42, pl. 2)

Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1930	1, 204				134, 848	520, 128
1931	615				88, 459	336, 238
1944	607	5	3, 767	1, 300	51, 200	158, 400
1945	1, 807	17	9, 445	2, 800	122, 400	488, 100
1946	989	10	3, 663	1, 400	52, 000	303, 200

MOUNTAIN TOP MINE

The Mountain Top, Lookout, and Annex claims cover the top and east slope of a flat-topped spur from Table Mountain and lie about 3 miles southwest of Goodsprings. They are accessible from the road over Columbia Pass, southward to the Argentena which lies a mile northwest. The Mountain Top (no. 43, pl. 2) claim was located prior to 1893 but the principal period of activity extended from 1912 to 1926 (Hewett, 1931, p. 149–150). Recent production is given below.

The workings of the three claims include many tunnels and trenches which extend along the contour of the spur for several thousand feet. The four principal tunnels explore tabular bodies of oxidized lead and zinc minerals that largely lie nearly parallel with the bedding of the enclosing Yellowpine limestone member which is nearly horizontal here. The ore bodies on the spur occur in a narrow block of the dolomite that is bounded on the east by the southward extension of the Fredrickson fault and on the west by another nearly parallel fault along which the west side has dropped. Both of these faults are premineral and some of the ore bodies lie along steep parallel fractures. The larger ore bodies are nearly horizontal and seem to be localized along flat breccia zones.

Recorded production of the Mountain Top mine since 1930 (no. 43, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Silver (ounces)	Lead (pounds)	Zinc (pounds)
1945	143	105	17, 000	43, 600
1946	45	30	5, 400	12, 000

MONTE CRISTO MINE

The Monte Cristo (Combination) mine (no. 45, pl. 2) lies about 4 miles due south of Goodsprings; it is one of the group of mines that occur on the spurs west of Porter Wash as far south as the Anchor mine. The Monte Cristo claim was located in 1907 and was operated almost continuously from 1908 to 1919, shipping only oxidized zinc minerals. After nearly 20 years of idleness it has been worked in a small way in recent years, shipping ore that contained more lead than zinc.

The mine explores several ore bodies in the partially dolomitized Anchor limestone member which here strikes north and dips 15°–25° W. The principal ore body is tabular but the shape in plan is irregular; it strikes roughly parallel to the enclosing limestone but the dip is flatter. There are minor crosscutting fractures. The principal zinc mineral was hydrozincite, but reports of the operators indicate that there was more smithsonite and calamine than in any other mine in the district; sphalerite was not found. Recently, work on a higher bed in the Anchor limestone member has shown the presence of considerable galena.

BULLION MINE

The Bullion mine (no. 46, pl. 2), about 5 miles due south of Goodsprings, is one of several mines that lie on the spurs extending eastward toward Porter Wash from the southern extension of Table Mountain. The first claims of the Bullion group was located about 1900 and the period of largest production extended from 1913 to 1927. There has been modest activity and production by lessees from 1931 to 1938.

On the ridges west of Porter Wash, the upper 500 feet of the Monte Cristo limestone and lower 500 feet of the Bird Spring formation strike slightly west of north and dip gently west but they are broken by many faults, some of which strike north and dip west and are premineral whereas others, more numerous, strike north and dip east and appear to be largely postmineral or show postmineral movement. The Bullion mine lies 500 feet east of a prominent premineral fault and 200 feet west of a large postmineral fault.

The mine workings reveal much dolomite breccia and fractures in the upper part of the Anchor limestone member and lower part of the Bullion dolomite member but the stopes are limited upward by a wall whose form is essentially a cone of elliptical cross section. The movement on this wall is small but the direction could not be determined. The wall is crossed by fractures that trend largely northwest; some are premineral but others are postmineral.

The stopes indicate that most of the ore occurred in tabular masses of breccia that lay under the elliptical wall. The distribution of ore bodies and their relation to circular hanging wall resemble those of the Potosi mine (p. 150).

Recorded production of the Bullion mine since 1930 (no. 46, pl. 2)

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Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1931	176	----------	----------	----------	25, 315	96, 224
1932	36	----------	----------	----------	----------	29, 684
1935	40	----------	229	----------	----------	15, 380
1937	51	1	433	100	35, 900	----------
1938	86	4	325	100	32, 000	----------

ANCHOR MINE

The Anchor mine (no. 47, pl. 2) lies about 6 miles due south of Goodsprings. It is the farthest south of the group of mines on the ridges west of Porter Wash. The Anchor claim was located in 1897 but the first shipment was made in 1908. It was operated by the Goodsprings Anchor Co. from 1912 until 1919, intermittently by lessees until 1932 and was almost continuously idle thereafter. The extent of the workings in 1949 was much as shown in plate 40 of the Goodsprings report (Hewett, 1931).

The workings include a shaft, 202 feet deep inclined at 38°; a winze, 212 feet deeper from the third level; and four levels. Most of the shipments were mined from the main or Anchor ore body, and the stopes indicate a tabular shoot about 100 feet wide and 400 feet long with stoping thicknesses 10 to 15 feet, but locally 20 feet. A smaller shoot or ore body, lay about 200 feet south. These tabular bodies lay in a central zone of the Anchor limestone member which here has an average strike of N. 25° W. and a dip that decreases from 35° SW. in the upper levels to 20° in the lower levels. The mine lies between a prominent fault that trends northwest, dips 60° SW., and is interpreted as premineral and another prominent fault that trends northwest, dips 50° NE., and is interpreted as postmineral. The workings reveal many fractures with small displacements whose place in the local history of deformation is obscure. The tabular Anchor ore shoot has a dip close to that of the bedding of the Anchor limestone member but its axis pitches about 60° S. In the upper part of the mine, a smaller shoot lies in the hanging wall of the Anchor shoot (Albritton, Richards, Brockaw, and Reinemunde).

During the period of mining at the Anchor mine much more lead has been produced than zinc, and among the larger mines of the district this is uncommon. Some parts of the Anchor ore body, that in the hanging wall, contained lead minerals with very little zinc. Galena is very common; the oxidized minerals of lead less common. Hydrozincite is the common zinc mineral; the sulfide is rare.

Recorded production of the Anchor mine since 1930 (no. 47, pl. 2)

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Year	Crude ore (tons)	Recoverable metals		
		Silver (ounces)	Lead (pounds)	Zinc (pounds)
1930	588	----------	108, 784	278, 837
1931	681	----------	97, 952	372, 320
1932	311	----------	39, 259	73, 680
1944	42	117	6, 800	8, 500

ROOT MINE

Tht Root group of five claims (no. 49, pl. 2) cover the crest and north slope of Bonanza Hill, an isolated ridge that lies south of Bonanza Wash, about 8 miles southwest of Goodsprings. The first location was made in 1893. The principal workings on the hill form three distinct groups, about 2,000 feet southwest, 2,000 feet south, and 1,000 feet southeast of Root Camp at the north end of Bonanza Hill. Most workings and the source of most of the production is in or near a 700-foot tunnel that extends from the south to the north side of the hill; it is among the first group of workings.

Beds that form the lowest 200 feet of the Bird Spring formation cap Bonanza Hill but most of the ore bodies yet found are in the upper part of the underlying Yellowpine limestone member. Viewed broadly, the beds of both formations strike northeast and dip at low angles southeast rarely higher than 15°. Recent detailed work (Albritton, Richards, Brokaw, and Reinemund, in press) indicates a low anticline that trends east. The hill is broken by many faults and minor fractures, but the displacements appear to be small. The two most prominent faults lie along the northwest slope of the hill; they strike northeast, dip steeply northwest and appear to be normal.

The explored ore bodies are tabular and most seem to follow flat breccia zones in the Yellowpine limestone member. Some bodies of oxidized zinc minerals follow steep fracture zones. Most of the bodies yield nearly pure zinc ore; one small area, about 150 by 500 feet, yielded lead ore.

The mine has a small record of production of zinc ore between 1911 and 1918, but new discoveries in the western group of workings since 1938 have yielded much more ore. Recent production is shown below.

Recorded production of the Root mine since 1938 (no. 49, pl. IV)

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Year	Crude ore (tons)	Recoverable metal				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1938	21	--------	278	--------	19, 400	--------
1939	367	--------	--------	--------	38, 800	206, 600
1942	89	--------	770	--------	48, 200	--------
1943	115	--------	--------	--------	15, 700	60, 000
1944	119	--------	426	--------	8. 600	53, 600
1945	251	1	2, 388	300	40, 100	130, 200
1946	773	6	1, 763	21, 800	59, 900	211, 100

SULTAN MINE

The Sultan mine (no. 51, pl. 2) is one of the group of mines that lie along a northwest spur from the Spring Mountains which culminate in Little Devil Peak, in the southwestern part of the Goodsprings district; it is about 6 miles southwest of Goodsprings. The Sultan claim was located in 1896.

Several isolated but distinct ore bodies have been explored in the Sultan mine and all occur in a lens of dolomite breccia that marks the location of a thrust fault. This thrust fault has been traced from Singer Wash on the north to a tear fault 4 miles south. The lens of breccia which is made up of small and large blocks of dolomitized limestone largely from the Bird Spring formation which forms the footwall. The hanging wall of the breccia is the Sultan limestone. Within the lens of breccia, locally 800 feet thick there are at least three persistent faults which strike northwest and dip northeast. The bodies of oxidized zinc and lead minerals with some galena have irregular shapes but each is underlain by one of the northwest-trending faults which seem to have determined the positions of the ore bodies. The largest and most persistent ore body is roughly pipelike and has been explored nearly 300 feet below the outcrop. The workings disclosed many other minor fractures in the breccia but their part in localizing ore is not clear.

The first epoch of exploitation began in 1910 and extended almost without interruption until 1926; the second extended from 1941 to 1946 and it yielded more output than the first. Production from 1937–46 appears below.

Recorded production of the Sultan mine since 1930 (no. 51, pl. 2)

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Year	Crude ore (tons)	Recoverable metal				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1937	1, 000	--------	4, 042	--------	109, 000	--------
1941	414	1	2, 163	100	58, 900	--------
1942	169	--------	--------	--------	20, 000	68, 500
1944	1, 042	7	9, 884	1, 200	193, 000	314, 000
1945	2, 190	2	4, 888	500	158, 300	63, 100
	1, 194	7	10, 784	2, 000	217, 200	369, 200
1946	4, 980	11	19, 392	3, 200	371, 700	527, 000

CARBONATE KING MINE

The Carbonate King (DeWitts) mine (no. 56, pl. 2) lies on the south slope of one of the ridges that separate Mesquite Valley from Ivanpah Valley. By road, it is 10 miles west of Roach. The discovery was probably made before 1880 when there was much mining in the nearby Ivanpah district. There have been several periods of exploration. A mill was built in 1926 and operated for a short period. Three tunnels with an aggregate of 1,200 feet of work constitute the principal workings. The outcrop zone was mined by trenches for 300 feet and is reported to have yielded about 400 tons of good-grade lead ore.

The zone of rocks in which the ore deposit occurs lies several hundred feet below the top of the Bird Spring formation. It therefore lies higher in the stratigraphic section than any other ore deposit in the region. The region is one of structural complexity (see pl. 2). The beds of the Bird Spring formation that are normally limestone at this horizon have been thoroughly dolomitized. They strike N. 45° W. and dip 35°–45° SW. The ore is largely found along a fracture that strikes N. 10° E. and dips 80°–85° E. Both the fracture and the beds are cut off several hundred feet north of the ridge by a fault that trends N. 75° E. The principal ore mineral noted is galena, but in places there is considerable pyrite and blende. In addition, the common products of oxidation of these minerals are present—anglesite, hard granular cerussite, calamine, hydrozincite, limonite, and jarositic chert. Although these minerals are largely confined to the breccia zone that crosses the bedding, locally they extend outward along the bedding as much as 20 feet.

Recorded production of the Carbonate King Mine (pl. 2, no. 56)

Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1917	71	--------	--------	--------	28, 407	--------
1918	20	--------	--------	--------	11, 654	2, 824
1927	600	0. 09	8, 412	1, 409	--------	--------
1928	28	--------	14	--------	22, 221	--------

CLARK MOUNTAIN MINE

At an elevation of 7,200 feet, high on the east slope of Clark Mountain, an inclined shaft (no. 68, pl. 2) has been sunk on an ore shoot that lies in a bedded breccia zone near the base of the Bullion dolomite member of the Monte Cristo limestone. The shaft is 120 feet deep at an inclination of 50° SW. There is 150 feet of drifts and raises on a level about 90 feet below the surface.

These workings explore some bodies of zinc ore, largely the mineral hydrozincite, that lie in the breccia zone. The localization of these bodies seems to be related to several crosscutting fractures that trend N. 35°–50° E. and dip steeply southeast. The striae on the fractures indicate nearly horizontal movement and lead to the inference that they are minor transverse faults of the compressive epoch.

The history of the mine is not available. Doubtless, it produced several hundred tons of zinc ore.

CARBONATE KING MINE[2]

The Carbonate King mine (no. 80, pl. 2) lies on the southwest slope of a conspicuous conical hill, Kokoweef Peak, that rises about 1,000 feet above the Ivanpah upland; it lies about 5 miles south of Wheaton Spring station on U. S. Highway 91. The Clark Mountain fault limits Kokoweef Peak on the northeast. North of the fault lies a large area of pre-Cambrian crystalline rocks, mostly gneiss; the peak is underlain by rocks of of Paleozoic age that range from the Goodsprings dolomite on the northeast to Bird Spring formation. These rocks largely strike northwest and dip steeply southwest. The zinc ore body explored in the mine appears to lie in a tabular body of crushed Yellowpine limestone member that roughly parallels the strike of the beds and dips more steeply. At the outcrop only a few stringers of zinc minerals can be seen. The main ore body was found at a depth of 60 feet, extending along the strike about 120 feet. Calamine is the most abundant zinc mineral, but in the lower levels smithsonite predominates, and locally it is altered to hydrozincite. A little sphalerite and galena have been found.

Recorded production of the Carbonate King mine (no. 80, pl. 2) (Clark Mountain district)

Year	Crude ore (tons)	Recoverable metals				
		Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1941	547	----------	----------	----------	800	404, 000
1942	749	----------	----------	----------	12, 100	458, 000
1943	3, 013	----------	----------	----------	----------	2, 169, 200
1944	Idle					
1945	Idle					
1946	2, 416	16	24, 117	----------	16, 600	1. 150, 400
1947	2, 350	----------	34, 160	----------	13, 500	1, 288, 813
1948	108	----------	23	----------	36, 900	----------
1950	52	----------	18	----------	15, 000	6, 600
1951	325	1	133	----------	79, 700	57, 200

[2] From a press release prepared by Arthur Richards and A. L. Brokaw, 1944.

When the surficial shoot had been explored to a depth of 150 feet, and yielded about 4,300 tons of ore, a flat fault abruptly cut off the ore. Study proved that this fault was postmineral and that exploration below the fault might reveal an extension of the ore shoot. As the result of study by Richards and Brokaw and drilling by the U. S. Bureau of Mines, the extension was found and 4,750 tons of zinc ore has since been mined.

PIUTE MINE

The Piute mine (no. 82, pl. 2) lies about a mile south of Kokoweef Peak on a low spur that extends west from Ivanpah Mountain. The principal working is a vertical shaft 200 feet deep, now dismantled, and some surface trenches. The underground workings were not examined. The principal period of activity extended from 1915 to 1917, when about 1,245 tons of ore, which contained about 15 percent lead, with some zinc and copper, were shipped. A small shipment was made by lessees in 1919. A portion of the shipments for 1915 probably was derived from another mine.

The mine lies in the dolomite of the Goodsprings dolomite which here trends N. 50°–80° E. and dips 40° SE. From what is known of the attitude of the lower contact of the quartz monzonite intrusive with Cambrian limestones further east, it seems clear that the dolomite at the mine will abut against the monzonite a few hundred feet southwest of the shaft.

The principal minerals on the dump are galena, plumbojarosite, and siliceous limonite, but the common zinc and copper minerals must have been present in the ore shipped.

MOLYBDENUM DEPOSITS

The single vein explored for its molybdenite content (Big Hunch, 97) is in Teutonia quartz monzonite. It seems to lie at the same general position with reference to the roof as the nearby tungsten veins.

BIG HUNCH MINE

The Big Hunch mine (no. 97, pl. 2) lies near the crest of the New York Mountains, north of Pinto Valley. In 1927, the workings included a tunnel 120 feet long which connects with an inclined shaft about 75 feet below the collar. The shaft is sunk along a quartz vein from 10 to 15 feet wide, which strikes N. 80° W. and dips 52° NE.; it is probably 150 feet deep but is filled with water to the level of the tunnel.

The vein crops out as a reef of quartz from 10 to 20 feet above the surrounding quartz monzonite. It contains a few percent of sulfide minerals which are distinctly confined to zones of shear and brecciation.

Pyrite is the most abundant sulfide, chalcopyrite next, and molybdenite is lowest. The products of oxidation, malachite, cuprite, and molybdite, were also noted; probably the fact that the ore contained molybdenum was the stimulus to exploration.

There is no record that ore has been produced from the mine.

TUNGSTEN DEPOSITS

Tungsten minerals have been found in many places in the quadrangle and in sufficient quantity at several places to justify extensive mining operations. Only two tungsten minerals were observed, wolframite, the tungstate of iron, and scheelite, the tungstate of calcium. Hubnerite, tungstate of manganese, has been reported from several mines (Sagamore), but it was not observed during this investigation. The first is restricted to a simple type of quartz vein; several veins have been found in each of three districts: Signal district, about 8 miles north of Goffs and 6 miles east of Vontrigger Spring; Clark Mountain district, about 2 miles due north of the summit of Clark Mountain; New York Mountains or Cliff Canyon district, about 2 miles southeast of Brant on the Union Pacific Railroad. Tungsten minerals have also been found at the Sagamore mine (no. 109) which has been considered in this paper as a lead mine, and at the Francis mine (no. 114) considered here as a copper mine. The accessory minerals in these veins are several sulfides; pyrite is the most common.

The veins of two of the districts, Signal and New York Mountains, are in the Teutonia quartz monzonite. At the first, the present outcrops of the veins are probably within 1,000 feet vertically below the restored roof (pre-Cambrian gneiss); at the second, the outcrops probably are from 2,000 to 3,000 feet below the restored cover of sedimentary rocks of early Paleozoic age. In the Clark Mountain district, the veins lie in pre-Cambrian granite gneiss, and the outcrops are too remote from outcrops of the monzonite to permit inference about their relations. The positions of the tungsten-bearing veins in the monzonite and their relations to known bodies of monzonite are broadly similar to those of many copper veins.

Scheelite, in contrast to wolframite, is found largely in the zone of contact of the carbonate rocks with intrusive monzonite. In 1929, the only known occurrence of scheelite in the contact silicates of lime and magnesia was on the Cottonwood Claim (no. 96), 4 miles southeast of Joshua (Hanlon). Here it was found in masses of garnet, epidote, hornblende, quartz, and magnetite, on the border of large bodies of limestone included in monzonite (p. 65). In recent years some scheelite concentrate has been produced from similar material at a small mine near Copper King (no. 87). The contact rock from several copper deposits (New Trail, no. 88 and others) was examined under ultraviolet light for scheelite, but none was found.

MOJAVE MINE

The Mojave (Green's) mine (no. 66, pl. 2) is located in an open valley that lies in the foothills on the north slope of Clark Mountain about one mile south of the Colosseum gold mine. The early history is obscure, but is was probably discovered about 1907. Most of the existing explorations were made between 1915 and 1918 by the Mojave Tungsten Co.; no work has been done since. An older shaft, reported locally to have been 350 feet deep with 1,200 feet of drifts, is caved and dismantled. A new shaft 100 feet east of the older is reported to be 250 feet below the surface. The shaft was equipped with a windmill and pump to raise water for a cattle trough.

The shafts explore a quartz vein in chloritized biotite granite gneiss (pre-Cambrian rocks) locally intruded by reddish granite. The vein strikes about due east and dips about 85° S. The Clark Mountain fault lies about 1,000 feet west of both the tungsten shafts and the Colosseum mine. It is reported that the vein was about 4 feet wide, largely quartz with calcite, wolframite, and scheelite.

Hess (1917, pls. 5*A*, 7*A*, and *B*, 13*A*) presents colored plates of polished specimens of high-grade tungsten minerals from this vein. According to Tucker and Sampson (1931) ore mined during 1916, 1917, and 1918, and milled at a local concentrating plant, yielded about 64,000 pounds of concentrate that contained 50 to 60 percent tungstic oxide.

COTTONWOOD CLAIMS

In an area several thousand feet in diameter which lies 4 miles southeast of Joshua (Hanlon), there are a number of rather angular blocks of limestone embedded in the quartz monzonite of the area (p. 65). Most are less than 300 feet long and 100 feet wide, but one is 1,200 feet long. The border zones of these blocks are sporadically altered over a width of a few feet to garnet (calcium-iron variety), epidote, and a few other similar minerals, of which humite, chlorite, and magnetite were definitely proven. At one place this material contained sufficient copper to encourage prospectors to sink a shaft (no. 96, pl. 2) about 100 feet deep, now inaccessible. It is locally reported that some of the bodies of contact silicates contained traces of tungsten in the form of scheelite, but none was found.

Some veinlike bodies of epidote are found in the intrusive monzonite, but most of the silicate minerals have been developed in the limestone. The order of genesis of some of the minerals is fairly well shown. The epidote is uniformly later than the garnet in which it forms veins. The sulfide minerals, pyrite, chalcopyrite, and blende, as well as magnetite and quartz, are found in the epidote veins.

CLIFF CANYON PROSPECTS

Cliff Canyon drains the north slope of New York Mountains; the mouth lies 2 miles southeast of Brant. Veins in the quartz monzonite have been explored by several tunnels and a shaft (nos. 99, 100, pl. 2). The longest tunnel (Carbonate, no. 100, 300 feet) lies on the west side of the canyon half a mile above its mouth. It explores several quartz veins, the widest of which attains 10 inches in width. The veins contain the usual assemblage of minerals; pyrite is most abundant with blende, tetrahedrite, and galena present in decreasing proportions. Another tunnel (no. 99) on the east side, near the mouth of the canyon, explores a similar vein for a distance of 230 feet. Some of these veins are reported to contain wolframite (Cloudman, Huguenin, and Merrill, 1917) but none was observed.

LORD AND IRISH MINE

Within an area of several square miles just north of the Leiser Ray mine, a number of shafts have been sunk on veins in search of tungsten minerals. Most of the shafts range in depth from 60 to 100 feet. In 1927 water in them stood at depths of 25 to 85 feet below the surface. More work has been done at the Lord and Irish mine (no. 138, pl. 2) than any other. Other veins lie 800 feet northwest (no. 137), 1,800 feet southeast (no. 139), and 5,000 feet southwest (no. 140).

The veins largely strike N. 30°–40° W. and dip 50°–70° NE. The width rarely exceeds a few inches. They lie in an intrusive typical of the Teutonia quartz monzonite.

TIN DEPOSITS

The only deposit in this quadrangle that contains noteworthy amounts of cassiterite, Evening Star (no. 85), occurs in Goodsprings dolomite within 1,000 feet above the Teutonia quartz monzonite body which undoubtedly underlies it. The associated minerals indicate that the cassiterite deposit is related to the copper deposits at the Copper World (no. 71) and Dewey (no. 72) 10 miles to the north, and the Standard No. 1 (no. 81) and Copper King (no. 87).

EVENING STAR MINE [3]

Explorations during August 1940 led to the discovery of a deposit (no. 85, pl. 2) containing cassiterite at the west end of a spur from a low ridge about 10 miles north of Cima and about 2½ miles east of the road from Valley Wells to Cima. During the next 3 years it was explored by two shafts and an opencut, and a mill to treat ore was built on Highway 91 near Valley Wells. The western of the two shafts is 100 feet deep to a level that extends eastward about 75 feet. An opencut extends eastward from this shaft about 75 feet nearly to the other shaft.

These workings explore a poorly defined tabular body of oxide, sulfide, and silicate minerals in dolomite above its contact with the Teutonia quartz monzonite, 600 feet east. The dolomite probably is the higher part of the Goodsprings dolomite; the strike is N. 10°–20° E. and the dip is 25° W. The tin-bearing tabular body trends east and dips steeply south. The body is serpentine and calcite, in the center of which there are discontinuous masses of cassiterite and magnetite with minor sulfides in the midst of the silicates, tremolite, serpentine, forsterite, and epidote. All of these minerals occur sporadically in a zone that is from 1 to 2 feet thick.

Nearby, mostly several hundred feet south, there are fragments and poor outcrops of pale-green fine-grained dike rock that closely resembles the quartz monzonite found at the Copper World, Dewey, and Mohawk mines to the north. Similar cassiterite-bearing rock was found in a shaft 500 feet northwest of the Evening Star shafts. This deposit and one near Gorman, Calif., are interesting because they are probably the only known occurrences in the United States of cassiterite in the contact aureole in dolomite near an intrusive rock.

In 1942, 25 tons of material was mined from the opencut and the western shaft and shipped to the tin smelter at Texas City, Tex., where it was found to contain about 6.4 percent tin.

ANTIMONY DEPOSITS

Stibnite, the sulfide of antimony, was noted at only two mines in the quadrangle. At the Wade antimony mine (no. 70, pl. 2) the mineral was found in quantities that encouraged mining. At the Mescal mine (no. 77) 6 miles south the mineral is abundant in the ore which was mined for its silver content. At both deposits the gangue is fine-grained silica (chert and quartz); barite is present in the Wade deposit. Both deposits lie within the zone of Laramide thrust faults.

WADE MINE

The Wade mine (no. 70, pl. 2) is located on the east slope of some rugged hills that lie north of Wheaton Wash, and east of Clark Mountain. The local rock is a schistose granite; the schistosity trends N. 30° W. and dips steeply northeast. Nearby westward, massive granite gneiss crops out.

Three veins have been explored in an area of 1 acre. The main vein, explored by a shaft 95 feet deep and by

[3] Abstracted from a report by J. H. Wiese, U. S. Geol. Survey, October 1944.

200 feet of drifts, strikes N. 25°–35° E. and dips steeply west. It therefore cuts across the local schistosity. In the workings the vein width largely ranges from 5 to 10 inches, but in places attains 20 inches. The vein has been largely stoped from the 50-foot level to the surface for a distance of 80 feet south of the shaft. Although it is narrow along the level, the vein widens again in the deepest work.

The most abundant mineral in that vein is stibnite, which forms compact masses of coarse tabular crystals. Quartz and white chert occur near the walls, and barite, in part well crystallized in druses, forms the central part. Although shipments have been made, records are not available. A pile of ore on the dump estimated at 15 tons is reported to contain 45 percent antimony. In contrast with that at the Mescal mine, this stibnite ore contains very little silver. A little oxide of antimony, probably stibiconite, occurs near the surface, but the sulfide persists in the outcrop.

Molybdenum, tungsten, antimony, and tin deposits

No.	Name	Country rock	Year examined
		Molybdenum	
97	Big Hunch	Teutonia quartz monzonite	1927
		Tungsten	
	Clark Mountain:		
66	Mojave	Pre-Cambrian granite gneiss	1926
	New York Mountain:		
96	Cottonwood	Dolomite-monzonite	1927
98	Prospect	Teutonia quartz monzonite	1927
99	Prospect	do	1927
100	Carbonate	do	1927
	Southeast:		
135	Prospect	do	1927
136	Prospect	do	1927
137	Prospect	do	1927
138	Lord and Irish	do	1927
139	Prospect	do	1927
140	The Duke	do	1927
		Tin	
85	Evening Star	Goodsprings dolomite	1942
		Antimony	
70	Wade	Granite schist	1926

IRON DEPOSITS

Explorations have revealed deposits of iron oxides in three widely separated areas in this region. One of the deposits has been thoroughly explored by drilling and promises to be an important source at some future time. Deposits are known in the northern part of the Kingston Range (nos. 2 and 3, pl. 2), on the northwest slope of Old Dad Mountain (no. 22), and in some low hills 3 miles northwest of Kelso (no. 25). The first three deposits contain the same minerals and seem to have similar geological associations; the fourth deposit is unlike the others.

BECK DEPOSITS

The Beck deposits (Hewett, 1948) lie along the south slope of a prominent westward-trending ridge in the northern part of Kingston Range (no. 2, pl. 2). Beck Spring, a perennial source of good water, lies several hundred feet southeast of the largest deposit. The deposits have been known for many years and in 1924 were thoroughly explored by drilling; no work has been done there since.

The deposits crop out prominently as lenses of magnetite and hematite in a bed of dolomitic limestone that lies near the base of the Crystal Spring formation of the Pahrump series (see section, p. 26). In this area, the beds of the Crystal Spring formation dip steeply, 80°–90°, and strike about N. 80° W. Two of the 14 drill holes, drilled northward under the croppings of iron ore, pass downward into sheared granite gneiss at about 3,750 feet; the same rock crops out 1,000 feet south of the iron ore. Beyond this to the south, the monzonite porphyry which forms the core of Kingston Range crops out prominently. The local as well as other regional features show clearly that the rocks of the Pahrump series as well as the overlying rocks of Paleozoic age are parts of a large plate that has been thrust some miles eastward upon the erosion surface carved on pre-Cambrian gneiss. Evidence at the deposit (no. 3, pl. 2) 2 miles east indicates that the iron ore is related to the beds of intrusive monzonite. Obviously, the lenses of iron ore do not extend downward into the gneiss.

Explorations show that the western lens, about 1,200 feet long and 60 feet thick, continues downward to the gneiss. Eastward, the limestone contains two narrower parallel lenses of iron ore, but one does not persist as deep as the gneiss. The average grade of the ore is about 55 percent iron.

IRON DEPOSIT EAST OF BECK DEPOSITS

A 10-foot trench exposes a small body of magnetite on the hillside 2 miles east of the Beck deposit (no. 3, pl. 2). The lens of magnetite several feet thick occurs in a bed of limestone of the Pahrump series, close to the portion of that containing the Beck deposits. A few feet east of the trench, the limestone and magnetite abut against monzonite porphyry. This deposit has no commercial value but indicates the genetic connection of the two deposits to the monzonite porphyry.

OLD DAD DEPOSIT

According to Lamey (1945), an iron deposit (no. 22, pl. 2) lies on a northwest spur from the central part of Old Dad Mountain, at an elevation of about 2,450 feet, probably in sec. 13 or 14, T. 12 N., R. 10 E., about 16 miles southeast of Baker. Old Dad Mountain is a rugged ridge that trends northwest and is bordered on the west by sand and sand dunes so that access is difficult.

The largest of two bodies of iron ore appears to be a lens about 75 feet by 400 feet that stands steeply at the contact of quartzite and limestone of unknown ages. Bodies of intrusive monzonite crop out nearby that may account for the formation of the iron ore. There are several impressive faults nearby and general relations are obscure. As at the Beck deposits, the principal minerals are magnetite and hematite. Small percentages of pyrite, chalcopyrite, calcite, and quartz are also present.

From the description by Lamey, it would appear that the quartzite and limestone are parts of the Prospect Mountain quartzite and Pioche shale. The deposit seems to lie below the plate of rocks of Paleozoic age that forms the upper part of Old Dad Mountain.

IRON PROSPECT NORTHWEST OF KELSO

In the low hills about 3 miles northwest of Kelso, an opencut (no. 25, pl. 2) 20 feet long and a short tunnel have been driven on a 2-foot vein of specular hematite which lies in a northward-trending fault. The nearby rocks are the dolomites of the Goodsprings dolomite that strike west and dip vertically. The lens of hematite is rather high grade.

LATE TERTIARY GOLD DEPOSITS

The only known metal deposits that assuredly are younger than the epoch of volcanism of middle Tertiary age are those which have been exploited for gold in the Hart district (Castle Mountains) and the Getchel district (Hackberry Mountain). In both districts, rhyolite flows, tuff, and breccias that appear to have been derived from a local source rest upon gneissic granite (pre-Cambrian rocks). These local sources of rhyolite have not been identified in the Castle Mountains but are inferred near Hackberry Mountain where rhyolite flows and tuffs dip outward from a central depression; they seem to be thickest in the central part of the mountain. No intrusive masses have been recognized in the flows in either district.

At both districts—Hart, discovered in 1907 and vigorously explored during 1908 and 1909, and Getchel, discovered in 1924—no work was in progress in 1927. In fact, in the Hart district the principal shafts from which a small production was derived are dismantled and no longer accessible. Consequently, only the veins exposed in the tunnels were examined. No veins were observed in the bedded tuffs (Hart, no. 129); a few were found in the flow breccias (no. 26); but there were many in the rhyolite flows (no. 129). Several veins in the tunnels of the Crater group of mine workings (no. 133) are in the rhyolite flows near the gneiss on which they rest. In both districts, the veins are simple breccia zones along which the wall rock is silicified and quartz and chert are deposited. At the Hart mine (no. 129), the central veinlet of chert lies between layers of greenish clay which represents altered rhyolite. In both districts, a little pyrite is present in both silicified wall rock and in the veinlets of quartz; metallic gold as small grains and wires is in both quartz veinlets and chert that replaces the country rock. Alunite may be present in the altered rock, but its presence was not proven. Under weathering, jarosite is deposited on fractures.

From this examination, as well as from printed accounts of the Hart mines when the mines were in operation, it would appear that the widths of the veins between the outer limits of altered rock commonly ranged from 1 to 3 feet. It seems doubtful that the widths of gold-bearing quartz and chert have exceeded a few inches. In the Getchel district (Crater group, no. 133), it was easy to find free gold in small fragments of quartz and assays of such material may show many ounces of gold to the ton. The veins that were examined, however, are limited to a few tens of feet along the strike; the quantity of gold-bearing quartz and chert is small. It is very doubtful that such gold-bearing material persists downward into the gneiss that underlies the flow.

This examination has not yielded any information concerning the factors that have determined the localization of these gold-bearing veins and an opinion cannot be expressed as to the possibility of finding more similar areas.

Gold deposits

[Examined in 1927]

No.	Name	Country rock
	Castle Mountains, Hart District	
128	Oro Belle	Rhyolite breccia.
129	Hart Consolidated	Rhyolite flows.
129	Big Chief	Rhyolite breccia.
	Hackberry Mountain, Getchell District	
133	Crater group	Rhyolite flow.

ORO BELLE MINE

More work has been done on the Oro Belle mine (no. 128, pl. 2) than any other in the Hart district. The principal workings include a tunnel about 1,000 feet long and a vertical shaft from which about 1,000 feet of workings have extended on the 100- and 200-foot levels (fig. 57). These lie near the head of a ravine that drains the south end of Castle Mountains. The first discoveries in the district were made on the Oro Belle

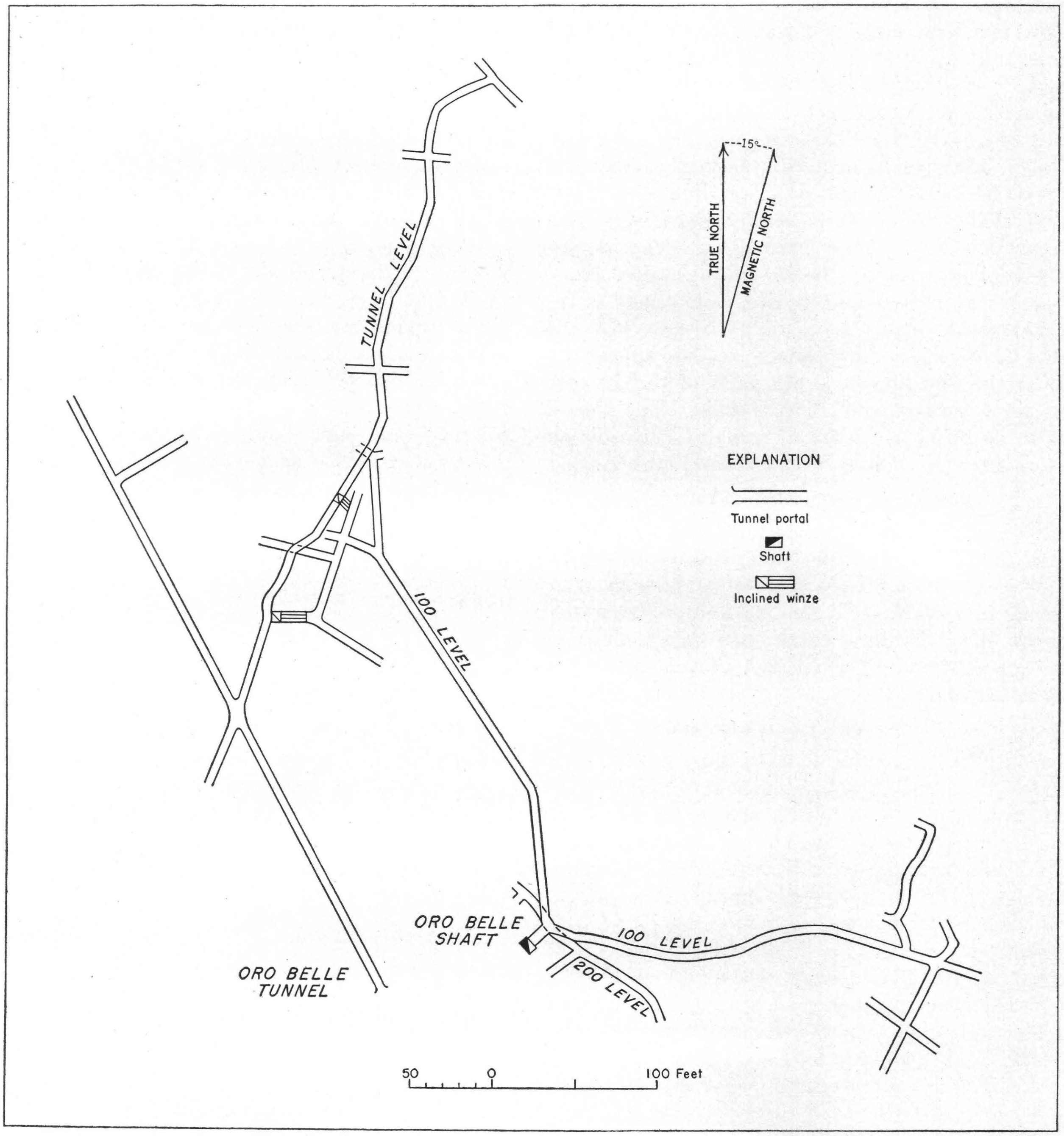

FIGURE 57.—Map of workings, Oro Belle mine.

claim in December, 1907. There was a small production between 1910 and 1913.

These workings explore several narrow veins in rhyolite flow breccia. The shaft is not accessible, but as the last material hoisted was thin-bedded white tuff and fragments of granite gneiss, it would appear that the workings had passed through the Tertiary volcanic rocks into the pre-Cambrian rocks.

According to early reports (Engineering and Mining Journal, v. 85, p. 308, 379, 519, 576, 1116, 1263; v. 86, p. 103, 780) assays of vein material from the shallow explorations commonly showed the presence of \$60–\$200 worth of gold to the ton. From what may now be seen, it would appear that the veins were narrow and not persistent; hence the quantity of material of these grades was small.

HART CONSOLIDATED MINE

The workings of the Hart Consolidated mine (no. 129, pl. 2) lie half a mine southeast of the Oro Belle mine near the head of a ravine, which is tributary to that draining southward from that mine. The explorations are confined to a tunnel, which, with drifts, winzes, and raises, includes about 1,100 feet of work (fig. 58).

The rocks exposed in these workings include rhyolite flows, flow breccias, and bedded tuff. For 430 feet from its mouth, the tunnel is in a flow of brown perlitic rhyolite. This flow strikes north and dips west at a low angle. At a point 430 feet from the entrance, the tunnel cuts a fault beyond which lie thinly laminated tuffs that strike N. 20° E. and dip 8° W. Farther in, there are numerous drifts that explore slightly altered flow breccia. These observations indicate that the flow breccia is the lowest member of the series; it is successively overlain by bedded tuffs and the brown rhyolite flow. Hence along the fault the flow on the west side has dropped against the tuff.

Both the flow breccia and the flow reveal the relations of the several types of alteration to the ore deposits of the district. At many places along the tunnel west of the fault, the rhyolite flow shows symmetrical zones of alteration on both sides of fractures. The fracture is generally clearly marked in the middle of a vein of fine quartz several inches thick. On both sides of each vein, the rhyolite is altered to pale-greenish clay for a distance that ranges from several inches to several feet. The fine quartz probably contains some free gold.

BIG CHIEF MINE

The Big Chief mine (Engineering and Mining Journal, v. 85, p. 309, 379, 578, 1025, 1116; v. 86, p. 296) lies

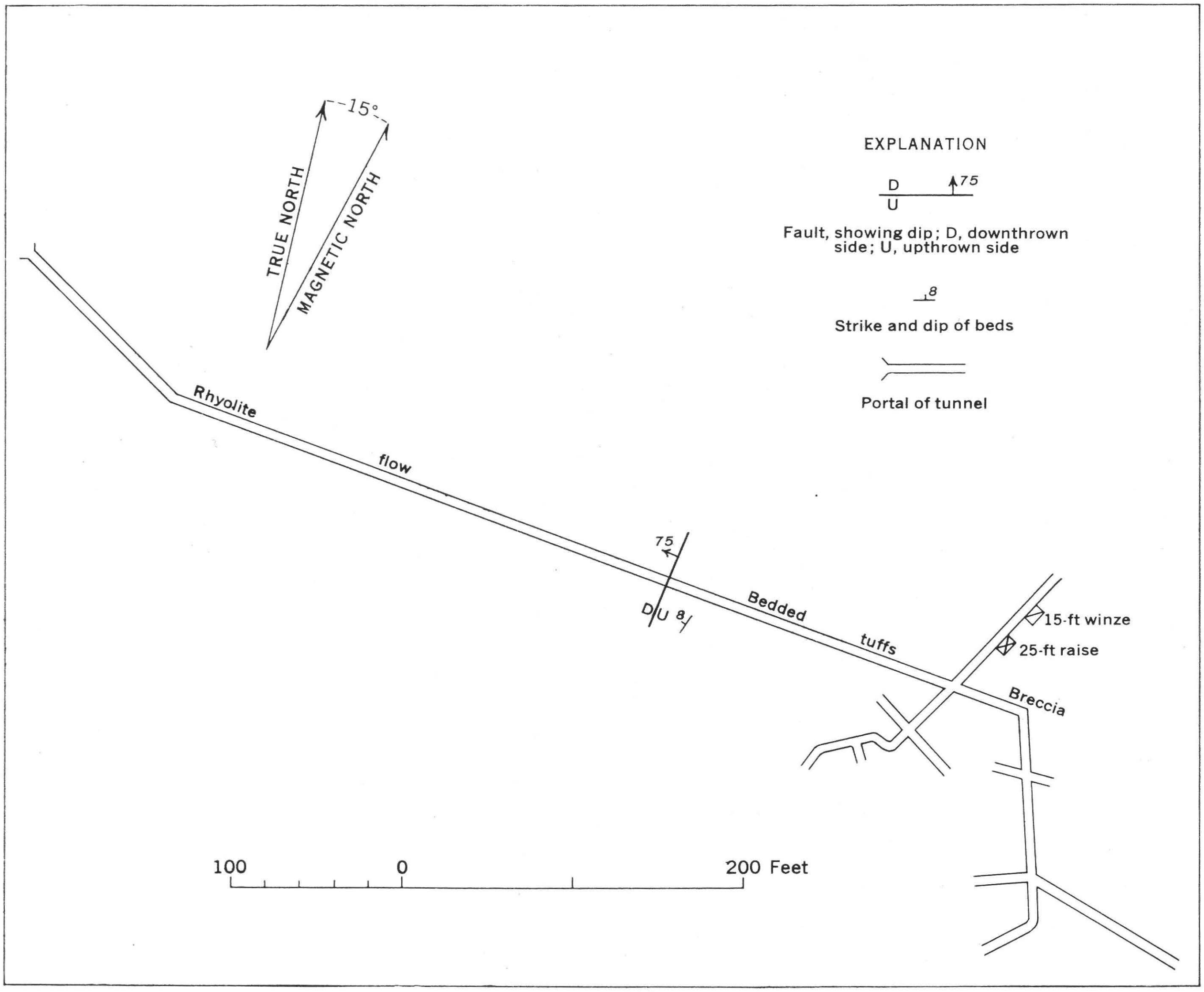

FIGURE 58.—Sketch map of tunnel, Hart Consolidated mine.

on the south side of a low hill that forms the southern end of Castle Mountains (no. 129, pl. 2), about a mile south of the Oro Belle mine. The workings include a shaft several hundred feet deep, now bulkheaded at 80 feet, and several opencuts. A tramway connects the shaft with a 10-stamp mill about 1,000 feet west. The mill was erected to treat the ore from several mines in the district.

The mine workings lie on the southern edge of an area of silicified rhyolite flow breccia about 350 by 150 feet. The silica has largely replaced the glassy matrix of the breccia, as only a border zone of the fragments about one-eighth inch thick has been altered. The nature of the ore bodies has not been determined, but they probably resembled those of the Oro Belle and Crater Group. A small production is recorded in 1909–1913.

CRATER GROUP

In 1924 gold was discovered in veins in the rhyolite flows that underlie much of the south slope of Hackberry Mountain, and numerous explorations were made in an area of about a square mile. The largest undertaking is a tunnel on the Crater group (no. 133, pl. 2), about 400 feet long. Above this, there is an opencut from the end of which there is a 30-foot tunnel.

Hackberry Mountain is made up of a series of rhyolite flows, flow breccias, and tuff (see p. 83). These rocks rest upon pre-Cambrian gneiss and schist which are intruded by alaskite dikes. The known veins lie wholly in the rhyolite flows and flow breccias. Latite that may be intrusive crops out in the ravine several hundred feet west of the Crater group workings. The flow breccia in which the veins of the Crater group lie contains angular blocks of alaskite as well as latite and pre-Cambrian crystalline rocks crop out nearby.

Native gold occurs in quartz veins as much as one inch wide that cut the basal flow breccia. The nearby rocks are locally silicified, and in a few places gold was found in the silicified material. The presence of iron oxide stains indicates that pyrite probably exists in unweathered material. No other minerals were found in the veins. The veins have diverse trends and none appear to persist more than 10 or 15 feet horizontally. In the opencut the veins strike generally north and dip 80° E., but the vein exposed near the face of the tunnel below strikes N. 70° E. and dips south. As numerous specimens showing free gold were found, it seems clear that ore yielding high assays is present. From what may be seen of the veins, some doubt arises concerning their horizontal and vertical extent.

About half a mile northeast of the Crater group, there are a number of other short tunnels and shafts, one of which attains a depth of 80 feet.

NONMETALLIC RESOURCES

FLUORITE

The largest body of fluorite, and therefore, the one that offers the greatest promise of commercial value, is explored in the Queen mine (no. 107). It is about 12 feet thick and contains minor amounts of sulfides, pyrite, and chalcopyrite. The Live Oak vein (no. 106) is about 8 feet thick but contains more impurities.

Fluorite is also common at the Calarivada mine (no. 58) and Birney's prospect (no. 65). A vein from 1 to 3 feet wide, largely fluorite, is reported on the McDermott claims (Tucker and Sampson, 1943), 4 miles east of Nipton; it was not examined.

LIMESTONE

Even though limestone forms most of the formations of the upper half of the group of Paleozoic age (Valentine limestone member and higher limestones), the beds have been exploited at only a few places in this quadrangle. Over large areas throughout the quadrangle, most of the limestone beds have been largely if not completely altered to dolomite. Quarries have been opened near Sloan and Jean on the Union Pacific Railroad. Other smaller quarries have been opened on beds of limestone in pre-Cambrian rocks 2 miles east of Ivanpah, and in Goodsprings dolomite, 1 mile southeast of Ivanpah; both have been idle for many years.

A limestone quarry has been operated for many years by the Nevada Lime and Rock Co. (no. 119, pl. 2) along the southwest face of the prominent ridge in sec. 13, T. 23 S., R. 60 E. A tramway extends from the quarry to a calcining plant at Sloan, a station on the Union Pacific Railroad, 1,500 feet away. The quarry mines the Crystal Pass limestone member of the Sultan limestone, 150 feet thick, but as it has been driven into the hill, the height of the face has increased so that recently considerable dolomitized limestone of the basal Monte Cristo limestone has been broken down. The limestone that is mined is a large lens that merges northwest with the completely dolomitized equivalent of the Crystal Pass limestone member. Just a short distance west of the present quarry every stage of the process of dolomitization may be observed.

In addition to the mining equipment, the local plant includes a crusher, rotary kiln, and hydrating plant. Four products are shipped: broken lime rock, burnt lime, hydrated lime, and dolomite. In 1927 about 300 tons of crude lime was shipped daily. The limestone products are shipped to the sugar refineries and building industries of southern California; the dolomite is used at the steel furnaces near Los Angeles.

The following analysis of carload shipments are considered typical:

Date	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3–Al_2O_3
Oct. 3, 1924	97.95	0.48	1.10	0.44
Oct. 5, 1924	97.52	1.70	.82	.22
Oct. 10, 1924	98.24	.58	.92	.40
Oct. 27, 1924	97.66	.80	1.06	.30

Analyses supplied by the company.

DOLOMITE

Nearly pure dolomite is more abundant in this quadrangle than pure limestone. It forms most of the Goodsprings dolomite and great thicknesses in the formations of late Paleozoic age have been formed by the dolomitization of the original limestone. As noted above, in mining limestone (Crystal Pass limestone member) at Sloan, large quantities of dolomite that have been formed by the dolomitization of the Crystal Pass limestone member have been mined also.

MAGNESITE

A small deposit of magnesite has been explored near the camp of the New Trail mine (no. 88, pl. 2) on the east side of Ivanpah Mountain. The magnesite forms a well-defined layer between good walls in dolomite beds of the Goodsprings dolomite. The beds of dolomite strike N. 55° W. and dip 40° SW., whereas the magnesite layer strikes N. 70° W. and dips 35° SW. The layer therefore cuts across the bedding of the dolomite and is related to a fracture.

The magnesite is nearly pure white. A simple test indicates the presence of several percent of silica and water; the calcium content is unknown. A part of the layer is fine grained and a part is faintly fibrous with the fibres extending normal to the walls. The layer is from 1 to 3 feet thick. It has been explored over an area of about 100 feet square. Undoubtedly it has been formed by replacing the gray dolomite of the Goodsprings dolomite. According to local reports, 125 tons has been shipped.

QUARTZ

Pegmatite dikes having characteristic mineralogy and structure are very rare in the intrusive rocks of this region, especially in the Teutonia quartz monzonite. The feldspar deposit described below shows the mineralogy of most pegmatites, but the structural features are uncommon.

About 1,000 feet N. 35° W. from Gold Valley Spring, a quarry has been opened on a large body of quartz. The quartz forms a lens about 20 feet wide and 60 feet long and is limited by nearly vertical walls that strike N. 35° E. It does not show any feldspar or mica, but in the face of the quarry there are several included angular blocks of monzonite in which the deposit occurs.

FELDSPAR

A feldspar mine (no. 126, pl. 2) was opened in 1926 on the west side of a conical hill that lies a mile north of Crescent Peak, Nev., and 8 miles east of Nipton, Calif. The explorations include three opencuts; the northern, 50 feet long and 25 feet wide; the middle, 25 feet in diameter; and the western, 20 feet in diameter. All lie within the area of one acre. The mine is equipped with a compressor, tracks, sorting tables, and storage bins.

The body of feldspar that is explored is tabular or lens shaped; it is considered to be a pegmatite, even though the proportion of quartz is less than normal. The trend is southeast, the dip about 10° NE., and the thickness is at least 50 feet but may be 75 feet. The body is largely white potash feldspar (microcline), but here and there it contains masses of plumose muscovite as much as 5 feet in diameter and sparse veins of quartz largely from 1 to 2 inches thick. On partings the feldspar is altered to a thin film of greenish sericite. Although the feldspar has not been studied closely, simple tests show that it contains a small percentage of albite in the form of small veinlets.

The feldspar body lies within an area of gray granite (monzonite?), which is intrusive into the dark gneissic hornblende granite that prevails in this region. The hornblende granite is assuredly pre-Cambrian and it is probable that the gray granite is also.

MICA MINE

According to Tucker and Sampson (1943), several pits and short tunnels explore some pegmatite dikes in the body of pre-Cambrian rocks that forms the lower east slope of Clark Mountain. About 1931 a plant was installed to recover mica, feldspar, and quartz. It contained a crusher, screens, and blower.

CLAY MINE

From time to time since 1929, the Standard Sanitary Manufacturing Co. has explored a deposit of clay half a mile south of the Hart Consolidated mine (no. 129, pl. 2) on the south end of a ridge that extends south from Castle Mountains. In 1929, there was a tunnel 200 feet long from which a large chamber to the surface has been opened. It has recently been mined. The nearly pure white clay represents rhyolite tuff in the section of flows and tuffs of middle Tertiary age that have been altered by hydrothermal action.

PERLITE

The name perlite is applied to a variety of rhyolite that shows perlitic structure or breaks readily into small spherules or pearls when struck with a hammer. The rock has become valuable recently because it possesses the property of swelling many times its original volume when heated. The resulting product finds a wide market as an insulating material. Actually, many glassy varieties of rhyolite that do not show perlitic structure possess this property of swelling when heated.

There are four areas in this quadrangle that show flows of glassy rhyolite which, when heated, swell into a light frothy pumice.

Secs. 17 and 20, T. 23 S., R. 58 E., Nevada. The character of the flows and their thickness is described in the report on the Goodsprings district (Hewett, 1931, p. 39–40).

Sec. 18, T. 26 S., R. 59 E., Nevada (p. 86).

Secs. 5 and 6, T. 30 S., R. 62 E., Castle Mountains, Nev. (p. 82). In recent years, a quarry has been opened in this area and a considerable tonnage of perlite has been shipped.

Secs. 6, 7, 8, 18, T. 11 N., R. 16 E., Hackberry Mountain, Calif. (p. 83).

GYPSUM

In this region, beds of gypsum occur at two definite stratigraphic horizons; in the upper part of the Supai formation and in the sandy zone that separates the two limestone members of the Kaibab limestone. Thus far, only the second horizon has been the source of commercial production; several large mines have been opened at this horizon 10 to 15 miles west of Arden, north of the boundary of Ivanpah quadrangle.

The section of the Supai formation measured in sec. 13, T. 23 S., R. 58 E., north of Goodsprings (Hewett, 1931, p. 30), contains at least five distinct beds of gypsum that range from 4 to 6 feet thick. The Supai formation crops our prominently in the central part of Ivanpah quadrangle, especially in the hills southeast of State Line Pass, but beds of gypsum are not conspicuous. No explorations have been made on beds of gypsum in the Supai formation in this quadrangle.

On the northeast slope of a hill in sec. 33, T. 22 S., R. 60 E., or about 5 miles west of Sloan, a trench 80 feet long reveals a bed of massive pure gypsum, 8 feet thick, in the zone of sandstone that separates the two limestone members of the Kaibab limestone. Nearby, another trench 30 feet long shows a bed of gypsum 10 feet thick. This may be another bed at a higher horizon or the same 8-foot bed faulted to a higher position. The Kaibab limestone is found as far southwest as Mesquite Pass, but no gypsum crops out.

RARE EARTH DEPOSITS

In April 1949, a vein (no. 76, pl. 2) containing large quantities of the rare mineral, bastnaesite, a fluocarbonate of cerium, lanthanum, and neodymium, was found near the Sulphide Queen gold mine (no. 75, pl. 2). It was discovered by Clarence Watkins and H. S. Woodward of Goodsprings, who were prospecting in the area with a Geiger counter. Early in 1950, a group of claims was bought by the Molybdenum Corporation of America which is exploring the area. Further prospecting by others has led to the discovery of numerous veins in a northwestward-trending belt that seems to be about 7 miles long and a mile wide. Most of the veins are characterized by barite, calcite, and quartz as well as small quantities of bastnaesite, fluorite, and other sulfides, galena, and pyrite.

On the basis of the study of 30 acres near the original discovery by W. N. Sharp and Lloyd Pray (1951) of the U. S. Geological Survey, late in 1949, it appears that the veins containing rare earths are related to bodies of syenite and shonkinite, intrusive in the pre-Cambrian gneisses of the region (p. 25). On the basis of geologic study of a larger area by a party of Survey geologists during 1950, 1951, 1952, a comprehensive report on the geology of the larger area and the rare earth deposits has been published recently. (Olson, Pray, Sharp, and Shawe, 1954).

TALC DEPOSITS

When this work was done, 1924–29, no talc deposits were known within the limits of this quadrangle, though deposits were being exploited in the region west of it. Talc was then being mined in three districts: near Acme, southeast of Riggs, and east of Silver Lake, all stations on the Tonopah and Tidewater Railroad, now abandoned. About 1935, a deposit was found and rapidly brought into production near Horse Spring on the east slope of Kingston Range; later another was opened near Beck Spring. Preliminary examination by the writer indicates that all of these deposits have many features in common and are found in one of the dolomite beds in the Crystal Spring formation of the Pahrump series. Most of the talc is nearly pure white and it finds a ready market in the ceramic trade.

EXCELSIOR MINE

The Excelsior mine (no. 7, pl. 2) is located on the south slope of a prominent ridge that extends southwest from a hill (5,100 feet) 3 miles east of Horse Spring. The mine workings aggregate several thousand feet and more than 10,000 tons of talc of a good grade has been shipped. The talc forms a definite bed about 20 feet thick that replaces part of a dolomite bed 100 feet thick in the Crystal Spring formation which overlies a sill of diorite recorded in the section of the formation measured at this locality (p. 26).

SMITH MINE

The Smith mine (no. 5, pl. 2) lies several thousand feet east of Beck Spring on the north slope of Kingston Range. It is explored by several tunnels and a shaft. Some talc was shipped, but the mine has been idle for several years. The workings explore a bed of talc that is part of a bed of dolomite in the Crystal Spring formation. Brief examination indicates that the bed may be that which contains the Beck iron deposit several thousand feet west.

TURQUOISE

Turquoise of gem quality has been found and the deposits explored in three separate areas in the quadrangle (pl. 2), as follows: no. 13, near Riggs Wash; no. 15, about 8 miles east of no. 13; no. 127, on the south slope of Crescent Peak, 8 miles east of Nipton. These deposits have been described many times by authors concerned either with the gem or the archeological features. When first found, there were small ancient workings and numerous stone hammers and artifacts nearby.

HIMALAYA MINE

Turquoise was discovered south of Riggs Wash in 1897, and the deposits were extensively worked by the Himalaya Mining Co. until 1903. No work has been done since then (Cloudman, Huguenin and Merrill, 1917, p. 75–78; Sterrett, 1912, p. 1071–1073). The explorations are scattered over three hills within an area 1,500 by 3,000 feet. Most of the work has been done within an area 100 by 300 feet that lies on the southwest slope of the middle hill (no. 13, pl. 2). Here a tunnel extends eastward 70 feet under an opencut from which there are several drifts and winzes.

The quartz monzonite of this region is characterized by coarse phenocrysts of reddish orthoclase about an inch long. The middle of the three hills contains an intrusive body of quartz monzonite porphyry. The contact of the monzonite with the granite gneiss to the south is shown along the south side of the road, half a mile south of the mine. The turquoise is found in an area within which the monzonite shows considerable alteration to sericite. The altered rock is separated from unaltered rock by a slightly silicified shear zone that trends east and dips south. Above this shear zone, the altered monzonite is divided into polygonal blocks by numerous veins of quartz, most of which are an inch or less thick. The turquoise forms pellets and small irregular masses that lie in the minor fractures near the quartz veins. The nearby rocks show veinlets and films of yellowish jarosite. In many places, some near and some remote from masses of turquoise, there are patches of nearly pure sericite in part altered to hard white alunite. Although no pyrite was observed in this area, it seems clear that the mineral was the source of the iron and sulfuric acid contained in the jarosite as well as the sulfuric acid that formed alunite by acting upon sericite. No turquoise was found more than 40 feet below the nearby surface. The relations of the associated jarosite and alunite indicate all three minerals were formed by supergene processes.

STONE HAMMER MINE

The first discovery of turquoise in this region was made at the Stone Hammer mine (no. 15, pl. 2) in September 1897 (Kunz, 1898, p. 504). The deposits were extensively explored in the following years by the Toltec Gem Mining Co., which also explored the deposits near Crescent Peak in Nevada (see below). Explorations are confined to an area about 600 by 1,200 feet. Near the center there is a tunnel 50 feet long which extends to an opencut 30 by 60 feet and 25 feet deep. Within the opencut there is a shaft 60 feet deep.

The turquoise is confined to an area within which the gray quartz monzonite of the region is considerably altered to a rock that is largely quartz and sericite and shows numerous reddish patches. Study of thin sections of this rock indicates that the reddish color is due to iron oxide, which is derived from jarosite. The unweathered rock contains small amounts of disseminated pyrite and molybdenite. So far as may now be seen, most if not all of the turquoise in the area forms rounded or irregular small masses embedded in veinlets of yellowish fine-grained jarosite-bearing chert. At one place, the chert is almost pure white, but it merges outward with the yellowish variety that contains jarosite. Most of the veins of jarositic chert are less than one-quarter inch wide but some are as much as an inch wide. Here and there, the rock adjacent to these veinlets contains patches of white alunite. It seems quite clear that here, as at the Himalaya mine near Riggs Wash, turquoise is localized in an area of monzonite that has been first altered to hypogene solutions to a quartz-sericite rock containing pyrite, and that the turquoise is the later product of supergene solutions which have converted the pyrite to oxides and formed jarositic chert and alunite. It is not clear whether the altered rock contains more phosphoric acid than the original fresh rock.

TOLTEC TURQUOISE MINE

Turquoise was discovered on the south slope of Crescent Peak by an indian known as Prospector Johnnie in 1894 (Lincoln, 1923, p. 19), but most of the exploration was done several years later by the Toltec Gem Co. At present, the property is owned by the Turquoise and Rare Metal Mining Co. The workings (no. 127, pl. 2) lie in a belt that extends about 1,000 feet in a general northwest direction along the south slope of Crescent Peak. The country rock of the area is the gneissic granite that prevails near Crescent, but as in the monzonite of the turquoise district west of Valley Wells, the foldspars are largely altered to sericite.

Most of the work has been done at the southeast end of the belt where there are two opencuts, the largest 25 by 75 feet, and two tunnels. The granite is highly altered and it is cut by many quartz veins one-half to one inch wide which divide the granite into many polygonal blocks. A tunnel which extends S. 40° E. about 100 feet follows two quartz veinlets about 4 feet apart. The turquoise occurs largely in the quartz veins where they are crushed, and to a less extent in jarosite-bearing chert veinlets in the altered granite nearby. Masses of turquoise that weigh from 10 to 25 grams are not uncommon, although most of them are smaller. At the middle group of workings where there is a tunnel and two opencuts, a quartz vein contains pyrite, and there is considerable jarosite in the fractures. At the opencuts at the northwest end of the belt, turquoise occurs in the druses of quartz veins intimately associated with an uncommon green variety of alunite. The common iron oxides and jarosite are conspicuously absent.

Although there are slight differences in the associated minerals and mode of occurrence of turquoise at the several deposits near Crescent Peak, Halloran Wash, and Riggs Wash, there can be no doubt that the origin is similar throughout. In each area, the enclosing rock is either monzonite or granite that has been highly altered to sericite and quartz and cut by numerous pyrite-bearing quartz veins. The abundant jarosite and alunite appear to represent the products resulting from the attack on sericite of iron-bearing sulfates and sulfuric acid. Like these minerals, the turquoise appears to be supergene and to be restricted to a shallow surface zone.

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