Geology of the Independence Quadrangle Inyo County, California

By DONALD C. ROSS

CONTRIBUTIONS TO GENERAL GEOLOGY

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By Donald C. Ross

ABSTRACT

The Independence, Calif., 15-minute quadrangle covers an area of about 240 square miles near the west margin of the Great Basin. About half of the area of the quadrangle is underlain by Cenozoic alluvium and volcanic rocks in the Owens Valley and the other half is underlain by Mesozoic granitic rocks and Paleozoic sedimentary rocks in the Inyo Mountains.

The Paleozoic sedimentary rocks, which range in age from Early Cambrian to Permian, are divided into 18 formations having an aggregate thickness of about 16,000 feet. The sequence is apparently conformable throughout except for an impressive erosional unconformity where Mississippian beds lie on Silurian beds. Some of the formations are grossly comparable to formations of the eastern (carbonate) assemblage of the Paleozoic of the Great Basin, but the variation of others from typical eastern assemblage lithologies, suggests that the Independence area is part of a transitional assemblage between the western (siliceous) assemblage and the eastern (carbonate) assemblage.

In the Mesozoic, the sedimentary rocks were invaded and contact metamorphosed by large granitic masses, which now make up half of the exposed bedrock. Four large plutons are distinguished. All are quartz monzonite except the Pat Keyes pluton, which is in part composed of granodiorite and of other more calcic granitic types presumably as a result of contamination from the wallrock. The Santa Rita Flat pluton, a mass a batholithic proportions along the front of the Inyo Mountains, is correlative with the Tinemaha Granodiorite of the Sierra Nevada.

Late Cenozoic basalt flows extend into the northwest corner of the quadrangle from the front of the Sierra Nevada to the west. Patches of basalt ash along the face of the Inyos, are derived in part from a volcanic center just north of the quadrangle at the base of the Inyo Mountains. Rhyolitic pumice and ash, whose source is unknown, are abundant in some layers of older alluvium which have been uplifted and are at present being dissected by the drainage.

The Paleozoic sedimentary rocks are primarily in a steep west-dipping homocline that is considerably faulted and locally folded and distorted, partly as a result of forcible invasion by the granitic rocks. Faults are abundant throughout the bedrock, but the most conspicuous are two sets of faults, one striking north and one striking northwest, that define a belt several miles wide along the west face of the Inyo Mountains. The presence of these faults and of prominent topographic benches that give a grossly stepped appearance to the range front

suggests that the uplift of the Inyo Mountains in this area was intermittent and that displacement was distributed over a wide zone.

Mining in the area dates back to 1851, but records show that production has been small. Gold, silver, lead, copper, tungsten, and talc have been produced from the area. Prospects have been dug for iron, dolomite, quartzite, asbestos, and quartz crystals. In addition, sand and gravel have been produced from pits in Owens Valley.

INTRODUCTION

PURPOSE AND SCOPE

The Independence quadrangle was mapped geologically (pl. 1) by the U.S. Geological Survey in cooperation with the California Department of Conservation, Division of Mines and Geology, as part of a long-range study of the geologically diverse and complex belt of country extending from Death Valley to the western foothills of the Sierra Nevada.

This report offers a descriptive summary of the geology of the quadrangle and an accompanying geologic map of the area at a scale of 1:62,500. More detailed accounts of the Cambrian, Ordovician, Silurian, and Mississippian stratigraphy and the petrography and petrology of the Mesozoic granitic rocks will be published separately.

GEOLOGIC SETTING

The Independence quadrangle, located near the west edge of the Basin and Range province, is intruded by batholithic granitic masses, which are part of the composite Sierra Nevada batholith. Thus the quadrangle is in a transitional zone between two great geologic provinces.

Stratigraphically, the area also occupies such a zone, for here the rocks are transitional between the eastern (carbonate) assemblage and the western (clastic) assemblage of the Paleozoic of the Great Basin (Roberts and others, 1958, p. 2817).

The Paleozoic section exposed in the Inyo Mountains is relatively unmetamorphosed, and the study of it may eventually permit stratigraphic correlations to be made with the metamorphosed roof pendants of the eastern Sierra Nevada. Facies differences, already evident in the Independence quadrangle, may preclude such correlations, but this Paleozoic section is probably the best place to attempt them.

LOCATION, ACCESSIBILITY, AND CULTURE

The Independence quadrangle covers an area of about 240 square miles in northwestern Inyo County (fig. 1). The area is readily accessible from U.S. Highway 6 and 395, which crosses the western part of the quadrangle. Many roads of variable quality branch off the highway to give excellent access to the Owens Valley and somewhat more limited access to the mountainous parts of the area. Although several of the mountain roads are suitable for passenger cars, a four-wheel-drive vehicle greatly extends the access possibilities. Both bus and truck freight service are available at Independence on the highway, but the nearest rail connection is at Lone Pine, 15 miles south of Independence.

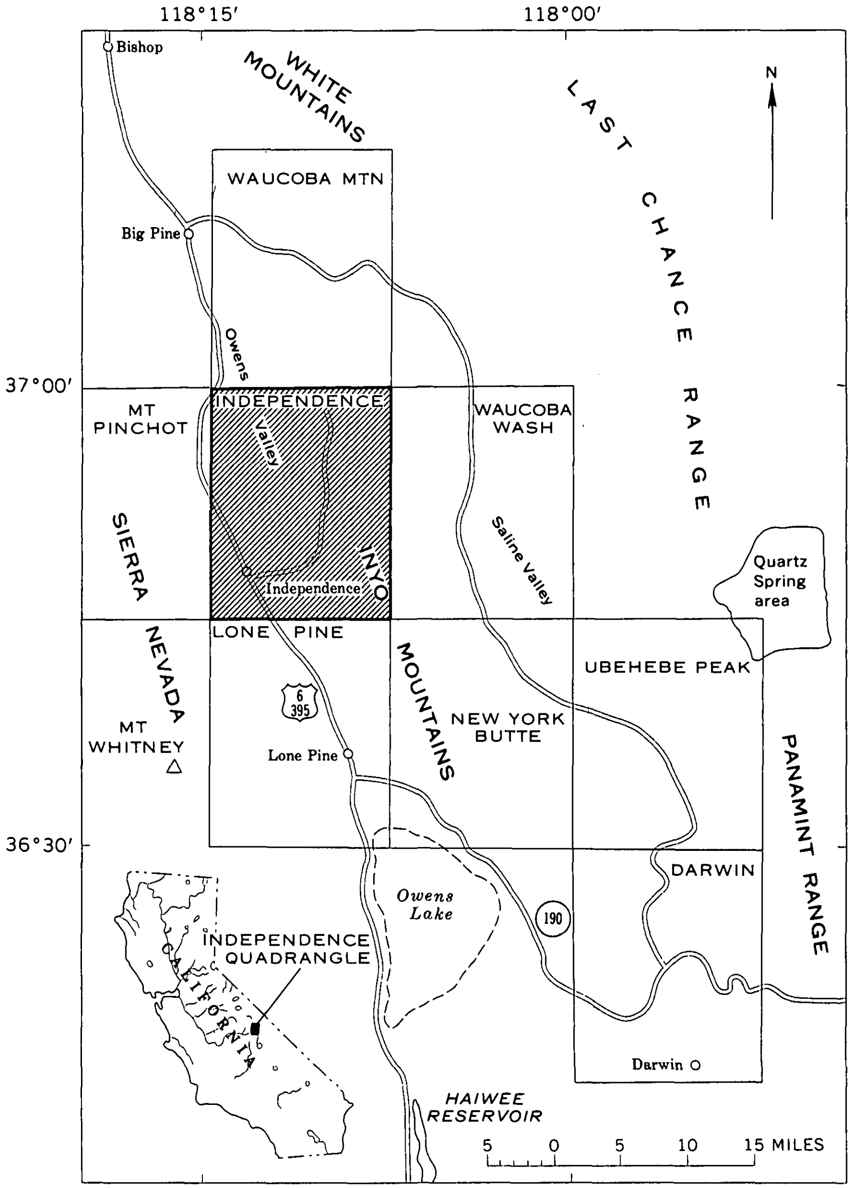

Figure 1.—Independence quadrangle.

Independence, the only town in the area (population about 1,000) and the county seat of Inyo County, is in the southwestern part of the quadrangle on U.S. Highway 6 and 395.

TOPOGRAPHY, DRAINAGE, AND WATER SUPPLY

The west front of the Inyo Mountains bisects the area diagonally and divides the quadrangle into the rugged mountains on the northeast and the relatively flat floor of Owens Valley on the southwest (fig. 2). The base of the range is about 4,000 feet in elevation, and the highest point on the crest is about 11,000 feet in elevation. The lowest point in the valley, however, is 3,700 feet in elevation; so, the maximum relief of the area is about 7,300 feet. Local relief, however, is as much as 2,500 feet within a horizontal distance of 1 mile.

No permanent streams flow in this part of the Inyo Mountains, but some 20 springs, shown on the topographic map, supply water at widely separated localities. Some of these springs, however, become dry during the summer, particularly after a dry winter. Owens River formerly flowed along the front of the Inyo Range for the entire length of the quadrangle, but the stream is now diverted into the Los Angeles aqueduct by a dam south of Aberdeen. Numerous wells and springs are in Owens Valley, and in addition, several small streams flow down the fans into the area from the Sierra Nevada west of the quadrangle.

CLIMATE AND VEGETATION

An arid to semiarid climate having a wide temperature range characterizes the area. The weather station at Independence records an average January temperature of about 40°F and an average July temperature of about 80°F over a 40-year period. During this interval the temperature extremes were 109°F and −5°F. A good idea of the summer temperatures in the lower parts of the quadrangle can be obtained from the average daily high of 102°F at Independence during July 1959, a reportedly unusually hot month. Temperatures are more moderate in the Inyo Mountains; above 6,000 to 7,000 feet in elevation, the working conditions are generally pleasant even on the hottest summer days.

Annual precipitation in the valley is from 4 to 5 inches, according to the records of Camp Independence from 1865 to 1902 and to records of the Independence weather station for the last 40 years. About half of this precipitation occurs in the period from December through February, and less than 1 inch falls in the period April through September. The annual precipitation in the Inyo Mountains is probably more than 10 inches, occurring mostly as snow in the winter.

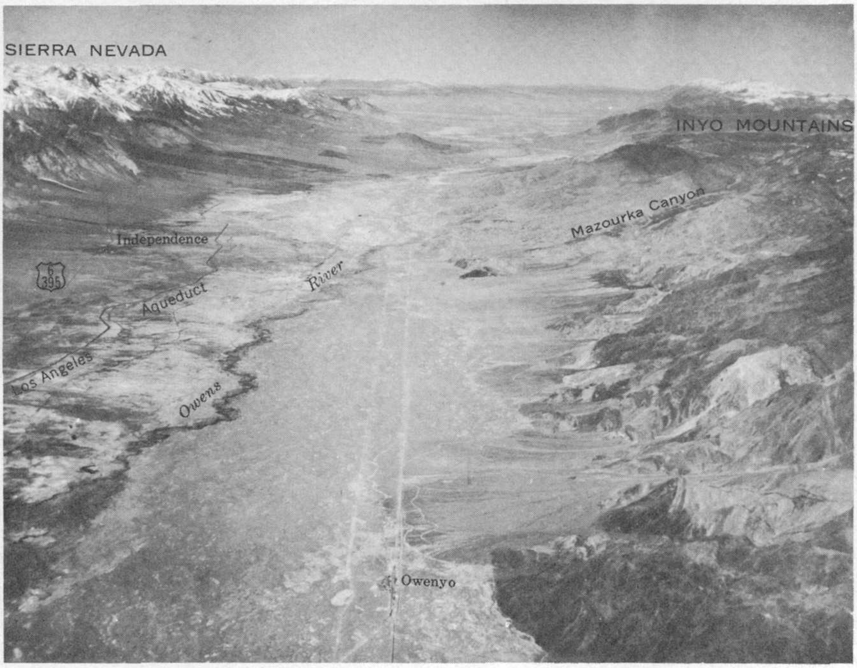

FIGURE 2.—Looking north up Owens Valley. Inyo Mountains at right, Sierra Nevada at left (photograph by Roland von Huene).

The lower slopes of the Inyo Mountains and Owens Valley generally support only scattered sagebrush and other desert-type bushy plants, although some parts of Owens Valley are grasslands, which support some trees. Above 7,000 feet in elevation, scattered piñon pine and juniper are present, and above 9,000 feet, mountain mahogany, limber pine, and bristlecone pine replace the piñon and juniper stands; along part of the crest of the range in the northeastern part of the quadrangle, the trees are exclusively bristlecone and limber pines.

PREVIOUS WORK

Very brief mention of the geology of the Independence quadrangle was made by Whitney (1865), Goodyear (1888), and Lee (1906). One of the first detailed geologic studies was made on the water resources of the Owens Valley near Independence by Lee (1912). At about this same time Trowbridge (1911) made a study of the terrestrial deposits of Owens Valley. A regional reconnaissance by Adolph Knopf and Edwin Kirk in 1912–13 (in Knopf, 1918) furnished the first description of the general geology of the area in a report that included several references to the Paleozoic stratigraphy and paleontology of the Mazourka Canyon area in the Independence quadrangle. Further work on the Ordovician faunas of the area was reported by Phleger, (1933) and on the Devonian (now considered to be Silurian) by Stauffer (1930). A report by Langenheim and others (1956) described several Ordovician stratigraphic sections and faunal collections. Pestana (1960) also published a paper describing Ordovician corals collected in Mazourka Canyon. The California Division of Mines and Geology has periodically published summaries of the mineral resources of the area; the most recent compilation of such data is by Norman and Stewart (1951).

FIELDWORK

The fieldwork on which this report is based was done in the summers of 1959–62 in a total of 12 man months. During part of the summer of 1960, I was assisted by R. J. Pickering, and during the 1961 field season by F. K. Miller. The geologic data were plotted on aerial photographs or on orthophotographs in the field, and these data were then transferred by inspection or Kail plotter, or in the case of the orthophotographs, by direct transfer, to the topographic base at a scale of 1:48,000. Photogeologic interpretation was used to some extent in the field, particularly for interpolation between identified spots where rugged terrain made access difficult.

ACKNOWLEDGMENTS

I would like to particularly express my thanks to F. K. Miller and R. J. Pickering for their help in the geologic mapping of the area in the summers of 1960 and 1961. Also, it is a pleasure to acknowledge the information and other aid given me by John Thompson, W. J. Sorenson, and L. D. Drew. The help of these men and the friendly associations with many other residents of both Lone Pine and Independence did much to assist me on this project. I also want to thank the men of the Inyo County Sheriff's Office in Independence for their friendly cooperation.

PALEOZOIC SEDIMENTARY ROCKS

A faulted and folded Paleozoic section comprising about 16,000 feet of strata in which all the systems except the Devonian are represented (table 1) is exposed in the Independence quadrangle (fig. 3). Almost everywhere in the area, the sedimentary rocks have been contact metamorphosed to some degree. Only rarely, however, was the metamorphism so intense as to destroy the original lithologic character of the formations. Nevertheless metamorphism, as well as folding and faulting, are ever-present problems in the area and dictate caution in drawing conclusions, particularly concerning thicknesses and stratigraphic relations.

The Lower and Middle Cambrian rocks are continuations of beds exposed over a large area north of the quadrangle where such rocks have been studied in detail by Nelson (1962, p. 139–144). Though these rocks are structually disturbed and metamorphosed, they are undoubtedly correlatives of Nelson's units.

The section from Upper Cambrian through Mississippian is well exposed, is fossiliferous, is in part almost homoclinal, and has some very interesting facies relations with other areas in the Great Basin. Descriptions of these units are summarized here, but more detailed treatment will be given in a separate stratigraphic paper.

The nomenclature for the Pennsylvanian and Permian rocks is carried into the area from the southern Inyo Mountains, where Merriam and Hall (1957, p. 1–13) used the formational names Keeler Canyon and Owens Valley. Neither formation has a complete section exposed in the quadrangle, and both formations are sufficiently metamorphosed so that fusulinids, which are useful in distinguishing within and between these units farther south, were not found. I am not sure the formations as they have been used in the Independence quadrangle are exact equivalents of Merriam and Hall's formations, but certainly in a gross way they are correlative. Lack of good, undisturbed sections in the quadrangle precludes any more detail than presented by the short lithologic descriptions in this paper.

CAMBRIAN

HARKLESS FORMATION

The Harkless Formation was named for exposures in the Waucoba Mountain quadrangle by Nelson (1962, p. 142). This formation is present as a discontinuous belt of outcrop in the northeastern part of the Independence quadrangle and as a septum(?) between two large plutons east of the Betty Jumbo mine. Nowhere in the Independence area is a complete section of the formation exposed. A conformable contact with the overlying formation is exposed at several places, but the lower contact is almost everywhere intrusive. At the northernmost exposure of the Harkless Formation, the basal few feet of beds, which are marble, are tentatively considered to be part of the underlying Poleta Formation (Nelson, 1962, p. 141). Here the Harkless is extremely thin, however, and the present exposed thickness is probably not an original thickness of the unit. Probably at least 1,000 feet of Harkless beds are exposed in a partial section east of Side Hill Spring. Nelson (1962, p. 140) gave an average figure of 2,000 feet as the thickness in the Waucoba Mountain area.

TABLE 1.—*Paleozoic rocks of the Independence quadrangle*

System		Series	Formation	Thickness (feet)	Lithology
PERMIAN			Owens Valley Formation	(Top not exposed) 1500	Hornfelsed silty and marly beds overlain by the Reward Conglomerate Member, which is composed of coarse clastics; the clasts range in size from sand to cobbles and consist dominantly of quartzite and chert. Weathers red to brown.
CARBONIFEROUS	PENNSYLVANIAN		Keeler Canyon Formation	1000(?)	Limestone, commonly clastic, thinly interbedded with hornfelsed dark-colored shale and siltstone. Contains spherical black chert nodules ("golf balls") near base. Weathers gray; thinly striped.
	--?--?--?--	--?--?--?--			
	MISSISSIPPIAN	Upper	Rest Spring Shale	2500	Dark gray shale and siltstone, commonly metamorphosed to andalusite hornfels. Contains cravenocerid goniatites near middle. Weathers dark reddish brown.
			Perdido Formation	300–600	Variety of coarse clastic rocks, siltstone, and shale. Chert and quartzite clasts common. Calcareous quartz sandstone abundant. Weathers gray to reddish gray; forms distinct outcrops.
Unconformity					
SILURIAN			Vaughn Gulch Limestone / Sunday Canyon Formation	1500 / 700	Thinly bedded argillaceous and bioclastic limestone rich in fragments of corals, sponges, and bryozoans in south part of quadrangle (1500 feet). Graptolite-bearing limy shale, argillaceous limestone, and minor bioclastic limestone in north part of the quadrangle (700 feet).
ORDOVICIAN		Upper	Ely Springs Dolomite	200–500	Dolomite, thin- to thick-bedded. Chert abundant in lower and upper part, absent in middle. Thins to north; upper and lower parts grade into massive chert.
		Middle	Johnson Spring Formation	100–400	Quartzite, limestone, dolomite, siltstone, and shale in intermixed sequence. Thins to the north and percentage of quartzite decreases to the north. Corals locally abundant in limestone.
			Barrel Spring Formation	100–200	Impure sandstone and limestone overlain by red brown weathering shale and mudstone in which fossils are locally abundant.

		Mazourka Group	Badger Flat Limestone	600	Silty limestone containing irregular siltstone lenses. Contains black chert nodules and nodular beds. Fossils abundant. Weathers blue gray.
	Lower		Al Rose Formation	400+	Siltstone, mudstone, shale, small amounts of limestone, and some chert. Contains graptolites and trilobites near top. Weathers brown.
CAMBRIAN	Upper	Tamarack Canyon Dolomite		900	Dolomite, thin- to thick-bedded; contains chert nodules. Weathers uniformly light gray.
		Lead Gulch Formation		300	Limestone, siltstone, dolomite, chert, and shale interbedded in thin regular layers. Contains trilobites near base. Weathers brown.
		Bonanza King Dolomite		2800	Dolomite, varied shades of gray; color-banded ("zebra striped"). Contains *Girvanella*? near base.
	Middle	Monola Formation		1250	Limestone, siltstone, and shale, thinly interbedded. Weathers brown.
	Lower	Mule Spring Limestone		400+	Limestone; contains *Girvanella*? locally. Weathers gray.
		Saline Valley Formation		800	Limestone and abundant siliceous and argillaceous layers. Contains rounded sand grains in limestone matrix near middle. To south, sand-size clastic material increases and commonly contains calcareous cement.
		Harkless Formation		1000+	Quartzite, siltstone, and shale (commonly metamorphosed to coarse shimmering mica schist). Quartzite weathers red to brown. Shale commonly greenish-gray where less metamorphosed.
		Poleta Formation (not mapped separately)		(Only a few feet exposed)	Marble

Note.—Total thickness about 16,000 feet

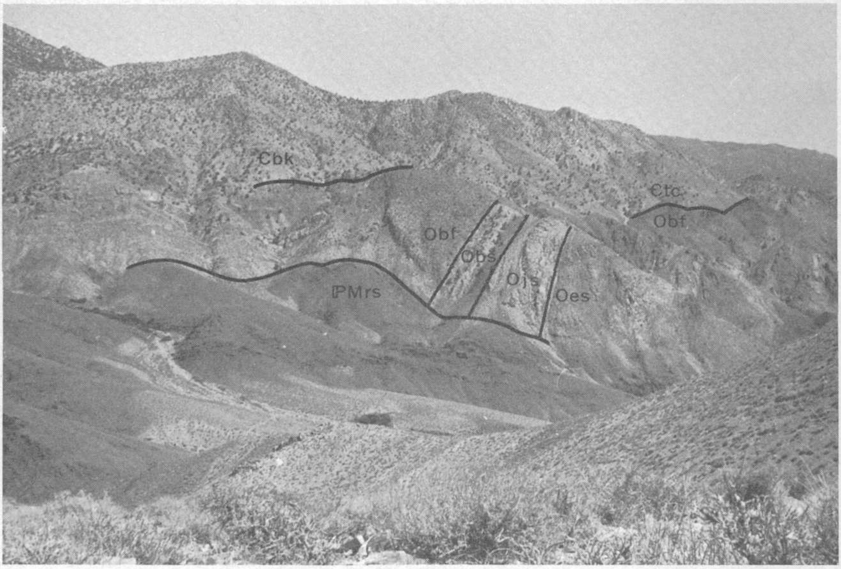

FIGURE 3.—East side of Mazourka Canyon. Looking southward from Hill 6971 south of Santa Rita Flat. General view of faulted Paleozoic formations: Bonanza King Dolomite (€bk), Tamarack Canyon Dolomite (€tc), Badger Flat Limestone (Obf), Barrel Spring Formation (Obs), Johnson Spring Formation (Ojs), Ely Springs Dolomite (Oes), and Rest Spring Shale (PMrs).

A clastic sequence of shale, siltstone, and sandstone originally made up the Harkless Formation. Everywhere within the area the Harkless is now metamorphosed to phyllite, schist, and quartzite, in which the original clastic grain outlines have been generally obliterated. The most conspicuous rock type is white to buff vitreous quartzite that weathers to red- and brown-colored surfaces. Much of the quartzite is well bedded in 1-inch to 1-foot layers, which are accentuated by micaceous partings. Commonly, mica is also disseminated in the quartzite, but some quartzite layers are remarkably pure.

The quartzite, being resistant, tends to form prominent outcrops and masks the interlayers of metamorphosed finer grained clastics with abundant quartzite debris. Nevertheless, phyllite and schist in various shades of dark gray are common in some areas, and in the east-central part of the quadrangle green shades are abundant, possibly because of the less intense metamorphism there. The schist, where it is coarsest along the north boundary of the quadrangle, is a very spectacular rock of coarse shimmering silver mica flakes, inset with larger crystals of andalusite or sericitic clots resulting from alteration of andalusite. Metamorphosed siltstone is also common as interbeds which range from a fraction of an inch to several inches in thickness. The proportions of these various rock types are difficult to assess, but probably quartzite and metamorphosed siltstone predominate over schist and phyllite. Individual beds range from less than an inch to several inches in thickness. Some coarse-grained marble is interlayered with micaceous schist near the upper contact of the Harkless near the north boundary of the quadrangle.

The quartzite and, locally, the siltstone are in part crossbedded, and ripple marks are well formed at some localities (fig. 4). Fucoids (fig. 5) and *Scolithus* are common enough locally to be a formational characteristic in the quartzite.

Near the Betty Jumbo mine, a generally south-dipping sequence of micaceous quartzite probably at least 1,000 feet thick is correlated with the Harkless Formation. These outcrops are 5 miles south of the nearest Harkless, but may have been split off the Harkless to the north by the intrusion of the Paiute Monument pluton. Along the north side of the pluton, both in the Independence quadrangle and in the adjoining area to the east, Harkless beds are part of the wallrock of the pluton. The rocks near the Betty Jumbo mine are predominantly well-bedded quartzite and micaceous quartzite in 1-inch to 1-foot layers, which commonly weather shades of red and brown. Mica partings accentuate the bedding in the quartzite. Near the east end of the largest outcrop (east of the mine road), a conglomerate contains quartzite pebbles and cobbles, as large as 8 inches in diameter, in a pure quartzite matrix and in association with sandy granule beds.

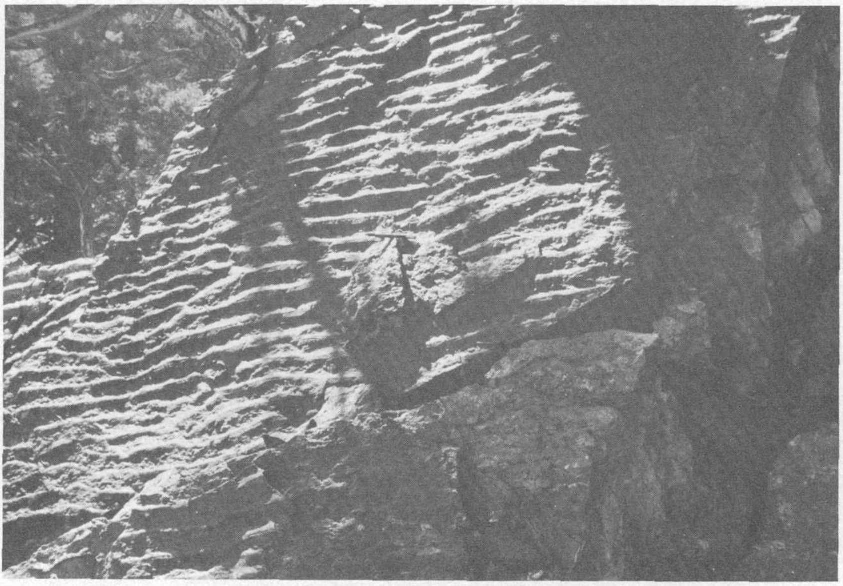

FIGURE 4.—Ripple marks in quartzite of the Harkless Formation east of Seep Hole Spring. Pencil near center of photograph for scale.

FIGURE 5.—Fucoids on bedding surface of micaceous quartzite of the Harkless Formation about 2 miles south of Seep Hole Spring. Pencil for scale.

Micaceous hornfels is present but subordinate to quartzite. Tactite, calc-hornfels, and marble are also present but are rare. Crossbedding, *Scolithus*, and fucoid markings are found in some outcrops. These beds near the Betty Jumbo have a much higher proportion of quartzite than other Harkless outcrops in the quadrangle.

SALINE VALLEY FORMATION

The Saline Valley Formation was named by Nelson (1962, p. 142) for exposures near Waucoba Spring, a short distance northeast of the quadrangle. Outcrops of this formation generally parallel those of the Harkless Formation along the north edge of the Independence quadrangle. The Saline Valley beds are also exposed east of the Inyo crest from a short distance south of Waucoba Canyon, discontinuously as far south as the upper reaches of Paiute Canyon, and in the Betty Jumbo mine area. The formation lies comformably on the Harkless and is in turn comformably overlain by the Mule Spring Limestone. South of Waucoba Canyon, the thickness of the Saline Valley is about 800 feet, and a generally similar thickness of beds is exposed on the spur east of Paiute Canyon. The exposed section near Side Hill Spring and to the west is probably tectonically thinned from its original thickness, as suggested by the lenticular and sheared bedding in the outcrops. Nelson (1962, p. 140) reported a thickness of 850 feet for the Saline Valley in his area but recognized the unit as lenticular and variable.

The Saline Valley Formation comprises a variety of rock types whose proportions vary from place to place. Along the east-trending valley west of Side Hill Spring, the formation is, in part, divisible into three units of approximately equal thickness. The lower unit is chiefly coarse-grained gray to white limestone, in part thinly banded and in part nodular, which contains siliceous and argillaceous lenses and layers. Near the top of this unit is a diagnostic layer of sparsely scattered to abundant well-rounded sand grains in a fine-grained gray limestone matrix. The middle unit is an alternation of nodular dark-gray limestone and brown-weathering silty layers. The upper unit is interlayered shale, finely laminated siltstone, and limestone. Alternating blue-gray-weathering limy layers and dark-yellowish-orange- to moderate-reddish-brown-weathering siliceous and argillaceous layers make a colorful and distinctive outcrop.

The east-trending belt of exposure south of Waucoba Canyon appears to have a higher percentage of fine-grained clastic rocks than does the Saline Valley to the northwest. In these exposures, a somewhat similar threefold split may be made, the lower unit being somewhat thinner than the other two. The lower unit is mostly a mixture of thinly bedded dark-gray limestone and siltstone. The top of this unit is marked by a poorly exposed thin layer of coarse porous somewhat friable sandstone, in which the well-rounded quartz grains are in part cemented by iron oxide. The middle member is composed of thin-bedded gray limestone with irregular red-brown-weathering argillaceous lenses. The upper unit is mainly phyllitic shale and siltstone and fine-grained laminated quartzite.

In Lead Canyon, subdivisions of the formation were not made, but immediately above the Harkless quartzite and phyllite is a conspicuous blue-gray limestone. This limestone is overlain by a mixed sequence of limestone, siltstone, shale, quartzite, calc-hornfels, and calcareous quartz sandstone. The northern exposures in the Canyon have abundant interlayered blue-gray-weathering limestone and orange- to brown-weathering argillaceous and siliceous layers. Along the south wall of the Canyon, distinctive yellow weathering marks the Saline Valley beds.

East of Seep Hole Spring and Paiute Canyon, there is some question about the distinction between the Harkless and Saline Valley Formations. Quartzite is more abundant here than in other Saline Valley outcrops. Some of the quartzite is relatively pure and is composed of rounded quartz grains and dominantly siliceous cement. More commonly, however, the quartzite has at least some calcareous

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cement, and limestone interbedded with the quartzites is not uncommon. In Paiute Canyon, white- to yellow-weathering quartzites, which had calcareous material as cement and interbeds, were mapped as Saline Valley, whereas red-brown-weathering quartzites almost devoid of calcareous material were mapped as Harkless. This was a good mappable distinction, but whether it represents the same formational break used by Nelson farther north is questionable.

The Paiute Canyon exposures also have a blue massive limestone at the base immediately overlying the Harkless quartzite. Quartzite is dominant in Paiute Canyon, but calc-hornfels and siliceous spotted hornfels are also present. Some of the quartzite is crossbedded, and fucoids are seen on some surfaces.

At the Betty Jumbo mine, a coarse gray thin-bedded marble and a sequence of overlying white crossbedded quartzite are tentatively referred to the Saline Valley Formation. The quartzite beds are white to pale green and are marked by splotches and trains of diopside crystals that accentuate bedding and crossbedding. This presence of diopside, an evidence of carbonate cement in the original sediments was the chief reason for referring these beds to the Saline Valley Formation, rather than to the Harkless Formation whose quartzite rarely has carbonate cement. These Saline Valley quartzite beds and those assigned to the Harkless Formation from the same area mark the southernmost known occurrences of Lower Cambrian rocks in the Inyo Mountains.

Very little can be concluded at this time from the lithologic variation of the Saline Valley Formation because such a small area of outcrop has been mapped, but to the south the Saline Valley seems to more closely resemble the Harkless Formation, and both formations show an increase in sand-size clastic material.

MULE SPRING LIMESTONE

The Mule Spring Formation was named by Nelson (1962, p. 142) for exposures at Mule Spring, a short distance north of the quadrangle. A discontinuous belt of outcrop is present west of Side Hill Spring; in addition there are several areas of outcrop on the east slope of the Inyo Mountains, including a rather large upland area east of Lead Canyon. The Mule Spring Limestone overlies the Saline Valley Formation conformably and in turn is overlain conformably by the Monola Formation. A thickness of about 400 feet was measured about 2 miles west of Side Hill Spring, but this section may be technically thinned. Possibly a somewhat thicker section is exposed east of Lead Canyon, but because of structural complications no measurement was made. Nelson (1962, p. 140) reported an average thickness of 1,000 feet for the Mule Spring in his area.

The Mule Spring Limestone is one of the most distinctive and easily recognized formations in the Independence area. It is chiefly a rather pure limestone or marble consisting of alternating 1- to 4-mm lenticular layers of varied shades of gray that give a thinly striped appearance. Much of the unit is coarsened owing to proximity of granitic rocks, and calcite crystals are in places as large as 1 to 2 mm across. In the largest area of outcrop, east of Lead Canyon, the impressively striped character is not present everywhere, and the limestone is, in part, finer grained and massive. Here also, thin lenses and interbeds of argillaceous and silty material—weathering light gray, gray, orange, and pale red—give the rock a distinctive nodular appearance. The thinly striped limestone associated with these rocks, however, leaves little doubt that the limestone here is also part of the Mule Spring Limestone, although isolated outcrops could be confused with some of the overlying Monola Formation.

The outcrops east of the Inyo crest also contain spherical concretionary masses, as large as 1 inch across, that are probably algal structures (*Girvanella*?). None of these algal structures were found west of Side Hill Spring, however.

The Mule Spring Limestone and the previously described Saline Valley and Harkless Formations contain Lower Cambrian fossils to the north, where these units have been studied in detail by Nelson (1962). All three formations in the Independence quadrangle are correlative with Nelson's units and are considered to be Lower Cambrian, although except for the possible algal structures in the Mule Spring Limestone, no fossils have been found in the quadrangle.

MONOLA FORMATION

The Monola Formation was named by Nelson (1965) for exposures in the Waucoba Mountain quadrangle. In the Independence quadrangle correlative rocks form a nearly continuous but considerably faulted arcuate belt of outcrop from the north boundary of the quadrangle to the area of Seep Hole Spring. These rocks conformably overlie the Mule Spring Limestone and are in turn conformably overlain by the Bonanza King Dolomite. A thickness of about 1,250 feet was measured about 2 miles west of Side Hill Spring. In the north-trending broad belt of outcrop south of Waucoba Canyon older formations are included in the area mapped as Monola.

Outcrops of the Monola Formation are easily recognized because they weather brown in contrast to the gray and white carbonate rocks both above and below them. This unit is an interbedded sequence of thinly laminated to very thin bedded siltstone, shale, and limestone. On the basis of the varying proportions of these rock types, the formation can be divided into four members. The lowermost member is dominantly medium- to dark-gray siltstone and shale that weathers brown and reddish brown. The clastic rocks are laminated to very thin bedded and are interlayered with minor amounts of gray laminated limestone. Overlying is a member in which medium-gray limestone in ½- to 4-inch beds predominates over red-brown-weathering siltstone. In part, this unit forms low bluffs. The next overlying member is also dominantly siltstone and shale much like the lowermost member. The uppermost member has a predominance of medium-gray to bluish-gray limestone in nodular, irregular layers ranging from a fraction of an inch to several inches thick. Interlayered are irregular silty lenses which weather pale to dark yellowish orange. The combination of these two lithologies gives the upper member a pronounced blue and gold mottled appearance, which is very striking. The members vary in thickness, but approximate average thicknesses along the two measured sections west of Side Hill Spring are as follows: lower siltstone member, 350 feet; lower limestone member, 320 feet; upper siltstone member, 330 feet; upper limestone member, 250 feet. These members have been recognized throughout the outcrop area of the formation but have been only in part delineated on the geologic map because further work is needed to show their distribution, particularly on the structurally complex east slope of the Inyo range.

The siltstone layers locally exhibit well-defined crossbedding and slump structures. Ripple marks are present on some outcrops.

Identifiable fossils have not been found in the Monola Formation of the Independence quadrangle. This formation is assigned a Middle Cambrian age on the basis of fossils identified in lithologically correlative rocks a short distance north of the quadrangle (Nelson, 1965). Trilobite fragments have been found locally in shaly beds, and pelmatozoan debris has been found in limestone. Fucoidal markings are locally abundant along shale bedding planes, and questionable spheroidal objects, as large as half an inch at some outcrops, may be algal structures (*Girvanella?*).

These Middle Cambrian rocks have been tentatively assigned to the Cadiz Formation by some workers in the Inyo Mountains; these rocks are probably, at least in part, equivalent to the Cadiz as originally defined from exposures in the Providence and Marble Mountains of southeastern California by Hazzard and Mason (1936, p. 230). More recently, the term Carrara Formation has been used by Cornwall and Kleinhampl (1961) for lithologically similar strata in the Beatty, Nev., area, about 75 miles east of Independence. The Carrara Formation, however, also includes Lower Cambrian strata and probably encompasses the Mule Spring and possibly part of the Saline Valley as well as the Monola of the Inyo Mountains.

BONANZA KING DOLOMITE

The Bonanza King Formation was named by Hazzard and Mason (1936, p. 234) from the Bonanza King mine in the Providence Mountains of southeastern California, and it is a widespread and distinctive unit in the southwestern part of the Basin and Range province. The formational name Bonanza King Dolomite is here applied to correlative rocks in the Inyo Mountains because lithologies other than dolomite are extremely scarce. (Code of stratigraphic nomenclature, 1961, art. 15, p. 654). This formation crops out in a broad arcuate belt from the North boundary of the quadrangle to the vicinity of Barrel Spring. South from there, the outcrop tails off to a thinner belt that extends nearly to the mouth of Mazourka Canyon. About 2,800 feet of strata was measured in a section east of the Bluebell mine where the Bonanza King conformably overlies the Monola Formation and is in turn conformably overlain by the Lead Gulch Formation.

Dolomite, in various colors and shades of gray, banded in layers from a few inches to a few tens of feet thick, exhibits a conspicuous "zebra striping" that is the most distinctive feature of the Bonanza King Dolomite in the field. The formation is almost exclusively dolomite, but locally a few thin beds of limestone, as well as slightly argillaceous dolomite layers, are present. Black chert in nodules and beds as much as 1 foot thick is also found locally. Metamorphic minerals—including phlogopite, tremolite, and forsterite—are sprinkled through much of the apparently unmetamorphosed dolomite, evidence attesting to impurities in the dolomite that have been reconstituted by the contact action of the nearby granitic rocks.

The Bonanza King Dolomite comprises a variety of lithologies, some of which are distinctive and unique to this formation in the Independence area. Commonly coarse-grained white dolomite in anastomosing thin layers and veinlets in a dark-gray finer grained dolomite matrix gives a distinctive irregularly bedded appearance. In places, coarse-grained white dolomite makes up the matrix of a breccia consisting of dark-gray angular fragments of dolomite. Another distinctive rock type is a mottled or dappled gray dolomite containing generally lighter gray patches or streaks in a darker gray groundmass, but the reverse is also found. Fucoidal markings are commonly associated with this lithology. Extremely thinly laminated dolomite, which generally splits into slabs or flags, is also present.

Along the measured section, it was possible to break the formation into five members, chiefly on the basis of color difference—that is, on the proportion of light-gray to darker gray color bands. The lowermost member is about 500 feet thick, and darker shades of gray predominate in this unit, which is not as obviously color banded on the aerial photographs as the overlying unit. Throughout this lowermost member, algal structures (*Girvanella*?) from 5 to 25 mm across are present, and in places fucoidal markings, some filled with coarse-grained dolomite which tends to weather out and leave irregular holes, are also abundant. Algal structures (*Girvanella*?) (fig. 6) are also common in the lower part of the formation elsewhere in the area.

The second unit is about 1,000 feet of predominantly lighter gray dolomite and appears as a distinctly striped unit on the aerial photographs. Fucoidal layers are locally abundant. Above the lighter dolomite unit is a third unit of about 600 feet of mostly color-banded dolomite in which darker gray shades predominate. Algal structures (*Girvanella*?) are also present in the upper part of this unit, but not as abundantly as in the lowermost member. Above this third unit is a fourth unit of about 500 feet of somewhat lighter gray-

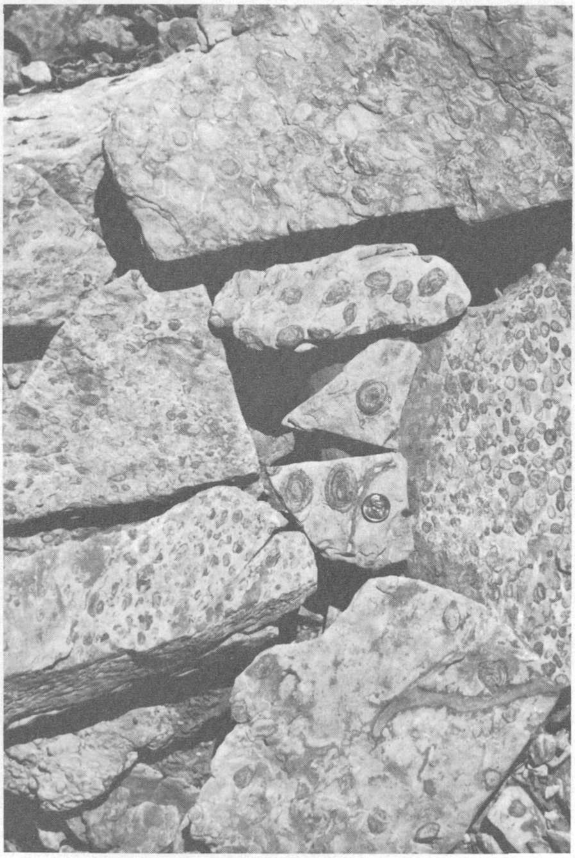

FIGURE 6.—*Girvanella*? in the Bonanza King Dolomite northeast of Badger Flat. Penny near center of photograph for scale.

striped dolomite in which some thin chert beds are found near the base. The uppermost 200 feet of the formation, in contrast to the well-bedded striped dolomite below, is commonly massive and poorly bedded and forms bold craggy yellow-weathering outcrops. Though coarse-grained and sugary dolomite is found elsewhere in the formation, it is much more common in this unit. Locally, but not along the measured section, oolites are present near the top of the formation.

South of the measured section, a distinctive black dolomite zone many feet thick marks the break between the massive uppermost member and the underlying striped sequence. This black dolomite is an excellent marker bed, and it can be traced for several miles to the south. Where it has been delineated on the geologic map, it is shown as a dotted line. Apparently this marker bed lenses out to the north, as it was not recognized along the measured section.

The algal structures (*Girvanella*?) and the fucoidal markings, which in part resemble worm trails, were the only organic evidence found in this formation. The formation is underlain by rocks that are correlative with the fossiliferous Monola Formation (Middle Cambrian) a few miles north of the quadrangle and is overlain by a formation that contains an Upper Cambrian fauna. The nearest correlative rocks that have been described in the literature belong to the Racetrack Dolomite in Racetrack Valley about 30 miles to the southeast (McAllister, 1952, p. 8), but these rocks are unfossiliferous. Recent work at the Nevada Test Site and nearby areas in southern Nevada about 100 miles east of the Independence quadrangle indicates the assignment of most of the Bonanza King Formation to the Middle Cambrian, but the uppermost part is considered to be Late Cambrian (Barnes and Palmer, 1961, p. C–103). A similar age range is tentatively assumed in the Independence quadrangle.

LEAD GULCH FORMATION

The Lead Gulch Formation was named for exposures along Lead Gulch in the Independence quadrangle (Ross, 1963, p. B74). It crops out as a thin relatively continuous though faulted and folded belt from the north edge of the quadrangle south to the latitude of Independence.

The maximum thickness of the formation is probably about 300 feet, although accurate thicknesses are impossible to obtain in this relatively incompetent unit. At several localities the formation is thinned markedly or entirely squeezed out by more competent dolomite formations. The overlying beds are undoubtedly conformable. The underlying beds are presumably also conformable, but structural contortion along the contact makes this presumption less certain.

The Lead Gulch Formation has a varied lithology of limestone, siltstone, dolomite, chert, and shale in a regularly interlayered sequence of beds from ½ inch to 5 inches thick. Dominant are distinctive outcrops of blue-gray to medium-gray limestone and thinly laminated siltstone that weathers in relief to bright orange and reddish tints. Olive-brown to dark-green shale, or its metamorphic equivalent, is as thick as 20 feet at the base of some sections.

About 2 miles northeast of Pops Gulch, a fossil collection was made which included agnostid trilobites, acrotretid brachiopods, and echinoderm parts. The trilobite genera *Homagnostus* and *Pseudagnostus* were identified by A. R. Palmer (written commun., 1961), who assigns these beds to the Upper Cambrian on the basis of the trilobite *Homagnostus*, which he considers a characteristic trilobite in faunas from the lower part of the Nopah Formation elsewhere in the Basin and Range province. Acrotretid brachiopods and unidentifiable trilobite fragments have also been found at other localities. The formation appears to be correlative with the limy and shaly unit that is a widespread fossiliferous regional marker at the base of the Nopah Formation. The Lead Gulch Formation may also be equivalent to the Dunderberg Shale and to rocks assigned to the lower part of the Catlin Member of the Windfall Formation of the Nevada Test Site (Barnes and Byers, 1961, p. C–103).

TAMARACK CANYON DOLOMITE

The Tamarack Canyon Dolomite was named for exposures within the Independence quadrangle (Ross, 1963, p. B77), and its distribution parallels that of the Lead Gulch Formation.

The thickness of the unit is about 900 feet. Where thickness variations exist in the quadrangle, they probably are chiefly the result of folding and faulting. Both the overlying and underlying beds are conformable.

The rocks are dominantly laminated to thick-bedded very light-gray to medium-gray dolomite and weather normally to a monotonous gray surface. Commonly, outcrops that seem to be grossly thick bedded to massive are actually thin bedded on close observation; the bedding is brought out by a fluted weathered surface that accentuates subtle differences in the dolomite layers. Black chert, in nodules and nodular beds as much as a few inches thick, is scarce to abundant in the dolomite, but though widespread, the chert is absent in many outcrops. The dolomite is, in part, very coarse grained and dazzling white on fresh surfaces near granitic contacts.

Fossils have not been found in the Tamarack Canyon Dolomite, but it is tentatively considered to be Late Cambrian and to be a correlative of Nopah Formation (Hazzard, 1937, p. 320) minus the lower shale and limestone of the Nopah that probably is a correlative of the Lead Gulch Formation. Although the Tamarack Canyon is in the proper stratigraphic position to be a Nopah correlative and has a grossly comparable lithology, the Tamarack Canyon lacks the conspicuous color banding so typical of the Nopah in most other areas.

ORDOVICIAN

The Ordovician rocks of the Independence quadrangle (fig. 7) are considered to be part of the transitional assemblage of the Great Basin, although they are both lithologically and geographically close to, the eastern or carbonate assemblage (Roberts and others, 1958, p. 2817). The only known exposures of similar rocks to the northwest extend north from the Independence quadrangle for a strike length of less than a mile along the south edge of the Waucoba Mountain quadrangle, where they have been mapped by C. A. Nelson (written commun., 1960). Metamorphism and faulting have affected these rocks, and also they are cut off by the north tip of the large Santa Rita Flat granitic mass.

MAZOURKA GROUP

Rocks that Phleger (1933, p. 2) described as the Mazourka Formation are separable into two units, the Al Rose Formation and the Badger Flat Limestone. The name Mazourka has been retained as a group name to include these two formations (Ross, 1963, p. B78).

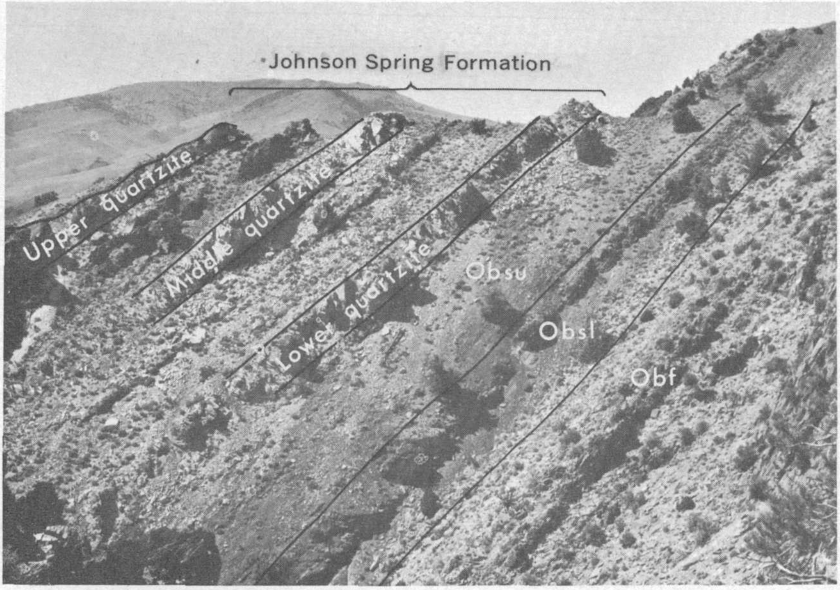

FIGURE 7.—Looking north at Ordovician section exposed about half a mile west of Johnson Spring. Formations shown from left to right are: Johnson Spring Formation; Barrel Spring Formation, upper member (Obsu) and lower member (Obsl); and upper part of Badger Flat Limestone (Obf).

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AL ROSE FORMATION

The Al Rose Formation, of Early Ordovician age, was named for exposures east of Al Rose Canyon, a tributary of Mazourka Canyon (Ross, 1963). The formation crops out as a relatively continuous but faulted belt along almost the entire length of the Independence quadrangle. To the north, the belt continues for about a mile into the adjacent Waucoba Mountain quadrangle, where it is cut off by Mesozoic granitic rocks and overlapped by Cenozoic deposits of Owens Valley. Southward, the belt of outcrop is also interrupted by Mesozoic granitic plutons, but at several places along the front of the Inyo Mountains east of Lone Pine, the distinctive lithology of the Al Rose Formation has been identified. The minimum length of the discontinuous belt of exposures is about 30 miles.

The thickness of the Al Rose Formation is difficult to determine accurately because the unit is relatively incompetent and, consequently, is folded and faulted, but I would estimate the average thickness to be about 400 feet. The base of the formation is commonly structurally disturbed or faulted out, but locally undisturbed parts of the contact that are at similar attitudes on both sides indicate that the Al Rose Formation conformably overlies Tamarack Canyon Dolomite. The overlying Badger Flat Limestone is also conformable on the Al Rose Formation.

Outcrops of the Al Rose Formation typically have orangish- to reddish-brown surfaces and are readily distinguishable from the overlying and underlying gray-weathering carbonate units. Siltstone, mudstone, shale, and—less commonly—chert, all of which are commonly hornfelsed, have very thing irregular bedding and are dominant in the formation. Medium-gray to bluish-gray generally silty limestone is subordinate to the reddish-weathering fine-grained clastic rocks. Commonly, the limestone occurs as elongate lenses which, being less resistant, weather back as holes or "eyes" in the outcrop. These "eyes" provide a very diagnostic weathered surface, particularly in hornfelsed outcrops.

The uppermost unit of the formation, which is about 50 feet thick, is a much more regularly interbedded sequence of 1- to 2-inch beds of gray limestone and light-brown-weathering shale and siltstone. In some areas this unit has a contrastingly darker brown outcrop than the rest of the formation. This unit, which bears an important graptolite fauna, is probably equivalent to unit 4 of the section of Langenheim and others (1956, p. 2087). The contact between the dominantly brown-weathering Al Rose Formation and the overlying blue-gray-weathering Badger Flat is one of the most easily recognized contacts in the Independence area.

Near the top of the Al Rose Formation, in the regularly bedded unit, graptolites have been collected from several localities and identified by R. J. Ross, Jr. (written commun., 1961) as *Didymograptus protobifidus* Elles and species of *Phyllograptus.* These are the first Early Ordovician fossils that have been reported from the Inyo Mountains and are considered by R. J. Ross, Jr. (written commun., 1961) to be of late Arenig age and to correlate with a horizon high in the Ninemile Formation of the Pogonip Group. Near the base of the Al Rose Formation trilobites and phosphatic brachiopods are also present, which suggest possible correlation with the Goodwin Limestone of the Pogonip Group (R. J. Ross, Jr., written commun., 1961). Examination of the section studied by McAllister in the Quartz Spring area, 30 miles to the east, suggests that his Pogonip units 4 through 7 (1952, p. 11) are equivalent to the Al Rose Formation. Similar comparison (fig. 8A) suggests equivalence of units "b" and "c" of the Pogonip Group in the Darwin area, 30 miles to the southeast (Hall and MacKevett, 1962, p. 8).

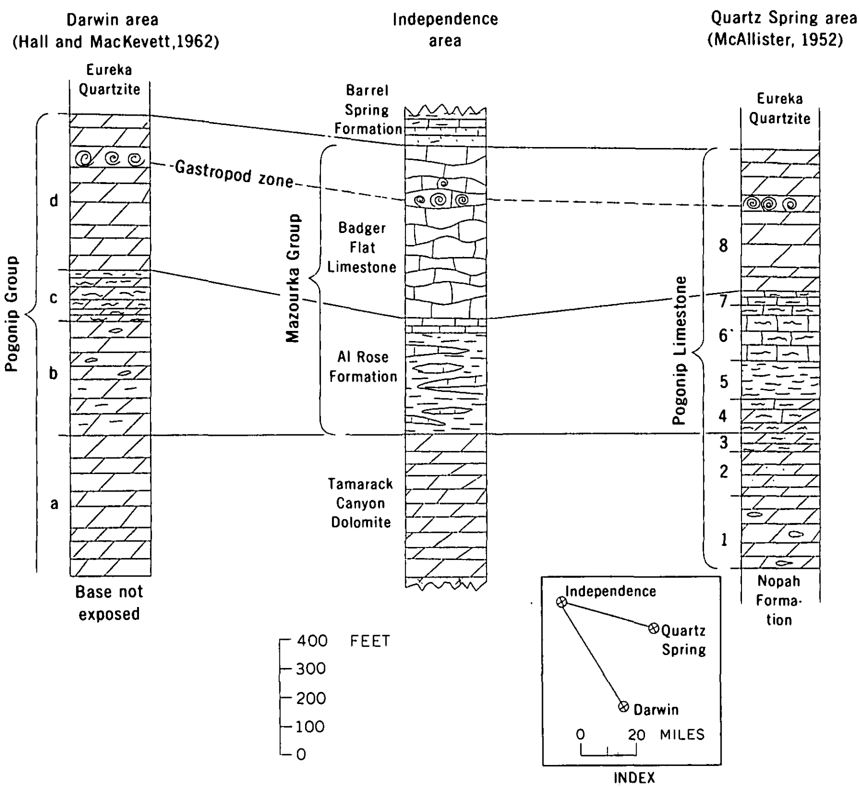

FIGURE 8.—Possible correlation of Pogonip Group of Quartz Spring and Darwin areas with the Mazourka Group of the Independence area.

BADGER FLAT LIMESTONE

The Badger Flat Limestone, of Middle Ordovician age, was named for exposures in and near Badger Flat (Ross, 1963, p. B80). The formation crops out in a faulted belt parallel to the Al Rose Formation.

The Badger Flat Limestone is about 600 feet thick. Some thickness variations variously due to structural complications and to original thickness differences, exist within the quadrangle, but the formation has a relatively constant thickness. The average thickness compares favorably with Phleger's (1933, p. 2) measurement of 550 feet for that part of his Mazourka Formation that is now the Badger Flat Limestone. Kirk's original description of about 500 feet of fossiliferous argillaceous limestone (in Knopf, 1918, p. 35) was probably also a description of the unit now called the Badger Flat Limestone. The Badger Flat rests conformably on the Al Rose Formation and is, in turn, conformably overlain by Phleger's (1933, p. 5) Barrel Spring Formation of Middle Ordovician age.

Outcrops of the Badger Flat generally weather to shades of gray and blue gray. The bluish color of outcrops is diagnostic of this formation, as is nodular irregular bedding. Dark- to medium-gray limestone is the dominant rock type. Almost invariably, specimens studied in thin section reveal an abundance of silty quartz grains scattered in a matrix of calcite grains. Thus, much of the limestone is calcarenite or calcilutite. Irregular lenses and beds of light-gray-, orange-, and reddish-brown-weathering silty and marly material occur in varying amounts throughout the formation. In outcrop, these more resistant layers distinctively weather out in relief as spines and ridges or as exotic irregular patterns. Black chert, both as nodules and nodular beds, is locally abundant, particularly in the lower part of the formation.

Fossils are notably abundant in the Badger Flat Limestone. In the interval from 100 to 200 feet below the top of the formation, gastropods, as large as 3 inches across, some of which belong to the genera *Palliseria* and *Maclurites*, are locally abundant enough to define a mappable unit. In this zone, *Palliseria robusta* Wilson, a guide to the Whiterock Stage of lowest Middle Ordovician, has been identified by E. L. Yochelson (written commun., 1961). This species is also present in the Antelope Valley Limestone of the Pogonip Group (E. L. Yochelson, written commun., 1961).

Brachiopods and trilobites have also been collected from several beds in the Badger Flat Limestone. Most abundant are the brachiopods *Plectorthis mazourkaensis* Phleger and *Plectorthis patula* Phleger (R. J. Ross, Jr., written commun., 1961). Pelmatozoan fragments are also widespread and abundant, and concentric structures, as large as half an inch across resembling the algal form *Girvanella*, are also present.

Comparison with the Quartz Spring area suggests correlation of the Badger Flat with unit 8 of the Pogonip (McAllister, 1952, p. 11). In the Darwin area, unit "d" of the Pogonip Group (Hall and MacKevett, 1962, p. 8) is probably also a Badger Flat correlative (fig. 8).

BARREL SPRING FORMATION

The Barrel Spring Formation was named by Phleger (1933, p. 5) from exposures along the east side of Mazourka Canyon. The type section of the formation was designated as Mexican Gulch, which is unnamed on the present topographic map, but is the first canyon north of Bonanza Gulch. The distribution of the formation parallels that of the underlying Mazourka Group. On Badger Flat and to the north, the Barrel Spring Formation is too thin to show separately on the map, so the unit is mapped with the Johnson Spring Formation. The same situation exists north of the Snowcaps mine near the mouth of Mazourka Canyon.

A maximum thickness of about 200 feet of beds are exposed south of Barrel Springs. From this maximum near the center of the outcrop belt, the formation thins southward to about 70 feet in Willow Springs Canyon and thins northward to less than 100 feet in the vicinity of Badger Flat. The thinning to the north may be due in part to faulting. Contacts with the underlying and overlying units appear to be conformable.

The type section of the Barrel Spring at Mexican Gulch consists of three members. A basal unit of impure sandstone and limestone about 50 feet thick is overlain by about 30 feet of medium-gray nodular bedded limestone, which contains abundant light-brown-weathering silty lenses. The upper member is dark-gray shale and mudstone, about 80 feet thick, and forms a most distinctive reddish-brown-weathering unit. Brachiopods, trilobites, and graptolites are found near the base of this upper unit. The threefold division of the formation can be traced north from Mexican Gulch for almost a mile, but elsewhere in the area the formation is most easily divisible into only two members. The lower two units of the type section combine to form a light-colored sandy and calcareous mixture, which is commonly hornfelsed. The light-colored lower unit appears to lens out both to the north and to the south, but the upper red-brown-weathering unit is persistent.

The age and correlation of the Barrel Spring Formation is at present problematical, but I tentatively consider the formation to be Middle Ordovician. Phleger (1933, p. 6), in his original description of the unit, was hesitant to assign an age to the formation because of the paucity of the fauna, but he did suggest a Trenton age, though with reservations. According to the Ordovician correlation chart (1954, p. 263), W. H. Twenhofel believed the Barrel Spring fauna to be of Richmond age, whereas G. A. Cooper believed the Barrel Spring to extend down to and include beds of Black River age. Langenheim and others (1956, p. 2092) believed the formation to be Mohawkian in age.

JOHNSON SPRING FORMATION

The Johnson Spring Formation was named by Pestana (1960, p. 862) for exposures along the east side of Mazourka Canyon. He designated as the type section, the Lead Canyon Trail section, which is located about three-fourth of a mile east of Johnson Spring at the east end of a mine road which branches east off the Mazourka Canyon road about 2½ miles north of Squares Tunnel. The formation rests upon and parallels the trend of the Barrel Spring Formation along the east side of Mazourka Canyon for nearly the entire length of the quadrangle. Both the overlying and the underlying beds appear to be conformable.

The thickness of the formation ranges from about 400 feet in Willow Springs Canyon to about 100 feet south of Badger Flat. Even thinner sections were observed north of Badger Flat, but these sections may be faulted. At the type section the formation is slightly more than 200 feet thick.

The Johnson Spring Formation is characterized by a variety of rock types and by lenticularity; white vitreous quartzite is conspicuous and in many sections is dominant. Limestone and dolomite are somewhat less abundant in the formation as a whole, but in some sections, these rocks are more abundant than quartzite. Siltstone, impure quartzite, and shale are also locally abundant, particularly in the lower part of the formation. In general, the proportion of quartzite increases southward from the type section. No one section can be classed as truly typical because of the variability of the formation, but the section designated by Pestana (1960, p. 862–863) as his type does show the lithologic variety of the formation very well. This section, if generalized, consists from the base upward of: (1) 35 feet of white to yellowish quartzite which is somewhat crossbedded and contains some calcareous cement, (2) 39 feet of siltstone, sandy dolomite, and quartzite in a reddish-brown belt of outcrop, (3) 26 feet of dark-gray limestone in nodular beds, (4) 34 feet of white vitreous quartzite; (5) 47 feet of dark-gray nodular limestone containing black chert nodules and coral and other fossil fragments, (6) 20 feet of dark-gray massive dolomite, and (7) 17 feet of white vitreous quartzite.

The stratigraphic position of the Johnson Spring Formation and the lithologically distinct vitreous white quartzites that define its upper and lower contacts leave little doubt that the formation is at least in part correlative with the widely known Eureka Quartzite. However, the abundance, and in some sections predominance, of rocks other than quartzite makes a local formational name advisable in order to call attention to the lithologic change from the "typical" Eureka Quartzite. The name Johnson Spring Formation, as proposed by Pestana (1960, p. 862), fulfills this need.

Fossils have been collected from some of the carbonate units in the Johnson Spring Formation and described by Langenheim and others (1956, p. 2093) and by Pestana (1960, p. 863). Corals are most abundant, but sponges, bryozoans, brachiopods, pelecypods, and gastropods, as well as pelmatozoan fragments, are also described. On the basis of the coral fauna, Pestana (1960, p. 864) suggested a Trenton age for the Johnson Spring Formation. I therefore tentatively consider the Johnson Spring to be of Middle Ordovician age.

ELY SPRINGS DOLOMITE

The Ely Springs Dolomite was named by Westgate and Knopf (1932, p. 15) from exposures in the Ely Springs Range near Pioche, Nev. In the Independence quadrangle, it crops out as a nearly continuous band from north of Badger Flat to the area of Barrel Springs. From there south, the outcrop is faulted into segments, paralleling outcrops of the Johnson Spring Formation, which lies conformably beneath the Ely Springs Dolomite. The contact with the overlying Silurian rocks, where there is a pronounced faunal break, as well as a distinctive lithologic change, shows no obvious break in deposition.

The maximum thickness of the formation is about 500 feet along Willow Springs Canyon. Northward, the formation thins to about 200 feet south of Badger Flat. Further thinning to the north is suspected, but faulting obscures the true stratigraphic relations.

Throughout the area the Ely Springs can be divided into three members. These units were distinguished in some areas during the mapping and in measured sections, but map scale precludes such detail to be shown on the geologic map. The lower unit is medium- to dark-gray dolomite in thin-bedded nodular layers that are interbedded with nodules and nodular layers of black chert. Locally, chert makes up as much as 30 percent of the unit. In Willow Springs Canyon, this member makes up 300 feet of the 500-foot formation; farther north, the lower member makes up from a third to a half of the formation. The next overlying unit is medium- to light-gray thick-bedded dolomite in which thin beds are locally present. The general appearance of outcrops is massive and light colored in contrast to the darker thinner bedded lower unit. In Willow Springs Canyon about 130 feet of the 500-foot section is made up of this massive middle member, which farther north varies from a fourth to a half of the formation. The upper unit is a combination of dark-gray and light-gray dolomite layers which are characteristically associated with black chert both as nodules and nodular beds and as massive black chert beds several feet thick. This unit is as much as 120 feet thick but is more commonly about 30 feet thick. Generally, it is capped with 5 to 20 feet of massive black chert which, in some sections, defines the top of the formation. In other sections, however, gray dolomite overlies the massive chert unit, and I have included this dolomite in the Ely Springs.

About 1 mile south of Badger Flat, in a distance along strike of less than a mile, the lower cherty dolomite member changes northward to massive black chert. North of Badger Flat, a similar change occurs in the upper member, and the formation comprises a basal massive chert, an intermediate gray dolomite, and a capping massive chert. Though this facies, so different from the typical Ely Springs, should logically be given a new formational name, it is not practical to do so because of the very small outcrop area of these rocks. The metamorphosed and faulted chert-rich outcrops referred to the Ely Springs in sec. 15, T. 11 S., R. 35 E., are the northwesternmost recognized exposures of the formation.

No diagnostic fossils have been recovered from the Ely Springs in the Independence area; although some coral fragments are present, and pelmatozoan debris is locally abundant. Langenheim and others (1956, p. 2095) reported poorly preserved *Streptelasma* sp. On the basis of lithologic comparison with areas where the Ely Springs has been dated by fossils, the Ely Springs is considered to be Upper Ordovician in the Independence area. Correlation of the lower two members with the basal dark-gray cherty dolomite and the overlying massive lighter gray dolomite of western Great Basin Ely Springs, as exemplified at Quartz Spring (McAllister, 1952, p. 13) and Darwin (Hall and MacKevett, 1962, p. 11), seems justified. On the other hand, the correlation of the upper cherty member is somewhat problematical. Though it is more clearly related to the underlying members of the Ely Springs than to the overlying shaly limestones of undoubted Silurian age, cherty dolomite is also present in the lower part of the Hidden Valley Dolomite as exposed in the Quartz Spring area (McAllister, 1952, p. 15). The three members of the Ely Springs Dolomite in the Independence area belong together as a mappable unit, even if in the future the upper member should prove to be Silurian rather than Late Ordovician in age.

SILURIAN

Two facies of Silurian rocks are present but neither is like the Hidden Valley Dolomite (McAllister, 1952, p. 15), which represents the Silurian elsewhere in the western part of the Great Basin. In the southern part of the Independence quadrangle, the Silurian consists of thin-bedded argillaceous limestone and bioclastic limestone rich in coral, sponge, bryozoan, and pelmatozoan debris. Northward this facies grades laterally to a sequence of graptolite-bearing calcareous shale, siltstone, and argillaceous limestone which is penetrated by tongues of bioclastic limestone of the coral-rich facies.

VAUGHN GULCH LIMESTONE

The Vaughn Gulch Limestone was named (Ross, 1963, p. B81) for exposures north of Vaughn Gulch, a small tributary to Owens Valley near the mouth of Mazourka Canyon. Discontinuous outcrops extend for about 7 miles along the front of the Inyo Mountains and up into Mazourka Canyon. The formation is terminated on the south by faulting and granitic rocks and on the north by the encroachment of the graptolite facies. At the type section, on the ridge north of Vaughn Gulch, the thickness is about 1,500 feet. Beds of the Ely Springs Dolomite are conformably overlain by the Vaughn Gulch, but the overlying Perdido Formation of Mississippian age rests with erosional unconformity on the Vaughn Gulch.

The Vaughn Gulch Limestone is dominantly thin-bedded limestone, much of which is argillaceous. Generally, the limestone is medium to dark gray and much has a bluish cast. Bioclastic limestone, crowded with fragments of corals, sponges, bryozoans, and pelmatozoans, is the most diagnostic rock of the formation. Somewhat more silty layers are subordinate and tend to weather to shades of yellow, orange, and red. Black chert in nodules and thin beds is common near the top of the formation and somewhat less common near the base.

The abundance of fossils near Vaughn Gulch was first noted by Kirk (in Knopf, 1918, p. 36–37), who at that time referred the beds to the Devonian. More recently, Waite (1953, p. 1521) concluded that faunal elements from this section preclude a Devonian age. He listed *Conchidium*, *Pycnostylus guelphensis* Whiteaves, *Atrypina*, cf. *A. disparilis* (Hall), and *Rhizophyllum*—a characteristic Silurian genus. Waite concluded that these fossils indicate a late Niagaran or early Cayugan age.

C. W. Merriam also made collections from the Vaughn Gulch Limestone, and he states (1963, p. 13):

> The faunas consist very largely of corals, only *Atrypa* and rhynchonellids (*Eatonia bicostata* Stauffer) being at all common among the brachiopods. The

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large dasycladacean algae (*Verticillopora annulata* Rezak) are most prolific here and provide a tie with the Hidden Valley of the type area as well as with the Roberts Mountain formation of central Nevada and the Laketown dolomite of western Utah.

Among corals of the limestone facies at Mazourka are many conforming to the general features of *Strombodes*. Others are assigned to *Chonophyllum*, *Rhizophyllum*, *Heliolites*, *Alveolites*, and *Cladopora*. Also present are large cyathophyllids and bushy forms of the *Phacelophyllum* and *Dishyphyllum* types.

SUNDAY CANYON FORMATION

The Sunday Canyon Formation was named for a small tributary of Mazourka Canyon about 1 mile west of the belt of the Silurian outcrop (Ross, 1963, p. B83). The formation crops out in a relatively continuous band from Water Canyon north for about 7 miles to a point north of Badger Flat, where it was presumably removed by erosion prior to the deposition of the overlying Mississippian beds. At the type section in Bonanza Gulch, it is 683 feet thick—the maximum exposed thickness of the formation. The Sunday Canyon Formation rests with apparent conformity on the Ely Springs Dolomite and is overlain unconformably by clastic rocks of the Perdido Formation of Mississippian age.

The Sunday Canyon Formation is an intermixed sequence of calcareous siltstone, calcareous shale, and argillaceous limestone. Outcrops are typically thin bedded, and they yield shaly to flaggy fragments which characteristically weather to slopes that are mostly light gray mixed with tints of yellow and orange. Tongues of bioclastic limestone of the Vaughn Gulch facies are common near Bonanza Gulch, and some tongues persist as far north as Badger Flat.

Graptolites are the most distinctive fossils in the Sunday Canyon Formation, and they have been collected from several localities along almost the entire strike length of the unit. Most commonly graptolites are found in the lower part of the formation. R. J. Ross, Jr., studied them, and he reported the following species of *Monograptus* (written commun., 1960, 1961): *M. vulgaris* Wood, *M. vomerinus* Nicholson, and *M.* aff. *M. tumescens* Wood. These forms are considered to indicate a late Wenlock or early Ludlow age, or mid-Silurian of the Great Britain stages. Locally *Tentaculites* cf. *T. bellulus* occurs along with the *Monograptus* species (R. J. Ross, Jr., written commun., 1961).

MISSISSIPPIAN

PERDIDO FORMATION

The Perdido Formation was named by McAllister (1952, p. 22) for exposures in the Quartz Spring area. In the type area, the lower part of the Perdido is mostly limestone containing chert beds, whereas the upper part has a mixed lithology of clastic and carbonate rocks. On the basis of lithology, the rocks mapped as Perdido in the Independence area resemble only the upper part of the Quartz Spring section. However, significant facies changes from carbonate rocks in the Quartz Spring area to clastic rocks of some Ordovician and Silurian formations in the Independence area suggest that a similar change in the Perdido would be likely. Though exact correlation of the Perdido in the two areas is not demonstrable, the abundance of coarse clastic rocks and a shale formation overlying the clastic rocks in both areas suggest sufficient possibilities of original physical continuity to carry the name to the Independence quadrangle. The Perdido lies on an eroded surface of Silurian rocks (fig. 9), which means rocks representing an interval of time spanning part of the Silurian, all the Devonian, and probably part of the Mississippian are missing at this contact. The Perdido is conformably overlain by the Rest Spring Shale, and this contact is defined in the field as the top of the highest sandstone in the Perdido.

The thickness of the Perdido generally ranges from about 300 feet to more than 600 feet. Locally, the formation is thinner than 300 feet, as for example, a short distance north and south of Barrel Springs. The section may be thicker at the north end of the belt of outcrop, but faulting and poorer exposures there make accurate thickness determinations impossible. Individual units are lenticular, and at least one small erosional unconformity has been recognized within the formation.

Lithologic variety characterizes the Perdido. The abundance of clastic rocks, particularly sandstone and conglomerate, makes the Perdido a resistant rib of outcrop that stands in relief between bounding shale sections. Probably the most striking single feature of the formation is the abundance of chert occurring as fragmental material in the sandstone and conglomerate. Chert and quartzite make up most of the clastic fragments, though carbonate is common both as scattered fragments and in calcarenite layers. In some conglomerates, boulders of carbonate and quartzite—some well rounded and as large as several feet across—are present, but more commonly the largest fragments in the conglomerates are either pebbles or cobbles. Calcareous quartz sandstone, quartzite, and granule and grit beds of mostly chert fragments are also present. Dark-colored shale and, less commonly, siltstone are also abundant. Bedded black chert is locally abundant only near the base of the formation. Light-gray lenses up to 1 inch across and as much as 1 foot long are characteristic of the chert at several localities and serve as a diagnostic feature of the formation.

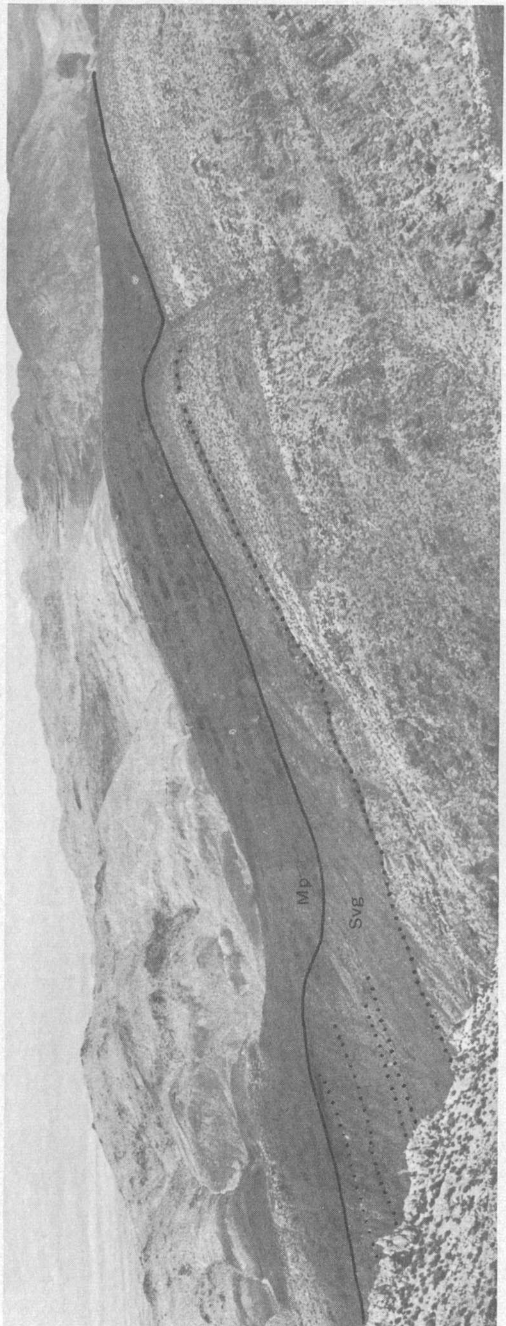

FIGURE 9.—Erosional contact of the Mississippian Perdido Formation (Mp) on the Silurian Vaughn Gulch Limestone (Svg), showing cutting out of Silurian layers. View looking west at north-northwest-trending spur northeast of Squares Tunnel in Mazourka Canyon.

Identifiable fossils have not been recovered from the Perdido, but fossil debris is locally abundant, particularly pelmatozoan fragments in some of the calcarenite. Trilobite fragments have also been found, and fucoidal markings are common in some of the shale. The Perdido is presumed to be Mississippian, as it is probably correlative with part of the fossiliferous Perdido, of Mississippian age, in the Quartz Spring area (McAllister, 1952, p. 24).

MISSISSIPPIAN AND PENNSYLVANIAN(?)

REST SPRING SHALE

The Rest Spring Shale was named by McAllister (1952, p. 25) for exposures in the Quartz Spring area. In the Independence quadrangle the formation crops out as a broad conspicuous dark-colored band, along much of Mazourka Canyon, and the Rest Spring underlies a large area west of Badger Flat. In addition, isolated faulted segments are present north and east of the site of Kearsarge. The underlying contact is gradational, and because it is defined by the absence of sandy lenses, the contact is not at the same precise stratigraphic level everywhere in the area.

The maximum thickness of the formation is presumably about 2,500 feet. Although the Rest Spring appears to be generally homoclinal, folding, lack of distinctive units, and poor exposure make thickness calculations somewhat doubtful where the section was measured east of Pops Gulch. Elsewhere, internal structure or complications along the contacts make thickness measurements meaningless.

In its type area, the Rest Spring Shale is only about 400 feet thick (McAllister, 1952, p. 26), though this may not be a true thickness because of the incompetence of the unit in the structurally complex Quartz Spring area. In the southern Inyo Mountains (New York Butte quadrangle), a shaly unit in the same part of the section—referred to by Merriam and Hall (1957, p. 4) as the Chainman Shale—is about 1,000 feet thick, but here also structural complications dictate caution in presuming a true thickness in the incompetent shale. Notwithstanding some doubt about the true thickness of the Rest Spring Shale interval, this formation appears to be much thicker in the Independence area.

Throughout most of its outcrop area, the Rest Spring Shale was originally a rather monotonous section of dark-gray to black shale, mudstone, and siltstone. Weathered surfaces are generally dark gray or desert varnished to dark-reddish brown, but some layers weather to light shades of gray. Most of the section is laminated or very thinly bedded, and parting is generally shaly to flaggy, though in places slabby to blocky outcrops are found. Contact metamorphism has had a widespread effect on the formation, and much, if not all, of the formation has been hornfelsed to some extent. Andalusite hornfels and rocks rich in sericite (at least, in part, the result of the alteration of andalusite) make up most of the formation. In the relatively homoclinal sequence west of Pops Gulch, the formation is more massive in the upper part, which is also nearest the Santa Rita Flat pluton. The massiveness is probably at least in part due to hornfelsing by the granitic intrusive rather than to original sedimentary character, as areas of thin bedding are locally preserved in the massive part of the section.

A single collection of cravenocerid goniatite fragments has been made from a black layer rich in carbonaceous material about 1,300 feet east-northeast of Johnson Spring. Though the genus of these fragments could not be identified, Mackenzie Gordon, Jr. (written commun., 1961), considered them to be Upper Mississippian (Chester). As these fossils were found about midway in the section, at least the lower half of the formation is Mississippian. At its type area, the Rest Spring Shale was given a Pennsylvanian (?) age assignment, but fossils were scarce and not definitive (McAllister, 1952, p. 26). In the Independence area, the Rest Spring Shale is best considered as Upper Mississippian, but the possibility of Pennsylvanian strata in the upper part cannot be ruled out.

PENNSYLVANIAN AND PERMIAN

KEELER CANYON FORMATION

The Keeler Canyon Formation was named by Merriam and Hall (1957, p. 4) for exposures in upper Keeler Canyon in the New York Butte quadrangle. The rocks assigned to it in the Independence quadrangle are lithologically similar to those of Keeler Canyon of the type area, but exact equivalence, particularly concerning the upper contact, is still in question. Keeler Canyon rocks crop out as an irregular band east of Santa Rita Flat and also as irregular discontinuous patches northwest of the Snowcaps mine. In both these areas, the formation forms the wallrock or is included as roof pendants in the Santa Rita Flat pluton. As a consequence, the Keeler Canyon is much contorted and contact metamorphosed. Another belt of outcrop trends south from Bee Springs to the border of the quadrangle; this belt is also disrupted by faulting and intrusion of the Pat Keyes pluton. On the basis of concordant attitudes near the poorly exposed contact north of Sunday Canyon, the Keeler Canyon presumably rests conformably on the Rest Spring Shale.

A reliable thickness estimate of the formation is impossible to obtain because faulting and igneous intrusion have not left any unquestionably complete section in the quadrangle. In sec. 33, T. 13 S., R. 36 E., a possibly complete section has a thickness of about 1,000 feet. This thickness should be regarded with suspicion, as the underlying considerably metamorphosed rocks are assigned to the Rest Spring Shale somewhat tentatively, and the contact might well be a fault. However, this thickness does represent a minimum for the Independence quadrangle.

From a distance, outcrops of the Keeler Canyon have a very distinctive thinly striped appearance. This striping is readily distinguishable from the "zebra striping" of the Bonanza King Dolomite, for the stripes in outcrops of the Keeler Canyon are much thinner and of more subtle shades of intermediate gray than the broader stripes that range in color from white to almost black in the Bonanza King. Probably the best place to observe these thin stripes is hill 6971, a prominent topographic feature west of the Mazourka Canyon road about 2 miles north of Squares Tunnel. Contact metamorphism, particularly along the range front northwest of the Snowcaps mine, has changed this distinctive rock into varicolored dark hornfels and tactite, but these rocks can be traced into the typically striped Keeler Canyon, which crops out north of the Green Monster mine.

Prior to metamorphism, rocks of the Keeler Canyon were dominantly thin-bedded gray limestone interbedded with dark-colored shale and siltstone. These rocks alternate in commonly laminated layers that range in thickness from a few inches to more than 1 foot. The proportion between limestone and fine-grained clastics varies, but limestone generally is greatly dominant, though commonly it is markedly clastic. Some clastic beds contain siliceous pebbles as large as one-half an inch across and finer grained siliceous sand-size material, though the dominant clasts are carbonate in most clastic layers.

Near the base of the formation, generally in the lower 200 feet, spherical to ellipsoidal black chert nodules from ½ to 2 inches in diameter are scattered to abundant (fig. 10), generally in a dark- to medium-gray limestone matrix. These beds are a widely recognized marker near the base of the Keeler Canyon Formation and are generally referred to as the "golf ball beds," an apt name for this distinctive regional marker.

In the type area only a few miles southeast of the Independence quadrangle, the formation contains abundant fusulinids. In the Independence area, however, none have been found. Outcrops of Keeler Canyon are almost everywhere adjacent to large granitic masses, and the effects of contact metamorphism have apparently included the recrystallization of any fusulinids beyond recognition. Undoubtedly, fusulinids were present in these rocks, as fusulinid-looking shapes—without any internal structure—have been found. In

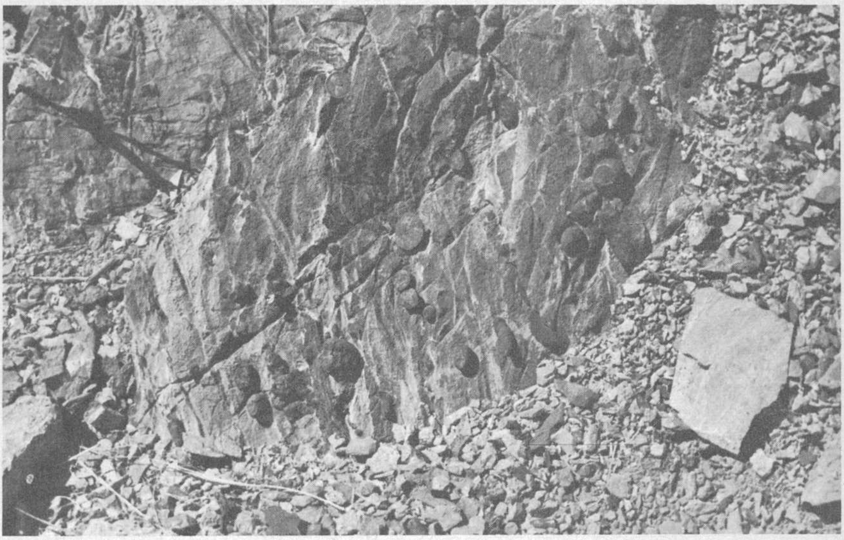

FIGURE 10.—Spherical to ellipsoidal chert nodules ("golf balls") in limestone near the base of the Keeler Canyon Formation southeast of Santa Rita Flat. Penny for scale near top of photograph.

accordance with the usage of Merriam and Hall (1957, p. 7), the Keeler Canyon of the Independence quadrangle is tentatively assigned a Pennsylvanian and Permian age.

PERMIAN

OWENS VALLEY FORMATION

The Owens Valley Formation was named by Merriam and Hall (1957, p. 7) for exposures along the west slope of the Inyo Mountains in the Lone Pine quadrangle. In the Independence quadrangle, rocks tentatively assigned to this formation crop out discontinuously for about 3 miles south from Bee Spring along the front of the Inyo Mountains. In addition, similar rocks underlie a small hill near Kearsarge on the south side of the Mazourka Canyon road. The contact of the Owens Valley Formation with the underlying Keeler Canyon Formation shows a remarkable color contrast when viewed from a distance or when seen on aerial photographs. On close observation, in a few places where the Owens Valley is well exposed, the actual contact is somewhat arbitrary. The attitudes near the contact are concordant or no more divergent than would be expected, if one considers the variable attitudes within the two formations near the contact. The beds at this contact appear to be conformable, though the evidence is not conclusive. In the New York Butte quadrangle, the Owens Valley

Formation rests with local angular unconformity upon the Keeler Canyon Formation, but this unconformity was not recognized in the Darwin quadrangle (Merriam and Hall, 1957, p. 6, 8).

Less than 2 miles south of the quadrangle boundary, fossiliferous sedimentary rocks of Early Triassic age overlie the Owens Valley Formation unconformably (Merriam and Hall, 1957, p. 10). These overlying rocks extend into Owens Valley and, along with an unknown thickness of the upper part of the Owens Valley Formation, are not exposed in the Independence quadrangle. The lower exposed part of the Owens Valley Formation in the Independence area exceeds 1,000 feet in thickness, and possibly is as thick as 1,500 feet. Merriam and Hall (1957, p. 6) report a thickness of about 2,000 feet for the formation in the Inyo Mountains southeast of the quadrangle.

The Owens Valley Formation in the Independence quadrangle comprises two lithologic members: a lower fine-grained clastic and in part marly unit now intensely hornfelsed and an upper coarse clastic unit, the Reward Conglomerate Member. Weathered outcrops of these units have very distinctive colors, which serve to distinguish them from the underlying Keeler Canyon Formation. The fine-grained lower member weathers to a rather uniform reddish brown despite the wide range of colors in the fresh rock. The coarse clastic upper unit weathers very dark brown to almost black, as it appears to be particularly susceptible to desert varnish.

The lower unit, which is at least 1,000 feet thick, is composed of dense aphanitic hornfels in a variety of colors, chiefly shades of gray and green. Much of the hornfels is laminated to very thin bedded. Minor sandy layers are present in the hornfels sequence, and near the top of the unit there is some interbedding with coarser clastic rocks. Probably this unit originally was chiefly shale, siltstone, and marl. Near the contact with the overlying coarse clastic rocks, marble layers are present on the hill west of Coyote Spring. The scarcity of carbonate layers or metamorphosed carbonate layers in the Independence area is in marked contrast to the Owens Valley Formation in the Lone Pine quadrangle a few miles to the south, where carbonate layers are abundant (Merriam and Hall, 1957, p. 6). Limestone also is abundant in this formation farther southeast in the Darwin quadrangle (Hall and MacKevett, 1962, p. 26), a fact that suggests that this formation, as well as several others, in the Independence quadrangle has a higher proportion of clastic rocks than is present to the southeast.

The upper unit, of which a thickness of probably 500 feet or less is exposed in the Independence quadrangle, is dominantly a coarse clastic unit composed of sand, pebble, and cobble-size material. Most of the clasts are quartzite or chert, which are commonly well rounded, particularly the larger fragments. The largest cobble measured was about 4 inches in maximum dimension. Some dense hornfels layers are interbedded with the coarse clastics. This unit was first described by Kirk (in Knopf, 1918, p. 42–43) as the Reward Conglomerate. Merriam and Hall (1957, p. 10) found the unit to be lenticular and reduced it to a member. As it is a distinctive map unit in the Independence quadrangle, the name Reward Conglomerate Member is applied to this unit.

No fossils have been found in the Owens Valley Formation, and considering the hornfelsed condition of the rocks, it is unlikely that any will ever be found. Fusulinids, brachiopods, mollusks, and corals, indicating a Permian age, have been recovered from much less metamorphosed beds a few miles south of the quadrangle (Merriam and Hall, 1957, p. 11).

MESOZOIC GRANITIC ROCKS

About half of the bedrock exposed in the quadrangle consists of granitic rocks in four large plutons, three of which are of batholithic proportions, if their known extension into adjacent areas is considered. These granitic plutons are probably part of the composite Sierra Nevada batholith.

PAT KEYES PLUTON OF THE HUNTER MOUNTAIN QUARTZ MONZONITE

The Pat Keyes pluton of the Hunter Mountain Quartz Monzonite underlies about 15 square miles in the southeast corner of the area and extends for about an additional 35 square miles to the south and east. A separate but presumably correlative mass intrudes Lower and Middle Triassic sedimentary rocks a few miles south of the quadrangle boundary in the New York Butte quadrangle (W. C. Smith, written commun., 1963). Generally, the wallrock contacts are steep and sharp.

The field relations of the Pat Keyes pluton and its petrographic features indicate the pluton to be correlative and, beneath Saline Valley, probably physically continuous with the batholithic mass named the Hunter Mountain Quartz Monzonite by McAllister (1956). Similar granitic rocks crop out in the Darwin Quadrangle where Hall and MacKevett (1962, p. 29) have applied the name biotite-hornblende-quartz monzonite. These correlative rocks plus the continuation of the Pat Keyes Pluton into the adjoining Waucoba Wash and New York Butte quadrangles suggest a not yet fully unroofed batholithic mass that is comparable in size to some of the larger intrusive units in the Sierra Nevada.

Outcrops are generally intermediate shades of gray, but along the western margin of the mass, over a width of as much as 1 mile, the rocks are noticeably darker. Outcrops range from bold much fractured exposures in areas of rugged relief to boulder piles and scattered boulders partly submerged in coarse granitic sand. On many of the boulder-laden slopes it is difficult to determine whether the rocks are in place or whether they have been moved somewhat. The most conspicous feature of the entire mass is the pale-red-purple color of the K-feldspar, though this color is not everywhere evident in the darker western marginal zone.

Much of the body is equigranular and has a grain-size range of about 2 to 4 mm. Commonly, it is weakly porphyritic or seriate, containing reddish K-feldspar crystals as large as 10 to 15 mm. The texture is granitic, and most grains are anhedral, though plagioclase and hornblende are in part subhedral to euhedral. The K-feldspar phenocrysts, though seemingly euhedral in hand specimen, are seen in thin section to have mostly irregular poikilitic margins.

Dark-colored fine- to medium-grained dioritic inclusions, rich in plagioclase and dark minerals, are scattered throughout the mass and locally are as abundant as 3 to 6 per square yard of exposure. Most are ellipsoidal and a few inches in maximum dimension; some are as large as 2 feet across. At none of the visited outcrops did these inclusions define a noticeable foliation.

The composition of the pluton ranges from quartz monzonite to diorite, but quartz monzonite and granodiorite are greatly dominant. Based on 40 modal analyses, the average is about: plagioclase (oligoclase-andesine), 43 percent; K-feldspar, 23 percent; and quartz, 15 percent. Thus the average modal composition falls about on the boundary between the quartz monzonite and granodiorite fields. The percentage of dark minerals ranges from about 10 percent to almost 30 percent, and, in general, biotite and hornblende are present in about equal amounts or hornblende is slightly in excess. In the dark-colored western margin, the variations in biotite and hornblende percentages are more erratic, and also a few percent of pyroxene are present; rarely as much as 20 percent of the rock is pyroxene. Metallic opaques (chiefly magnetite), sphene, apatite, zircon, and allanite also are present in small amounts.

The dark-colored western margin of the pluton is probably a border facies rather than a separate intrusive. Although in part diorite, this facies is dominantly dark granodiorite and quartz monzonite that grades eastward into the "normal" Pat Keyes lithology. Inclusions of metamorphosed calcareous rock, textural variations within the dark-colored zone, and the gradation eastward to "normal" quartz monzonite suggest that contamination by wallrock material has produced this dark-colored border zone. If so, the principal contamination occurred at some distance below the presently exposed sharp contacts, which do not suggest much contamination at the present level of exposure.

PAIUTE MONUMENT PLUTON

About 20 square miles of the east-central part of the quadrangle is underlain by rocks of the Paiute Monument pluton. This pluton also extends for a considerable distance into the adjoining quadrangles to the east and southeast, and a small stock of the pluton intrudes the Pat Keyes pluton. The relatively sharp and steep intruded walls of the Paiute Monument pluton consist of Cambrian and Ordovician metamorphosed sedimentary rocks and the Pat Keyes pluton. Though the intrusive relations with the Pat Keyes pluton are not clear cut within the quadrangle, about 1 mile east of the quadrangle boundary, dikes and inclusion relations indicate that the Paiute Monument pluton is the younger.

Outcrops are typically light gray and are characterized by impressive boulder piles—some boulders are as much as 50 feet across. Generally, boulders of the Pat Keyes pluton are much smaller, and their size serves as a means for distinguishing between these two masses, particularly from a distance. Large pale-red to pale-red-purple crystals of K-feldspar and the coarse-grain size of the rock in general make this an easily recognized rock unit in the field.

The rock has a texture that is distinctly coarse grained and seriate, containing reddish K-feldspar crystals as large as 25 mm across. Quartz and plagioclase crystals are as large as 10 mm, but range down to 3 to 5 mm across, the common size of the dark minerals. Most crystals are anhedral to subhedral, though plagioclase is commonly well formed. Most of the large K-feldspar crystals are prominently poikilitic and have ragged margins. Dioritic inclusions are not as common in this pluton as in the Pat Keyes pluton but are widespread and of about the same dimensions as those in the Pat Keyes pluton; these inclusions define no obvious foliation.

The average modal composition of the pluton based on 35 modes, most of which were obtained from stained slabs, is: plagioclase (calcic oligoclase), 35 percent; K-feldspar, 32 percent; quartz, 26 percent; biotite, 4 percent; hornblende, 1 percent; and other constituents, mostly metallic opaques but also including sphene, zircon, apatite, and allanite, 2 percent. The average composition is thus an intermediate quartz monzonite. Though individual modes have a considerable range, almost all fall within the quartz monzonite field. The limited area of some modes and the coarse grain size of this mass undoubtedly accounts for some of the modal spread. In general, the modal data bear out the field observation that this mass is a rather homogeneous intrusive, both in regard to composition and texture. The only obvious variation of this mass in the field is the local extreme bleaching and alteration of the plagioclase. Identification, however, is not difficult because the bleaching and alteration serve to accentuate the coarse grain size and the strikingly reddish K-feldspar.

In the Darwin quadrangle some of the masses called leucocratic quartz monzonite by Hall and MacKevett (1962, p. 31) resemble the Paiute Monument pluton, and a correlation is tentatively suggested.

SANTA RITA FLAT PLUTON OF THE TINEMAHA GRANODIORITE

An area of about 40 square miles along the west front of the Inyo Mountains is underlain by the Santa Rita Flat pluton. The mass extends a short distance north into the adjoining quadrangle, and the westward limit is concealed beneath Cenozoic deposits of Owens Valley, but this mass is correlative with the Tinemaha Granodiorite of the Sierra Nevada (Ross, 1962, p. D86). The pluton intrudes rocks as young as the Keeler Canyon Formation of Pennsylvania and Permian age. The contacts with the wallrocks are mostly steep and sharp.

In the field this mass looks medium to dark gray from a distance, though weathered boulders are commonly stained red brown. On close observation the rock is a combination of white to clear quartz and feldspar and abundant black hornblende and biotite. Boulder piles and scattered boulders partly buried in their own coarse sandy weathering debris typify most outcrops. The abundance of dark minerals and the presence of scattered relatively well-formed hornblende crystals from 10 to 20 mm long are features that distinguish this pluton in the field. Scattered small brown sphene crystals are also commonly visible in hand specimens.

The texture is granitic, generally equigranular, and the grain-size range is about 2 to 5 mm across. Most crystals of plagioclase and some of the dark minerals are well formed; the other constituents are anhedral. Throughout the mass, but generally not abundant, are tabular to equant K-feldspar crystals as long as 25 mm that give a seriate appearance to some outcrops. These crystals typically have irregular margins and are markedly poikilitic, though in hand specimen many appear to be euhedral.

Fine- to medium-grained ellipsoidal dioritic inclusions are present throughout the mass but are common only in a few places. Their abundance ranges from rare to 2 per square yard, although in a couple localities, swarms of these dark inclusions are found. Most are 1 to 4 inches in maximum dimension, but some are as large as 10 inches across. The smaller ones tend to be subspherical. No systematic distribution of these inclusions is apparent, and only locally are the inclusions abundant enough and well enough alined to define a foliation.

The average modal composition of this pluton, based on 80 modal analyses, is: plagioclase (andesine), 36 percent; K-feldspar, 31 percent; quartz, 20 percent; biotite, 4 percent; hornblende, 6 percent; other constituents including magnetite, sphene, apatite, zircon, allanite, and apatite, 3 percent. The average modal composition is an intermediate quartz monzonite. Modes range across the entire breadth of the quartz monzonite field, and only a few fall outside this field in the granodiorite field. The plagioclase in this body, though mostly andesine, ranges locally to sodic labradorite in the cores of some crystals, and commonly oscillatory zoned crystals have oligoclase rims. Hornblende in excess of biotite, a characteristic of this mass, is one of the features that suggested its correlation with the Tinemaha Granodiorite. In many specimens the hornblende is relatively fresh, whereas the biotite is extensively or completely altered to a mixture consisting chiefly of penninite and sphene.

A distinctive feature of this pluton is abundant epidote, both as veinlets and as permeating masses that cover areas several feet across. Some of this epidote may come from the segregation of alteration products of the dark minerals, but most must have been introduced from some other source. In many areas of epidote veining and "soaking," dark minerals, though altered, do not occur in less than average amounts, but some veinlets do have bleached rims—evidence suggesting lateral migration and concentration of epidote from altered dark minerals.

PAPOOSE FLAT PLUTON

In the northeast corner of the quadrangle, about 6 square miles is underlain by the Papoose Flat pluton. It extends for an additional 25 square miles north and east, mainly into the Waucoba Mountain quadrangle (C. A. Nelson, written commun., 1959). The pluton intrudes Precambrian and Cambrian strata, the contact between the pluton and these rocks being generally sharp. In the western part of the mass, the contact is generally concordant and has an intermediate dip; in contrast, in the eastern part, the contact is strongly discordant and steep. Though other plutons in the quadrangle lack internal structures, the Papoose Flat pluton is strongly sheared and foliated in a zone along the concordant segment of the contact. The foliation becomes weaker to the east and is absent south of Waucoba Canyon. Where the foliation is most conspicuous, about 1½ miles northeast of the Bluebell mine, the strongly sheared rock shows anastomosing trains of biotite and other sheared minerals in granoblastic layers. These layers are studded with lenticular fractured "eyes" of quartz or feldspar, though some, particularly those of K-feldspar, appear to have healed and grown somewhat, as indicated by their subhedral form. The foliation northeast of the Bluebell mine is parallel to the margin of the pluton, which in turn is concordant with the quartzite and schist of the Harkless Formation. Farther east, northwest of Side Hill Spring, the foliation and the contact are steeper than the bedding in the wallrocks.

Outcrops of the Papoose Flat pluton are noticeably light gray or pale yellow. Boulder piles and deeply weathered scattered boulders partly buried in coarse granitic sand are the most common outcrops. The light color of the outcrops, the paucity of dark minerals, the presence of muscovite, and large K-feldspar crystals distinguish this mass from the other plutons; and, of course, in its foliated parts, the Papoose Flat is unlike the other granitic bodies in the area.

The Papoose Flat pluton is strongly porphyritic with K-feldspar crystals as large as 50 mm in longest dimension. The commonly euhedral K-feldspar phenocrysts are studded with small crystals of quartz, plagioclase, and biotite. Growth zoning in the large crystals is emphasized by the alinement of these inclusions. At some outcrops the euhedral phenocrysts weather free and are abundant on the sandy slopes. The groundmass is generally about 3 to 5 mm in grain size, but it is not uncommon for irregular quartz and plagioclase grains to be as large as 10 mm across. Except for the K-feldspar phenocrysts, the minerals are notably anhedral. No dioritic inclusions were seen in this pluton.

The modal composition of this mass is difficult to determine because of the coarse porphyritic texture. Some 11 modes from specimens that did not contain phenocrysts have the following average modal composition: plagioclase (calcic oligoclase), 42 percent; K-feldspar, 19 percent; quartz, 33 percent; other constituents, mostly biotite but including some muscovite, a trace of hornblende, and the usual accessory minerals, total 6 percent. These data indicate a groundmass composition in the granodiorite field but near the quartz monzonite boundary. The addition of the K-feldspar phenocrysts would surely yield an average modal composition in the quartz monzonite field, but as yet no data have been collected on the volume percentage of the large and somewhat sporadically distributed K-feldspar phenocrysts.

The presence of muscovite as a primary constituent distinguishes the Papoose Flat pluton from the other granitic masses in the quadrangle. The muscovite occurs as isolated, presumably primary flakes as large as 2 mm across and in places is interleaved with the olive-brown biotite. Muscovite also occurs as crosscutting veinlets that are as much as 25 mm across, some of which also contain fluorite. North of Side Hill Spring this greisenlike veining is most common.

The Papoose Flat pluton has a unique lithology among granitic rocks of the Inyo Mountains. Where the mass is not foliated, it bears most resemblance to rocks in the Sierra Nevada that have been referred to as being similar to the Cathedral Peak Granite. A mineral age of biotite from the Papoose Flat pluton is 81 million years, as determined by means of the potassium-argon method (see p. O47). It is similar to mineral ages of Cathedral Peak type rocks in the Sierra Nevada. Although the present data do not permit more than speculation, I believe that the possible correlation between the Papoose Flat pluton and the Cathedral Peak Granite should be considered.

McGANN PLUTON

A small outlier of granitic rocks of the Sierra Nevada protrudes into the quadrangle southwest of the Mount Whitney Fish Hatchery (sec. 11, T. 13 S., R. 34 E.). This outlier comprises the eastermost exposure of the McGann pluton, which was mapped and described in the Mount Pinchot quadrangle to the west by Moore (1963, p. 92). The rounded hill has a hummocky surface of weathered piles of boulders, which are generally intermediate shades of gray when viewed from a distance and a combination of black and white when viewed closely.

The small outcrop within the quadrangle is rather coarse grained and equigranular, having a grain size of about 2 to 5 mm. Dark minerals are abundant, and shiny brown sphene crystals are also evident. Dark dioritic inclusions are scattered and have a maximum dimension of 10 inches, though most are smaller.

Only two modal analyses were made from specimens within the quadrangle. Their average modal composition is: plagioclase, 30 percent; K-feldspar, 33 percent; quartz, 25 percent; and dark minerals, 12 percent—an intermediate quartz monzonite. An average of 9 modes in the Mount Pinchot quadrangle (Moore, 1963, p. 92) shows about 11 percent of dark minerals, in which biotite markedly exceeds hornblende, 36 percent each of plagioclase, and K-feldspar, and 17 percent of quartz. The most notable contrast between the two areas is reflected in the quartz percentages. Although the average amount of quartz is significantly less in the Mount Pinchot quadrangle, the two specimens nearest the Independence quadrangle have 21 and 23 percent or modal quartz respectively; this evidence suggests that there may be more quartz in the eastern part of the mass.

ALASKITE, APLITE, AND PEGMATITE

Numerous small light-colored fine- to medium-grained granitic masses are present in the quadrangle Most are peripheral to, or within, the Santa Rita Flat pluton, but a rather large dikelike mass is peripheral to the Paiute Monument pluton southeast of Barrel Springs, and another dikelike mass cuts the McGann pluton along the west margin of the quadrangle. Because of their paucity of dark minerals, most of these masses are very distinctive from the other granitic plutons. Some, particularly the finer grained bodies, weather into sharply angular fragments, or blocky outcrops, which are in sharp contrast to the well-rounded massive bouldery appearance of the coarser grained granitics.

Medium-grained alaskite composed predominantly of sodic plagioclase, K-feldspar, and quartz makes up most of this unit. It is not uncommon for the alaskite to grade into sugary, fine-grained aplite. Aplite also occurs as small stocks and, more commonly, as dikes, particularly common in the other granitic types. Aplite dikes are probably most numerous in the Papoose Flat pluton, where they are closely associated with veins of muscovite and quartz.

Pegmatite is much less abundant, occurring commonly as pods in aplite dikes or masses. Most of the pegmatite is composed solely of quartz and feldspar in crystals as large as 30 mm across. Less commonly, muscovite is found in the pegmatite, and rarely black tourmaline is present. At one locality a mass of coarse-grained quartz and tourmaline occurs in a shear zone. At another locality coarsely crystalline green epidote is intergrown with coarse quartz and feldspar.

DIKE ROCKS

Throughout the quadrangle, but more commonly within the outcrop area of the Santa Rita Flat pluton, igneous dikes are intruded. These dikes are of a variety of types, but they can be generally divided into dark- and light-colored dikes.

LIGHT-COLORED DIKES

The light-colored dikes are dominantly aplite and not all have been plotted on the map; most of the light-colored dikes plotted south and east of Santa Rita Flat are aplite. North and west of Santa Rita Flat, however, a series of generally light-colored dikes is different from the aplite dikes.

These dikes are generally medium gray to medium light gray, and some are light bluish gray, but most weather a distinctive reddish brown. Some are fine grained and equigranular; others are medium grained and porphyritic, and many have abundant small phenocrysts in a fine-grained groundmass, which is a texture commonly found in hypabyssal rocks. This latter type is characterized by quartz phenocrysts having somewhat square outlines that suggest cross sections of doubly terminated crystals typical of quartz crystallized as beta- or high-temperature quartz. The composition of these rocks is variable; many are quartz monzonite or granodiorite.

DARK-COLORED DIKES

The dark-colored dikes are found sporadically scattered throughout the quadrangle, and intrude nearly every pre-Cenozoic formation, but they are much more abundant in the Santa Rita Flat pluton west and northwest of Santa Rita Flat. In this vicinity they have a dominant northwest trend, though many trend north. In the south half of the quadrangle the trend is more eastward, and there are many fewer dikes. These dikes are in sharp contact with their wallrocks, and many have chilled margins.

Most of the dikes are medium gray to medium dark gray when viewed from a distance but have a greenish cast when viewed closely. Thicknesses range from a few inches to 20 feet. Almost all are nearly vertical in attitude. These dikes are obvious on aerial photographs in the light-colored granitic areas but are not as easily seen where they cut the sedimentary rocks. For this reason many dark-colored dikes in the sedimentary areas were not plotted. However, there is little doubt that, even if all had been mapped, the relatively greater concentration of dikes west and northwest of Santa Rita Flat would still be evident.

The dike rocks are fine grained and equigranular to porphyritic, containing phenocrysts as large as 2 mm across. The phenocrysts are generally dark minerals, mostly hornblende or alteration products, pseudomorphic after hornblende. A few dikes have plagioclase phenocrysts. Some dike rocks are made up of a network of well-formed lath-shaped plagioclase, hornblende, and biotite, but the great majority are extensively altered to albite, epidote, and chlorite.

The petrography of the few unaltered parts of dikes and the gross assemblage of alteration products suggests that these dikes were originally lamprophyric dikes rich in plagioclase, hornblende, and biotite and commonly containing hornblende phenocrysts. If unaltered, they would probably most closely compare with the spessartite lamprophyres.

The dark-colored dikes as well as most of the light-colored dikes that weather red brown are apparently near the east margin and in the northern part of a northwesterly-trending dike swarm that is as much as 15 miles wide and possibly 150 miles long. (Moore and Hopson, 1961; Smith, 1962.)

AGE OF GRANITIC ROCKS

Within the Independence quadrangle granitic rocks intrude Paleozoic sedimentary rocks as young as Permian, and in the New York Butte quadrangle to the southeast rocks correlative with the Pat Keyes pluton intrude Middle Triassic sedimentary rocks (W. C. Smith, oral commun., 1962). The granitic rocks are therefore younger than these sedimentary rocks and older than the overlapping late Cenozoic sedimentary deposits along the Inyo front.

Physically determined mineral ages provide data on the age of these rocks. R. W. Kistler (written commun., 1963) determined the following biotite ages by the potassium-argon method. The ages and data for the calculations are shown on table 2.

TABLE 2.—*Biotite mineral ages of granitic rocks in the Independence quadrangle*

[The following constants were used in the age calculations: $\lambda\beta=4.72\times10^{-10}$ year^{-1}, $\lambda\epsilon=0.584\times10^{-10}$ year^{-1}, 1.22×10^{-4} gm K^{40}/gm K]

	Sample	Ar^{40} (moles/gm) 10^{-11}	K^{40} (moles/gm) 10^{-8}	$Ar_{40}/K_{40}\times10^{-3}$	Radiogenic argon (percent)	Age (million years)
Papoose Flat pluton	I-2031 [1]	112. 61	23. 32	4. 829	93	81
	W-90 [2]	105. 28	23. 55	4. 470	75	75
Santa Rita Flat pluton	I-2107 [1]	144. 84	19. 44	7. 449	95	123
Paiute Monument pluton	W-53 [2]	170. 58	17. 98	9. 487	91	156
	I-305 [1]	201. 97	21. 08	9. 580	97	157

[1] Potassium analyses by FrankWalthall.
[2] Potassium analyses by Lee Beatty.

LOCATION OF SAMPLES, CALIFORNIA GRID SYSTEM, ZONE 4

I-2031. 2,282,900 E.; 605,700 N.—about 1 mile north of Side Hill Spring.
W-90. 2,294,700 E.; 599,100 N.—about 2 miles east-southeast of Side Hill Spring.
I-2107. 2,255,500 E.; 596,800 N.—about 3 miles southwest of Badger Flat.
W-53. 2,293,400 E.; 553,000 N.—about 2 miles southeast of Paiute Monument.
I-305. 2,281,700 E.; 541,000 N.—about 3 miles south of Paiute Monument.
W-13. 2,292,800 E.; 520,200 N.—near southeast corner of quadrangle.

T. W. Stearn (written commun., 1962, 1963) determined the following zircon ages by the lead-alpha method. The ages and data for the calculations are shown on table 3.

TABLE 3.—*Zircon mineral ages of granitic rocks in the Independence quadrangle*

[The lead-alpha ages were calculated from the following equation: $t=C\ Pb/\alpha$, where t is the calculated age in millions of years, C is a constant (2485) based upon the U/Th ratio (assumed to be 1.0), Pb is the lead content in parts per million, and α is the alpha counts per milligram per hour. The ages are rounded off to the nearest 10 million years. The error quoted is that due to uncertainties in analytical techniques]

Pluton	Sample [1]	α/mg per hr	Pb [2] (ppm)	Calculated age (million years)
Santa Rita Flat	114-62 (I-2107)	493	32. 5	160±20
Paiute Monument	112-62 (I-305)	461	31. 8	170±20
	245 Z (W-53)	443	34. 5	190±20
Pat Keyes	205-62 (W-13)	211	18. 2	210±20

[1] See table 2 for locations.
[2] Lead analyses by Charles Annell, I. H. Barlow, and Harold Westly.

These age determinations show a range of more than 100 million years for zircons and biotites from the granitic rocks of the Independence area. If the assumption is made that these mineral ages equate to the ages of the emplacement of the granitic plutons, some drastic reappraisals of the Mesozoic intrusive history of this region is in order. For the present, however, the meaning of these mineral ages is somewhat uncertain.

In this report, for the purpose of age assignment, I am tentatively assuming that the biotite and zircon can in some measure be used as a basis for estimating the age of emplacement of the granitic rocks. It seems preferable to use the preliminary mineral-age data for estimating the age of these rocks rather than to merely state that the age is somewhere in the broad and almost meaningless time span possible on the basis of crosscutting and overlap relations. It is beyond the scope of this paper to discuss the possible explanations for the ranges in mineral-age particularly those of biotite and zircon from the same specimen. Assignment of these plutons to geologic systems is based on recent geologic time scales (Holmes, 1960; Kulp 1961), which place the boundary between the Triassic and Jurassic at about 180 million years and the boundary between the Jurassic and Cretaceous at 135 million years.

The oldest mass by mineral age is the Pat Keyes pluton, which has a zircon age of 210±20 million years (Triassic). The probably correlative Hunter Mountain Quartz Monzonite in the Ubehebe Peak quadrangle yielded a zircon age of 190 million years or Triassic (W. E. Hall, written commun., 1961). Petrographically similar, and probably also correlative rocks in the Argus Range about 50 miles southeast of the Independence quadrangle, have yielded zircon ages of 180±20 to 210±25 million years and a biotite age of about 180 million years. These rocks are considered to be very Early Jurassic by Hall and MacKevett (1962, p. 31). The Pat Keyes pluton is therefore provisionally considered to be Triassic or Jurassic.

The Paiute Monument is provisionally assigned to the Jurassic, even though one zircon age falls within the Triassic, and the Papoose Flat pluton is considered to be Cretaceous. The Tinemaha Granodiorite of the Sierra Nevada was previously assigned to the Cretaceous on the basis of zircon and biotite ages (Bateman, 1961, p. 1527). Mineral ages of the correlative Santa Rita Flat pluton in the Inyo Mountains of both Jurassic and Cretaceous suggest a broader range in the possible age of the Tinemaha Granodiorite. The Santa Rita Flat pluton of the Tinemaha Granodiorite is presently considered to be Jurassic or Cretaceous.

LATE CENOZOIC VOLCANIC ROCKS

BASALT

In the northwest corner of the quadrangle about 3 square miles is covered by the east ends of two basalt flows that originated from faults along the front of the Sierra Nevada about 3 to 4 miles west of the quadrangle boundary. These flow remnants present a rough blocky surface which is dark gray to black or shades of brown and red; cindery parts are more often reddish. Much of the basalt is vesicular and some is very scoriaceous. Some of the basalt is ropy, and in a few places incipient columnar jointing is present.

Along the front of the Inyo Mountains, several small patches of chiefly dark-gray to black volcanic ash and fine-grained lapilli were mapped. These originated, at least in part, from a volcanic area a short distance north of the quadrangle boundary and along the Inyo front. The ash forms distinctive dark-colored outcrops in the field or on aerial photographs. Additional areas of scattered basaltic ash material mixed with the granitic sand are present, but only the predominantly ashy slopes were delineated on the geologic map. Undoubtedly these basalt ash patches represent preserved remnants of an ash blanket that covered a much more extensive area.

In the SE¼ sec. 30, T. 11 S., R. 35 E., there is a small ringlike outcrop, a few hundred feet across, of basalt ash, lapilli, bombs as long as 1 foot, and cinder chunks as long as 5 feet. This outcrop apparently represents a single pulse of basaltic material that reached the surface, erupted a small amount of basalt, and then ceased activity A shear zone in the granitic country rock, upon which the extrusive puff of basalt seems to be superimposed, probably served as the conduit for the basaltic material. The cindery blocks contain phenocrysts of olivine, clinopyroxene, and plagioclase (calcic labradorite). Also, small accidental granitic fragments are found in the cinders.

About 2 miles north of the Mount Whitney Fish Hatchery, thin fingerlike outcrops of basalt protrude into the quadrangle from a flow to the west in the Mount Pinchot quadrangle. These outcrops, partly buried by the alluvium, are older than the larger basalt remnants to the north, according to Moore (1963).

LATE CENOZOIC SEDIMENTARY ROCKS

The Late Cenozoic sedimentary rocks can be grossly divided into: (1) younger alluvial deposits that are integrated into the present intermittent drainage pattern and are at present being alluviated, and (2) older deposits that have been uplifted and dissected and are in part consolidated.

OLDER DEPOSITS

From Coyote Spring north to the vicinity of Squares Tunnel, discontinuous patches of sedimentary rocks markedly older than the valley fill are exposed. These deposits include the following: Isolated patches of well-rounded pebbles, cobbles, and boulders plastered on the mountain side; rather well consolidated arkosic and conglomeratic beds along the range front; and finer grained clayey sediments and fresh-water limestone, which at the southernmost exposure contains small gastropods.

Along the front of the Inyo Mountains from the vicinity of Bee Spring for about 2 miles to the north, a series of spurs of late Cenozoic sedimentary rocks project out from the mountain front. These spurs are continuations of bedrock ridges, suggesting that the spurs are eroded remnants of an apron of Cenozoic sedimentary rocks that have been much dissected.

These sediments, which can be divided into three units on the basis of color (fig. 11), dip rather consistently 10° to 15° to the west. Bedding, which appears well defined from a distance, is generally not as obvious on close observation. Locally, however, lenticular beds from ½ to 3 feet thick are well exposed.

FIGURE 11.—Looking north at the late Cenozoic deposits at the base of the Inyo Mountains west of Bee Springs. Note the three-fold division: lower, light-colored beds rich in ash and pumice; middle, dark layer rick in dark hornfels fragments; and upper, fairly well consolidated, poorly bedded, coarse gravel layers.

The lowermost of the three units is best exposed south of the Whiteside mine. White to very light gray layers rich in fine-grained volcanic glass fragments and pumice are common. In addition to somewhat pure layers of ash and pumice, there are other layers studded with granitic and metamorphic pebbles. Areas underlain by this unit are very soft and powdery to walk on, evidence which also suggests an abundance of volcanic ash and fine pumice.

Probably this same unit is represented by a small patch of rhyolitic, tuffaceous material, only a few feet thick, that is exposed in the north-central part of sec. 6, T. 13 S., R. 36 E. This outcrop overlies granitic rock of the Santa Rita Flat pluton and was first noted by Knopf (1918, p. 52).

The outcrop is very light gray to very pale orange, and bedding is shown chiefly by varying amounts of pumice; differential weathering accentuates this layering. The rock is rich in angular to well-rounded quartz, sanidine, and albite crystals as large as 2 mm and rounded pumice fragments as large at 5 mm. Biotite flakes are present in trace amounts. Calcareous cement is abundant.

The rounding of some fragments and the layering suggests water working and deposition, but the origin of this material or how it was deposited is unknown. Knopf commented on the similarity of this exposure to rhyolitic beds east of the Haiwee Reservoir, 40 miles to the southeast (1918, p. 52). The nearest rhyolitic source is a small dome about 18 miles to the northwest, which has abundant associated pumice (Mayo, 1944).

The middle unit is much darker and when viewed from a distance has almost a purplish cast. Abundant fragments of dark hornfels, chiefly from the Rest Spring Shale, are the diagnostic clasts in this generally poorly consolidated unit. Granitic, quartzite, and carbonate fragments are much less common. Clay and calcite cement mixed with fine-grained granitic debris commonly forms a matrix for the larger clasts.

The upper unit is chiefly a light yellow brown and is characterized largely by granitic debris ranging from sand size to boulders several feet in diameter in crudely bedded layers cemented at least in part by calcite. Much of this unit is rather well consolidated. South of Coyote Spring somewhat similar beds are exposed that are richer in clay and calcareous material. This sequence, which is generally finer grained and better bedded, dips 5°–10° W. Yellowish beds of limestone that contain small gastropods are also present.

The entire sequence, though divisible into members that reflect the dominance of particular rock types, is nevertheless a closely related sequence of lenticular conglomeratic beds, in which water working and deposition are reflected by the presence of well-rounded clasts and at least local bedding. Trowbridge (1911, p. 732) considered these beds to be of lacustrine origin. This possibility cannot be ruled out, but the beds do not have the thin and regular bedding so commonly found in lake beds, although these beds could be nearshore deposits, in which coarse material and irregular lenticular bedding would not be incompatible with a lacustrine environment.

Also probably related in origin to the consolidated arkose and conglomerate beds are isolated patches of gravel that are preserved on relatively gentle slopes on the front of the Inyo Mountains from about Squares Tunnel south almost to Bee Springs. These deposits range in elevation from about 5,300 feet near Squares Tunnel to about 4,700 feet near Bee Springs and are characterized by strikingly well-rounded pebbles, cobbles, and boulders of granitic and metamorphosed sedimentary rock types. The well-rounded nature of many of the fragments suggests that they have been well worked by water and are not merely talus collections. A patch of this gravel near Bee Springs has a small mound of spongy calcareous tufa protruding from it.

Farther north up Mazourka Canyon patches of older alluvial material, not now in equilibrium with the present drainage, commonly coat bedrock spurs. Some of these areas of older alluvium are impressively terraced to a previous drainage level of Mazourka Canyon. These deposits may be younger than the consolidated deposits and the rounded gravels. On the higher slopes north and northeast of Johnson Spring, however, gravel patches containing rounded material may be older.

At the mouth of Mazourka Canyon directly west of the road, a prominent terrace represents a former level of the Mazourka Canyon drainage. Probably this terrace level is related to the terraces and spurs of alluvium farther up the canyon and is younger than the consolidated deposits across the road to the east.

YOUNGER DEPOSITS

These deposits cover areas in the present intermittent drainage pattern of Mazourka Canyon and its tributaries, Owens Valley, and the part of the Sierra Nevada draining into Owens Valley from the west. Also included in the Inyo Mountains are alluviated upland areas, the most prominent being Santa Rita Flat and Badger Flat.

The alluvial deposits are heterogeneous mixtures of gravel, sand, and finer grained materials. Most of the alluviated areas in the Inyo Mountains are rather shallow accumulations of rock debris on gentle slopes or, less commonly, talus debris on steeper slopes. Along the Inyo front, discontinuous alluvial fans are present, which, except for the one at the mouth of Mazourka Canyon, are rather small. In contrast, along the west boundary of the quadrangle a continuous apron of fan material projects into the quadrangle from the coalescing fans along the east front of the Sierra Nevada. The boundary between the apron of coarse-grained alluvial-fan material and the finer grained valley-fill deposits of the floor of Owens Valley is rather gradational in part, but on aerial photographs the contact seem very abrupt in places. The contact marks a contrast between the relatively smooth, even-sloping fan and the bumpy, pock-marked surface of the valley fill (fig. 2). Also a vegetation contact is evident in places—a contrast between sagebrush-covered fans and the grassland of the area of valley fill.

STRUCTURE

SETTING

The Independence quadrangle is near the west margin of the Basin and Range province and is intruded by batholithic granitic bodies. This location brings together in the quadrangle parts of the Paleozoic sedimentary section of the western Great Basin and large Mesozoic granitic masses, some of which at least are correlative with granitic types in the main batholithic mass in the Sierra Nevada proper. The Paleozoic rocks are in a large T-shaped roof pendant composing about one-half of the bedrock; both north and south of the quadrangle, however, the percentage of pregranitic material is much higher.

The invasion of these large granitic masses into the Paleozoic terrane has had a profound effect on the layered sedimentary rocks. In addition to contact metamorphic effects, which are widespread, forceful displacement of the sedimentary rocks is suggested by the present configuration of the beds. We can thus speculate that at least some of the folding that has taken place in this area might be the result of the emplacement of the granitic rocks. The cause and timing of much of the faulting is more speculative; some faulting undoubtedly is the result of dislocation of the sedimentary rocks by granitic emplacement, but much is younger and presumably related to the rise of the present Inyo Mountains in the late Cenozoic.

FOLDS

Probably the most impressive single feature of the structure of the quadrangle is the monoclinal roll in which the rocks of the Inyo crest gently dip down to the Mazourka Canyon, where the dip becomes steeper. This feature has possible regional significance, because east of the quadrangle gently dipping Paleozoic rocks in open folds are dominant and west of the quadrangle in the Sierra Nevada roof pendants steep to vertical dips are dominant. One can speculate that this is a transition zone that extends to the downbuckled trough region of the Sierra Nevada, but the steepening could also be a local result of the pushing aside of the Paleozoic rocks by the Santa Rita Flat pluton.

West of Badger Flat for several miles is a north to northwest-trending syncline that causes a major reversal in the regionally steep dips to the west. The fold plunges southeastward for an unknown distance but presumably not steeply except possibly near the northwest end. The axial region is also faulted. The location of this fold, marginal to the large mass of the Santa Rita Flat pluton suggests that the sedimentary rocks were peeled up by the intruding granitic mass. South of Sunday Canyon on Hill 6971 along this same trend several smaller folds occur in the Keeler Canyon Formation, which suggest that the granitic mass has pushed aside and crumpled its wallrock; these small wrinkle-like folds contrast to the simple syncline to the north.

One of the most conspicuous features of the sedimentary rocks as a whole is the change in strike from north near the southern part of the area swinging around to almost east along the north border of the quadrangle. Because of this swing of almost 90 degrees to the east, the strike parallels the contact of the Papoose Flat pluton. A major swing in strike also occurs on the north side of this granitic mass in the adjacent quadrangle to the north (Waucoba Mountain quadrangle). These major changes in strike suggest that the Papoose Flat pluton may have pushed a prominent west-facing bulge into the regionally north- to northwest-trending sedimentary section.

Along the west margin of the Paiute Monument pluton, the Middle and Upper Cambrian sedimentary rocks are thrown into tight folds and overturned. Here also the folding seems to have resulted from the shouldering aside of wallrocks by the intruding granitic rock.

About 3 miles east of the former site of Kearsarge, a syncline is well exposed along the front of the Inyo Range. The varicolored Ordovician formations wrapping around the duller gray Silurian rocks make a rather impressive sight. The syncline is asymmetrical having a steep east limb and a much gentler west limb and plunges south moderately, as estimated from the divergence of the two limbs to the south. The origin of this fold, which is somewhat complicated by faulting, is not yet fully understood, but the fold could have resulted from the tearing off and subsequent doubling back of the sedimentary rocks brought about by the intruding Pat Keyes pluton.

Many other folds of lesser magnitude are present in the sedimentary rocks, some of which are seemingly also directly attributable to intruding granitic rocks. The relation of the folds to the igneous masses strongly suggests forcible intrusion was a major force if not the major force responsible for much of the folding in this area.

FAULTS

On figure 12 the traces of most of the mapped faults have been plotted on a simplified base that distinguishes only the granitic masses, the Paleozoic sedimentary rocks as one unit, and the Cenozoic fill of Owens Valley. From this generalized picture certain trends appear to be prevalent in parts of the area, and in other areas no pronounced pattern is apparent. At least two major periods of faulting occurred: one in connection with the emplacement of the granitic rocks and one, much later, in connection with the uplift of this prominent basin range, the Inyo Mountains. The faulting in response to the granitic emplacement is indeed not one closely restricted period but may span

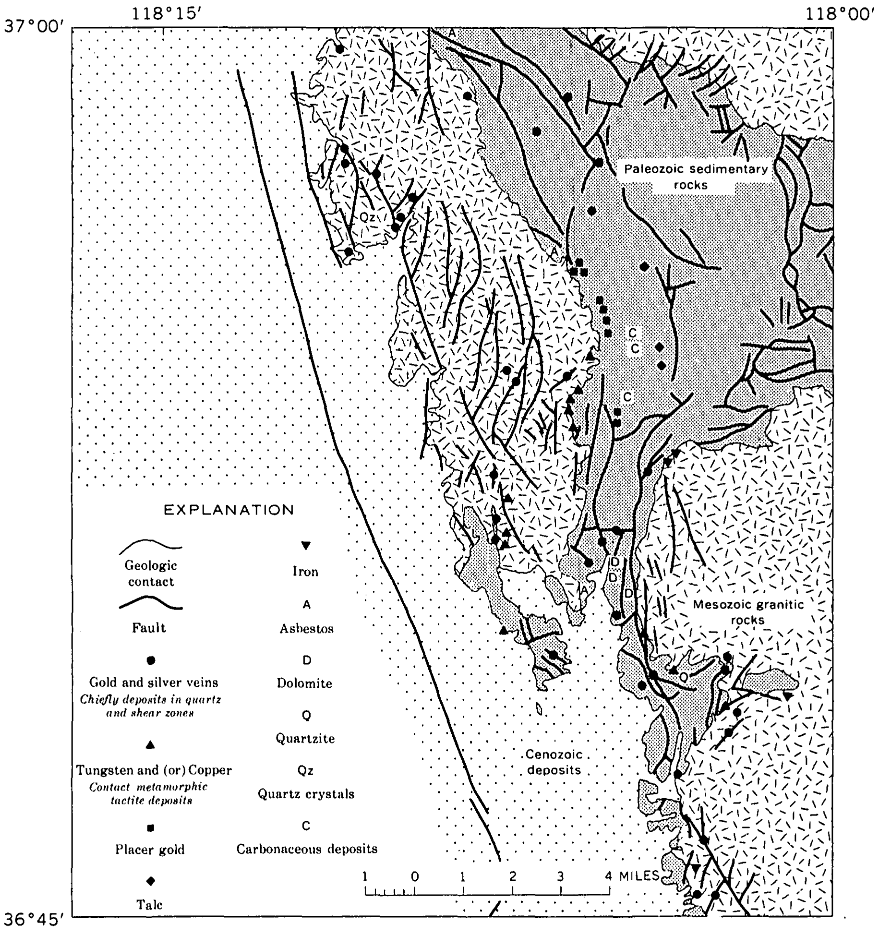

FIGURE 12.—Distribution of mines and prospects on simplified geologic map showing fault distribution, Independence quadrangle.

a period of more than 100 million years (based on mineral age determinations, p. O47).

Some of the faults in the sedimentary rocks appear to be cut off by the plutons, as for example the faulted contact between Lower and Upper Cambrian rocks on the north and south side of the Paiute Monument pluton. Also, many of the virtually east-trending cross faults in the sedimentary rocks may be old faults. Probably most of the cross faults that cut the margin of the Papoose Flat pluton are the result of readjustments of the wallrock in response to the force of the intruding magma. Many other faults, particularly those in the sedimentary rocks, are of unknown age, except that these faults are obviously younger than the rocks they cut. On the basis of the present surface distribution of granitic rocks, however, much of the sedimentary area is probably underlain at no great depth by granitic rock. Also, these granitic masses have probably exerted considerable force along their margins, as demonstrated by folds and faults that seem directly attributable to the granitics. Extrapolating from these observations, much of the faulting in the sedimentary rock could be the result of vertical adjustments of roof rocks in response to pressures upward from intruding magmas. Because a great many of the faults are steeply dipping to vertical, an origin in response to upward granitic movements is indicated.

Probably the most conspicuous exposed fault in the quadrangle is the north-trending fault, about 3 miles east of Kearsarge, that cuts through Bee Springs. This fault, which has been traced for about 10 miles, has a stratigraphic throw of as much as several thousand feet and is downthrown on the west. Its trace across Vaughn Gulch and the canyon north of the Whiteside mine indicates that the fault is nearly vertical. It is exposed as a conspicuous red-brown zone—rich in jasper and, locally, quartz—which is as much as 130 feet wide. The trend of this fault, parallel to many that cut the granitic rocks, suggests that it is a young fault connected with the physiographic uplift of the range. Its position and possible relation to the syncline east of Kearsarge, however, suggests that it might reflect a wallrock adjustment to the emplacement of the Pat Keyes pluton; possibly it is an old fault that was reactivated during the uplift of the range.

Along the front of the Inyo Mountains, particularly in the Santa Rita Flat pluton, a series of northwest-trending faults occur in a belt as much as 2 miles wide. These faults are generally characterized by bleached soft zones readily apparent on aerial photographs or on the ground and by intense shearing of the granitic rocks across thicknesses of a few feet to a few tens of feet. Rocks best described as augen gneiss, mylonite, gouge, and a green schistose rock formed by the smearing and comminution of abundant dark minerals in the granitic rock are formed in these shear zones. Hill 3851, 3 miles south of Aberdeen, is made up entirely of such sheared granitic rock. Figure 13 gives some idea of the effects of this shearing on a coarse-grained massive granitic rock. The small spurs of bedrock protruding into Owens Valley south and north of Hill 3851 also consist dominantly of sheared granitic rock, which suggests a strong shear zone as shown on plate 1. Locally, some displacement is indicated by truncated or offset dikes, but normally the sheared zones transect massive granite, and the amount of movement is indeterminate. The character of the rocks in these zones, however, leaves little doubt that these zones are shear zones along which there has been movement; they are not merely bleached joints that are visible on the aerial photographs. The age of these faults is also somewhat problematical. Little is known about their age; the faults cut the granitic rocks, and some of the shear zones are cut by quartz veins. Several of the old gold mines along the Inyo front are located along these shears, but the age of the mineralization is not known.

This zone of faults parallels the fault that cuts the alluvium in Owens Valley and extends for about 16 miles parallel to the Inyo front. It is one segment of a fault zone that extends nearly 100 miles from Big Pine south to the vicinity of Haiwee Reservoir and along which there was movement during the earthquake of 1872 (Bate-

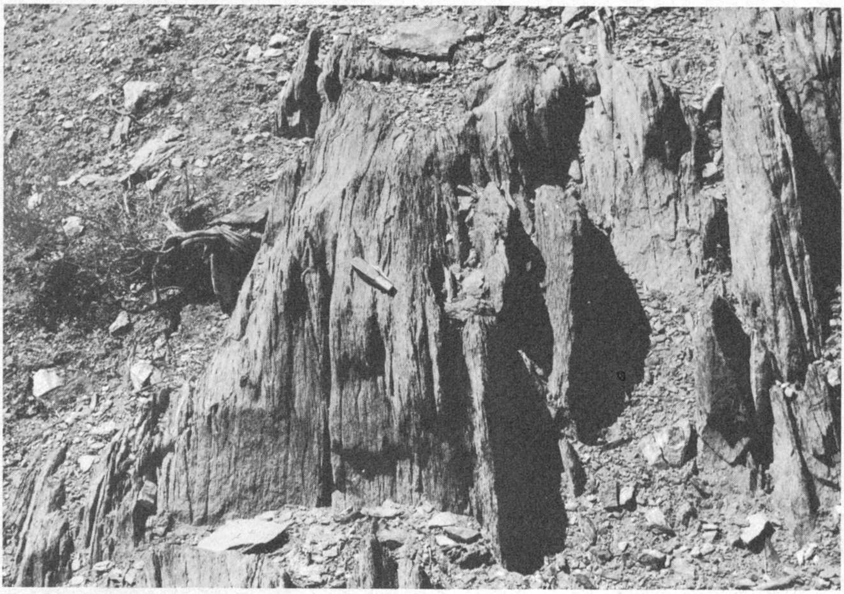

FIGURE 13.—Extremely sheared quartz monzonite of the Santa Rita Flat pluton on Hill 3851 (about 3 miles south-southeast of site of Aberdeen station on the abandoned narrow gage railroad).

man, 1961). The fault in Owens Valley, where the most recent movement is downthrown on the east side, probably further broadens the zone along which movement took place along the front of the Inyo Mountains.

Complementary to the northwest-trending faults is a group of near north-trending faults, which also cut the Santa Rita Flat pluton. These faults have the same sheared features as the northwest-trending set. In general, the north-trending faults are farther back from the range front, but the two sets do intersect in part and therefore probably did form contemporaneously and are related in origin. These north-trending faults are probably responsible for the north-trending indentations in the generally northwest-trending range front, the most notable examples of which are the indentations at the mouth of Mazourka Canyon and the smaller indentation east of the Jack Black mine. A smaller but similar feature about 3 miles southeast of the Jack Black mine still preserves remnants of some rather recently faulted spurs, in contrast to most of the Inyo Mountains where frontal faulting is not readily obvious.

The mapped area along the front of the Inyo Mountains does not suggest a master frontal fault, but rather a zone several miles wide in which two intersecting sets of north- and northwest-trending faults have been active. The impressive shear zone, south of Aberdeen, that cuts Hill 3851 may well continue south along the front, but even so, this zone is but one fault in a rather wide zone of distributive movement that seems to have controlled the frontal displacement of the Inyo Mountains. The absence of evidence of recent faulting at the base of any substantial part of the range front probably reflects in part the fact that erosion has proceeded at a faster rate than faulting and uplift. Also, in this part of the range the front probably never existed as a continuous scarp but consists of a series of steps and benches and also probably of warped segments. In addition to the broad zone of faulting, the topographic benches such as Santa Rita Flat, Badger Flat, and the area north of the Green Monster mine, as well as the bench gravels east of Mazourka Canyon, suggests a series of uplifts through a broad zone, rather than a master faulted front.

GEOLOGIC SUMMARY

The Independence quadrangle combines a geologic record of Paleozoic events of the western Great Basin and Mesozoic granitic events of the Sierra Nevada. The Paleozoic is represented by formations, some of which are lithologically similar to the eastern (carbonate) assemblage, and others that are transitional to lithologies of the western (clastic) assemblage. The sedimentary section can therefore most correctly be considered part of the transitional assemblage of the Great Basin. The 16,000 feet of Paleozoic strata represent a time span from Early Cambrian to Permian; a presumably continuous record were it not for a major erosional gap from mid-Silurian to Late Mississippian.

The preserved geologic record begins with fine- and medium-grained locally crossbedded and ripple-marked clastic rocks, which are of Early Cambrian age. The Middle and Late Cambrian is marked by deposition of about 4,000 feet of dominantly carbonate rocks containing substantial silty admixtures in the Middle Cambrian. The Ordovician is characterized by dominantly silty, sandy, and fossiliferous calcarenite deposits during the Early and Middle Ordovician and by dolomite containing considerable chert in Late Ordovician time.

Although no compelling evidence of a physical break between Ordovician and Silurian rocks has been recognized, a faunal discontinuity is apparent; near the base of some Silurian sections, *Monograptus* species indicating a mid-Silurian age are found. Bioclastic limestone beds rich in corals, sponges, and bryozoans characterize the Silurian in the southern part of the Independent quadrangle. These layers suggest off-reef or reef flank deposits. Silty material is abundant also, and along the strike, to the northwest, the silty fraction markedly increases, graptolites are found, and the bioclastic limestone layers decrease in abundance, suggesting increasing distance from a possible reef complex toward a basin.

An erosional unconformity separates these Silurian beds from overlying Mississippian rocks. Though this is a significant erosional interval, at many places the beds appear to be conformable along this contact, and physical evidence of unconformity is lacking. The overlying Mississippian rocks, about 3,000 feet in total thickness, comprise a mixed sequence of shale, siltstone, calcareous sandstone, chert, and conglomerate containing boulders several feet in diameter. Locally, cravenocerid goniatites, indicating Late Mississippian age, were found. The Mississippian sequence is overlain with apparent conformity by thinly bedded limestone interlayered with dark shale, siltstone, and chert, all of Pennsylvanian and Permian age. These beds are in turn overlain, possibly also conformably, by chiefly hornfelsed siltstone and conglomerate, tentatively correlated with Permian rocks farther south in the Inyo Mountains.

Though sedimentation continued in this region during the early Mesozoic, the resulting rocks are not preserved in the Independence quadrangle. Probably sometime in the Late Triassic, great changes began to take place. Batholithic masses, part of the composite Sierra Nevada batholith, shouldered their way into the Paleozoic rocks and formed folds and at least some of the faults seen today. The heat from these granitic masses produced widespread contact-metamorphic effects. As yet the range of time during which these granitic masses were emplaced is not known, but mineral-age dating of granitic plutons has yielded ages ranging from 80 to 210 million years, a remarkably long interval of granitic invasion, if the mineral ages do indicate the intrusive ages of these bodies.

The geologic record in the Independence quadrangle is very spotty for the period following the long interval of granitic invasions. Early in the Quaternary, or perhaps late in the Tertiary, volcanic activity in nearby areas showered the quadrangle variously with basalt ash and rhyolitic glass and pumice. Small patches of this material are still preserved in older alluvial deposits near the west front of the Inyo Mountains. In addition, basalt flows, which originated along frontal faults of the Sierra Nevada, have encroached on the west edge of the quadrangle.

Late Cenozoic activity in the area is largely responsible for the landscape as it appears today. Much faulting, the uplift of the Inyo Mountains, and the blocking out of Owens Valley are probably late Tertiary and Pleistocene events. The uplift of the range may have progressed in a series of uplifts punctuated by periods of quiescence. The range front suggests this manner of uplift by its topography, which is an alternation of steep rises and rather flat areas. Older alluvial material perched on benches, east of Mazourka Canyon, indicates uplifted remnants of erosion surfaces.

MINERAL DEPOSITS

Mining in the area dates back to 1851 when the Russ mining district was established in the Inyo Mountains east of Independence. A wide variety of metals and other materials of potential economic value are present in the quadrangle, and the abundance of iron-stained shear zones, vein quartz, and copper staining must have seemed very inviting to the early prospectors. The workings of many small mines and prospects remain as evidence of this search, but judging from available production records, one must conclude that most of these enterprises were very disappointing to their owners.

In the past, gold, silver, lead, copper, tungsten, and talc have been produced in the quadrangle. Prospects on small deposits of iron and on potentially commercial dolomite and quartzite have also been worked, but production, if any, has been small. In addition, small pits have been dug on asbestos showings, a small quarry has been opened on aplite, quartz crystals have been recovered from one vuggy deposit in granitic rocks, a carbon-rich(?) layer in the Rest Spring

Shale has been prospected at several places, and small sand and gravel pits have been worked in Owens Valley.

Figure 12 shows the distribution of mineral deposits in the quadrangle. Many prospects and possibly even some formerly productive properties are probably omitted from this map, and many symbols obviously represent prospects from which no production has been made. The map merely shows in a gross way where the various commodities have been sought and gives some idea of the density of prospecting. A belt of country a few miles wide near the range front has been more heavily prospected and developed than have other areas. This concentration of mines and prospects is due partly to greater accessibility along the front and in Mazourka Canyon and partly to the fact that some of the faults trending north and northwest in this belt are mineralized. Contact metamorphic tactite deposits that have yielded some copper production seem to be more common along the margin of the Santa Rita Flat pluton than along the margins of the other granitic masses, though contact metamorphic iron and tungsten deposits seem to favor the Paiute Monument and Pat Keyes plutons. These generalizations should be viewed with suspicion, however, as a relatively small number of mineral occurrences are involved, and most of these had little or no production.

The most abundant and widespread deposits are fissure veins which have been exploited chiefly for gold and silver, but copper and lead have also been produced. The fissure filling material is most commonly vein quartz, which is stained red or brown from the ferruginous weathering products of sulfides. In some fissures, however, vein quartz is scarce or absent, and the filling is soft ferruginous material or hard red jasper. Some of north-trending faults have several tens of feet of this material. Many of the mineralized veins are along north- and northwest-trending shear zones, but other veins trend northeastward. The dumps, consisting of red and brown iron oxides and blue and green copper minerals on most properties, reflect the oxidized nature of the ore near the surface. Pyrite, chalcopyrite, and galena have been identified from some of the fresher rock, and old reports indicate that native gold was also present.

The next most abundant deposits are in contact-metamorphic tactite containing associated tungsten, copper, and iron minerals. Occurrence of tactite is common along contacts of the Keeler Canyon Formation with the Santa Rita Flat pluton. Tactite is much less common where this formation is in contact with the Pat Keyes pluton. Garnet, epidote, pyroxene, and quartz are the most common tactite minerals, and these are locally associated with scheelite, chalcopyrite, copper oxidation products, specular hematite, and magnetite. Some tungsten was produced from disseminated scheelite in tactite from the Betty Jumbo mine in the 1950's. A small amount of copper was produced from the Green Monster mine in the early 1900's. In addition to these two properties, there are many small workings in tactite but no other known production.

Many small pits, adits, and shafts in the alluvium of Mazourka Canyon and some of its tributaries, like Pops Gulch, attest to the search for placer gold in the area. Knopf (1918, p. 118) reported that the workings were formerly of some economic importance, but in 1912 only a few men were making bare wages. Most of the early placer mining apparently was done by dry washing, though where water was available, as near Barrel Spring, there was some sluicing and hydraulic mining.

Talc has been produced from the Blue Stone mine where it occurs in replacement bodies at a contact between a quartzite layer and a dolomite layer in the Johnson Spring Formation. About 800 tons of probable steatite-grade talc has been produced from this property (Page, 1951, p. 32). About 2 miles north of the Blue Stone, in a similar setting, pits and short adits have also been dug in talc.

Dolomite of potentially commercial value is present in both the Bonanza King and Tamarack Canyon Formations, particularly in the area east of the Mazourka Canyon road where these formations have been bleached and markedly coarsened by the contact-metamorphic effects of the Paiute Monument pluton. A small amount of dolomite was crushed and shipped during the summer of 1961, but the property was idle in 1962.

Small contact-metamorphic iron deposits are present east of the Betty Jumbo mine and southeast of Barrel Springs. Both are at contacts between carbonate rocks and quartz monzonite. Specular hematite, in places very coarse grained, is associated with epidote and quartz. The property southeast of Barrel Springs has some relatively recent bulldozer scrapings that resulted from iron prospecting as well as some rather old workings, in which precious metals had presumably been sought from a quartz vein.

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