Geology and Mining History of the Darwin District, Inyo County, California: A compilation

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Acknowledgement and Disclaimer

The information in this compilation is taken largely from published and public sources. I have reproduced this material and present it pretty much as I found it, not trying to harmonize discrepancies in mine or geologic descriptions. I have changed verb tenses for readability and have used some paraphrase. I have expanded abbreviations or special characters with full text (e.g. feet instead of ft., inches instead of ") *Italics indicate quotations*. Authors of the original information are indicated at the end of each paragraph. Paragraphs without a citation are our own materials. The maps in this report have been compiled and rectified from digital and paper copies of original sources that were made at different scales and in different geographic projections. Therefore, many of the maps had to be adjusted or stretched. They do not fit perfectly. Most are accurate to within 100 feet, but reproduction and projection errors can be as much as 300 feet for some maps. PLSS means Public Land Survey System. That survey data was obtained from the U.S. Bureau of Land Management website.

MRDS, 2011, Mineral Resources Data System, U.S. Geological Survey, https://mrdata.usgs.gov/mrds/. This database relies on records that, in many cases, are inaccurate or imprecise. For example, if a report describes a mine as being in "Section 9", with no other information, MRDS plots the mine location in the center of the section. If a mine is reported in "SW ¼" of a section, MRDS plots the mine in the center of that SW quarter-section. Where I could confidently adjust an MRDS location of a mineral deposit to features identifiable in aerial photographs or topographic maps, I did so.

When I found more than one report about a topic, I list the information in chronological order. I do this so the reader can see the evolution in geologic and historical interpretations for these topics.

Help me make this report better. If you have any photographs, memories or reports for this mine that you can share, please send them to yosoygeologo@gmail.com so that I can incorporate that information and material into this paper.

Contents

LOCATION

NAME	TOWNSHIP-RANGE-SECTION	LATITUDE	LONGITUDE
Darwin Mine	19S 40E Sec. 23 MDM	36.26664000010	-117.60090000000
Darwin Mines	19S 40E Sec. 12 MDM	36.29025000030	-117.59978999900
Darwin Group	19S 40E Sec. 14 MDM	36.28024999990	-117.60062000000
Darwin Mines	19S 40E Sec. 13 MDM	36.27577000030	-117.59620000000
Darwin Zinc Prospect	19S 41E Sec. 02 MDM	36.30716999990	-117.50780000000

Darwin District	19S 41E Sec. 19 MDM	36.26667000010	-117.56760000000

1917

Darwin is situated in Inyo County, Cal., 24 miles southeast of Keeler, the southern terminus of the Nevada & California Railroad. It is a small settlement which in 1913 contained but a score or two of inhabitants. It lies at an altitude of 4,750 feet on the west slope of a low desert range, sometimes known as the Darwin Hills. It is within this range that the mines here described are situated, and the Darwin district, as the term is used in this report, is coextensive with the Darwin Hills. The legally constituted mining district within which it is situated is known as New Coso (Knopf, 1917, p. 1).

1938

The Darwin Silver-Lead mining district is located in the Darwin Hills, Inyo County, California. These hills rise 1000 to 1500 feet above the more or less flat top of a large mountain mass which lies between Owens Valley on the west and Panamint Valley on the east (Kelley, 1938, p. 504).

The Darwin district is located within the desert basin and range province of eastern California about 20 miles east of Owens Lake (Fig. 1). Darwin is 230 miles from Los Angeles and 24 miles from Keeler, the branch terminus of the Southern Pacific railroad. The Death Valley highway which passes through Darwin has been steadily improved since the establishment of the Death Valley National Monument in 1933. Eastward from Darwin for many miles the road follows the wash which drains a large upland area subject to summer cloudbursts. Because of the repeated destruction of the section of the highway in the wash a new road has been proposed and surveyed which will pass six or eight miles to the north of Darwin (Kelley, 1938, p. 507).

The area described herein as the Darwin silver-lead district is coextensive with the Darwin Hills which in turn fall within the legal confines of the New Coso mining district. The town of Darwin lies at an altitude of 4750 feet along the western edge of the Darwin Hills. The population of Darwin and the adjacent camps in 1937 was about three or four hundred (Kelley, 1938, p. 507).

1951

Location: North of Darwin in the Darwin hills, 30 miles east of Olancha and U. S. Highway 6, in sees. 11, 12, 13, 14, 23 and 24, T. 19 S., R. 40 E., M.D.M. **(**Norman and Stewart, 1951, p. 59).

1957

Sections 11, 12, 13 14, 23, 24, 25, T.19S, R.40E MDM and Section 30, T.10S, R.41E. MDM (Goodyear, 1957, p. 466, Inyo County Table).

1958

The Darwin silver-lead-zinc district, which is in the southern part of the Darwin quadrangle, is within the New Coso mining district. The Darwin district is coextensive *with the Darwin Hills. The district is 39 miles by paved road from Lone Pine, the nearest supply center. The nearest railroad is at Keeler, the southern terminus of the Southern Pacific Railroad Company's narrow gauge line from Keeler to Laws, California. The Anaconda Company maintains a modern mining camp, including housing, grocery store, and recreational facilities, 1 mile north of Darwin (Hall and MacKevett, 1958, p. 18).*

1962

The Darwin quadrangle is in eastern California in the central part of Inyo County. The area is between longitude 117°30' and 117°45' W. and latitude 36°15' and 36°30' N. (fig.1). Darwin, a small mining town in the southern part of the quadrangle, has a population of several hundred. A large modern mining camp is maintained by The Anaconda Co. at the Darwin mine 1 mile north of Darwin, and residences are maintained at some of the smaller mines and at the principal water supplies in Darwin Wash and at China Garden Spring. Lone Pine, 27 miles northwest of the quadrangle, is the principal marketing center for the area. It is on a branch line of the Southern Pacific railroad from Mojave to Owenyo. Paved State Highway 190, extending from Lone Pine to Death Valley, passes through the center of the quadrangle. A paved road extends from State Highway 190 to Darwin and to the Darwin mining camp. An improved dirt road leads from State Highway 190 through the northern part of the quadrangle to Saline Valley. Many secondary roads lead to mines and prospects from these main roads (Hall and MacKevett, 1962, p. 2).

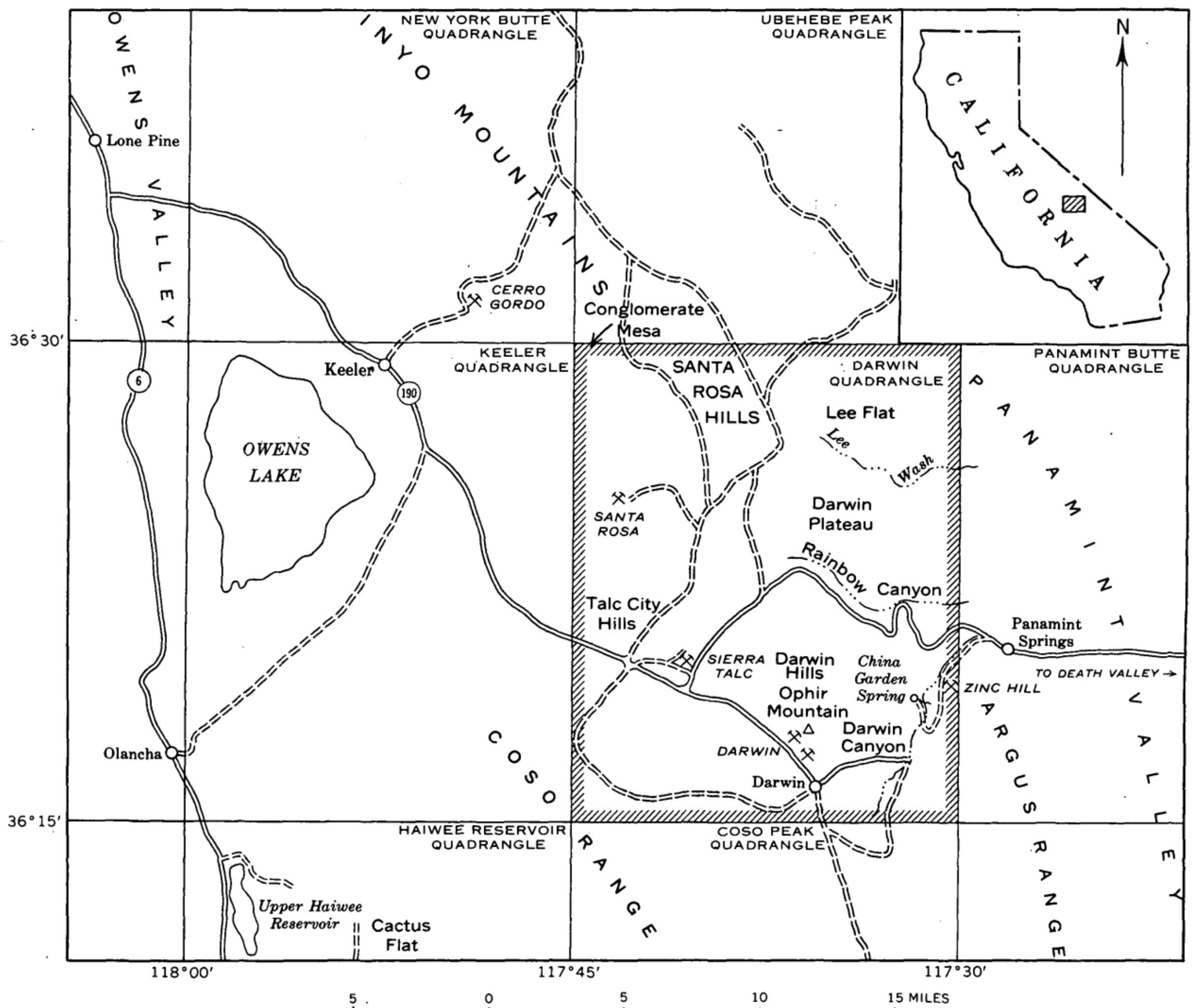

FIGURE 1.—Index map showing location of the Darwin quadrangle.

Figure 1. From Hall and MacKevett, 1962, p. 2.

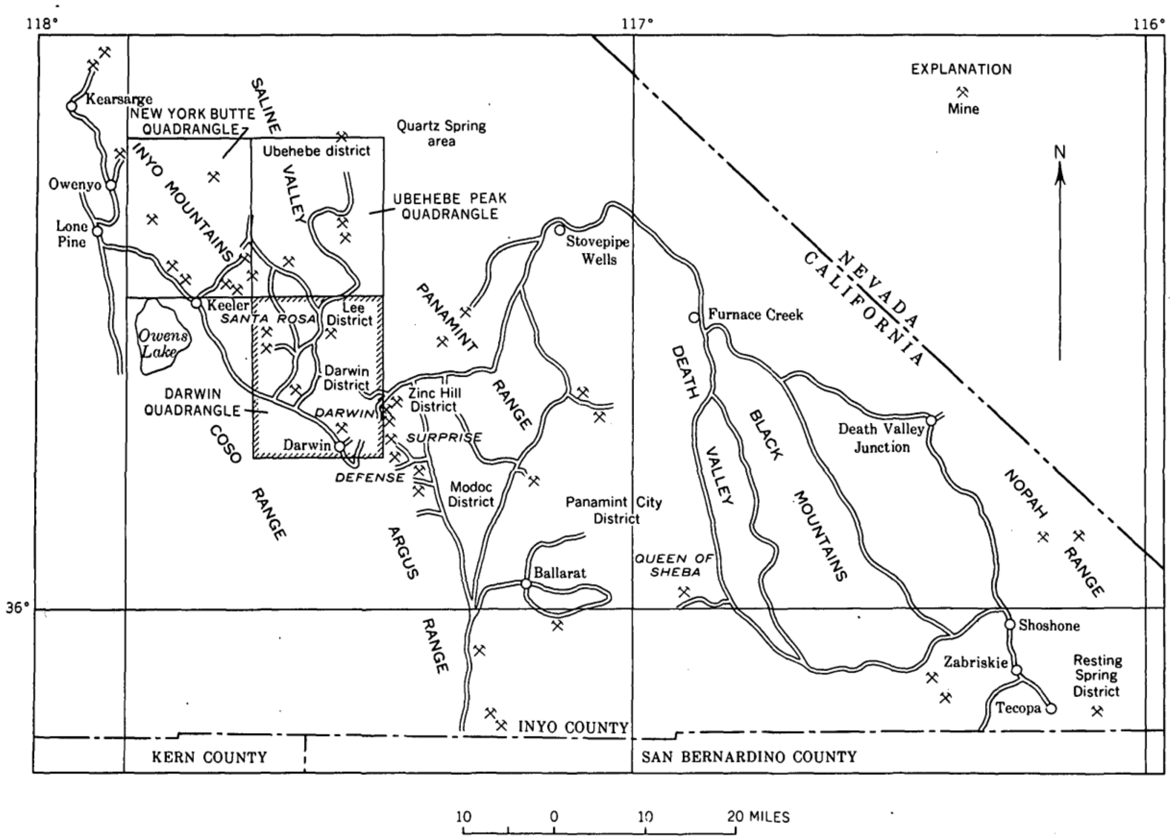

FIGURE 2.—Index map showing the location of Inyo County lead-silver-zinc deposits.

Figure 2. From Hall and MacKevett, 1962, p. 3.

2011

The Darwin lead-silver-zinc district comprises the area of the Darwin Hills within the Darwin Plateau of west central Inyo County, California. The district has produced over $29 million in lead, silver, zinc, tungsten, and copper. Ore bodies occur as structurally controlled replacement and fissure filling deposits within a contact metamorphic cacl-silicate aureole developed within Keeler Canyon Formation limestones surrounding the intrusive Darwin quartz monzonite stock. While there were many mines and prospects within the Darwin District, most of the district's production has come from the larger and more important workings on the west side of the Darwin Hills which were ultimately consolidated and operated by the Anaconda Company as the Darwin Mine. These included the Bernon, Defiance, Essex, Independence, Intermediate, Rip Van Winkle and Thompson workings. Since little information is available about the many earlier workings, Anaconda's Darwin Mine workings are considered typical of the district for the purpose of this report. Paleozoic rocks on the east side of the Darwin Hills also harbor several smaller tungsten deposits which have been sporadically developed in years past but are not considered in this report. No mines in the district are currently active (USGS, 2011).

The Darwin District includes many individual mines and prospects distributed throughout an area encompassing approximately 9 square miles in the Darwin Hills *within the western margin of the Basin and Range geoprovince. Since the mines are within the Darwin Hills of which Ophir Mountain is the highest point, this mountain was chosen to represent the district location. The location latitude and longitude identify the 6,010 feet peak of Ophir Mountain on the USGS Darwin 7.5 minute quadrangle (approximately the southwest corner of Sec. 12-T19S-R40E). The Darwin District is 39 miles from the town of Lone Pine in the Owens Valley. It is reached by taking State Highway 136 east to the intersection of State Highway 190 at the south end of dry Owens Lake, then proceeding on Highway 190 approximately 13 miles to the Olancha Darwin Road turnoff. Turn south on Olancha Darwin Road and travel 5 1/2 miles to the ghost town of Darwin at the foot of the Darwin Hills. The mine workings are located just northeast of the town on the flanks of the Darwin Hills* (USGS, 2011).

PREVIOUS NAMES **(MRDS, 2011)**

Acme
Alameda
Bernon
Bruce
Chipmunk
Columbia
Custer
Durham
Defiance
Dividend
Driver
Essex
Fairbanks
Fernando
Giroux
Imperial Metals Inc Mines
Independence
Intermediate
Lane
Liberty Group
Lucky Jim
Jackass
Kingman
Ophir Mountain
Promentory
Raidore-Tunnel
Rip Van Winkle
Santa Anna
Southwest
St. Charles
Toga
Thompson

PREVIOUS REPORTS

1913, Knopf
1918, Knopf
1936, Hewett and others
1938, Kelley
1958, Hall
1958, Hall and MacKevette
1962, Hall and MacKevette
1975, Czamanske and Hall
1991, Newberry and others

OWNERSHIP

1951

Ownership :The Anaconda Copper Mining Company, 25 Broadway, New York [P.O. Box] 4, New York, [New York]. William H. Hoover, president, owns 45 patented and 44 unpatented mining claims plus several millsites. S. K. Droubay, manager, Dudley L. Davis, chief engineer-geologist (Norman and Stewart, 1951, p. 59).

1957

Anaconda Copper Company, 25 Broadway, New York City (1953)(Goodwin, 1957, p. 466 Map No 54).

HISTORY

1917

The name Darwin is said to come from Dr. Darwin French, who in May 1860, led a party of 15 men in search of the Gunsight lode. This lode was a mythical silver deposit believed to have been found by the emigrant party that was lost in Death Valley in 1850 (CMB, 1883). In the early part of the decade between 1870 and 1880 argentiferous lead ores were discovered in the vicinity of Darwin. A town soon sprang up here and is said to have had at one time a population of several thousand inhabitants.. The pipe line which brings water from a spring in the Coso Mountains 8 miles distant and which still supplies all water used for mining and domestic purposes in the district was completed in July, 1875 (Knopf, 1917, p. 3).

Between 1875 and 1877 three smelters were built near the town of Darwin. The largest of these, stated to have had a capacity of 100 tons a day, was erected by the New Coso Mining Co., which owned the Christmas-Gift and Lucky Jim mines. This smelter *commenced operations in 1875, the lead being started with lead obtained from Cerro Gordo, and a heavy production was maintained during 1876. The Defiance furnace is said to have had a capacity of 60 tons a day and the Cuervo a capacity of 20 tons* (Knopf, 1917, p. 3-4).

These furnaces, after the activities of the first few years, were operated in a desultory way. Expenses were high, because prior to the completion of the railroad to Keeler in 1883, all freight had to be brought across the desert by teams from Los Angeles, a distance of 275 miles. The richer and more easily mined ore bodies were early exhausted, and as the policy of mining in those days did not consider the wisdom of keeping reserves in advance of extraction, the district soon lapsed into stagnation, occasionally interrupted by periods of moderate activity. The smelters have long been dismantled and destroyed, and the ores now produced are shipped to reduction works at Selby or Salt Lake (Knopf, 1917, p. 4).

In the early part of 1913 there was considerable activity in the district, especially at the Christmas Gift, Lucky Jim, and Ouster mines, and it is hoped that the introduction of modern machinery and the inception of systematic exploration work in some of the old properties may result in a permanent revival of the mining industry. A telephone line connecting Darwin with Keeler was completed in May, 1913. (Knopf, 1917, p. 4).

1938a

At Darwin, the properties of the American Metals Inc. have been acquired by the Darwin Lead Company of Los Angeles, which has installed a 50-ton concentration plant on the property to treat low-grade ores of the Defiance, Independence, and Thompson mines (Tucker and Sampson, 1938, p. 373).

1938b

During the early seventies the rich ores of Panamint City and the Ballarat district were shipped by pack train through Shepherd Canyon in the Argus Range and thence by a route following springs along the east front of the Coso Mountains to Owens Valley. A Mexican searching for a mule lost from the packers' camp at Old Coso or Coso Springs is reported to have discovered an outcrop of ore in the Darwin Hills. The initial discovery is reported to have been made in 1874. The lode which was found was evidently rich enough to have attracted considerable attention, for during the year many other deposits in the district were located. Most of the important mines were started during the years 1874 and 1875. A good-sized town soon sprang up and was named after Dr. Darwin French who had lead a party of 15 men through Darwin Canyon in 1860 in search of the mythical Gunsight silver lode in Death Valley (Kelley, 1938, p. 551). *During the early boom days of the [eighteen] seventies there were eight blocks of buildings along the main street and six in the other direction. The population is said to have then exceeded that of Los Angeles. In the early days, Darwin was twice burned to the ground by wind-whipped fires, which probably accounts for the present lack of indications of the former size or character of the town* (Kelley, 1938, p. 551).

*From 1875 to 1877 three smelters were built near Darwin. The Cuervo had a capacity of 20 tons per day ; the Defiance 60 tons ; and the New Coso 100 tons. The lead well of the New Coso smelter was started from lead obtained from Cerro Gordo. Iron oxides used at the smelter were obtained from iron mines on Centennial Flats in the Coso Mountains. Charcoal was obtained from timber burned in the Coso Mountains. It is also interesting to note that many of the eight [ft] by Eight [ft] stulls still present in some of the older workings were hand-hewn from timber obtained in the Coso Mounta*ins (Kelley, 1938, p. 551).

During the early days of mining all freight had to be hauled by team from Los Angeles, and consequently costs were very high. Only the richest ores were sent to the smelter ; according to De Groot (1890) about one foot broken out of the ledge averaging twelve feet in width constituted ore at the Defiance mine. About four-fifths by bulk and about one-half of the value went into the dumps. Because of the excessive transportation costs and the exhaustion of these more easily mined rich ores, the smelters were shut down within a few years, prior to the completion of the narrow-gauge railroad to Keeler in 1883. After shutdown of the smelters, jigging of the ores came into practice and concentrates obtained from newly mined ore and from the dumps were shipped to smelters at Selby or Salt Lake (Kelley, 1938, p. 551-552).

During the eighties and nineties mining and production were sporadic and at times practically dormant due to poor transportation, lack of modern mining facilities, and some litigation. Some leasing and shipping were carried on from 1900 to 1910, but only small activity was reported by Knopf in 1914. In 1915 the Darwin Development Company consolidated the Lucky Jim, Promontory, Lane, and Columbia mines and began the construction of a mill on the Lane property. This company soon gave way to the Darwin Lead-Silver Development Corporation, and finally, in 1917 the Darwin Silver Company consolidated the above properties with the Defiance and Independence mines purchased from the Keddy Estate. Modern equipment, roads, and camps were constructed with the view of mining on a large scale, and although considerable ore was blocked out and nearly a half million in richer ore was shipped, real mining awaited camp building and surface developments. The camp was financed by E. W. Wagner and development was managed by A. G. Kirby in 1921. During the height of the development Wagner committed suicide because of reverses in speculation growing out of the grain crash in 1920. Kirby leased the properties from the Wagner Estate during the period of 1922 to 1924 and produced some ore, but on account of estate complications was forced to quit (Kelley, 1938, p. 552).

The Lucky Jim mine, one of the big producers of the district, was mined extensively in the early days. According to J. A. McKenzie, who owned the mine at the time Goodyear reported on the district m 1888, the mine at that time produced about $1,250,000 or $1,500,000, but probably more money had been spent on the mine than had been taken out. At the time of Goodyear 's visit the mine had been opened 300 feet by vertical shaft and 180 feet below the bottom level by an inclined winze. Although some mining had been done during the intervening time, no greater depth had been attained at the time of Knopf's work in 1913. The Darwin Development Company working the mine in 1915 *had deepened it to 600 feet. The Lucky Jim camp above the mine was built about this time, and the Lucky Jim continued to be deepened and mined until about 1926 when a depth of about 1000 feet was reached. The Defiance, Independence, and Lane mines were also worked to a considerable extent during the period from the World War to about 1927. The larger ore body in the Independence mine was opened up and worked during this period (Kelley, 1938, p. 552-553).*

With the straightening out of the Wagner Estate affairs, the American Metals Company under C. H. Lord of Chicago leased the properties and operations again began. Considerable ore was concentrated and shipped during the period 1925 to 1927. But by 1927 the lead industry was becoming depressed and the camp was again shut down. In 1928 an open switch in the Lucky Jim mine caused a fire which burned out much of the shaft and mine timbering. As a consequence this mine, perhaps the largest in the district, is inaccessible (Kelley, 1938, p. 553).

In 1936 with the return of more favorable mining conditions and better prices for lead and silver, the Darwin properties were again opened up in preparation for mining. The Wagner Estate properties were reorganized as the Darwin Lead Company. By the end of 1936 the Lane mill had been rebuilt to 200-ton capacity and early in 1937 the Thompson tunnel was cleaned out in preparation for working the Independence orebody at a lower level. A. A. Rubel in 1936 purchased the Keystone properties in the south end of the hills and constructed a modern camp in preparation for extensive development under the name of Keystone Darwin Limited (Kelley, 1938, p. 553).
It is evident from the history of the camp that there have been two contrasting periods of production. The first, in the early seventies, was halted because of depletion of the rich surface ores, and because of lack of modern methods of mining and milling and transportation applied to low-grade ores. The second began with the World War impetus to mining during which consolidation of properties and large-scale operations were effected. This later period faltered during the unprecedented depression, but should now swing into full stride again. With modern methods of mining, ore treatment, and transportation the Darwin district should prove its position as a silver-lead producer (Kelley, 1938, p. 553).

1951

The first mines at Darwin were located in November 1874 (Chalifant, 1933, p. 294) Before 1880, several mills and smelters were in operation and the town of Darwin had a population of more than 5000. The district flourished during the mining of the rich, oxidized lead-silver ores. As these surface ores were exhausted, however, the isolation of the district and unfavorable price fluctuation of metals allowed only intermittent operations until World War I, during which some of the principal mines, the Lucky Jim, Promontory, Lane and Columbia, were operated by the Darwin Development Company, the Darwin Lead-Silver Development Company, and finally by the Darwin Silver Company. The Darwin Silver Company consolidated the Defiance and Independence mines with the others (Norman and Stewart, 1951, p. 68).

In 1919, the brokerage firm of E. W. Wagner and Company gained control of the properties, and under the management of A. G. Kirby, installed surface equipment, prepared some of the properties for production and remodeled the Lane mill. In 1921 the Wagner Company went bankrupt, and the Wagner Assets Realization Corporation, a creditors' organization, was formed to take charge of the assets. From 1922 to 1925 A. G. Kirby operated the properties on a lease. In 1925, C. H. Lord obtained a lease and bond on the properties and operated them as C. H. Lord, Trustee, until 1927. He then formed the American Metals, Incorporated, and continued operations until the end of that year. The Wagner Assets Realization Corporation then attempted to regain possession of the properties, but certain legal difficulties were not straightened out until 1936. Two of C. H. Lord's financial backers formed the Darwin Lead Company, obtained a lease and bond on the properties, and commenced operations in the fall of 1936 and continued until the summer of 1938. The Imperial Smelting and Refining Company, Mr. Sam Mosher and Mr. Ralph Davies and associates began operating the property in 1940. Later Mr. Davies withdrew, and Mr. Mosher and an association of officers of the Signal Oil Company continued operations as the Imperial Metals, Incorporated. In March 1943, Arthur J. Theis and associates took over the operation under the name of Darwin Mines, although Imperial Metals, Incorporated retained an interest. The Anaconda Copper Mining Company purchased the property on August 1, 1945. (Norman and Stewart, 1951, p. 68).

1958

Oxidized silver-lead ore bodies were discovered at Darwin in November 1874 (Chalfant, 1933, p. 274), and between 1875 and 1880 the rich near-surface ores were mined extensively. The town of Darwin was reported to have had a population of 5,000 people by 1880 (Kelley, 1938, p. 507). Between 1875 and 1877 three smelters were built near Darwin-the Cuervo with a capacity of 20 tons per day, the Defiance with a capacity of 60 tons, and the New Coso with a capacity of 100 tons (Goodyear, 1888, p. 226)(Hall and MacKevett, 1958, p. 14).

In May 1875 the New Coso Mining Company purchased the Christmas Gift and Lucky Jim mines, then only prospects, and under the management of L. L. Robinson the company recovered 226,672 ounces of silver and 1,920,261 pounds of lead by April 1, 1877, (Robinson, 1877, p. 38) with a total value of $410,350. By 1883, $750,000 in bullion had been recovered, but the properties were idle at that time (Burchard, 1884, p. 164). (Hall and MacKevett, 1958, p. 14).

The Defiance and Independence mines were in production by 1875 as reported in the Coso Mining News of December 24, 1875, and by 1883 they yielded bullion worth $1,280,000. The district was nearly dormant by 1888 owing to the exhaustion of the easily mined, highgrade, near-surface ores (Goodyear, 1888, p. 226), and properties were operated only intermittently by lessees until World War I (Hall and MacKevett, 1958, p. 14).

The history from World War I until 1945 is quoted from Norman and Stewart (1951, p. 60) (Hall and MacKevett, 1958, p. 14).

As these surface ores [of the Darwin district] were exhausted, however, the isolation of the district and unfavorable price fluctuation of metals allowed only intermittent operation until World War I, during which some of the principal mines, the Lucky Jim, Promontory, Lane and Columbia, were operated by the Darwin Development Company, the Darwin Lead-Silver Development Company, and finally by the Darwin Silver Company. The Darwin Silver Company consolidated the Defiance and Independence mines with the others (Norman and Stewart, 1951, p. 60) (Hall and MacKevett, 1958, p. 14).

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The Anaconda Company has operated the Darwin mines since 1945, except for brief shutdowns in 1948 and from March 1954 to January 1955. Most of their production has come from the Defiance, Essex, Independence, and Thompson mines. The Lucky Jim mine was rehabilitated in 1948, but no ore has been mined from it since then (Hall and MacKevett, 1958, p. 14).

Talc was first mined in the Talc City Hills sometime prior to 1919. Waring and Huguenin (1919, p. 126) describe operations at the Talc City mine-then called Simonds talc mine-in their biennial report for 1915- 1916. In 1918 the Simonds talc mine was purchased by the Inyo Talc Company, which later became known as the Sierra Talc and Clay Company. The Sierra Talc and Clay Company operated the Talc City mine and several smaller deposits continuously since 1918 (Hall and MacKevett, 1958, p. 14).

Scheelite was recognized in the eastern part of the Darwin district during World War I and was mentioned by Kelley (1938, p. 543), but no deposits were developed until 1940. The principal production of tungsten was in 1941 and 1942 by the Pacific Tungsten Company (Hall and MacKevett, 1958, p. 14).

2011

By the 1860's, the draw of the California Motherlode gold fields had faded. Fueled by the discovery of the Comstock Lode, prospectors headed back east over the Sierra Nevada in search of rumored bonanzas reported by the early argonauts and Death Valley 49ers. In early 1860, a prospecting party headed by Dr. E. Darwin French (after which Darwin is named) set out for the Panamint Valley in search of the fabled "Lost Gunsight Mine" and "Silver Mountain". While these bonanzas eluded them, they did discover rich silver deposits in the Coso Range which became the first major silver strike in Southern California. The new town of Coso became a regional base camp from which later exploratory parties would be launched. In 1874, a party discovered oxidized silver-lead ore assaying $700/ton 10 miles northeast of Coso on the southwest slope of the Darwin Hills and by 1875, Darwin had become a booming town with its own post office, stores, and two baseball teams. In May 1875, the new Coso Mining Company purchased the Christmas Gift and Lucky Jim prospects. By April 1877, the company had produced 226, 672 ounces of silver and 1,920,261 pounds of lead with a total value of $410,350. By 1883, they had recovered over $750,000 but the properties were then idled. By 1875, the Defiance and Independence mines were in production and by 1883 they yielded bullion worth $1,280,000. By 1878, Darwin's population had grown to 5,000 as the rich near surface ores were exploited and three smelters were built to process the ore; the Cuervo with a capacity of 20 tons/day, the Defiance with a capacity of 60 tons, and the New Coso with a capacity of 100 tons. Darwin had become the biggest town in Inyo County and had earned a reputation as one of the west's most violent towns plagued by gunplay, shootings, and stage robberies. Its murder rates rivaled those of early Tombstone, Deadwood, and Dodge City. After 1880, the easily mined rich surface ores played out and Darwin declined to a population of 85 as many miners headed to the new boomtown of Bodie, California. A suspected arson fire in 1879 and most of downtown Darwin was destroyed. By 1888, Darwin was nearly deserted. Due to the area's isolation and fluctuating metals prices, the Darwin mines were operated only intermittently by lessees until World War I. In 1908, some mines were briefly reactivated to work some of the lower grade ore bodies. The ore was shipped to a smelter in nearby Keeler. During the following decade, new deposits were opened, older mines were reworked and the town was slowly rebuilt. During the war many of the mines were heavily worked. The Lucky Jim, Promontory, Lane, and Columbia mines were operated by the Darwin Development Company, the Darwin Lead-Silver Development Company, and finally by the Darwin Silver Company. The Darwin Silver Company also consolidated the Defiance and Independence mines with their operations (USGS, 2011).

In 1919, E. W. Wagner and Company took over the properties and major development began on Mt. Ophir at the Wagner & Company Mine. The company built a major mining camp to house all the miners, installed new surface equipment, and remodeled the

Darwin Mill. In 1921, however, the company went bankrupt and the Wagner Assets Realization Company, a creditors organization, took over the assets. From 1922 to 1925, A. G. Kirby leased and operated the properties. In 1925, C.H. Lord leased and operated them until 1927. He then formed American Metals, Incorporated and continued operations until the end of the year. C. H. Lord's financial backers formed the Darwin Lead Company, and operated the properties from 1936 until 1938. In 1940, the Imperial Smelting and Refining Company, Sam Mosher, and Ralph Davies and associates began operating the property. They built a mill of 150 ton/day capacity to treat low grade slightly oxidized lead-zinc ores. Later, Mr. Davies withdrew, and Mr. Mosher and an association of Signal Oil Company officers formed Imperial Metals Incorporated to continue operations. In March, 1943, Arthur Theis and associates took over operations under the name Darwin Mines. The Anaconda Copper Company purchased the properties on August 1, 1945. Under Anaconda, the Darwin Mine became California's largest lead producer during the late 1940s, accounting for over two-thirds of the state's production. Most of their production came from the Defiance, Essex, Independence, and Thompson workings. Anaconda continued operations at the Darwin Mine until 1952 when the operation was shut down. Aside from some minor lessee work that was principally confined to the 400 level and above in the Defiance workings and in the upper Thompson workings during the early 1960's, the Darwin Mine remained inactive until 1968. In 1968, Brownstone Mining/West Hill Exploration leased the properties from Anaconda and proceeded to recondition the mill and underground power and air systems. Reconditioning the mill took almost a year as the mill circuits had not been flushed in 1952 and the flotation cells were frozen with residual lead/zinc concentrates. By late 1969 mining was resumed and ore was being received at the mill in 1970. In 1971 the Defiance shaft was deepened to the 1300 level and the Thompson shaft was deepened to the 900 level. The development of new ore bodies, resulted in higher grade ore being produced through 1971 and into 1972 when the decline in metal prices caused the closure of the Darwin Mine in early 1972. In 1973, the Anaconda Company was taken over by ARCO. Arco reprocessed many of the mine tailings between 1974 and 1975 after which all operations ceased. In the mid 1990s, the Darwin Mill and the Darwin Mining Camp were dismantled. Today the Darwin mines are idle and the ghost town of Darwin is home to some 40 souls.
(USGS, 2011).

REGIONAL GEOLOGY

1958

The Paleozoic rocks range in age from Early Ordovician to Permian in an essentially conformable sequence more than 14,000 feet thick. Silurian and Ordovician rocks are predominantly dolomite; Devonian rocks are limestone, dolomite, shale, and quartzite; and Mississippian and younger Paleozoic rocks are mainly limestone. the Paleozoic strata are intruded by the batholith of the Coso Range in the southwestern part of the quadrangle, the batholith of Hunter Mountain in the northeastern part, and by many small plutons. Most of the northern half of the quadrangle is covered by olivine basalt flows and andesite of late Cenozoic age (Hall and MacKevett, 1958, p. 4).

2011

The Darwin District is one of several lead-silver-zinc districts in a mineralized trend extending over 100 miles from the Cerro Gordo District in the southern Inyo Mountains to the Tecopa District in the Nopah Range of southeastern Inyo County. The smaller Ubehebe, Modoc, and Panamint districts are also included within this mineralized trend. The Darwin region includes some of the most important lead-silver-zinc mines in the state as well as the largest steatite-talc producing area in the state in the Talc City Hills near the south end of the Inyo Mountains. The Darwin District lies on the western fringe of the Basin and Range geoprovince which is characterized by Cenozoic age northwesterly trending parallel mountain ranges separated by structurally controlled valleys. The district is located within the Darwin Plateau and surrounded by the Inyo Mountains, the Coso Range, and the Argus Range. Regionally, the area is drained into two closed basins, the Panamint Valley to the east and Owens Lake to the west (USGS, 2011).

REGIONAL STRATIGRAPHY

1958

Below is a stratigraphic table for the Darwin Quadrangle by Hall and MacKevett (1958, p. 7).

Table 1. Stratigraphic section of the Darwin quadrangle.

Era	Period	Age	Lithologic unit		Thickness (feet)
CENOZOIC	QUATERNARY	Recent	Alluvium, including fanglomerate, playa deposits, and minor lake beds		
CENOZOIC	QUATERNARY	Pleistocene	Olivine basalt flows, fanglomerate, and Darwin Wash lake beds of Hopper, 1947		0–600
CENOZOIC	TERTIARY(?)	Pleistocene or Pliocene	Coso formation of Schultz, 1937		
CENOZOIC	TERTIARY(?)	Pliocene(?)	Andesite, basaltic pyroclastics, basalt flows, pumice		910+
MESOZOIC		Cretaceous(?)	Hypabyssal rocks—andesite porphyry and alaskite dikes		
MESOZOIC		Cretaceous	Batholith of Hunter Mountain, batholith of the Coso Range, and related intrusive rocks—mainly quartz monzonite but includes granodiorite, syenodiorite, gabbro, leucogranite, and aplite		
PALEOZOIC		Permian	Owens Valley formation	Limestone-conglomerate member—includes limestone conglomerate, siltstone, and calcarenite	180+
				Shale member—brick-red and yellowish-brown shale; subordinate siltstone and limestone	200
				Lower limestone member—mainly fine-grained calcarenite; some thick limestone lenses, shale, and siltstone	2,800
		Permian and Pennsylvanian	Keeler Canyon formation	Upper member—calcilutite and fine-grained calcarenite with lesser shale and limestone-pebble conglomerate	1,700
				Lower member—thin-bedded limestone with intercalated limestone-pebble conglomerate	2,300±
		Pennsylvanian(?)	Rest Spring shale—dark-brown fissile shale, minor siltstone. The Rest Spring shale is present only as fault slivers in the northwest part of the quadrangle. It is the stratigraphic equivalent of the upper part of the Lee Flat limestone		0–50+
		Pennsylvanian(?) and Mississippian	Lee Flat limestone—thin-bedded medium-gray limestone; equivalent to the upper part of Perdido formation and to the Rest Spring shale		520+
		Mississippian	Perdido formation—limestone and bedded chert		330
			Tin Mountain limestone—fossiliferous thin- to thick-bedded limestone with chert lenses and nodules		430
		Devonian	Lost Burro formation—coarse-grained white and light-gray marble; dolomite and limestone in lower part of formation; minor quartzite and shale		1,770+
		Devonian and Silurian	Hidden Valley dolomite—light-gray, massive dolomite		1,000±
		Ordovician	Ely Springs dolomite—dark-gray dolomite with chert beds and lenses; some light-gray dolomite		920±
			Eureka quartzite—light-gray to white vitreous orthoquartzite		440
			Pogonip group—light- and medium-gray thick-bedded dolomite; some thinner-bedded dolomite and limestone		1,570+

1962

TABLE 1.—*Sequence of rocks exposed in the Darwin quadrangle*

Age	Name	Character	Thickness (feet)
Recent	Alluvium	Unconsolidated alluvium, playa deposits, fanglomerate, landslide debris.	
	Lakebeds	White to light-gray fine-grained pumiceous ash, silt, clay, and diatomaceous earth.	58+
Pleistocene	Fanglomerate marginal to Darwin Wash	Gravels composed mainly of subrounded fragments of Pennsylvanian and Permian limestone, quartz monzonite, and basalt in a sandy matrix.	25+
	Olivine basalt	Mainly flows 10-100 ft thick. A few undifferentiated flows in Darwin Canyon are younger than fanglomerate marginal to Darwin Wash.	0–600
	Fanglomerate from Inyo Mountains	Gravel. Angular to subrounded fragments of Ordovician and Silurian rocks up to 18 in. in diameter in a clay and silt matrix. Probably is contemporaneous with the Coso formation.	30+
—?—?—?—	and Coso formation	Arkose and clay, poorly bedded, white to buff, fine- to medium-grained.	30+
Pliocene	Andesite	Forms broad dome in upper pyroclastic unit; contains phenocrysts and clusters of plagioclase and hornblende in an aphanitic groundmass.	0–1, 230
	and Pyroclastic rocks	Upper unit: poorly bedded, mainly tuff-breccia and agglomerate and cinders.	
		Lower unit: well-bedded lapilli-tuff, scoriaceous basalt, and tuff-breccia.	0–910+
	Hypabyssal rocks	Andesite porphyry, diorite, alaskite porphyry, and altered quartz latite(?) dikes.	
Cretaceous (?)	Aplite and leucogranite	Includes aplite, pegmatite, and leucogranite.	
	Amphibolite	Includes amphibolite, epidote amphibolite, hornblende gabbro, and diorite.	
Cretaceous	Biotite-hornblende-quartz monzonite and leucocratic quartz monzonite.	Mainly quartz monzonite with other granitic rock types.	
Permian	Owens Valley formation	Upper unit: limestone conglomerate 60 ft thick overlain by siltstone, calcarenite, and orthoquartzite	180+
		Middle unit: brick-red and yellowish-brown shale, subordinate siltstone and limestone.	200
		Lower unit: mainly fine-grained calcarenite in beds 1 to 2 ft thick; some thick limestone lenses, shale and siltstone.	2, 800

Figure 3. From Hall and MacKevett, 1962, p. 5.

TABLE 1.—*Sequence of rocks exposed in the Darwin quadrangle*—Continued

Age	Name		Character	Thickness (feet)
Permian and Pennsylvanian	Keeler Canyon formation		Upper unit: calcilutite and fine-grained calcarenite with lesser pink fissile shale and limestone pebble conglomerate.	1,700
			Lower unit: thin-bedded limestone with intercalated limestone pebble conglomerate.	2,300
Pennsylvanian(?)	Rest Spring shale 0-50+	Lee Flat limestone	Thin-bedded dark-medium-gray limestone that is equivalent to Rest Spring shale and upper part of the Perdido.	960+
Mississippian	Perdido formation		Limestone and bedded chert	330
	Tin Mountain limestone		Fossiliferous thin- to thick-bedded limestone with chert lenses and nodules.	435
Devonian	Lost Burro formation		Coarse-grained white and light-gray marble; dolomite and limestone in lower part of formation; minor quartzite. Brown fissile shale locally in upper part.	1,770+
Devonian and Silurian	Hidden Valley dolomite		Light-gray massive dolomite..	1,000±
Upper Ordovician	Ely Springs dolomite		Dark-gray dolomite with chert beds and lenses; lesser light-gray dolomite	920±
Middle Ordovician	Eureka quartzite		Light-gray to white vitreous orthoquartzite	440
Lower Middle(?) and Lower Ordovician	Pogonip group		Light- and medium-gray thick-bedded dolomite; lesser thin-bedded dolomite and limestone.	1,570+
Unknown	Gneiss			

Figure 4. From Hall and MacKevett, 1962, p. 6.

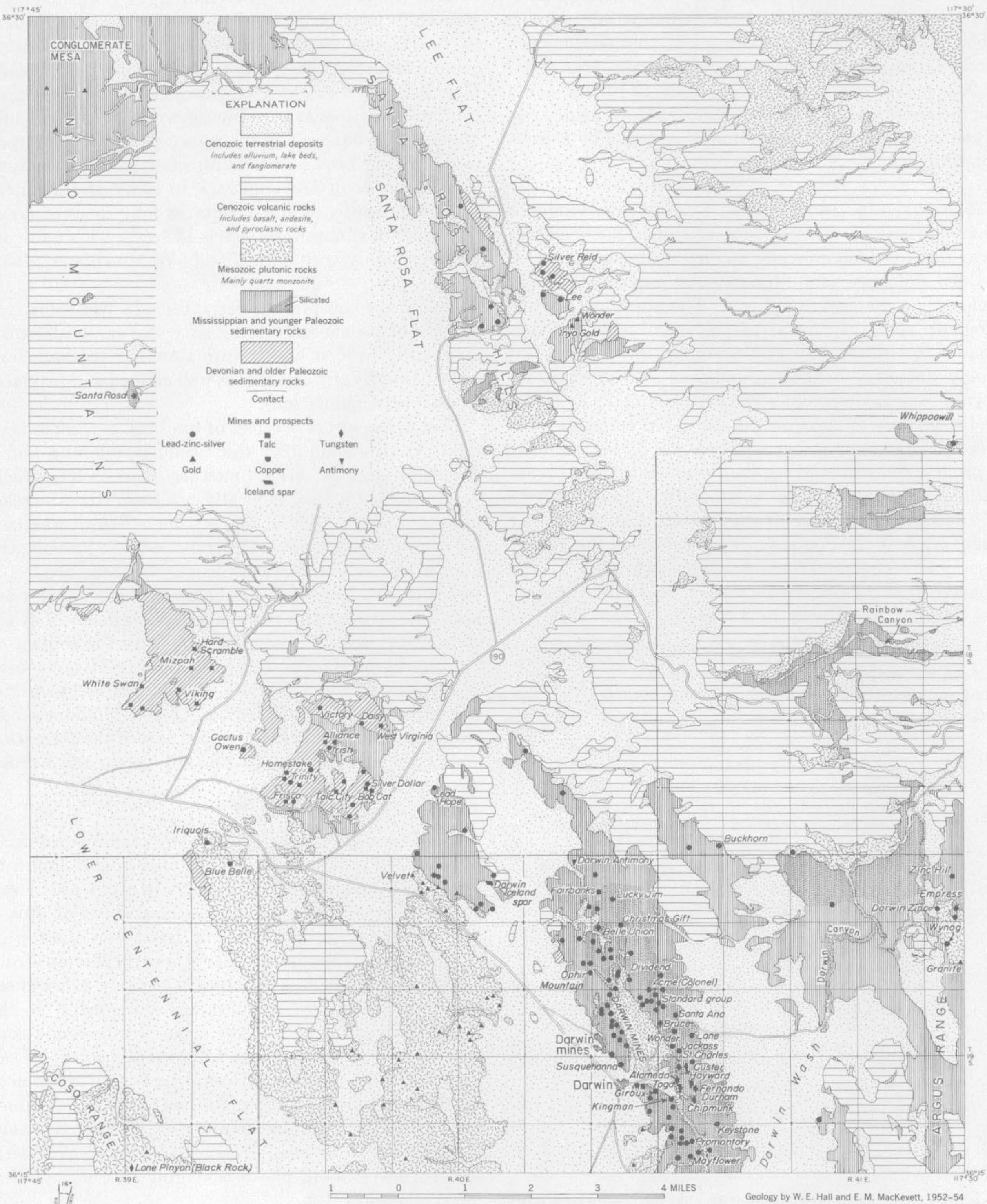


FIGURE 3.—Simplified geologic map of the Darwin quadrangle showing the geologic setting of the ore deposits.

Figure 5. From Hall and MacKevett, 1962, p. 7.

The rock record in the Darwin region consists of Ordovician through Permian miogeoclinal sedimentary rocks, Mesozoic plutonic rocks, and Cenozoic volcanic rocks and sediments. The Ordovician - Permian section consists of over 14,000 feet of carbonate rocks in which pre-Mississippian rocks are largely dolomite and Mississippian through Permian rocks are primarily limestone (Hall and MacKevett, 1958). The Paleozoic marine sequence was deposited in the thick Precambrian-Paleozoic miogeoclinal wedge that formed on the passive continental margin, and later thrusted eastward as allochthonous thrust sheets during the Antler and Sonoma orogenic events. Ordovician beds are exposed in outcrop in the Talc City Hills (6 miles northwest of Darwin) where the Early-Middle Ordovician Pogonip Group dolomite is overlain by the middle Ordovician Eureka Quartzite. The thick bedded late Ordovician Ely Springs dolomite overlies the Eureka Quartzite. Silurian-Devonian rocks are represented by of the Hidden Valley Dolomite and the Lost Burro Formation which is exposed on the east side of the Talc City Hills and on the west flank of the Darwin Hills where it consists primarily of dolomite, quartzite, shale, and chert. The Mississippian Tin Mountain Limestone and the upper Mississippian Perdido Formation both outcrop on the west flank of the Darwin Hills. The Tin Mountain is composed of gray fossiliferous and cherty fined grained limestone. The Perdido Formation resembles the Tin Mountain Limestone but contains thick continuous chert beds and lacks the abundant fossils. The Mississippian-Pennsylvanian Lee Flat Limestone rests conformably of the Perdido Formation. The Pennsylvanian Rest Spring Shale is present only in in the northern Darwin Hills and the Talc City Hills. Considered by some workers to be the stratigraphic equivalent of the upper Lee Flat Limestone (McAllister, 1952), the unit is generally thin (0-50 feet thick) (USGS, 2011)

The Permo-Pennsylvanian Keeler Canyon Formation is a thick (4,000? ft.) limestone unit that can be divided into upper and lower members (Hall and MacKevett, 1958). The lower member (2,300? ft.) is composed predominantly of bluish-gray Pennsylvanian limestone. The lead-silver-zinc deposits of the Darwin District are associated with a metamorphosed and silicified section of the lower member where it has been folded and intruded by the Darwin quartz monzonite stock. The lower Keeler Canyon member outcrops throughout most of the Darwin Hills. The upper member is composed of pink shale, silty limestone and limy siltstone. The youngest Paleozoic rock units include calcarenite, silty limestone, pure limestone, and shale of the Permian Owens Valley Formation. These units are exposed throughout much of the Darwin area and underlie the east side of the Darwin Hills, Darwin Canyon, and the west flank of the Argus Mountains. Regionally, the Paleozoic section was intruded by several Mesozoic bathloliths and plutons. These include the Hunter Mountain batholith to the northeast , Coso Range batholith to the southwest, and the satellite stock at Darwin Hills where biotite-hornblend quartz monzonite is the primary rock type. Stocks at Talc City Hill and Zinc Hill in the Argus Range are composed of leucocratic quartz monzonite. The Coso Range intrusion which has been dated 154-156 m.y. (Dunne and others, 1978) as well as plutons in the Argus Range, are considered to be Sierra type batholiths that are coeval satellites of the Sierra Nevada batholith. Tertiary and Quaternary sedimentary deposits abound. Much of the area is covered by Plio-Pleistocene fanglomerates which flank the Inyo Mountains and the Coso and Argus Ranges, and by lacustrine beds of ash, silt, and clay in the Darwin Wash area. During the Cenozoic, regional extension produced widespread normal and strike-slip faulting, volcanism, and shallow intrusive activity. Cenozoic volcanic rocks are common north of Darwin in the Inyo Mountains, Santa Rosa Hills, and on parts of the Darwin Plateau. Pyroclastic basaltic rocks rest unconformably on the Paleozoic sedimentary rocks and granite in the Inyo Mountains and layered olivine basalt flows cover a much of the area ranging from 10 to 100 feet thick (Hall and MacKevett, 1958). (USGS, 2011)

REGIONAL STRUCTURES

1958

Structurally the area is on the west limb of a major anticlinorium where the Paleozoic strata strike predominantly north to N. 30°W. and dip gently to the west. Within 2 or 3 miles of major intrusive bodies the structure is much more complex; the beds are tightly folded and faulted, and much of the bedding is overturned. Inverted anticlines and synclines are common (Hall and MacKevett, 1958, p. 4).

The Darwin quadrangle is on the west limb of a major anticlinorium, the axis of which trends approximately N. 15° W. near the crest of the Panamint Range about 15 miles east of the quadrangle. The Paleozoic rocks are folded and faulted. Bedding strikes predominantly north to N. 30° W. and dips southwest, except in the Talc City Hills where the strike is N. 60 °to 80° W. as a result of deformation by forceful intrusion of the batholith of the Coso Range. Thrust faults and steep faults, some probably with large strike-slip displacement, were formed during the late Mesozoic orogeny. Basin and Range faults of Cenozoic (Hall and MacKevett, 1958, p. 14).

The only major unconformity truncates the Paleozoic rocks and the Cretaceous plutonic rocks. Minor unconformities are represented in the Pennsylvanian and Permian strata by recurrent limestone-pebble conglomerates and by local angular discordances. Pronounced differences in lithology between formations of Paleozoic age may represent minor hiatuses (Hall and MacKevett, 1958, p. 14).

The Paleozoic rocks are deformed into broad open folds with moderate dips at distances greater than several miles from a major intrusive. The trend of the folds is north to N. 20° W. Within 2 to 3 miles of the batholith of the Coso Range in the Darwin Hills and Talc City Hills folding is much more intense and bedding is overturned. Inverted anticlines and synclines are common, and faults are abundant. The structure of the Darwin Hills is an overturned syncline with an axial plane that strikes N. 15° W. and dips about 50° W. along the eastern margin of the hills. The rocks range in age in a conformable sequence from Devonian on the west to Permian on the east. Bedding, which is overturned, strikes north and dips predominantly to the west, except locally on limbs of minor folds. The structure in the Talc City Hills is also synclinal; Devonian and Silurian rocks are in the core and Ordovician rocks on the flanks of the syncline (pI. 2). (Hall and MacKevett, 1958, p. 14).

Two general periods of faulting are recognized-a late Mesozoic period of faulting and late Cenozoic faulting producing the present basin-and-range topography. Late Mesozoic faults include thrust faults and steep faults that have mainly a strike-slip displacement. The major thrust fault is in the Talc City Hills where rocks of Devonian to Ordovician age have been thrust toward the northeast over limestone of predominantly Pennsylvanian and Permian age. The stratigraphic throw on the fault is 5,900 feet, and the net slip is estimated to be 3.6 miles. The Davis thrust is an important ore controlling structure in the Darwin Hill (Hall and MacKevett, 1958, p. 14).

Strike-slip faults are common in the Darwin Hills and the Santa Rosa Hills. The Darwin tear fault is the major fault in the Darwin Hills. It is a left-lateral transverse strike-slip fault with a displacement of 2,200 feet, north side west. Strike-slip faults in the Santa Rosa Hills are also left lateral, but the net slip is not known (Hall and MacKevett, 1958, p. 14).

Faults of late Cenozoic age account for many of the present topographic features. These faults strike north and dip steeply. Most of them are normal faults with an en-echelon pattern. A swarm of Basin-Range faults in the northeastern part of the quadrangle is responsible for the escarpment on the west side of Panamint Valley. Most of the faults are normal faults with their downthrown side to the east, but some are reverse faults with the valley or east side faulted up. Another swarm of faults on the western flank of the Argus Range forms a series of step-like benches. The cumulative vertical displacement on these faults is about 1,600 feet; in the northeastern part of the quadrangle on the west side of Panamint Valley it is about 2,000 feet. The Basin and Range faults are less conspicuous in other parts of the quadrangle (Hall and MacKevett, 1958, p. 14).

1962

Structurally the Darwin quadrangle consists of folded Paleozoic rocks that are intruded by several plutons and interrupted by many faults (pl. 1). Bedding strikes north to N. 30° W. except in the central part of the quadrangle from the Talc City Hills eastward to Panamint Valley where bedding trends N. 60° to 85° W. and has been tightly folded. Faults have broken the Paleozoic rocks into several structural units. Thrust faults and steep faults, some with possible large strike-slip movement, were formed during the late Mesozoic orogeny. Normal faults of late Cenozoic age were important in tilting the beds and forming the present basin and range topography (Hall and MacKevett, 1962, p. 39).

2011

[Regional] Structural features are the result of several periods of deformation in the western Basin and Range including Mesozoic folding and faulting which dictated the overall structural fabric of the Paleozoic rocks, and late Cenozoic faulting which produced the present Basin and Range topography. Dunne and others (1978) recognized three major pulses of Mesozoic deformation in the general area of the White, Inyo, Slate, and Argus ranges. However, the most significant in terms of the Darwin region was of mid to late Jurassic age and associated with the Nevadan Orogeny. Deformation is reflected in the Swansea-Coso Thrust System, a thrust belt characterized by generally high angle thrusts with little lateral slip that extends almost

continuously from the southern Inyo Mountains to the Slate Range. This deformation was associated with the emplacement of the Sierra Nevada batholith and many coeval satellite plutons in the White and Inyo Mountains and the Coso batholith. The Paleozoic rocks were compressed into a series of broad open northerly trending folds. The major fold in the Darwin area is the Darwin Wash Syncline, a broad syncline which trends N 20? W and is located just east of the Darwin Hills in Darwin Wash. The east limb of the syncline occurs as a dip slope on the west flank of the Argus Range. The west limb is largely obscured by alluvium in Darwin Wash but is exposed in the low hills at the north end of the wash (USGS, 2011).

REGIONAL STRUCTURAL HISTORY

1938

Following the metamorphism and the consolidation of the stock, the rocks were fractured and faulted. These fractures fall into two prominent sets. One set trendsnorthwesterly and the other east-northeasterly nearly at right angles to the stock. The major or master fracture of the district is a large fault on which the greatest component of displacement appears to be horizontal. This fault crosses the northern end of the hills where it is made plain by both structural and physiographic effects. The principal movement on most of the faults has been such as to displace the north walls westward (Kelley, 1938, p. 505).

The ore mineralization took place after the fracturing, and the localization of the ore mineralization shows three structural controls: igneous contacts, bedding planes, and cross fractures. Of the fractures only those trending east-northeasterly have proved productive. The northeasterly-southwesterly stresses which caused the faulting and which were active during part of the mineralization at least were such as to more effectively open the east-northeasterly fractures to the ore-bearing solutions. On the west side of the stock the beds roughly parallel the igneous contact and only on this side are important deposits of ore found at the contact between the stock and the country rock. Deposits along favorable bedding planes are found on both sides of the stock. Deposits along faults or fissures are more numerous and more productive on the east side of the stock (Kelley, 1938, p. 505).

1962

The probable sequence of events during the late Mesozoic orogeny is summarized below. The Paleozoic strata were first deformed into a series of broad open folds that formed the Darwin Wash syncline and tilted the Paleozoic rocks in the Santa Rosa Hills homoclinally westward. These folds have flat-lying axes that trend northward. The gently folded Paleozoic strata were then forcefully intruded by biotite-hornblende quartz monzonite in the Coso Range and in the northeastern part of the quadrangle during the Jurassic period. In the Darwin Hills older strata brought up by the intrusion in the Coso Range were overturned, tightly folded, and faulted. With release of pressure by cooling and crystallization of the batholith, minor adjustments took place on-the west limb of the Darwin syncline and formed normal bedding plane faults (pl. 1, section C-C1). The

Paleozoic rocks were folded and faulted before silication of the limestone around the intrusive body. The tight folds spatially are directly related to the periphery of the batholith, but the folding cannot be due to a buttressing effect of a large intrusive body during late compression. The tightly folded structures in calc-hornfels reflect plastic deformation of incompetent beds and indicate that the folding preceded silication of the limestone (Hall and MacKevett, 1962, p. 45).

The Paleozoic strata in the Talc City Hills and southern Santa Rosa Hills were squeezed between the two major intrusive masses (pl. 1). The beds were rotated from a northerly to a N. 60° to 80° W. strike. Deformation caused rupture along the Darwin tear fault and Standard fault. The Darwin tear fault must have moved both before and after silication. It controlled in part the silication of the limestone in the Darwin Hills, hut the silicated limestone has also been sheared. After rotation of the beds, older Paleozoic rocks were thrust northeast over Carboniferous and Permian beds in the Talc City Hills, and the thrust sheet was broken by steep strike faults (Hall and MacKevett, 1962, p. 45).

REGIONAL GEOLOGIC HISTORY

1962

The Paleozoic era was marked by nearly continuous deposition of marine sediments from the Early Ordovician to well within the Permian; no major unconformities or hiatuses were recognized. Lithology and fossils of the Lower Ordovician Pogonip group, the oldest rocks in the quadrangle, indicate that the predominantly carbonate rocks were formed in a deepwater marine environment. Local admixing of sand grains .and crossbedding near the top of the formation manifest a transition from deepwater deposition for the older dolomites and limestones to shallow-water conditions during the Middle Ordovician. Littoral subzone or beach conditions probably prevailed during Middle Ordovician time and resulted in the deposition of well-sorted quartz sand of the Eureka quartzite, probably a second cycle orthoquartzite. Ely Springs dolomite and Hidden Valley dolomite were formed in seas that covered the area during Late Ordovician time and during the Silurian and Devonian. Marine deposition continued through the Devonian, mainly forming limestone in contrast to the preponderance of dolomite in pre-Devonian seas (Hall and MacKevett, 1962, p. 51).

Marine sedimentation continued throughout the Mississippian. The limestone units of the Tin Mountain. limestone and Perdido formation were largely formed in placid seas devoid of foreign detritus. Calcilutite of the Lee Flat limestone records marine deposition that was likely derived from a low-relief landmass Continued marine deposition in a nearshore environment formed the calcarenite and calcilutite characteristic of the Pennsylvanian and Permian. Recurrent emergences are indicated by intercalated limestone conglomerate and minor unconformities, and widespread crossbedding indicates a nearshore environment. Most of the emergences probably were short lived and of limited extent, but locally folding was·concomitant with uplift. The coarse limestone conglomerate of the upper part of the Owens Valley formation probably *accumulated in a local basin as a result of rapid local differential uplift* (Hall and MacKevett, 1962, p. 51).

Orogeny was the dominant feature of the Mesozoic era, although the exact age of the diastrophism is not well documented. The Paleozoic rocks were uplifted and folded before the advent of the Mesozoic intrusions. The Paleozoic rocks were then regionally warped in response to the forceful intrusion of the Hunter Mountain batholith and the Coso batholith. Faulting and fracturing, some subsequent to the partial solidification of the granitic rocks, preceded the deposition of ore and gangue minerals during the late stages of orogeny. Subarea! erosion probably was active throughout most of the era (Hall and MacKevett, 1962, p. 51).

There is a gap in the geologic record between the Mesozoic intrusions and ore deposits and the advent of volcanism during the late Pliocene. This gap probably represents a period mainly of erosion. By late Pliocene time the land surface had been eroded to a mature surface of low relief. This surface has been correlated by Hopper (1947, p. 400) with the late Pliocene Ricardo erosion surface of Baker (1912, p. 138; Merriam, 1919, p. 529) cut across tilted lower Pliocene beds in the El Paso Range about 75 miles to the south. The Darwin senesland of Maxson (1950, p. 101) between the Argus Range and the Inyo Mountains contains part of this mature surface (Hall and MacKevett, 1962, p. 51).

Note: Regional plate tectonic reconstructions indicate that there was Miocene extension throughout the Basin and Range province, which extends to the Darwin area. There may have been volcanic Miocene formations here which have now been eroded.

The present basins and ranges had their inception at least as far back as late Pliocene time when uplift of the Coso Range and Inyo Mountains caused the formation of extensive piedmont fans that interfinger with lacustrine deposits in Owens Valley. Volcanic activity was common during the Pliocene, and. it continued intermittently into the Quaternary. Pyroclastic rocks of basaltic composition are abundant in the lowermost beds of the late Pliocene or early Pleistocene Coso formation at Cactus Flat on the west flank of the Coso Range in the Haiwee Reservoir quadrangle. Andesite, which locally is interbedded in the Coso formation at Cactus Flat and is interbedded in basaltic pyroclastic rocks ill the Inyo Mountains near the Santa Rosa mine, was extruded as domes during the late Pliocene or early Pleistocene. The pyroclastic rocks were tilted locally before the outflow of the extensive olivine basalt flows that cap most of the northern part of the Darwin quadrangle (Hall and MacKevett, 1962, p. 51).

Uplift of the Argus and Coso Ranges, and the Inyo Mountains continued through the Pleistocene and Recent. The olivine basalt flows of Pleistocene age have been tilted and step faulted. A lake was formed in Darwin Wash during middle or late Pleistocene. Headward erosion of Darwin Canyon subsequently captured the drainage of Darwin Wash and in this way lowered the base level of erosion to Panamint Valley and caused dissection of the lake beds. Erosion and intermittent uplift have continued in the Recent (Hall and MacKevett, 1962, p. 51).

2011

During emplacement of the Nevadan intrusives such as the Coso Range batholith, adjacent bedding was severely deformed. The gently folded strata was forcefully intruded and further deformed in and adjacent to the Darwin Hills as older strata was forced upward by the intrusion, overturned, tightly folded, and faulted. Thrust faulting was associated with the emplacement of the Coso batholith and is localized along the east margin of the batholith. The largest of these is the Davis Thrust in the Darwin Hills which exhibits eastward thrusting. The Davis thrust strikes northerly through the Darwin Hills and is an important control in the deposition of the Darwin District lead-silver-zinc ores (Hall and MacKevett, 1962). It dips 23? to 60?W. Throw and net slip are unknown. The west limb of the Darwin Wash Syncline is further deformed adjacent to the Darwin quartz monzonite stock where the beds are overturned. The Paleozoic rocks of the Darwin Hills were largely folded and faulted before silication of the limestone around the intrusive body. Accompanying the thrusting of the Swansea-Coso trend, at least three periods of pre-Cenozoic strike slip faulting occurred. (Dunne and others, 1978). These faults consist of steep high angle left lateral strike slip faults exhibiting mainly a strike-slip displacement. The most pronounced of these are northwest trending sinistral faults and fractures that are present form the Southern Inyo Mountains to the Argus range. The faults and fractures truncates structures as young as the Swansea-Coso Fault system, and they are intruded by dikes of the Independence Dike swarm of late Jurassic age (Dunne and others, 1978). The largest of these faults in the area is the Darwin Tear Fault, a major northwest-southeast trending sinistral strike-slip fault which offsets the Darwin Wash Syncline near the northern edge of the Darwin Hills. The fault can be traced for almost 10 miles from the Talc City Hills to the Argus Range and exhibits a maximum known displacement of 2,200 feet (Hall and MacKevett, 1958). The Standard Fault, in the Darwin Hills is another example. Additional Mesozoic faulting includes sets of northeasterly trending sinistral faults and northerly striking nearly vertical faults and fractures. Cenozoic tectonics are responsible for the current topographic features of the Basin and Range. Stewart (1978) believes that back-arc spreading and right hand transform wrenching of the western continental margin is responsible for the characteristic Basin and Range horst and graben topography and extensive volcanic activity. Cenozoic faults are generally northerly striking high angle en-echelon normal faults with their downthrown side to the east, and superimposed on the earlier Mesozoic structures. All the mountain ranges in both the Darwin and adjacent Panamint Butte quadrangle are east tilted fault blocks with adjacent alluvial basins including the southern Inyo, Coso, Argus, and Panamint ranges. A swarm of Basin and Range faults northeast of the Darwin area form the escarpment on the west side of the Panamint Valley where the cumulative vertical displacement is about 2,000 feet (Hall and MacKevett, 1958). Another swarm of faults on the western flank of the Argus range forms a series of step like benches. The cumulative vertical displacement on these faults is 1,600 feet. Extensional tectonics of the basin and range topography began before the late Pliocene as shown by the fanglomerates of that age marginal to the Inyo Mountains and Coso Range (USGS, 2011).

AREA GEOLOGY

Overview

At Darwin, Paleozoic beds of the Permo-Pennsylvanian Keeler Canyon Formation were folded, overturned, faulted, and locally metamorphosed during emplacement of the nearby Coso Range batholith and satellite Darwin stock. The main structural feature of the Darwin District is a north trending overturned syncline intruded by the quartz monzonite Darwin stock near its axis and complexly faulted. Intrusion of the stock into the overturned syncline resulted in a contact metamorphic aureole consisting of calc-silicate minerals peripheral to the intrusive which was later faulted and fractured prior to mineralization. The Davis Thrust Fault strikes northerly along the west side of the Darwin Hills and confined mineralization to the rocks in the footwall between the fault plane and the Darwin stock to the east.. Later introduction of ore solutions created structurally controlled ore bodies which include bedded replacement deposits, irregular replacement bodies, and fissure deposits along faults and fractures within the altered carbonate country rocks. Proximity to faults and intrusive contacts was largely responsible for ore body localization with most ore bodies near N 50? -70? E striking feeder faults. The primary hypogene sulfide ores are argentiferous galena, sphalerite, and chalcopyrite. Gangue minerals include calcite, fluorite, pyrite, and pyrrhotite. A zone of rich oxidized ore extends form the surface to almost 1,000 feet with cerrusite and hemimorphite being the main ore minerals (USGS, 2011).

1938

Kelley (1938) was the first to produce geology maps of the Darwin District. Those maps also show claim locations. They are reproduced in Appendicies 01A, 01B and 01C.

The flat portion of this large mountain block or horst covers some 250 square miles and is called the Darwin plateau. It is delineated on the north and the northeast by abrupt descents into Saline and Panamint Valleys. On the southeast the plateau is bounded by the Argus Range which rises abruptly by a series of faults above a somewhat dissected portion of the plateau. On the southwest the plateau is bounded by the Coso Range which has been elevated also by a recent fault. On the west the plateau is bounded in part by the southern end of the Inyo Range, and in part merges into broad washes dissected in lake beds and descending gradually into Owens Lake (Kelley, 1938, p. 504-505).

The Darwin Hills owe their origin to faulting, particularly on the west side, and to recent dissection of the southern part of the plateau by the Darwin Wash (Kelley, 1938, p. 505).

Two contrasting rock types underly the Darwin plateau. The southwestern portion, generally south and west of the road from Darwin to Keeler, is underlain by granodioritic rock closely comparable in texture, composition, and structure to the intermediate rock of the Sierra Nevada batholith. Occasional patches of older rocks are present as for example on Centennial Flats where large deposits of iron ore occur in a remnant of *schist and marble. Commonly the granodiorite of this region is cut by basic dikes which often display marked persistency for considerable distances. The widespread granodioritic body of the area is referred to in this report as the Coso batholith* (Kelley, 1938, p. 511).

The northeasterly part of the plateau is underlain chiefly by folded upper Paleozoic rocks similar to those in the Darwin Hills and in the north end of the Argus Range. Knopf (pp. 36-48, 1918) has described these rocks in the south end of Inyo Range southeast of Keeler where they form folds of Mesozoic age. In the Inyo Range southeast of Keeler these folds are covered by extensive lava sheets, but they emerge again along the strike to the southeast of the Darwin plateau. There they are partially cut off and offset in their distribution around the Coso batholith. The same system of folds passes through the Darwin Hills and thence southeastward, by step-faulting into the Argus Range (Kelley, 1938, p. 511).

Here and there the Paleozoic rocks are pierced by small intrusives which may well be off-shoots from the Coso batholith. Knopf (p. 5, 1918) described such intrusives as common in the Inyo Range. In the general Darwin region they are exemplified by the quartz diorite stock of the Darwin Hills, the small granitic intrusion near the Lee mine, the gabbroic stock at Darwin Falls, the monzonite plug at the north end of the Argus Range, and several smaller intrusives southward in the same range. Northeast of Darwin, the truncated Paleozoic beds are extensively capped by basaltic flow which form a large part of the plateau surface and may conceal the presence of other intrusive stocks extensively capped by basaltic flows which form a large part of the plateau surface and may conceal the presence of other intrusive stocks (Kelley, 1938, p. 511).

1958

The mineral deposits are concentrated around the margin of the batholith in the Coso Range. The Darwin silver-lead district is in the Darwin Hills on the east side of the Coso batholith. Lead-silver-zinc deposits are ma inly on the western side of the Darwin Hills and tungsten deposits are on the eastern s ide. Talc deposits are in the Talc City Hills at the north end of the batholith. Limestone-altered to calc-hornfels and tactite-is the host rock for most of the lead-sliver-zinc deposits and the tungsten deposits; dolomite and to a lesser extent quartzite are the host rocks for the ta lc deposits. Fractures have controlled the deposition of most ore bodies (Hall and MacKevett, 1958, p. 4).

Lead-Silver-Zinc Deposits

Deposits of lead-silver-zinc are widely distributed throughout the Darwin quadrangle. The largest deposits are in the southern part of the quadrangle in the Darwin Hills north and east of the town of Darwin. Other deposits have been mined at Zinc Hill 6 miles northeast of Darwin, in the Lee district at the south end of the Santa Rosa Hills, at the Santa Rosa mine in the Inyo Mountains, and at a few small deposits in the Talc City Hills (PI. 1) (Hall and MacKevett, 1958, p. 16).

Most of the lead-silver-zinc deposits are in calc-hornfels close to an intrusive contact. The deposits in the Darwin Hills are in calc-hornfels of the lower member of the Keeler Canyon formation of Pennsylvania and Permian age. The Santa Rosa mine is in calc-hornfels of the lower member of the Owens Valley formation of Permian age. A few small deposits are in marble or limestone. (Hall and MacKevett, 1958, p. 16).

No individual formation can be considered as particularly favorable for ore deposits, although within mineralized areas certain beds are favorable. In general, all formations consisting of limestone seem to be favorable for lead-silver-zinc deposits, and formations of dolomite and quartzite appear unfavorable. The deposits in the Lee district are in the Lost Burro formation of Devonian age and the Tin Mountain limestone of Mississippian age. The Cactus Owen prospect and the Homestake mine in the Talc City Hills are in a limestone unit of the Lost Burro formation. Deposits in the Zinc Hill district are mainly in Mississippian limestone. The Silver Dollar mine is in limestone of Pennsylvanian age near a thrust fault contact with older dolomite. Dolomite and quartzite in the Talc City Hills contain talc deposits, but only the limy parts of the formations contain lead-zinc deposits (Hall and MacKevett, 1958, p. 16).

The generalization that limestone is favorable for lead-silver- zinc deposits and dolomite is unfavorable is also true in the Cerro Gordo area northwest of the Darwin quadrangle. However, the major lead-silver mines in the Ubehebe Peak quadrangle, the Lippincott and Ubehebe mines, are mainly in dolomite (McAllister, 1955, p. 20). (Hall and MacKevett, 1958, p. 16).

Within mineralized areas, certain beds in a formation are more favorable than other beds. In the Darwin district a medium-grained wollastonite-garnet-idocrase calcsilicate rock formed from a fairly pure limestone is favorable but dense, gray or greenish-gray calc-hornfels formed from silty limestone is unfavorable. At the Zinc Hill mine all the known ore bodies are in one favorable marble bed 200 feet thick, while other limestone beds are only slightly mineralized. (Hall and MacKevett, 1958, p. 16).

Individual deposits occur within favorable horizons as replacement bodies along faults, as bedded replacements commonly near the crests of folds, and as steep irregular or pipelike ore bodies. A fault control is apparent for nearly all the deposits, although it may be only one of several controls instrumental in localizing ore. In the Darwin district, most of the ore bodies are in favorable beds in or close to steep-dipping strike-slip faults striking N. 50°-70° E. that served as feeder channels for the ore solutions. The ore is in the N. 50°-70° E. faults at the Christmas Gift, Lucky Jim, and Rip Van Winkle mines. At the Thompson mine the ore is in north-striking fractures that are close to the N. 50° to 70° E. faults, and the fractures are progressively less mineralized away from the northeast-striking faults. An exception is the Essex ore body, which is in a fault that strikes N. 65° W. (Hall and MacKevett, 1958, p. 16).

Bedded replacement bodies are at the Defiance, Independence, Jackass, Custer, Promontory, Empress, and Zinc Hill mines. At both the Defiance and Independence mines the bedded replacement bodies are at the crests of gentle folds close to a *granodiorite sill. The bedded ore body at the Defiance mine becomes progressively thinner outward along bedding away from the northeast- trending Defiance fault.* (Hall and MacKevett, 1958, p. 16).

The largest steep pipelike ore body is at the Defiance mine; this ore body has been developed from the 400- foot level to the 1000-foot level. It is adjacent to the Defiance fault and is localized in a zone broken up by numerous small fractures that strike northerly from the Defiance fault (Hall and MacKevett, 1958, p. 16).
In the Lee district, ore bodies are localized in flat lying fractures between major steep-dipping faults. The flat fractures may parallel bedding or transect bedding. A similar structural environment at the Ubehebe mine has been described by McAllister (1955, p. 27) and also has been observed by the writers about 11 miles southeast of Darwin at the Defense mine in the Argus Range (Hall and MacKevett, 1958, p. 16).

The ore bodies range in size from small pods that contain a few tens of tons of ore, as in the Lee mine, to the large bedded replacement bodies of the Independence mine or pipelike ore body of the Defiance mine in the Darwin district. The bedded ore body at the Independence mine is mineralized, although not all of it is ore grade, for a maximum strike length of 500 feet, a thickness as much as 160 feet, and a distance of 700 feet down the dip. The pipelike ore body of the Defiance mine has been developed 700 feet vertically from 125 feet above the 400-foot level to the 1000-foot level, but its total vertical extent is not delimited. The mineralized area is approximately 5,000 square feet in cross section, but it is not all ore (Hall and MacKevett, 1958, p. 16).

AREA STRATIGRAPHY

1938

The oldest rocks within the [Darwin] hills are a series of Pennsylvanian limestones, shales, and quartzites. The strata of this series are considerably folded, especially along the eastern slopes of the hills. Impure limestones comprise the bulk of the Pennsylvanian rocks which aggregate some 5000 feet as exposed in the Darwin Hills (Kelley, 1938, p. 505).

Intruded into the folded series is an elongated stock. This stock, five miles in length and two-thirds of a mile in maximum width, parallels the north-northwesterly trend of the stratified rocks. The stock widens in depth and cuts across the west limb of a large fold. The intrusive rock is medium-grained quartz diorite on the average, be more acidic and basic phases are common. (Kelley, 1938, p. 505).

The igneous intrusion has effected marked transformations in the country rock, particularly in the limestones. The metamorphic aureole is as much as 2500 feet in width. Within this zone the limestones have been converted into silicate-carbonate rock termed tactite. The silication of the limestone was caused by the action of igneous emanations which accompanied the intrusion. The original stratification of the limestones is retained despite the transformations. The zone as a whole has been *bleached to a grayish or greenish white, which stands in contrast to the gray or brown of the unaltered sedimentaries. (Kelley, 1938, p. 505).*

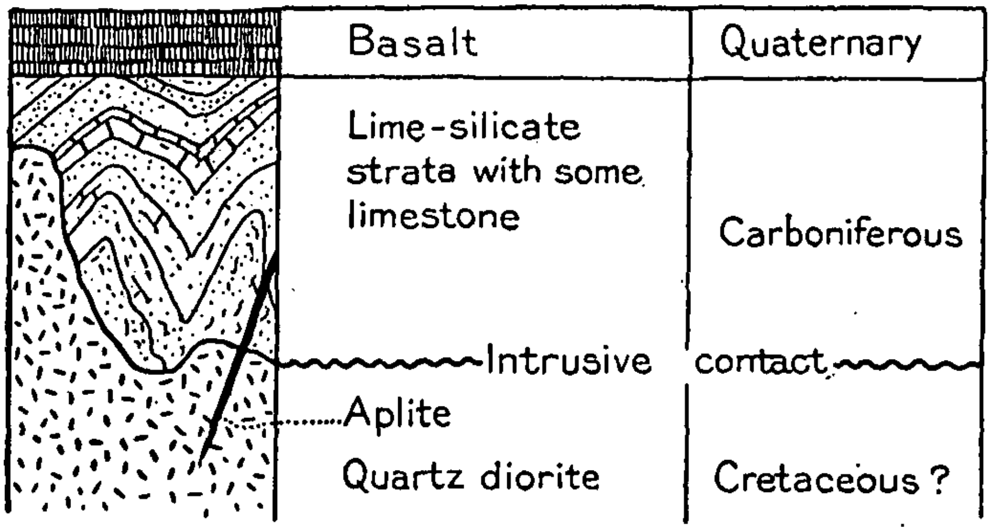


FIGURE 2.—Generalized columnar section for the Darwin district, Cal.

Figure 6. From Knopf, 2015.

PENNSYLVANIAN SERIES

A series of Pennsylvanian strata consisting largely of pure and impure limestones intercalated with some quartzite and shale constitute the oldest rocks of the Darwin Hills. Fossil corals, crinoids, fusulinae, bryozoa, and occasional ammonoids occur in these beds. The state of preservation of the fossils is usually rather poor and exact determinations are therefore difficult. On the basis of determinations made by George H. Girty, Knopf (1914) called the formation Pennsylvanian. The strata dip westerly across most of the width of the hills and therefore, excluding complete overturning for which there is no evidence, the younger beds crop out on the west flanks of the hills. The oldest beds, or the lowest in the exposed series, crop out on the east side of the hills and locally they are considerably folded. The lower strata east of the stock and on the east side of the hills are generally drab and uniform gray or brown with few distinct horizons or marker beds. The younger strata, on the other hand, which crop out on the western slopes of the Darwin Hills, consist of and are marked by prominent, contrasting light and dark colored members. The beds along the western half of the hills generally dip steeply west and aggregate about 2500 feet in thickness. The contrasting nature of the members of a portion of this series is shown by the following section between the sill beneath the east escarpment of Ophir Peak to the western edge of the hills (Kelley, 1938. P. 511-512).

(1) 2-300 feet of thin-bedded, dark-gray, impure limestone

(2) 4-500 feet of white and grayish white limestones
(3) 3-400 feet of dark-gray to black limestones
(4) 4-500 feet of pure, massive, white limestones

Alluvium overlaps the youngest strata at the base of the hills and the Coso granodiorite probably intrudes the limestones a short distance beneath the alluvial cover. The members of the above series appear to finger and wedge out southward toward the Darwin Lead Company's camp, where they are further confused, and their identity obliterated by local folding and silication. An isolated patch of folded, pure white limestone probably equivalents to the third member listed above occurs at the entrance of the Radiore tunnel (Kelley, 1938, p. 512).

A section across the southern end of the hills shows an inclined series dipping 40-60° west. The thickness of this section, although neither the top nor the bottom of the series is exposed, approximates 5000 feet. At the top of this section is a prominent member of dark-gray impure limestone which marks the bold front of the hills southward from the town of Darwin. To the north near Darwin the character of this member is obliterated by bleaching and silication ; to the south it is partially cut out by a lobe of the Coso batholith. In the center of the hills along this east-west section silication has again obliterated the original nature of the sedimentary material, but along the southeastern tip of the hills at the statigraphic bottom of the section a dark-gray to black limestone member 6-700 feet in thickness makes up the oldest Pennsylvanian rocks in the Darwin Hills. This member occurs just east of the Columbia mine where it forms bold cliffs 2-300 feet high facing the Darwin Wash (Kelley, 1938, p. 512).

The east slope of the Darwin Hills consists of closely folded, thin-bedded limestone strata in which conspicuous lithologic members are absent except as noted above. The beds in general are drab brown and gray color. No white limestone strata occur and only occasional relatively thin, blue-gray limestone beds are present (Kelley, 1938, p. 512).

The blue-gray limestone which makes up so much of the Pennsylvanian rocks throughout the hills is commonly spotted in texture. In many instances *this is due to fusulinal and crinoidal remains which, because of their differential coloring and solubility, cause a spotted texture in the outcrop. A similar spotty texture is also due to small lenses and nodules of chert in the limestone* (Kelley, 1938, p. 512).

The lithology in the north end of the Darwin Hills north of the large east-west fracture here referred to as the Darwin tear fault is noticeably different. Magenta, lavender, and brown, thin-bedded shales are common. A massive quartzite bed 30-40 feet in thickness crops out as a prominent ridge about 1300 feet north of the Lucky Jim mine. An even more striking feature of these beds is the increased spottiness of the limestones. Although some of this texture indicates organic origin, much of it is fragmental and undoubtedly many of the beds are depositional limestone breccias. No age determination was made of those beds north of the fault, but because of the *structure and direction of displacement along the fault they are thought to be older than the beds south of the fault* (Kelley, 1938, p. 512-513).

In connection with studies of the silication process a chemical analysis of a sample of typical blue-gray limestone from the ridge above the Thompson mine was made. This showed a content in CaCO considerably higher than the average for limestones of Carboniferous age (Kelley, 1938, p. 512-513).

The table below shows the comparison of the Darwin limestone with Daly's (1909) analyses of Carboniferous and Cretaceous limestones (Kelley, 1938, p. 512-513).

Limestones	Ratio $CaCO_3 : MgCO_3$	Ratio Ca : Mg
Carboniferous	8.8 : 1	12.4 : 1
Darwin	22.8 : 1	31.5 : 1
Cretaceous	40.2 : 1	56.3 : 1

(Kelley, 1938, p. 512-513).

Richard Wallace of Darwin reports analyses of the white limestone on the west slope of the hills which show 98 per cent $CaC0_3$. The high ratio of calcium to magnesium in the Darwin limestone suggests that dolomitization has been relatively unimportant in the Pennsylvanian rocks (Kelley, 1938, p. 512-513).

PLEISTOCENE LAKE BEDS

About 50 feet of nearly horizontal white lake beds have been exposed by recent dissection in the wash east of the Darwin Hills. The material of the beds is fine-textured and thick-bedded and probably originated, in part at least, from volcanic ash. The beds are capped by recent alluvium; their base is unexposed. In the Coso Mountains, J. R. Schultz (undated) has found similar beds of early Pleistocene or late Pliocene age overlying older gravels and in turn capped by basaltic lavas which are probably age equivalents of the lava sheets at Darwin. At Darwin, however, the age relationship between the lake beds and the lava sheets is reversed. The lake beds in the Darwin Wash are not capped by lava. Furthermore, about 700 feet east of the lake beds in the wash, on a small tilted fault block at the base of the Argus Range, basalt directly overlies Paleozoic beds and lake beds are absent. Prom this relationship it appears that the lake beds are not only younger than the basaltic lavas, but also that they are younger than the faulting which dislocated the basalt. Although beyond the scope of this report, the evidence suggests that the lowermost step fault in the Argus Range was at one time the obstruction to the drainage of the wash which created the lake in which the white beds accumulated. These hike beds, then, are distinctly younger than those described by Schultz in the north end of the Coso Mountains. If those in the Coso Mountains are early Pleistocene, then the Darwin lake beds may be middle or even late Pleistocene in age. No fossils have been found. Headward erosion in the Darwin canyon has subsequently dissected the lake beds by cutting through the outlet of the lake. (Kelley, 1938, p. 513-514).

RECNT ALLUVIUM

The alluvial deposits of the broad washes and fans surrounding the Darwin Hills are of two types, older dissected gravels, and recent gravels. The younger gravels are in part derived from the older and in places they grade into each other. These two types do not result from diastrophic rejuvenation, but rather from the down-cutting of the outlet to the Darwin lake which was the former temporary base level for the erosion around the Darwin Hills. The dissected gravel, where it overlies the exposed lake beds, is usually not more than 10 to 20 feet in thickness. Upstream from the exposed lake beds and especially in the wash south of the Darwin Hills the gravels are much thicker, and arroyos as much as 50-75 feet in depth have been carved. Dissection of the gravels on the west side of the hills is very slight compared to that on the east by reason of the bench of hard rock through which the stream flows at the south tip of the Darwin Hills. At this point is a "dry falls," 50-60 feet in height. Adjacent to the limestone hills not only the alluvium but also the lake beds are well cemented by calcium carbonate (Kelley, 1938, p. 514).

IGNEOUS ROCKS

Coso Granodiorite

The Coso granodiorite is batholithic in extent and underlies most of the plateau south and west of the Darwin Hills. A small area of this rock crops out in the southwest edge of the hills where it forms low rounded hills in contrast with the sharper relief of the limestones. Along the road to the Promontory mine it can be seen in intrusive contact with dark-gray limestones. Although thin sections from the rock of this area indicate it to be granite, the designation granodiorite is retained because it more nearly proximates the average composition of the batholithic material throughout the plateau. Megascopically it is a coarse-grained, light-colored, granitoid rock in which the principal minerals are quartz, feldspar, and green hornblende. Under the microscope most of the feldspar proves to be orthoclase or microcline. Biotite is common and such accessory and secondary minerals as sphene, apatite, chlorite, and epidote may be present. A few dark-green kersantite dikes cut the granite in the Darwin Hills (Kelley, 1938, p. 514).

Darwin Quartz Diorite

General Features. The formation name Darwin quartz diorite is here applied to the elongated stock which occupies the center of the Darwin Hills. All metallization is associated with this intrusive. The stock is about 3500 feet in its greatest width just northeast of Darwin. To the north and south it narrows and terminates in smaller isolated stocks, dikes, and sills. It ends within the hills and its total length is about five miles. The drab brown color of the intrusive causes it to stand out nearly everywhere in strong contrast to the surrounding white silicate zone. The greater ease with which the intrusive weathers has caused it to form a lower interior belt of subdued topography surrounded by boldly outcropping stratified rocks. Variations in composition and texture within the igneous mass itself have also resulted in differential weathering. Thus, near the Defiance mine are several small knobs and ridges of quartz diorite standing out in otherwise subdued relief (Kelley, 1938, p. 514-515).

Composition and Variations. The stock as a whole displays considerable heterogeneity of composition, but for the most part these variations are only phases of the one intrusive. In nearly all of its phases the rock is medium-grained and nonporphyritic. It is normally a light colored, white or light-gray rock when fresh. Pinkish and greenish-gray types are also common. In general, variations in the intrusive range from quartz monzonite to diorite or gabbro. Nearly all of the phases with the exception of the gabbro are of the oversaturated type in which quartz is always present in essential quantities. In the quartz diorite or even the granodiorite the euhedralism of the plagioclase is the striking textural feature under the microscope (Kelley, 1938, p. 515).

In the over-saturated phases the ferromagnesian minerals are ordinarily not abundant. The most common ferromagnesian mineral is biotite. Hornblende and augite are decidedly less common and, in many phases, absent. Where the ferromagnesian content is high the mineral is most commonly augite (Kelley, 1938, p. 515).

Distribution and Origin of the Phases. The more basic phases of the rock occur in the north and south ends of the elongate stock. The change towards basicity is gradual yet very irregular. There is greater heterogeneity of phases and greater concentration of the melanocratic phases in the narrower terminations. Examples of the basic rock areas are well shown near the Christmas Gift mine where the rock is augite diorite or gabbro. Near the southern end of the Christmas Gift extension claim is a considerable area of very dark-colored rock which is almost entirely composed of augite with a little labradorite. In the southern end of the hills west of the Silver Spoon mine and south of the Promontory mine are areas of diorite or locally augitic rocks. These various types of rocks are not separate intrusions but different expressions of one magma (Kelley, 1938, p. 515).

There is little to indicate that the stock differentiated in place. Furthermore, except locally, reactions with the country rock do not appear to have influenced the composition. No regular border phase of more basic rock exists. Instead, phases appear to be due to original variations in the intruded material (Kelley, 1938, p. 515).

Perhaps the first intruded material was basic and later surges, intermediate in composition, pushed the basic material outward and toward the ends. As the stock grew, more acidic material continued to concentrate at the center (Kelley, 1938, p. 515).

Related Dikes.

In places the border portion of the intrusive and the nearby contact aureole contain many dikes. Some of these are direct offshoots of the stock and cut only the country rock, while others are later and also cut the intrusive. The dikes are all more acidic than the main intrusive. In a few cases offshoots from the intrusive, where traced outward, become increasingly acidic, changing- sometimes to alaskitic or syenitic dikes. The syenite dikes are very common in the contact aureole between the Defiance mine and the Thompson mine. They are coarse-grained and composed almost entirely of orthoclase. The color varies between pink, green, and white. Whereas these and other dikes may have originated as magmatic dikes in the ordinary sense, the evidence *suggests in some cases an origin by metasomatic processes. South of the George Washington shaft in the southern part of the hills, alaskitic material has spread in an anastomosing manner from stratification planes through several adjacent beds converting them completely to alaskite or quartz-orthoclase rock. In other places feldspar dikes appear to fray out and permeate adjacent walls in a manner suggesting-replacement. This subject is treated more fully under igneous metamorphism. The subject of alteration of the intrusive is dealt with in the same chapter* (Kelley, 1938, p. 515-516).

Basalt and Tuff

Many square miles of the Darwin plateau are covered by basaltic flows. The surface upon which this material was extruded was remarkably smooth, but it has since been broadly warped and block- or stepfaulted. As a result the sheets are not everywhere continuous and in large areas they have been entirely removed by erosion. Furthermore, in downwarped or downfall] ted areas much of the volcanic material has been covered by alluvium (Kelley, 1938, p. 516).

The northeastern edge of the Darwin Hills is covered by a basaltic sheet sloping 10°-15° toward the east. At the west edge of the sheet the thickness is about 20 feet, but eastward it thickens to 400-500 feet and four of five flows are distinguishable. Several thin isolated remnants of basaltic cap occur at distinct levels along the west flank of the hills, and while the uppermost of these is being exhumed by erosion, the lower patches are being covered by the outspreading alluvial apron. The pronounced difference in thickness of the sheet on the higher slopes of the Darwin Hills and to the east near Darwin Wash and Panamint Valley may be in part due to the lateral stripping of the flows in the higher area, but for the most part this difference is probably original. The difference in thickness and number of flows together with the occurrence of agglomeratic ejectaments beneath the lavas in the lower course of the Darwin Wash suggest that the source of the volcanic flows in the northern part of the Darwin Hills was in the east, probably near the edge of the present Panamint Valley. The base of the basalt series is nearly everywhere characterized by loosely consolidated brown cinder beds. Near Darwin these are only a few feet in thickness, but toward the east they thicken considerably (Kelley, 1938, p. 516).

The extensive basaltic sheets of this region are all pre-basin and range faulting and were thought by Knopf to be probably of early Quaternary age. In this respect it is interesting to note the presence in this region of small basaltic cones which are younger than most of the basin and range faults. As in Owens Valley to the west many of these have had their position determined by the basis and range faults. To the east of the Darwin Hills along the flank of the Argus Range are two such cones. One of these has its locus along the Darwin tear fault and the other rose along one of the step-faults of the Argus Range (Kelley, 1938, p. 516).

1958

DEVONIAN – LOST BURROW FORMATION

*The Lost Burro formation of Devonian age is the oldest formation present. It crops out on the west side of the Darwin Hills 3,700 feet N. 47° W. of Ophir Mountain. It is about 600 feet thick and consists of banded white and light gray coarsely crystalline marble and minor gray limestone. The marble is correlated with the Lost Burro formation on the basis of stratigraphic succession, lithology, and very poor fragmentary fossils that r semble **Cladopora**.* (Hall and MacKevett, 1958, p. 20).

MISSISSIPPIAN – TIN MOUNTAIN LIMESTONE

*The Tin Mountain limestone of Mississippian age crops out in a band east of the Lost Burro formation. The formation is about 300 feet thick and consists of thin to medium-bedded gray limestone that locally is bleached white. Fragmentary solitary corals and **Syringopora** are resent. The Tin Mountain limestone is in fault contact with the Lost Burro formation, but the bedding-plane fault probably has little displacement, and almost all of the formation is believed to be present* (Hall and MacKevett, 1958, p. 20).

MISSISSIPPIAN – PERDIDO FORMATION

The Perdido formation of Mississippian age crops out on the west side of the Darwin Hills in a band approximately 350 feet thick adjacent on the east to the Tin Mountain limestone. It consists of thinly bedded medium gray limestone, bedded chert, and siltstone. Bedding plane faults of small displacement separate the Perdido formation from the Tin Mountain limestone on the west and from the Lee Flat on the east. The previously described formations-the Lost Burro, Tin Mountain, and Perdido-are present only at the 'north end of the Darwin Hills northwest of Ophir Mountain, and they project into alluvium in the vicinity of the Darwin mine (Hall and MacKevett, 1958, p. 20).

MISSISSIPPIAN – LEE FLAT LIMESTONE

The Lee Flat limestone of Mississippian and Pennsylvanian age is the oldest formation in the Darwin mine area. It crops out from the north end of the Anaconda Company mining camp to the north end of the Darwin Hills. The formation consists of thin- to medium bedded gray limestone that contains thin beds of chert and iron-stained hornfels. Locally the limestone is bleached white and is recrystallized to marble. The formation is about 500 feet thick, but part of the section may be cut out by faulting. (Hall and MacKevett, 1958, p. 20).

PENNSYLVANIAN – PERMIAN – KEELER CANYON FORMATION

The Keeler Canyon formation of Pennsylvanian and Permian age underlies most of the Darwin Hills, and it is the host rock for most of the ore deposits in the Darwin, district. It crops out along the crest and east slope of the Darwin Hills north of the Darwin mine, and constitutes all of the Paleozoic rocks in the Darwin Hills south of the Darwin mine. The formation is about 4,000 feet thick and consists of bluish-gray limestone, silty limestone, sandy limestone, pink shale, and siltstone. The lower part of the formation is mostly limestone, and the upper part contains abundant shale and interbedded limestone. The unaltered formation is well exposed north of the Darwin tear fault in the *vicinity of the Darwin Antimony mine. South of the Darwin tear fault the formation is mostly altered to calc-hornfels and tactite* (Hall and MacKevett, 1958, p. 20).

The Golfball horizon, which is thinly bedded bluish gray limestone with ½ to 1 ½ -inch spherical chert nodules and which locally contains sparse tiny fusulinids, crops out along the western contact of the limestone sequence between Ophir Mountain and the Darwin mining camp. This horizon is characteristic of the base of the formation throughout the Darwin, New York Butte, Panamint Butte, and Ubehebe Peak quadrangles. (Hall and MacKevett, 1958, p. 20).

PERMIAN: OWENS VALLEY FORMATION

The Owens Valley formation of Permian age is present on the east side of the Darwin Hills 2,700 feet east of the Darwin Antimony mine and 3,500 feet east of the Christmas Gift mine. It consists of light- to medium-gray thin- to medium-bedded calcarenite, siltstone, shale, and lenses of massive pure limestone. The calcarenite commonly is cross-bedded (Hall and MacKevett, 1958, p. 20).

INTRUSIVE ROCKS

The rocks of Paleozoic age are intruded by a stock along the central part of the Darwin Hills and by a small concordant pluton on the west slope of Ophir Mountain. The batholith of the Coso Range crops out locally along the west edge of the Darwin Hills (Hall and MacKevett, 1958, p. 20).

1991

Darwin area regional geology is summarized in Dunne et al. (1978) and Stone et al. (1989). Upper Paleozoic sedimentary rocks(Stone,1984; Stevens, 1986) in the immediate Darwin mine area were deformed into broad folds in late Triassic time and subsequently intruded by mid-Jurassic alkalic plutons (including the 174-Ma Darwin stock (Chen,1977) and, on the west side, by calc-alkalic granite plutons (including the 156-Ma Coso batholith (Chen,1977). A 4- to 6-km depth of emplacement ($P_{lithostatic}$ 1-2 kbars) has been suggested for the calc-alkalic plutons (Sylvester et al., 1978). Contact metamorphic recrystallization of impure carbonate rocks formed idocrase-wollastonite calc-silicate hornfels, garnet-rich skarnoid, and bleached marble around the Darwin stock (Fig. 2; Hall and MacKevett, 1962; Eastman, 1980; Newberry, 1987). Tungsten-bearing skarns are locally present along contacts of the more differentiated units of the Darwin stock with the surrounding carbonate-bearing rocks and are distributed symmetrically around the Darwin stock (e.g., Fig. 2; Newberry, 1987). Thrusting along the Davis fault system (Fig. 1) took place at 154 to 148 Ma (Dunne et al.,1978) and resulted in 1- to 3-km eastward displacement of the upper plate juxtaposing the Coso batholith and its adjacent Cu skarns with the Darwin pluton and its adjacent W skarns(Newberry, 1987). Subsequent to thrusting, a series of granite porphyry dikes and breccia pipes (Fig. 2) intruded the metamorphic and igneous rocks along the northwest margin of the Darwin stock; aplite geobarometry indicates these rocks crystallized at a pressure of approximately 0.5 kbars (depth -- 1.5 km, assuming P = lithostatic; (Newberry, 1987). Pb-Zn-Ag skarns (restricted to the west side of the Darwin pluton) *and Pb-Zn-Ag veins of the Darwin district formed along steeply dipping faults, which are commonly marginal to the granite breccia bodies and, less commonly, along granite porphyry dike contacts and along the Davis thrust (Fig. 2). Minor extensional reactivation of the Davis thrust accompanying Cenozoic basin range uplift (Dunne et al., 1978) caused slight deformation of ores in the vicinity of the thrust* (Newberry and others, 1991, p. 963).

2011

The Darwin District is primarily a lead-silver-zinc district located in the Darwin Hills along a zone of mineralization near the east margin of the Coso Range batholith. Lead, silver, and zinc deposits are concentrated on the west side of the Darwin Hills and several tungsten deposits are located on the eastern side. The majority of the district's production has come from structurally controlled replacement ore bodies within silicified limestone of the lower member of the Permo-Pennsylvanian Keeler Canyon Formation (USGS, 2011).

AREA STRUCTURES

1938

SHAPE OF THE STOCK

The Darwin stock has a length of five miles and a maximum width of about two-thirds of a mile midway of its length . From the central part it tapers irregularly into narrow north and south tips which are only a few tens of feet wide. The general trend, N. 25° W., is parallel to that of the sedimentary formations into which it is intruded. In detail its original outline was rather irregular with many large and small protuberances and outliers. However, much of its present irregularity has been caused by subsequent cross faults which have offset the body in many places. In the northern part, the stock is characterized by many inliers of tactite which attest to the proximity and irregularity of its apex in this region (Kelley, 1938, p. 517).

In general the contact of the stock dips outward on both sides and so it widens in depth. On the west side the contact dips under the tactites approximately parallel to their stratification which is inclined, on the average, 50° to 60° westward. On the east side, especially in Lane canyon, the contact crosscuts the westward dip of the tactites. Toward the north and south ends of the stock the contact may conform to the west dip of the tactites in which places the stock would appear sill-like in cross-section (Kelley, 1938, p. 517).

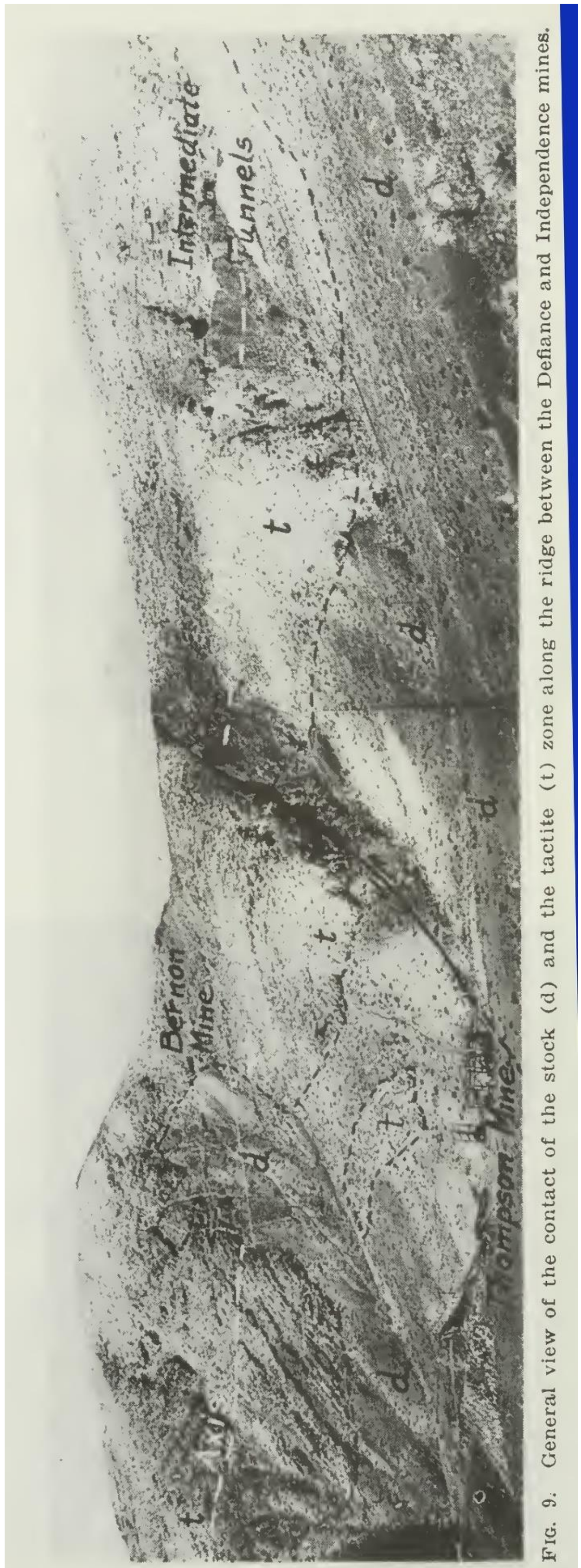


Figure 7. From Kelley, 1938, p. 526.

FOLDS

The stock is intruded into steeply inclined beds of a folded Pennsylvanian series. The deformation of the Pennsylvania rocks on the west side of the stock differs from that on the east side. The series on the west side of the stock is practically homoclinal and dips generally S. 65° W. at 50°. Two types of small local folds interrupt this general attitude of the beds. One consists of small, nearly upright and horizontal folds with axes parallel to the trend of the formation. Only two or three such folds occur in the series, the most noteworthy of which is the one near and parallel to the intrusive contact between the Defiance and Essex mines. The second class of local folds represents warps in the regional trend and, although the exact axial attitudes are difficult to determine, they are steep and usually at a considerable angle to the general strike of the beds. One such fold with axis pitching steeply westward occurs in the hills west of the Fairbanks mine. Another occurs high on the slope of Ophir Peak and can be seen from the highway approaching Darwin. These folds are like local knots in the otherwise even grain of the formation. It seems likely that the stresses which produced this second class of folds were different in direction from those which caused the first class of folds (Kelley, 1938, p. 517).

The beds on the east side of the stock are considerably folded. Immediately east of the contact the beds dip west into the stock, and the first fold is usually encountered at a distance of 1000 to 2000 feet from the contact. In places this is a large anticlinal fold with limbs dipping 60° to 80°. Along the highway through the hills the folding consists of one anticline and syncline between the east contact of the stock and the alluvial edge, a distance of about one-half mile. If this simple folded belt is followed northward to the steep slopes of the hills east and southeast of the Christmas Gift mine, the folding resolves into an intricate belt consisting of many closely spaced and nearly isoclinal folds. To the south of the highway along this same folded belt, which generally occupies the east front of the hills, are similar closely folded zones particularly in the vicinity of the Fernando mine and south of the Keystone mine. Immediately east of the Lucky Jim mine in the north end of the hills, another zone of close folds exists in which one of the folds is overturned and broken into a high angle overthrust to the east. In many other places the close folds are slightly overturned toward the east, and, if the isoclinal belts are viewed from the east front of the hills, the beds appear as a simple inclined series dipping steeply west. The eastern edge of this zone of close folds coincides approximately with the base of the hills. It seems best to consider the zones as incompetent folds superimposed upon the larger and broader folds of the region. There is some suggestion that these zones may be due to crowding of the stock during emplacement, but where the stock is widest and crumpling by shouldering of the intrusive might be expected to be the greatest, the folding consists of a single anticline and syncline. The zones of close folding parallel the narrower portions of the stock. Furthermore, since protuberances from the stock cut the limbs of the broader folds it is probable that most of the folding antedates the intrusion of the stock (Kelley, 1938, p. 517-518).

Faults in the Darwin Hills and displacements thereon can be given the following age grouping : (1) post-Pennsylvanian and pre-intrusive, (2) post-intrusive and pre-mineralization, (3) post-mineralization and pre-lava sheets, and (4) post-lava sheets (Kelley, 1938, p. 518).

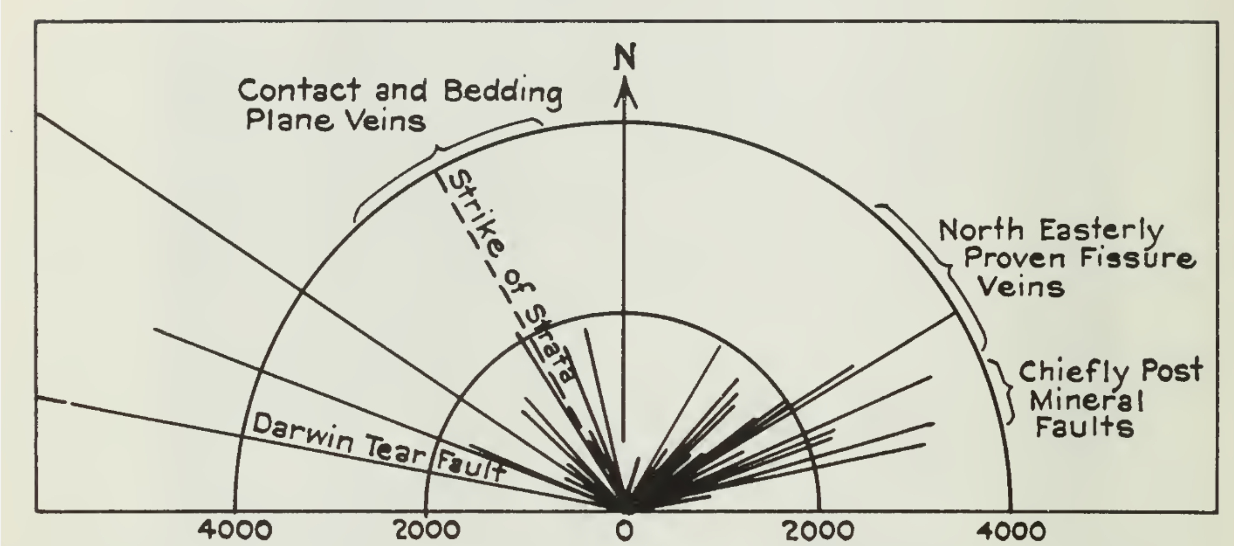


FIG. 6. Analysis of direction and magnitude of faults and of veins in the Darwin Hills.

Figure 8. From Kelley, 1938, p. 524.

No faults of the first group have been positively identified in the district. It is probable, however, that the folding of the Pennsylvania beds prior to the intrusion of the stock was accompanied by some fracturing. A few of the faults described as post-intrusive in age may have had their inception before the intrusion. No evidence of the age relationship between the Darwin tear fault and the intrusive is available, inasmuch as the fault crosses the hills north of the stock. This fault may be older or younger than the stock. All of the displacements, however, on the smaller cross-faults which cut the stock are in the same direction as that on the Darwin tear fault. This may be evidence that the large fault is also later than the intrusion and hence belongs to the following group. Faults of the second group are numerous and they are the structural feature which controls much of the metallization in the district. These faults, many of which were later mineralized to form fissure veins, developed after the consolidation of the stock, and may be divided into two subgroups. The first, which has proved to be of the most economic significance, are most numerous, shorter, and roughly normal to the intrusive contact. Practically all of their strikes fall between N. 54° E. and N. 65° E. Many show no measurable displacement. The maximum displacement is not over 100 or 200 feet. Some of the more persistent, such as the Lane and Standard Extension have lengths of 4000 feet. Most of them occur within the tactite zone around the intrusive and end at or shortly within the intrusive contact. Only rarely do they cut entirely across the stock as in the *case of the Standard Extension fissure. Where the direction of displacement is ascertainable the movement is dominantly horizontal with the north side moving relatively westward* (Kelley, 1938, p. 518-519).

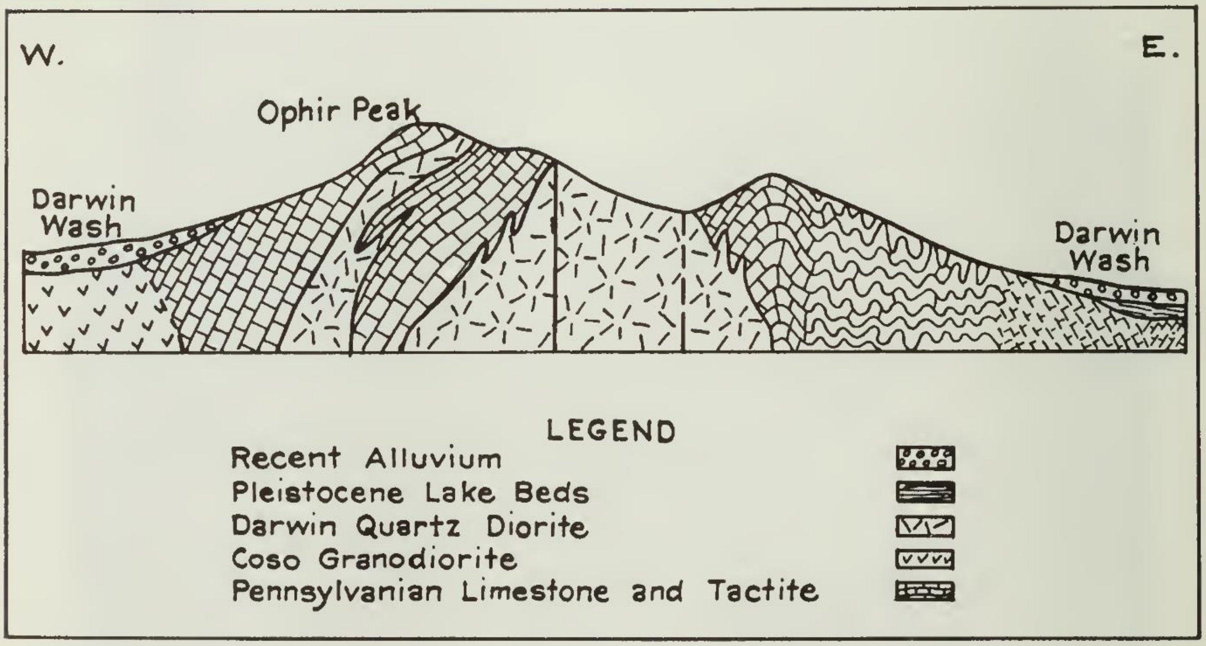


FIG. 7. Generalized structure section through the Darwin Hills near Ophir Peak.

Figure 9. From Kelley, 1938, p. 524

The faults of the second subgroup of this age are rather limited in their distribution and they strike N. 50°-70° W. These faults, few in number, constitute a shear zone which cuts through the entire stock in the first canyon and valley north of Lane canyon. (See Plate VII.) The direction of movement is the same as that on the previous group, but the displacement is greater and later. Both subgroups have been subjected to post-consolidation mineralization. The length of this zone of faults is 8000 or 9000 feet. Although they crosscut the strata on the east, to the northwest and on the west side of the stock they either die out or are taken up by strike slip along bedding planes. The northwesterly faults which displace the Lucky Jim vein belong to this group although they are not within the immediate zone (Kelley, 1938, p. 519).

The time period represented by the next group of faults, post-mineralization and pre-lava sheets, is great, several distinct periods of movement are suspected, but can not be definitely proven. Many of the fissures previously described show signs of movement after mineralization, and this movement in some cases appears to have had steep vertical components as evidenced by the slickensided gouge zones in many of the fissures. Some of this may represent minor " adjustments which resulted from the block faulting following the lava eruptions in early Quaternary time (Kelley, 1938, p. 519).

A few faults which offset veins are also present. These faults have a trend which is more nearly east-west than the previously described fissures. (See Fig. 6.) They strike N. 70°-80° E. and the direction of movement on them was the same as on the previous two groups, that is, the north side shifted relatively west. A notable example is the Christmas Gift fault which offsets the Christmas Gift vein and oreshoot. The displacement on this fault near the mine is 300-400 feet. Another such fault crosses the ridge east of the Darwin Lead Company's camp and near the Rip Van Winkle shaft. Here the displacement is about 150 feet (Kelley, 1938, p. 519).

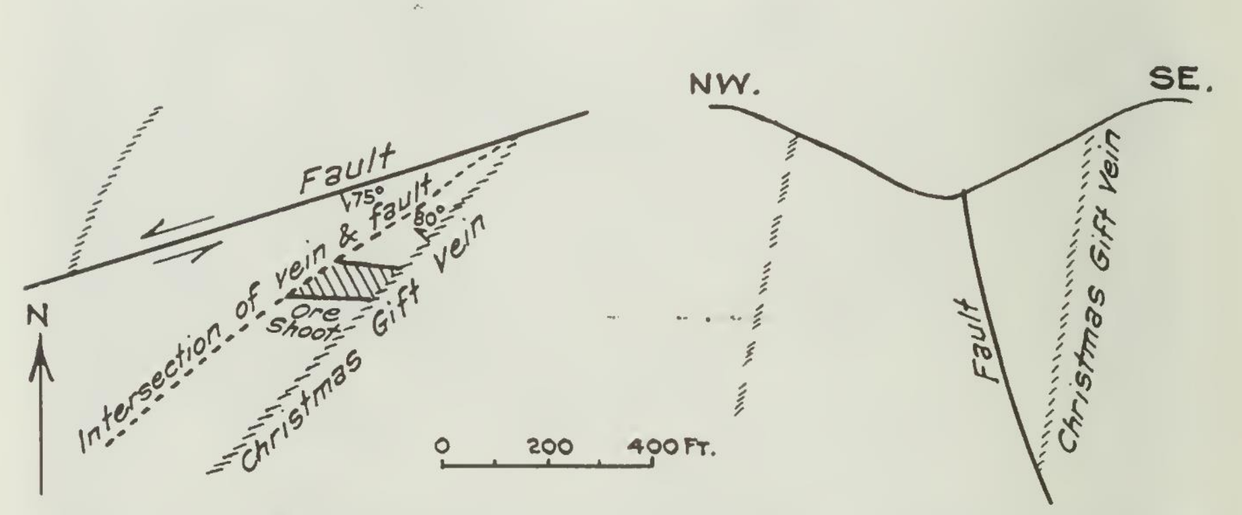


Fig. 25: Diagrammatic section (right) and plan sketch (left) of Christmas Gift vein and fault showing rake of ore shoot.

Figure 10. From Kelley, 1938, p. 534.

*The largest fracture in the district is the Darwin tear fault. It cuts across the hills about 1000 feet north of the Lucky Jim mine. The fault strikes N. 75° W. and dips 75° S. This steep southerly dip is also characteristic of the above described faults offsetting the fissure veins. In most places it is a shear zone 200-300 feet in width. The striking manner in which the northerly trending beds are dragged parallel to the fault zone clearly indicates the direction of movement. The Darwin tear is of considerable extent and can be traced for several miles to the west of the hills where it gradually passes into a series of folds. About three miles east of the hills it causes the Darwin Wash to swing easterly along the belt of weakness. It is traceable to the top of the Argus Range where it passes beneath the basalt capping. It has a total length of at least ten miles (*Kelley, 1938, p. 519).

Dr. Richard Hopper of the California Institute of Technology has since shown in the Argus Range that the Darwin tear fault has a considerable vertical component of displacement such that the north side has moved upward as well as westward (Kelley, 1938, p. 519).

The Darwin tear fault appears to be the master fracture of the district and all of the smaller dislocations formed prior to the lava flows are in a way related to it. The direction of movement on the smaller faults in the hills is the same as that on the large tear. In strike the Darwin tear fault appears closely related to the northwesterly trending fractures described above. The age of the Darwin tear is rather uncertain. It may have had its inception prior to, during, or after the development of the fissure veins, but evidence is present that at least some of the movement is later than the lava caps of early Quaternary age. Near the top of the Argus Range the lavas appear to be somewhat deformed by late movements on this fault (Kelley, 1938, p. 520).

The fourth group of faults are large fractures which trend northwesterly and are to be identified as basin and range faults developed in Quaternary time. These were undoubtedly instrumental in forming the Darwin Hills. Their presence and position is in part based on physiographic evidence, but this is supported by the positions of certain remnants of basalt flows surrounding the hills. From several such remnants located at levels along the northwestern edge of the hills it appears that they have been elevated or perhaps tilted toward the east along at least two parallel faults. On the east side of the hills the slopes are very steep, a fact 'which caused Knopf (1913) to postulate a fault along their base. He also noted that toward the north the fault must terminate because unbroken lava sheets cross the extension of the postulated fracture. The ruggedness of the eastern slope, especially in its southern part, is due to some extent to undercutting by the Darwin Wash, but that some of the relief is due to faulting appears evident from the position of the lake beds and the lava caps in the giant step faults in the Argus Range east of the Darwin Wash (Kelley, 1938, p. 520).

From the geologic map it is evident that the regional trend of the folded Pennsylvanian rocks determined the trend and elongate shape of the stock. The question arises as to the influence of the intrusion on the development of fracturing in the adjacent rocks. Ingersoll and Zobel (1913) have supposed that the cooling and contraction of the rocks behind a heat wave advancing from the intrusive have been the cause of fracturing in which later mineralization takes place. Emmons (1933) has pointed out that the fissures formed in the outer part of intrusives and in the adjacent country rocks are often formed by the forces of intrusion or the pressures generated during cooling (Kelley, 1938, p. 520).

At Darwin the displacements on the fracture systems are closely related to tectonic forces. The uniform direction of displacement and accompanying shearing attests to this fact. It may be true, however, that some of the fractures upon which displacements later took place owed their origin to forces developed by the intrusion. The answer to this could be obtained by the determination of the relative abundance of fissures adjacent to the stock as compared to their abundance and trend at a distance. Not enough detailed mapping has been done in areas outside of the Darwin Hills to determine whether the outlines of the fracture systems are extensive over the larger terrain of the plateau (Kelley, 1938, p. 520).

It might be noticed in favor of the tectonic character of the fracture systems that Knopf and Kirk (p. 21, 1918) found much the same trend of fractures on a larger scale in the Inyo Range. The general conclusion reached for the Darwin Hills is that the fractures and especially the subsequent movements thereon are not related to intrusion, but rather to tectonic forces (Kelley, 1938, p. 537).

In summary, the structure of the Darwin Hills is characterized bv a considerably folded series of impure Pennsylvanian limestones intruded by an elongated stock which occupies the center or core of the range of hills. Although parallel to the strike of the formations the stock transects the west limb of a large fold in depth. The major axis of this large fold is generally about 1000 feet east of the stock. The east limb generally occupies the steep eastern slope of the hills. It is considerably crumpled into a series of closely spaced nearly isoclinal folds. A system of northeast and northwest fractures transverses the whole. The common direction of movement on all of these has been westward on the north side. The total affect of the displacements on all of the fractures has been to move the tip of the elongate stock several hundred feet west of its original position with reference to the south tip. Uplift along faults roughly bounding the hills slightly tilted the range above the plateau in Quaternary time. (Kelley, 1938, p. 537).

DISTRICT MINE GEOLOGY

1958

The rocks in the Darwin district are marble, limestone, silty limestone, shale, and siltstone in an overturned section that ranges in age from Devonian at the northwest end of the Darwin Hills to Permian on the east side. A stock intrudes the Pennsylvanian and Permian rocks along the east side of the Darwin Hills. The Paleozoic rocks strike northerly and dip predominantly to the west. Within 4,000 feet of the stock the sedimentary rocks are mostly altered to calc-hornfels, marble, and tactite. (Hall and MacKevett, 1958, p. 20).

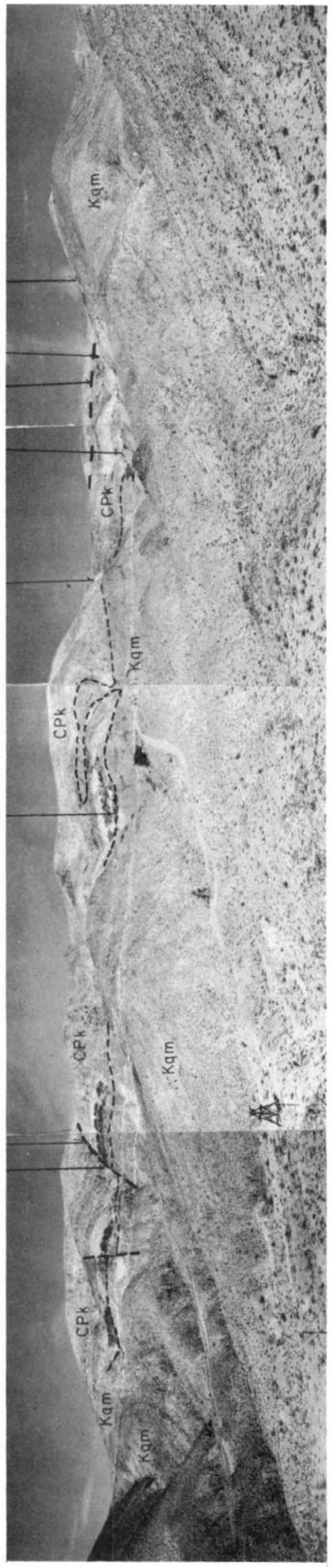


PHOTO 4. View looking west at the east slope of the Darwin Hills showing the surface workings of the Darwin mine. The smooth slopes in the foreground are underlain by the stock of the Darwin Hills (Kqm) and the skyline is calc-hornfels of the Keeler Canyon formation (CPk).

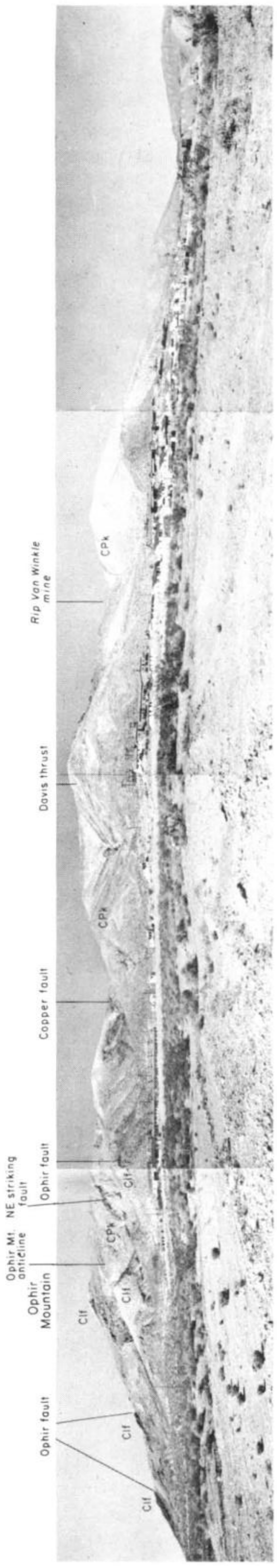


PHOTO 5. View looking east at the Darwin mining camp and the west side of the Darwin Hills. The hills are composed mainly of an overturned section of calc-hornfels of the lower part of the Keeler Canyon formation (CPk). On the left side are remnants of the Lee Flat limestone (Clf) of Mississippian and Pennsylvanian (?) age in fault contact with the Keeler Canyon formation. The Copper fault and the parallel northeast-striking fault are one of the structural controls for ore.

Figure 11. Panoramas from Hall and MacKevett, p. 24.

1962

The lead-silver-zinc deposits are concentrated in Paleozoic limestone close to intrusive contacts. The largest deposits are adjacent to the stock in the Darwin Hills in the southern part of the quadrangle. The principal mines are the Darwin, Lucky Jim, Christmas Gift, Lane, Custer, and Promontory. Other ore deposits are near the stock at Zinc Hill at the north end of the Argus Range, the Santa Rosa mine in the Inyo Mountains, the Lee mine on the east side of the Santa Rosa Hills, and a few small deposits in the Talc City Hills (fig. 3). The name "Darwin mine" is used in this report to include all the properties through which the Radiore tunnel passes (pl. 3). This includes the former Bernon, Defiance, Essex, Independence, Rip Van Winkle, and Thompson mines, and each of these·properties will be referred to as workings of the Darwin mine (Hall and MacKevett, 1962, p. 55).

1991

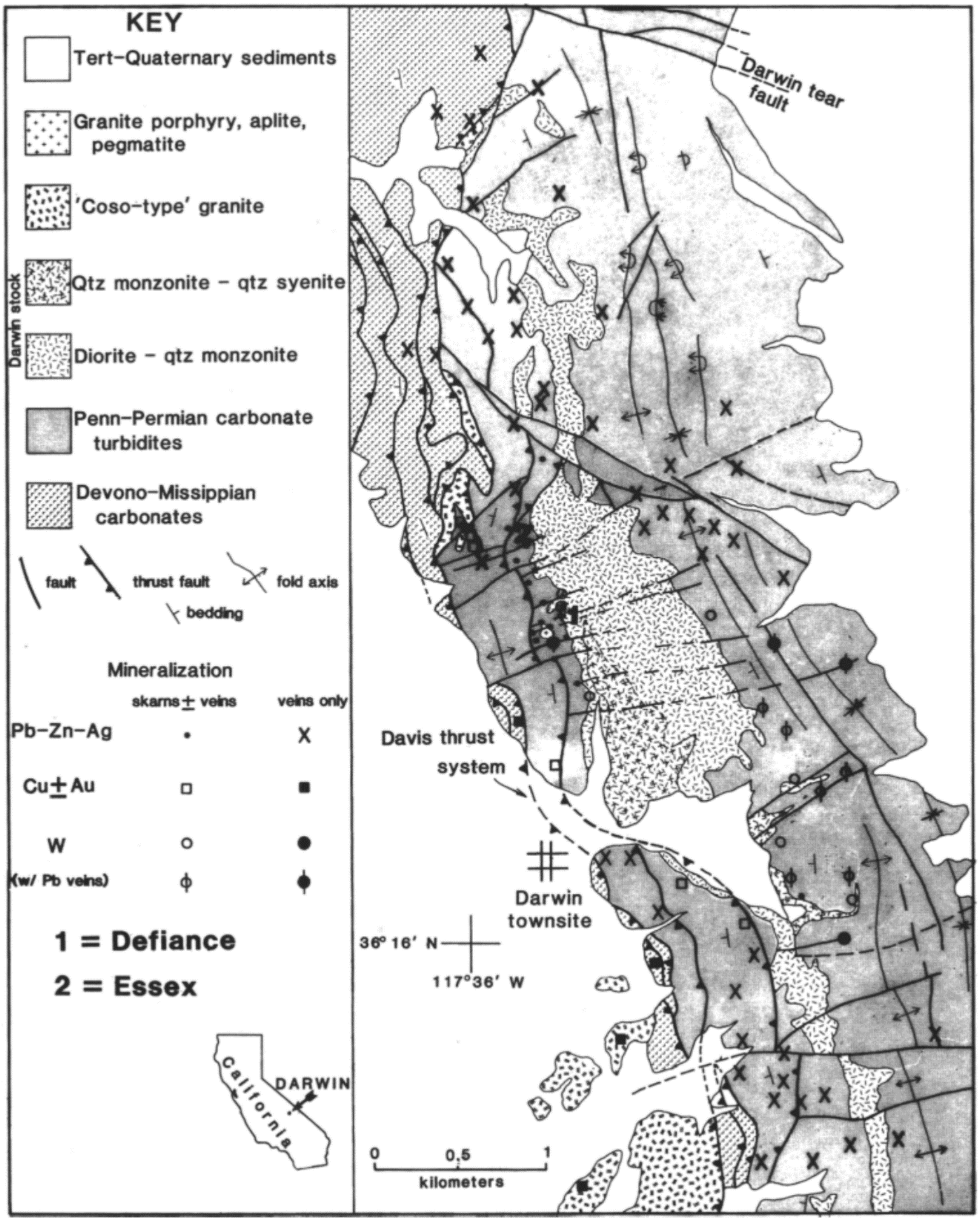


FIG. 1. Generalized geologic map of the Darwin district, showing distribution of various ore types. The Darwin mine consists of several orebodies located along the west margin of the Darwin stock; two of the major orebodies are the Essex (1) and Defiance (2). Modified from Newberry (1987) and Stone et al. (1989).

Figure 12. From Newberry and others, 1991, p. 961.

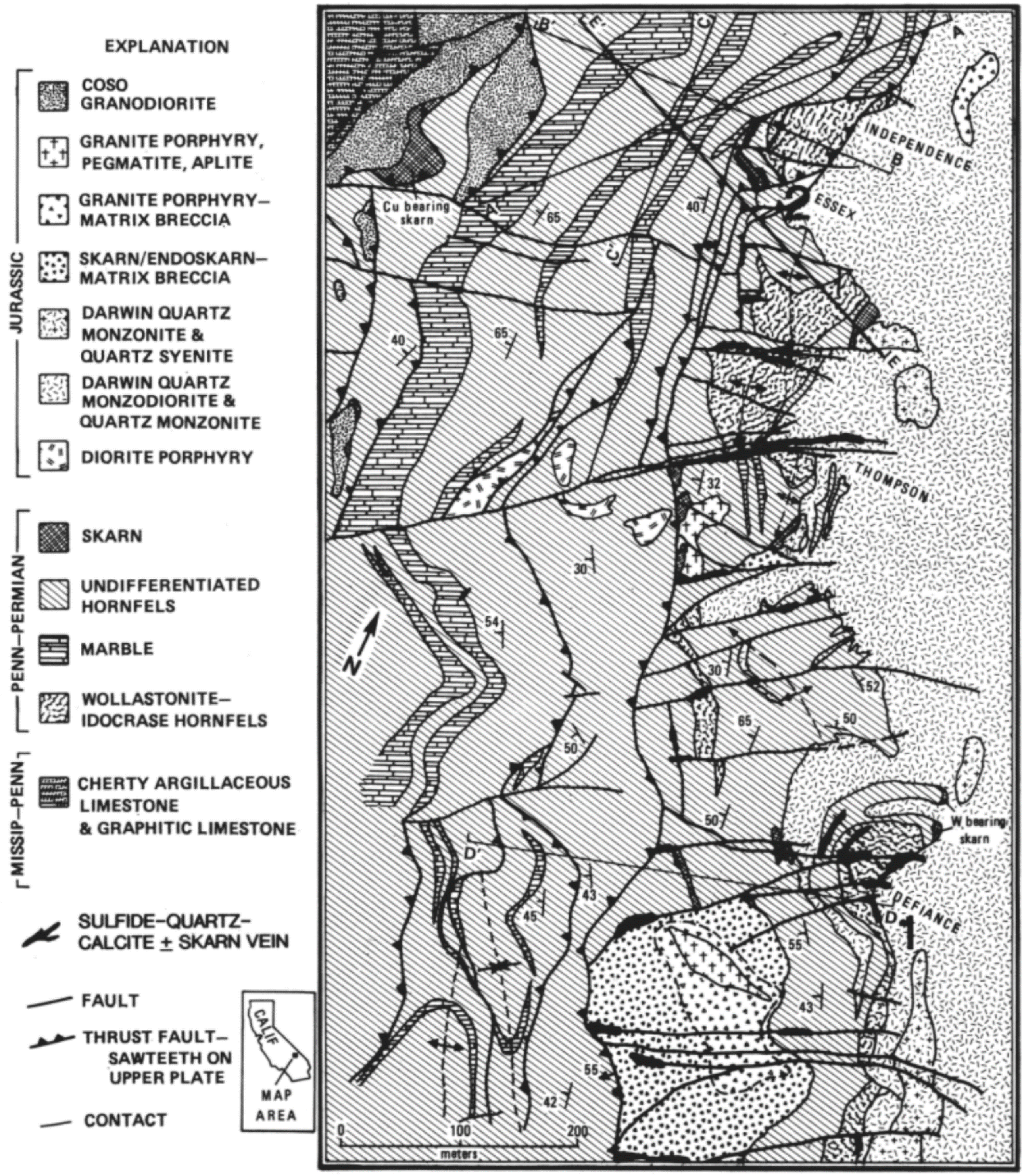


FIG. 2. Detailed geologic map of the Darwin mine area, based on unpublished mapping by R. Newberry and T. Sisson (1980–1982). Note the Pb-Zn-Ag skarn veins that cut and displace the Darwin pluton.

Figure 13. From Newberry and others, 1991, p. 962.

DISTRICT MINE STRUCTURES

1958

Structurally the Darwin Hills are an overturned syncline with an axial plane that dips west; the syncline is intruded by the stock of the Darwin Hills along the crest of the hills. The Paleozoic rocks west of the stock strike northerly and dip mainly 30° to 70° W. in an overturned section on the west limb of the overturned syncline. East of the stock the beds also dip west in an overturned section as far east as the Lucky Jim, Christmas Gift, Wonder, St. Charles, and Durham-Fernando mines, that is, about 800 to 1,200 feet east of the stock. The evidence for the overturning is mainly on stratigraphic succession. The oldest beds are on the west side of the Darwin Hills, and the rocks become progressively younger to the east. Bedding, however, dips predominantly west. Paleozoic rocks on the west side are similar lithologically to Devonian and Mississippian rocks elsewhere in the quadrangle, while fossiliferous Pennsylvanian and Permian rocks underlie the central and eastern parts of the Darwin Hills. The lithology of some of the formations is sufficiently distinctive to recognize that the lower parts of some formations are to the west. The Golfball horizon is the best example. The faunal evidence is also suggestive of an overturned section, but fossils are poorly preserved, and the faunal evidence is not conclusive except for fusulinids of late Wolfcampian (Permian) in many places along the east side of the hills (Hall and MacKevett, 1958, p. 21).

Locally the upper part of the Keeler Canyon formation and much of the Owens Valley formation is cross-bedded. Cross-bedding in the silty limestone of the upper Keeler Canyon formation 2,000 feet northeast of the Darwin Antimony mine corroborates the overturned section there (Hall and MacKevett, 1958, p. 21).

East of the Lucky Jim, Christmas Gift, Wonder, St. Charles, and Durham-Fernando mines is a belt of highly iron-stained, dense calc-hornfels that is intensely folded. This belt of iron-stained calc-hornfels is the axis of the syncline and forms the transition between overturned beds to the west and right-side-up beds along the east edge of the hills (Photo 2) (Hall and MacKevett, 1958, p. 21).

In some places, bedding in this deformed belt is readily apparent and the folds are easily resolved, but in most places the rocks are fractured and their folded nature is not apparent except by close examination. The crests of folds, in particular, are commonly shattered. Fracture cleavage locally is well developed in this deformed belt and is an aid in determining tops of beds. In tight, overturned folds fracture cleavage is usually well developed on the right-side-up limb, but it is poorly developed on the overturned limb where it tends to be nearly parallel to bedding (Hall and MacKevett, 1958, p. 21).

The folded beds are exposed in the canyon that drains east from the Lucky Jim mine and in the canyon to the north. At the Lucky Jim mine the overturned beds strike northerly and dip west. An overturned minor syncline with an axial plane that dips west is about 600 feet northeast of the main shaft. If one continues east down the canyon from the mine, the beds may be seen to pass through· several tight minor anticlines and synclines before passing into right-side-up beds with broad folds 2,200 feet east of the *mine. The beds continue to dip gently east in Darwin Wash to Darwin Canyon, and the beds dip west on the east side of the canyon* (Hall and MacKevett, 1958, p. 21).

In the Durham-Fernando mine area the beds likewise are overturned and dip to the west. The axis of an overturned syncline crops out in the gully 500 feet N. 77 ° E. of the Durham shaft. (See pl. 9) An open anticline is 30 feet east of the overturned syncline, and the beds pass through gentle folds with right-side-up beds continuing to the east. (Hall and MacKevett, 1958, p. 21).

At many places, although the exact nature of the transition from right-side-up to overturned beds is not evident because of inadequate exposures, some tight folds are recognized. At some places, as at the Custer mine faults separate overturned from right-side-up beds (see pl. 9) (Hall and MacKevett, 1958, p. 21).

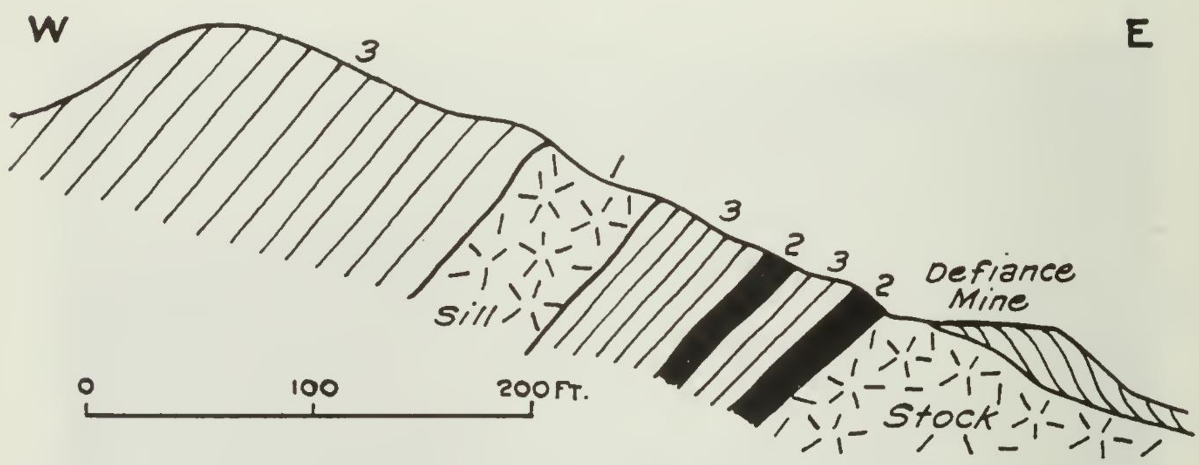


FIG. 30. Generalized section through the Defiance orebodies. 1. Quartz diorite. 2. Orebody. 3. Stratified tactites.

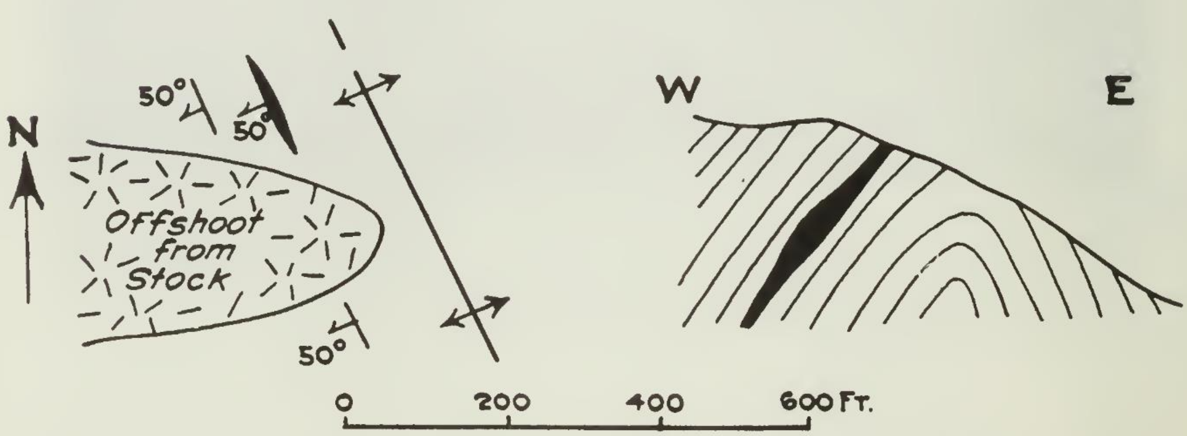


FIG. 31. Plan (left) and section (right) of the Custer orebody showing its relationship to the stock and the structure of the tactite.

Figure 14. From Kelley, 1938, p. 536

The Paleozoic rocks are intersected by four sets of faults. The four sets are described under the subtopic "Darwin mine" as the faults are important in localizing ore. The largest fault is the Darwin tear fault, which is a left-lateral strike-slip fault that strikes N. 70° W. Displacement on the fault is 2,300 feet, the north block moving west (Hall and MacKevett, 1958, p. 21).

1962

MINERALIZED STEEP STRIKE FAULTS

Steep mineralized strike faults are in both the Darwin Hills and the Talc City Hills. In the Darwin mine, ore is localized in steep north -striking faults. The faults are concentrated near the· faults that strike N. 60° to 80° E. and die out away from these transverse faults. Displacement on the northward-striking faults is negligible. They are probably tension fractures formed at about the same time as the transverse N. 60° to 80° E. faults (Hall and MacKevett, 1962, p. 44).

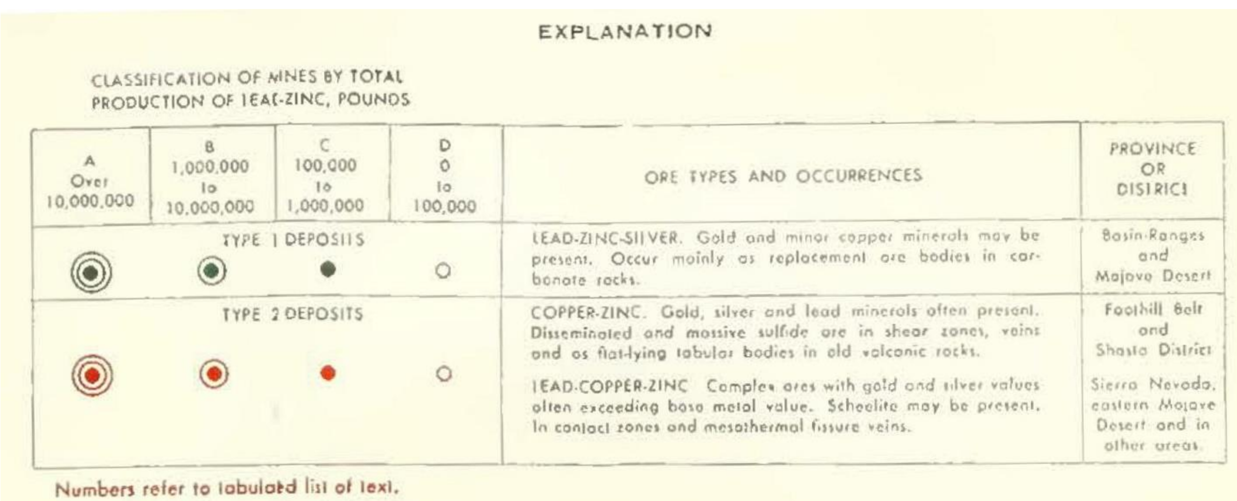
DARWIN MINE GEOLOGY

1951

The orebodies occur as replacements of silicated limestone rocks, as bedded replacements, or as fissure fillings (Davis and Peterson, 1949, p. 137). All of these are in a thick series of Paleozoic (probably Pennsylvanian) limestone, dolomite, shale and quartzite which have been folded and faulted (Norman and Stewart, 1951, p. 60).

1957

Class A, Type 1.


EXPLANATION

CLASSIFICATION OF MINES BY TOTAL PRODUCTION OF LEAD-ZINC, POUNDS

A Over 10,000,000	B 1,000,000 to 10,000,000	C 100,000 to 1,000,000	D 0 to 100,000	ORE TYPES AND OCCURRENCES	PROVINCE OR DISTRICT
TYPE 1 DEPOSITS				LEAD-ZINC-SILVER. Gold and minor copper minerals may be present. Occur mainly as replacement ore bodies in carbonate rocks.	Basin-Ranges and Mojave Desert
TYPE 2 DEPOSITS				COPPER-ZINC. Gold, silver and lead minerals often present. Disseminated and massive sulfide ore in shear zones, veins and as flat-lying tabular bodies in old volcanic rocks.	Foothill Belt and Shasta District
				LEAD-COPPER-ZINC Complex ores with gold and silver values often exceeding base metal value. Scheelite may be present. In contact zones and mesothermal fissure veins.	Sierra Nevada, eastern Mojave Desert and in other areas.

Numbers refer to tabulated list of text.

Figure 15. Deposit classification table of Goodwin, 1957.

Comprises 45 patented claims, 44 un-patented claims, and several mill sites. Argentiferous galena, sphalerite, chalcopyrite, tetrahedrite, and py-rite occur in a quartz, *calcite, fluorite, hydromica, gypsum, clay, jarosite, jasper, and iron oxide gangue in folded and faulted Paleozoic limestone, dolomite , shale, and quartzite which has been intruded along the cast flank of a northwest pitching anticline by the Darwin granodiorite stock. Three types of ore bodies are recognized: replacements of silicated limestone, bedding re-placements, and fissure fillings. Production in recent years has been 8000 to 10,000 tons per month reduced to about 20% of its volume by milling and flotation. Mill heads have averaged about 6 ounces of silver, 6.5% lead, 6.4% zinc, and some gold. High-grade oxidized ore is shipped directly to the smelter. The total estimated pro-duction before the Anaconda operation began is about $7,000,000. Copper and tungsten have also been produced as a by-product. Ore mined at Darwin around 1880 was oxidized and much higher in lead and silver. Some of the recent stopes at Darwin have been much higher in silver than the average. (Davis 1946; Chalfant 1933:294; Eric 1948: 241; Hamilton 1920:37; Hamilton, 1922:47; Kelley, 1938:503-62; Knopf, 1915: 1-18; Newman, 1923:420; Norman and Stewart, 1951:59-68, 173-74; Stewart 1948:56; Tucker and Sampson, 1938:426, 436-37, pl. 3; Tucker and Sampson, 1941:567-68; Tucker and Sampson, 1943:118)*(Goodwin, 1957, p. 466-467, Inyo County Table).

1958

The Darwin mine includes the workings owned by the Anaconda Company that are developed by the 6,300-foot long Radiore adit. They are the Bernon, Defiance, Essex, Independence, Rip Van Winkle, and Thompson workings and Driver. prospect-most of which are visible in photo 4. The mine is about a mile north of Darwin.
(Hall and MacKevett, 1958, p. 25).

The rocks in the Darwin mine area are limestone, silty limestone, and minor siltstone in an overturned section that ranges in age from Mississippian on the west side of the Darwin Hills to Permian on the east side (pI. 5). A stock intrudes the Pennsylvanian and Permian rocks along the east side of the Darwin Hills in the vicinity of the Defiance, Thompson, and Independence workings. The Lee Flat limestone of Mississippian and Pennsylvanian (?) age is the oldest formation in the mapped area. It crops out in a band along the west side of the Darwin Hills and at the top of Ophir Mountain (photo 5). It is a thin- to medium bedded, medium- to dark-gray limestone. Locally the limestone is bleached white and recrystallized to marble close to its contact with the batholith of the Coso Range. The limestone is altered to massive, buff-colored dolomite 1,300 feet west of the Bernon workings (pI. 5). The dolomite resembles the Hidden Valley dolomite except for occasional relicts of the Lee Flat limestone (Hall and MacKevett, 1958, p. 25).

The Keeler Canyon formation underlies most of the mine area. It is in fault contact with the Lee Flat limestone on the west side of the Darwin Hills and along the prominent ridge trending S. 60° W. from the top of Ophir Mountain. The lowermost part of the Keeler Canyon formation is exposed on the southeast side of the Ophir fault. The golfball horizon (limestone with spherical chert nodules) and limestone with sparse tiny fusulinids are in the prominent inverted syncline on the west flank of Ophir Mountain. Between the golfball horizon and the Davis thrust on the east side of the hills are interbedded bluish-gray thinly bedded limestone, silty limestone, and minor siltstone. Much of the limestone is altered to a white, gray, brown, or greenish-gray *dense calc-hornfels.* (Hall and MacKevett, 1958, p. 25).

Nearly all of the ore is in the Keeler Canyon formation between the Davis thrust and the stock of the Darwin Hills. The formation in this interval consists of dense white calc-hornfels and white, fine- to medium grained calc-silicate rocks. Idocrase crystals commonly 1/8 to1/4 inch in diameter are characteristic of the calcsilicate rocks on the east side of the Davis thrust and are rare or absent in the calc-hornfels on the west side of the thrust. The idocrase-bearing calc-silicate rocks are west of the stock from the Independence workings south to the Susquehanna mine. This horizon also crops out north of Ohpir Mountain as far as Belle Union mine. The Keeler Canyon formation is intruded by the stock of the Darwin Hills in the vicinity of the Independence, Thompson, and Defiance workings, and by a nearly concordant intrusive on the southwest side of Ophir Mountain. The stock is made up of a heterogeneous mixture of diorite, granodiorite, quartz monzonite, and aplite. The intrusive rocks are deeply weathered, and north of the Defiance workings they are highly iron stained, which makes them easy to distinguish from the hard, lighter-colored calc-hornfels. The stock is composed predominantly of quartz monzonite and granodiorite. Granodiorite and quartz diorite are prevalent around the Defiance and Thompson workings but quartz monzonite and minor aplite are prevalent in the area extending from the Thompson workings to the Independence workings. Aplite also crops out south of the Defiance workings. (Hall and MacKevett, 1958, p. 25).

Quartz monzonite crops out on the west flank of Ophir Mountain as an essentially concordant intrusive 1,400 feet long and 600 feet wide. The sill is 1,100 feet east of the batholith of the Coso Range and is probably an offshoot from it. The south end of the sill is in contact with diorite and gabbro. Several small diorite and gabbro bodies are 200 to 700 f eet west of the Bemon workings and are similar to the diorite at Darwin Falls, which is considered a granitized silty limestone (Hall and MacKevett, 1958, p. 25).

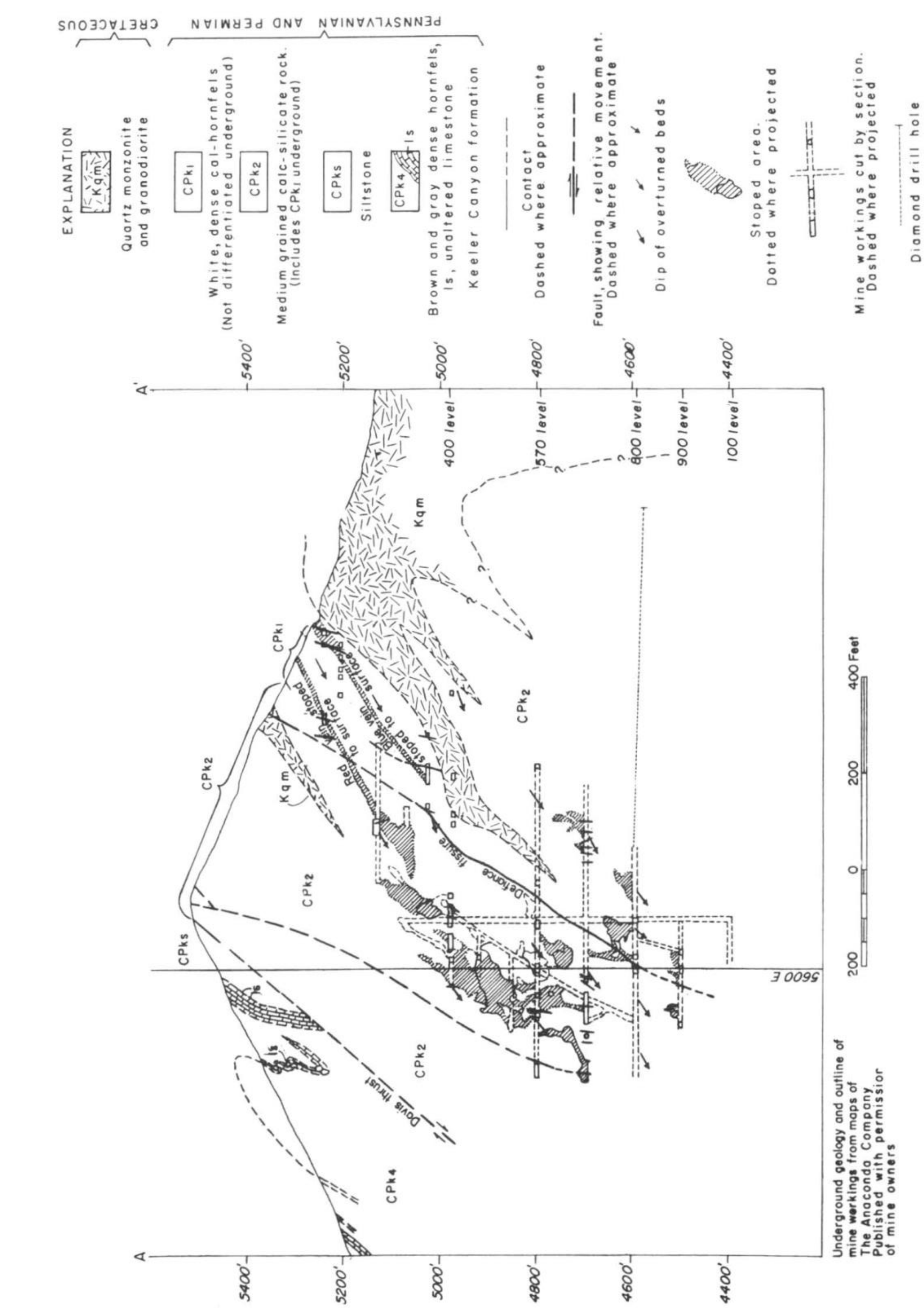


FIGURE 2. Geologic section of the Defiance workings showing stope outlines.

Figure 16. From Hall and MacKevett, 1958, p.26.

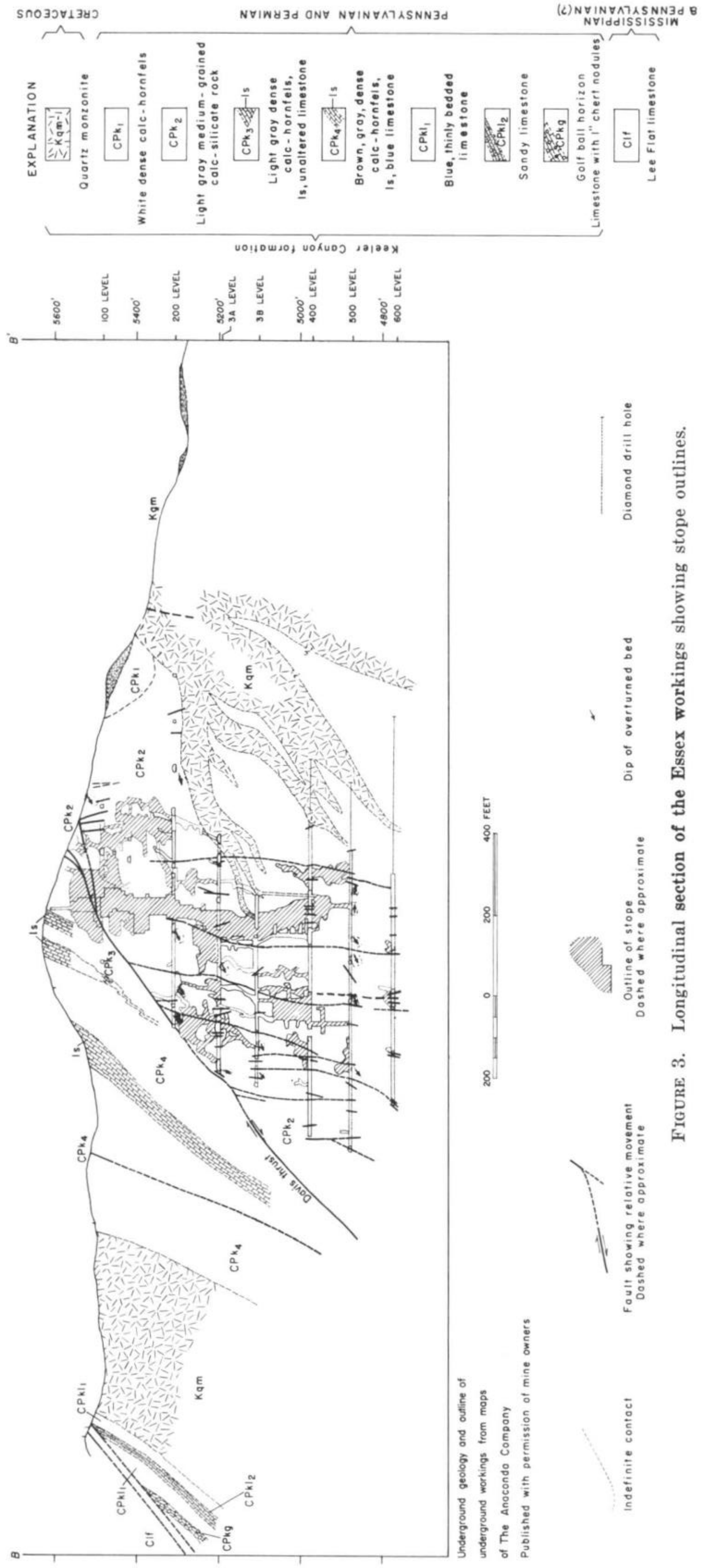


Figure 17. From Hall and MacKevett, 1958, p. 28.

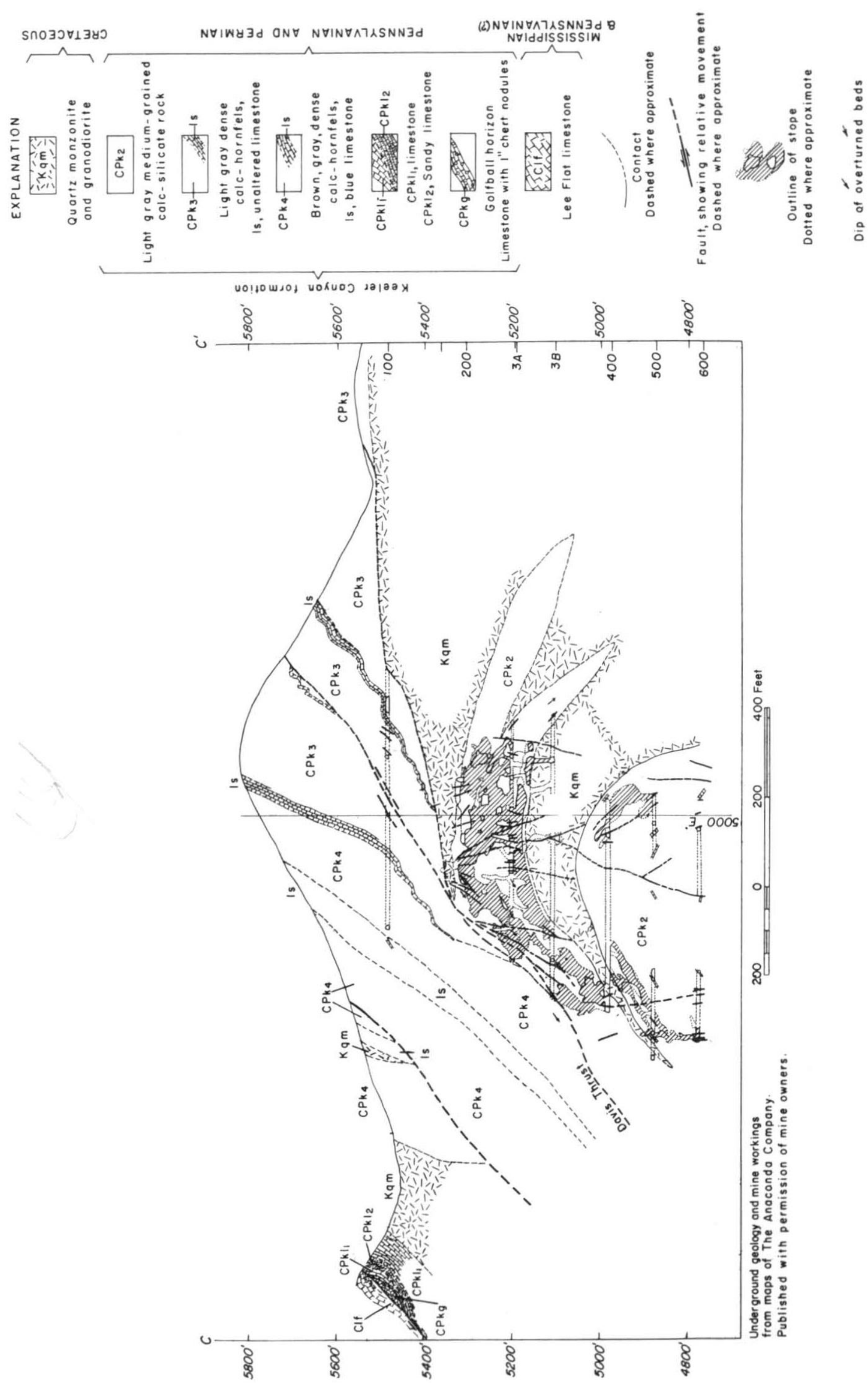


FIGURE 4. Geologic section of the Independence workings showing stope outlines.

Figure 18. From Hall and MacKevett, 1958, p. 29.

1975

The geology of the Darwin area has been described by Hall and MacKevett (1958, 1962). The ore occurs in a sequence of upper Paleozoic sedimentary rocks (limestones, silty and sandy limestones, shales, and siltstones) that is intruded by a biotite-hornblende, quartz monzonites stock of Jurassic(?) age -- the Darwin stock. The Paleozoic rocks are altered to calc-silicate minerals within 4,000 feet of the stock. The mine area is on the west limb of an overturned and partly inverted syncline between the Darwin stock on the east and the Davis thrust fault on the west (Fig. 1) (Czmanske and Hall, 1975, p. 1092).

2011

Lead, zinc, and silver are the primary commodities of the district and are largely mined from deposits on the western flank of the Darwin Hills. Less extensive silver-lead-zinc and tungsten deposits have been mined on the eastern flank. While their genesis and ore body controls are considered similar to those on the western flank, little has been recorded about the particular workings. Available information is limited to the more significant mines in the district. The most important workings were consolidated during World War I. Thereafter, these consolidated workings which included the Bernon, Columbia, Defiance, Driver, Essex, Independence, Lane, Liberty Group, Lucky Jim, Promontory, Rip Van Winkle, and Thompson workings, were referred to as the Darwin mines (Hall and MacKevett, 1962). After Anaconda Company's acquisition of these properties in 1945, the name Darwin Mine referred only to those workings operated by Anaconda and through which the main Radiore access tunnel passed. These workings included the Bernon, Defiance, Essex, Independence, Thompson, and Rip Van Winkle (Hall and MacKevett, 1962). Stratigraphy Rocks in the Darwin Hills represent the limbs of an overturned syncline. Accordingly, the oldest rocks are on the west side of the Darwin Hills and become younger to the east. The oldest rocks are a section of approximately 600 feet of coarsely crystalline marble and gray limestone of the Devonian Lost Burro Formation which outcrop on the northwest end of the Darwin Hill near Ophir Mountain. The Mississippian Tin Mountain limestone, 300 feet of thin-medium bedded gray limestone outcrops in a narrow band east of the Lost Burro Formation. The Mississippian Perdido Formation, a unit of thin bedded limestone, chert, and siltstone outcrops east of the Tin Mountain limestone in a band approximately 350 feet thick. Small bedding plane faults separate the Perdido Formation from the Tin Mountain limestone on the west and the Lee Flat limestone to the east. These formations outcrop only at the northwest end of the Darwin Hills and are obscured by alluvium farther south. The Mississippian - Pennsylvanian Lee Flat limestone, consisting of thin bedded limestone and chert outcrops from the north end of the Darwin Mine area (approx. one mile northwest of the town of Darwin) and extends to the north end of the Darwin Hills where it is about 500 feet thick. The Pennsylvanian-Permian Keeler Canyon Formation is in fault contact with the Lee Flat limestone. It outcrops along the crest and east slope of the Darwin Hills. Its exposures form almost all of the Darwin Hills with the exception of the Darwin Stock intrusion. It is about 4,000 feet thick and consists of bluish-gray limestone, silty limestone, sandy limestone, pink shale, and siltstone. The lower part of the formation is mostly limestone, and the upper part contains shale and *interbedded limestone. Silicified Keeler Canyon Formation limestones extend several thousand feet from the Darwin Stock intrusion where they have been metamorphosed to calc-hornfels and tactite and comprise the country rock for the Darwin ore bodies. North of the Darwin Tear Fault, which cuts the Darwin Hills to the north, the unit is not metamorphosed. Thin-medium bedded calcarenite, siltstone, shale, comprise the Permian Owens Valley Formation which outcrops on the lower flanks on the eastern side of the Darwin Hills. Quaternary olivine basaltic flows are preserved only in the very northern Darwin Hills. The Darwin Hills are also flanked by Plio-Pleistocene fanglomerates shed from the surrounding Inyo Mountains, Coso Range, and Argus Range and by lacustrine beds of ash, silt, and clay in the Darwin Wash area. The folded Paleozoic rocks of the Darwin Hills are intruded along the folds axis by a northeast-southwest trending biotite-hornblend quartz monzonite stock which is exposed on the surface within the beds of the Keeler Canyon Formation* (USGS, 2011).

DARWIN MINE STRUCTURES

1938

From the position and nature of the deposits about the Darwin stock it is evident that structure was the dominant controlling factor in their location. However, to some extent the composition of the enclosing wall rocks has had a modifying influence on the local accumulation of ore. There are three types of structural controls: (1) intrusive contacts, (2) bedding planes, and (3) transverse fissures. A single deposit may be localized by two controls, or pass from one into another. Commercial deposits of the first type are found only along the west contact of the stock (Kelley, 1938, p. 546).

DEPOSITS ALONG INTRUSIVE CONTACTS

The deposits formed at igneous contacts are the largest in the district. Along straight stretches of the contact, deposits of this type may be long, narrow, tabular bodies resembling the fissure deposits. In general, however, the contact deposits are lenticular in plan and although shorter in outcrop length than the cross fissure deposits, they are usually thicker. They vary in length along the contact from a few feet to two or three hundred feet. Likewise the width may vary from less than one foot to 20 or 30 feet. They extend downward irregularly along the igneous surfaces (Kelley, 1938, p. 546)..

Irregular protuberances of the intrusive into the country rock often show more pronounced mineralization. Local warping of the adjacent strata or flattening of the contact surface also appear to be instrumental in impounding of ore. Such features may have been effective along the contact between the Defiance and Independence mines, where the intrusive has forced its way into a small anticlinal fold paralleling the stock and thus flattening the contact surface to some extent. Underground development of these deposits has, however, not been sufficient to permit a full analysis of their localization (Kelley, 1938, p. 546-547).

The Defiance and Independence orebodies are the outstanding examples of deposits along igneous contacts; but smaller deposits of a similar nature are to be found at *several points north and south of these. On the west side of the stock the contact roughly parallels the stratification of the tactites, forming an effective structural trap along the surface for deposition of ore. In contrast the east side of the stock bears cross-cutting relationships to the stratification. Here the contact surface formed practically no effective trap for the ore solutions, which probably passed outward along the bedding planes and fractures. As a result of this structural condition, there are no mines of any consequence located on the east contact of the stock. The only deposits at the contacts which have produced are those located on the west side of the stock. The type of ore mineralization together with the associated gangue is similar or identical to that of many of the bedding-plane and fissure deposits* (Kelley, 1938, p. 547).

BEDDING-PLANE DEPOSITS

Numerous deposits have been formed along bedding planes, particularly along the east side of the stock where ore solutions found easier avenues of escape from the contact both by reason of more numerous cross fractures and by bedding planes which dip steeply into the contact. The outstanding deposits of this type are the Custer, Jackass, Fernando, and Keystone on the east side, and the upper Defiance and Promontory on the west side. Many of the deposits are layered or sheeted as a result of replacement of several thin beds. Others, such as the Fernando and Keystone, have formed at the intersection of fissures with favorable stratification planes, and as a result have a chimney-like shape. At the Keystone the deposit is dominantly on the fissure. In some instances where the igneous contact cuts slightly across the stratification, contact deposits continue or branch into bedding-plane deposits. The Custer and upper Defiance bedding-plane deposits are only 20 or 30 feet from the igneous contact. Others such as the Promontory and the Keystone deposits, are 1000 to 1500 feet from the contact (Kelley, 1938, p. 547).

TRANSVERSE FISSURE DEPOSITS

Deposits of this type are the most numerous in the district; although of considerable importance it is doubtful whether they will outproduce the deposits formed at the igenous contacts. The fissure deposits are most important and numerous on fractures trending northeasterly, nearly at right angles to the elongate direction of the stock. Many of these are confined to the tactite or extend only a short distance into the intrusive, where they are taken up by multiple adjustments along joint planes. Others, such as the Standard or Lane veins, cut entirely across, or extend well into the stock. Fissures of this type are mostly vertical, or dip steeply to the north (Kelley, 1938, p. 547).

Fissure veins of this type are intersected by a northwesterly belt of mineralized fissures which lie north and east of Ophir Mountain. On these fissures much shearing is evident, accompanied by greater width of mineralization, in the form of jasper, calcite, and barite. Metallization, however, is sporadic and the ground of these veins is as yet unproven. (Kelley, 1938, p. 547-548).

The Christmas Gift, Lucky Jim, Lane, and Columbia mines are the outstanding producers of fissure veins. The width of the fissure veins averages two to six feet; locally, stopes 25 to 30 feet in width have been mined. Ore and gangue mineralization *in the transverse fissure veins is in many places the same as in the deposits along the igneous contacts. Those veins which extend from the tactite into the igneous rock show by contrast the influence of the wall rock on deposition. In the intrusive the veins become restricted and ore and gangue scarce and sporadic* (Kelley, 1938, p. 547).

In the following table the mines of the district are arranged according to their distance from the stock, and the dominant structural control and mineralization are indicated. Mines on deposits along contacts are restricted to the west side of the stock: (Kelley, 1938, p. 547).

Side of stock	Mines	Structural control			Feet from Ig. contact	Characteristic gangue minerals				
		Contact	B. plane	Fissure		Pyrite	Jasper	Quartz	Calcite	Fluorite
West side of stock	Independence	x			0	x	x		x	
	Essex	x			0	x				x
	Defiance	x	x		0	x	x	x	x	x
	Bernon		x		50	x	x			
	Thompson			x	100	x	x	x	x	
	Lucky Jim	x		x	200	x	x	x		
	Bell Union		x		200	x	x			
	Rip Van Winkle			x	500	x	x	x	x	x
	Promontory		x		1,000	x	x	x		
	Fairbanks			x	1,500	x	x	x		
East side of stock	Standard Ext.			x	50	x	x	x	x	x
	Custer		x		50	x	x	x	x	x
	Christmas Gift			x	300	x	x			
	Standard			x	400	x	x		x	x
	Silver Spoon			x	500	x	x	x		
	Wonder		x		1,000	x	x	x	x	x
	Fernando			x	1,000	x	x	x		
	Jackass		x		1,200	x	x			
	Keystone		x		1,500	x	x			
	Santa Ana			x	2,000	x	x			
	Lane			x	2,200	x	x			
	Columbia			x	3,000		x			

Figure 19. From Kelley, 1938, p. 548.

1951

The principal structure is a northwest-pitching anticlinal fold, the crest of which lies just west of the ridge line of the Darwin hills. The east flank of this fold has been intruded by the Darwin granodiorite stock and its associated dikes and sills which grade from granite to gabbro. Peripheral to the stock is a silicated (tactite) zone which is as much as 2500 feet wide. All metallization is related to this stock.90 The sedimentary series has been intruded on the west and south by the Coso granite batholith (Norman and Stewart, 1951, p. 60).

The three principal systems of faults are post-intrusion and pre-mineralization in age with some post-mineralization movement. The Darwin tear fault is the largest in the district. It strikes N. 60° to 75° W., dips steeply south, and is traceable for 10 miles (Norman and Stewart, 1951, p. 60-61).

1958

The Paleozoic rocks in the mine area strike northerly and dip mostly 30° to 70° W. in an overturn ed section that ranges in age from Mississippian to Permian on the west limb of a major overturned syncline. The stock of the Darwin Hills intruded near the axis of the syncline. Several minor open folds are superposed on the overturned limb of the syncline. One of these folds on the west flank of Ophir Mountain is visible from the Darwin mining camp. The strata are fold ed into the form of an open anticline that plunges gently to the north, but younger strata are in the core and older rocks are on the flanks of the fold. Therefore, this fold, which commonly is referred to locally as the Ophir Peak anticline, is a minor inverted syncline according to the definition of White and Jahns (1950, p . 196). Similar inverted synclines are exposed in the Defiance and Bernon workings, in the Intermediate workings, and on the west side of the Darwin Hills adjacent to the Darwin mining camp (Hall and MacKevett, 1958, p. 25).

The Paleozoic rocks are intersected by four sets of faults. One set strikes N. 50 °.70° E. and dips steeply to the north. Displacement on the faults is left lateral with the north block moving west a few feet to 100 feet relative 'to the south block. The horizontal displacement is shown by offset of beds and by abundant nearly horizontal slickensides and mullion structure exposed on fault planes in underground workings. The N. 50° to 70° E. faults are mineralized, and many ore bodies are localized in or close to them. The Defiance fault, Copper fault, Water Tank fault, and Mickey Summers fault are in this group. (Hall and MacKevett, 1958, p. 25).

A second set strikes N. 65° W. and dips steeply. They are parallel to the Darwin tear fault, which is a left· lateral strike-slip fault. The Essex vein exemplifies this set (Hall and MacKevett, 1958, p. 25).

The third set of faults are thrust faults that strike northerly and dip 30° to 40° W. The Davis thrust crops out along the side of the hill above the Independence, Essex, and Bernon workings, and at the south end of the mine area it is exposed on the west side of the hills above the mining camp at the water tanks. This fault is well exposed in the Essex workings and in the upper Independence workings. Right-hand drag folds *localized close to the fault plane indicate that the west block moved upward toward the east relative to the east block (pl. 5). The amount of displacement is not known. The Ophir fault is west of, and parallel to, the Davis thrust, but the amount of displacement on it is small. The drag folds associated with it are left-hand drag folds instead of right-hand drag folds like those along the Davis thrust. Four parallel faults also are exposed between the Ophir fault and the alluvium on the west side of the Darwin Hills. The writers believe that the overthrust block above the Davis thrust broke along several parallel planes as it was moving and that each underlying block moved slightly farther to the east than the overlying block. Therefore, the overlying block on the west side of the Ophir fault moved downward relative to the overthrust block between the Ophir fault and the Davis thrust. Thus, left-hand drag folds were formed along the Ophir fault while right-hand drag folds were formed along the Davis thrust* (Hall and MacKevett, 1958, p. 25).

2011

Structure The Darwin Hills are centrally located within the Darwin Plateau, a geomorphic area surrounded by the Inyo Range, Coso Range, and Argus Range which have been uplifted above the plateau by Cenozoic faulting. Paleozoic rocks of the Darwin Plateau are deformed into broad north-northwest trending folds throughout the plateau and into the Argus Range where they are step faulted up into the Argus Range (Kelley, 1937). The Darwin Hills are an overturned syncline on the west limb of one of these larger folds called the Darwin Wash Syncline. They trend northwest-southeast for approximately 6 miles and are approximately 1.5 miles wide at their widest. Relief is 1,200 feet from the peak of Ophir Mountain to the Darwin townsite in Lucky Jim Wash on the west, but the relief is generally less throughout the rest of the Darwin Hills. The axial plane of the overturned syncline strikes N15?W and dips about 50? west. Its axis is in a belt of tight folds about 1,000 feet east of the Darwin Stock which is exposed for 5 miles collinear with the axis. This belt is the axis of the syncline and forms the transition between overturned beds to the west and right-side up beds along the east edge of the hills (Hall and MacKevett, 1962). Folding was caused by lateral compression during emplacement of the Coso Range batholith approximately 2 miles to the west. The folded Paleozoic section is cut by the Davis Thrust Fault which strikes northerly along the west flank of the Darwin Hills and dips to the west. This fault was formed during the later stages of the Coso intrusion which overturned the Keeler Canyon beds before thrusting them upward to the east. The fault cuts the lower part of the Keeler Canyon Formation and defines the western limit of mineralization, which occurs exclusively in the foot wall below the fault plane. The Paleozoic rocks in the overturned syncline were later intruded along its axis by the biotite-hornblend quartz monzonite of the Darwin Stock and its associated dikes and sills which grade from granite to gabbro. All of the major folds preceded the intrusion of the Darwin Stock. The Darwin Mine area is isolated between the Davis Thrust on the west and the Darwin stock on the east. West of the stock, the Paleozoic rocks on west limb of the overturned syncline strike northerly and dip mainly 30? - 70? west. Several small overturned secondary folds are superimposed on the western limb and some of the principle ore bodies in the Defiance workings and Essex workings are localized along the axes of these folds. East of the stock westerly dipping beds in the overturned section beds extend about 800-1,200 feet *east of the stock in the vicinities of the Lucky Jim, Christmas Gift, Wonder, St, Charles, and Durham-Fernando mines. The rocks range in age in a conformable sequence become progressively younger to the east from Devonian on the west to Permian on the east. Faults and Fractures The folded rocks of Darwin District are broken by four groups of late Mesozoic faults, all of which have played a part in ore body localization. These faults include sinistral strike-slip faults, thrust faults, and northerly striking normal faults and fractures. Later Cenozoic Basin and Range faulting overprints the Mesozoic structures* (USGS, 2011).

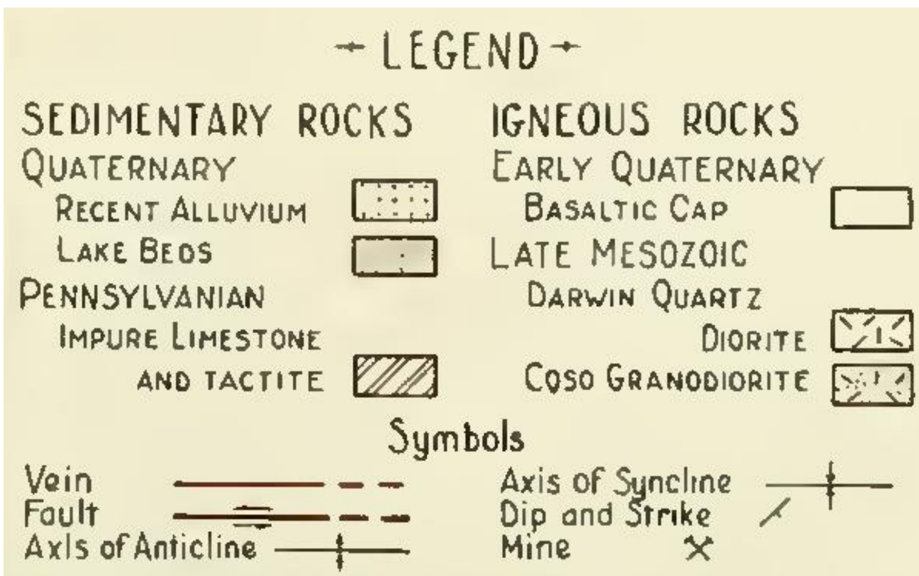
Two orthogonal sets of sinistral strike-slip faults cut the Darwin Hills. The major set trends N 65º-70º W and the minor set N 50º -70º E. These faults underwent displacement between intrusion of the stock and mineralization. While the northwest trending faults have the larger displacements, more shearing, and greater width of mineralization, the northeasterly trending faults, almost normal to the stock, have proven to be most important in ore localization. Most of the fractures are marginal to the stock and confined to the silicified limestones. Others extend into the stock or cut completely across it. The genetic relationship, if any, of these 2 sets of sinistral faults has not been determined. McKinstry (1953) interpreted the two sets as conjugate systems. N 65?-70? W striking sinistral strike-slip faults Of the N 65º -70º W striking sinistral strike-slip faults, the Darwin Tear Fault is the largest. It strikes N 70º W and dips steeply to the south. The fault cuts across the northern end of the Darwin Hills and has been attributed with a displacement of approximately 2,300 feet. As if related to this major break, all of the fractures in the Darwin Hills, regardless of trend, exhibit the same direction of movement. Another fault of this group is the Standard Fault which cuts the Darwin Hills between the Darwin Tear Fault and the Independence workings to the south. The Standard Fault zone is as much as 50 feet thick that cuts across the Darwin quartz monzonite stock. Displacement is on the order of several hundreds of feet. Faults of this group are poorly mineralized with the exception of the Essex Fault which contains the primary ore reserves in the Essex workings. N 50º -70º E striking sinistral strike slip faults The N 50º -70º E striking sinistral strike slip faults dip steeply to the northwest. Displacement ranges from a few feet to 200 feet. These faults are considered pre-mineralization feeder fissures that provided pathways for the polymetallic ore solutions. They cut both the cacl-silicate host rock and the Darwin quartz monzonite stock. These faults are abundant in all the principle lead-silver-zinc and tungsten mines in the Darwin Hills south of the Darwin Tear Fault. These fault planes are generally mineralized and most of the Darwin District ore bodies occur as massive vein deposits, bedded deposits, and vertical irregular replacement bodies near these fractures (Czamanske & Hall, 1975) Low angle thrust faults The only significant thrust fault in the Darwin District is the Davis Thrust Fault which trends northerly and dips 23º -60º to the west. Where it is exposed along the west side of the Darwin Hills and through the Darwin Mine area, it involves only beds in the lower Keeler Canyon Formation. At the south end of the mine area it is exposed on the west side of the hills above Darwin. As it is traced northward, it obliquely crosses the small ridge to crop out along the side of the hill above the Essex, Independence, and Bernon workings. The fault is well exposed in the Essex workings and in the upper Independence workings. Drag folds localized close to the fault confirm eastward thrusting, but the amount of *displacement is not known. The Ophir Fault is parallel to, and west of the Davis thrust, but the amount of displacement is small. The Davis Thrust Fault was a pre-mineralization fault that served to control ore deposition by confining ore solutions to the calc-silicate rocks and fractures in the foot wall between the fault plane and the Darwin Stock. Regionally, the Davis Thrust Fault has been attributed to folding and deformation within the Swansea-Coso Fault System (Dunne and others, 1978). It was formed by the forceful intrusion of the Coso batholith, which overturned the Keeler Canyon Formation, then thrust it up and toward the northeast (Hall and MacKevett, 1962)* (USGS, 2011).

Northerly striking, steeply dipping normal faults A fourth set of faults includes northerly striking normal faults and fractures that dip steeply to the west. These faults are characterized by small displacements and are attributed to tension fractures formed at about the same time as the N 50?-70? E faults (Hall and MacKevett, 1962). Despite their limited displacement, these faults are important in localizing some of the principle ore bodies in the district along them. In some of the Darwin Mine workings, ore is concentrated in these steep north striking faults near the intersection of the N 50?-70? E faults with ore quality and quantity dying out away from these transverse faults. Darwin Stock and Silicification The Darwin stock is a Jurassic intrusive composed largely of grayish green medium grained non-porphyritic biotite-hornblend quartz monzonite similar to the Coso Range batholith from which the Darwin stock is an offshoot. Locally, the stock can be a heterogeneous mixture of quartz monzonite, diorite, granodiorite, and aplite. The stock is generally concordant and parallel to the intruded sedimentary bedding and to the strike of the folding. The stock has an exposed length of five miles, and a maximum width of 2/3 miles which tapers to only a few tens of feet wide to the north and south. The quartz monzonite is more easily weathered than the surrounding calc-silicate rock causing it to form a belt of lower relief within the central Darwin Hills surrounded by stark outcrops of hard white silicified carbonates. In many places surrounding the intrusive and within the silicated aureole are many dikes some of which are direct offshoots of the stock and cut only the country rock; others are later and cut the intrusive also (Kelley, 1937). The dikes tend to be more acidic than the intrusive with syenite dikes being the most common within the contact aureole between the Defiance and Thompson workings of the Darwin Mine (Kelley, 1937). The eastern contact of the stock is more irregular than the west with many dikes and sills extending from the main body. Metasomatism and/or contact metamorphism associated with the emplacement of the Darwin stock resulted in a wide silicified skarn aureole. Kelley (1937) attributes metasomatism to have been the dominant role in the replacement process while Hall and MacKevett (1962) attribute the majority of alteration to contact metamorphism. Less pure limestones were selectively altered to extensive calc-hornfels beds and locally to tactites while the purer limestones were altered to tactites consisting of a silicified mass of garnet, wollastonite, diopside, idocrase, orthoclase, oligoclase, epidote, and quartz. Recrystallization and replacement was determined by heat and the materials carried by magmatic emanations. The resulting rocks are whitish and fine to coarse grained calc-hornfels and tactites (Hall and MacKevett, 1962) that often retain the original stratification of the original sedimentary carbonates. The width of the zone varies from a few tens of feet to 2,500 feet, but is usually 1,000-1,500 feet wide. Ore deposition took place distinctly later than silicification of the host rock and fracturing of the altered *carbonate rock during which most of the faults and fissures of the district were developed* (USGS, 2011).

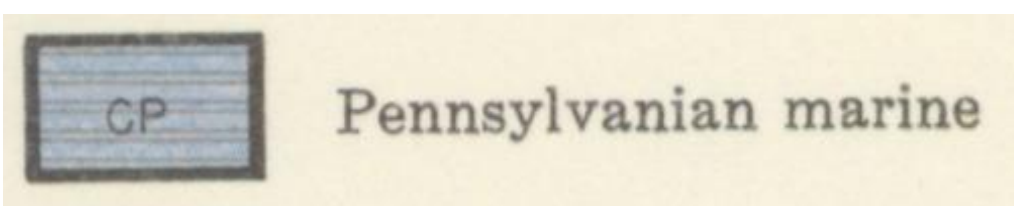
MAPPING

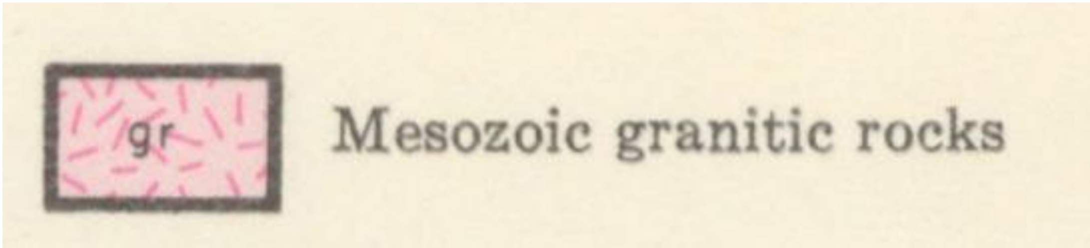
1938

Kelley produced a map of the Darwin District and also of areas around the Defiance-Independence and Christmas Gift workings (Appendices 01A, 01B and 01C). He recognized the basic stratigraphy of the area. He distinguished the Darwin Quartz Diorite (later termed “Darwin Stock”) from the Coso Granodiorite. In 1938 formation names had not been assigned to the sedimentary units. His district map also shows the mining claims in 1938. This map was not easy to rectify as an ArcGIS shapefile. PLLS section corners do not match well with prominent topographic features.



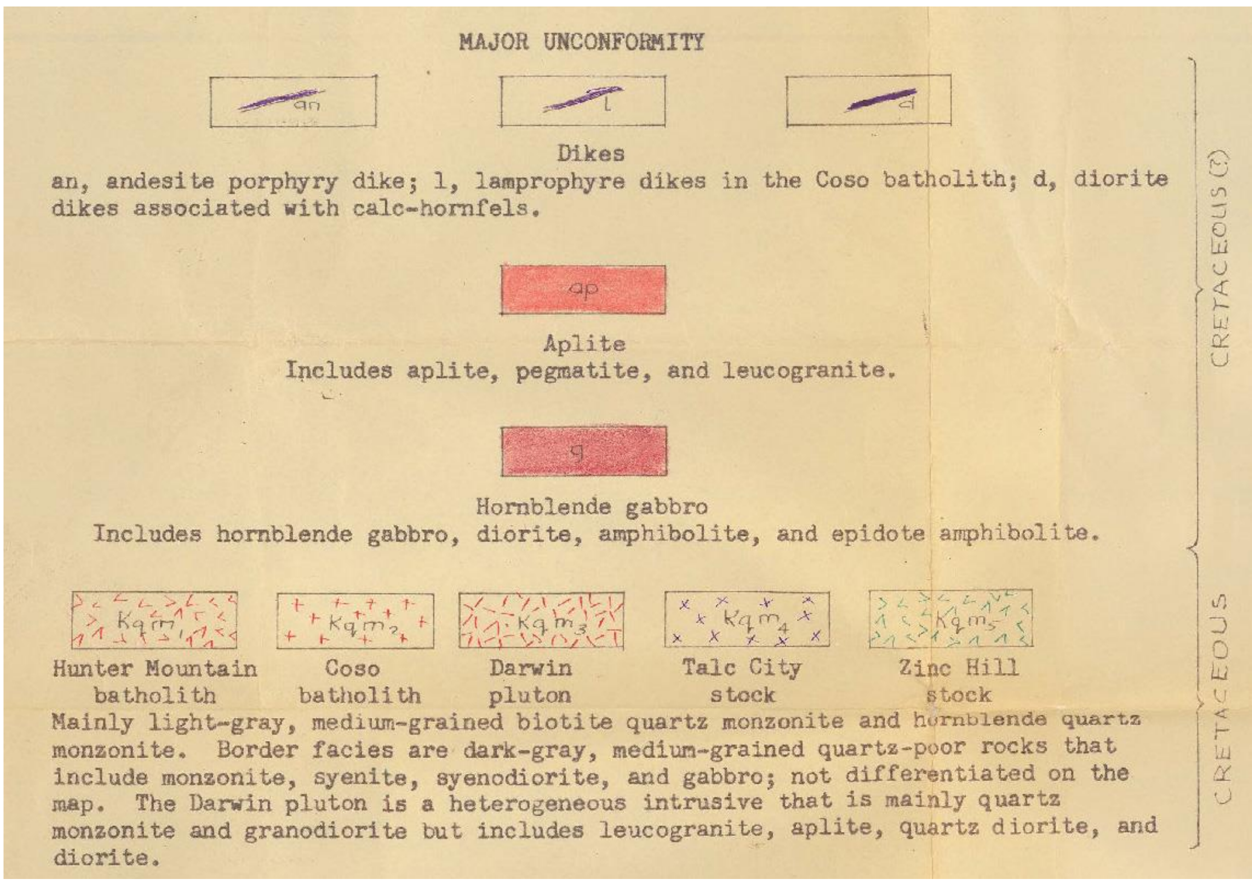
Jennings (1958) mapped the area of the Darwin District as Mesozoic granite (gr)and Pensylvanian marine sediments (CP).





1958

Hall (1958) produced a colored series of maps for the Darwin Quadrangle, Darewin mine area and several important mine workings in the Darwin District. These are available for download at https://doi.org/10.3133/ofr5842. On these maps, the Darwin mine area is shown as having Mississippian Lee Flat (Mlf) and Perdido Formation (Mp), Pennsylvanian Keeler Canyon Formation (Ppkc), and Darwin quartz monzonite pluton (Kqm)



Undifferentiated silicated Paleozoic rocks.

gn

Gneiss, age unknown.

Upper (?) Permian

Povu

Upper limestone conglomerate member. Includes limestone conglomerate, siltstone, and sandstone.

Lower and Middle (?) Permian

Povl

Lower limestone member
Mainly thin- to medium-bedded bluish-gray calcarenite, locally crossbedded. Contains lenses of pure limestone and limestone breccia that are abundantly fossiliferous, and lesser siltstone and shale.

Pov

Undifferentiated lower and middle members

Owens Valley formation

PERMIAN

PKcu

Upper pink shale member
Interbedded gray, thin- to medium-bedded calcarenite, pink fissile shale, siltstone, and silty limestone.

PKc

Undifferentiated

PKcl

Lower limestone member
Thin- to medium-bedded calcarenite. Contains some limestone pebble conglomerate beds that contain abundant fusulinids. Basal part contains spheroidal chert nodules ½ to 1½ inches in diameter and sparse Fusulinella of Middle Pennsylvanian age.

Keeler Canyon formation

PENNSYLVANIAN

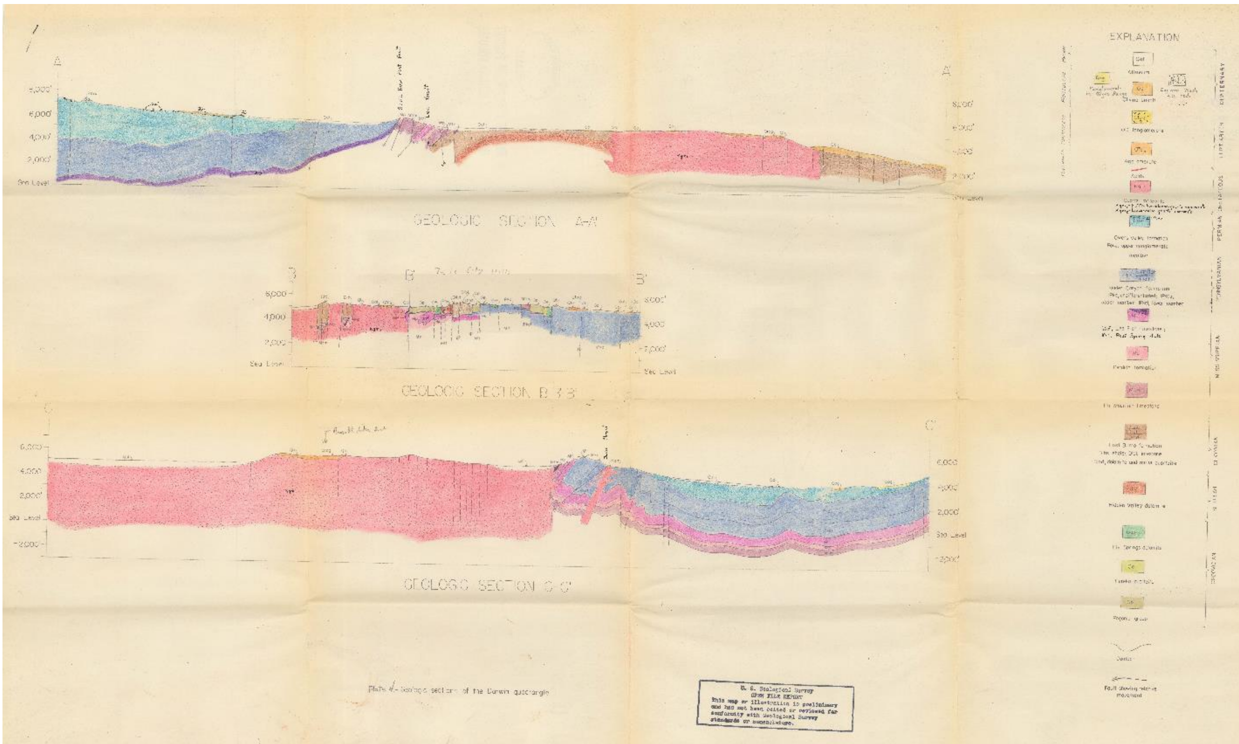
Mlf

Lee Flat limestone
Thinly bedded medium- to dark-gray limestone with thin sandy ironstained partings. Locally contains chert lenses and thin beds. The Lee Flat limestone is a time-stratigraphic equivalent of McAllister's Rest Spring shale and the upper part of his Perdido formation.

Mp

Perdido formation

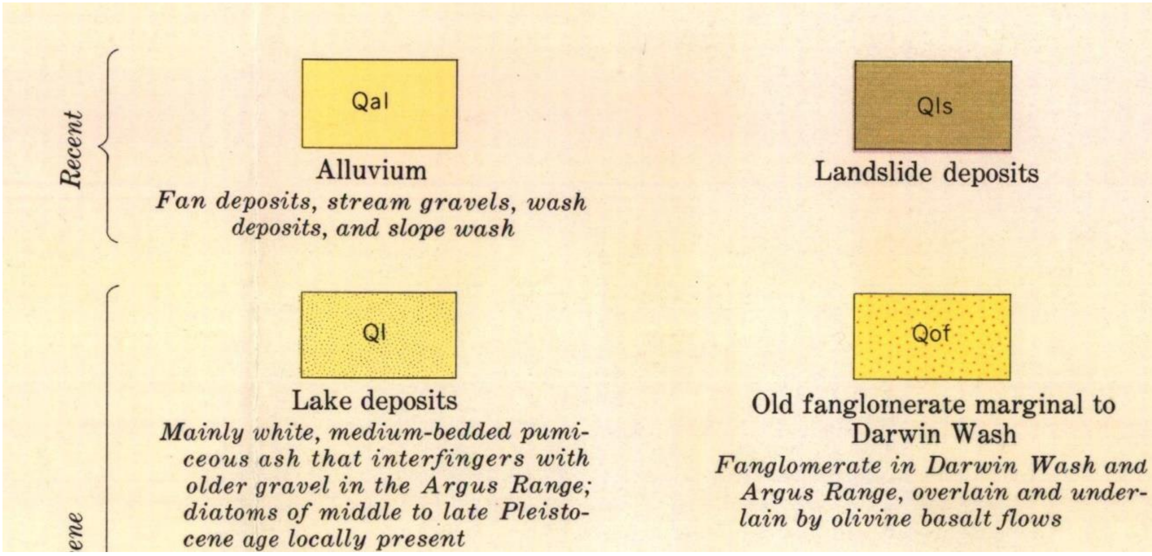
Interbedded thin- to medium-bedded gray limestone and brown-weathering chert. Some limestone beds consist predominantly of crinoid columnals. Correlates with the lower part of McAllister's Perdido formation.



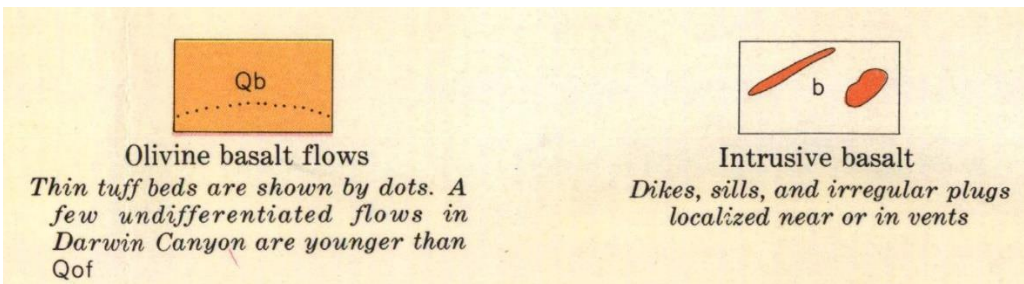
1962

Hall and MacKevett (1962) mapped the following units in the Darwin area:

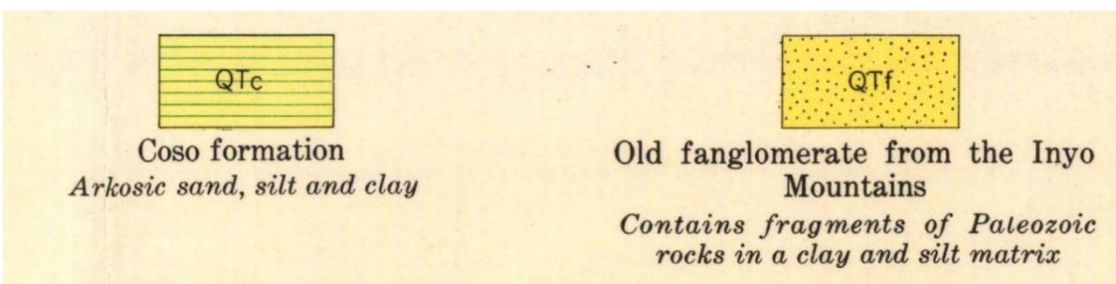
Recent Alluvium, lake deposits, landslides and older alluvium:



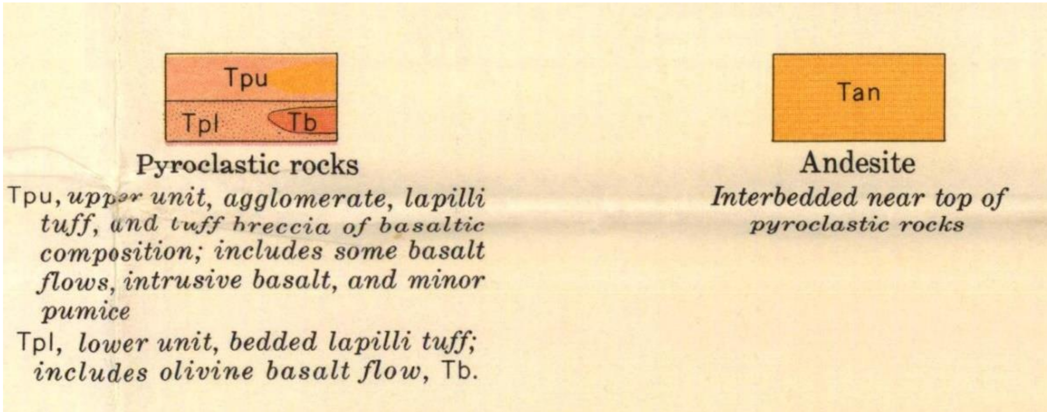
Pleistocene volcanics:



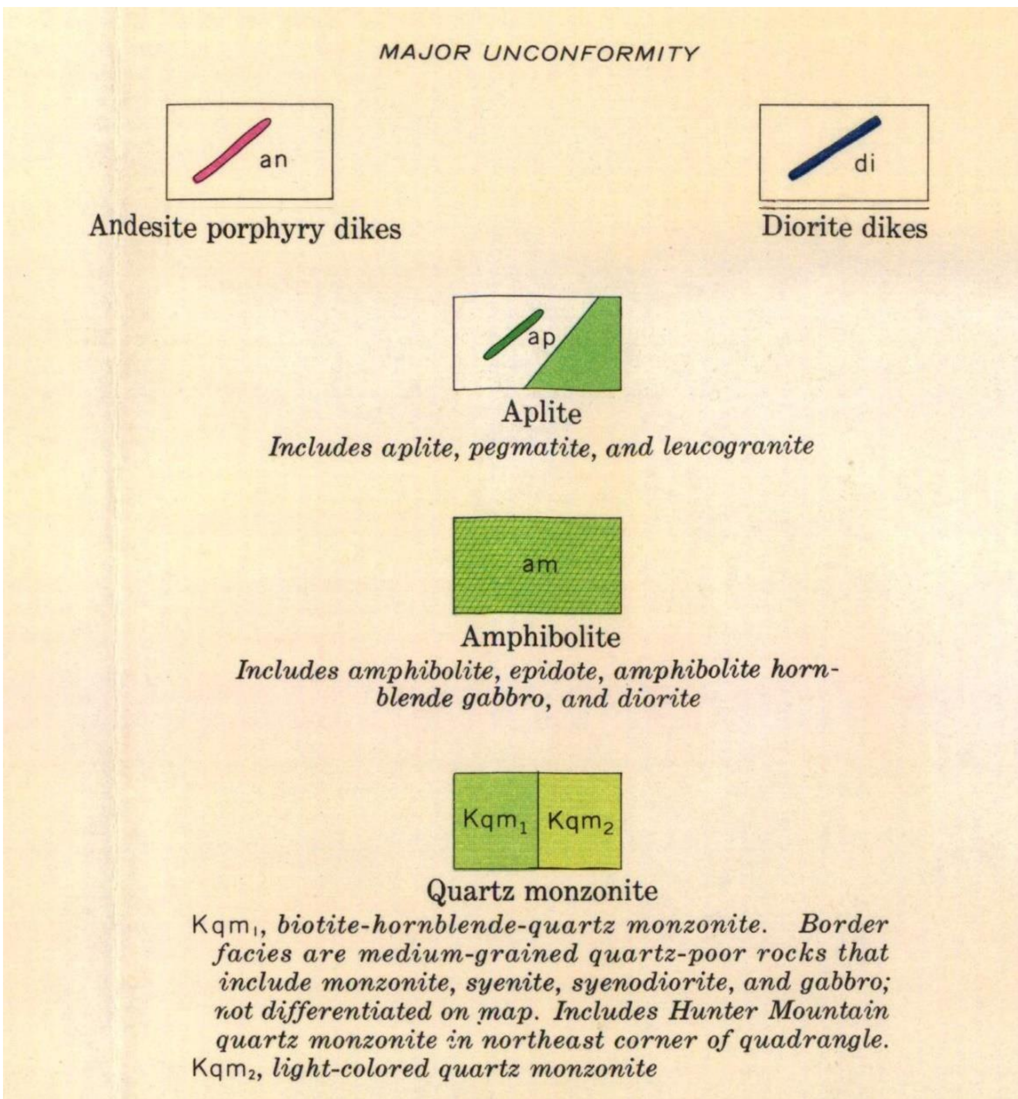
Plio-Pleistocene Coso Formation and Old fanglomerate:



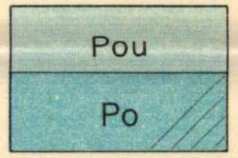
Pliocene volcanics:



Cretaceous intrusive rocks:



Permian Owens Valley Formation:



Owens Valley formation

Pou, *upper unit, limestone conglomerate, siltstone, and sandstone.*

Po, *middle and lower units, undifferentiated. Middle unit, brick-red and yellowish-brown shale, siltstone and blue-gray limestone. Exposed only around base of Conglomerate Mesa. Lower unit, mainly thin to medium bedded bluish-gray calcarenite. Contains lenses of pure limestone and limestone breccia that are abundantly fossiliferous, and lesser siltstone and shale. Silicated zones shown by overlining*

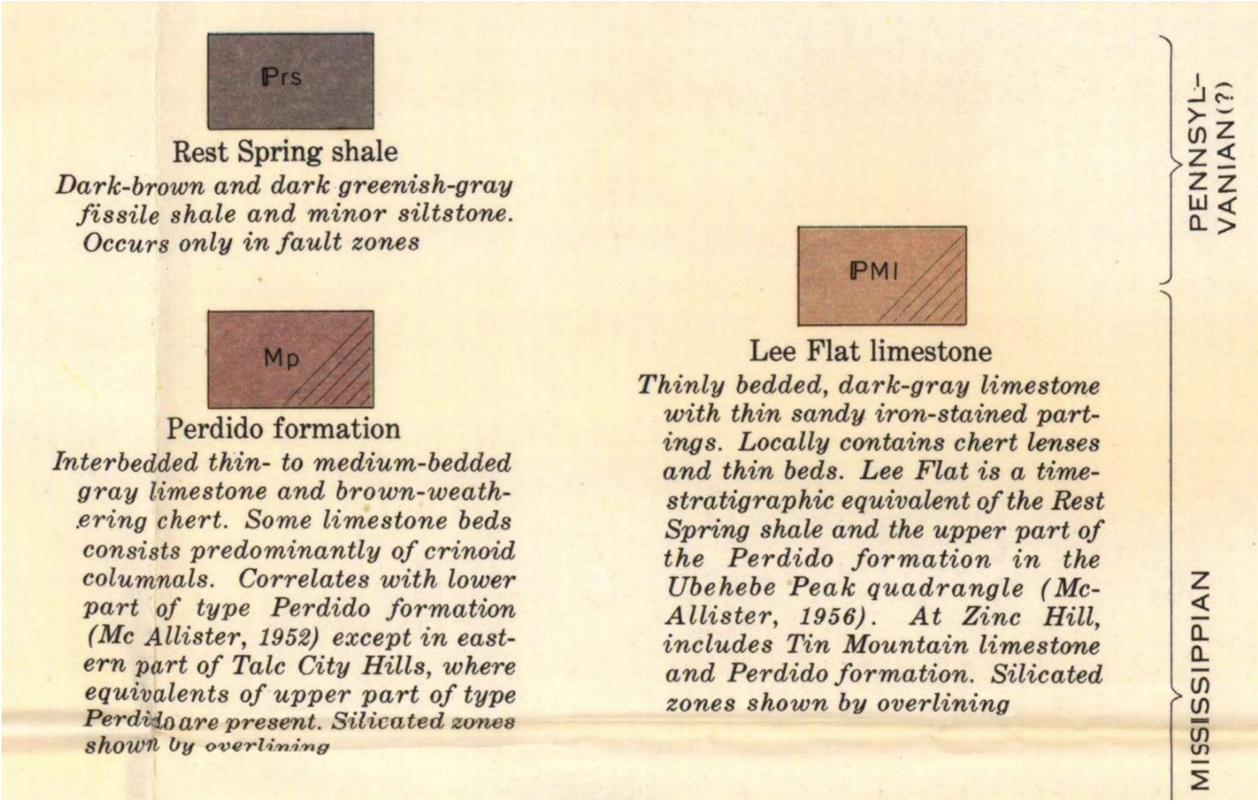
Pennsylvanian and Permian Keeler Canyon Formation:

Keeler Canyon formation

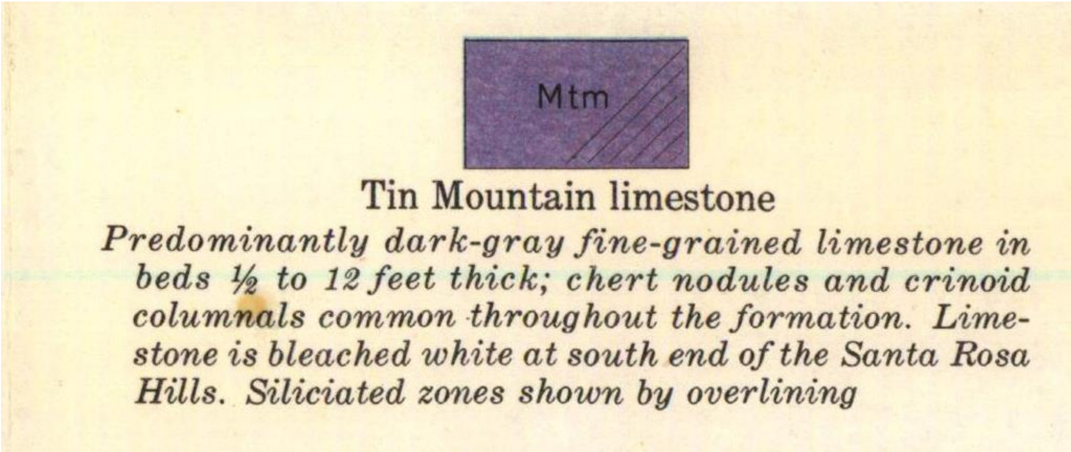
Pku, *upper unit, interbedded gray, thin- to medium-bedded calcarenite, calcilutite, pink fissle shale, siltstone, and limestone pebble conglomerate.*

Pℙkl, *lower unit, thin- to medium-bedded calcarenite, containing some limestone pebble conglomerate beds with abundant fusulinids; in basal part of unit, spheroidal chert nodules ½ to 1½ inches in diameter and sparse* Fusulinella *of Middle Pennsylvanian age. Silicated zones shown by overlining*

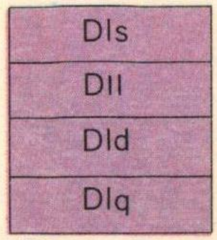
Pennsylvanian and Mississippian Resting Spring Shale, Perdido Formation and Lee Flat Limestone:



Mississippian Tin Mountain Limestone:



Devonian Lost Burrow Formation



Lost Burro formation

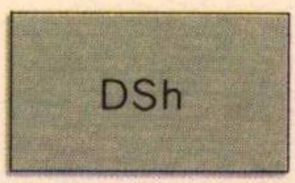
Dls, *shale unit, brown fissile shale restricted to upper part of Lost Burro formation in the Talc City Hills.*

Dll, *limestone and marble unit, thinly bedded white and light-gray limestone and marble, characteristically banded by streaks and thin beds of gray marble. Dark-gray limestone beds near base of unit contain cladoporoid corals and stromatoporoids*

Dld, *dolomite unit, light-gray, massive to thickly bedded dolomite with a mottled appearance and minor quartzite. Contains several dark-gray limestone beds 40 to 50 feet thick that are partly dolomitized.*

Dlq, *white, vitreous quartzite at the base of the formation. Correlates in part with the Lippincott member described by McAllister (1955)*

Devonian- Silurian Hidden Valley Dolomite:



Hidden Valley dolomite

Light-gray massive dolomite

Ordovician units (Ely Springs dolomite, Eureka quartzite, Pogonip Group).

Upper Ordovician

Oes

Ely Springs dolomite

Thickly bedded dolomite, dark-gray in lower part and lighter gray in upper part. Black chert nodules and thin beds are in the lower part

Middle Ordovician

Oe

Eureka quartzite

White to light-gray vitreous quartzite; lower part is stained dark brown

Lower and Middle(?) Ordovician

Op

Pogonip group

*Mainly light to medium gray, thickly bedded dolomite and minor limestone. Upper part contains several dark-brown siliceous units 8 to 178 feet thick that contain interbedded iron-stained chert, sandy limestone, and dolomite. Dolomite in upper part contains abundant large gastropods (*Palliseria robusta* Wilson)*

1989

Stone and others (1989) mapped the region around the Darwin Hills and Talc City. They recognized the following:

Alluvium and other recent units

QTvs **Volcanic and sedimentary rocks (Quaternary and Tertiary)**—Pleistocene and Holocene alluvium, talus, and lake deposits; upper Miocene and Pliocene basalt, andesite, pyroclastic rocks, and alluvium (Hall and MacKevett, 1962; Hall, 1971; Larsen, 1979; Schweig, 1983)

Mesozoic Igneous rocks

1983)

TMzb **Breccia (Tertiary or Mesozoic)**—Silicified, hydrothermally altered fault breccia and brecciated skarn mapped locally in the Darwin Hills

KJc **Calc-alkalic granitoid rocks (Cretaceous? and Jurassic)**—Quartz-rich granitoid rocks of calc-alkalic composition, consisting of: hornblende-biotite quartz monzonite and subordinate granite exposed along west flank of the Darwin Hills; biotite-bearing leucocratic granite and quartz monzonite exposed in Osborne Canyon and at Zinc Hill in the Argus Range; and small bodies of leucocratic granite exposed near Darwin Canyon. Cut by Jurassic dikes (Jd) in the Darwin Hills and Osborne Canyon. A sample from west flank of the Darwin Hills has yielded a U-Pb age of 156 Ma (sample 78 of Chen and Moore, 1982). Undated body at Zinc Hill lacks crosscutting Jurassic dikes and may be Cretaceous. Previously mapped as Cretaceous(?) quartz monzonite by Hall and MacKevett (1962) and as Jurassic leucocratic quartz monzonite by Hall (1971)

Jd **Dikes (Jurassic)**—Greenish-gray porphyritic dikes of predominantly dioritic composition, averaging about 1.5 m wide, present throughout map area and most abundant in the Argus Range. Only the largest, most continuously exposed dikes are mapped. Interpreted as part of the Independence dike swarm of Moore and Hopson (1961), which has been dated as 148 Ma (Chen and Moore, 1979). Previously mapped as Cretaceous(?) andesite porphyry and diorite dikes by Hall and MacKevett (1962) and Hall (1971)

Ja **Alkalic granitoid rocks (Jurassic)**—Texturally and compositionally heterogeneous, quartz-poor granitoid rocks of alkalic composition, consisting of hornblende-biotite-clinopyroxene quartz monzonite and subordinate monzonite, quartz monzodiorite, and monzodiorite exposed in the Darwin Hills, Santa Rosa Hills, and near Panamint Springs in the Argus Range. Includes small bodies of skarn breccia in the Darwin Hills. Cut by Jurassic dikes (Jd). A sample from the Darwin Hills has yielded a U-Pb age of 174 Ma (sample 77 of Chen and Moore, 1982); a sample from the Argus Range has yielded a K-Ar age of 185 Ma (sample DW–1 of Hall and MacKevett, 1962; age recalculated by Dunne and others, 1978). Considered part of the Hunter Mountain batholith (Dunne, 1986)

Jdf **Darwin Falls pluton (Jurassic?)**—Composite body of cross-intruded gabbro, granodiorite, and subordinate quartz monzonite exposed in the vicinity of Darwin Falls. Primary mineral layering present in gabbro. Characterized by intense saussuritic alteration in most places. Locally cut by Jurassic dikes (Jd). Previously mapped as Cretaceous(?) amphibolite by Hall and MacKevett (1962)

Triassic marine sediments:

Cretaceous(?) amphibolite by Hall and MacKevett (1962)

Sedimentary rocks (Lower Triassic)—Heterogeneous sequence composed of mudstone, limestone, sandstone, and siltstone containing Early Triassic conodonts, ammonoids, and pelecypods (Lewis and others, 1983). Previously mapped as part of the Bird Spring(?) Formation by McAllister (1956) and as part of the Owens Valley Formation by Hall and MacKevett (1962). Divided into:

TRs_5 — **Unit 5**—Light- to medium-gray silty and sandy limestone, locally containing abundant pelecypods. Maximum exposed thickness 50 m; top covered

TRs_4 — **Unit 4**—Dark-brown, massive siltstone. Thickness 50 m

TRs_3 sh — **Unit 3**—Medium- to dark-gray, thin-bedded to massive limestone forming cliffs and ridges. Interval of greenish-gray shale (**sh**) 20 m thick present in upper part. Thickness 200 m

TRs_2 — **Unit 2**—Calcareous mudstone, siliceous mudstone, and limestone. Upper part composed predominantly of yellow, yellowish-brown, and light-brown, thin-bedded calcareous mudstone and calc-hornfels interbedded with medium- to dark-gray, thin- to thick-bedded limestone and limestone conglomerate. Lower part composed predominantly of brown, thin-bedded siliceous mudstone and hornfels that locally contain dark-gray limestone concretions. Ceratitic ammonoids locally abundant. Thickness 500 m

TRs_1 — **Unit 1**—Tan to gray, mottled, thick-bedded calcareous siltstone, sandstone, and silty to sandy limestone. Thickness 20–100 m

Upper Permian marine units of the Owens Valley Group

Owens Valley Group (Upper and Lower Permian)—Sandstone, siltstone, limestone, limestone conglomerate, shale, mudstone, conglomeratic mudstone, and conglomerate. Consists of:

Pc **Conglomerate Mesa Formation (Upper Permian)**—Gray to brown, thick-bedded pebble and cobble conglomerate and subordinate fine- to coarse-grained sandstone exposed in the Conglomerate Mesa area. Conglomerate clasts composed of limestone, quartzite, gray chert, and siltstone. Lowermost 5 m locally consists of light-gray, thick-bedded sandy and pebbly limestone. Age based on correlation with type section of the Conglomerate Mesa Formation in the southern Inyo Mountains (Stone and Stevens, 1987), which is dated as late Guadalupian on the basis of ammonoids, brachiopods, and gastropods (Merriam and Hall, 1957; Gordon and Merriam, 1961). Thickness 10–150 m

Sedimentary rocks of Santa Rosa Flat (Lower Permian)—Heterogeneous sequence composed of sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone, exposed in the Conglomerate Mesa area. Divided into:

Psr$_{12}$ **Unit 12**—Yellow, maroon, and greenish-gray shale. Color predominantly yellow in southern exposures and greenish-gray to maroon in northern exposures. Thickness 200–300 m

Psr$_{11}$ **Unit 11**—Brown, yellowish-brown, and reddish-gray, fine- to coarse-grained sandstone, siltstone, and subordinate conglomerate. North and west of Conglomerate Mesa, lower part includes massive limestone conglomerate. Thickness 200–250 m

Psr$_{10}$ **Unit 10**—Medium-gray micritic limestone in which fusulinids, corals, and brachiopods are locally abundant. Dated as Leonardian on the basis of fusulinids (Stone, 1984). Present south and east of Conglomerate Mesa where thickness is 20–40 m

Psr$_{9}$ **Unit 9**—Yellow to light-gray shale. Color predominantly yellow in southern exposures and light gray in northern exposures. North of Conglomerate Mesa, includes minor bioclastic limestone containing Leonardian fusulinids (Magginetti and others, 1988). Thickness 150–300 m

Psr$_{8}$ **Unit 8**—Medium- to dark-gray, thin- to thick-bedded, silty bioclastic limestone and limestone conglomerate, interbedded with varying amounts of gray to maroon calcareous shale and siltstone. Graded bedding and Bouma sequences common except in uppermost part of unit and in northern exposures. Fusulinids, corals, and other marine fossils abundant. Dated as latest Wolfcampian to Leonardian on the basis of fusulinids (Stone, 1984; Magginetti and others, 1988). Thickness ranges from 50 m north of Conglomerate Mesa to at least 1,000 m south of Conglomerate Mesa

Psr$_{7}$ **Unit 7**—Light-gray, massive echinodermal limestone that locally contains fusulinids and brachiopods. Dated as latest Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east and north of Conglomerate Mesa where thickness is 20–100 m

Psr$_6$ ls

Unit 6—Brown to yellowish-brown, thin- to thick-bedded, very fine to fine-grained sandstone, calcareous sandstone, and siltstone; and medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate in which fusulinids and other marine fossils are abundant. Contains marker beds of limestone and limestone conglomerate (**ls**) 1–5 m thick. Dated as late Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present south and east of Conglomerate Mesa where thickness is 350–600 m

Psr$_5$

Unit 5—Dark-gray micritic limestone and subordinate brown to yellowish-brown siltstone and pink shale. Present east of Conglomerate Mesa where thickness is 150 m

Psr$_4$ ls

Unit 4—Brown to yellowish-brown sandstone, calcareous sandstone, siltstone, and shale; medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate; and minor pink conglomeratic mudstone. Graded bedding and Bouma sequences common. Fusulinids, corals, and other marine fossils abundant in limestone, limestone conglomerate, and conglomeratic mudstone. Contains marker beds of limestone, limestone conglomerate, and conglomeratic mudstone (**ls**) 1–10 m thick. Dated as middle to late Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 450–650 m

Psr$_3$

Unit 3—Light- to medium-gray bioclastic limestone and limestone conglomerate that contains abundant fusulinids. Consists of a single graded bed. Dated as middle Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 20 m

Psr$_2$

Unit 2—Brown, thick-bedded, very fine grained sandstone and siltstone. Present east of Conglomerate Mesa where thickness is 150–250 m

Psr$_1$

Unit 1—Yellowish-brown to brown, thin-bedded calcareous siltstone and shale, interbedded with subordinate medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate. Graded bedding and Bouma sequences present. Fusulinids and corals locally present in limestone. Dated as middle Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 380 m with base covered

Lower Permian Units of the Darwin Canyon Group:

Darwin Canyon Formation (Lower Permian)—Sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone, exposed in the Darwin Hills, Darwin Canyon area, and Argus Range. Consists of:

Panamint Springs Member—Sandstone, siltstone, and minor limestone. Divided into:

Pdpu ls

Upper part—Brown to reddish-brown, thin-bedded, very fine grained sandstone and siltstone, interbedded with subordinate medium-gray, fine-grained limestone. Graded bedding and Bouma sequences present. In the Argus Range, contains interval of fine-grained limestone (ls) approximately 50 m thick. A few beds in lowermost 150 m contain late Wolfcampian fusulinids; uppermost part may be Leonardian in age (Stone and others, 1987; Magginetti and others, 1988). Maximum exposed thickness 1,000 m; top eroded or covered

Pdpl

Lower part—Medium- to dark-gray limestone, predominantly fine grained; subordinate pink shale and brown, very fine grained sandstone and siltstone. Contains late Wolfcampian fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 30–100 m

Millers Spring Member—Sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone. Divided into:

Pdmu ls

Upper part—Brown, medium- to thick-bedded, very fine to fine-grained sandstone and siltstone; medium- to dark-gray, predominantly thick-bedded and massive bioclastic limestone and limestone conglomerate; gray, tan, and pink calcareous shale; and minor pink conglomeratic mudstone. Graded bedding and Bouma sequences common in limestone and limestone conglomerate; sandstone beds commonly crosslaminated. Fusulinids, corals, and other marine fossils abundant in limestone, limestone conglomerate, and conglomeratic mudstone. Where metamorphosed, as in the southern Darwin Hills, consists of quartzite, calc-hornfels, and marble. Contains marker beds of limestone, limestone conglomerate, and conglomeratic mudstone 1–10 m thick, and mappable groups of such beds (ls) as thick as 100 m. Dated as middle and late Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 300–400 m. Equivalent to units 3–7 of the Millers Spring Member of Stone and others (1987)

Pdmm

Middle part—Limestone, limestone conglomerate, conglomeratic mudstone, and siltstone. In Darwin Canyon and the Argus Range, consists of, in ascending order: 20–30 m of medium- to dark-gray, thick-bedded bioclastic limestone, limestone conglomerate, and siltstone; 15–25 m of light-gray to grayish-orange, massive conglomeratic mudstone that contains limestone clasts as much as 1 m in diameter; and as much as 50 m of light-gray, thin-bedded siltstone. Fusulinids, corals, and other marine fossils abundant in limestone and conglomeratic mudstone. Where metamorphosed in the southern Darwin Hills, consists of a single bed of light-gray conglomeratic marble about 10 m thick. Dated as middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Equivalent to unit 2 of the Millers Spring Member of Stone and others (1987)

Pdml

Lower part—Brown, thick-bedded, very fine grained sandstone and siltstone. Beds commonly crosslaminated. Thickness 120 m. Equivalent to unit 1 of the Millers Spring Member of Stone and others (1987)

Po lscg

Osborne Canyon Formation (Lower Permian)—Gray to maroon, thin-bedded to massive calcareous mudstone, medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate, and light-brown to gray, plane-laminated calcareous siltstone, exposed in the Darwin Hills, Argus Range, and Santa Rosa Hills. Dark-gray, subspherical limestone concretions common in mudstone. Graded bedding and Bouma sequences present. Limestone conglomerate (lscg) locally present in lowermost part. Fusulinids and corals abundant in limestone and limestone conglomerate. Dated as early and middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 100–400 m in the Argus Range, 600 m in the Darwin Hills, and 300 m in the Santa Rosa Hills where top is covered

Ps

Sedimentary rocks (Lower Permian)—Brown to yellowish-brown calcareous sandstone, siltstone, shale, and mudstone, and medium- to dark-gray bioclastic limestone and limestone conglomerate, exposed in the Talc City Hills and southwestern Darwin Hills. Limestone and limestone conglomerate contain middle to late Wolfcampian corals and fusulinids. May be equivalent to parts of the Osborne Canyon Formation, Millers Spring Member of the Darwin Canyon Formation, and units 1–6 of the sedimentary rocks of Santa Rosa Flat. Previously mapped as the Keeler Canyon and Owens Valley Formations by Hall and MacKevett (1962)

PIPk

Keeler Canyon Formation (Lower Permian to Lower Pennsylvanian)—Medium- to dark-gray, thin- to thick-bedded, silty and sandy calcarenitic and bioclastic limestone exposed in the Conglomerate Mesa area, Talc City Hills, and western Darwin Hills. Characterized by graded bedding, Bouma sequences, and abundant fusulinids. Tan, thin-bedded calcareous siltstone present in lower part. Lowermost 10 to 30 m consists of medium- to dark-gray, thin- to thick-bedded micritic limestone containing small spherical nodules of dark-gray chert ("golfball" horizon). Unit age in this area is considered to range into the Early Pennsylvanian based on lithologic correlation of its lower cherty limestone part with the Tihvipah Limestone (see Stone and others, 1987). Thickness 430–600 m in the Conglomerate Mesa area and 500 m in the Talc City and Darwin Hills where top is covered

ℙs **Sedimentary rocks (Upper? and Middle Pennsylvanian)**—Lenticular unit of calcareous and siliceous rocks that underlies the Osborne Canyon Formation in the southern Darwin Hills. Consists of 15 m of massive limestone conglomerate overlain by 50 m of gray to brown, thin-bedded, silicified limestone and siltstone, and minor bioclastic limestone. Conglomerate in lower part composed exclusively of clasts derived from the Santa Rosa Hills Limestone. Unit appears to occupy a channel that cuts out the Tihvipah Limestone, the Indian Springs Formation of Webster and Lane (1967), and the uppermost part of the Santa Rosa Hills Limestone. Matrix of basal conglomerate contains Middle Pennsylvanian fusulinids (Moffitt, 1978)

ℙt **Tihvipah Limestone (Middle and Lower Pennsylvanian)**—Medium-to dark-gray, thin- to thick-bedded, cherty micritic limestone exposed mainly in the Darwin Hills, Argus Range, and Santa Rosa Hills. Contains abundant nodules, lenses, and thin beds of dark-gray chert; pebbly micritic limestone present locally. In the southern Darwin Hills and northern Santa Rosa Hills, lowermost part contains a thin zone of phosphate-pebble conglomerate. Previously mapped as part of the Keeler Canyon Formation by Hall and MacKevett (1962) and Hall (1971). Thickness 50–120 m in most areas and 250–300 m on east side of the Argus Range

Mississippian marine units:

side of the Argus Range

Mi **Indian Springs Formation of Webster and Lane (1967) (Upper Mississippian)**—Quartzite, siltstone, and minor limestone that underlies the Tihvipah Limestone in the southern Darwin Hills and Santa Rosa Hills. Late Mississippian brachiopods present in the Santa Rosa Hills (M. Gordon, Jr., written commun., 1983). Previously mapped as the Rest Spring Shale by Hall and MacKevett (1962) in the Santa Rosa Hills. Thickness 10–30 m

Mr **Rest Spring Shale (Upper Mississippian)**—Dark-brown to black shale exposed in the Conglomerate Mesa area, Talc City Hills, and western Darwin Hills. Locally altered to green, yellow, or black andalusite hornfels. Thickness 50–200 m

Ms **Santa Rosa Hills Limestone (Upper Mississippian)**—Light- to very light-gray, thick-bedded, fine- to coarse-grained echinodermal limestone exposed mainly in the Darwin Hills, Argus Range, and Santa Rosa Hills. Contains sparse nodular gray chert. Named by Dunne and others (1981) for rocks previously mapped as the Lee Flat Limestone by Hall and MacKevett (1962). Late Mississippian (Meramecian) foraminifers and conodonts present in the Santa Rosa Hills (Dunne and others, 1981; Klingman, 1987). Thickness 80–100 m in the southern Darwin Hills and Santa Rosa Hills, and 200–300 m in the Argus Range

Perdido Formation (Upper and Lower Mississippian)—Limestone, siliceous limestone, siltstone, and chert. Unit age in this area is considered to range into the Early Mississippian based on conodonts from the limestone (lower) member (see below). Consists of:

Mps **Siltstone member (Upper Mississippian)**—Light- to medium-brown, platy-weathering siltstone exposed in the Conglomerate Mesa area and Talc City Hills. Interbedded in upper part with thin graded beds of medium-gray, bioclastic limestone. Correlated with upper part of type section of the Perdido Formation in the Cottonwood Mountains (northern Panamint Range) (McAllister, 1952). Thickness 50–75 m

Mpl **Limestone member (Upper and Lower Mississippian)**—Medium- to dark-gray, thin- to medium-bedded, fine-grained limestone interbedded with abundant brown-weathering siliceous limestone and chert, exposed mainly in the Argus Range, Darwin Hills, and Santa Rosa Hills. Early Mississippian (Osagean) conodonts present in the Argus Range; Late Mississippian (Meramecian) conodonts present in the hills east of Conglomerate Mesa (Klingman, 1987). Includes the Lee Flat Limestone Member of the Perdido Formation as used by Dunne and others (1981). Correlated with lower part of type section of the Perdido Formation in the Cottonwood Mountains (northern Panamint Range) (McAllister, 1952). Thickness 450 m in the Santa Rosa Hills, and 400 m in the southern Darwin Hills with base covered

Msp **Santa Rosa Hills Limestone (Upper Mississippian) and Perdido Formation (Upper and Lower Mississippian), undivided**—Structurally complex limestone outcrops in the Santa Rosa Hills. Perdido Formation here consists only of its limestone (lower) member

Mpt **Perdido Formation (Upper and Lower Mississippian) and Tin Mountain Limestone (Lower Mississippian), undivided**—Mapped primarily in the Argus Range where thickness is 250 m. Perdido Formation here consists only of its limestone (lower) member

Mt **Tin Mountain Limestone (Lower Mississippian)**—Medium- to dark-gray, thin- to medium-bedded, fine-grained limestone containing gray to black chert lenses and nodules. Brachiopods and corals locally abundant. Thickness 100–130 m

2009

Jayko mapped the Quaternary geology of the Darwin Hills 100K quadrangle. Units he recognized were alluvium, geomorphic features, Coso Formation and bedrock units.

ALLUVIAL DEPOSITS

Qaw	**Active wash deposit (Holocene)**
Qav	**Active valley-axis deposit (Holocene)**
Qaa	**Active alluvial fan deposit (Holocene)**
Qaae	**Active alluvial fan deposit (Holocene)**
Qaa1	**Active alluvial fan deposit (Holocene)**
Qyw	**Young wash deposit (Holocene and late Pleistocene)**
Qya	**Young alluvial fan deposit (Holocene and late Pleistocene)**
Qyao	**Young alluvial fan deposit (Holocene and late Pleistocene)**
Qiw	**Intermediate wash deposit (late to middle Pleistocene)**
Qia	**Intermediate alluvial fan deposit (late to middle Pleistocene)**
Qiao	**Intermediate alluvial fan deposit, older (late to middle Pleistocene)**
Qoa	**Old alluvial fan deposit (middle to early Pleistocene)**
Qau	**Alluvial fan deposit undifferentiated (Quaternary)**
QToa	**Extremely old alluvial fan deposit (early Pleistocene to Pliocene)**
QTs	**Sedimentary rocks (early Pleistocene and (or) late Pliocene)**

GEOMORPHIC FEATURES

Qapd	**Pediment surfaces (middle and late Quaternary)**
ff	**Faceted bedrock spur (Pleistocene and (or) late Pliocene)**
ve	**Volcanic vent area (Quaternary and (or) late Pliocene)**
Tvpd	**Pediment inset onto (Quaternary and (or) late Pliocene)**
Tcpd	**Pediment inset onto Coso Formation (Quaternary and (or) late Pliocene)**
Tbpd	**Pediment inset onto basalt (Quaternary and (or) late Pliocene)**
KJpd	**Pediment developed on granitic substrate (Quaternary and (or) late Pliocene)**
MzPzpd	**Pediment developed on Paleozoic and (or) Mesozoic substrate (Quaternary and (or) late Pliocene)**
Tves	**Pediment developed on Tv (Quaternary and (or) late Pliocene)**
Tbes	**Old erosion surface developed on top of basalt (early or middle Pliocene)**
Es	**Old erosion surface on bedrock (late Miocene and early Pliocene)**
Tblag	**Cobble lag deposit (late Miocene and early Pliocene)**
Kgu	**Old relief above Es (late Miocene and early Pliocene)**

Coso Formation (Pliocene)—Divided informally into :

Tvd	**Rhyodacite (Pliocene)**
Tcs	**Mainly sedimentary rocks (Pliocene)**
Tcu	**Coso Formation, undifferentiated (Pliocene)**
Tcv	**Coso Formation, undifferentiated volcanic rocks (Pliocene)**
Tvrc	**Red weathering rhyodacitic volcanic rock (Pliocene)**
Tca	**Mainly volcanic ash and tephra (Pliocene)**
Tcla	**Lower volcanic ash and tephra (Pliocene)**

Tvdo	**Older dacitic volcanic rock (Pliocene)**
Tb	**Mainly flood-like basalt flows and other mafic volcanic rocks (Pliocene)**
Tbc	**Eruptive centers for basalt flows and other mafic volcanic rocks (Pliocene)**
Tcvr	**Volcanic ash flow and ash (early Pliocene and (or) late Miocene)**
Tvcf	**Volcanic ash flow and ash(early Pliocene and (or) late Miocene)**
Trb	**Sedimentary rocks (early Pliocene and (or) late Miocene)**
Tsa	**Sedimentary rocks (late Miocene ?)**
Tv	**Volcanic rock (early Pliocene to late middle Miocene)**

BEDROCK LITHOLOGIES

KJg	**Plutonic rocks (Cretaceous and (or) Jurassic)**
MzPz	**Sedimentary and metamorphic rocks**
ca	**Meta-sedimentary, Metamorphic, and Plutonic Rocks of the Panamint Range (Mesozoic, Paleozoic, and Precambrian)**

MINERALOGY

1938

The original ore mineralization of the deposits consists principally of galena with lesser quantities of sphalerite and chalcopyrite and minor quantities of the gray-coppers, luzonite and tennantite. Near the surface the sulphides have been extensively oxidized and much of the ore consists of gossan in which is found principally the lead-carbonate, cerusite. Lesser quantities of anglesite, smithsonite, malachite, and chrysocolla with small quantities of horn silver are also present. The associated gangue consists of pyrite, jasper, calcite, fluorite, kaolin, and occasionally barite (Kelley, 1938, p. 506).

The mineralization belongs to the intermediate or upper mesothermal group of ore deposits having thus originated in the presence of temperatures and pressures neither extremely high nor extremely low. The geologic epoch or period of mineralization probably occurred during late Mesozoic comparable in time with the formation of the gold deposits of the Mother Lode of California (Kelley, 1938, p. 506).

ALTERATION OF THE SEDIMENTARY ROCKS

General Character

Since most of the minerals of the silicate zone about the intrusive are calcium silicates, the term tactite, proposed by Hess (1918) is applied herein to these rocks as a whole. Hess applied the term to calcium silicate strata or rock affected by magmatic emanations. The term hornfels tactite is used for the fine-grained or aphanitic tactites. Other descriptive terms are prefixed to the name, such as wollastonite tactite or garnet-diopside tactite (Kelley, 1938, p. 537).

At Darwin the tactites are whitish, medium- to fine-grained, stratified rocks. The width of the tactite zone about the stock varies from a few tens of feet to nearly 2000 feet. The outer limit of the zone is roughly determinable by the extent of bleaching of the original rocks. An aureole about 1000 to 1500 feet in width is most common. The retained stratification is the principal existent structure. Although in many places the tactite is fine-grained or aphanitic, large areas of stratified tactite composed of visibly felted aggregates of wollastonite occur. Locally, decidedly coarse textures are found. Light green garnets one to three inches in diameter imbedded in wollastonite are common, and one garnet a foot in diameter was found south of the Defiance mine. On the prominent white ridge south of the Lucky Jim camp are areas of tactite in which wollastonite prisms three to six inches in length are abundant associated with garnet and considerable idocrase. Idocrase crystals attain dimensions of one to two inches. In general, the coarser the texture, the less is the mineral diversity. Coarseness of grain, except in a broad way is not related to proximity of the igneous contact. Thus, at the Defiance mine the tactite at the igneous contact is dense, fine-grained, white rock, while westward from the contact to the top of the ridge there are many beds of medium and coarse-grained tactite (Kelley, 1938, p. 537).

Kelley (1938, pp. 538-540) provides detailed mineralogical and textural descriptions of

Calcite
Diopside
Epidote
Garnet
Idocrase
Orthoclase
Plagioclase
Quartz
Wollastonite
Miscellaneous minerals: Tourmaline, sphene, apatite, tremolite, fosterite, tremolite, actinolite, fluorite

Here is Kelley's paragenetic sequence:

…wollastonite, idocrase, garnet, diopside, plagioclase, and orthoclase. If this order of formation is correct, then it may be observed that the earlier minerals are the highest in lime and that the trend is toward increased silica and alkalies. This is perhaps the trend to be expected in the metamorphism of a carbonate rock adjacent to a siliceous intrusive, and it further demonstrates the metasomatic nature of the silication process (Kelley, 1938, p. 541).

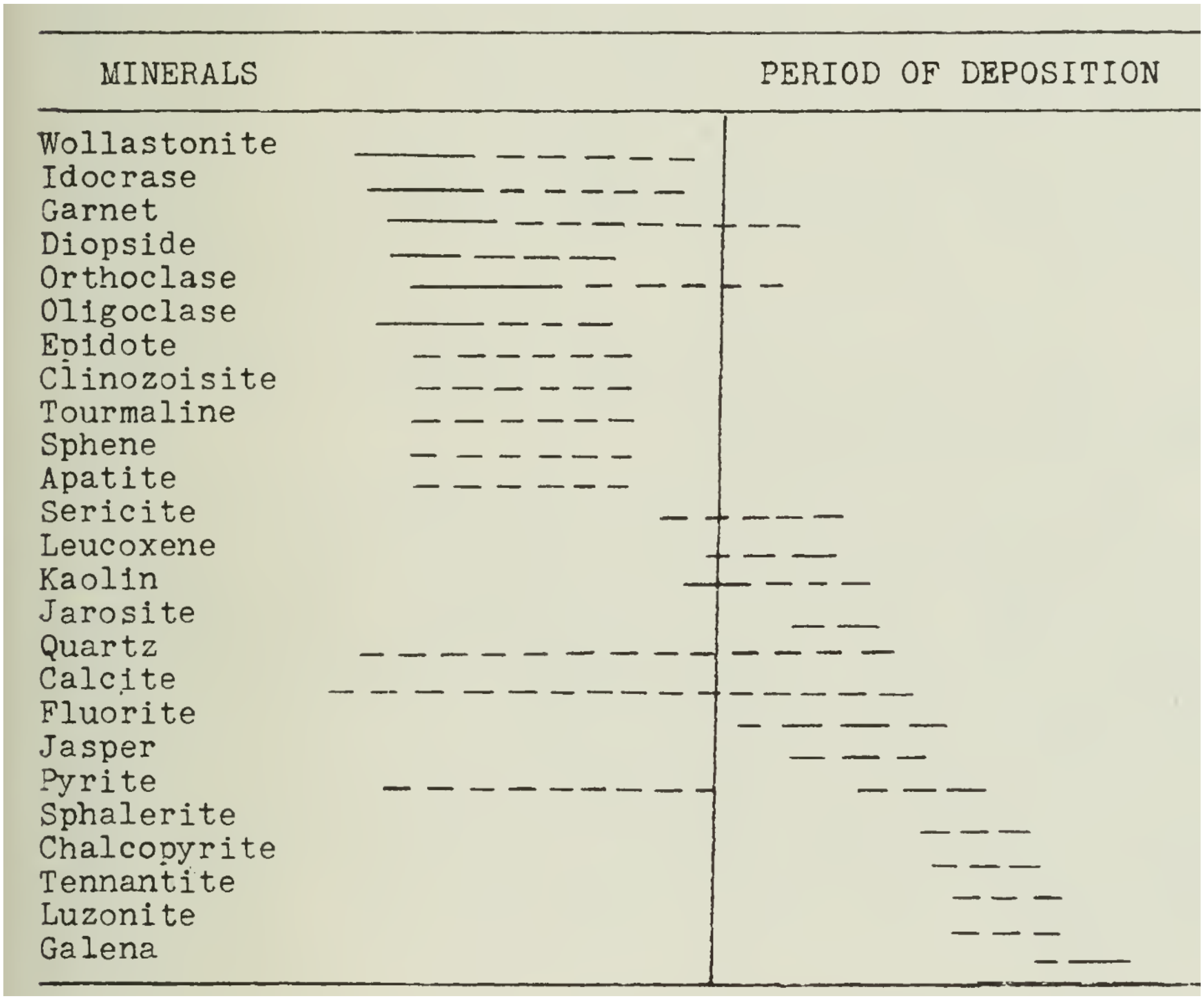


Figure 20. From Kelley, 1938, p. 545.

ALTERATION OF THE IGNEOUS ROCK

The intrusive rocks have suffered considerable yet variable alteration paralleling that in the tactites and in the ore-bodies. The alteration minerals fall into two groups. The earlier higher temperature group includes garnet, orthoclase, diopside, calcite, clinozoisite, and epidote. The second, lower temperature group includes sericite, chlorite,- pyrite, quartz, kaolin, leucoxene, and possibly jarosite. It must be admitted, however, that the division between the two groups is not sharp, and proof that some of the minerals in the two groups did not develop contemporaneously is wanting. In general, garnet, diopside, calcite, and epidote are products which involve some transfer of material, particularly lime, from the sedimentaries. These minerals are common in the intrusive near the contacts. Thus, in the quartz diorite near the Thompson mine there has developed considerable calcite, epidote, and pyrite, the last mineral being clearly related to fractures. In addition, diopside, clinozoisite, chlorite, sericite, and tourmaline are present in smaller quantities (Kelley, 1938, p. 541).

Garnetization of the intrusive has already been mentioned and this type of alteration is very well shown in many places. In the sill-like offshoot of the stock about 200 feet above the Defiance mine, garnet is abundantly developed. In some places here nearly the entire rock may be converted to light green, granular garnet. In other places the garnet is distinctly developed along joints. Another area of intense garnetization occurs about 300 yards west of the Charistmas Gift mine on the Hahn claim where the igneous material has been almost entirely converted to medium-grained, light brown garnet (Kelley, 1938, p. 541).

It is a noticeable feature that orthoclase is more abundant in many of the border phases and offshoots of the intrusive. The intrusive near the Definance mine is quartz diorite, but at the immediate contact back of the blacksmith shop orthoclase makes up nearly 90 per cent of the rock. Sometimes this development of orthoclase takes the form of small dikes or veins which in places so permeate the rock as to lose identity. Where orthoclase forms much of the rock poikilitic plagioclase, diopside, epidote, or sphene are commonly present. Perhaps epidote is the most common associate of orthoclase of this occurrence. The formation of the potash feldspar is roughly correlated with orthoclasization of the limestones (Kelley, 1938, p. 541).

Sericitization is widespread and sometimes very intensely developed. In places near the igneous contacts the rock is composed almost entirely of quartz and sericite. Sericitization first begins in the plagioclase, and pseudomorphs of sericite after plagioclase are preserved in completely altered rock. In feeble alteration where only the plagioclase is attacked, orthoclase is more or less kaolinized. In the more advanced stages, sericite spreads to the potash feldspar and at the same time quartz appears to increase as though it were a by-product of the sericite. In the final stage sericite even invades the quartz (Kelley, 1938, p. 541-542).

Much leucoxene accompanies the sericitization process and most of the leucoxene is an alteration of a black metallic mineral, possibly ilmenite. Associated with the leucoxene alteration is a small quantity of jarosite. The jarosite occurs partly as veins cutting all other minerals and partly as grains intimately associated with leucoxene and sericite alteration in areas clouded with kaolin and containing minute grains of sphene. The occurrence of jarosite intimately associated with leucoxene and sericite may indicate that the assemblage is of hydrothermal origin. Sericitization probably represents a lower temperature, hydrothermal continuation of orthoclasization. This process of forming orthoclase, along with the development of garnet, tourmaline, sphene, calcite, diopside, and epidote is best correlated with the bulk of silication of the limestones. On the other hand, sericitization and accompanying products are more nearly to be correlated with later hydrothermal processes and the metallization epoch. (Kelley, 1938, p. 542).

Pyrite is extensively developed in the igneous rocks and for the most part is of late hydrothermal origin contemporaneous with metallization (Kelley, 1938, p. 542).

HYPOGENE ORE AND GANGUE MINERALIZATION

The mineralization which gave rise to the silver-lead deposits at Darwin is sharply set off from the silication process mentioned above. The silication of the limestones is conceived as having taken place during the emplacement of the stock, whereas the ore and gangue mineralization occurred after the formation of the tactite zone in subsequent fractures and other structural loci. Quantitatively, the major metalliferous deposition occurred within the tactites. This post-consolidation mineralization may be discussed in two groups: gangue and ore mineralization (Kelley, 1938, p. 542).

The main gangue minerals are calcite, pyrite, jasper and fluorite. The main or mineral is galena (Kelley, 1938, p. 542-543).

1951

The ore minerals in the unoxidized ore zones are argentiferous galena and sphalerite with lesser amounts of chalcopyrite and tetrahedrite in a pyrite, fluorite, and calcite gangue. Extensive near-surface leaching of zinc, sulphur and iron has produced high-grade ores consisting of cerussite, anglesite, plumbojarosite and some bunches of galena. Several rare minerals and several hundred tons of high-grade tungsten ore (scheelite) were mined from one of the stopes in the oxidized zone. Accessory minerals in the oxidized zone are iron oxides, jasper, clays, sulphur, gypsum, jarosite, calcite, hydromica, quartz and fluorite. (Norman and Stewart, 1951, p. 64).

1958

The minerals identified in the lead-silver-zinc deposits in the Darwin quadrangle are listed below (Hall and MacKevett, 1958, p. 16).

Hypogene minerals	
Ore and sulfide minerals	
Andorite	$PbAgSb_3S_6$
Argentite	Ag_2S
Arsenopyrite	$FeAsS$
Bismuth (?)	Bi
Bornite	Cu_5FeS_4
Chalcopyrite	$CuFeS_2$
Enargite-famatinite (?)	Cu_3AsS_4-Cu_3SbS_4
Franckeite	$Pb_5Sn_3Sb_2S_{14}$
Galena	PbS
Guanajuatite (?)	Bi_2Se_3
Matildite	$AgBiS_2$
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Scheelite	$CaWO_4$
Sphalerite	ZnS
Stannite	Cu_2FeSnS_4
Tetrahedrite-tennantite	$(Cu, Fe)_{12}Sb_4S_{13}$-$(Cu, Fe)_{12}As_4S_{13}$
Unknown lead-bismuth-selenium sulfosalt	
Gangue minerals	
Barite	$BaSO_4$
Calcite	$CaCO_3$
Chalcedony	SiO_2
Deweylite	$Mg_4Si_3O_{10}\cdot 6H_2O$
Diopside	$CaMgSi_2O_6$
Fluorite	CaF_2
Garnet sp. andradite	$(Ca)_3(Al, Fe)_2Si_3O_{12}$
Graphite	C
Idocrase	$Ca_6[Al(OH, F)]Al_2(SiO_4)_5$
Jasper	SiO_2
Kaolinite	$H_4Al_2Si_2O_9$
Montmorillonite	$(OH)_4Al_4Si_8O_8\cdot xH_2O$
Quartz	SiO_2
Sericite	$(H, K)AlSiO_4$
Wollastonite	$CaSiO_3$
Supergene minerals	
Sulfide minerals	
Argentite	Ag_2S
Chalcocite	Cu_2S
Covellite	CuS
Oxide zone	
Anglesite	$PbSO_4$
Antlerite	$Cu_3(OH)_4SO_4$
Aurichalcite	$2(Zn, Cu)CO_3\cdot 3(Zn, Cu)(OH)_2$
Azurite	$2CuCO_3\cdot Cu(OH)_2$
Bindheimite	$Pb_2Sb_2O_6(O, OH)$
Brochantite	$CuSO_4\cdot 3Cu(OH)_2$
Caledonite	$Cu_2Pb_5(SO_4)_3(CO_3)(OH)_6$
Cerargyrite	$AgCl$
Cerussite	$PbCO_3$
Chrysocolla	$CuSiO_3\cdot 2H_2O$
Creedite	$Ca_3Al_2F_4(OH, F)_6(SO_4)\cdot 2H_2O$
Crocoite	$PbCrO_4$
Cuprite	Cu_2O
Goslarite	$ZnSO_4\cdot 7H_2O$
Gypsum	$CaSO_4\cdot 2H_2O$
Hemimorphite	$H_2Zn_2SiO_5$
Hydrozincite	$2ZnCO_3\cdot 3Zn(OH)_2$
Jarosite	$K_2Fe_6(OH)_{12}(SO_4)_4$
Limonite (and goethite)	Hydrous iron oxide
Linarite	$(Pb, Cu)SO_4\cdot(Pb, Cu)(OH)_2$
Malachite	$CuCO_3\cdot Cu(OH)_2$
Melanterite	$FeSO_4\cdot 7H_2O$
Plumbojarosite	$PbFe_6(OH)_{12}(SO_4)_4$
Pyromorphite	$(PbCl)Pb_4(PO_4)_3$
Silver	Ag
Smithsonite	$ZnCO_3$
Sulfur	S
Vanadinite	$(PbCl)Pb_4(VO_4)_3$
Wulfenite	$PbMO_4$

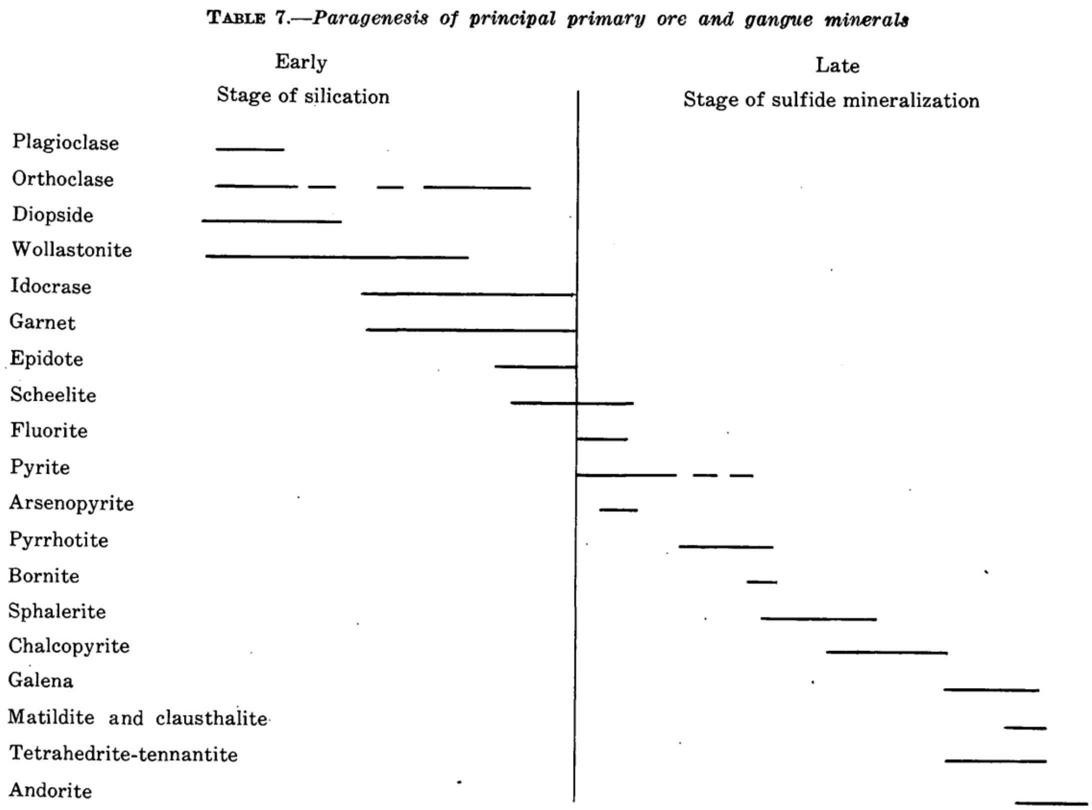


Figure 21. From Hall and MacKevett, 1958, p. 64.

1975

Four important sulfide mineral assemblages are recognized The most common is a pyrite-sphalerite-galena. Chalcopyrite and scheelite assemblage that includes all the replacement ore in calc-silicate rock near the Darwin stock (Fig. 1). The second is a pyrite-pyrrhotite-magnetite-sphalerite-galena assemblage that occurs on the footwall of the Davis thrust fault and is the greatest distance from the Darwin stock. The third is fine-grained heavy galena ore containing abundant silver, bismuth, and selenium and minor associated pyrite. This ore was most abundant near the surface in the Essex and Thompson workings and was the high-grade ore mined extensively during the early history of the district. The fourth type, which is very minor, is a late Ag-Bi-Se-Te sulfosalt assemblage. It contains a dominant silver colored sulfosalt mineral similar to heyrovskite, which occurs in ragged, subparallel plates in a gangue of coarse white calcite, disseminated green andradite, and pyrite cubes. This assemblage was observed only on the 400 level in the Independence workings of the Darwin mine (Czamanske and Hall, 1975, p. 1092*).*

1991

SKARN MINERALOGY

The mineralogy of the Darwin Pb-Zn-Ag skarns is relatively simple, although there are complex mineral compositional patterns. The most abundant mineral is granitic garnet, with compositions ranging from 100 to 5 mole percent andradite (Fig. 6). Four generations of garnet have been identified, based on overgrowth textures, rare vein relationships, and optical and compositional properties (Figs.6 , 7). Several garnet types are typically present in the same sample and in many cases three generations are present in the same grain (Fig. 7A) (Newberry and others, 1991, p. 966).

1991

PARAGENESIS

A generalized paragenetic diagram (Fig. 9) for the minerals at Darwin illustrates the series of metamorphic-skarn events and the complexities of the sulfide silicate and sulfide-sulfide relationships for the main Pb-Zn ore event. This diagram differs from that of Hall and MacKevett (1962) largely in indicating a Considerable overlap in time of formation between skarn (garnet, idocrase, epidote) and ore (pyrite, sphalerite, chalcopyrite, galena). We attribute this difference in the diagrams to the availability of deep level exposures and samples for this study and to our successful discrimination between metamorphic (hornfels-related) and metasomatic (skarn-related) talc-silicate minerals. Given that the development of hornfels accompanied intrusion of the Darwin stock (Hall and MacKevett, 1962; Eastman, 1980; Newberry, 1987), structural constraints indicate that third and fourth generation garnet and Pb-Zn ore deposition postdated formation of garnet in the calc-silicate hornfels by more than 20 Ma. (Newberry and others,1991, p. 969).

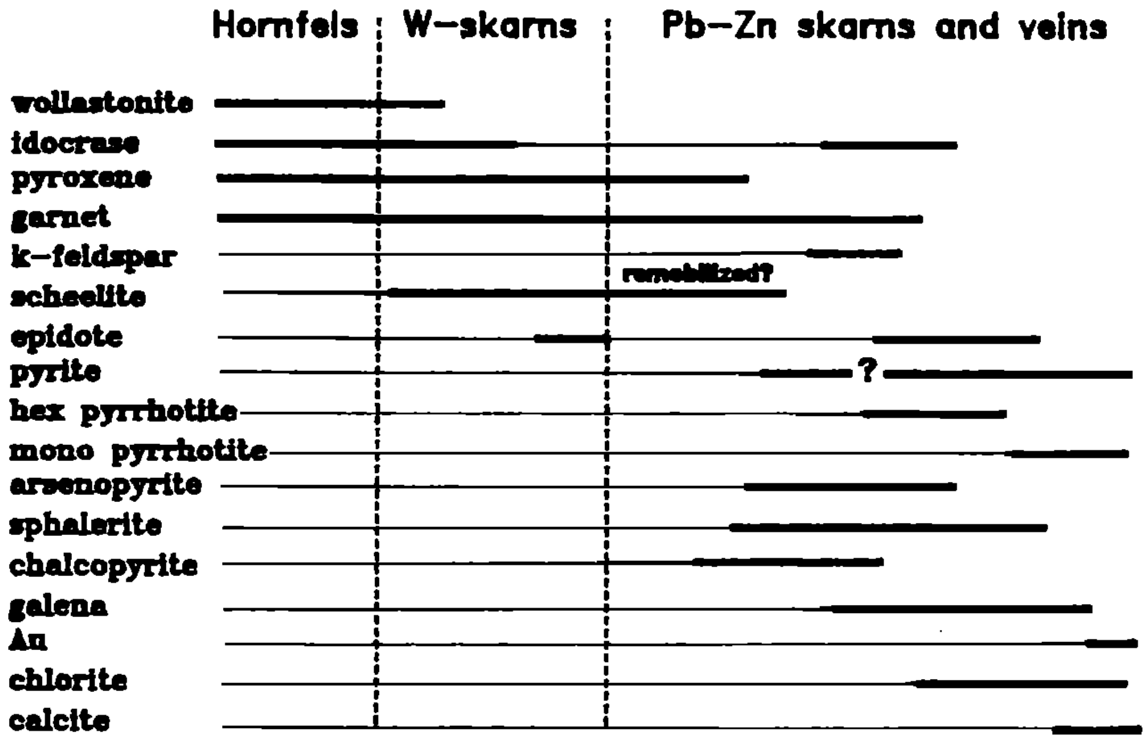


FIG. 9. Simplified paragenesis diagram for the Darwin ores.

2011

SUPERGENE MINERALS

The Darwin ores are largely oxidized to considerable depth except where they are protected by a shallower impermeable layer. Extensive near surface leaching of zinc, sulfur, and iron from the primary argentiferous galena and sphaleraite ores have produced high grade oxidized ore that occurs in a crumbly porous mass composed of limonite, hemimorphite, cerussite, anglesite, plumbjarosite with some altered and unaltered relicts of galena. Anglesite forms a thin alteration halo around much of the galena. Native silver, cerargyrite, and sooty argentite also occur. Some of the early near surface oxidized ore in the Darwin District is said to have run 950 ounces of silver per ton. In the Defiance workings, the ore was almost completely oxidized to the 400 foot level with both oxide and primary ore extending from the 400 foot level to below the 1,000 foot level. In the Lucky Jim Mine, only small relicts of primary sulfides were found in the deeper workings below 900 feet. Secondary copper minerals accompany the secondary lead and zinc minerals and include aurichalcite, azurite, bronchantite, cledonite, chrysocolla, linarite, and malachite (USGS, 2011).

HYPOOGENE ORE MINERALS

The hypogene ore and sulfide minerals consist principally of galena, sphalerite, pyrite, pyrrhotite, and chalcopyrite with minor tetrahedrite, scheelite, andorite, franckeite, and stannite. Argentiferous galena is the chief lead and silver ore mineral. It ranges in texture from fine to coarsely crystalline masses. Corroded inclusions of tetrahedrite, *pyrrhotite, and chalcopyrite are common. Sphalerite is the chief zinc ore mineral and often occurs in coarse crystalline masses with cleavage faces 1-2 inches in diameter. Pyrite is abundant in both the lead-zinc deposits and throughout the country rock. Pyrrhotite is most common in the deep levels of the Thompson workings where it often occurs in a banded structure with galena and sphalerite. Chalcopyrite is a minor constituent of the ore and occurs as corroded inclusions in sphalerite and galena. Zoning and ore assemblages Hypogene mineralization displays a zonal distribution which has been correlated with a temperature gradient at the time of ore deposition (Hall and MacKevett, 1962). Near surface ores contain more lead and silver, but with depth, the zinc to lead ratio increases and the silver decreases. The shallower ores in the bedded deposits of the Defiance workings consisted mainly of galena with an above average silver content. The upper part of the deeper irregular replacement ore body consisted primarily of galena with a lower silver content than the overlying bedded deposits. With increasing depth in the irregular ore body the proportion of zinc to lead increases and the silver content continues to decrease. Zoning is also evident between the lead-silver ore bodies and the tungsten ore bodies on the east side of the Darwin Stock where the lead-silver ore bodies are farther out along the same faults that control the tungsten ore bodies. In a number of mines, scheelite with little or no associated galena is found in tactite and calc-hornfels closer to the Darwin Stock and lead-silver ore is located farther from the stock. Czamanske and Hall (1975) recognized four hypogene sulfide assemblages in the Darwin District ores. The most common is a pyrite-sphalerite-galena ? chalcopyrite and scheelite assemblage that includes all the replacement ore in the calc-silicate rocks near the Darwin Stock. A second assemblage of pyrite-pyrrhotite-magnetite-sphalerite-galena occurs in the footwall of the Davis thrust and only occurs at a great distance from the Darwin stock. Ores comprising the near surface high grade primary ores in the Essex and Thompson workings and the high grade primary ore mined in the early days consisted of a fine grain heavy galena ore containing abundant silver, bismuth, selenium, and minor pyrite. Lastly, a fourth assemblage consisting of a late Ag-Bi-Se-Te sulfosalt was identified only in the 400 foot level of the Independence workings. Czamanske and Hall (1975) also divided the Darwin galena into three groups based on electron microprobe analysis. The majority of galena (90?%) in the district consists of relatively pure galena containing no exsolved phases and less than .22 weight % silver. Most of the galena in the replacement ore bodies of the Defiance workings and those in the deeper parts of the Essex, Thompson, and Independence workings are of this type. Galena with 1.7-3.3 weight % silver and 3.9-7.3 weight % bismuth in solid solution was identified as common in the fine grained heavy galena in the shallower levels of the Essex and Thompson workings. A rare galena containing Ag, Bi, and Se in amounts up to 4.6, 10.8, and 9.0 wt % respectively was found only in the rare ore type from the 400 level of the Essex workings* (USGS, 2011).

ORE BODIES OF THE DARWIN DISTRICT

1962

OVERVIEW

Both primary. and secondary lead-silver-zinc ore is mined in the Darwin quadrangle. Prior to 1945 mainly oxidized lead-silver ore was mined, but since then more primary than oxide ore has been produced. In the Darwin district sulfide minerals generally constitute more than 75 percent of the primary ore. The ore consists principally of galena and sphalerite· and lesser amounts of pyrite, chalcopyrite, and pyrrhotite. The average grade of ore is about 6 percent lead, 6 percent zinc, 6 ounces of silver per ton, and a small amount of copper. Gangue minerals are calcite, fluorite, jasper, and the relict host-rock minerals garnet, idocrase, diopside, wollastonite, quartz, and feldspar. Jasper and calcite are the abundant gangue minerals in most of the fissure deposits and relict host-rock minerals in the replacement ore bodies (Hall and MacKevett, 1962, p. 55-56).

The texture of the primary ore ranges from very fine grained steel galena to coarsely crystalline ore containing galena and sphalerite crystals ½ to 1 inch in diameter. Steel galena is particularly abundant in the Essex vein. Banded ore, although not characteristic of the Darwin· district, occurs jn some of the mines where pyrrhotite is abundant (Hall and MacKevett, 1962, p. 56).

The oxidized lead-silver ore in the Darwin district, except where jasper is the principal gangue mineral, is a soft friable mass consisting principally of cerussite and limonite, and most of it can be disintegrated easily by hand. (Hall and MacKevett, 1962, p. 56).

Silver ore containing a little galena occurs near the margins of some of the lead-silver-zinc ore bodies in the Darwin mine. The silver ore contains andorite, clausthalite, galena, matildite [$AgBiS_2$,] *and pyrite in a gangue of calcite and relict host rock. Matildite and clausthalite* [PbSe] *are in exsolved laths in galena. Whereas sulfide minerals are predominant in the lead-silver-zinc ore, the silver ore commonly contains only several percent of metallic minerals.* (Hall and MacKevett, 1962, p. 56).

Most of the ore mined from the Santa Rosa and Lee mines was oxidized. Oxidized ore at the Lee mine is much harder than that from Darwin and consists of a hard light- to dark-gray porous mass composed mainly of hemimorphite and includes thin coatings and crystals of cerargyrite. Some relict primary ore is present that consists of coarse galena and small amounts of sphalerite in a gangue of calcite and barite (Hall and MacKevett, 1962, p. 56).

FORMS OF ORE BODIES

The ore bodies occur as bedded deposits, irregular replacement bodies close to major faults, fissure or vein deposits, and small ore bodies in flat-.lying fractures (Hall and MacKevett, 1962, p. 56).

BEDDED DEPOSITS

Bedded deposits economically are the most important. They are common in the Darwin and Zinc Hill districts. Notable examples in the Darwin district are the bedded ore bodies in the Independence workings (pl. 3); the 430 stope ore body; the Blue and Red veins in *the Defiance workings; and the ore bodies at the Custer, Jackass, and Promontory mines. Small, bedded ore bodies are also at the Empress and Zinc Hill mines in the Zinc Hill district. The ore bodies contain from a few tens to more than half a million tons of ore. The contacts between the bedded deposits and barren or slightly pyritized wallrock are sharp. However, the grade within the ore body is not uniform along strike, and some lower grade parts have been left behind as pillars*. (Hall and MacKevett, 1962, p. 56).

IRREGULAR REPLACEMENT ORE BODIES

The only important irregular replacement ore body is in the Defiance ~or kings of the Darwin mine (pl. 3). It is a vertical pipe-shaped zone about 250 by 350 feet in horizontal section and contains many isolated ore bodies. It has been mined vertically for about 550 feet. The downward extent has not been determined. Ore bodies within the zone have gradational contacts with barren or pyritized ·calc-silicate rock. (Hall and MacKevett, 1962, p. 56).

VEIN DEPOSITS

Fissure or vein deposits are present in the Darwin district, at the Santa Rosa mine in the In yo Mountains, and at a few small deposits in the Talc City Hills. In the Darwin district the veins are as much as 460 feet long; they average 2 to 8 feet in thickness and are as much as 35 feet thick~ The Essex vein has been mined for 800 feet down dip (pl. 3) ; the Lucky Jim vein for 920 feet. All the other veins apparently have a lesser length downdip. Contacts of the veins with barren country rock are sharp. Minable high-grade ore is commonly localized in ore shoots within the veins. At the Christmas Gift and Lucky Jim mines, the ore is localized in the part-s of the veins that have approximately a northeast strike, and the parts that have a more easterly strike are nearly barren. These ore shoots plunge toward the west (Hall and MacKevett, 1962, p. 56).
(Hall and MacKevett,1962, p. 56).

ORE BODIES OF THE DARWIN MINE

Overview 1975

Most of the ore is massive and occurs in veins, bedded deposits, and steep irregular replacement bodies near feeder fissures that strike N 50º-70º E and cut medium-grained, light-colored calc-silicate rock. The ore consists of galena, sphalerite, pyrite, and lesser amounts of chalcopyrite, pyrrhotite, magnetite, arsenopyrite, scheelite, tetrahedrite, and the here-described phases rich in Ag, Bi, Se, and Te. Gangue minerals are calcite, fluorite, host-rock calcsilicate minerals, and a little jasperoid (Czamanske and Hall, 1975, p. 1092*).*

1958

Ore in the Darwin mine occurs mainly in a favorable stratigraphic zone more than 840 feet thick close to pre-mineral feeder faults that strike N. 50°-70" E. and dip steeply to the northwest. Individual ore bodies occur as replacements of certain favorable beds close to the N. 70° E. faults, as replacement bodies in fault zones, and as irregular or pipelike bodies in calc-hornfels. The bedded deposits have sharp contacts with the wall *rock both stratigraphically above and below the favorable bed, although the ore within a mineralized bed has a considerable range in grade and some blocks of low grade ore were left behind as stope pillars. A description of the ore bodies and ore controls for Each of the workings is given below* (Hall and MacKevett, 1958, p. 27).

BERNON WORKINGS.

The Bernon workings adjoin the Defiance workings on the north and the Thompson workings on the south. The workings are in white, medium-grained calc-hornfels along the crest of a minor inverted syncline that extends southward to the Defiance workings. The Paleozoic rocks are intruded by a sill of quartz monzonite south of the 434 fault, and by a dike south of the Bernon fault. The rocks are cut by the pre-mineral Bernon fault and the 434 fault, both of which strike N. 50°-600 E. and dip steeply to the northwest. The faults are cut off on the west by the Davis thrust. All ore is in the Bernon fault in medium-grained calc-silicate rock (Hall and MacKevett, 1958, p. 27). *Defiance Wor-kings. The Defiance workings are in the southeast part of the Darwin mine area 0.7 miles north of the town of Darwin. Two bedded ore bodies crop out along the crest of an inverted syncline where it is cut. by the' Defiance fault. The Red vein is in dense white calc-hornfels near the upper contact of a granodiorite sill. The vein is 300 feet long and has been mined 400 feet down the dip from the surface to the 215-foot level (fig. 2).· The Red vein is in dense white calc-hornfels 60 feet stratigraphically above the Blue vein and 80 feet stratigraphically below an upper sill of granodiorite. This vein is 460 feet long at the Defiance tunnel level, 5 to 10 feet thick, and has been mined 670 feet down the dip from the surface to the 400-foot level. Other smaller bedded ore bodies have been mined in the deeper mine workings. Both the Red and Blue veins lie between two sills of granodiorite that are stratigraphically about 200 feet apart. Both sills pinch out in depth. The upper sill does not extend to the 110-foot level from the surface; the lower sill terminates between the 570-foot and 700-foot levels. The lower sill cannot be delimited on the surface as it merges with the main Darwin Hills stock at the level of the present erosion surface (fig. 2). The bedded ore in the Defiance workings is approximately coextensive in depth with the extent of the sills* (Hall and MacKevett, 1958, p. 27).

Below the 400-foot level the principal ore bodies change from concordant veins to an irregular, vertical replacement ore body that has been developed for 570 feet vertically to the 1,000-foot level. The ore is localized close to the Defiance fault but extends outward from the fault along closely spaced fractures for distances as much as 270 feet. On both the 800- and 900-foot levels about 25 percent of the calc-hornfels over an area 200 feet by 270 feet is replaced by ore (pI. 6). Insufficient exploration work has been done to delimit the ore on the 1,000-foot level (Hall and MacKevett, 1958, p. 27).

DRIVER PROSPECT

The Driver prospect is 1,000 feet S. 10° E. of the Defiance workings. The prospect is developed by several small open cuts, adits, and winzes. It is in dense white calc-hornfels 30 to 50 feet west of the contact with the stock of the Darwin Hills. Bedding in the calc-hornfels strikes northerly and dips 35° to 53° W. The Mickey Summers fault displaces the contact of the quartz monzonite and calc-hornfels 75 feet, the north side *moving west relative to the south side. A parallel fault cuts the calc-hornfels 230 feet south of the Mickey Summers fault.* (Hall and MacKevett, 1958, p. 27).

The calc-hornfels is highly iron stained parallel to bedding close to the N. 70° E. faults. A belt of white calc- hornfels 20 to 30 feet wide is highly iron stained 30 feet west of the stock of the Darwin Hills and north of the :Mickey Summers fault. Gossan 1 to 2 feet thick is locally distributed along a bedding--plane fault on the east side of the iron-stained zone. The calc-hornfels is similarly heavily iron stained for 50 feet north of the fault that is south of the Mickey Summers fault and parallel to it. It is not known if any ore was mined from the shallow workings. (Hall and MacKevett, 1958, p. 27).

ESSEX WORKINGS

The Essex workings are 230 feet southwest of the portal of the Independence workings and 820 feet northwest of the portal of the Thompson workings. The surface workings are in medium-grained calc-silicate rock 50 feet east of the Davis thrust. Bedding strikes northerly and dips 32° to 68° W. The calc-hornfels is cut by the Essex fault, which strikes N. 70° W. and dips vertically to very steeply south. The Essex fault is cut. off by the Davis thrust (Hall and MacKevett, 1958, p. 27).

Ore minerals are not conspicuous at the surface of the Essex workings. The Essex fault is iron stained over a width of 10 feet and contains jasper near the Essex shaft. The open cut and short adits 40 feet northeast of the shaft are on a branch of the Essex fault, and they expose only minor iron staining. The main ore body in the Essex workings does not crop out at the surface, but lies below the Davis thrust in the Essex fault zone and along steep ' north-striking fractures in calc-hornfels close to both the Essex fault and an intrusive contact (fig. 3). (Hall and MacKevett, 1958, p. 27).

Ore has been mined from the Essex fault from 50 feet below the surface to the 600-foot level, a vertical distance of 780 feet. The ore is localized in the fault in calcsilicate rock between the stock of the Darwin Hills and the Davis thrust. Between the surface and the 3B level the Davis thrust and the west contact of the stock are approximately parallel and are about 360 feet apart. Ore is discontinuous over this distance and has a maximum thickness of 30 feet. This is one of the few places in the mine where ore extends up to the Davis thrust (fig. 3). Below the 3B level the trend of the contact between the calc-silicate rock and the Darwin Hills stock dips vertically or steeply to the east. As the distance between the stock and the Davis thrust becomes progressively greater with depth, the amount of known ore is proportionately less. Ore along north-striking fractures is best developed on the 200- and 400-foot levels (see pI. 7, plan of 400-foot level). On the 200-foot level ore extends 175 feet north of the Essex fault, and on the 400-foot level it extends 400 feet north of Essex fault close to the intersection of a steep north-striking fault and a sill of quartz monzonite that dips 34° W. The ore is localized within 40 feet of the intrusive contact (Hall and MacKevett, 1958, p. 27).

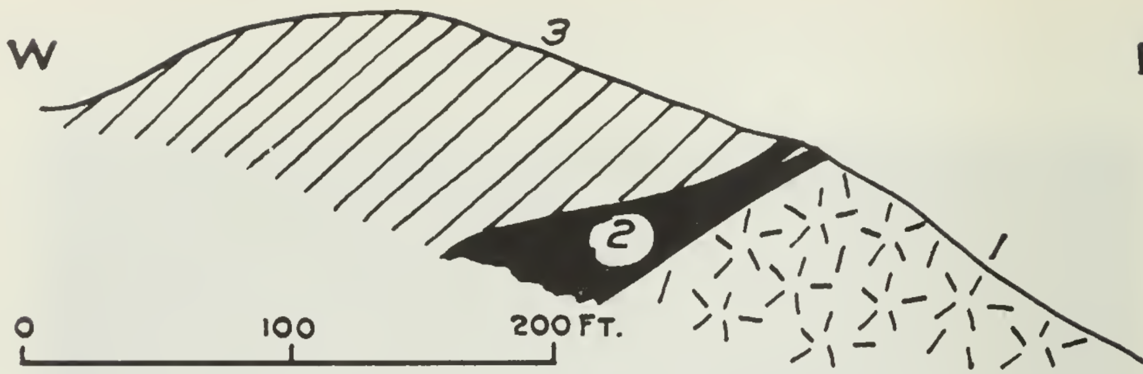


FIG. 28. Diagrammatic section through the Independence orebody. 1. Quartz diorite. 2. Orebody. 3. Stratified tactite.

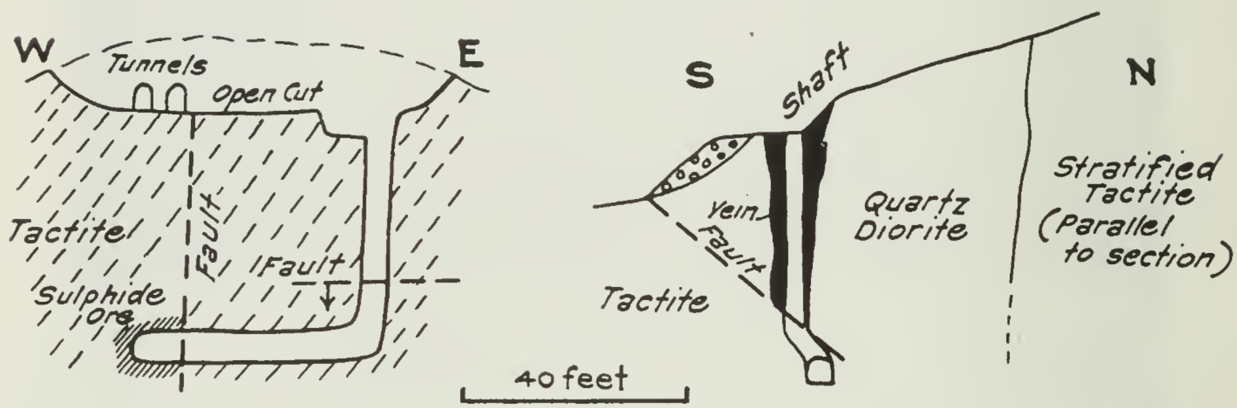


FIG. 29. Diagrammatic sections through the Essex orebody. Left, parallel to the vein. Right, across the vein.

Figure 22. From Kelley, 1938, p. 536.

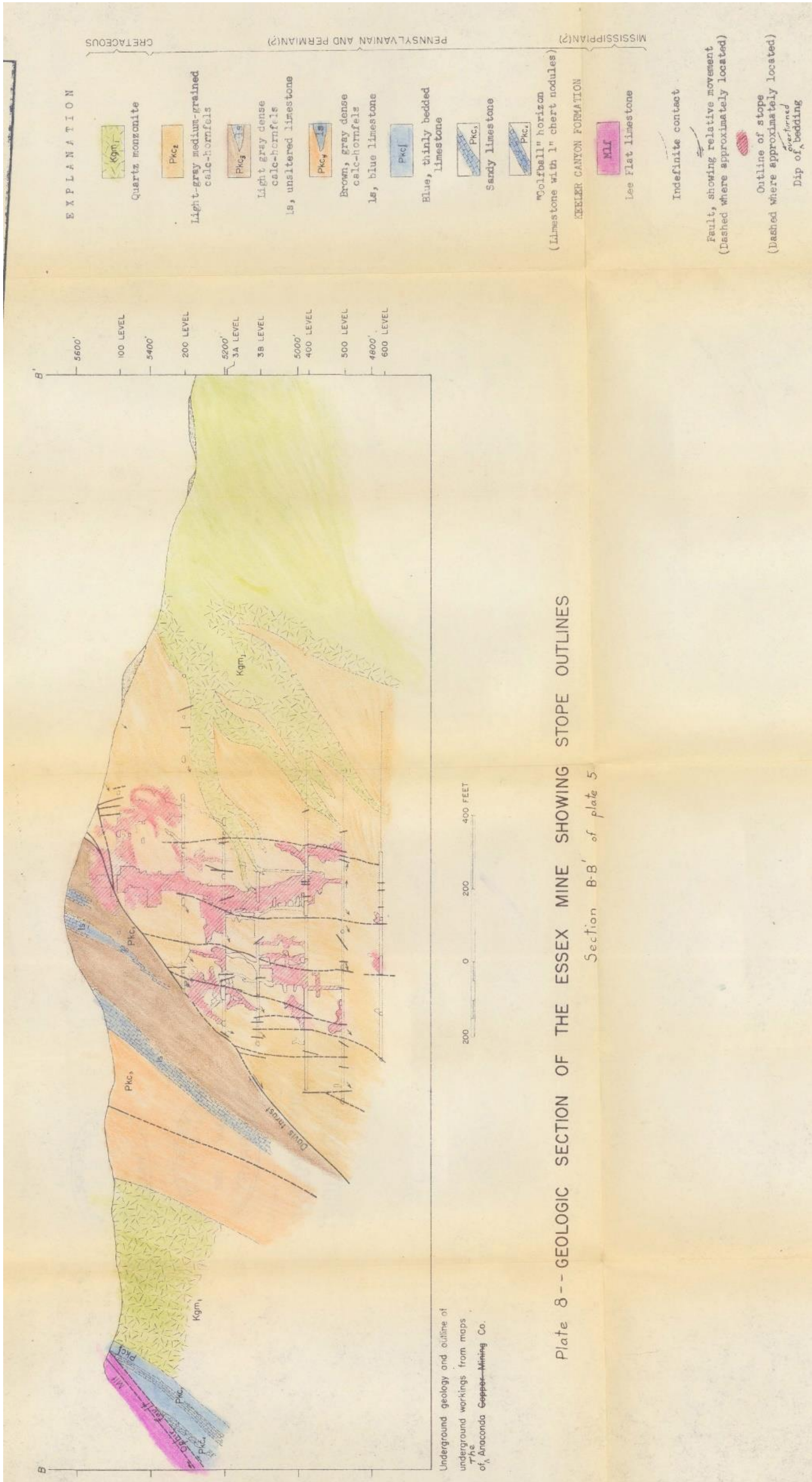


Figure 23. From Hall, 1958.

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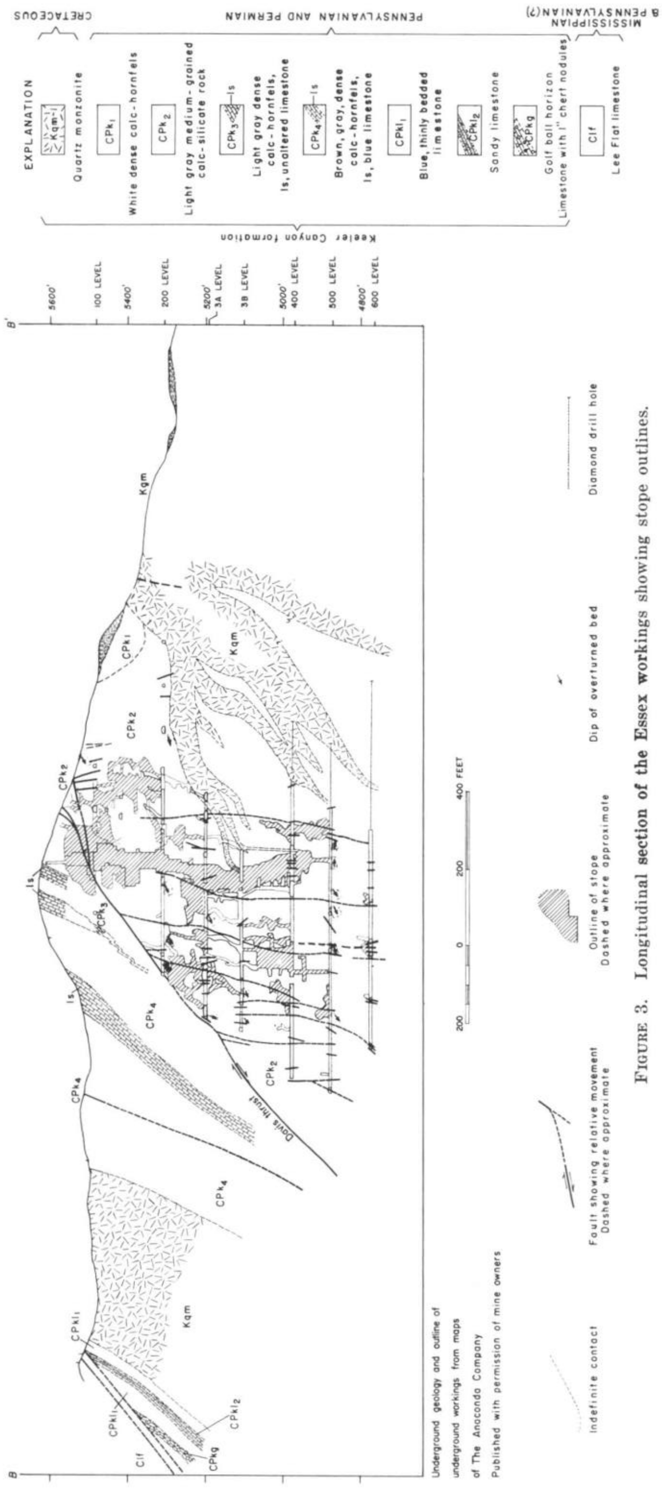

Figure 24. From Hall and MacKevett, 1958. p. 28.

INDEPENDENCE WORKINGS

The Independence workings are at the north end of the Darwin mine 850 feet N. 25° W. of the Thompson workings. Medium-grained calcsilicate rock is exposed at the surface in most of the area over a width of 130 feet from the stock of the Darwin Hills west to the Davis thrust. Fine-grained gabbro and diorite crop out southwest of the portal of the Independence adit around the base of the mine dump. North of the Independence workings the favorable calc-silicate rock is cut off by the Davis thrust, and an unfavorable overthrust block of dense greenish-gray calc-hornfels is in contact with the stock. Gossan is exposed at the surface in medium-grained calc-silicate rock along its contact with the stock. The contact strikes northerly and dips 43° to 72° W. A prospect pit 30 feet deep 60 feet north of the Independence adit exposes a highly iron stained zone 10 feet thick along a fault contact between the stock and calc-silicate rock. An open cut at the crest of the ridge 250 feet N. 25° E. of the Independence ad it exposes gossan about 20 feet thick that dips 43 ° W. along the calc-hornfels-intrusive contact. (Hall and MacKevett, 1958, p. 27).

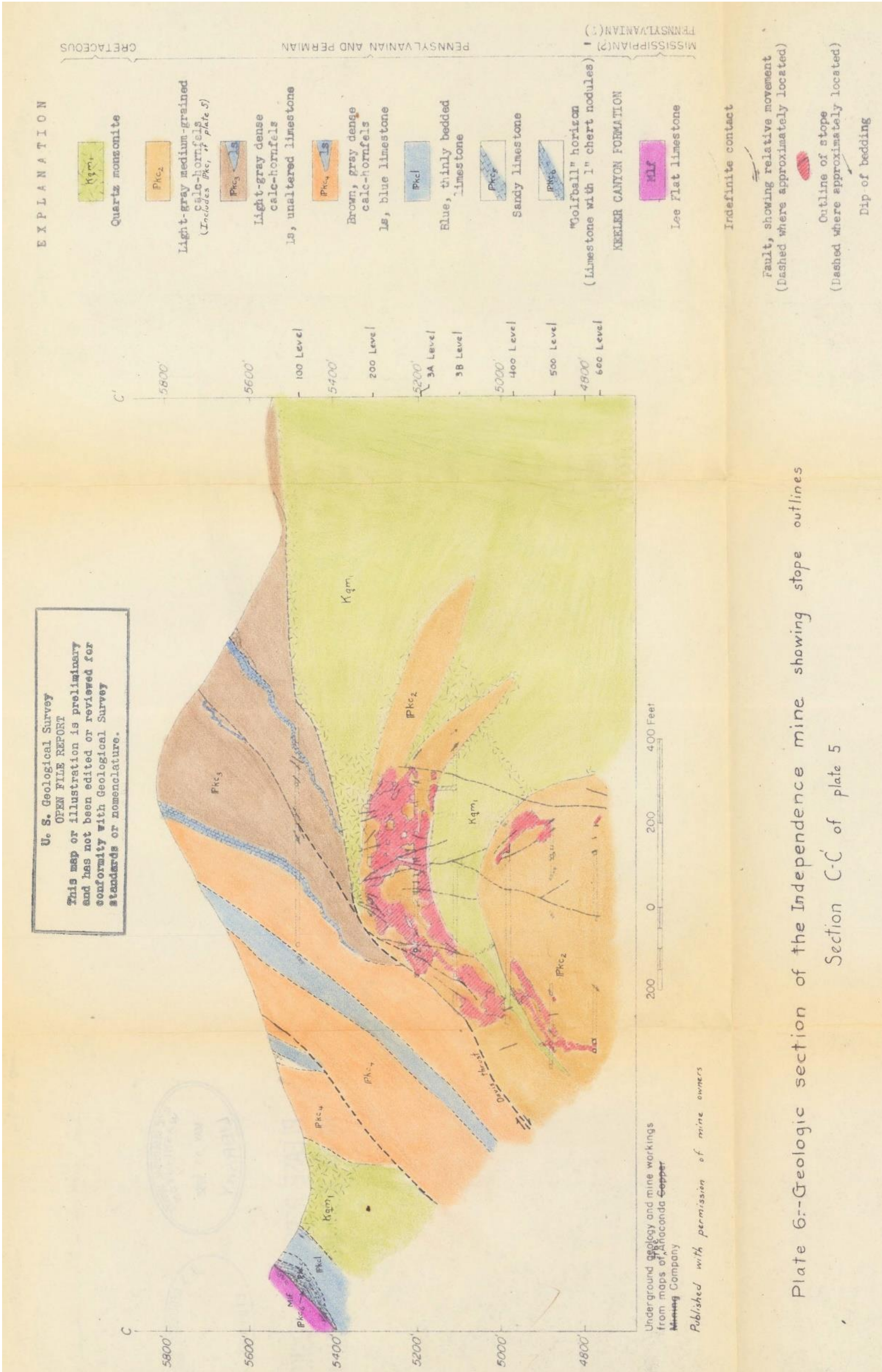

Figure 25. From Hall, 1958.

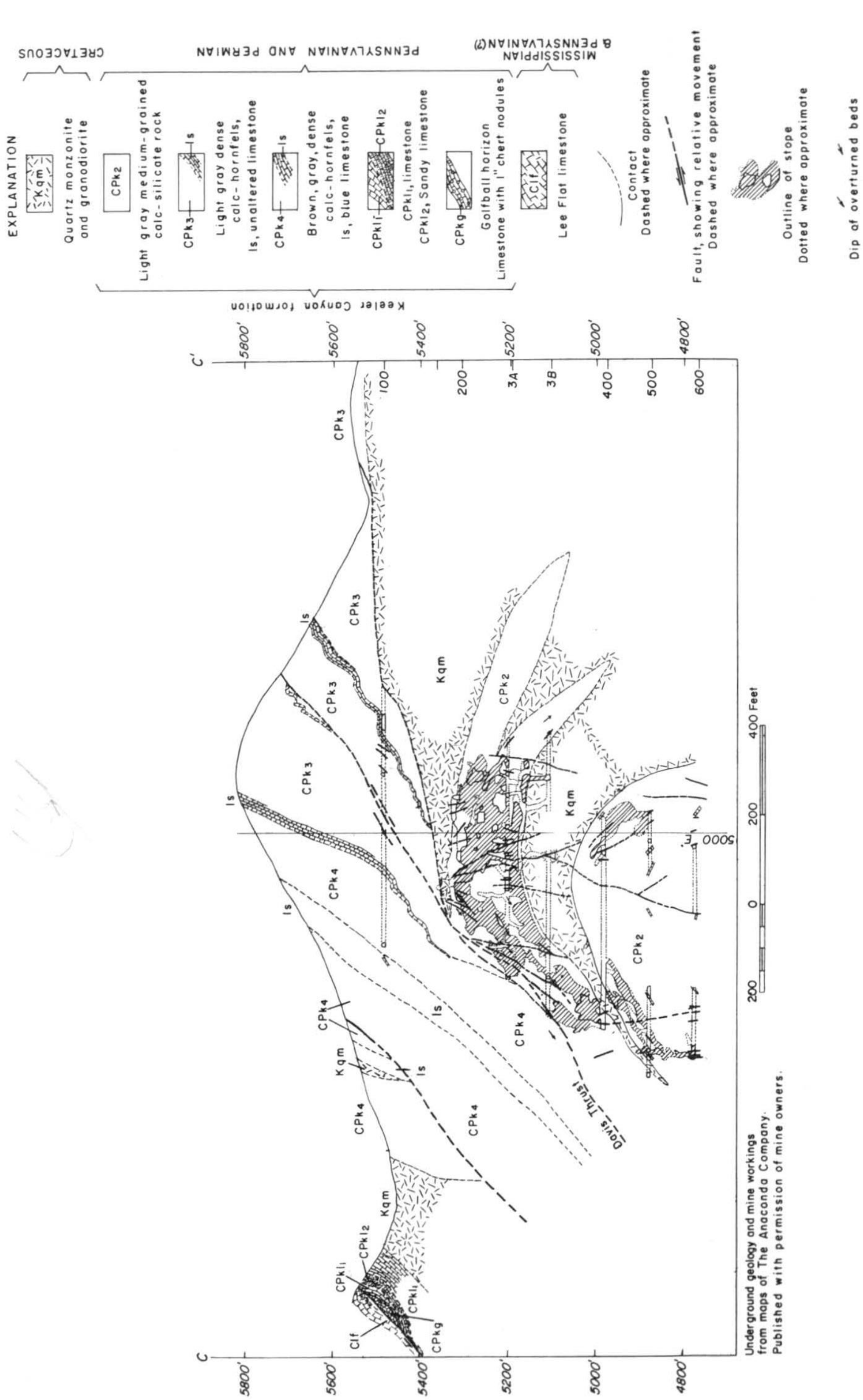

FIGURE 4. Geologic section of the Independence workings showing stope outlines.

Figure 26. From Hall and MacKevett, 1958, p. 29.

The underground workings show that the stock of the Darwin Hills terminates to the west in a series of sills that commonly are anticlinal shaped and pinch out in depth to the west (fig. 4). Ore above the 100-foot level is in medium-grained calc-silicate rock above the uppermost sill and below the Davis thrust. The Davis thrust terminates the favorable calc-hornfels in the workings on both the Independence and 100-foot levels. The ore is an irregular bedded replacement body that has a strike length of 250 feet and a width of 120 feet on the Independence level. Approximately 30 percent of the calcsilicate rock over this area is replaced by ore. The ore is stoped from the 100-foot level to the surface. A sill of quartz monzonite is between the 100- and 200-foot levels (Hall and MacKevett, 1958, p. 27).

The largest bedded ore body in the district is between the 200-foot and 3B levels over a lower anticlinal-shaped quartz monzonite sill (fig. 4). Bedded ore has been stoped discontinuously between the quartz monzonite sills, a vertical distance of 160 feet, along the crest of the anticlinal- shaped fold (an inverted syncline) for a maximum strike length of 500 feet on the 3B level. Ore has been mined westward down the dip above the upper contact of the lower sill for a distance of 700 feet to the 400-foot level (Hall and MacKevett, 1958, p. 27).

Smaller bedded ore bodies are below the lower sill between the 400-foot and 600-foot levels (fig. 4). All the known ore is within 100 feet of the lower contact of the sill. The ore body on the west limb of the inverted syncline is 200 feet long and as much as 50 feet thick; it has been mined 260 feet down the dip below the 400-foot level. A smaller bedded ore body was mined Oil the east limb of the inverted syncline from the 400 level to 40 feet below the 500 level (Hall and MacKevett, 1958, p. 27).

RIP VAN WINKLE WORKINGS

The Rip Van Winkle workings are on the west side of the Darwin Hills above the Darwin mine camp. They include the workings on the Water Tank fault, the Mickey Summers fault, and the workings 680 feet N. 40° E. of the portal of the Radiore adit (pI. 5) (Hall and MacKevett, 1958, p. 27)*.*

The shaft on the Water Tank fault 80 feet east of the water tanks is in calc-hornfels at the intersection of the Water Tank fault with the Davis thrust. The favorable medium-grain ed calc-silicate rock lies east of the Davis thrust and unfavorable dense, greenish-gray calc-hornfels is west of the thrust. An irregular plug of quartz monzonite crops out at the surface 300 feet northeast of the shaft. The Water Tank fault, which strikes N. 70° E. and dips 85° N., is highly iron stained at the surface. (Hall and MacKevett, 1958, p. 27).

The Radiore adit crosses the 'Water Tank fault in the favorable calc-silicate rock on the east side of the Davis thrust, and the fault is mineralized on this level alo'ng its strike for 360 feet (pI. 6) . (Hall and MacKevett, 1958, p. 27).

The Mickey Summers fault strikes N. 74° E. and dips 80° SE. A parallel mineralized fault 60 feet north of the Mickey Summers fault is developed by two shafts 220 feet *apart. Mineralization is continuous between the two shafts. Kelley (1938, p. 558) reports one of the vertical shafts to be 250 feet deep but inaccessible at the time of his fieldwork. He states the ore is highly pyritic but is reported to be unusually high in silver.* (Hall and MacKevett, 1958, p. 27).

The inclined shaft 680 feet N. 40° E. of the portal of the Radiore adit is on a vein 6 feet thick that strikes N. 20° W. and dips 54 ° SW. parallel to heiliIing. The vein. which can be traced for about 50 feet on the surface, is in dense white to light-gray calc-hornfels 70 feet east of a small outcrop of quartz monzonite. Only a small amount of ore minerals is exposed in the Radiore adit 218 f eet below the collar of the shaft (Hall and MacKevett, 1958, p. 27).

THOMPSON WORKINGS

The Thompson workings are 1,200 feet N. 25° W. of the Defiance workings near the western contact of the stock of the Darwin Hills. Quartz monzonite crops out at the portal of the Thompson adit, and it extends 370 feet N. 67° W. into the adit and 220 f eet on the surface west of the adit. "White medium grained calc-silicate rock is exposed west of the quartz monzonite and extends over an outcrop width of 300 feet to the Davis thrust. Bedding in the calc-silicate rock strikes north and dips 16° to 53° VV. The Copper fault, which strikes N. 60° E. and dips steeply to the north, is exposed near the portal of the Thompson adit. Two parallel faults cut the calc-silicate rock 300 and 360 feet north of the Copper Fault (Hall and MacKevett, 1958, p. 27).

The ore in the Thompson workings ae in medium grained calc-silicate rock in the same stratigraphic horizon as in the Independence and Bernon workings. Gossan 1 foot to 6 feet thick is exposed in a surface stope in calc-silicate rock at the contact with quartz monzonite 250 feet S. 75 ° W. of the Thompson portal and 40 feet north of the Copper fault. Most of the ore mined underground was north of the gossan that is exposed at the surface, and only minor mineralization is exposed on the 200-foot level 77 feet below the surface stope. The' ore underground is in faults striking N. 50°- 70° E. in calc-silicate rock close to intrusive contacts and also in fractures in calc-silicate rock closely parallel to intrusive contacts. The 234 and 229 north-east striking faults are mineralized discontinuously for distances as much as 400 feet from a minor sill or dike of quartz monzonite. Ore has been stoped along the 234 fault for as much as 190 feet along its strike. The thickness of ore ranges between 4 and 20 feet between the 200-foot and 3B leveIs, a vertical distance of 200 feet. Above the 200-foot level and below the 3B level the ore is in north-striking faults between the 234 and 229 faults. The 229 fault has been less productive than the 234 fault, and has yielded ore for 135 feet along strike with a thickness of 10 feet between the 200-foot and 3A levels. A nearly horizontal sill cuts out the ore at the 3B level, but the faults and a little ore continue beneath the si ll. In addition, a considerable tonnage of ore has been mined from bedded replacement bodies between the 229 and 234- faults. (Hall and MacKevett, 1958, p. 27).

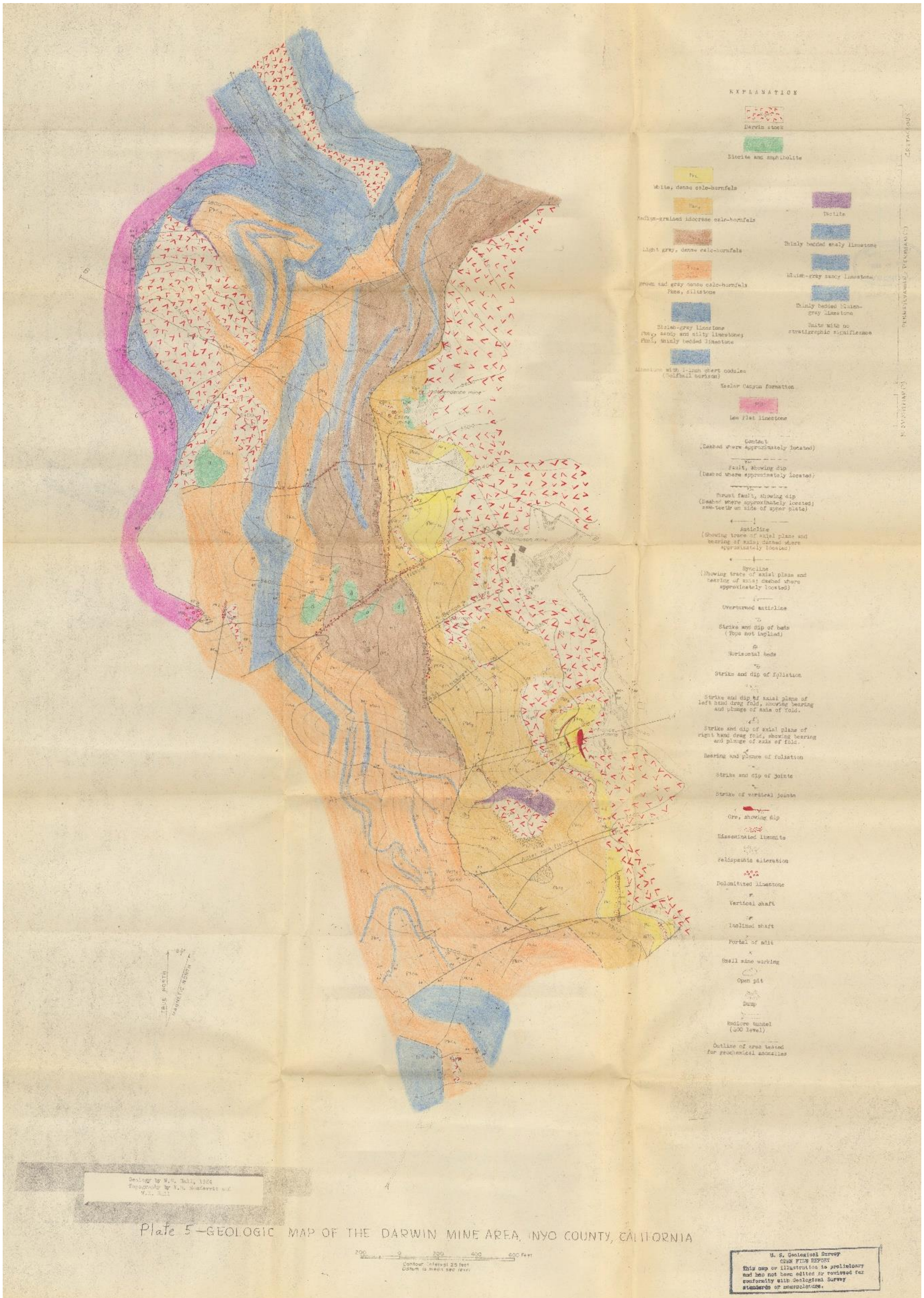

Figure 27. From Hall, 1958

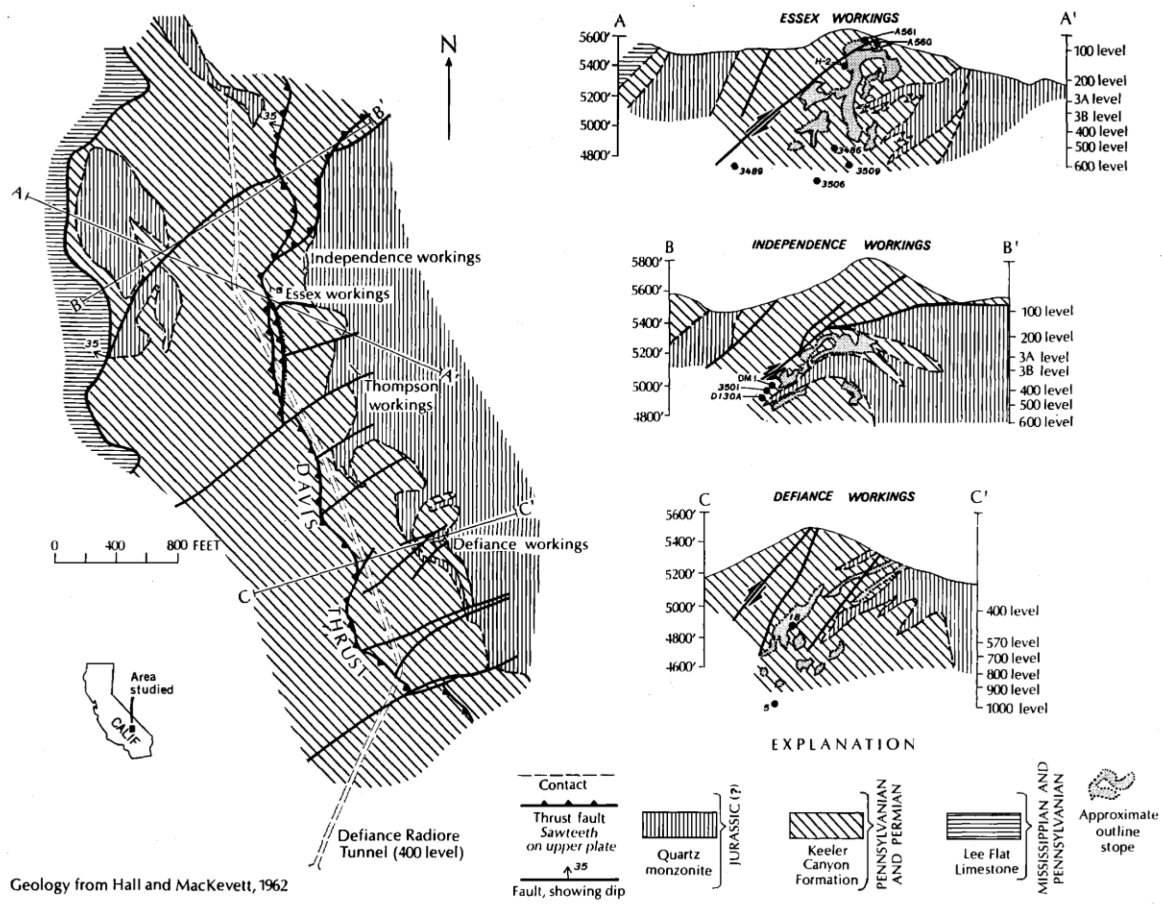

FIG. 1. Simplified geologic map and cross sections of the Darwin mine area showing sample localities.

Figure 28. From Czamanske and Hall, 1975, p.193.

1991

ESSEX PIPE

Pb-Zn-Ag ores of the Darwin deposit occur predominantly as bedded replacement and veins(Hall and MacKevett,1962;Eastman, 1980) in skarn calcsilicate hornfels and marble. There are, in addition, at least two major pipe-like orebodies: the Defiance and Essex pipes. The Essex pipe is an irregular body elongated to the northwest-southeast and plunging at about 70º to the southwest. Its shape is controlled by intersections of the N 65º W Essex fissure zone with receptive carbonate units near the hinge zone of the doubly plunging N 30º W trending Darwin anti-form (Figs. 3 and 4). Major bedded skarn zones also are present adjacent to the main pipe in marble beds immediately underlying sills of the Darwin pluton. This is especially the case in the upper levels of the mine (Newberry and others, 1991, p. 964).

In the Essex pipe area narrow skarn and/or sulfide veins are present in calc-silicate hornfels the bulk of skarn appears to replace marble. Unreplaced marble is locally *present between skarn and the Darwin stock (Fig. 5). Sulfides occur disseminated throughout the skarn* (Newberry and others, 1991, p. 964).

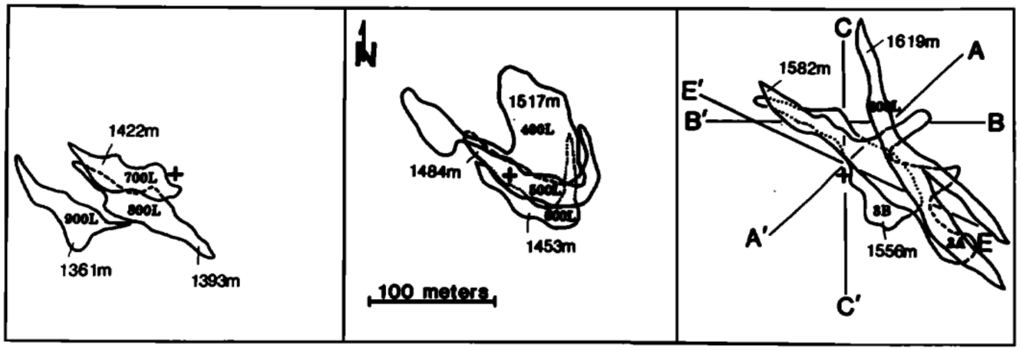

FIG. 3. Generalized outlines of skarn body in the Essex pipe area as a function of elevation. Variable skarn shapes are due to the intersections of the northwest-trending Essex zone with folded carbonate beds; larger skarn bodies are in the hinge region of the Darwin antiform. Most of the sulfide is in or immediately adjacent to the skarn. Based on underground mapping by R. Newberry and G. Wilson (unpub. map, 1982). Surface projections of cross-section lines are shown in Figure 2.

Figure 29. From Newberry and others, page 964.

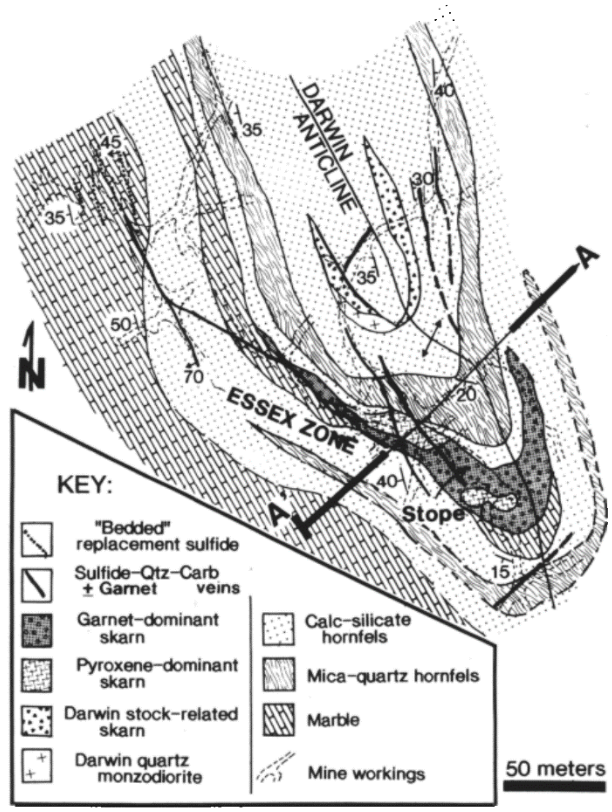

FIG. 4. Geologic map of the Essex pipe, 600 level, showing distribution of various skarn and ore types and relations to structure and lithology. Most of the skarn replaces marble; some pyroxene-rich skarn may replace calc-silicate hornfels. The bulk of the sulfides are restricted to the skarns. Mapping by R. Newberry and G. Wilson (unpub. map, 1982).

Figure 30. From Newberry and others, 1991, p. 964.

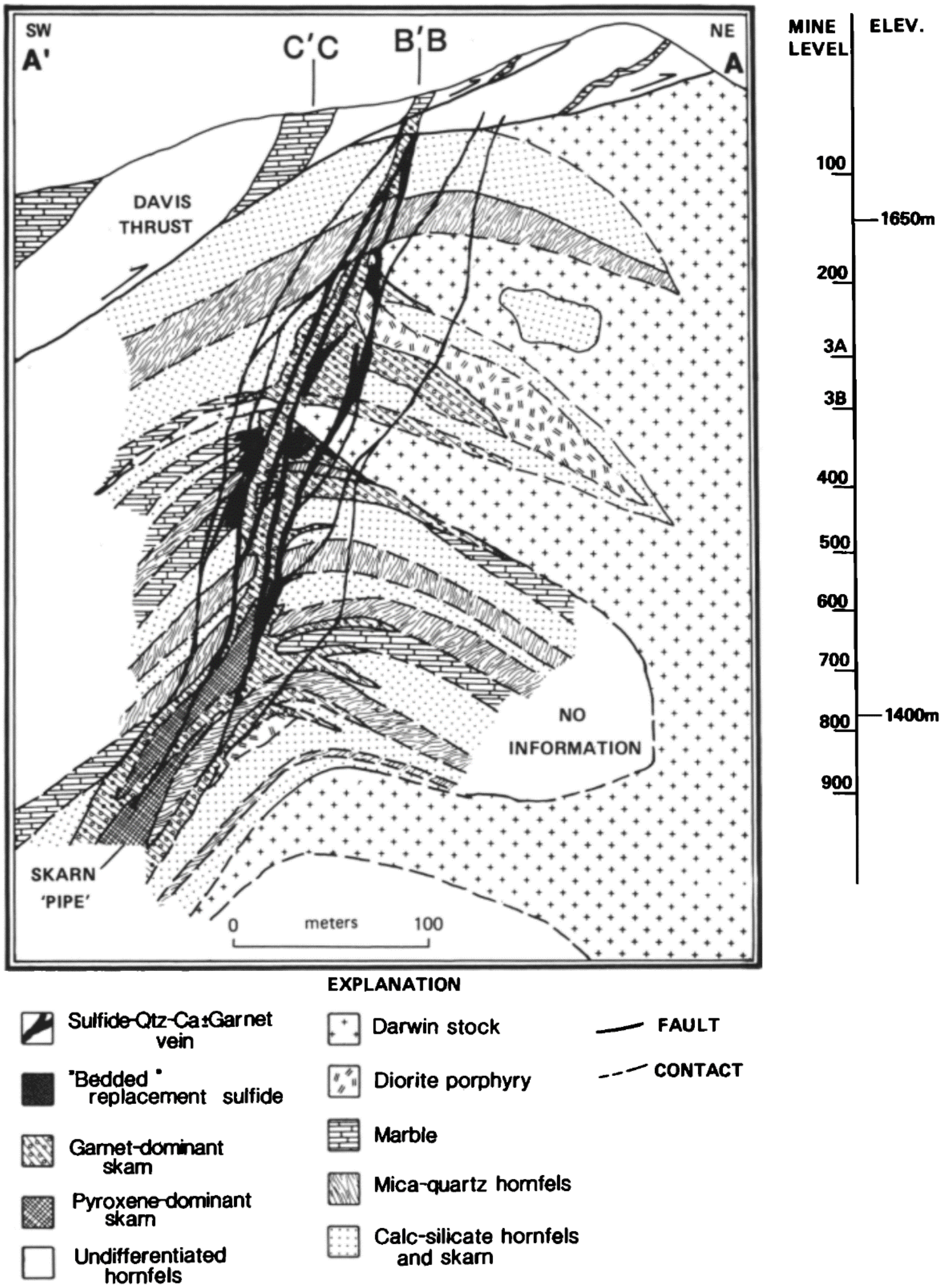

FIG. 5. Northeast-southwest cross section through the Essex pipe, at approximately right angles to the pipe elongation, showing pipe morphology and southwest rake to the pipe. Skarns dominantly replace marble, but narrow replacements of calc-silicate hornfels also are present. Massive sulfide replacements and veins are more abundant toward the surface; sulfide-bearing skarns are present throughout the vertical exposure. Based on underground mapping by R. Newberry and G. Wilson (unpub. map, 1982).

Figure 31, From Newberry and others, 1991, p. 965.

Lateral and vertical zoning in the Essex pipe is illustrated by a vertical (A;A) cross section (Fig. 5) constructed at approximately right angles to the northwest-southeast elongation of the pipe (Fig. 3). The Essex pipe contain subequal amounts of pyroxene and garnet-rich skarn at depth; pyroxene skarn is both cut and vertically supplanted by garnet-rich skarns. Coarse-graine vuggy, garnet-rich skarns are in metasomatic contact with marble in many localities and show no evidence of replacing pyroxene-rich skarn at the marble contact. Pyroxene skarn does not contact marble. Garnet skarns cut across and replace calc-silicate hornfels and skarnoid beds and form laterally extensive strata-bound replacement bodies in marble and hornfels adjacent to the pipe (Fig. 5). In many cases the light-colored, green granite garnet skarns could not easily be distinguished from the light colored, green idocrase garnet hornfels during underground mapping and AX core logging; most of these contacts probably are gradational. Rocks were classified with confidence as skarn during underground mapping and core logging if they contained coarse-grained (green) garnet +/- pyroxene with interstitial sulfides and/or obvious garnet veins (Newberry and others,1991, p. 965-966).

With increasing elevation, sulfide-rich, garnet bearing veins become common; however, coarse grained garnet skarn with interstitial galena is present throughout the vertical exposures of the pipe (e.g., as the surface expression of the Essex pipe; Fig. 2). Sulfides mostly occur as disseminations is the skarn below the 500 level. Sulfide-rich veins commonly contain a few to 20 percent fine- to medium-grained euhedral garnet and are surrounded by an envelope of garnet idocrase skarn where they cut hornfels or marble (Eastman, 1980). Relations between these sulfide-rich veins and normal, sulfide-bearing skarn are problematic; the veins cut skarn but contain euhedral skarn minerals and are grossly transitional (with depth) to garnet-rich skarn (Fig. 5). We interpret these veins as representing a stage of hydrothermal activity which postdates the bulk of normal skarn formation but under conditions where garnet and idocrase continued to form. A few massive quartz-carbonate- sulfide +/- garnet bodies are present as replacements of marble adjacent to sulfide-rich veins (Fig. 5); cross cutting relations indicate that these bodies were formed after the skarns, possibly contemporaneously with the sulfide-rich veins. Although sulfides, especially galena, commonly enclose or fill vugs and fractures in skarn minerals unaltered garnet is present adjacent to sulfide throughout the pipe (Newberry and others,1991, p. 966).

Very late veins (generally <0.3 m wide), with extremely coarse-grained calcite and pyrite and with sporadic native gold and tellurides, are especially common along lithologic contacts and faults. These veins were generally not mined and are not shown in the maps and cross sections. Where the late quartz calcite veins cut skarn, they are surrounded by poorly defined 0.1- to 1-m-wide envelopes of calcite-quartz-hematite alteration of the skarn (Newberry and others,1991, p. 966).

DEFIANCE PIPE

The Defiance pipe is a steeply dipping body located 700 m southeast of the Essex pipe (Fig. 2). This part of the Darwin deposit is currently accessible only at the 400 and 570 levels, and consequently it was less well studied. On the 400 level it contains quartz, carbonate, bustamite, garnet, and retrograded pyroxene with massive to disseminated *sulfides. Limited logging of AX drill core indicates that garnet-pyroxene skarns are present at deeper levels. Drill core also shows that a small body or bodies of granite porphyry (with quartz-K feldspar veinlets), porphyry matrix breccia, and skarn matrix breccia (which contains galena and sphalerite) occurs below the 1000 level. The granite porphyry and porphyry matrix breccia are surrounded by galena-sphalerite-bearing sk arn. Above the 400 level the pipe horsetails into several quartz-carbonate sulfide +/- garnet veins which lie along the bedding of, and partly replace, garnet skarn (Hall and MacKevett,1962; Fig. 2)* (Newberry and others,1991, p. 966).

Reconnaissance logging and examination of 10,000 m of AX drill core and logging of 1,000 m of BX drill core suggests that underground and surface exposures of ore accessible in 1980-1982 are representative of the ore mined and sampled before 1970. If this is the case, then some generalizations can be made about the relative amounts of the various ore types present. In the Essex area, the bulk of ore (75%) below the 200-level consisted of sulfides in skarn, with intergrown sulfide-garnet-pyroxene textures more common than obvious sulfide veins. Above the 200 level, sulfide-bearing skarns and sulfide-rich (+/- garnet) veins are subequal in abundance. The Defiance pipe is dominated by sulfides disseminated in skarn below the 570 level, with highly retrograded skarn, sulfide-replaced marble and sulfide-rich veins more common than simple sulfide-bearing skarn above the 400 level (Newberry and others,1991, p. 966).

2011

ORE DEPOSITS

While mines in the Darwin region have produced lead, silver, zinc, talc, tungsten, antimony, copper, gold, limestone, and dolomite, the most important deposits are the lead-silver-zinc deposits that occur along a mineralized belt extending from the Cerro Gordo District southeast to the Tecopa District. Lead-silver-zinc deposits are widely distributed throughout the northern part of this trend. The most productive mines were in the Darwin Hills but smaller deposits have been mined in the Talc City Hills, Zinc Hill, in the Lee District in the Santa Rosa Hills, and at the Santa Rosa Mine in the Inyo Range. Staring in 1941, tungsten was also produced from ore bodies on the east side of the Darwin Hills. Many of the lead-silver-zinc deposits occur in Pennsylvanian-Permian age limestone host rocks which have been folded and faulted about northerly axes and that have been altered to calc-hornfels and tactites by contact metamorphism and metasomatism peripheral to intrusive igneous bodies. These bodies include a biotite-hornblend quartz monzonite stock in the Darwin District and leucocratic quartz monzonite stocks in the Talc City Hills and at the Zinc Hill Mine. Calc-hornfels were generally formed by recrystallization of impure limestones while tactites resulted from contact metamorphism of the purer limestones. While no particular formations are exclusive to lead-silver-zinc deposits, lithology is an important aspect of ore localization. Limestone beds are more conducive to lead-silver-zinc deposits whereas dolomite and quartzite units are unfavorable. In general, the ores are almost always in altered limestone and marble. In the Talc City Hills, for instance, dolomites and quartzite contain only talc, while only the limy parts of the formation contain lead-silver-zinc deposits. This association also holds true in the Cerro Gordo District to the north (Hall *and MacKevett, 1958). Further, certain beds within a particular formation are more conducive to lead-silver-zinc ore deposits that others. In the Darwin District, for instance, a medium grained wollastonite-garnet-idocrase calc-hornfels formed from a fairly pure limestone is highly mineralized while dense, greenish gray calc-hornfels formed from silty limestone is not. Similarly, at the Zinc Hill Mine, all ore bodies are in one favorable marble bed, while other limestone beds are only slightly mineralized (Hall and MacKevett, 1958). Mineralization is contact metamorphic and metasomatic ranging to mesothermal (Hall and MacKevett, 1962). Individual ore bodies occur in silicified carbonate rocks along the periphery of plutonic rocks as (1) bedded replacements localized near the axes of folds, (2) irregular vertical pipe-like replacement bodies associated with the intersection of faults and fractures, and (3) replacement and filling deposits along faults and fractures. Fault control is apparent for nearly all deposits, although it is only one of several controls in localizing ore (Hall and MacKevett, 1958). Primary ore controls also include proximity to silicic to intermediate plutonic rocks, stratigraphic controls in certain carbonate formations, and association with steeply dipping faults and fractures that served as feeder channels for the ore solutions. Generally fractures are progressively less mineralized away from the faults* (USGS, 2011)*.*

The largest deposits are in the Darwin Hills deposits within in calc-hornfels host rocks of the lower member of the Keeler Canyon Formation. A few smaller deposits in the Talc City Hills also occur within sheared limestone of the Keeler Canyon Formation. Farther north, in the Santa Rosa District of the southern Inyo Mountains, lead-silver-zinc ores are found in calc-hornfels in the Permian Owens Valley Formation. In the Zinc Hill District in the Argus Range replacement ore bodies occur along faults in Mississippian marble. In the Cerro Gordo and Lee districts, replacement ore bodies occur along faults and along bedding planes in the Devonian Lost Burro Formation marbles (Hall and MacKevett, 1962). Ore Minerals The primary hypogene ore minerals in the lead-silver-zinc deposits are argentiferous galena (chief lead and silver ore mineral) and sphalerite (zinc ore mineral). Silver is produced as a byproduct of argentiferous galena. Lesser ore minerals are enargite, tetrahedrite, pyrite, pyrrhotite, and chalcopyrite. Minor to very minor occurrences of scheelite, andorite, franckeite, stannite, matildite, bornite, chalcocite, covellite and bismuth are present. Sphalerite is the primary hypogene zinc mineral at the Zinc Hill Mine. Pyrite is abundant in most of the lead-silver-zinc deposits with the exception of the Lee Mine. Scheelite is the primary tungsten ore mineral in the ore bodies on the east side of the Darwin Hills. Gangue minerals include calcite, fluorite, and garnet with lesser amounts of barite, clay minerals, diopside, idocrase, orthoclase, quartz, jasper, and wollastonite (Hall and MacKevett, 1958). Calcite and fluorite are directly associated with ore minerals whereas garnet, idocrase, diopside, and wollastonite are considered to have been formed by silicification and recrystallization of the limestone before the period of mineralization. In many cases these minerals can be seen replaced by ore minerals. Metallogeny Given the clear association of the known lead-silver-zinc deposits in California's Basin and Range province with granitic intrusives, altered carbonate rocks, and fracture systems, future ore body discoveries would be expected to be within close proximity to the known bathloliths or associated stocks. However, while the developed deposits were originally located by virtue of their *rich oxidized surface ores, future deposits would be expected to be more obscure requiring an exploration program involving detailed regional geologic studies and employing all available geological, geochemical, and geophysical tools to define areas exhibiting promising geological and structural histories* (USGS, 2011).

ORE GENESIS

Overview

Early interpretations (Knopf, 1917) of the Darwin ores proposed that they were contact metamorphic deposits. Kelley (1938) does not use the word "skarn". He recognized an early alteration event of the carbonates in contact with the Darwin Stock. He attributed the base metal mineralization to later hydrothermal events. His insight was proved correct 40 years later. Early contact metamorphism by the Darwin Stock created zoned calc-alkaline rock assemblages. Twenty million years later, mineralizing fluids took advantage of this ground preparation and preferentially replaced beds within the Paleozoic limestone formations that had undergone the earlier calk-alkaline alteration, or produced hydrothermal fissure vein deposits. The origin of those fluids was a deeper granitic plug (Czamanske and Hall, 1975, p. 1992). There are several generations of ore genesis at Darwin. Some are skarns, others are bedded replacements, others are veins. Age relationships between these remain unclear in many of the ore deposits.

1917

Genetically classified, the ore deposits range from the contact metamorphic type to fissure fillings of hydrothermal origin at moderate temperatures (Knopf, 1917, p. 7).

The contact-metamorphic type is represented most clearly by the ore body at the Independence mine. The primary lead ore here consists of galena associated with andradite [garnet], and the deposit is situated at the contact of quartz diorite and lime-silicate rocks. Some dark gray limestone appears a few hundred feet from the deposit, and it is probable that the ore body is a replacement of a limestone bed that escaped alteration to lime-silicate rock. It is noteworthy that -the garnet associated with ore deposits is the lime-iron variety andradite, whereas that in the lime-silicate rocks produced by the general metamorphism that affected the district is the lime-aluminum variety grossularite (Knopf, 1917, p. 7).

The ore body at the Custer mine is probably also of contact metamorphic origin. The deposit occurs in the broken arch of an anticline, along which the brecciated strata have been recemented by calcite and garnet. The extraordinary coarsely crystalline development of the calcite, cleavage individuals ranging from 12 to 18 inches in diameter being not uncommon, makes this deposit unique in the district. Fluorite is abundantly associated with the galena. Microscopic examination of some veinlets traversing lime-silicate rock, which occurs as an inclusion in the calc-spar on the 300-foot level, shows that they consist of wollastonite, andradite, calcite, and sphalerite. (Knopf, 1917, p. 7).

A transitional type of ore deposit, intermediate between the kind commonly termed contact-metamorphic and fissure veins, is represented at the Defiance mine. The ore occurs as a replacement of a limestone bed underlain by quartz-augite diorite, as illustrated in figure 3 (p. 13). The primary ore as seen in hand specimens consists of galena, pyrite, and sphalerite embedded in a gangue apparently composed wholly of calcite and fluorite. The microscope reveals in addition considerable orthoclase, commonly in euhedral forms. Apatite in characteristic hexagonal cross sections and in stout prisms is inclosed in the feldspar and more rarely in the calcite, where it may even develop in relatively large irregular aggregates. As orthoclase is an uncommon constituent of ores of this kind, its presence was corroborated chemically. Its optical properties show that it is not the adularia variety* (Knopf, 1917, p. 7).

The quartz diorite forming the footwall of the deposit has obviously been pyritized, and examination under the microscope shows further that the augite has been uralitized and the feldspar partly sericitized. It follows, then, that the solutions which brought in the ore minerals caused the formation of orthoclase in the limestone and sericite in the adjacent igneous rock (Knopf, 1917, p. 7).

Fissure veins constitute the most numerous type of ore deposit in the district. They differ very considerably from those in most lead-producing districts in that the country rock traversed by the fissures is lime-silicate rock. They differ notably, for example, from those of the Cerro Gordo district, nearby, where the galena generally occurs as a replacement of a pure calcitic marble. The walls of the fissures are clean-cut, and the filling along barren stretches consists of large masses or breccias of lime-silicate rock. The ore consists of practically solid masses of galena and its oxidation products; the gangue as a rule contains only small quantities of fluorite (Knopf, 1917, p. 7).

In addition to the various kinds of mineralization described in the foregoing paragraphs, one other was noted, which, although it produced no deposit of commercial importance, is briefly described for the sake of completeness. On the trail half a mile north of the Defiance mine there is a broad zone of fracturing and brecciation in the quartz diorite. Along this zone the quartz diorite has been much formalinized, so that the rock is largely replaced by aggregates composed of small radial groups of tourmaline. In places it has also been impregnated with pyrite crystals, now largely converted to limonite (Knopf, 1917, p. 7).

The ore bodies, ranging from contact-metamorphic deposits to fissure veins, are inclosed in lime-silicate strata of late Carboniferous age. The metamorphism of originally calcareous and magnesian beds to wollastonite, diopside, and grossularite rocks is a result of the invasion of the region by quartz diorite, probably in Cretaceous time. Somewhat later than this general metamorphism came the introduction of the ore, and the evidence seems strong that the metallic constituents were given off from deep-seated portions of the same magma from which the quartz diorite now seen at the surface crystallized. The enclosure of the ore bodies in lime-silicate strata is the distinguishing feature of the Darwin district (Knopf, 1917, p. 7).

The ores consist of argentiferous galena, with minor pyrite and sphalerite, and are associated in most of the deposits with a gangue of calcite and fluorite. As a rule the galena is largely oxidized to lead carbonate and sulphate. There is, however, no evidence of important migration and secondary concentration of silver, lead, or zinc through the action of oxidizing solutions; indeed, such concentration appears unlikely, from the prevalence of calcite in the deposits (Knopf, 1917, p. 7).

1938

The position of the Darwin silver-lead deposits is clearly controlled by the form and extent of the stock. The stock was guided in its emplacement by the structure of the strata of Pennsylvanian age Advancing with and ahead of the igneous material were emanations which carried great quantities of silica and lesser quantities of other metals, chief among which was iron. Heat energy which promoted recrystallization and metasomatism was carried largely by the magmatic emanations. The effect of conducted or diffused heat was distinctly subordinate to that of conveyed heat. The heat and chemical action of the pervading emanations caused great quantities of carbon dioxide to be liberated and driven off. Simultaneously with the liberation of carbon dioxide, silica and other metals were added, thus preventing any appreciable volume reduction and consequent obliteration of bedding structure (Kelley, 1938, p. 548-549).

The stock was intruded into rocks already considerably silicated and thoroughly heated. This is evidenced by the absence of chilling on the margins of the stock or the small dikes in the tactite, and by the lack of any detailed relationship of silicate aureoles to these offshoots of the stock. That a lesser amount of silicate replacement accompanied or followed the intrusion is shown by garnet zones marginal to the stock or replacing it (Kelley, 1938, p. 549).

The development of the tactite aureole and the final consolidation of the intrusive was followed by a period of fracturing. Many of the fissures of the resulting fracture system are rather persistent and continue through the stock and the wide silicate aureole alike. Displacements, which offset the igneous contacts occurred along some of the fissures prior to their mineralization. (Kelley, 1938, p. 549).

All of the hypogene lead mineralization and deposition of ore in general occurred after this period of major fracturing. Some dislocations actually post-date the period of metallization and have brecciated or offset the orebodies. This period of fracturing distinctly separates the period of silication, in which the tactites developed, from the period of metallization in which all of the ore of the district was formed. The silication developed under high temperatures in advance of and attendant upon the intrusion. The ore deposition developed under low temperature, hydrothermal conditions (Kelley, 1938, p. 549).

Knopf thought the deposits indicated a " sequence in time" with decreasing temperature as "The fissure veins are regarded as representing the low temperature end of a genetically related series of deposits formed at progressively decreasing temperatures," *Knopf, (p. 9, 1914) and "the galena ore of the Darwin district began to be deposited under pyrometasomatic conditions, but its maximum deposition occurred at a lower temperature,' Knopf, (p. 533, 1933) and further, in comparison, "the Coeur d'Alene district represents a sequence in time.' Knopf, (p. 10, 1914)*(Kelley, 1938, p. 549).

A temperature gradient existed away from the intrusive, but this only effected a crude zoning of grain size and to a lesser extent of mineralization. If decreasing temperature determined the place of deposition it is more likely that deposition would first take place at a distance from the intrusive in fissures and bedding planes, and later, as the temperature fell, at the contact; but there is no indication of long continued deposition of ore with falling temperatures, and temperature was apparently not the controlling factor in the relative time or position of the deposits. The simplicity of the ore and paragenesis does not warrant a long-continued deposition, and there is little or no overlapping of mineralization. Instead, the controlling factors were (1) a deep-seated supply of differentiated metals and their associated gangue substances following consolidation of the intrusive and fracturing of the rocks, and (2) the effective opening of fissures, stratification, and contacts to the ore-bearing solutions. The ore deposition was all accomplished during a single short period under nearly constant temperature conditions following fracturing. The only division or classification to be made is one of structural control as already described (Kelley, 1938, p. 549-550).

Knopf (1933) has chosen Darwin as an example of a pyrometasomatic lead deposit. As evidence of a connection between pyrometasomatic deposits and fissure veins Knopf (1914) cited the Independence orebody as an example of the contact pyrometasomatic type of deposit, and the Defiance orebody as intermediate or transitional link between the contact type and the fissure veins of the district. This conclusion was based on finding apatite in orthoclase associated with primary sulphides at the Defiance mine and andradite garnet with galena at the Independence (Kelley, 1938, p. 549-550).

The deposits occur near each other along the same intrusive contact, and on the whole the mineralization is much the same except that in the Defiance orebody exceedingly coarse calcite is more abundant. Galena and other sulphides have impregnated the tactite walls to some extent in both deposits, but such close association does not necessarily indicate that the sulphides formed under the high temperature and pressure conditions that the garnet or orthoclase did. In fact, there is little in either deposit which can be used to set them apart, or to set either apart genetically from the fissure veins, especially as regards time, sequence, and substances available through ore-forming solutions. In a sense, it is better to view them all as fissure deposits. During metalization some fissures were effectively opened along contacts and bedding planes, and others along transverse fractures. (Kelley, 1938, p. 549-550).

The deposits along contacts and in fissures are similar mineralogically and structurally. There is little necessity for demonstrating a transition, for they are genetically identical. The fissures have the regularity of strike and dip of mesothermal deposits. The walls are smooth and well-defined. Furthermore, the regularity and sharp definition of the contact deposits compares with that of the fissures. The mineralization directly associated with *the deposits is not on the whole of the pryometasomatic type. Jasper, which is one of the most common gangue minerals in the deposits, is indicative of formation at temperatures attributed to mesothermal deposits. Both fluorite and barite are common minerals in low temperature deposits. During the existence of the pyrometasomatic environment about the stock, the characteristic minerals developed were garnet, orthoclase, quartz, specularite, and scheelite ; but this mineralization was not great. The lead mineralization developed at a later stage in association with fluorite, calcite, barite, and jasper in a mesothermal environment. There is no pyrometasomatic galena. Both fluorite and barite are common in mesothermal or epithermal deposits (Lindgren, 1933) Initial pressures and temperatures may have been such that a hypothermal stage was not represented.* (Kelley, 1938, p. 549-550).

Umpleby (1916) from findings at Mackay, Idaho, and from study of numerous other districts, has formulated the generalization that ore about intrusive bodies tends to form on the limestone side of garnet zones. It was his observation that where ore came directly against the igneous contact practically no barren lime silicate would extend beyond the ore. Darwin appears to be an exception to this, for the silicate rocks in most cases extend far out beyond orebodies at contacts. Of the two contacts, silicate-igneous and silicate-limestone, the latter would in all probability be more easily penetrated by ore solutions. Where the silicate zone is wide, stratification well preserved, and fissures common, the rule formulated by Umpleby would be less applicable because of the preponderance of structural control (Kelley, 1938, p. 549-550).

1975

Because exsolved mineral phases persist in samples annealed at 350^{o}C, ore deposition at Darwin is presumed to have occurred at higher temperatures (Czamske and Hall, 1975).

1991

The > 1-million-metric-ton Darwin Pb-Zn-Ag-W skarn deposit has been previously described as a group of sulfide replacement bodies zoned away from the Darwin quartz monzonite pluton and formed from magmatic fluids at 325^{o}C. Detailed surface mapping and available radiometric data, however, indicate that the Pb-Zn skarn sulfide bodies are appreciably (>20 Ma) younger than the Darwin pluton, and underground mapping and core logging indicate there are several skarn sulfide pipes with strong concentric zoning. One of the pipes is zoned around a deep granite porphyry plug. The pipes exhibit outward zoning in wt percent Pb/Zn and oz/ton Ag/wt percent Pb (both ratios 1.0 margin). The pipes show mineralogical zoning, with a core defined by higher sphalerite-galena, higher chalcopyrite, darker sphalerite, more abundant pyrite inclusions in sphalerite, and evidence for multiple sulfide depositional events. In contrast, both graphite in marble and pyrrhotite in sulfide ores are zoned around the Darwin pluton, which suggests that pyrrhotite stability is influenced by pre-Pb-Zn skarn (Darwin pluton related?) bleaching of marble beds. Garnet zoning is highly complex, with four generations identified by petrographic and compositional relations; younger garnet types are more abundant in upper and lateral parts of the pipe. Retrograde alteration of garnet is concentrated in the upper and laterally distal parts of the skarn, but garnet in apparent equilibrium with sulfide is present throughout the vertical extent of skarn. Systematic mineral compositional patterns include outward increase in hedenbergite + johannsenite components in clinopyroxene (20 outward), increase in Sb -I- Bi contents of galena, initial increase followed by decrease in Mn contents of sphalerite (range *from 1% Mn), and an initial increase followed by outward variable increase and decrease in FeS contents of sphalerite (range of 20% FeS). Previously published sulfur isotope data are compatible with a decrease in sulfur isotope ratios outward around the pipe core. Published isotopic data combined with temperature estimates from phase homogenization and arsenopyrite-sphalerite geothermometry show a systematic decrease in temperature from the skarn sulfide pipe center (>425^{o}C) to the margin* (Newberry and others, 1991, p. 960).

Comparison of stope maps to isotherm cross sections indicates that the bulk of mined sulfides were from areas surrounding the pipe core, in which temperatures declined f rom approximately 375º to 300ºC (gradient of 1ºC/m). Combined mineral composition and assemblage and sulfur isotope systematics indicate that the ore fluids flowed outward they underwent progressive decrease in oxidation state (about 1 log unit) and increase in pH (2-3 units); upward moving fluids underwent initial decrease in oxidation state and increase in pH followed by a reversal to higher oxidation state and lower pH. The process of ore deposition was chemically complex and may have involved remobilization of earlier deposited sulfides. Realistic ore depositional models at Darwin require simultaneous changes in (at least) temperature, pH, and oxidation state (Newberry and others, 1991, p. 960

The Darwin Essex and Defiance pipes show mineralogical zoning. This zonation can be explained by multiple phases of skarn formation the followed by or coincident with hydrothermal mineralization. There is progressive reduction of ore fluids by reaction with organic matter in distal carbonate rocks:

> *The spatial coincidence of unbleached marble (Fig. 12H), graphite in skarn and pyrrhotite-bearing Ores (Fig.1 2E) suggests that progressive reduction of the ore fluid by reaction with organic matter in the distal carbonate rocks controlled the deposition of pyrrhotite and graphite in skarn* (Newberry and others,1991, p. 966).

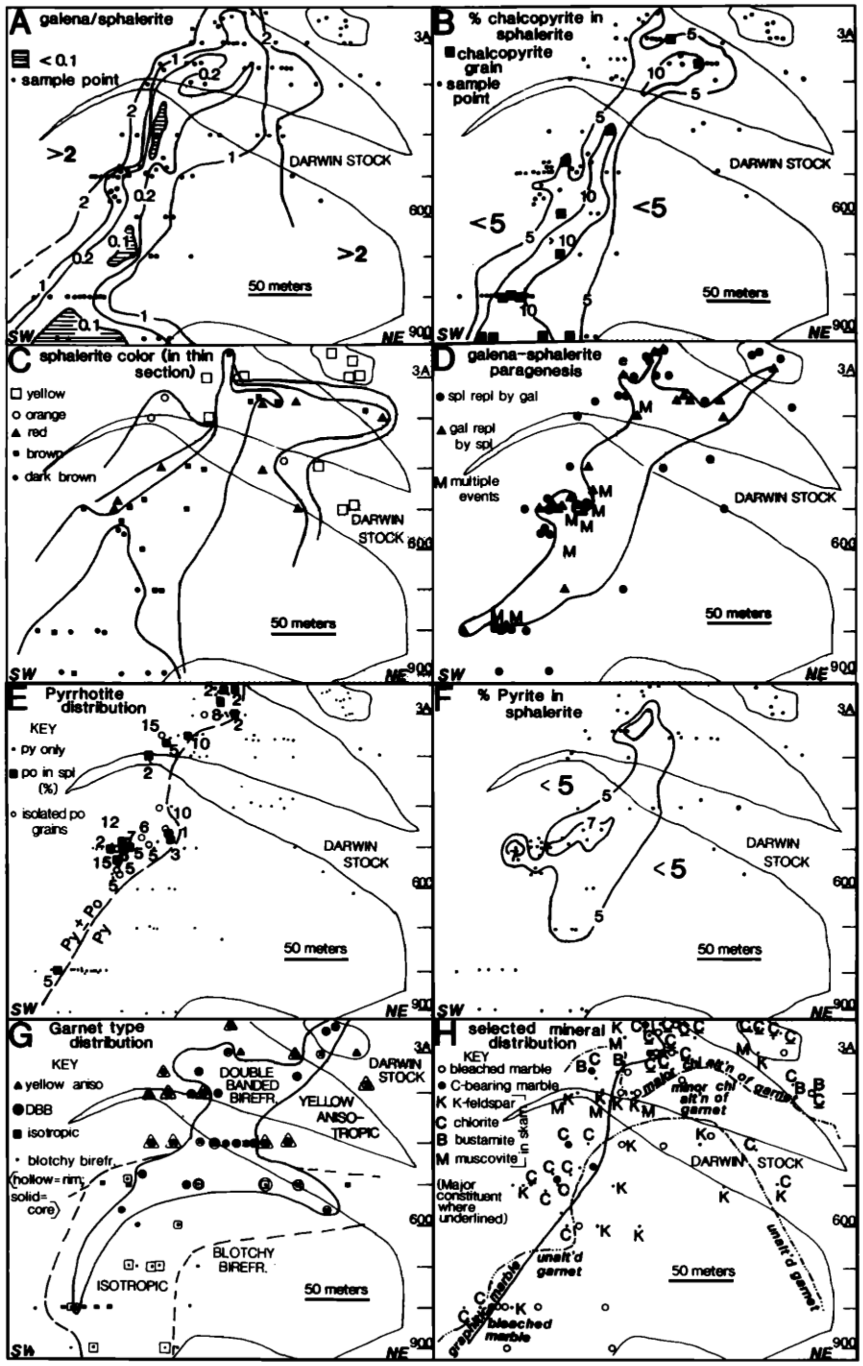

FIG. 12. Mineralogical variations along cross section A′-A (Figs. 2 and 5) in the Essex pipe, based on thin section, polished section, and hand specimen studies. Data points located within 50 m of the cross-section line were projected onto that line, so that the lateral distribution of skarn samples is greater than the lateral extent of skarn shown in Figure 5. A. Galena/sphalerite ratio (note correspondence between the low galena-sphalerite core and the low Pb/Zn ratios of Fig. 10C). B. Chalcopyrite distribution, showing a high chalcopyrite core similar in location to the low galena-sphalerite zone. C. Sphalerite color (thin section transmitted light). D. Galena-sphalerite paragenesis. E. Pyrrhotite distribution. F. Distribution of pyrite inclusions in sphalerite. G. Distribution of garnet types and garnet zoning. Each shape within a composite symbol represents a different garnet type, with the zoning as seen in thin section replicated in the composite symbol. Note the restriction of major andradite (isotropic) garnet to the lower parts of the pipe. H. Distribution of selected nonsulfide minerals, showing boundary

Figure 32. From Newberry and others, 1991 p. 972.

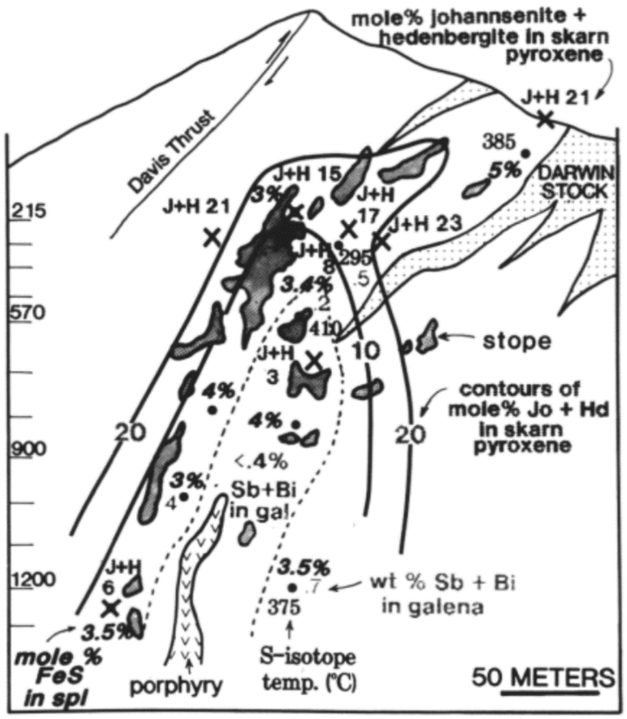

FIG. 14. Cross section through the Defiance pipe (section D′-D, Fig. 11), showing progressive outward zoning of (a) maximum Jo + Hd component in clinopyroxene and (b) wt percent Bi + Sb in galena, similar to shape of Pb/Zn >1 metal ratio zone (Fig. 11A). Also shown are average FeS contents of sphalerite and S isotope-based temperature estimates, which show little variation. Major stope locations (taken from unpub. Anaconda Company maps) are marginal to the porphyry plug and show an inverted cup morphology. Analytical data from Hall and MacKevett (1962), Hall (1971), Rye et al. (1974), Czamanske and Hall (1975), Eastman (1980) [most sphalerite and pyroxene microprobe analyses], and this study. Abbreviations: Hd = hedenbergite, Jo = Johonnsenite.

Figure 33. From Newberry and others, 1991, p. 975.

1991b

ORIGIN OF ORE DEPOSITS

The Darwin deposit illustrates several characteristics of skarn deposits and several problems inherent in skarn studies.

1. The Darwin Pb-Zn-Ag deposit fits in the continuum between skarn deposits and carbonate-hosted Pb-Zn-Ag [replacement] deposits. Metal deposition in the Darwin deposit clearly began after some, but not all, calcsilicate deposition, as indicated by skarn with interstitial sulfides, sulfide-rich veins which contain and/ or are enveloped by garnet, sulfide-quartz-carbonate veins associate with destruction of garnet, and sulfide veins and replacements in marble. Thermal gradients, pressure of formation, and longevity of individual fluid flow conduits, among other variables, probably determine the *degree of spatial proximity of skarn and non-skarn ores in a given district* (Newberry and others, 1991, p. 981).

2. Coincidence of zoning patterns for skarn silicates and for Pb-Zn-Ag ores at Darwin indicates that although ore and gangue were not deposited simultaneously, they belong to the same evolving hydrothermal system, and they should be treated as a single entity (Newberry and others, 1991, p. 981).

3. Because sulfur isotope fractionation factors are relatively insensitive to temperature in the 300º to 400º C range, metal deposition at Darwin has been treated as a simple, essentially isothermal process. In detail the process was complex, probably took place over a temperature decrease of >125 º C, and probably involved complex (Fig. 15) but interrelated changes in solution temperature, pH, oxidation state, and major element chemistry (Newberry and others, 1991, p. 981).

4. This study illustrates the difficulty in assigning a skarn to a mineralizing pluton. The spatial proximity of pluton and skarn, although taken by many as prima facie evidence for cause and effect, is, in itself, not very compelling evidence for a genetic link (Newberry and others, 1991, p. 981).

2011

ORE CONTROLS

Nearly all of the ore in the Darwin District is in a calc-hornfels and tactite zone over 800 feet thick in the lower Keeler Canyon Formation. Mineralization is also confined to the footwall of the Davis thrust between the fault plane and the Darwin stock. Structure and proximity to an intrusive body were important controls for the Darwin ore deposits. Fault control appears to be important for nearly all ore bodies. Deposits may be localized by one or more structural controls or pass from one control onto another (Kelley, 1937). Within this zone, ore bodies are almost always in close proximity to the N *50º-70º E trending strike-slip faults which served as ore solution feeder faults. Three types of ore bodies exist in the Darwin District, all structurally controlled in part or in whole: bedded deposits, irregular replacement ore bodies, and vein deposits in fissures. The ore bodies range form small pods with a few tens of tons of ore to the large bedded replacement bodies of the Independence Mine or the or the pipe-like body in the Defiance Mine. All ore bodies in the Darwin Mine are within a few hundred feet of an intrusive contact. In the defiance and Independence workings, much of the ore is adjacent to the Darwin stock or sills and dikes emanating from the stock. Bedded Ore Bodies Bedded deposits are the most common and commercially important form of ore body at Darwin having been localized along bedding planes within anticline shaped closures. Ore solutions found easy access to theses structures by virtue of the numerous faults and cross fractures, and bedding planes dipping into the contact. Many of these deposits are mutli-layered, the result of selective replacement in several thin beds of the more favorable purer limestone beds. Others have formed at the intersection of fissures with favorable stratification planes and as a result have a chimney-like shape. The bedded deposits have sharp contacts with overlying and* *underlying unmineralized beds. Ore within a particular bed may grade from very high grade to blocks of low grade ore which were often left as stope pillars. Important bedded ore bodies occur in the Independence workings, Promontory workings, and in the 430 stope ore body and Blue and Red veins in the Defiance workings. In the Defiance and Independence workings, the bedded replacement bodies are at the crests of gentle folds close to a granodiorite sill. In the Defiance workings, the bedded ore body thins progressively along bedding away from the northeast trending Defiance Fault. In the Defiance workings bedded deposits are generally no more than 30 feet from the igneous contact. Elsewhere, such as in the Promontory workings and the Keystone mine, ore bodies are 1,000-1,500 feet from the contact (Kelley, 1937). Bedded deposits also are common in some of the mines on the eastern flank of the Darwin Hills including the Custer, Jackass, Fernandon, and Keystone mines. Irregular Replacement ore Bodies The only significant irregular replacement ore body is in the Defiance workings of the Darwin Mine. It is a roughly vertical pipe-shaped zone of mineralization adjacent to the Defiance Fault. It is a vertical mineralized zone that has been developed from the bottom of the bedded ore bodies at the 350 foot level to below the 1,000 level. The average cross sectional area of the mineralized zone is about 350 feet long and 200 feet wide, but all is not ore. The zone actually contains many isolated ore bodies within the zone and have gradational contacts with barren or calc-silicate rock (Hall and MacKevett, 1962). On the 700 level, 12 percent of an area 400 feet long and 130 feet wide is ore, and on the 800 level 15 percent of an area about 320 feet long and 220 feet wide is ore. The ore zone was localized in a zone of northerly trending fractures emanating from the Defiance Fault by numerous small fractures that strike northerly from the Defiance Fault* (USGS, 2011).

FISSURE/VEIN DEPOSITS

Three sets of faults have also localized ore at Darwin. As previously described, these include the N 50º -70º E and N 65º -70º W sinistral strike-slip faults and the steep northerly trending normal faults. The most common and important of these are the N 50º -70º E faults in which fissure deposits are common where the northeasterly trending fractures are nearly at right angles to the axis of the Darwin stock. Fissures of this type are nearly vertical, but where inclined dip steeply to the north. The Christmas Gift, Lucky Jim, Lane, and Columbia are the outstanding producers among the fissure veins. Fissure deposits are as much as 460 feet long and average 2-8 feet thick but stopes 25-30 feet wide have been mined (Kelley, 1937). Contacts with the barren country rock are sharp and wall rock alteration from the invading ore solutions was minimal Veins within the Christmas Gift, Lane, Columbia, and Lucky Jim mines, on the east flank of the Darwin Hills are the best examples of fissure veins. At the Christmas Gift Mine, the Christmas Gift vein was mined from the surface to a depth of 146 feet along a plane that dipped steeply to the southwest. The mineralized strike length was approximately 160 feet and the vein averaged 3 feet thick At the Lucky Jim Mine, an ore shoot along a northeasterly trending fracture has a strike length of over 450 feet. The ore shoots at both mines are localized in parts of the faults that strike nearly northeast, and the parts of the faults with more easterly strike are mostly barren. Other northeastward-striking veins include the 229 and 235 ore bodies in the Thompson workings, and ore bodies along the Mickey Summers and Water Tank faults south of the Defiance workings and *the important northeasterly trending Defiance Fault. The pre-mineralization Defiance Fault is surrounded by many small parallel faults which formed a strongly brecciated zone that later served to localize ore solutions. The only economically important, northwesterly trending vein is the Essex vein in the Essex workings of the Darwin Mine. This high-grade vein has a maximum strike length of 500 feet, an average thickness of 8 feet, and has been mined vertically for more than 650 feet. The two other major northwesterly striking faults in the Darwin area, the Darwin Tear Fault and the Standard Fault are very poorly mineralized. The third important type of fissures are the steep north-striking normal faults which have helped localize ore. Rather than containing distinct vein deposits, these fissures were more important in providing avenues to ore solutions which caused replacement of the adjacent carbonates and to provided a source for the adjacent bedded ore bodies)* (USGS, 2011).

EMPERATURES AND TEXTURS OF ORE FORMATION

Annealing studies on the exsolved mineral phases indicated that all three groups of galena and the Darwin ores were deposited above 350ºC (Czamanske and Hall, 1975). Based on based on sulfur isotope fractionation between sphalerite and galena, Rye et al (1974) estimated the temperature of sulfide ore deposition at 325º-355ºC. Rye also attributed the origin of the ore fluids to magmatically derived fluids, but his isotope studies did not rule out ore fluids wholly or partly attributable to deeply circulating meteoric waters. Hall (1971) estimated ore deposition at 377º-382ºC and 416º-420ºC respectively based on the distribution of Cd and Mn between coexisting galena and sphalerite. Gangue Minerals Gangue minerals consist of calcite, fluorite, garnet, and jasper with minor amounts of barite, clay minerals, diopside, idocrase, orthoclase, quartz, and wollastonite. Coarsely crystalline calcite and fluorite are directly associated with ore minerals, particularly galena. Calcite occurs in all the mines in the Darwin District and is commonly intergrown with galena. Calcite rhombohedrons up to 18 inches on the side are common. In the Custer Mine, on the east side of the Darwin Hills, calcite makes up most of the vein with galena occurring in interstitial pockets. Gangue mineralization was formed by the recrystallization of the calc-silicate wall material to silicate minerals, after the silicification of the calc-silicate aureole, but before the period of metallization. In many places gangue minerals have been replaced in part by ore minerals (Hall and MacKevett, 1958). In the Essex workings, galena commonly replaces silicate minerals in the wall rock, gangue minerals, and locally replaces the igneous rock minerals along fractures. Kelley (1937) describes polished specimens, in which small veinlets of pyrite and galena cut quartz, fluorite, and calcite (Kelley, 1937) (USGS, 2011).

ORIGIN AND CLASSIFICATION OF THE DEPOSIT

The Darwin lead-silver-zinc deposits were controlled by the emplacement and extent of the Darwin Stock which in turn was guided by the structure of the Paleozoic strata. Silica laden solutions advanced ahead of the intrusion causing the widespread silicification of the lower Keeler Canyon Formation carbonates. The introduction of the silica in to the limestones began at an early stage and continued until the deposition of the sulfide ores and to a lesser extent continued afterward with precipitation of quartz and jasper in the fissure deposits. Many of the fissures in and marginal to the Darwin stock may have been caused by intrusive forces or cooling contraction, but the principal *movements were tectonic. The fracturing and movement took place after the silicification of the aureole and solidification of the Darwin stock* (USGS, 2011).

The U.S. Geological Survey classifies the Darwin District Mines as USGS ore deposit model 19a: Polymetallic replacement (USGS, 2011).

DEVELOPMENT

Overview

While many mines and prospects dot the Darwin Hills, most of the district's production has come from the larger workings on the west flank of the Darwin Hills. These workings were consolidated during World War I and a later operated from 1945 until the 1970s as the Darwin Mine by the Anaconda Company. These properties included the Bernon, Defiance, Essex, Independence, Intermediate, Rip Van Winkle, and Thompson workings and are considered typical of the district for this report. A noteworthy collection regarding Anaconda's operation of the Darwin Mine is maintained in the Anaconda Geological Documents Collection at the University of Wyoming. This collection has not been reviewed in the preparation of this report, but instead relies heavily on the accounts of operations contained in Hall and MacKevett's 1958 Economic Geology of the Darwin Quadrangle, Inyo County, California and other sources. The various workings of the Darwin Mine were originally worked through individual westerly driven adits in a small ridge in the western Darwin Hills. Under Anaconda, these workings were ultimately connected through raizes and winzes to the Radiore Tunnel, a main haulage way and portal at the 400 level. The raises and winzes generally became the main working shafts of the respective workings. From its portal on the west flank of the Darwin Hills near the Darwin Mill, the Radiore Tunnel was driven 1,430 feet N 20? E then 2,740 feet N 15?-20? W to intersect the original workings. Its total length is more than 6,300 feet (Norman & Stewart, 1951). Generally, the mining methods used by Anaconda were adapted to the specific ore zones. Square sets were used in the predominantly oxidized zone. A slot method was used in these square set stopes, somewhat modified from the Butte method in that waste fill was seldom used. In the large replacement ore bodies, pillars were left between the large square set stopes and were subsequently recovered by a modified Mitchell top-slicing method. In the unoxidized zones, the narrow ore bodies were mined by open or rill-type stopes, and the larger hard sulfide ore bodies were mined by sub-level stoping. The sub-levels were spaced at 21 foot intervals, and each level was developed to the limits of the ore before actual mining was started. Some shrinkage stopes were used (Norman & Stewart, 1951). Under Anaconda, electric locomotives were generally used for haulage and modern equipment was used throughout the mine. Mucking was done with mechanical loaders. Headings on the main level are drilled with drifters mounted on hydraulic jumbos. Electric hoists were used in all shafts and winzes. The mill had a capacity of about 300 tons/day and was located below the Radiore Tunnel portal. Ore was processed in a jaw crusher and ball mill before the lead and zinc was concentrated separately by flotation (Norman & Stewart, 1951)(USGS, 2011).

1917

The district lies in the desert region of southeastern California and is therefore arid. The average annual rainfall at Keeler, which is the nearest locality for which records are available, is 3.15 inches, and it is unlikely that the precipitation at Darwin exceeds this, although Darwin is 1,100 feet higher than Keeler. Water is piped by gravity from the Coso Mountains, a distance of 8 miles, and was in 1913 sold at half a cent a gallon for mining purposes and 1 cent a gallon for domestic purposes. An ample supply is said to be available at the well at the lower end of the Darwin Wash, but for most of the mines in the district the utilization of this supply would require a lift of 2,000 to 2,500 feet. Ore is hauled from the mines to the railroad at Keeler at $6 to $8 a ton, either by team or auto truck. Freight brought out to the district costs $1 a ton more. Miners' wages are $3.50 to $4 a day (Knopf, 1917. P. 1).

1938a

Darwin District. The mining of lead-silver ores in this district has been from 1870 to date, and the approximate production has been between $3,000,000 and $5,000,000. The ore deposits are generally inclosed in lime-silicate rocks, and consist of argentiferous galena, with small amounts of pyrite and sphalerite. As a rule, the galena is largely oxidized to lead-carbonate and sulphate. The productive mines have been Argus-Sterling, Christmas Gift, Custer, Defiance, Independence, Lucky Jim, Keystone, Thompson, and Wonder. In the past year the Darwin Lead Company acquired a lease on the Defiance-Independence- Thompson Group of mines, and installed a pilot concentration and flotation plant for the treatment of the low-grade ores from these mines. In development work on lower levels of Defiance mines, leasers have developed 6 ft. of high-grade galena and lead-carbonate ore. This ore is being shipped to smelters at Salt Lake City, Utah. Shipments are reported to carry 40% lead with 20 oz. to 30 oz. in silver. Another important development made in the district in 1937 was the development of Keystone Mine by the Darwin Keystone Mining Company, and the shipment of a considerable amount of ore (Tucker and Sampson, 1938, p. 426).

Darwin Cyanide Plant. It is situated in the Darwin Wash, 4 miles south of Darwin, operating on tailings from the Darwin Lead Co. Richard Wallace has a lease on the tailings, and has given a sub-lease to Louis Warmkin, Darwin; Fritz Schwram, superintendent. The plant consists of steel tanks 8 by 10 by 4 deep ; capacity 18 tons; one water tank, capacity 5000 gallons and one cyanide solution tank, capacity 5000 gallons. Tailings are leached for 6 days in a solution containing 2.5 lb. of sodium cyanide per ton of water and precipitated in 6 barrel-type zinc boxes. Barren solution flows to sump tank and is pumped back to the solution tank by a centrifugal pump. Water is secured from a well in Darwin Wash. Heads are reported to carry $3 per ton in silver (Tucker and Sampson, 1938, p. 435).

1938b

The following table of production from the more important mines in the district is based partly upon figures and estimates made by previous writers and partly upon estimates from information gained during the present survey (Kelley, 1938, p. 553).

Mine	Estimated Production
Lucky Jim	$2,000,000
Defiance	1,500,000
Christmas Gift	550,000
Independence	500,000
Lane	300,000
Custer	250,000
Promontory	200,000
Thompson	100,000
Columbia	100,000
All others	300,000
Total	$5,800,000

Kelley (1938, pp 554-561) provides development and geologic descriptions of all the major mines in the Darwin District. Kelley (1938, p. 562) also had some suggestions for further exploration. He discounted then-new geophysical methods of exploration in favor of traditional geological surface, underground and drill hole sampling.

1951

The main haulage way and entry for the Darwin Mines is the Radiore tunnel, the 400-level, which was started in 1926. This crosscut has connected the workings of the Defiance mine, the Bernon mine and the Independence-Thompson group (pi. 2). The tunnel was driven 1430 feet N. 20° E., then 2740 feet N. 15°-20° W., then more than 1200 feet north. Its total length is more than one mile of which the Anaconda Company has driven more than 2400 feet. (Norman and Stewart, 1951, p. 64).

The Defiance Mine was formerly worked through an adit and a 500- foot shaft inclined at 35 degrees. The altitude of the shaft collar and adit portal is 5234 feet. Workings from these openings are connected to the Rediore tunnel by raises, but an inclined winze goes down to the 570 level. A raise and winze, now jointly called the main working shaft, connect the Independence and Thompson group with the Radiore tunnel and extend to the 600 level. These mines were formerly worked through tunnels, the portals of which are at altitudes of 5617 feet for the Independence and 5291 for the Thompson. Two other tunnels are the Essex, at 5557 feet, and the Intermediate, at 5472 feet. (Norman and Stewart, 1951, p. 64).

Mining methods are adapted to the conditions in the ore zones. Square sets are used in the oxidized zone. A slot method is used in these square-set stopes, somewhat modified from the Butte method in that waste fill is seldom used. In the large replacement orebodies, pillars are left between the square-set stopes and are subsequently recovered by a modified Mitchell top-slicing method (Norman and Stewart, 1951, p. 64).

In the unoxidized zones, the narrow orebodies are mined by open or rill-type stopes, and the larger, hard sulphide orebodies are mined by sub-level stoping. The sub-levels are spaced at vertical intervals of 21 feet, and each level is developed to the limits of the *ore before actual mining is started. Some shrinkage stopes have been used* (Norman and Stewart, 1951, p. 64).

Underground workings total several miles in length and new workings are advanced at a rate which has averaged more than 7000 feet per year since 1947. Diamond drilling is used for exploration and has averaged about 9000 feet per year for the years 1947-49. Core recovery is high. Practically all mining and development work is done on a contract basis (Norman and Stewart, 1951, p. 64).

Storage battery locomotives are used for haulage, and modern equipment is used throughout the mine. All mucking is done with mechanical loaders. Headings on the main level are drilled with drifters mounted on hydraulic jumbos. Detachable throw-away bits are used. Electric hoists are used in the shaft and winzes (Norman and Stewart, 1951, p. 64).

The mill, which has a capacity of about 300 tons per day, is just below the portal of the Radiore tunnel. Both oxidized and mixed oxide sulphide ores were treated after Anaconda started operations. The mill was enlarged to its present capacity and the flow sheet changed so that now only the sulphide ores are treated (figs. 4-6). Lead and zinc are concentrated separately in the flotation process. The zinc concentrate is shipped to Great Falls, Montana, and the lead-silver concentrate is shipped to Tooele, Utah. Only shipping-grade oxidized ore is mined. Any lower-grade oxidized ore obtained is stockpiled. Mill heads before 1947 average about 10 percent lead, 4.5 percent zinc and 7 ounces of silver,91 and since then have averaged approximately 7.5 percent lead, 7.5 percent zinc and 5 ounces of silver. (Norman and Stewart, 1951, p. 64 and 68).

Power is obtained from the City of Los Angeles through Anaconda 's own 18-mile line to the Olancha cut-off. Compressed air is supplied by 3 Ingersoll-Rand compressors with a total capacity of 3000 cubic feet per minute.
(Norman and Stewart, 1951, p. 68).

Water for milling and all camp purposes is obtained from Darwin Wash about three miles from the camp. Water is pumped from shallow wells, 24 to 50 feet deep, into a 30,000-gallon tank. An automatic float control regulates the operation of the pumps. A 120-gallon-per-minute triplex pump then lifts the water 1800 feet through a 4-inch line to three 50,000-gallon storage tanks above the mill and camp (Norman and Stewart, 1951, p. 68).

The production record of these properties is not complete. For the period October 1941 to mid-July 1943, 28,400 tons of ore was mined, of which 11,400 tons was milled before it was decided that the oxidized ore was not amenable to the treatment. The 17,000 tons shipped to the smelter averaged 9 percent lead and 4 percent zinc. The total production of the district before the Anaconda operation is estimated at $7,000,000 worth of lead, silver and zinc. Anaconda's current production averages about 8000 tons of ore per month. The usual crew is 180 men; the mine operates on two shifts and the mill on three. (Norman and Stewart, 1951, p. 68).

Norman and Stewart (1951, p. 65-67) has a series of flow sheets illustrating Anaconda's milling process.

1957

Comprises 45 patented claims, 44 un-patented claims, and several mill sites. Argentiferous galena, sphalerite, chalcopyrite, tetrahedrite, and py-rite occur in a quartz, calcite, fluorite, hydromica, gypsum, clay, jarosite, jasper, and iron oxide gangue in folded and faulted Paleozoic limestone, dolomite , shale, and quartzite which has been intruded along the cast flank of a northwest pitching anticline by the Darwin granodiorite stock. Three types of ore bodies are recognized: replacements of silicated limestone, bedding re-placements, and fissure fillings. Production in recent years has been 8000 to 10,000 tons per month reduced to about 20% of its volume by milling and flotation. Mill heads have averaged about 6 ounces of silver, 6.5% lead, 6.4% zinc, and some gold. High-grade oxidized ore is shipped directly to the smelter. The total estimated pro-duction before the Anaconda operation began is about $7,000,000. Copper and tungsten have also been produced as a by-product. Ore mined at Darwin around 1880 was oxidized and much higher in lead and silver. Some of the recent stopes at Darwin have been much higher in silver than the average. (Davis 1946; Chalfant 1933:294; Eric 1948: 241; Hamilton 1920:37; Hamilton, 1922:47; Kelley, 1938:503-62; Knopf, 1915: 1-18; Newman, 1923:420; Norman and Stewart, 1951:59-68, 173-74; Stewart 1948:56; Tucker and Sampson, 1938:426, 436-37, pl. 3; Tucker and Sampson, 1941:567-68; Tucker and Sampson, 1943:118)(Goodwin, 1957, p. 466-467, Inyo County Table).

1958

The Darwin quadrangle comprises 225 square miles in the west-central part of Inyo County and includes parts of the Inyo Mountains, Coso Range, Argus Range, and Darwin Hill s. the dollar value of the mine production through 1951 is estimated at $37,500,000. The principal commodities are lead, silver, zinc, steatite-talc, tungsten, and small amounts of antimony and gold (Hall and McKevett,1958, p. 4).

The Darwin quadrangle is best known economically for its deposits of lead-silver-zinc ore, but in addition, talc, tungsten, antimony, copper, and gold have been produced, and vast deposits of limestone and dolomite are known. The total value of the ore produced from 1875 to 1952 is approximately $37,500,000. Production from the Darwin district has accounted for $29,000,000 of this amount. Most of the silver, lead, and zinc was mined from the Darwin Hills. Smaller deposits have been developed in the Zinc Hill area, the Lee district, and at the Santa Rosa mine. Steatite-grade talc has been mined continuously since 1917 from the Talc City Hills, principally from the Talc City mine. The only other commodity exploited in any quantity is tungsten, which was first produced in 1941 from mines on the east side of the Darwin Hills, and intermittent production has been maintain since then (Hall and MacKevett, 1958, p. 14).

The Darwin district can be divided into two parts. Lead, zinc, and silver are the principal commodities mined in the western part, while tungsten is the principal commodity mined in the eastern part. Most of the mines in the western part of the district have been consolidated under one management since World War I, and they are commonly *referred to as the Darwin mines. The Darwin mines consist of the Bernon, Columbia, Defiance, Driver, Essex, Independence, Lane, Liberty Group, Lucky Jim, Promontory, Rip Van Winkle, and Thompson. In this report the name Darwin mine will be restricted to the mines through which the Radiore tunnel passes. This includes the Rip Van Winkle, Defiance, Bernon, Thompson, Essex, and Independence mines, and each of these deposits will be referred to as workings-the Defiance workings, Essex workings, etc. All the production of The Anaconda Company from the Darwin district has come from the Darwin mine. The term Darwin mines will be used in the former unrestricted sense. The mines in the eastern part of the district were originally mined for their lead and silver content, but since 1940 they have been mined only for tungsten* (Hall and MacKevett, 1958, p. 18-19).

DARWIN QUADRANGLE 19

Table 3. Ore produced from the Darwin silver-lead-zinc district. †*

Year	Gold (oz)	Silver (oz)	Copper (lbs)	Lead (lbs)	Zinc (lbs)	Operator or Mine
1875-1883	--	1,571,000 (estimated)		--	--	Defiance mine; New Coso Mining Co.
1888-1892	23.51	--	--	--	--	Phoenix mine
1893	7.26	26,759	--	--	--	Custer mine; J. A. McKenzie; H. Mettler; Phoenix mine
1894	--	70,095	--	--	--	Christmas Gift mine; Henry Mettler
1895	--	19,362	--	--	--	Custer mine; J. A. McKenzie; Henry Mettler
1897	--	5,517	--	--	--	J. A. McKenzie and W. W. Boswell
1898	64	54,800	--	--	--	R. C. Troeger
1899	53	37,349	--	--	--	Custer mine; Last Chance Mining Co.; J. A. McKenzie; Phoenix mine
1900	741	13,178	--	--	--	W. W. Boswell; J. A. McKenzie; Phoenix mine
1901	591	14,333	--	--	--	W. W. Boswell; J. A. McKenzie; Phoenix mine
1902	--	4,360	--	--	--	J. A. McKenzie; Phoenix mine
1903	39	14,814	--	11,905	--	J. A. McKenzie
1904	25	12,276	--	3,200	--	Inyo County Mining and Dev. Co.; J. A. McKenzie
1905	24.19	5,036	2,600	2,042	--	Christmas Gift mine; Inyo County Mining and Dev. Co.
1906	--	3,970	--	36,842	--	C. R. Bradford; Inyo County Mining and Dev. Co.; New Coso Mining Co.
1907	--	12,600	--	100,000	--	New Coso Mining Co.
1908	4	17,785	--	182,405	--	New Coso Mining Co.
1909	23.87	3,271	462	75,235	--	Christmas Gift mine; New Coso Mining Co.; S. H. Reynolds
1910	75	11,358	904	170,609	--	New Coso Mining Co.; S. H. Reynolds
1911	1	4,292	--	5,667	--	C. A. Bradford; Custer mine; New Coso Mining Co.; S. H. Reynolds
1912	38.32	11,670	13,210	215,710	--	Christmas Gift mine; Independence Mining Co.; New Coso Mining Co.
1913	62.99	28,174	6,097	440,624	--	Christmas Gift mine; Custer mine; New Coso Mining Co.; J. C. Roeper; M. J. Summers
1914	6.02	13,043	1,256	195,667	--	New Coso Mining Co.
1915	3.0	10,028	314	121,363	--	Christmas Gift mine; Darwin Development Corp.; Theo Peterson
1916	38	103,546	27,207	1,361,401	--	Christmas Gift mine; Darwin Mines Corp.
1917	275	145,870	232,222	1,672,569	--	Christmas Gift mine; Custer mine; Darwin Mines Corp.; Theo Peterson; M. J. Summers
1918	114.61	50,568	11,854	997,038	--	A. A. Belin; Custer mine; Darwin Silver Co.; A. G. Kirby; Rooney and Bradford
1919	7.06	12,698	1,400	149,945	--	Custer mine; Darwin Silver Co.; Theo Peterson; M. J. Summers
1920	4.66	6,827	648	92,613	--	Custer mine; Darwin Silver Co.; Theo Peterson; M. J. Summers
1921	--	1,186	--	18,918	--	Darwin Silver Co.; A. G. Kirby
1922	61	89,116	7,712	937,538	--	A. G. Kirby
1923	152	125,899	18,098	2,026,692	--	Christmas Gift mine; A. G. Kirby
1924	54	40,242	8,920	731,249	76,947	A. G. Kirby
1925	3	10,467	3,804	84,822	--	A. A. Belin; L. D. Foreman and Co.
1926	31.11	33,145	4,320	978,001	--	American Metals Inc.; Christmas Gift mine; L. D. Foreman and Co.
1927	48	38,238	7,916	1,223,534	--	American Metals Inc.; Christmas Gift mine; L. D. Foreman and Co.
1928	1	635	--	22,395	--	American Metals Inc.
1935	90.21	1,161	1,935	21,192	--	Custer mine
1937	111	64,076	9,521	1,049,491	--	Custer mine; Darwin Keystone Ltd.; Darwin Lead Co.; L. D. Foreman and Co.; Louis Warnken, Jr.
1938	23	6,829	2,457	119,679	--	Darwin Keystone Ltd.; Darwin Lead Co.; Louis Warnken, Jr.
1939	5	146	--	--	--	J. B. Anthony
1940	7	748	170	32,712	--	Custer mine; Theo Peterson
1941	77	32,244	16,501	1,424,236	--	Imperial Metals, Inc.
1942	175	53,072	4,422	1,510,000	--	Imperial Metals, Inc.; L. D. Foreman and Co.
1943	--	138,662	--	4,896,000	--	Darwin Mines
1944	--	252,900	--	5,218,000	1,110,000	Darwin Mines; L. D. Foreman and Co.; Wonder mine
1945	377	575,069	130,931	10,428,000	1,992,000	The Anaconda Co.; L. D. Foreman and Co.
1946	442	871,091	198,307	15,416,000	1,708,000	The Anaconda Co.; L. D. Foreman and Co.
1947	529	1,093,709	86,690	13,102,000	1,206,000	The Anaconda Co.; Custer mine; L. D. Foreman and Co.; Wonder mine
1948	472	393,761	131,022	12,156,000	8,994,000	The Anaconda Co.; Custer mine; L. D. Foreman and Co.; Keystone mine; St. Charles mine
1949	232	352,482	130,527	9,856,000	8,124,000	The Anaconda Co.; Custer mine; Keystone mine
1950	361	600,440	202,829	16,958,000	10,474,000	The Anaconda Co.
1951	441	570,595	225,140	14,382,000	9,440,000	The Anaconda Co.; Belle Union; Lane; Promontory
	5,913.81	7,630,492	1,489,396	117,566,900	52,124,947	
short tons	--	--	744.7	58,783.5	26,062.5	

* See text page 19 for sources of production data.
† Published with the permission of the mine owners.

Figure 34. From Hall and MacKevett, 1958, p. 18.

1962

The Darwin quadrangle contains commercially important- deposits of lead-silver-zinc· and steatite-grade talc, and some tungsten, copper, gold, and· antimony (fig. 3). Large deposits of limestone, dolomite, and quartzite are known, put they have not been exploited owing to remoteness from market and railroad transportation. The total value of mineral production to 1952 is about $371;2 million. The Darwin lead-silver-zinc district has accounted for $29 million and the talc deposits for about $5 million. The remainder of the production has come ·from other lead-silver-zinc deposits scattered throughout the quadrangle and from the tungsten deposits in the Darwin Hills. The major lead-silver-zinc deposits are in the Darwin 'Hills, but smaller deposits have been developed at Zinc Hill in the Argus Range, the Lee district in the northeastern part of the quadrangle, and the Santa Rosa mine in the Inyo Mountains. Steatite-grade talc has been mined continuously since 1917 from the Talc City Hills, principally. from the Talc City mine. Scheelite was first mined in 1940 from deposits about 1 mile east of Darwin, and production has been intermittent since then. Small amounts of copper, gold, and antimony have been recovered from deposits in the Darwin Hills (Hall and MacKevett, 1962, p. 52).

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TABLE 4.—*Gold, silver, copper, lead, and zinc produced from the Darwin quadrangle* [1]—Continued

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Operators
1933	4.20	2,609	1,325	104,112		Do.
1934	6.39	7,777	8,364	242,415		Do.
1935	95.14	5,575	10,290	155,457		Custer mine, Santa Rosa mine.
1936	14.25	9,755	16,563	269,850		Santa Rosa mine.
1937	174	70,526	14,417	1,240,741		Custer mine, Darwin Keystone Ltd., Darwin Lead Co., L. D. Foreman & Co., Santa Rosa mine, Louis Warnken, Jr.
1938	26	7,860	2,846	143,756		Darwin Keystone Ltd., Darwin Lead Co., Santa Rosa mine, Louis Warnken, Jr.
1939	5	146				J. B. Anthony.
1940	7	748	170	32,712		Custer mine, Keystone mine, Theo Peterson.
1941	81	32,915	16,501	1,434,884	383,720	Imperial Metals, Inc., Keystone mine, Zinc Hill mine.
1942	185	54,935	4,422	1,543,824	650,400	Imperial Metals, Inc., L. D. Foreman & Co., Zinc Hill mine.
1943	0.31	138,880		4,901,412	38,760	Darwin Mines, Zinc Hill mine.
1944	4.00	252,900	10,327	5,218,000	1,110,000	Darwin Mines, L. D. Foreman & Co., Wonder mine.
1945	377	575,069	130,931	10,428,000	1,992,000	The Anaconda Co., L. D. Foreman & Co.
1946	443	871,621	200,340	15,450,891	1,720,539	The Anaconda Co., Empress mine, L. D. Foreman & Co.
1947	557	1,126,906	148,949	14,055,988	1,231,641	The Anaconda Co., Custer mine, Empress mine, L. D. Foreman & Co., Santa Rosa mine, Wonder mine, Zinc Hill mine.
1948	495	418,263	165,708	12,773,984	9,016,300	The Anaconda Co., Custer mine, Empress mine, L. D. Foreman & Co., Santa Rosa mine, St. Charles mine.
1949	232	354,861	131,583	9,994,337	8,148,444	The Anaconda Co., Custer mine, Empress mine, Santa Rosa mine, Zinc Hill mine.
1950	365	602,263	208,118	16,991,027	10,474,000	The Anaconda Co., Santa Rosa mine.
1951	422	574,765	223,091	14,395,209	9,441,670	The Anaconda Co., Empress mine, Lee mine.
	6,296.43	8,089,256	1,989,702 994.9 (tons)	131,122,098 65,561	46,683,717 23,341.9	

[1] Compiled from records of the U.S. Bureau of Mines and from Minerals Yearbook. The data for the Darwin district from 1888 to 1942 was compiled by Charles W. Merrill of the U.S. Bureau of Mines (from Hall and MacKevett, 1958).

Figure 35. From Hall and MacKevett, 1962, p. 55.

A summary description of the ore bodies, ore controls, and workings for each of the main workings follows:

DEFIANCE WORKINGS

The Defiance workings are in the southeast end of the Darwin Mine area. The Defiance workings are characterized by two types of ore bodies - shallow concordant bedded replacement ore bodies and a larger and deeper irregular replacement body. Two readily accessible bedded ore bodies, the "Blue vein" and the "Red vein", outcrop along the crest and west limb of an inverted syncline, the axis of which has been eroded exposing the westerly dipping the beds at the surface. Both ore bodies are surrounded by dense white calc-hornfels. The contacts with the pyritized country rock are sharp and the ore grade within each zone is erratic. The Blue vein is the stratigraphically lower of the two and is near the upper contact of a granodiorite sill extending westward from the Darwin stock. The bed is 300 feet long, 2-8 feet thick, and was stoped for more than 400 feet up dip at the 215 level to the surface. The Red vein is 60 feet stratigraphically above Blue vein and 80 feet below an upper sill of the Darwin stock. This ore body is 460 feet long in the vicinity of the Defiance adit and generally 5-10 feet thick. It has been stoped for over 670 feet from the 400 foot level to the surface. Other smaller bedded ore bodies have been mined in the deeper mine workings. The Red and Blue veins lie between two sills that are about 200 feet apart and pinch out at depth. The upper sill pinches out at about the 100 foot level while the lower sill pinches out between the 570 and 700 level. The lower sill merges with the main Darwin stock before outcropping at the surface. The lower sill cannot be delimited on the surface as it merges with the main Darwin Hills stock at the surface. The bedded ore bodies are approximately coextensive with the extent of the overlying and underlying sills. The principle ore bodies change from bedded replacement deposits to a large irregular, near vertical pipe-shaped replacement ore body below the 400 level. This ore body was developed for more than 570 feet to below the 1,000 level. The ore is localized along the northeasterly striking Defiance Fault within a zone of intersection with numerous northerly striking near vertical fractures. Mineralization extends outward from the fault along closely spaced fractures for distances of over 270 feet. On the 800 and 900 levels about 25% of the calc-hornfels over an area 200 x 270 feet is replaced by ore (Hall and MacKevett, 1958). Bernon Workings The Bernon workings adjoin the Defiance workings to the southeast and the Thompson workings on the northeast. The ore bodies are concordant bedded replacement beds within white calc-hornfels along the crest of a small inverted syncline that extends southward towards the Defiance workings. The rocks are cut by two important pre-mineralization feeder faults, the Bernon and 434 faults, both of which strike N 50º - 70º E and dip steeply northwest. The faults are truncated on the west by the Davis Thrust Fault. The Paleozoic rocks are also intruded by a sill of quartz monzonite south of the 434 fault, and by a dike south of the Bernon Fault (USGS, 2011).

THOMPSON WORKINGS

The Thompson workings are 1,200 feet northwest of the Defiance workings near the western contact of Darwin Stock within the Keeler Canyon Formation. Quartz monzonite outcrops at the Thompson adit and extends 370 feet into the adit. The adit passes into *white medium grained calc-silicate beds which strike northerly and dip 35º to the west. The Copper Fault, which strikes N 60º E and dips steeply to the north, is exposed near the portal of the adit. Two paralleling faults occur 300 and 360 feet north of the Copper fault (Hall and MacKevett, 1958). Ore bodies are within medium grained calc-silicate rock in the same stratigraphic zone as those in the Independence and Bernon workings. The ore bodies are in faults striking N 50 º -70 º E close to intrusive contacts and also within fractures closely paralleling the intrusive contacts. The "234" and "229" faults are mineralized discontinuously for distances of up to 400 feet from a minor sill or dike of the Darwin Stock. The 234 fault has been stoped for 190 feet along its strike. The thickness of ore ranges between 4 and 20 feet between the 200 and 3B levels, a vertical distance of 200 feet. Above the 200 level and below the 3B level the ore is in north striking fractures between the 234 and 229 faults. The 229 fault has been less productive than the 234 fault, and has yielded ore for 135 feet along strike with a thickness of 10 feet between the 200 and 3A levels (Hall and MacKevett, 1958)*(USGS, 2011)

ESSEX WORKINGS

The Essex workings are about 800 feet northwest of the Thompson adit. The surface workings are in medium grained calc-silicate rocks approximately 50 feet east of the Davis Fault. Bedding strikes northerly and dips 32-68? west and is cut by the Essex Fault. The Essex Fault is cut off by the Davis Fault on its west end. Unlike most of the Darwin district ore bodies, the Essex ore body is in a fault that strikes N 65º W and dips steeply to the south. At the surface, the Essex ore bodies are expressed only by zones of iron staining along the Essex fault zone. The main ore body does not outcrop at the surface, but lies below the Davis Fault within the Essex Fault zone along steep north striking fractures and near a series of sills emanating from the Darwin stock to the east. Ore has been mined from the Essex Fault from 50 feet below the surface to the 600 foot level, a vertical distance of 780 feet. The ore is localized in the fault zone with calc-slicate host rock between the Darwin Stock and the Davis thrust fault. Between the surface and the 3B level, the Davis Fault and the west contact of the stock are approximately parallel and are about 360 feet apart. Ore bodies are discontinuous over this distance and exhibit a maximum thickness of 30 feet. Below the 3B level the Davis Fault dips gently to the west while the west flank of the Darwin Stock steepens and diverges to the east. As the distance between the stock and the Davis Fault increases with depth, the quantity of ore decreases. Ore along the north striking fractures is best developed on the 200 and 400 levels. On the 200 level, ore extends 175 feet north of the Essex Fault and on the 400 level it extends 400 feet north near the intersection of a north striking fault and a quartz monzonite sill. The ore is localized within 40 feet of the intrusive contact (Hall & MacKevett, 1958)(USGS, 2011.)

INDEPENDENCE WORKINGS

The Independence workings are the northernmost workings of the Darwin Mine approximately 850 feet northwest of the Thompson workings. Medium grained calc-hornfels rock is exposed at the surface for 130 feet from its contact with the Darwin Stock west to the Davis Thrust Fault. Ore bodies occur along the crest of a fold in the footwall below the Darwin Fault. North of the Independence portal, calc-hornfels rock is cut off by the Davis thrust, but extends below an overthrusted block of unmineralized *dense gray calc-hornfels in fault contact with the Darwin Stock. The Darwin Stock terminates to the west in a series on folded anticlinal shaped sills which pinch out with depth to the west. The upper ores are bedded replacement deposits above the uppermost sill and below the Davis Thrust. These upper bedded replacement deposits exhibit a mineralized strike length of approximately 250 feet and a width of up to 120 feet. The Davis Fault truncates the ore zone in the uppermost workings including the 100 level. Approximately 30% of the host rock in this zone is replaced by ore. Contacts with overlying and underlying unmineralized beds are sharp. The upper ore was stoped from the 100 foot level to the surface. Stopes measured 140 feet long, 60 feet wide and 40 feet tall. A sill of quartz monzonite underlies the zone. The Independence workings contained the largest bedded ore body in the district between the 200 and 400 foot levels. A section of bedded ore 160 feet thick lies along the crest of an anticinally shaped fold between overlying and underlying anticlinally folded quartz monzonite sills and directly below the Davis Thrust Fault. This ore zone has a maximum strike length of 500 feet, a maximum of 160 feet thick, and a distance of 700 feet across the crest of the fold and down the west limb of the fold. The bedded ore body in the Independence workings is mineralized although not all of it is ore grade. The contacts of individual ore bodies in this ore zone are sharp, and only barren calc-hornfels or highly pyritized calc-hornfels lies between individual ore bodies. The upper sill is truncated near the axis of the fold by the Davis Fault. The bedded ore has been stoped discontinuously between the quartz monzonite sills along the crest of the inverted syncline for a mineralized strike length of 500 feet on the 3B level. Ore has been mined westward down dip between the upper sill contact with the Davis Fault and the lower sill for a distance of 700 feet to the 400 level. Smaller bedded ore bodies occur below the lower sill between the 400 and 600 foot levels where they are invariably within 100 feet of the base of the sill. A lower ore body 200 feet long and up to 50 feet thick on the west limb of the fold was mined 260 feet down dip below the 400 foot level. A smaller lower bedded ore body on the east limb was mined from the 400 level to 40 feet below the 500 level (Hall and MacKevett, 1958)*(USGS, 2011).

RIP VAN WINKEL WORKINGS

The Rip Van Winkle workings are located southwest of the Defiance workings just above the former Darwin Mining Camp. They include the workings on mineralized portions of the Water Tank Fault and the Mickey Summers Fault northeast of the portal of the Radiore Tunnel. The Water Tank Fault strikes N 70º E and dips 85 º N. The Mickey Summers fault strikes N 75 º E and dips 80 º southeast. The Rip Van Winkle deposit was originally worked through a shaft at the intersection of the Water Tank Fault with the Davis Thrust Fault. A mineralized fault 60 feet north and parallel to the Mickey Summers Fault was also developed by two shafts 220 feet apart. Mineralization within the Water Tank Fault was continuous along strike between the two shafts. Mineralization is in medium grained calc-silicate rock on the foot wall of the Davis Fault. The thrusted hanging wall is composed of unmineralized dense gray calc-hornfels. The Radiore Tunnel later accessed this deposit where it crosses the Water Tank Fault. The Water Tank Fault is mineralized on this level along its strike for a distance of 360 feet.

PRODUCTION

The total production of the Darwin district, through 1972 was over 8,409,580 ounces of silver, 126,209,848 pounds of lead, 66,907,584 pounds of zinc, 1,700,451 pounds of copper and 6,715 ounces of gold valued at over $34 million (Hall and Mackevett, 1958, Taylor, 2002, personal communication). Thirty-five thousand short tons of tungsten trioxide was also reportedly produced. Before 1942 mainly high grade oxidized silver-lead ore with some relict galena was mined from the shallow workings later consolidated as the Darwin Mine. Smelter returns prior to 1877 show that 20.5% lead and 47 ounces of silver per ton of ore were recovered from the furnaces. Ore from the Defiance workings averaged 30% lead and 31 ounces of silver per ton. Some ore from the Defiance was reportedly assayed at 56% lead and 950 ounces of silver. Production data compiled by the US Bureau of Mines during WWII show the average recovery was 0.03 ounce gold, 8.7 ounces silver, 0.2% copper, and 7.3% lead. Since 1942, production of sulfide ore from the Darwin Mine exceeded that of oxide ore. The grade of oxide ore averaged 6% lead, 6% zinc, and 6 oz silver per ton. A considerable tonnage of high grade ore containing approximately 20-30% lead was produced and direct shipped from 1944-1952 (Hall and MacKevett, 1958). Average mill heads for the final years of operation (1970-1972) were 4.43 ounces silver, 3.16% lead, 5.54% zinc, 0.048% copper, and 0.005% gold (USGS, 2011).

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MAPS

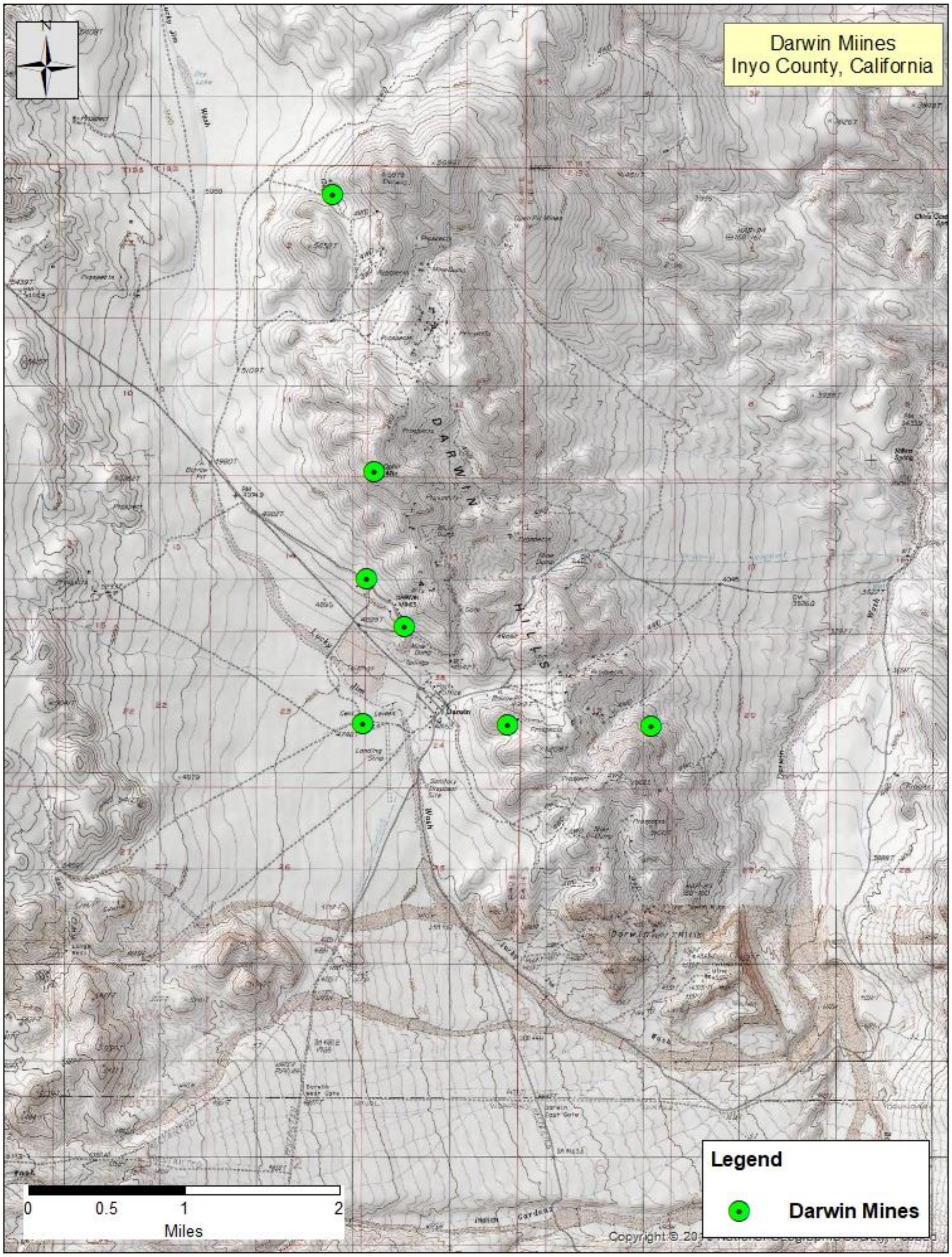


Figure 36. Regional topographic map of the Darwin Mining District and surrounding areas.

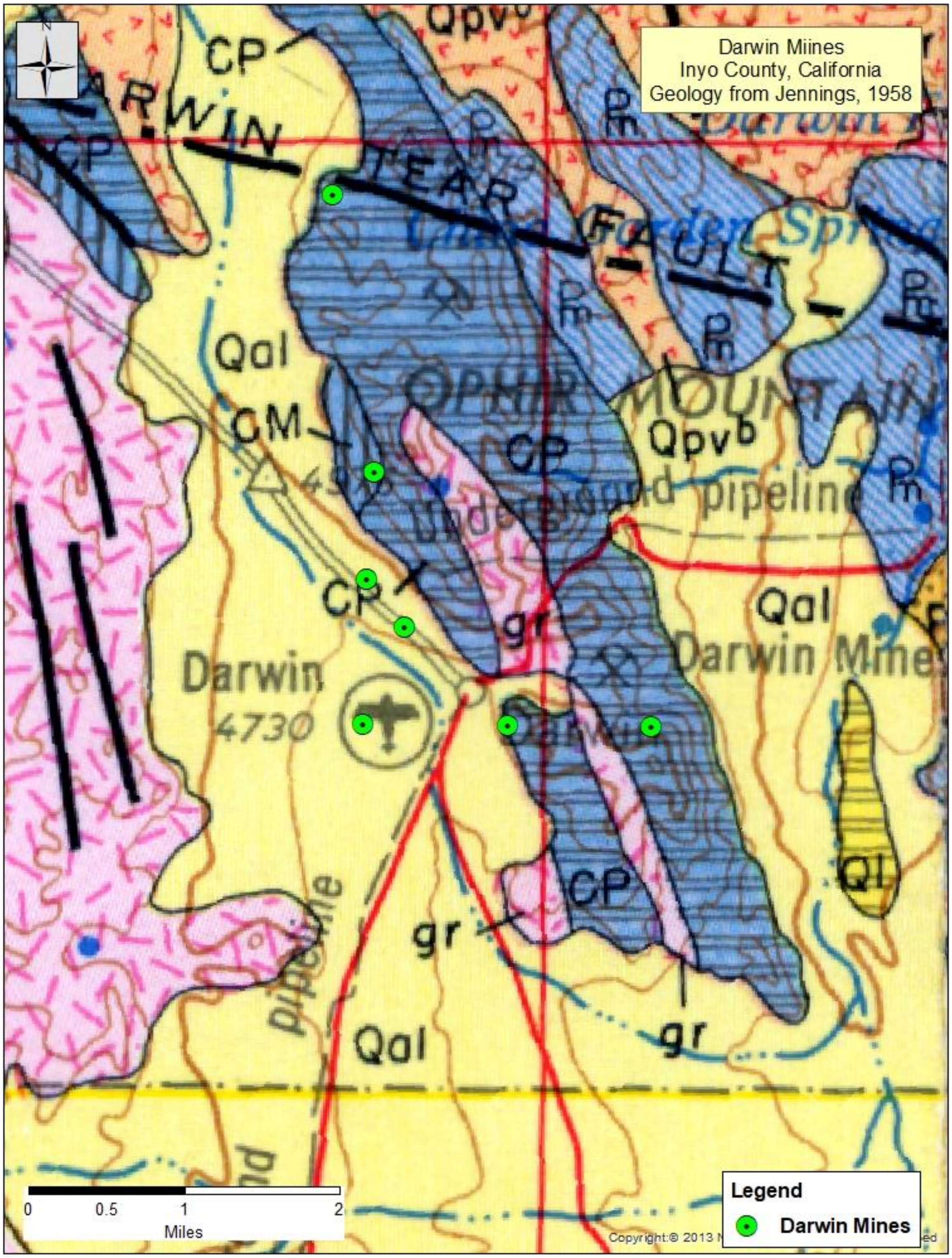


Figure 37. Regional geologic map of the Darwin Mining District and surrounding areas.

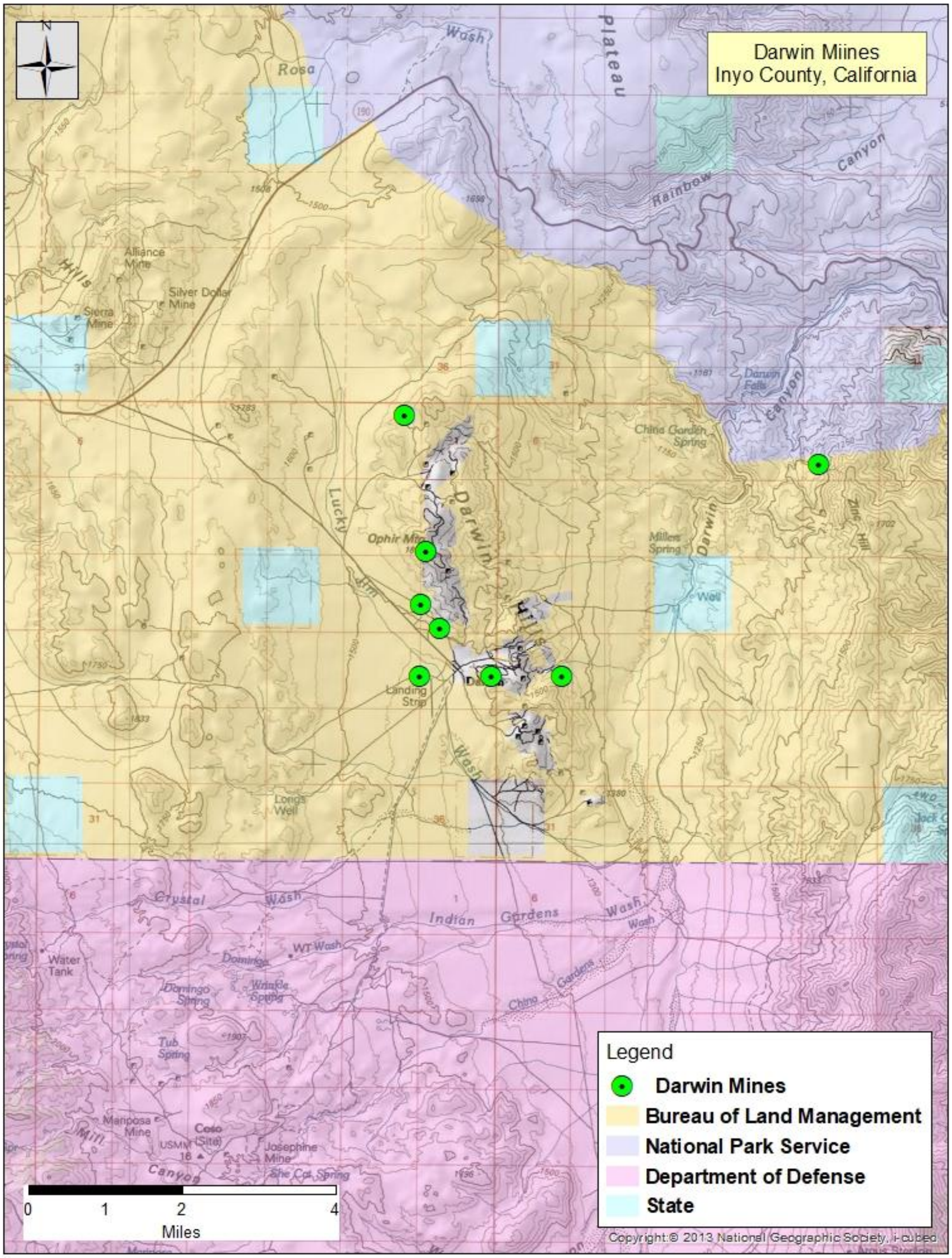


Figure 38. Regional land status map of the Darwin Mining District and surrounding areas.

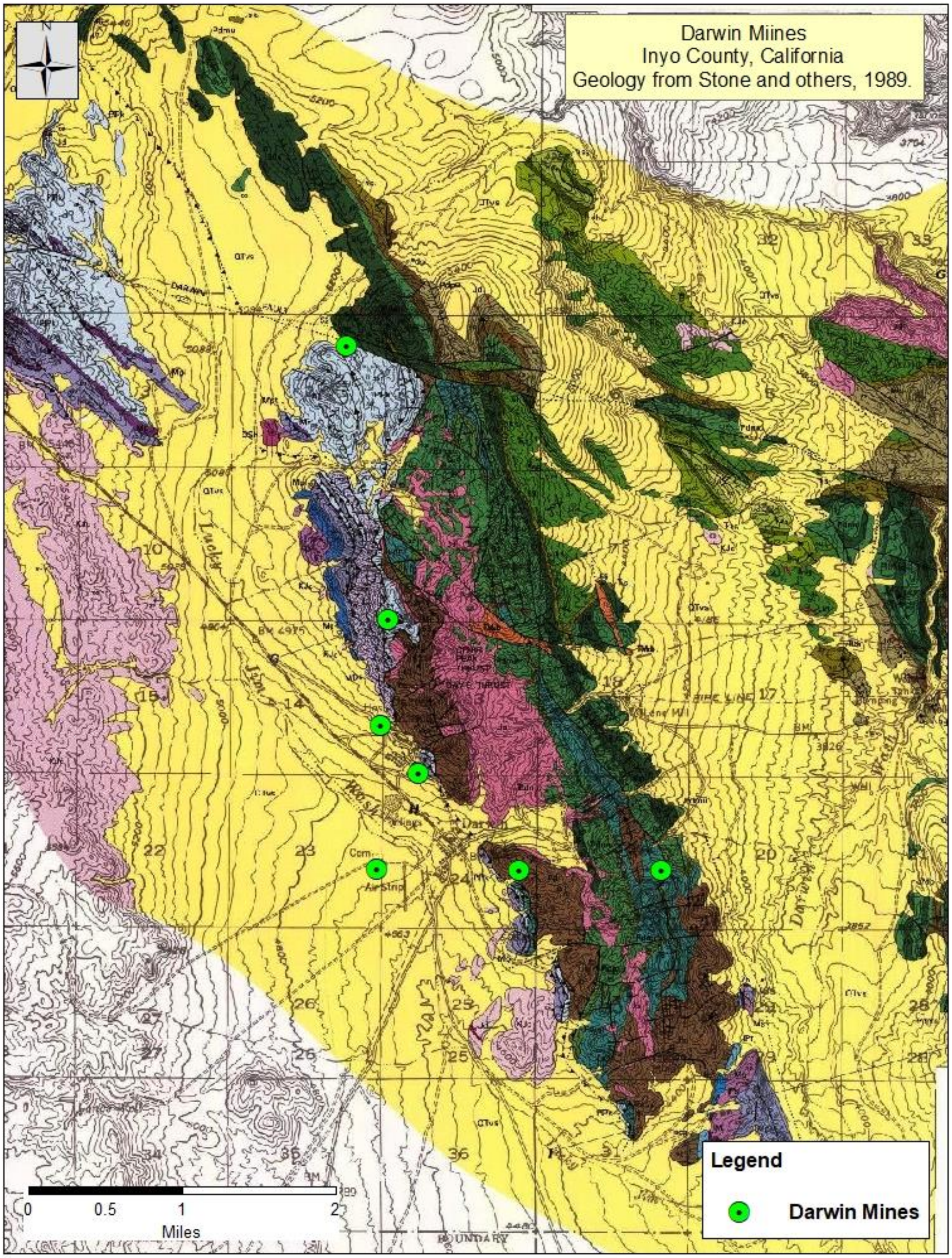


Figure 39. Area geologic map of the Darwin Mining District and surrounding areas.

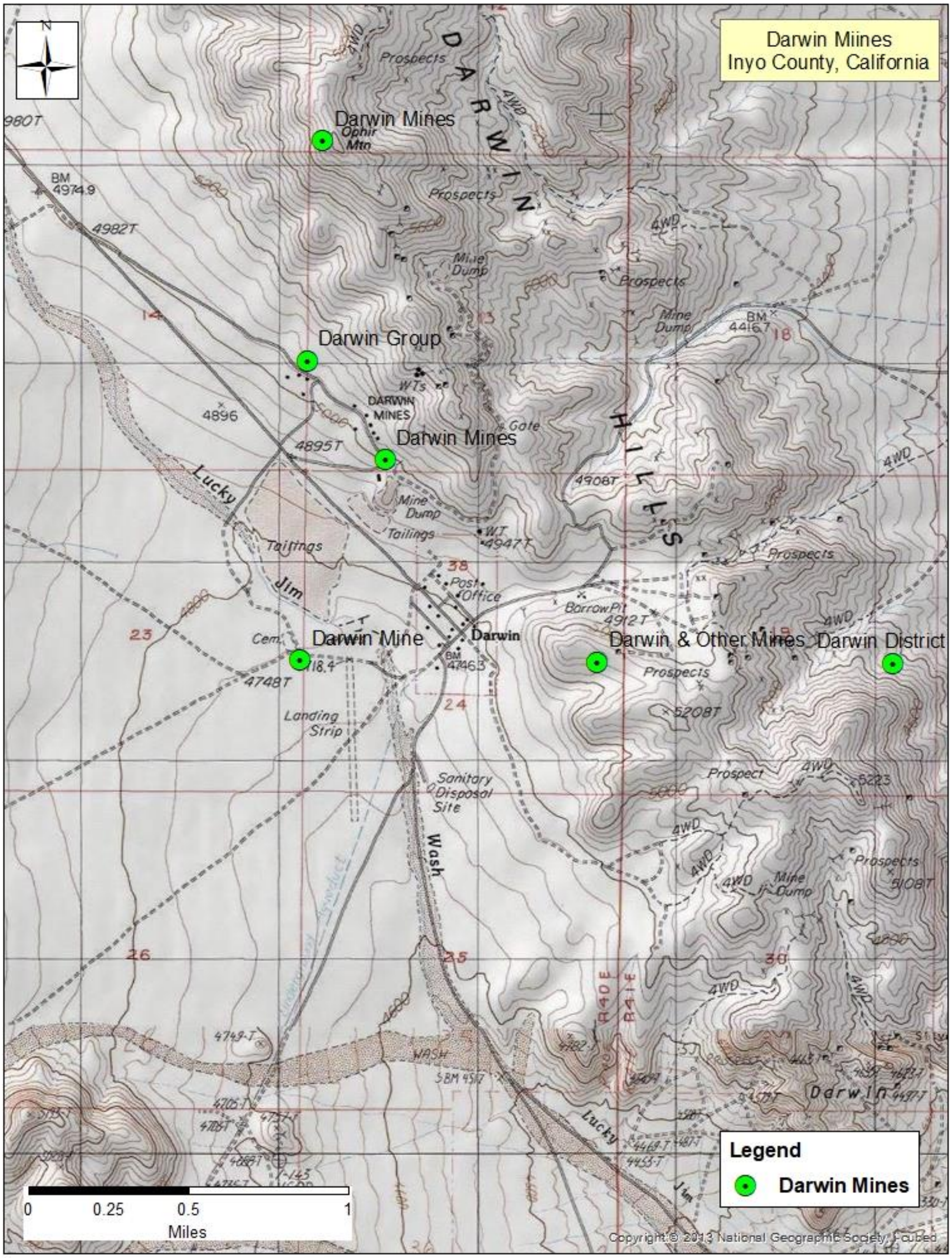
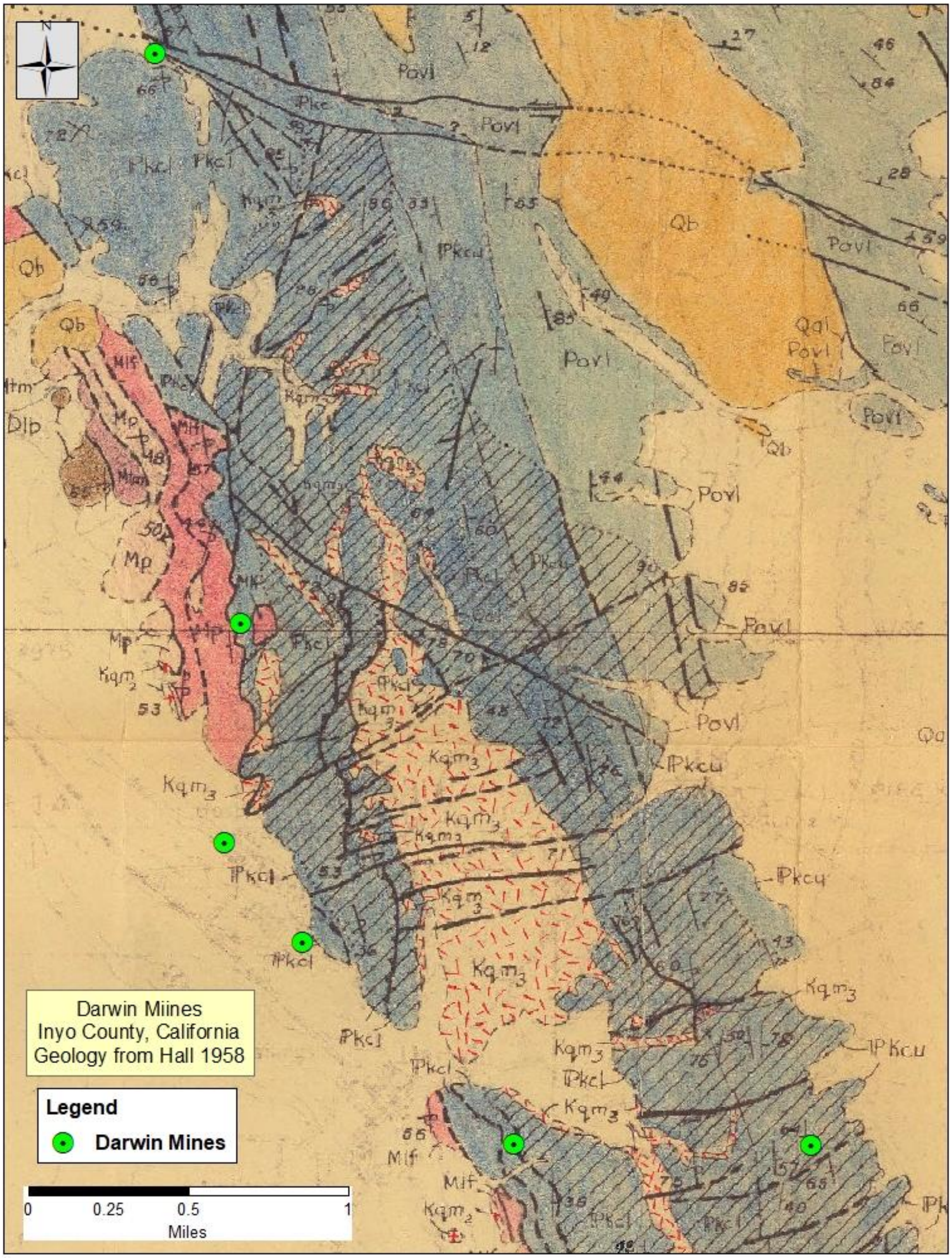


Figure 40. Area geologic map of the Darwin Mining District and surrounding areas scale 1:24,000


Darwin Miines
Inyo County, California
Geology from Hall 1958
Legend
Darwin Mines
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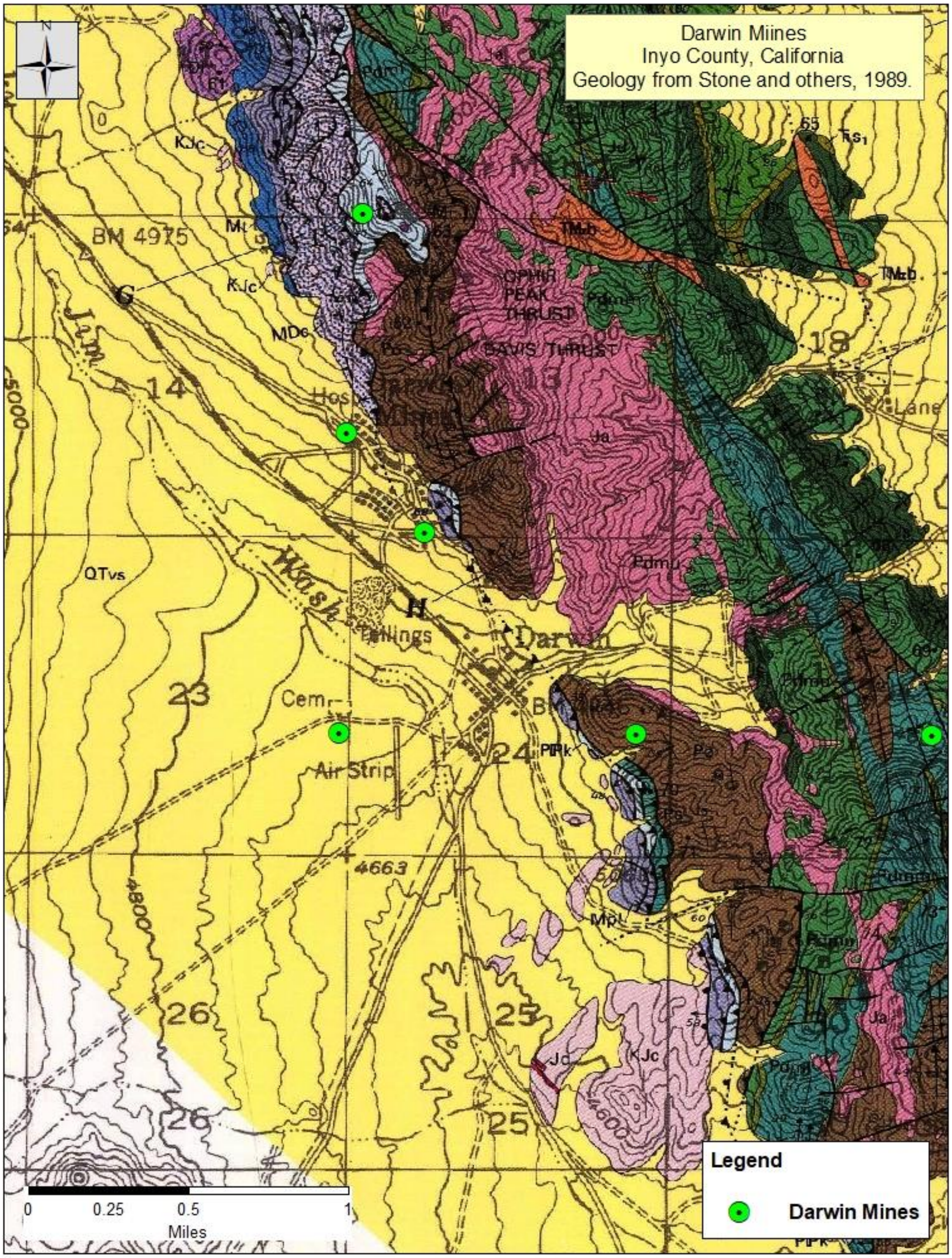

Figure 41. Geologic map of the Darwin Mining District and surrounding areas

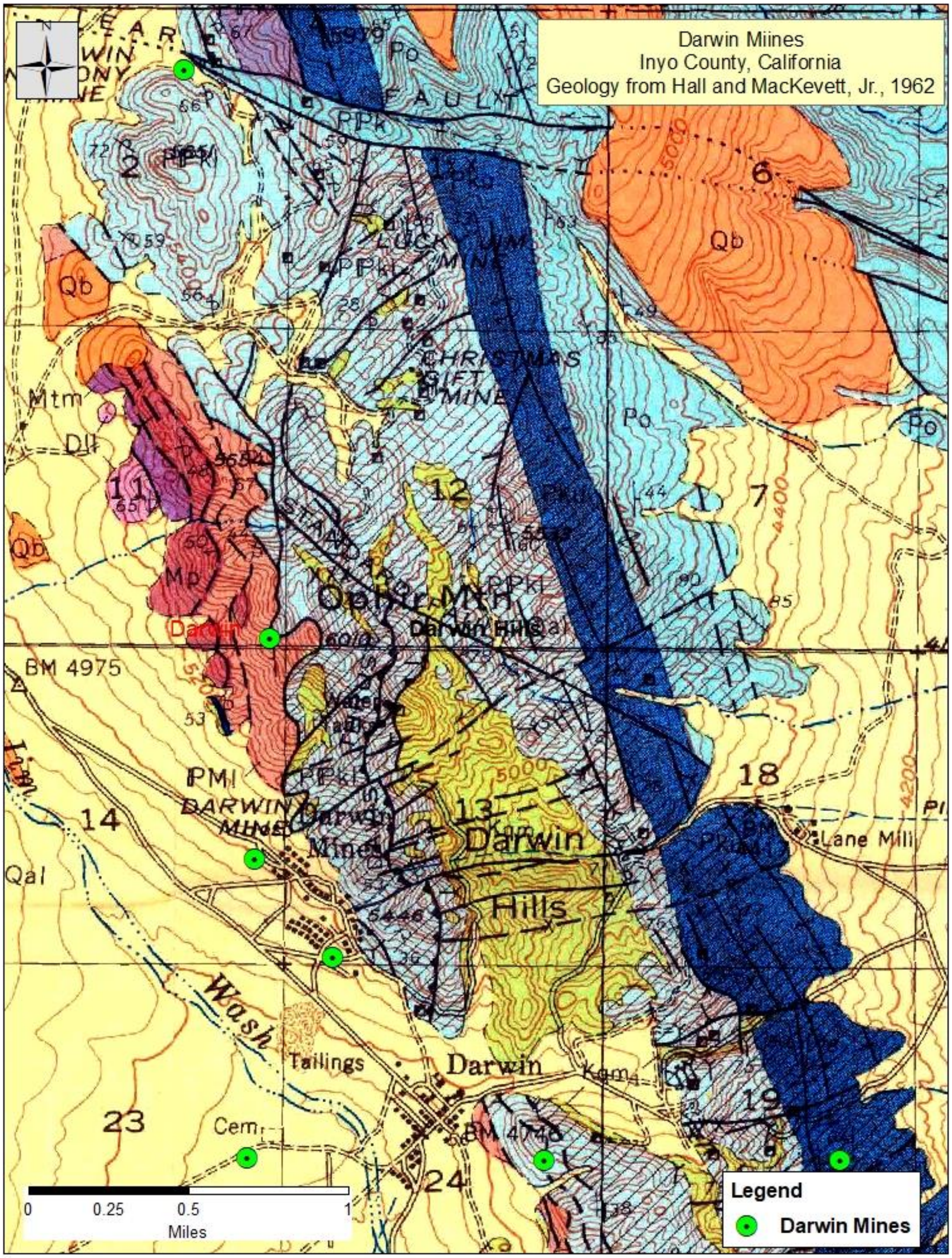

Figure 42. Geologic Map of the Darwin District and surrounding areas.

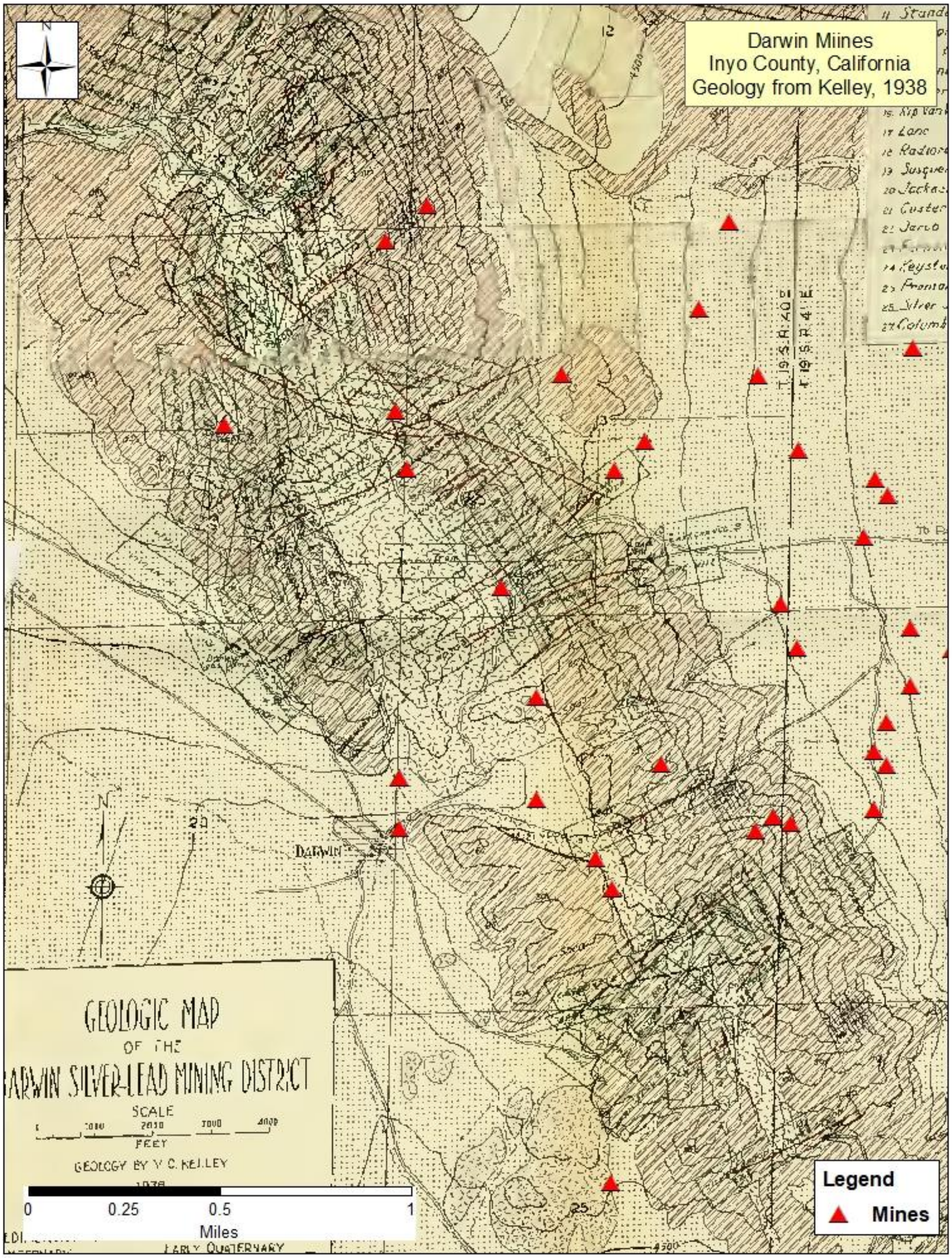

Figure 43. Area map of Darwin mines and surrounding areas with mining claims (Kelley, 1938)..

Figure 44. Aerial photograph of the Darwin Mining District and surrounding areas.

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Figure 45. Darwin Mill. From Hall and MacKevett, 1958, front cover. Photo by Mary Hill., 1957

Figure 46. From exploringusa.com. Accessed Oct. 13, 2022.

Figure 47. From westernmininghistory.com. Accessed Oct. 13, 2022.

Figure 48. From eofp.net. Accessed Oct. 13, 2022

Figure 49. From southwestrockhounding.org. Accessed Oct. 13, 2022

Figure 50. From pininterest.com. Accessed Oct. 13, 2022.

Figure 51. From legensofamerica.com. Accessed Oct. 13, 2022.

Figure 52. From blogspot.com. Accessed Oct. 13, 2022

Figure 53. From dronstagram.org. accessed Oct. 13, 2022.

Figure 54. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 55. From fourth-millinium.net. Accessed Oct. 13, 2022.

Figure 56. from owensvalleyhistory.com. Accessed Oct. 13, 2022.

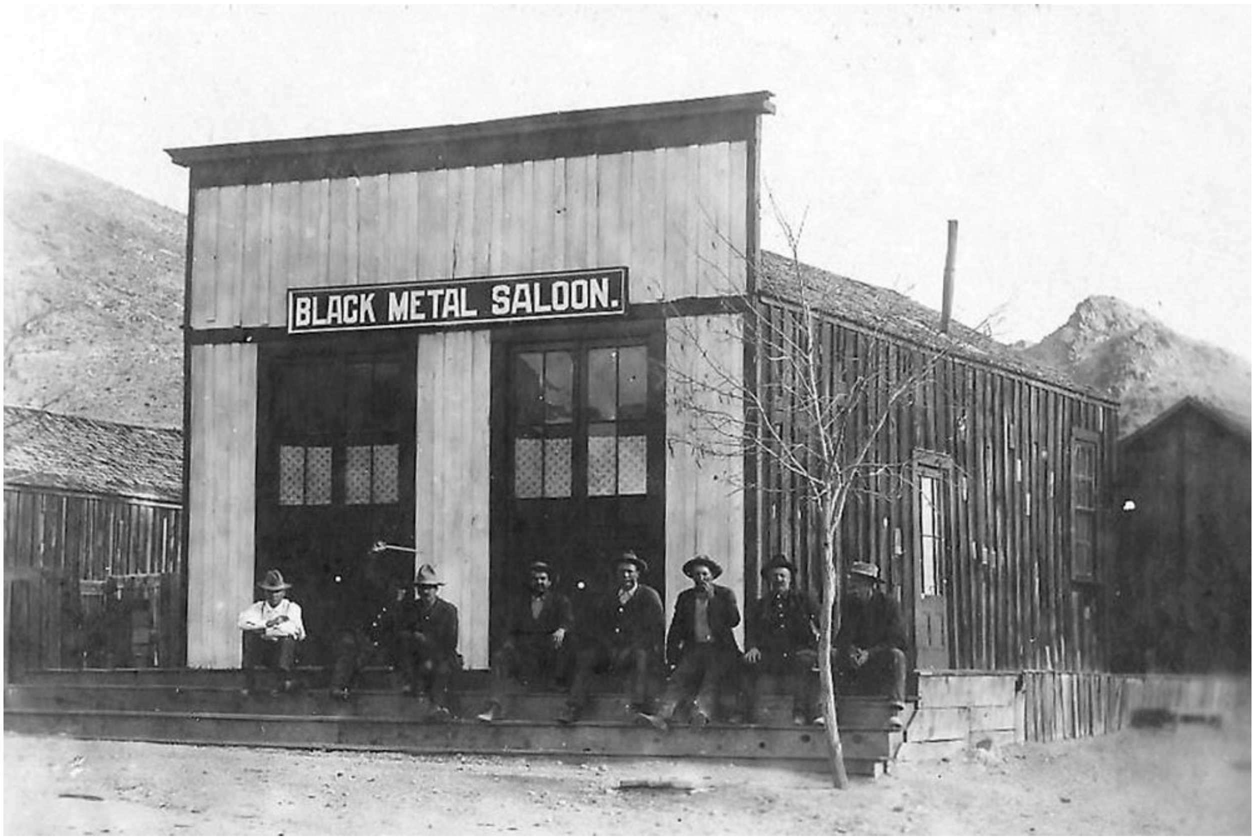

Figure 57. From pineinterest.com. Accessed Oct. 13, 2022.

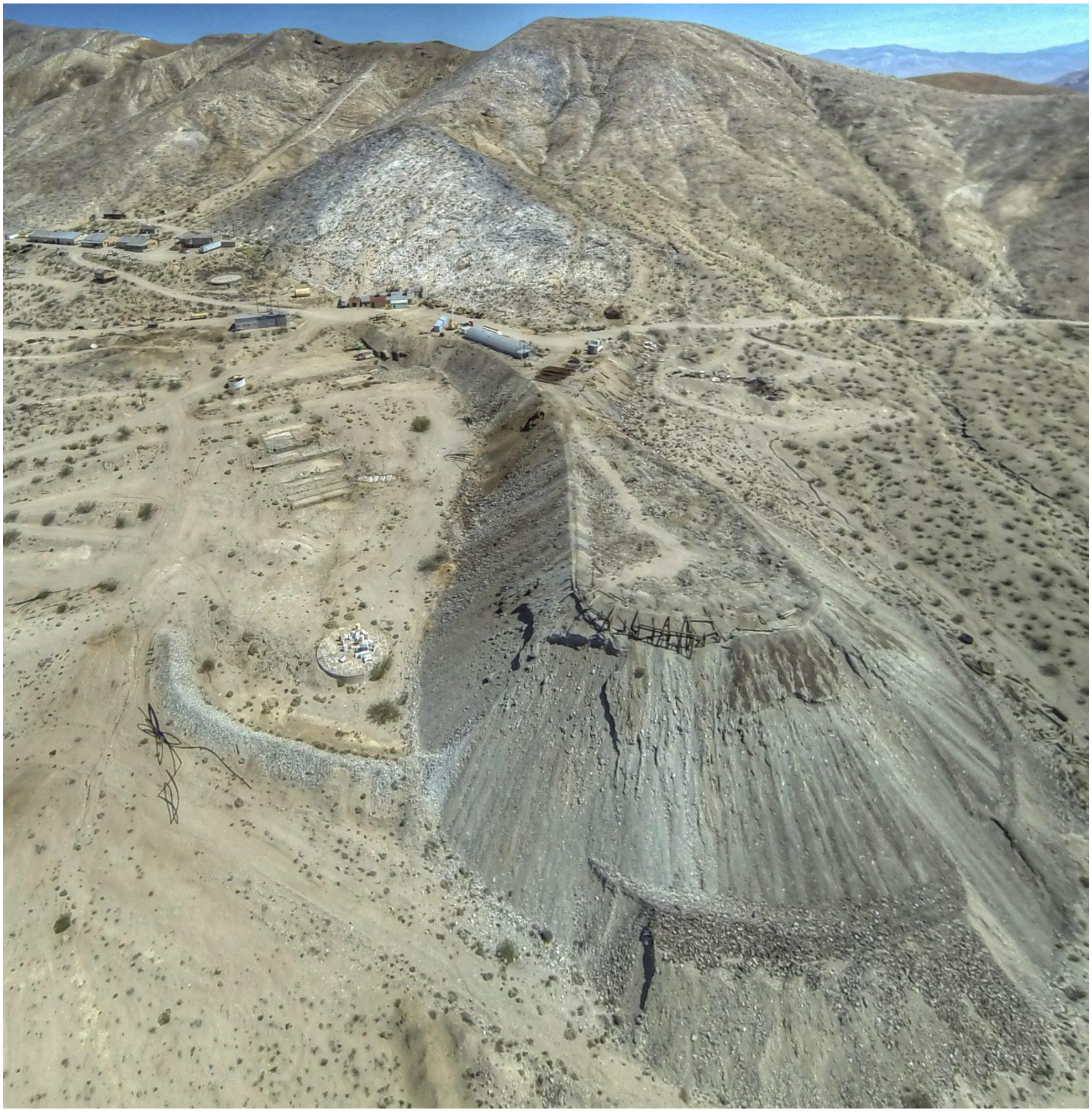

Figure 58. From dronstagram.org. Accessed Oct. 13, 2022.

Figure 59. From youtube.com. Accessed Oct. 13, 2022.

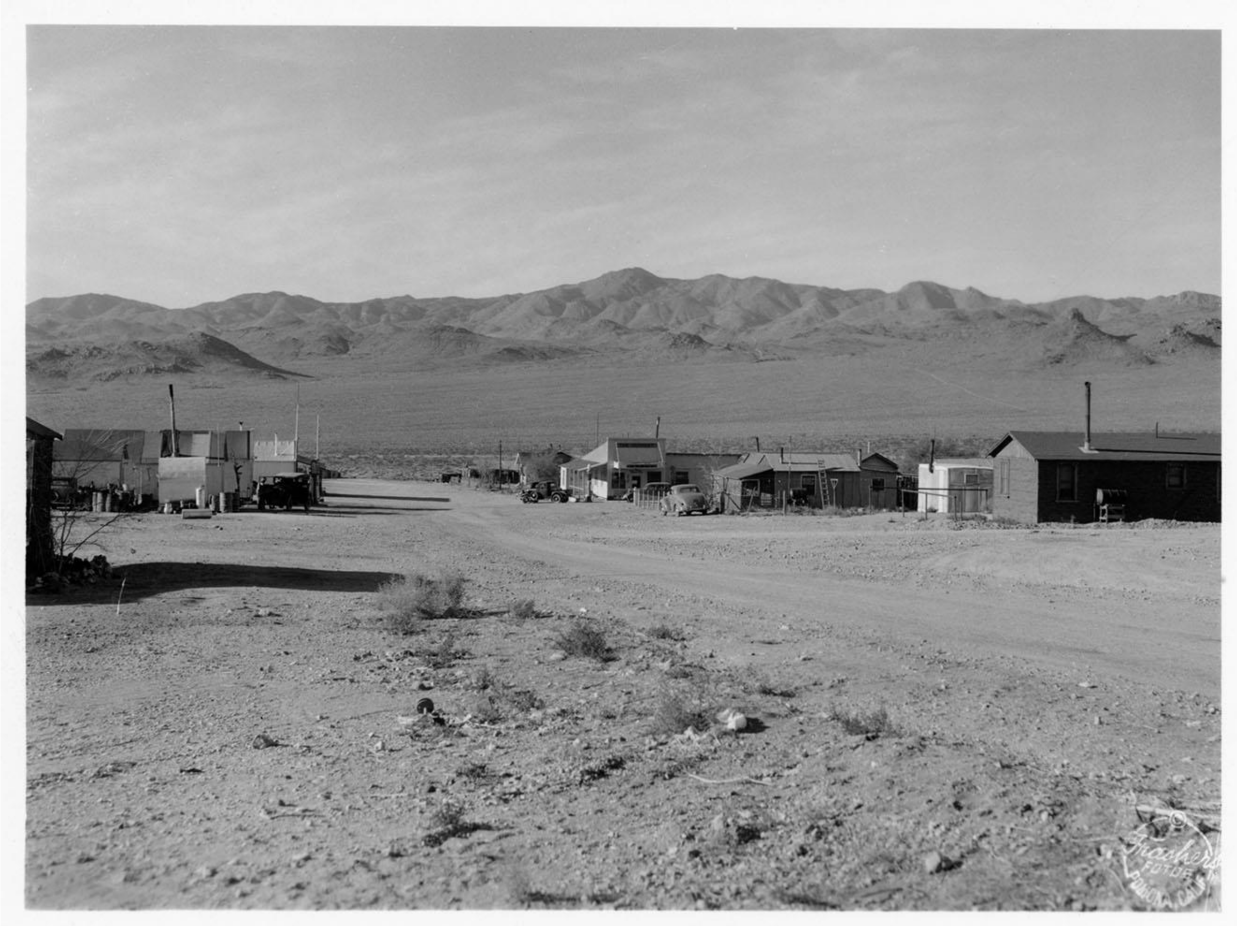

Figure 60. From owensvalleyhistory.com. accessed Oct. 13, 2022.

Figure 61. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

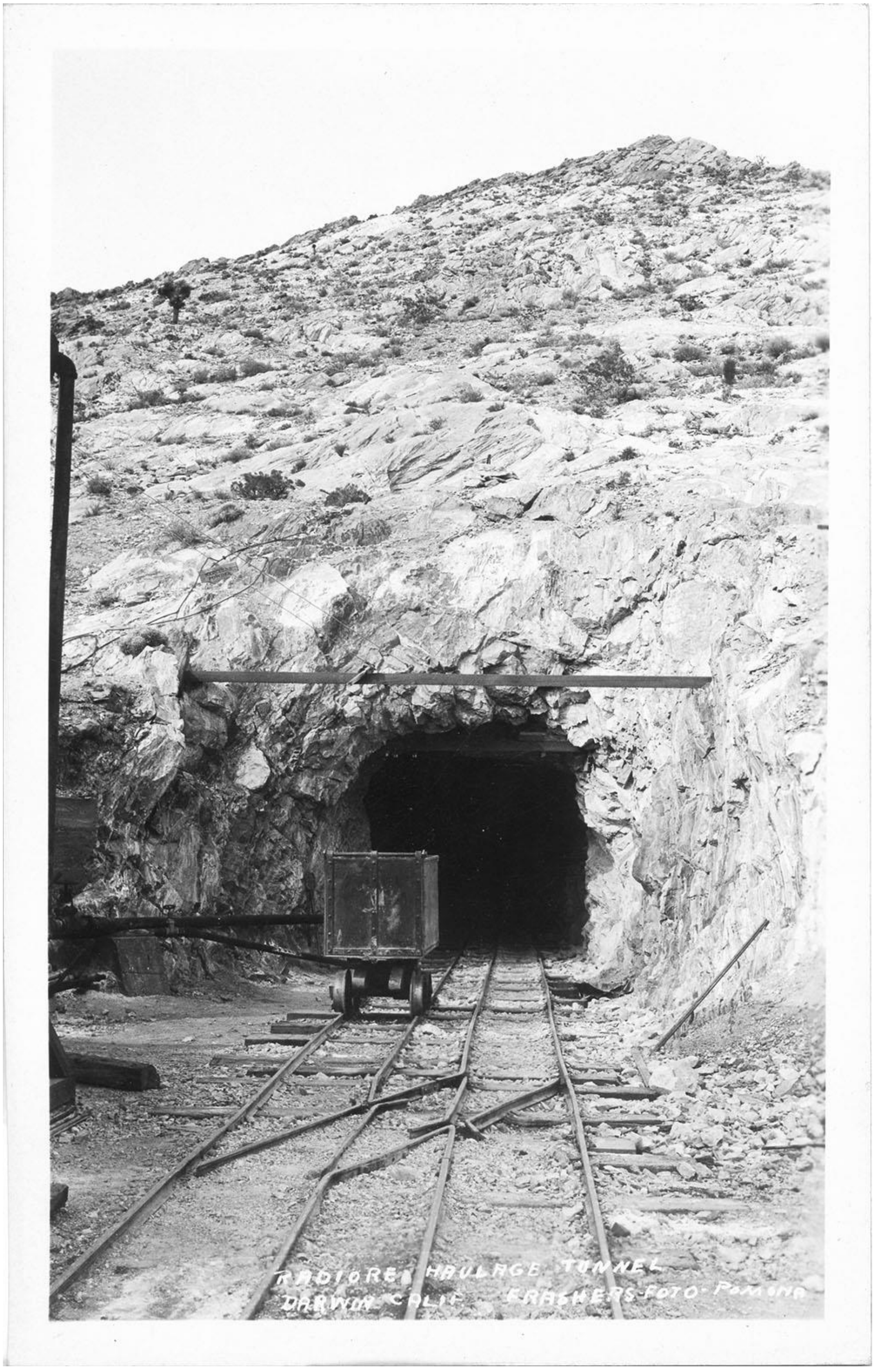

Figure 62. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

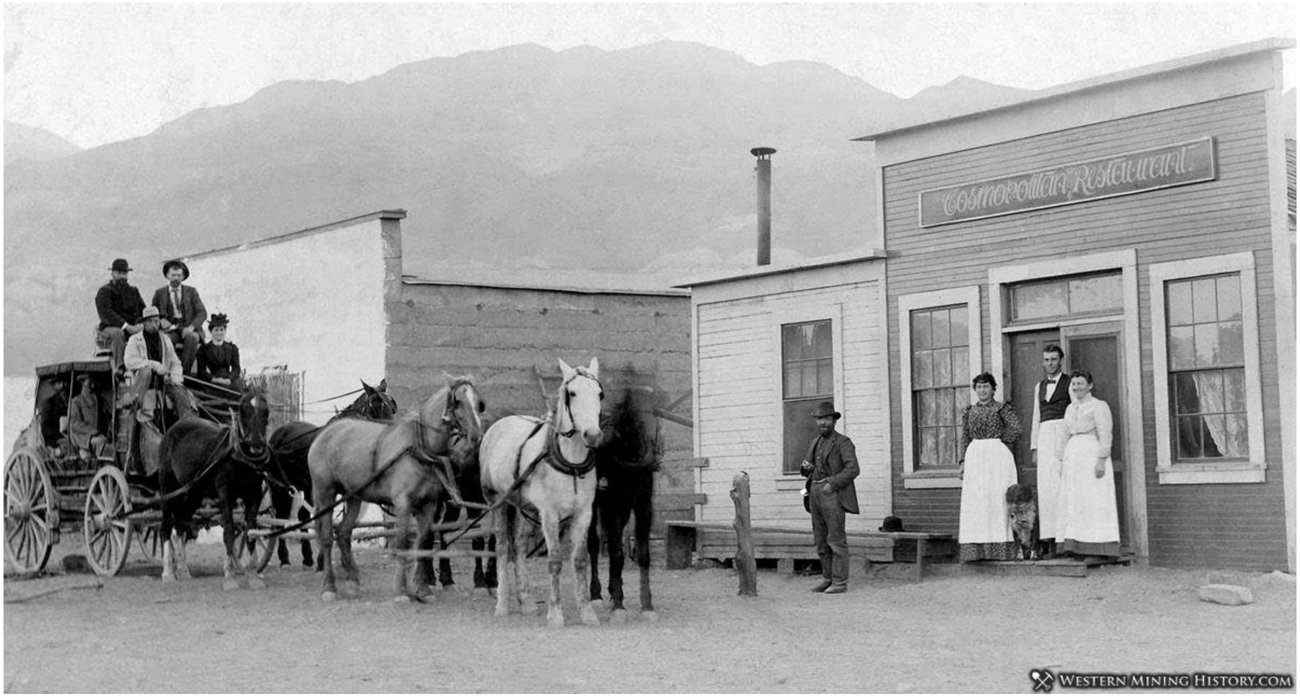

Figure 63. From westernmininighistory.com. Accessed Oct. 13, 2022.

Figure 64. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

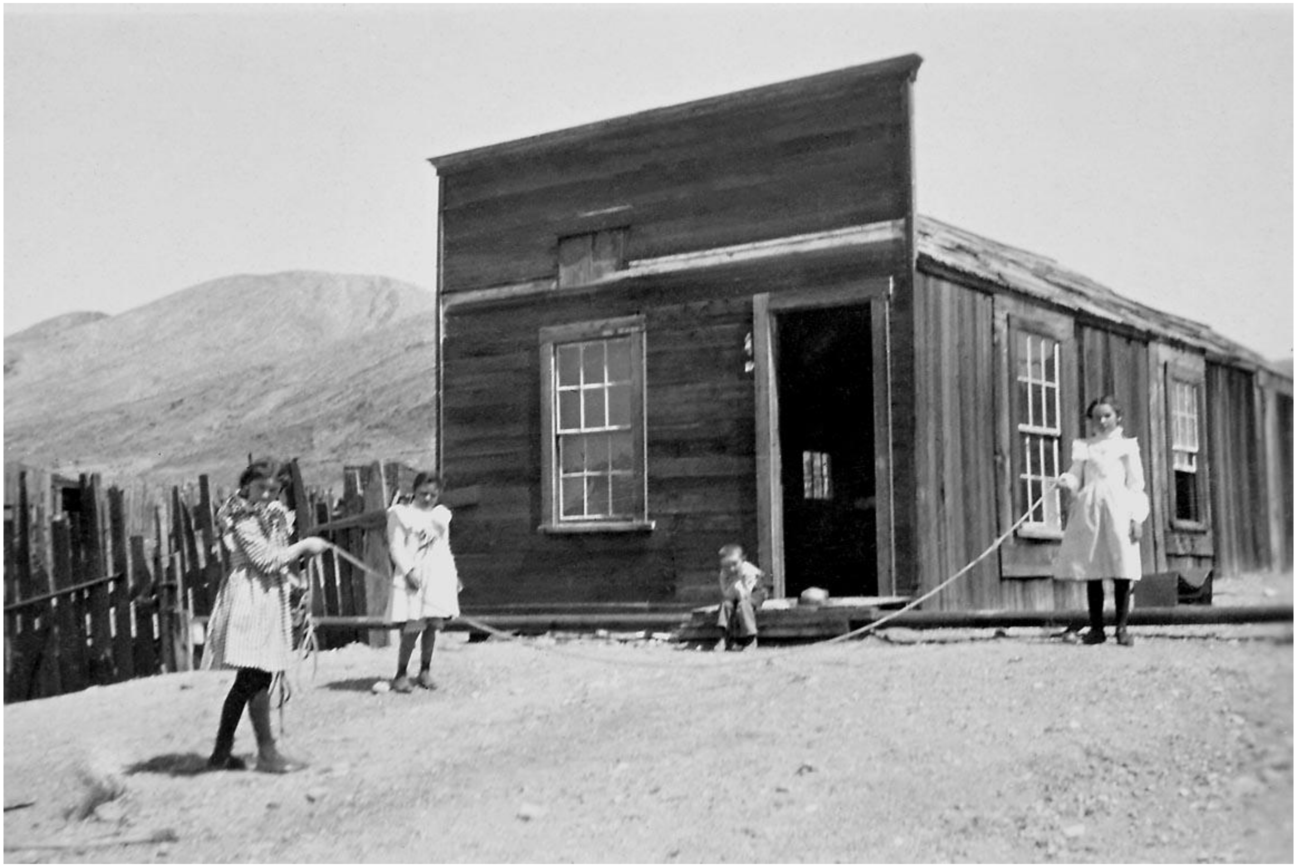

Figure 65. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 66. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 67. From youtube.com. Accessed Oct. 13, 2022.

Figure 68.From KCET.com. Accessed Oct. 13, 2022.

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Figure 69. From fineartsamerica.org. Accessed Oct. 13, 2022.

Figure 70. From flicker.net. Accessed Oct. 13, 2022.

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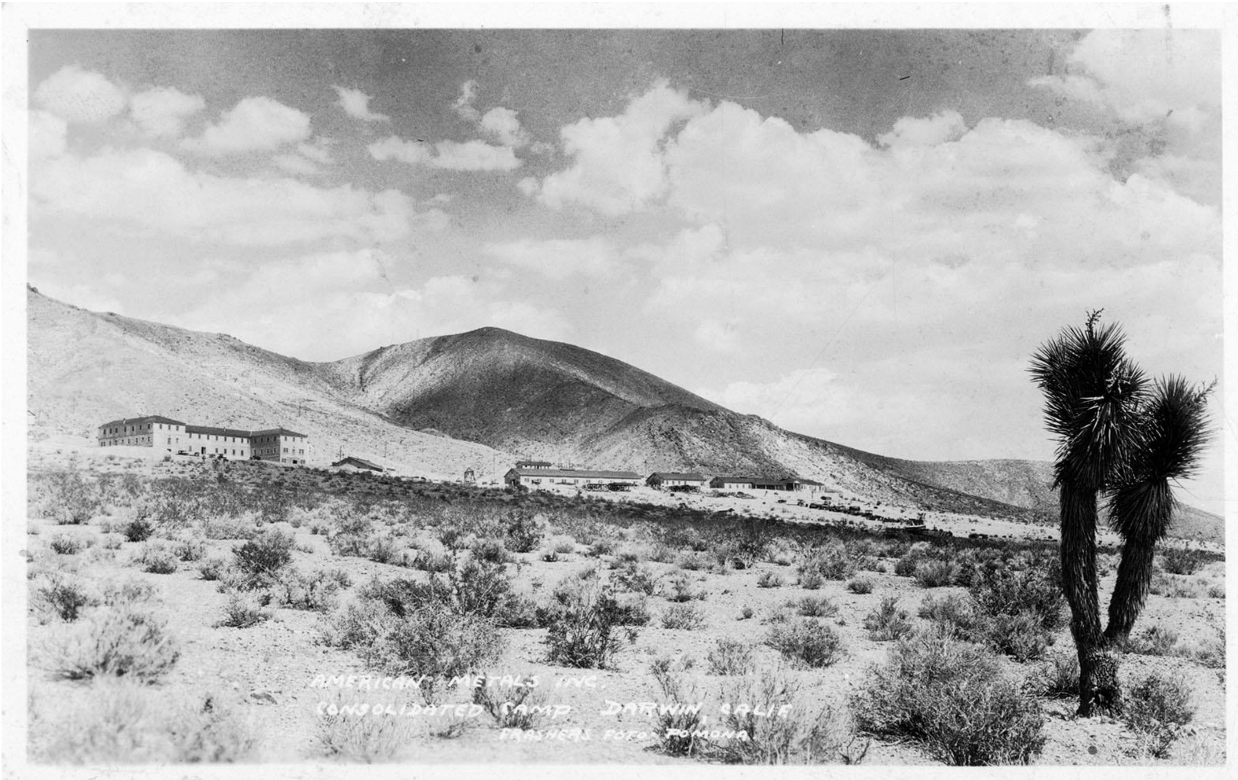

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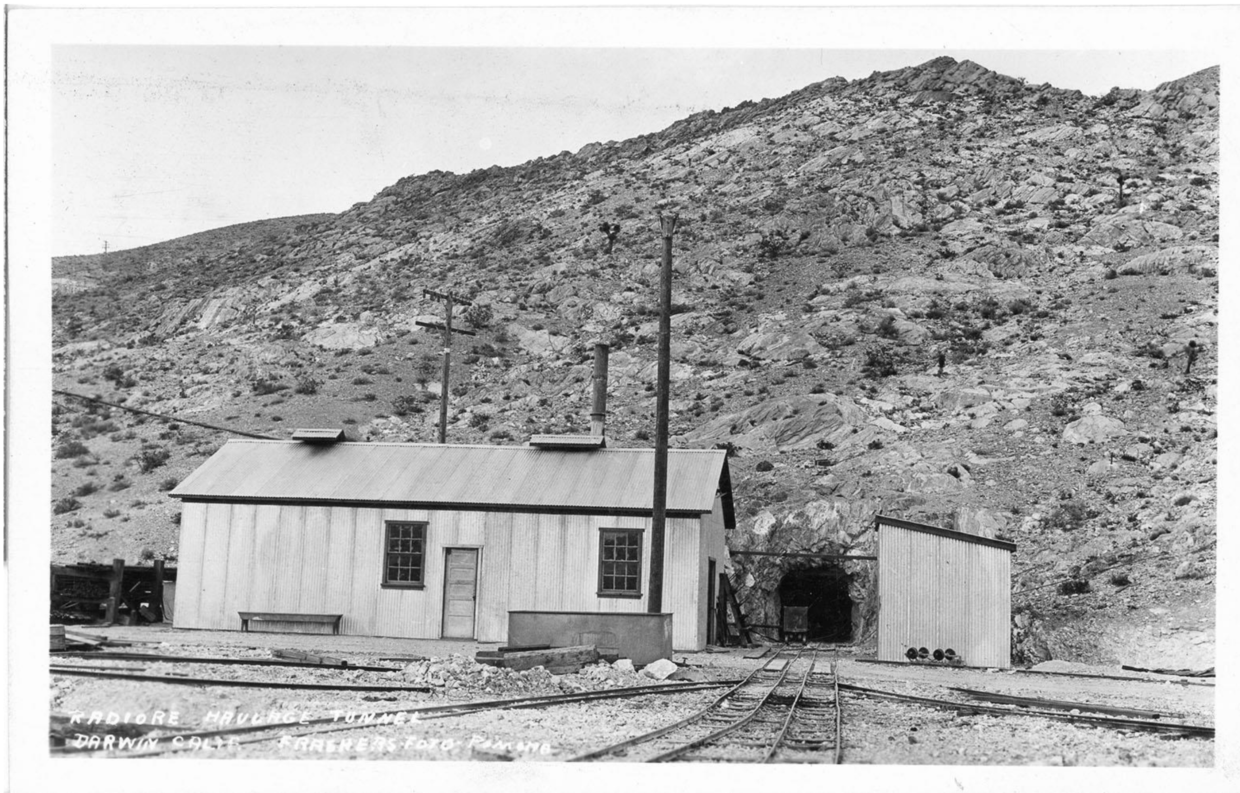

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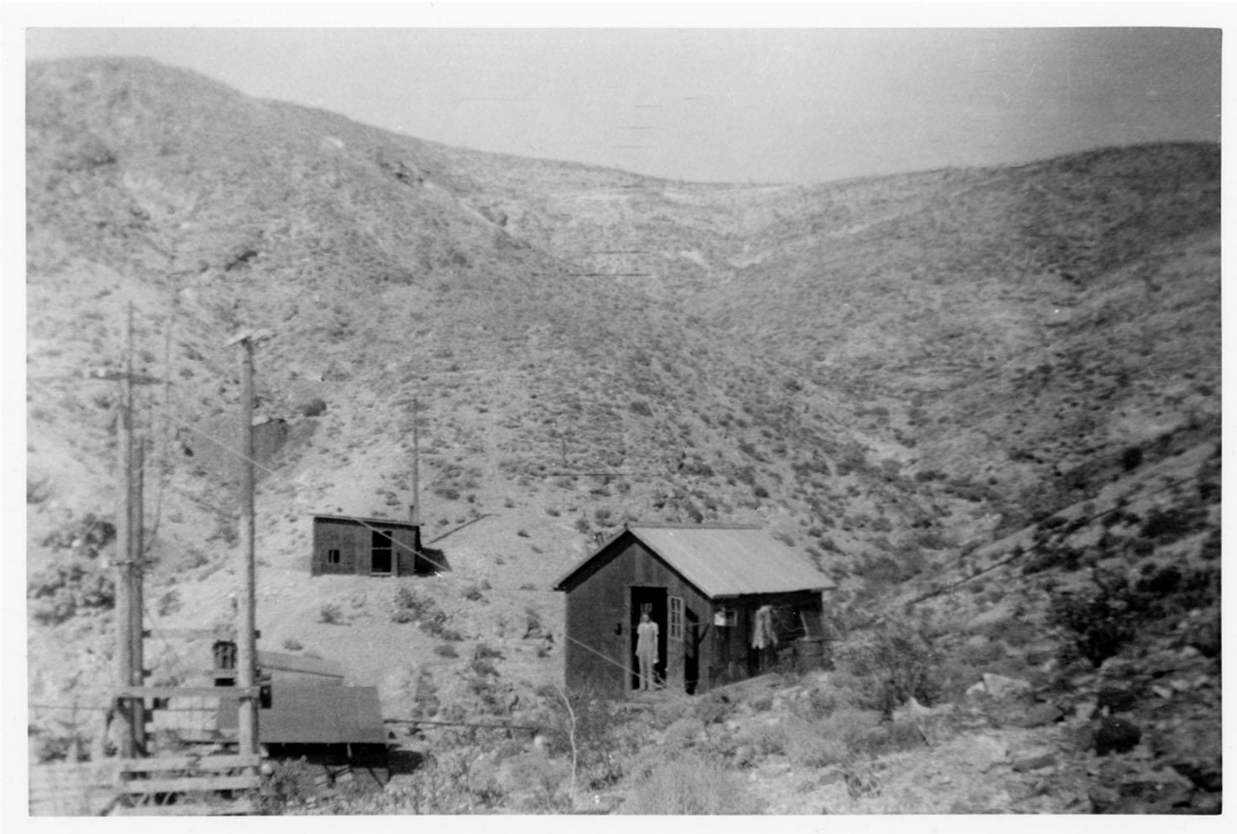

Figure 80. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

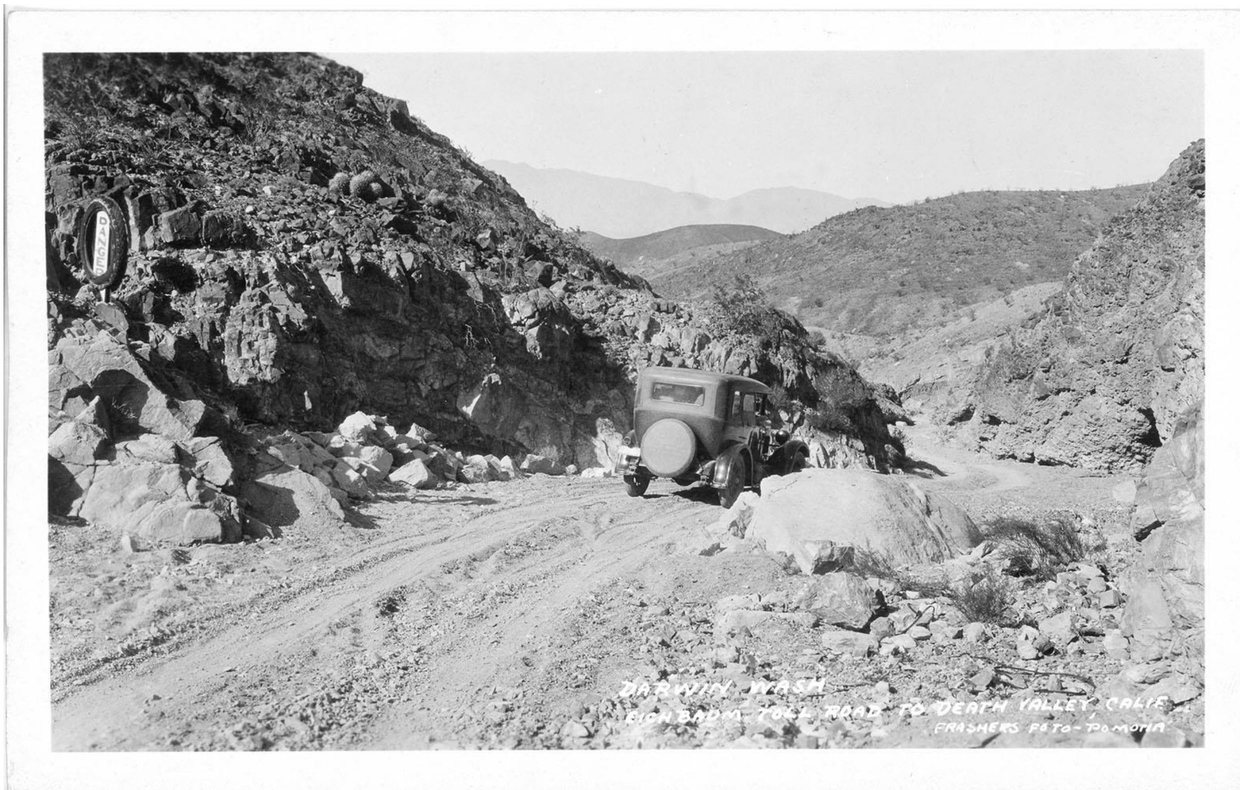

Figure 81. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 82. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 83. From owensvalleyhistory.com. Accessed Oct. 13, 2022

Figure 84. From owensvalleyhistory.com. Accessed Oct. 13, 2022.

Figure 85. Dawin Bunk Houses. By Gregg Wilkerson, 2003.

Figure 86.Dawin Mine Dumps, now eroded. By Gregg Wilkerson, 2003.

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Figure 90. Dawin house with small statue. By Gregg Wilkerson, 2003.

Figure 91. Dawin tram towers. By Gregg Wilkerson, 2003.

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01A: Geologic map of the Darwin Silver-Lead Mining District (Kelley, 1938, Plate VII)

01B: Geologic map of the Defiance-Independence Mine Group (Kelley, 1938, Plat VI)

01C: Geologic map of the Christmas Gift Claim (Kelley, 1938, Plate V)

APPENDIX

01A: Geologic map of the Darwin Silver-Lead Mining District (Kelley, 1938, Plate VII)

APPENDIX

01B: Geologic map of the Defiance-Independence Mine Group (Kelley, 1938, Plat VI)

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01C: Geologic map of the Christmas Gift Claim (Kelley, 1938, Plate V)