GEOLOGY AND ORE DEPOSITS OF A PART OF THE PANAMINT RANGE, CALIFORNIA.

A thesis by F. Mac Murphy presented in partial fulfillment of the requirements for the degree of Master of Science, California Institute of Technology, Pasadena, California

(1929)

CONTENTS.

CONTENTS.

CONTENTS.

CONTENTS

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS.

ILLUSTRATIONS

OUTLINE OF THE REPORT.

The Panamint Range is a normal basin-range tilted fault-block, uplifted probably in Tertiary time and rejuvenated by very complex recent faulting on the west. This great block is approximately 100 miles long, but the area covered by the reconnaissance geologic map embraces a tract of country in the southern portion of the range about 25 miles from north to south. The range occupies a commanding position, forming the west wall of Death Valley almost throughout its entire length and the east wall of the somewhat smaller, but very similar, Panamint Valley. The rocks consist of a great thickness of undifferentiated metamorphic complex, embracing schists, gneisses, and marble, predominantly of sedimentary origin, unjected by granitic rocks and cut by diabase dikes. These are overlain by less highly metamorphosed slaty schists and dolomitic limestones, separated by a nonconformity from a succession of rocks consisting largely of limestones, dolomites and schists. The age of the rocks is unknown, but is believed to range from pre-Cambrian to lower Paleozoic. Structure within the range is not entirely clear and that of certain rock masses is indeterminable. The older rocks on the west slope show a westward dip of the foliation, while the younger rocks forming the crest of the range and the Death Valley side, dip gently eastward. A general lenticular character of the older rocks is characteristic, and, in general, folding is of major importance. Deposits of gold, lead and antimony occur in various places in the range, but the silver-bearing quartz veins in the Panamint district are of chief interest. The latter occur principally in limestone, but also in schist, and are strong fissure veins of Mesozoic age.

PART 1. GENERAL FEATURES.

INTRODUCTION

FIELD WORK AND ACKNOWLEDGMENTS.

Field work was begun on the geology of the Panamint Range in October, 1926 and continued with but few interruptions until December of that year. About one month of this time was spent in detail geologic mapping by plane table on a scale of 1: 7,200 of the Panamint district, using for control a triangulation system which had previously been made by C. L. Tibbals and F. Percival, United States Deputy Mineral Surveyors. The latter work was undertaken in connection with a patent survey of the entire district for the Panamint Mining Company and included the establishment of about 35 bench marks from Wyoming Hill to Marvel Canyon. Only a few of these have been recorded on the map. (See Plate II, in pocket). The datum point, from which the levels of the Panamint map were reckoned, was an iron pipe driven into the ground near the portal of the Lewis tunnel and was assumed to be 7100 feet above sea level. This was made necessary in the absence of U. S. Geological Survey or U. S. Coast and Geodetic Survey bench marks in the immediate vicinity. It is believed that the assumed elevation does not differ more than 100 feet from the actual elevation with sea level datum. The district was visited again in June, 1927, and a topographic map on the above scale, covering an area approximately 2½ square miles, was undertaken, employing the usual transit and stadia method. Mr. A. P. Patterson was engaged as transit man while the author acted as rodman. The geologic mapping was in part extended and numerous checks with the plane table survey begun the year before, were made from time to time. An extension of the control system further to the north was made necessary. Six weeks were taken up with topographic surveying, while the major part of the time until September was spent in completing the plane table geologic mapping and in surveying and studying several of the more important accessible mines in the district.

A reconnaissance study of the southern part of the ra range was begun during the latter part of the summer using a base enlarged from the U. S. Geological Survey's maps of the Ballarat, Searles Lake and Furnace Creek quadrangles. The reconnaissance study was continued in June, 1928, when 6 weeks was spent in the area. A few weeks spent in 1929 complete the field work on this part of the Panamint Range.

The writer desires to thank his many friends in the South Park mining district, particularly Messrs. Christopher Wicht, James S. Cleburne, G. R. McFadden, and J. V. Lehigh, for numerous courtesies extended, and to express his appreciation of the active interest shown during the progress of the work. The study was undertaken at the suggestion of L. F. Noble. I am indebted to F. L. Ransome, John P. Buwalda, and J. E. Wolff for their kindness in accompanying me on short field trips to the region, for suggestions concerning

many of the problems involved in the work, and for a critical reading of the manuscript of this report. Further appreciation is due Rene Engel for petrologic assistance and advice.

SITUATION.

The area covered by the reconnaissance geologic

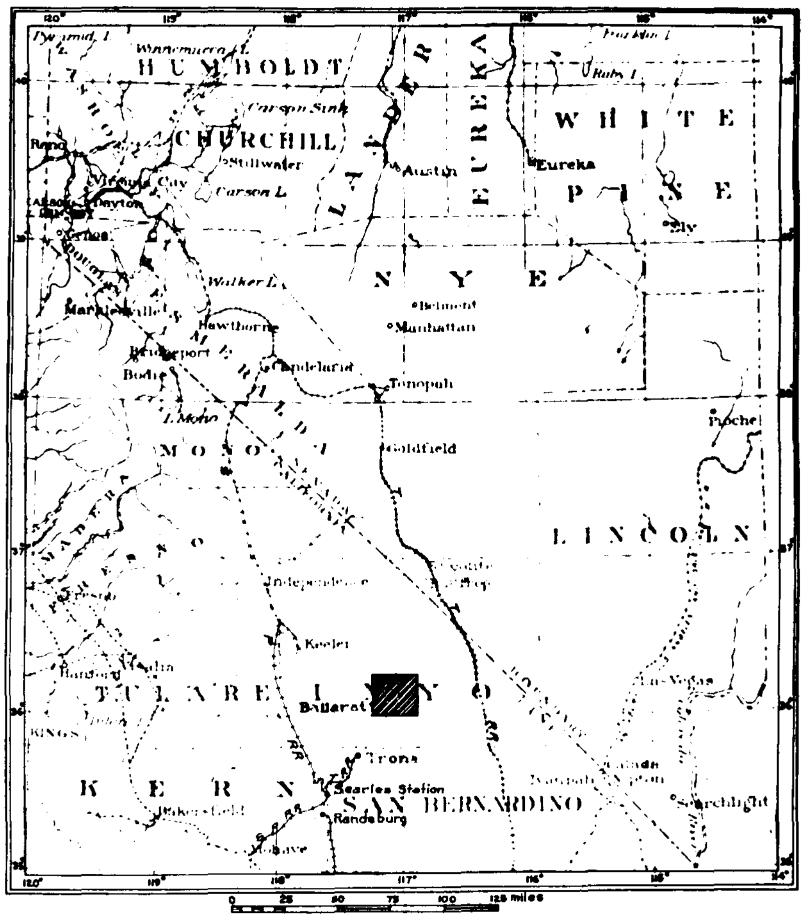


FIG. 1.- INDEX MAP SHOWING LOCATION OF AREA COVERED IN THIS REPORT (SHADED AREA)

map (Plate 1, in pocket) embracing the tract of country that forms the particular subject of this investigation is approximately 21 miles from north to south and 24 miles wide and lies between parallels 36°00' and 36°16' and meridians 116°53' and 117°15'. It is situated in Inyo county, southeastern California and its general geographic position is shown on the index map (fig. 1). The area thus outlined contains about 500 square miles and includes a portion of the southern part of the Panamint Range.

The almost deserted town of Ballarat, the only settlement in the area, is located at the foot of the range in Panamint Valley. A fairly good desert road, 25 miles in length, connects Ballarat with Trona the nearest railroad point, crossing the extreme northern end of the Slate Range. A standard gauge line of the Trona Railway Company, owned and controlled by the American Potash and Chemical Corporation affords daily connection at Searles Station with the Owens Valley branch of the Southern Pacific Railroad. This railroad extends by standard gauge to Owenyo from whence it proceeds northerly as a narrow gauge, through Owens Valley, to Mina and other Nevada points. Southerly from Searles Station, the branch connects with the main line of the Southern Pacific at Mohave. From Mohave, direct connections are made north to Los Angeles and San Pedro. The eastern side of the Panamint Range is considerably more inaccessible, the nearest railroad points being Ryan, Shoshone, and Beatty. Ryan is situated in the Funeral Mountains, and is reached by the Death Valley Railroad, a narrow gauge line from Death Valley Junction. This railroad is operated by the Pacific Coast Borax Company. Shoshone is a station on the Tonopah and Tidewater Railroad in Amargosa Valley. Beatty is a station on the Tonopah and Tidewater Railroad about 33 miles by road from Bungalow City. Aside from a few canyon roads on the west side of the range, the accessibility of the higher parts is confined to a few rather unsatisfactory trails.

PREVIOUS WORK.

The following publications deal with the geology of this portion of California but few of them specifically relate to that part of the Panamint Range discussed in this report. In fact very few studies have been made of the geology of the Panamint Range, aside from brief sketches by Ball, Spurr and Fairbanks as noted below.

1874. Stetefeldt, C. A., Report on Panamint mining district to the U. S. Commissioner of Min. Statistics, Eng. and Mining Jour., Oct. 7th., 1874. Or -- Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1875, pp. 33-39, 1877. This report, written by a mining engineer, contains a sketch of the geology and ore deposits of the Panamint district and a general description of the geology of Surprise Canyon.

1894. Fairbanks, H. W., Preliminary report on the mineral deposits of Inyo, Mono, and Alpine counties; California State Mining Bureau Twelfth Ann. Rept., pp.472-478, 1894. The report is an outgrowth of a several months reconnaissance trip in this part of California.

Referring to the Panamint Range it is stated that - "Limestone, quartzite, slate, and mica schist form the predominating rocks". Brief mention is made of the silver deposits in the Panamint and Wild Rose districts.

1896. Fairbanks, H. W., Notes on the geology of eastern California: Am. Geol., Vol. 17, pp. 63-74, 1896. The paper adds very little to our knowledge of the geology of the Panamint Range and merely mentions the occurrence of granite, gneiss and liparite.

1896. Fairbanks, H. W., Mineral deposits of eastern California; Am. Geol., Vol. 17, pp. 144-158, 1896. The paper includes some very brief notes on the mineral deposits of the Panamint Range.

1905. Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 200-205, 1905. The work embodies the results of reconnaissance trips in south-central Nevada and eastern California of the country lying about 25 miles north of 35° north latitude made by Spurr and Weeks in 1899 and 1900, together with abstracts of the work of the earlier pioneer surveys. The reconnaissance geologic map includes the entire Panamint Range, but that portion of the report dealing with the range is largely a compilation.

1907. Ball, S. H., A geologic reconnaissance of southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, pp. 201-212, 1907. Contains the results of a reconnaissance survey of the area lying between $36^\circ30'$ and 38° north latitude and $116^\circ00'$ and $117^\circ30'$ west longitude. The work is much more detailed than Spurr's reconnaissance, but the southern boundary of the region covered lies 16 miles north of the area studied for this report. Some 11 pages are devoted to descriptions of the general and economic geology of the northern part of the Panamint Range.

1914. Gale, H. S., Salines in the Owens, Searles, and Panamint basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 251-323, 1914. An account, pages 312-323, of the existence of an ancient lake in Panamint basin with a few notes on the geologic structure.

1926. Noble, L. F., The San Andreas Rift and some other active faults in the desert region of southeastern California, Carnegie Institution Year Book No. 25, pp. 415-428, 1925-1926. Pages 425 to 428 deals with a general description and interesting features of the fault which forms the escarpment along the east side of Death Valley - the Death Valley fault; and that which forms a similar escarpment along the east side of Panamint Valley - the Panamint Valley fault.

1927. Davis, W. M., The rifts of southern California, Am. Jour. Sci., 5th. Ser., 13, pp. 57-72, 1927. A general paper on some of the major faults of California in which mention is made of a few significant features of the Panamint Valley and Death Valley faults.

CLIMATE, VEGETATION AND ANIMAL LIFE.

In consequence of the considerable difference in altitude there is a corresponding variation in both climate and flora between Panamint Valley and Death Valley on the one hand, and those of the Panamint Range on the other. The distinction ranges from those exemplified by the comparatively well watered crest of the range, with its substantial timber growths, to the arid valleys with their scant growth of typical desert plants.

In the valleys the air is relatively dry throughout the year, the winters are moderately cold with occasional light flurries of snow, and the period from June until October is usually oppressively hot, both day and night. The mean summer temperature for Death Valley is about 96° Fahrenheit. In 1913 the United States Weather Bureau station at Furnace Creek (Greenland) Ranch, altitude 178 feet below sea level, recorded a shade temperature of 134° Fahrenheit. This is the highest officially reported natural shade temperature in the world. The mean winter temperature, as registered over a period of many years at the Furnace Creek Ranch, is about 60° Fahrenheit. Over a long period, the annual average precipitation for Death Valley is about 1.5 inches, but it is approximately twice that amount in Panamint Valley. In occasional years the precipitation which largely occurs during the winter months is less than one inch.

The prevailing weather in the range is similar to that of desert ranges generally. Owing to the high altitude Spring is late and Fall is early. In the upper reaches of the Panamint Range, the winters are moderately cold; summer days are warm and the nights delightfully cool. Generally there is a marked variation in temperatures between summer and winter, and day and night, on the higher parts of the range. It would be extremely difficult to estimate the precipitation in any considerable part of the Panamint Range, but it is of course very largely in excess of the precipitation in the adjacent valleys. The heaviest precipitation is along the crest line where considerable snow falls during a normal winter, making traveling exceedingly hazardous and difficult. The snow line rarely falls below an elevation of 6500 feet, although there are occasional exceptions. The traveled roads through the canyons have been rendered impassable and largely swept away upon many occasions during the last half century. This results from cloudbursts or local excessively heavy rains which have occurred both during the summer and winter.

The vegetation of the Panamint Range is typical of that of the higher desert ranges generally. For the most part bushes, shrubs and trees are evenly spaces, considerable distances apart (as though they had been planted by hand) to conform to the supply of ground water. Distribution in the main is dependent upon the amount of moisture for a given altitude and exposure. Three distinct zones of plant growth can be made out in the range. The lowest occupies the valleys on either side of the range and the desiccated slopes up to an altitude of about 6500 feet. The sparse vegetation of this zone includes Cresote Bush (Larrea tridentata var. glutinosa) while along living streams in the canyons one finds Mesquite (Prosopis juliflora var. glandulosa), Fremont Cottonwood (Populus fremontii), willow and Desert Grape (Vitis girdiana), The second zone is the lower half of the conifer belt and extends to an altitude of about 8500 feet. It is marked by the Desert Juniper (Juniperus californica var. utahensis) and the Pinon Pine (Pinus cembroides var. monophylla) while common shrubs occurring in this region are: Mexican Tea (Ephedra viridis), Cliff Rose (Cowania mexicana var. stansburiana), and Common Sagebush (Artemisia tridentata). The third zone is the upper conifer belt and extends from 8500 feet to the highest peaks and ridges of the range. The important representatives include the Limber Pine (Pinus flexilis) and the Hickory Pine (Pinus aristata) with an occasional Sierra Juniper (Juniperus occidentalis). Other shrubs are: Desert-sweet (Chamaebariaria millifolium), Small-leaf Mahogany (Cercocarpus intricatus) while Mountain Mahogany (Cercocarpus ledifolius) is conspicuous as a shrub or tree.

Animals are not abundant in the area under consideration. The predatory animals, with the exception of a few coyotes, are not often seen. A few coveys of Mountain or California quail live in the better watered portions of the range and fortunately are not hunted during any season of the year. Both wild and domesticated burros are rather plentiful but the presence of Mountain sheep is of particular interest in that they are probably more plentiful in the Panamint Range than in any other range in the southwest.

SPRINGS.

There are a large number of springs in the range and most of them have been located during the mapping. The volume of water from most of these increases considerably in the Fall of the year.

BROAD TOPOGRAPHIC FEATURES.

The Panamint Range is about 100 miles long and extends from latitude 35°35' N. to 37°00' N. The line of demarcation between the Last Chance Range on the north and the Panamint Range on the south is not sharply defined. On the south the range terminates at Leach trough. Near the south end the broad low Wingate Pass, filled with desert wash, separates the range proper from Brown Mountain. Its dominant trend is N-NW by S-SE but the portion of the range covered in this report substantially parallels the meridian. Its width in the area studied is about 18 miles. The range occupies a commanding position, forming the west wall of Death Valley throughout almost its entire length and the east wall of the somewhat smaller but very similar Panamint Valley.

"The Panamint Range was named for the Panamint tribe of Indians, who belonged to the Shoshonian family, and lived around the Panamint Valley".* The name Panamint was applied by John Lilliard of the Darwin French party - a group of prospectors from San Francisco, who in May, 1860, set out in search of a mythical silver deposit, the Gunsight lead" which was believed to have been discovered by the emigrant party that was lost in Death Valley in 1850.** According to a newspaper account by Dr. S. G. George appearing in the Panamint News of March 9th., 1875, a second party set out in the fall of 1860 to search for the lost lode. The highest peak in the range was named by them Telescope Peak. It had been priviously known as "Chiombe" in the native vernacular.

The maxium elevation of the crest of the range is attained within the area studied and averages approximately

---

* Sanchez, Nellie Van De Grift, Spanish and Indian place names of California, San Francisco, Bruce Brough printer, 1922.

** California Min. Bureau Third Ann. Rept., p. 33, 1883.

9500 feet above sea level. The rather sharp crested ridge gradually culminates in Telescope Peak, altitude 11,045 feet. It enjoys a commanding eminence. From its summit magnificient views of Death and Panamint valleys as well as Sierra Nevada, San Gabriel Mountains and other peaks in the four states of California, Nevada, Utah and Arizona may be had. The full relief is attained within a short horizontal distance. From the sea level contour line in Death Valley to the summit of Telescope Peak the average grade is 1000 feet to a mile for a horizontal distance of 11 miles. This sheer rise is perhaps only exceeded in North America by that of San Jacinto Peak in the San Jacinto Mountains. While the east slope of the range is therefore extremely abrupt and unusually rugged, it is yet somewhat less precipitous than that of the west flank. Its axis marks the center of the range for that portion studied in this report.

The range is scored by a considerable number of great canyons, spaced at fairly equal intervals and extending generally normal to the trend of the range. These are separated by long rather even-crested ridges as shown in Plate IV, B, which presents a southerly view taken from the summit of Telescope Peak. The canyons are notably steep and rugged, with walls often rising sheer for hundreds of feet. In some instances they are actually vertical. This is especially true of canyons on the west versant of the range. Locally they are mere slits in bedrock. A particularly impressive example is found in Surprise

Canyon about 2 miles from the entrance. Here the canyon narrows to a bedrock gorge some 15 to 25 feet wide for a distance of about a half a mile where the canyon has been cut through hard massive aplite. The feature is known locally as the Narrows. This is true of several canyons in the range where they enter any hard massive rock, notably granite-gneiss. A few of them contain falls. The grade of the canyons on both versants of the range average generally from 15% to 18%. A second period of faulting has, however, resulted in a steepening of the canyon grades in their central portions on the west versant of the range and the resulting rejuvenation of their streams, while a uniformly decreasing slope maintains throughout their length on the east versant or backslope of the range.

A debris fan containing large boulders at the mouth of Surprise Canyon, for example, shows the torrential character of the water course, which ordinarily is entirely dry, and is striking testimony of the power of a stream that is active for perhaps a few hours each year. This fact has made the building and upkeep of canyon roads difficult. Parts of the road up Surprise Canyon have required rebuilding three times during my stay in the region. Striking examples of fresh boulders weighing upwards of 50 ton can be found many miles from their sources. Not unlikely mudflows have contributed their part of the upbuilding of the fans although it is not believed that they were a paramount agent of canyon erosion in the Panamint Range.

A mudflow of considerable magnitude occurred in Surprise Canyon late in the afternoon of July 26th., 1917, occasioned by a cloudburst near the head of Woodpecker Canyon, a north branch of Surprise Canyon. According to the only living witness of the flood the water was 40 feet deep in the Narrows of the canyon and the road was lowered 12 feet below its original level for a distance of about a mile. Like many of the mudflows described by Blackwelder,* the Surprise Canyon flow is characterized by preponderance of boulders. (See Plate V, A). Its recency is indicated by absence of stream lines on its surface. It could not be ascertained how far the large fresh boulders incorporated within the mudflow were carried at the time of the flood and it seems more probable, in view of their well rounded condition, to assume that at least the larger number of them were not transported directly from their sources at the time of the flood. However, trees up to 2½ feet in diameter were moved many miles down the canyon and were completely or partially buried in the layer of mud and rocks which covered the former surface of the fan. At the time of the flood the flow of mud and rocks was estimated to have reached a maximum thickness of 4 feet and the present lobate layer of bouldery mud is 2 feet thick at its margin

---

*Blackwelder, Eliot, Mudflow as a geologic agent in Semiarid Mountains: Bull. of the Geological Society of America, Vol.39, pp. 465-484, 1928.

and covers roughly 10% of the present fan area. Cutting by streams in the canyon below the mudflow surface varies widely from place to place and reaches a probable maximum of 15 feet. How much of this figure represents dissection by water immediately after the flow of mud and rocks, can not of course be estimated but it may have been considerable. Subsequent rains would as a result be underloaded, and cutting could go on at a more rapid rate below the mud flow surface.

On the east side of the range the boundary between rock in place and valley fill is irregular, in marked contrast to the sharp lines of demarcation on the west front of the range. Between the remarkably level floor of Death Valley and the base of the range is a barren belt of alluvial wash, which averages about 4 miles wide and attains a height of approximately 2000 feet above the valley floor. It marks a continuous alluvial apron very similar to, but on a grander scale than that of the east front of the Argus Range to the west. It reaches its greatest development in that part of the range included within the area represented by Plate 1, and is less marked in the northern part of the range. Moreover, it is in striking contrast to the bold exceedingly rugged escarpments on the west flanks of the Panamint Range and that of the Black Mountains to the east with their isolated small alluvial cones built up at intervals along the west fronts of these ranges. Also, the highly decomposed granitic rocks of the Death Valley fans contrasts sharply with the fresh material of the Panamint Valley fans.

An old erosion surface is preserved in this part of the Panamint Range, as has previously been noted by Ball for the northern part of the range. Ball* further mentions the existence of similar old topographic forms on the Kawich, Amargosa and Belted ranges. Ferguson** found a similar mature topography on the Toquima Range. Meinzer* reported similar topographic forms on the Toyabe Range and Buwalda-* described the occurrence of an early old-age topography on Cedar Mountain. Physiographically, the Panamint Range was reduced by long-continued erosion to mature topographic forms and the upper reaches of many of the canyons are characterized by gently rounded slopes and well graded stream channels. In the southern part of the range the greatest development of this land surface is represented by the peculiar depressions known as South Park and Middle Park, while similar mature topography characterizes the large area north of Wildrose Canyon. The Parks, lying at an elevation

* Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, pp. 16-17, 119, 161, 202, 1907.

**Ferguson, H. G., Geology and ore deposits of the Manhattan district, Nevada: U. S. Geol. Survey Bull. 723, pp. 61-62, 1924.

* Meinzer, O. E., Ground water in Big Smoky Valley, Nevada: U. S. Geol. Survey Water-Supply Paper 375, p. 90, 1915.

-* Buwalda, J. P., Tertiary mammal beds in west-central Nevada: California Univ. Dept. Geology Bull., Vol. 8, pp. 358-359, 1914.

of nearly 6500 feet, drain west through South Park and Middle Park canyons. In the country north of Wildrose Canyon, the drainage divide lies somethat south of the center of the area. The country south of the divide drains into Wildrose Canyon and Panamint Valley while that north of the divide drains through Emigrant Canyon into Death Valley. The upper part of Wildrose Canyon, (Plate VI,A), is typical of this late mature land surface. Although vestiges of mature topography are everywhere present on the western slope of the Panamint Range, the belt varies considerably in width and in degree of topographic development. The transition from youth to more mature forms is at times very abrupt as in the case of Wildrose Canyon, South Park and Middle Park: whereas in the case of Surprise Canyon, for example, the change takes place gradually for a distance of a mile or more. It is believed that this is due, in part at least, to the difference in the amount of vertical component of uplift which the western face of the range has suffered in comparatively recent time. As a direct consequence of this fact, the streams in many of the canyons have not had opportunity to cut back into the older land surface as far in some instances, as in others. Owing to the absence of Tertiary volcanic rocks in the area considered, this mature land surface can not be definitely assigned to any particular age, although it is undoubtedly a counterpart of others described in the Basin Ranges where a late Pliocene age has been generally recognized.

As previously stated, rejuvenation has greatly affected the range within comparatively recent time. This is shown most plainly along the west flank of the southern portion of the range, where all possible evidence of complex recent faulting is indicated. Many interesting features in connection with this faulting have previously been recored by Noble* and Davis.** The subject was not studied in detail by the author and only a few significant features of the complex structural history of the range will be mentioned. Its western flank is here unusually steep and rugged and the escarpment of the range displays a remarkable development of triangular facets, so recently formed that new talus cones are just appearing along the base of the precipitous slope. Many of the facets have hardly had time to assume a true triangular shape. In this connection it is interesting to note that, although Hall Canyon is 8 miles long, it has a very insignificant fan which is no larger than the fans of many mere gashes. Consequently one has some difficulty in a drive along the base of the range in locating this, a major canyon of the range. (See Plate VII, B). Other similar examples of canyons south of Ballarat are at once brought to the attention of a passing observer.

---

* Noble, L. F., The San Andreas Rift and some other active faults in the desert region of southeastern California, Carnegie Institution Year Book No. 25, pp. 415-428, 1925-1926.

** Davis, W. M., The rifts of southern California, Am. Jour. Sci., 5th. Ser., 13, pp. 57-72, 1927.

Thus, while many of the large pre-faulting fans have been completely buried under post-faulting alluvium, a mile or more north or south along the escarpment these old fans have not been entirely depressed. The best example of this is in the large fan at the mouth of Wildrose Canyon. Here recent faulting has produced a large and well-defined trench which runs across the fan near its apex. (See Plate VIII, B). The feature is undoubtedly a graben, although in keeping with the structural history of the range, many have had a complex history. A rather remarkable system of fans exists in the vicinity of Ballarat where four fan levels including the present were counted, all, with the exception of the present, in a greater or less degree of dissection. However, the most outstanding feature is the abrupt truncation of pre-faulting fanglomerate just south of Ballarat which has given the deposit a peculiar mesa-like appearance, as shown in Plate VII, A. Its flat-topped surface rises nearly 500 feet above the valley floor. It seems proper to regard it as a remnant of the fan from Pleasant Canyon that has been cut off by an oblique fault which runs in a southwesterly direction from near the present mouth of Happy Canyon. Moreover, the truncated fan lines up fairly well with other features to the south.

Another interesting feature that is immediately brought to the attention of a passing observer is the enormous thickness and recent dissection of fanglomerate of such remnants of pre-faulting fans as exist. Moreover, faulting has resulted in considerable tilting and dips up to 45° either west or east are not uncommon. Unconformities in fan material have also been noted in several places. One of these is shown in Plate VIII, A.

As a direct consequence of the tilting of the Panamint block toward the east, the large fans on the east versant have been greatly dissected. A view taken from near the mouth of Johnson Canyon is shown in Plate V, B. The streams issuing from this canyon have cut a wide trench over 75 feet below the original flat-topped fan surface. However, other factors may have brought about a similar result, such as change of climate or altered relations between load and carrying power through headwater changes.

The remarkable steep front frequently persists to the very base of the cliffs and often the playa flat, occupying the deepest part of Panamint Valley, lies directly against ~~t~~ the escarpment. As has been suggested by the foregoing remarks, the range is not bounded by one continuous fault, and as Noble has pointed out "...rather, a succession of faults, each of which is offset from the other alo g the strike". "Consequently their escarpments [of both the Panamint Valley and Death Valley faults] have a roughly zig-zag pattern and are indented by great concave bights or cusps where the offsets occur". "At some places the bights mark cross-faults; at others they appear to represent areas of great and sudden downwarp". "At many places the faults exhibit enormous changes in amount of throw in distances of a few miles". * The escarpment reaches

PLATE III.

PLATE III.

GENERAL VIEW OF EASTERN FRONT OF THE PANAMINT RANGE, FROM MESQUITE WELL IN DEATH VALLEY.

Showing even-crested skyline.

TOPOGRAPHY

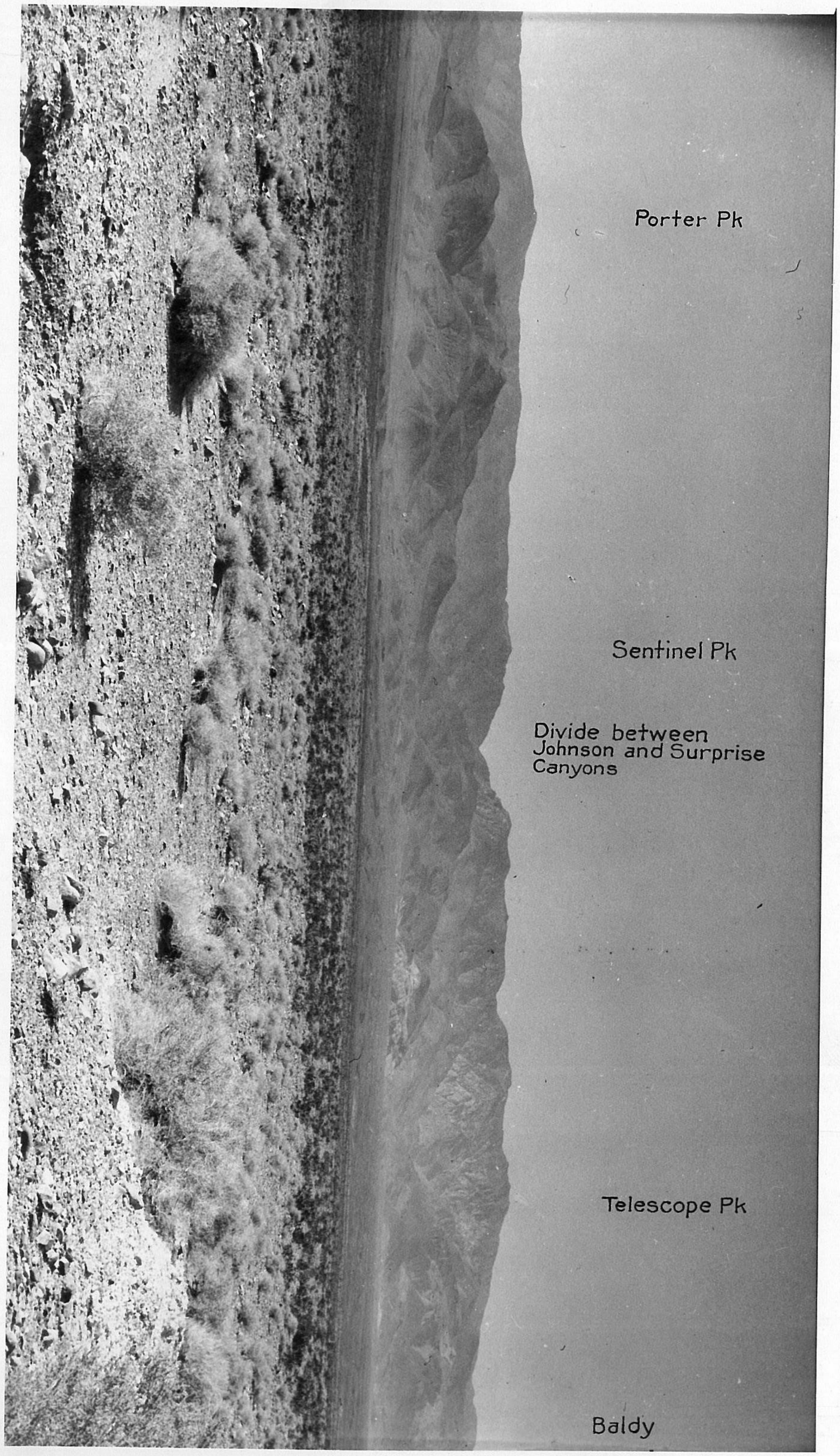

Porter Pk
Sentinel Pk
Divide between
Johnson and Surprise
Canyons
Telescope Pk
Baldy

PLATE IV.

A. SENTINEL PEAK FROM THE SOUTH, SHOWING OLDER MATURE TOPOGRAPHY.

a, marble of the Panamint metamorphic complex; c, Marvel dolomitic limestone; d, Surprise formation; e, Sentinel dolomite. Surprise formation occupies the foreground.

B. SOUTHERLY VIEW FROM SUMMIT OF TELESCOPE PEAK, SHOWING THE PARALLEL, CONTINUOUS AND RATHER EVEN-CRESTED RIDGE LINES CHARACTERISTIC OF BOTH THE EAST AND WEST VERSANTS OF THE PANAMINT RANGE.

The white peak in the foreground is the Redlands dolomitic limestone.

TOPOGRAPHY


a
d
e
c


Sentinel Pk

PLATE V.

PLATE V.

A. VIEW SHOWING THE BOULDERY MUDFLOW SURFACE NEAR THE MOUTH OF SURPRISE CANYON.

B. VIEW LOOKING EAST FROM A POINT NEAR THE MOUTH OF JOHNSON CANYON, SHOWING RECENT DISSECTION OF FAN.

The Black Mountains in the distance here forms the east border of Death Valley.

TOPOGRAPHY

PLATE VI.

PLATE VI.

A. WILDROSE CANYON FROM A POINT ON RIDGE SOUTH-WEST OF CHARCOAL KILNS.

Showing late mature land surface. In the distance, across Panamint Valley, is the Argus Range. To the right and beyond are the Inyo Mountains and the Sierra Nevada. To the left and west of the Argus Range lies the mining camp of Darwin, nearly due west of the observer.

B. VIEW SOUTH FROM NEAR CAMP BIRD MINE, SHOWING THE RUGGED TOPOGRAPHY OF THE INTRICATELY FOLDED AND FAULTED MARVEL DOLOMITIC LIMESTONE IN THE PANAMINT DISTRICT.

The observer is looking up Marvel Canyon, a branch of Surprise Canyon. The road in Surprise Canyon crosses the extreme lower central part of the illustration. A narrow wagon road, built in about 1875, connects the Hemlock and Wyoming mines. The ridge on the skyline to the left is the Surprise formation. The two darker areas (a) are interbedded schist in the Marvel dolomitic limestone.


Wyoming mine
limestone tunnel
Hemlock mine
a
a

PLATE VII.

PLATE VII.

A. VIEW LOOKING SOUTH, FROM A POINT IN PANAMINT VALLEY SEVERAL MILES NORTH OF BALLARAT.

Showing remnant of fan which has been abruptly truncated on the north and west by recent faulting. To the left of view several dissected fan levels can be noted.

B. PANAMINT VALLEY FAULT SCARP FROM A POINT ABOUT 3 MILES AWAY, SHOWING THE INSIGNIFICANT POST-FAULTING FAN AT THE MOUTH OF HALL CANYON.

The dark rocks are schist and the light is sheared granite. Telescope Peak shown in the background.

TOPOGRAPHY

PLATE VIII.

PLATE VIII.

A. VIEW SHOWING UNCONFORMITY IN FAN MATERIAL NEAR THE MOUTH OF WILDROSE CANYON.

B. VIEW LOOKING NORTH ALONG FAULT-TRENCH, FROM A POINT ON THE WESTERN ESCARPMENT ABOUT 4 MILES SOUTH OF WILDROSE CANYON.

The trench is nearly a mile wide and 4 miles long and is composed of old Quaternary alluvial deposits. It crosses the pre-faulting fans of Wildrose and Tuber canyons near their apices.

TOPOGRAPHY

a probable maximum of 40° as measured on the nose 6 miles north of Ballarat in the vicinity of the Indian Ranch. All the faults which bound the range where I have seen them are normal and dip west from 60° to 90°. No evidence of support the view that the slant of the approximately 35° rock-faces approaches that of the dissected fault-plane was obtained. The tremendous brecciation of rocks along the range front is another interesting feature in connection with the recent faulting.

PART 2. GEOLOGY

ROCKS

PANAMINT METAMORPHIC COMPLEX.

DISTRIBUTION AND GENERAL FEATURES.

The name Panamint metamorphic complex, is applied to a series of interbedded metamorphic crystalline rocks, presumably in large part of sedimentary origin, which occupy a large area in the southern part of the Panamint Range. They cover a strip of country, roughly 5 miles wide, on the western side of the range.

The types making up the complex are numerous and various. There exists an infinite series of gradations between coarse gneisses, sheared granite, finer-grained banded gneisses,

* Noble, L. F., op. cit., p. 427.

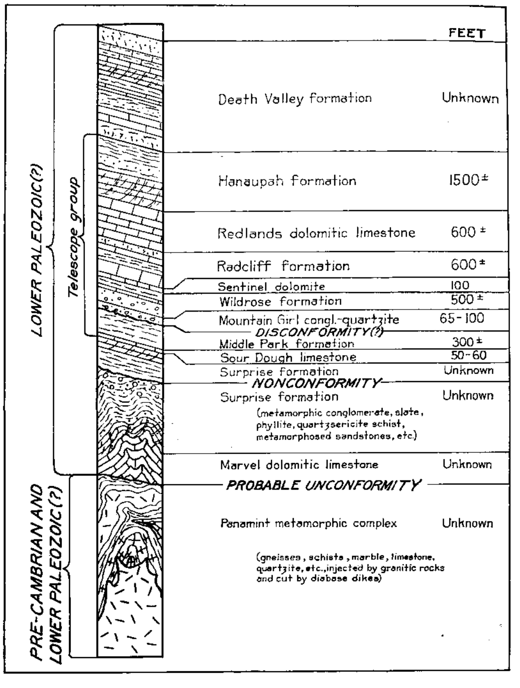


FIGURE 2.—Generalized columnar section of rock formations in the southern part of the Panamint Range.

coarse and fine-textured schists. The prevailing ones, to be discussed later are: granite-gneiss or sheared granite, biotite-quartz gneiss, actinolite-biotite-quartz schist, marble, and limestone. These have been injected by granite and aplite and cut by diabase dikes.

An observer obtains a magnificent view of these rocks in crossing the northern part of the Slate Range, particularly in late afternoon. Various colors are exhibited, especially white, gray, buff and brown. Perhaps the most significent feature is the streaked effect of several of the rock masses, due to their lenticular character.

PRINCIPAL ROCK TYPES.

Granite-Gneiss.

The largest body of an original igneous rock within the Panamint metamorphic complex, may be variously termed a granite-gneiss or sheared granite. It forms an irregular strip of country near the west base of the range. The extent of the area is unknown but is in the neighborhood of from 8 to 20 square miles. There is a general uneven distribution of gneissic structure and the development of foliation is more marked in some parts of the rock mass than in others, but the rock is never massive. Metamorphism, however, has not proceeded far enough to obscure its original igneous texture.

The rock is white to gray in color, notably fresh, and in its most typical form is a coarse banded gneiss, composed

PLATE IX.

PLATE IX.

A. GRANITE-GNEISS, JAIL CANYON NEAR NEW DISCOVERY MINE.

B. PHOTOMICROGRAPH OF SHEARED GRANITE.

Showing cataclastic structure and shearing effects. The larger quartz grains (a) have been largely destroyed with the production of mortar structure of the irregular, interlocking and dovetailing quartz granules (a'); b, sericite; c, orthoclase; d, microcline. Magnified approximately 80 diameters. Nicols crossed.

PANAMINT METAMORPHIC COMPLEX.


INCHES
1
2
3


b
a'
a
a
c
d
a
a

of feldspar, quartz, muscovite, and more rarely biotite. (See Plate IX, A). Even the cleavages of small feldspar crystals often do not reflect at one surface, but as a number of disconnected areas. Specimens from Jail Canyon in the vicinity of the New Discovery mine were selected for study. The most conspicuous feature of the rock in thin section under the microscope, is the manifestation of extreme shearing. The peripheral shattering and granulation of the large grains has given rise of typical mortar structure of the irregular, interlocking and dovetailing granules. (See Plate IX, B). The large feldspars are generally microcline, with whatever crystalline boundary they may have once possessed obliterated by the great mechanical changes they have undergone. Evidently unmixing during metamorphism has resulted in blebs and streaks on the feldspars which prove to be albite. In addition, shearing has produced a very pronounced pressure twinning of the original feldspar crystals as well as marked undulatory extinction. Other primary minerals are orthoclase, albite-oligoclase, and muscovite. Secondary minerals are muscovite, sericite, chlorite, and magnetite with frequent variations in the proportions of these.

Biotite-Muscovite-Quartz Schist.

Biotite-muscovite-quartz schists are well represented in the complex. They are rusty brown on weathered surfaces but dark gray to black when freshly broken. There is much variety in coarseness of crystallization, cleavability, and megascopical appearance, but in their most typical form, are finely banded rocks, with well marked foliation. However, coarsely banded types are not uncommon. They are generally rather coarse-grained with relatively large development of biotite, muscovite and quartz in a finer-grained matrix of the same materials. These minerals are often closely intergrown. Microscopically, it is clear that the rock has been wholly reorganized and recrystallized with the highly interlocking and interpenetration characters of a typical schist.

Quartz-Muscovite Gneiss.

Another important member of the Panamint metamorphic complex is a quartz-muscovite gneiss or quartzite gneiss. It is a massive rock, predominantly gray in color. There is no great uniformity in the megascopic and microscopic appearance of this rock. The several intergrading facies vary somewhat in composition and texture from a true gneiss with well marked foliation, to less highly metamorphosed impure quartzitic rocks, with foliation hardly perceptible.

Under the microscope it is evident that shearing and the development of muscovite, quartz and feldspar parallel to planes of breaking and sliding has had a great deal to do with the development of the parallel structure. Severe cataclastic effects are everywhere evident. Recrystallization has been complete, and all traces of the primary features which it may have once possessed are now wholly obliterated. Shearing, however, is in a more advanced stage in some sections than in others.

Quartz is by far the most abundant constituent, occurring in large irregular interlocking grains alternating with finer grained portions, composed of small fragments of quartz associated with more or less feldspar. These areas of smaller grains, at times form a microbreccia. Relatively small grains of microcline, albite and occasionally orthoclase and microcline perthite occur and these may become abundant in some parts of the rock mass. Numerous inclusions of one mineral in another are common. Other minerals occasionally noted are biotite, epidote and magnetite.

Biotite-Quartz Gneiss.

The biotite-quartz gneiss covers an area of unknown extent. Owing to the fact that the formation contains an infinite series of gradations between coarse gneisses and finer grained banded gneisses, any description of one variety would not be entirely applicable to another. The transition from one quite distinct type to others takes place rapidly and the rock passes by insensible gradations into a biotite-quartz schist. At times it may be termed an augen-gneiss. Foliation is in general strongly developed.

Broadly speaking, the biotite-quartz gneiss is a fine to very coarse textured, well banded rock, in which black, irregular and generally lenticular bands or streaks of biotite alternate with white laminae of quartz. In addition the siliceous bands contain widely varying proportions of microcline, muscovite and biotite. Frequently, large or small "augens" of irregular elliptical areas of quartz are made up of aggregates of interlocked and interpenetrated grains, inclosed in a matrix of biotite, muscovite and quartz. At times, "augens" up to one inch in size of orthoclase or microcline occur. The highly interlocking quartz grains, show considerable evidence of shearing, and strain shadows are prominent. Apatite, magnetite, epidote, and rounded clastic grains of zircon are other minerals noted. The latter mineral would suggest that the rock is a paragneiss. Microscopically, it is clear that the rock has been entirely reformed, reorganized and recrystallized.

Actinolite-Biotite-Quartz Schist.

The actinolite-biotite-quartz schist, is a rather unimportant member of the complex. It is characterized by a peculier brecciated appearance, due in large part to schistose streaks and lenticles of biotite and quartz, and ill-defined "eyes" of actinolite. Sheared quartzite pebbles were noted which had not been completely destroyed by metamorphism, indicating original conglomeratic material. The rock has been injected by narrow granitic and aplitic dikes, generally parallel to the foliation but commonly also cutting the usual direction of schistosity.

In thin section under the microscope, the rock is coarse-grained and foliated with numerous large elliptical aggregates as "augens" of actinolite, surrounded by and alternating with, schistose streaks and lenticular layers of biotite and quartz. Other minerals, varying considerably in abundance from place to place, are zoisite or clinozoisite, muscovite, plagioclase,

PLATE X.

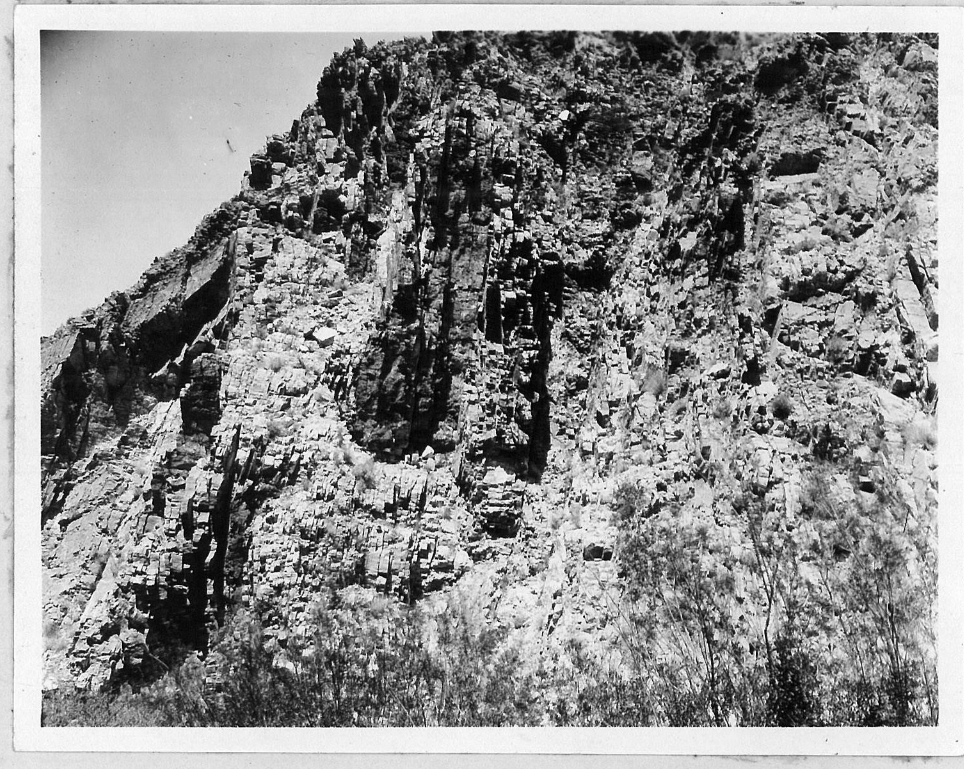
PLATE X.

A. CLOSE SHEETING OF MARBLE, SURPRISE CANYON.

B. LOOKING NORTH FROM A POINT IN HALL CANYON ABOUT 5 MILES FROM MOUTH, SHOWING LENTICULAR AND INTERBEDDED CHARACTER OF ROCKS OF THE PANAMINT METAMORPHIC COMPLEX.

The light rock is marble and the dark, mica and actinolite schists.

PANAMINT METAMORPHIC COMPLEX.



augite and titanite. Some of the quartz may possibly be detrital.

Marble.

A rather extensive area of marble or more accurately crystalline dolomite, occurs on the western side of the range. The general distribution is unknown, but it is thought to be a lenticular body thinning to the north and south. It is a fine to medium-grained, massive, white to grayish white rock when fresh, and buff to light brown, when weathered. It is frequently characterized by irregular lenticular dark streaks of probably carbonaceous matter. Sericite and bladed tremolite are common megascopic constituents. The latter is particularly noticeable along shearing planes. Plate X, A, shows the close sheeting or jointing which is an interesting and rather characteristic feature. Intercalated schist lenses are not uncommon. An analysis of a specimen of the rock from the vicinity of Jail Canyon gave the following results: CaO -- 30%, MgO -- 19%.

Limestone.

Most of the limestone bodies occur near the west base of the range. They are varicolored but often light brown to buff on weathered surfaces and of varying degrees of crystallinity. They are generally contorted and irregularly banded in light and dark bands. A large lenticular body of buff limestone occupies a considerable area near the west base of the range in the vicinity of Ballarat. The limestones are always impure and cherty, and frequently finely speckled with sericite.

Although the limestones have been locally folded, the regional dip appears to be easterly. Some of the darker bands contain white calcite stringers. These limestones are often intercalated with finely banded dark green to black quartz-biotite-sericite schists.

Other Rock Types.

A few other rock types which have been recognized will be briefly mentioned.

A massive schist composed largely of coarsely crystalline actinolite was noted near the west base of the range. Other minerals present are: feldspar, quartz, epidote, biotite, titanite and magnetite.

Another variety was found to be made up largely of common green hornblende with a few grains of plagioclase, Other minerals occasionally noted in thin section are biotite, quartz and magnetite.

World Beater Porphyry (Porphyritic Granite).

The World Beater porphyry, forms a roughly quadrangular area of about 6 square miles, and stretches from Pleasant Canyon to Happy Canyon. The age relations of the mass are not entirely clear. It may have intruded other rocks of the Panamint metamorphic complex, although no evidence to substantiate this supposition was obtained. It is not always easy to draw a definite contact between the granite and the quartz-biotite gneiss with which it is in contact on the west. There is a possibility that the granite and the gneiss grade into each other and

PLATE XI.

PLATE XI.

A. HORNBLENDE DIABASE DIKE CUTTING APLITE, THE NARROWS, SURPRISE CANYON.

Striking contrast shown between the unusual aplite, snow white in color, and the dark green diabase, here filling a fissure or joint. The walls of the canyon rise perpendicular for several hundreds of feet at this point.

B. WORLD BEATER PORPHYRY (PORPHYRITIC GRANITE), PLEASANT CANYON, 1 MILE EAST OF RADCLIFF MINE.

PANAMINT METAMORPHIC COMPLEX.


INCHES
1
2
3

if this be true, it is likely a result of absorption of the gneiss by the granite when injected. It is provisionally regarded as pre-Cambrian. The rock is decidedly gneissic in places with very irregular streaks of biotite alternating with siliceous streaks containing little or no feldspar. This is especia ly true near the borders of the mass.

The porphyritic granite is a coarse-grained grey rock, brownish when weathered, containing fair sized phenocrysts of potassium feldspar and smaller ones of plagioclase, and in addition biotite, muscovite and abundant quartz.

Although the rock would probably be called a coarse-grained porphyritic granite from field evidence, it exhibits considerable cataclastic effects in thin section under the microscope. Moreover, these effects vary considerably in magnitude in the few sections examined, which were selected from several different localities. The most significant feature is the tremendous shattering of the grains and the subsequent development of biotite, quartz, albite and muscovite. The feldspars have been given a microperthetic effect due to prominent streaks and blebs. These have probably resulted from unmixing during metamorphism, and their index of refraction would indicate albite. Such streaks generally possess the same orientation in adjacent feldspar crystals but there are many exceptions to this general arrangement. Albite also occurs as a filling around primary orthoclase and microcline. An acid plagioclase and quartz were other primary minerals. The small shreds and plates of biotite are segregated in patches while muscovite occurs in large plates.

The original texture and structure, now largely obliterated was hypidiomorphic granular.

Other Granitic Rocks.

Dikes and irregular intrusive granitic rocks invade the gneisses and schists of the complex. No attempt was made to differentiate them. Frequently the injection has taken place along the parting planes of a schist or gneiss.

Aplite.

Dikes and irregular masses of aplite occur in various places invading rocks of the Panamint metamorphic complex, at times riveting together the rocks of different formations. A rather large mass of aplite intruding schist, outcrops in Surprise Canyon about 2 miles from the entrance. It covers an area roughly a half a square mile. The rock is schistose on the margins and there is a general uneven distribution of gneissic structure in places throughout the rock mass, although in no place is is developed to any marked degree. Aplitic rocks were not separated in mapping. They are undoubtedly diifferentiation products from the sheared granitic rocks making up the complex. They are probably pre-Cambrian in age and may or may not have been intruded prior to the regional metamorphism of the complex. The comparatively slight granulation in them and the lack of metamorphic minerals might indicate a later and feeble dynamic metamorphism.

The rock is snow white in color and notably massive with megascopic feldspar, quartz and muscovite. The microscope reveals a medium-grained hypidiomorphic granular aggregate of plagioclase, orthoclase, quartz, microcline and muscovite in apparent order of abundance. Plagioclase is the most abundant consitutent and is notably fresh in section. Its extinction angles indicate oligoclase-albite. The rock is rich in quartz in both small and large grains but the smaller grains are secondary and arranged in typical sutured texture. The large quartz grains show strong to moderate undulatory extinction. Dark minerals are wholly lacking aside from sporadic crystals of biotite and the rock is a true aplite. It is not unlikely that minerals of rare type are present but none were observed microscopically. Aplite is an accessory mineral.

In hand specimens certain parts of the rock mass show dark blotches and dendritic forms which are conspicuous in contrast with this otherwise pure white rock. The several sections from this material which were studied, show that these portions were minutely fractured and the rock in general evidences decided shearing effects. The irregular network of interlacing pressure cracks have at all times been filled with limonite which accounts for the dark blotches observed in the hand specimen. Certain parts of the slides are wholly crushed, and granulation has resulted in typical mortar structure. Grains that withstood the crushing, show marked undulatory extinction. However, as a whole the rock has withstood metamorphic processes to a marked degree.

Diabase.

Diabase dikes and more rarely sills, occasionally occur, cutting the gneisses, schists and granitic rocks of the Panamint metamorphic complex. The dikes were not distinguished in the reconnaissance mapping. They frequently have been injected parallel to planes of schistosity and as such generally strike N-S and dip west from 45° to 70°. Often they occupy zones of fissuring or jointing. They vary in width from 2 to 8 feet and average perhaps 4 feet. One of these dikes, cutting aplite, is shown in Plate XI, A. Striking contrast is shown between the unusual aplite, snow white in color, and the dark green diabase, here filling a fissure or joint. The wearing out of the softer diabase has resulted in a marked change in the course of the canyon at this point. The age of the dikes is unknown.

The diabase is an aphanitic, fine to medium-grained dark green rock with usually no minerals visible to the naked eye. Microscopically, it consists essentially of augite and labradorite. At times green hornblende is an important constituent, paramorphic after a brown to yellow pleochroic variety approaching barkevikite. The minerals are panidiomorphic with medium crystalline ophitic aggregates in which the usual place of augite is more rarely taken by hornblende. Frequently, green hornblende is closely intergrown with augite and these minerals have at times been altered to chlorite. Crystals of olivine are occasionally noted, now largely serpentinized. The dark minerals do not merely occupy the spaces between the feldspars, but prisms of the former minerals often project into or cut entirely through the latter. Clearly plagioclase has crystallized earlier than augite and hornblende. Frequently, however, the roughly triangular spaces between feldspar laths are occupied by feldspar. Labradorite, like the ferromagnesium minerals, always occurs in more or less perfect idiomorphic crystals which have been only slightly altered to sericite and kaolin. Calcite is an abundant decomposition product. Magnetite and biotite are accessory minerals.

STRUCTURAL FEATURES.

Structure within the complex is not entirely clear and that of certain rock masses is indeterminable. No attempt was made to study in detail the intense folding of many of the rocks of the complex. The highly crumpled condition of certain of these rock masses, seriously hampers any attempt to unravel the probable complex structural history. The rocks are generally highly foliated. The dominant trend in any of the schist and gneiss areas of any considerable size, appears to be about north and south following the trend of the range, and with a usual dip of the foliation of from 45° to 70° westward. However, wide departures from this generalization are frequently encountered. In smaller masses, the strike and dip of the schistose cleavage is often quite variable. It would appear that more often the schistosity is approximately parallel with whatever larger banding, due to differences in composition of the rocks, may be discernable. This would be accepted as an indication that the schistosity is roughly parallel with the original bedding planes of the rocks. However, more detail work would be necessary to substantiate this view.

Faulting does not seem to have been important. A comparatively few minor faults have been noted and the greater number of these strike north and south. Many of the faults in the complex, occur parallel to planes of schistosity. One of the more important faults between sheared granite and schist, dips 45° west, and follows the usual dip of the foliation.

ORIGIN AND METAMORPHISM.

The rocks of the Panamint metamorphic complex are so thoroughly crystalline and have been so greatly metamorphosed, that but little trace remains of their elements, whether of sedimentary or igneous origin. However, the general character of the larger number of the schists and gneisses, suggests the probability that they were at one time original sediments. In some instances it is impossible to determine the nature of the original material. In certain rock masses there is decisive indication of former bedding and in others it is wholly lacking, depending entirely upon the type of the original rock, the extent of folding, and the degree of metamorphism. The marked change in composition from place to place as well as the lithologic variation across apparently bedded bands from mere laminae to those several feet thick, suggests a sedimentary series. Also, certain lenses and layers are at times found to be parallel to the bedding at contact with other rocks of the series, where the alternation of material shows which is the plane of stratification, hence such lenses can be provisionally accepted as indications of stratification elsewhere. In addition, it is clear that some of the material was originally conglomeratic. However, the presence of original granitic material is not entirely discounted and in the case of the quartz-muscovite gneiss, it is here suggested that the original material was an impure quartzite which had been injected by granitic dikes and the entire mass later metamorphosed.

The manifestation of extreme shearing is the most conspicuous feature of the rocks in thin section under the microscope and is in a far more advanced stage in some parts of the same rock mass than in others. This has resulted in the obliteration of original features. In most of the sections examined it was not possible to recognize the remains of detrital material, the rocks having been wholly reorganized and recrystallized. However, the preponderance of quartz over all other mineral constituents, and still greater preponderance of quartz, muscovite and biotite together, and the general absence of calcic minerals, are strongly suggestive of the derivation of the rocks from quartzose sediments. Also, the presence of interbedded limestones and marble, and similarity to metamorphic rocks of known sedimentary origin, strengthens the view of the supposed sedimentary origin of most of the rocks making up the complex.

It is impossible to retrace all of the changes through which these rocks have passed or determine each step in the probably complex history of their metamorphism. Though intrusive granitic rocks have played their part in the local folding and recrystallization of the rocks, yet the more important process seems to have been more regional in character, occasioned by deep burial and mountain-making forces. A general uneven distribution of gneissic structure is recognized. Also, some rock bodies do not appear to have been very greatly metamorphosed. Nevertheless, it does appear that there has been a more or less uniform result produced by metamorphism in originally dissimilar rocks. For the most part the original sediments and granitic rock bodies have been metamorphosed, subsequent to the injection of the latter. In a large measure also, the folding is attributed to the forces attending regional metamorphism.

No attempt was made to determine the order of succession of the various members of the complex. Secondary structures have complicated such an investigation. The irregularity is perhaps partially original, many of the members having been laid down in lenses. A unique and characteristic feature is the lenticular and interbedded character of many rocks of the complex. Several schist and limestone bodies occur in great lenses, thinning to the north and south. The general strike is N-S and whereas several rock bodies have a westerly dip, the major number of them are believed to have a regional easterly dip.

AGE.

The age of the rocks making up the Panamint metamorphic complex is unsolved by this reconnaissance. It has been impossible to correlate any of the rock formations in this part of the Panamint Range with other sections in the general region. Judging solely from the general character of the rocks, (in large part coarse-textured gneisses and schists), it seems most probable to regard them as pre-Cambrian. The fact that they have been regionally metamorphosed and locally intensely folded, would tend to strengthen such a conclusion. It is suggested, however, that a highly brecciated and crumpled limestone occupying a large lenticular body near the west base of the range, locally bears close lithologic similarity with the Eldorado limestone (formerly called "Prospect Mountain limestone") of Cambrian age.

The thickness of the rocks is unknown but is in the neighborhood of several thousands of feet.

PROBABLE UNCONFORMITY.

It is here suggested that an unconformity separates the rocks of the Panamint metamorphic complex from the Marvel dolomitic limestone and the Surprise formation, although no direct evidence to support this supposition was obtained. While the complex is made up largely of highly metamorphosed coarse-grained gneisses and schists with well developed foliation and which have locally been intensely folded, the overlying formations are in large part fine-textured slaty rocks which are probably less highly folded. When two series of rocks, are more crystalline, more intensely

PLATE XII.

PLATE XII.

A. MARVEL DOLOMITIC LIMESTONE SHOWING CHARACTERISTIC MOTTLING DUE TO BRECCIATION.

About natural size.

B. TREMOLITE IN LIMESTONE, LEWIS TUNNEL, PANAMINT DISTRICT.

An exceptional variety of Marvel dolomitic limestone.


INCHES
1
2
3

folded and more metamorphosed than the other occur together, it is a legitimate supposition that the former is older than the other and separated by a change in dynamic conditions meaning a considerable time interval. This assumes that the two series of rocks are of comparable susceptibility to metamorphism.

MARVEL DOLOMITIC LIMESTONE.

Marvel dolomitic limestone, named from a branch of Surprise Canyon in which general region it covers such a prominent area, consists essentially of light bluish gray limestone of varying degrees of crystallinity. The rock is often irregularly cherty with both dark and light colored patches. All traces of organic structure have been obliterated aside from localization of carbonaceous material which gives the rock a darker color, particularly on fresh fracture. Tremolite, occurring in irregular intersecting nodules and ramifying, lustrous crystals is often abundant, an unusual feature in a limestone not very highly crystalline. (Plate XII, B). Muscovite also can occasionally be noted on weathered surfaces. Near the south base of Sentinel Peak a few small areas of the limestone are made up entirely of oolitic-like nodules. The peculiar pisolite rock is very similar to a specimen of limestone collected by Wendell P. Woodring from the Ordovician of the Inyo Range, California.*

---

* Personal communication.

There are several systems of joints and the rock has undoubtedly been subjected to a number of forces. It has, moreover, been more highly squeezed than is readily apparent and at times is greatly contorted and decidedly schistose. Furthermore, it shows frequent irregular mottling due to brecciation, (see Plate XII,A), and suggestions of fine lines of stratification can occasionally be noted in fragments making up the mottled breccia. Analysis of crystalline unaltered material from the Lewis tunnel gave the following results: CaO -- 31%, MgO -- 20%, which analysis very closely approximates that of a pure dolomite.

Typical thin sections of material from this formation revealed a calcite-dolomite mosaic varying from very fine to medium granular texture with a suggestion of schistose structure in the parallel shreds or seams of carbonaceous matter generally segregated along parallel directions. At times such seams inclose somewhat larger granules of carbonates, rarely they cut across the usual orientation. Occasionally detrital grains of quartz and biotite can be noted. Although the brecciated appearance of the rock is often strikingly seen in hand specimens, it is not always readily apparent in thin sections under the microscope. The boundary between adjacent fragments is frequently characterized by slightly finer carbonate granules presenting an indistinct narrow band usually scattered with minute opaque particles, largely magnetite. A section of material from the Lewis tunnel showed prominent pressure twinning of carbonates.

The contact of this formation with the overlying Surprise formation is never sharply defined and in no case is a normal depositional contact. There is usually a gradation from a true limestone to a true schist for a distance of from 5 to 30 feet where masses of limestone are very irregularly surrounded by schist. The limestone simulates an intrusive relation to the schist and this suggests a squeezing into the less competent layers of the overlying Surprise formation. The very irregular and unusual contact with the Surprise formation is well shown on the detail map of the Panamint district, (see Plate 2, in pocket), although it has here been accentuated to some degree by faulting.

Twelve separate areas have been distinguished in the reconnaissance mapping of this formation. All of them are of irregular shape and vary considerably in relative area. The largest of these is in the general vicinity of the Panamint mining district, its great apparent thickness is due to intricate folding and faulting. (See Plate VI, B). The irregular shape of these limestone areas is probably due to a combination of several causes. The fact that the limestone sometimes contains interspersed irregular but generally lenticular beds of schist, indicates that the deposition of the limestone was an interrupted process. The several areas represent infolded portions and very probably it was deposited as a lens or series of lenses, thickest at the middle and tapering out at the edges. Then followed intense compression and complex folding to such a degree that bedding has been almost wholly destroyed and consequently structure could not be determined. With the subsequent planing off by erosion of all the upper parts of the folds and their truncation down to the level of the present surface, it is possible to visualize the present shape and distribution of these irregular areas. It thus is a counterpart of limestones in the Calavaras formation of California and the Zanzibar limestone of the Manhattan district, Nevada. In a few places where bedding has been recognized, dips up to 45° were measured.

Suggestions of fossils at times are noted on the weathered surfaces of the rock but the material could not be identified.

The limestone is assumed to be of lower Paleozoic age from its general characteristics, particularly the mottled appearance, the high magnesium content, and its intensely folded and often schistose condition.

SURPRISE FORMATION.

DISTRIBUTION AND GENERAL FEATURES.

The name Surprise formation, is given to a series of predominantly fine-textured flaggy or slaty rocks which occupy an irregular strip of country on the western side of the range varying, from one-half to nearly 2 miles in width. One of the most significant features, is the erratic distribution of the different rock types. Here and there suggestions of bedding indicate their original interbedded character.

The general color of the formation is brown and the rocks are usually highly altered. Though the rocks are uninteresting megascopically, their rather complex characteristics are readily apparent in thin sections under the microscope. The classification rests entirely with the microscope. Due to their fine-grained, compact character, few minerals can be identified by the unaided eye. Quartz, muscovite, sericite, and biotite, can, however, be recognized in some specimens. Although most of the rocks are schistose to a greater or less degree, this feature is not always marked in the hand specimen and many are rather massive. Striated surfaces are often marked in some varieties. The prevailing rock types to be described in detail later are: conglomerate-schist, actinolite schist, ottrelite schist, quartz-sericite schist, slates and phyllites, quartz-biotite-tourmaline schist, metamorphosed sandstones and grits, and metamorphosed quartzites. There exists, however, an infinite variety of intermediate types. Their fine-textured slaty character is in marked contrast to the more highly metamorphosed gneisses and schists of the Panamint metamorphic complex.

The schists interbedded with the Marvel dolomitic limestone, shown on the detailed map of the Panamint district, (Plate 2, in pocket), are similar in composition to many of the type rocks of the Surprise formation.

Interstratified irregular beds of brown limestone are also included.

MINERALS.

The minerals identified in rocks of the Surprise formation, are quartz, biotite (brown and green), sericite, muscovite, actinolite, carbonates, chlorite (one or more varieties), hornblende, rutile, titanite, epidote, apatite, tourmaline, clinozoisite or zoisite, ottrelite, staurolite, magnetite, kaolin, plagioclase, pyrite, andalusite (?), carbonaceous matter, obscure alteration products and other undeterminable impure micaceous materials. No one specimen contains them all, and a description of one of the type rocks might be wholly unlike a description of another type.

PRINCIPAL ROCK TYPES.

Conglomerate schist.

A large portion of the Surprise formation, is made up of a type of rock which may be variously termed metamorphic conglomerate, conglomerate schist, or more rarely conglomerate slate. The rock apparently has an erratic distribution and is rarely traceable as a formation for any considerable distance. However, it does occur largely near the upper part of the formation.

On weathered surfaces the rock often has the appearance of a basalt due to the weathering out of limestone fragments. Again, it has the appearance of a pebbly quartzite. The pebbles and boulders very widely in size in any given exposure, from a maximum of 4 feet in diameter, to those of microscopic dimensions, but the fragments under 4 inches probably predominate. They are always ill-sorted, (see Plate XIV, A), and although subangular to angular fragments occur, the generally well rounded fragments are much more conspicuous. They are of quartzite and of limestone and very rarely of granitic material. A notable exception is in the vicinity of Pleasant and Happy canyons where many fragments of orthoclase, microcline and granite were noted. More rarely, pebbles of limestone boulders, weathering in rounded oolitic-like forms occur. In some places limestone fragments predominate, and again those of quartzite may constitute the bulk of the fragments making up the rock in a given outcrop. Many of the limestone boulders are themselves conglomeratic. Most of the fragments have been sheared and at times flattened and elongated forms occur.

The red to brown or black cementing medium is wholly metamorphic and although it varies somewhat in composition from place to place, it is generally a combination of sericite, biotite, muscovite, finely interlocking grains of secondary quartz, and more rarely carbonates. Magnetite and pyrite are usually abundant.

Actinolite Schist.

In another type, actinolite is abundant, although this mineral is very seldom detected by the unaided eye. The rock is everywhere stained by limonite to a rusty brown color. As seen under the microscope the material is composed almost entirely of actinolite, generally in well developed closely interlocked individuals and fibrous cluster-like aggregates. A basic plagioclase, probably an acid labradorite, is a rather minor constituent intergrown with actinolite. Widely scattered grains and irregular masses of magnetite and grains of golden brown rutile also were noted. Alteration products may be present in minor amounts but are too obscure to be definitely identified.

Ottrelite Schist.

In a few specimens a little ottrelite has been noticed, and at several localities this mineral occurs in such amount that the rock must be called an ottrelite schist. In color the rock is olive green, with a silvery satiny luster on fresh fracture, and dotted with numerous dark green oblong plates of ottrelite. In thin section, the porphyroblasts of ottrelite occur in comparatively large crystals and sheaf-like forms embedded in a schistose matrix of sericite, quartz and biotite. Ottrelite is arranged in diverse directions to the foliation and thus was developed subsequent to the foliation produced in the dynamo-metamorphism of the rock. Frequently, the mosaic of quartz grains of the matrix penetrates or cuts entirely through ottrelite crystals while the sericite of the matrix was absorbed by ottrelite during the crystallization of the latter mineral. Optically, the ottrelite is well characterized by its pleochroism, low double refraction, high relief, and repeated lamellar twinning parallel to the base. The mineral is rich in inclusions, especially of quartz, but also of magnetite and biotite and moreover shows typical hour-glass structure. Rocks of this character usually contain more or less microscopic tourmaline.

Quartz-Sericite Schist.

Schists of largely quartz-sericite composition are not uncommon in the Surprise formation. They are fine-grained gray rocks with typical silvery satiny luster characteristic of sericite schists generally. The rock often splits on irregular lumpy cleavage faces.

Under the microscope, it is seen that although the rock has been subjected to metamorphic processes with the resultant typically schistose structure, nevertheless it has not resulted in the entire obliteration of the original minerals of the rock. The elongated and much corroded primary quartz is crowded with inclusions of various minerals and even the smaller grains show marked undulatory extinction. Typically cataclastic effects, evinced in the severe shattering and granulation of the grains is a noteworthy feature of the rock. The irregular biotite blotches have been considerably altered, in part chloritized, and in some sections it would appear that this mineral was formed during the early stages of the metamorphism. The secondary minerals include, muscovite, sericite, tourmaline, magnetite, apatite, and ottrelite. Muscovite occurs in lath shaped crystals inclosing quartz or ottrelite, in arrangement very similar to ophitic texture of igneous terminology, and more rarely in microlitic-like individuals. Sericite is present in scales and flakes, aggregated into confused masses. Occasionally original quartz veinlets cut the rock normal to the foliation. These veinlets have been wholly recrystallized into highly interlocking grains in roughly shelf-like pattern with no very sharp line of demarcation between the quartz grains of the veinlets and those of the rest of the rock.

Slate and Phyllite.

Slates and phyllites are important members of the Surprise formation but owing to the infinite series of gradations represented between the more typical rocks, they are here treated together. They are very fine-textured rocks and in some places show typical slaty cleavage. In color they are dark gray or black, but on weathered outcrops have a more or less rusty appearance. Indistinct narrow banding can often be detected. The rocks usually split on flat cleavage faces and such surfaces are frequently striated.

Microscopically, the rock is made up of irregular and generally elongated grains of quartz embedded in a fine-textured matrix of sericite and other undeterminable impure micaceous materials mingled with minute opaque particles, at times magnetite and pyrite. An outstanding characteristic of the matrix is the presence of large numbers of fine rutile needles. The rock is decidedly schistose and often shows poorly defined alternate layers of different degrees of fineness, the finer layers wholly lacking in quartz. The schistose structure is well shown by the arrangement of the elongated and ragged shreds of sericite in a common direction inclined to the planes of stratification, which causes them to extinguish simultaneously when the stage of the microscope is revolved. A complete recrystallization has resulted in the obliteration of all traces of primary features.

Quartz-Biotite-Tourmaline Schist.

They are usually fine-textured rocks, varying in color from gray to brown. Their schistose character is not always readily apparent and at times they are rather massive. Usually no minerals can be identified by the unaided eye.

Viewed in thin section under the microscope, the quartz-biotite-tourmaline schist, is found to be a very fine-textured, wholly recrystallized and reorganized rock, with typical crystalloblastic texture. A finely recrystallized mosaic of quartz grains usually makes up the larger part of the rock and is always crowded with inclusions, notably swarms of tourmaline in acicular habit. Ill defined "eyes" made up of finely recrystallized quartz mosaics inclosing blebs of biotite are occasionally met with, suggesting, but not proving, original grains which were not wholly destroyed in the metamorphism of the rock. Biotite occurs in blades with partially developed basal faces and frayed ends; rarely it has altered to a chloritic mica. In some sections the quartz granules are moulded in a matrix of biotite. The schistose structure is well shown by the arrangement of the ragged shreds of biotite in a common direction inclined to the planes of stratification, which causes the larger number of them to extinguish simultaneously, when the stage of the microscope is revolved. Sericite makes its appearance in segregated patches and lenses always following the usual directions of schistosity. The most interesting feature of the rock is the widespread occurrence of microscopic tourmaline, frequently, however, in comparatively large crystals. Most of these are set at an angle to their elongation, indicating extreme recrystallization in the production of the present schistosity. Other minerals noted are muscovite and feldspar.

Metamorphosed Sandstones and Grits.

These rocks are normally fine-grained, with quartz usually the only constituent that can be identified by the unaided eye. They vary in color from gray to brown or green and are generally rather massive in the hand specimen.

Microscopically, this facies of the formation is composed essentially of detrital grains of quartz, which show little uniformity as to either size or shape, completely cemented by confused aggregates of various metamorphic minerals. In some sections, which were selected from different localities, the clastic quartz grains are rounded, in others they are subangular to angular and in still others round and angular grains are equally represented. There is usually no definite arrangement of grains, and sizes vary widely in even a single section. A few detrital grains of plagioclase were noted in two of the sections analysed. The complex metamorphic filling also varies somewhat in composition in different sections, but is generally some combination of sericite, muscovite, biotite, calcite and secondary quartz. Other minerals occasionally noted are actinolite, clinozoisite, microscopic prisms of tourmaline, magnetite and strings of probably carbonaceous matter.

Metamorphosed Quartzites.

The metamorphosed quartzites are rather massive in the hand specimen and vary in color from gray to brown. They are not uniform in their megascopic appearance from place to place. Quartz is usually the only component visible to the unaided eye.

The essential minerals are generally quartz in irregular patches and grains, biotite in more or less equidimentional crystals with interstitial calcite, sericite, and finely recrystallized quartz granules, Muscovite, titanite and rutile are important in some sections. Dynamic action is evinced in the peripheral shattering of the larger grains giving rise to poorly defined mortar structure and marginal reaction effects in the crenulated grain margins. Further, all quartz grains indicate by irregular polarization their strained condition, and the closely dovetailing of adjacent grains is an interesting feature, as well as their frequent biaxial character in convergent light. A secondary growth of quartz was occasionally observed.

Other Rock Types.

As previously stated, there exists all gradations and combinations of the above very generalized types of rock formations making up the Surprise formation. Some of them are of rather simple character, particularly in their megascopic appearance, but the greater number of them are more or less complex, as seen in thin sections under the microscope. A few other types will be briefly described.

A very dense siliceous rock, not unlike novaculite is a minor constituent of the formation. The rock contains cryptocrystalline quartz, plates of biotite and muscovite, minute limonified pyrite cubes and veinlets of epidote.

Another type is difficult to classify. It is made up of a medium coarsely equigranular very complex aggregate of kaolin, quartz, hornblende, chlorite (probably two varieties and frequently intergrown with biotite), muscovite, epidote, titanite, magnetite, zoisite or clinozoisite, carbonates, apatite and tourmaline, named in apparent order of abundance. A true banding is absent, but a distinct foliation is shown by the parallel disposition of minerals in lenticles. Clearly the rock has been wholly recrystallized and reorganized and all traces of original features is lost.

Knotted schists also occur, some with spots of biotite and others with numerous dark elliptical areas of complex mineral aggregates.

The slates and schists are occasionally intercalated with brown siliceous limestone in beds usually but a few feet in thickness.

In a few places the formation has been intruded by granite and narrow pegmatite dikes.

ORIGIN, METAMORPHISM AND STRUCTURE.

Nearly all traces of primary sedimentary characters which the rocks may have once possessed are now largely obliterated. Under the microscope, the rocks are fine-grained and usually schistose. The interstitial cement is entirely metamorphic. Perhaps the most significant feature is the large number of rock types represented, and there is in consequence a marked change in composition from place to place. Though bedding is not often seen, it is frequently suggested and there can be no doubt as to the original sedimentary character of the rocks of the formation. Their general mineral composition and often slaty character further substantiates this view.

In some sections detrital quartz grains have been noted, in others the remains of detrital material is wholly lacking and the rock entirely recrystallized. Although the material is ill-sorted and the size and shape of detrital grains varies widely, nevertheless it may have been uniform in distribution originally. The formation may be regarded as a metamorphosed series of sandstones, grits, shales, and conglomerates, intercalated with a few limestone beds. Quite likely the sandstones were arkosic. If this be true, the feldspars have been almost wholly altered by metamorphism. Most of the feldspars noted appear to be secondary.

Although in general the schistosity of the rocks strikes north-south, and often dips as high angles, yet the angle between directions of schistosity and bedding varies widely from place to place. Frequently, the schistosity is normal to the contact of the Surprise formation with the Marvel dolomitic limestone. Several types of rock formations are in contact with this limestone.

No regular stratigraphic sequence of the various members of the formation can now be worked out. Folding, faulting and metamorphism have made an attempt in this direction unsuccessful. In addition, the formation has been greatly eroded.

Bedding has been largely destroyed and the rocks have been intricately folded to such a degree that structure could not be determined. Faulting, also, has complicated the determination of structure.

AGE AND THICKNESS.

The age of the formation is unknown but from the general lithologic character of the rocks and their intense folding, a lower Paleozoic age is assumed.

The Surprise formation has undergone considerable erosion and it was impossible to determine the succession of strata. Folding and faulting have accentuated the apparent thickness and consequently any estimate would be an exceedingly rough one, but it would probably be measured in hundreds of feet.

NONCONFORMITY.

The Surprise formation is separated from the Telescope group of rocks by a nonconformity. Though structure could not be determined in either the Marvel dolomitic limestone or the Surprise formation, the rocks of the Telescope group dip rather gently eastward.

TELESCOPE GROUP.

STRATIGRAPHIC SEQUENCE AND GENERAL FEATURES.

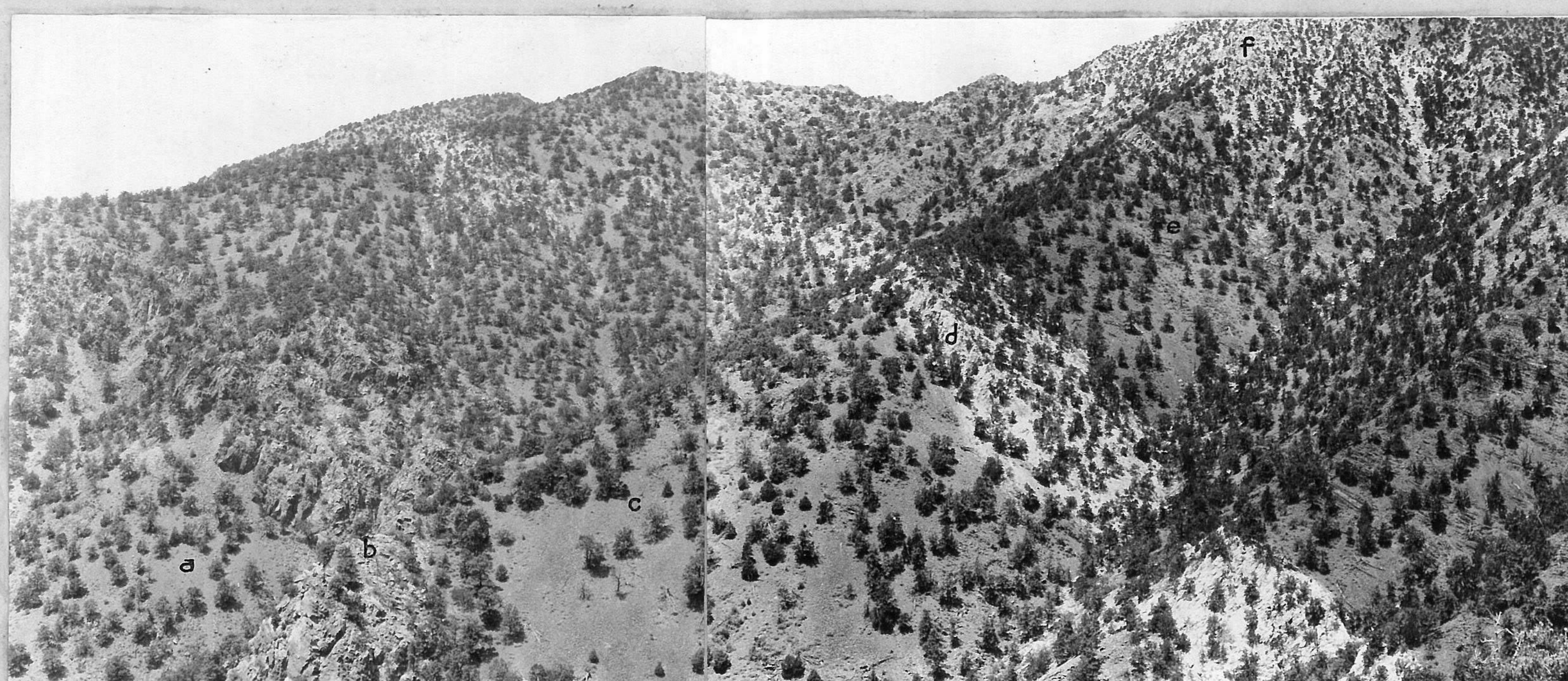
The names, thicknesses and succession of 8 members comprising the Telescope group of rocks which rest with unconformity upon the Surprise formation, are graphically summarized in the columnar section (fig. 2, page 32). These rocks form the higher parts of that portion of the range included on the geologic map (see Plate 1, in pocket). The names of the various formations are derived from cultural terms used in this part of the Panamint Range. The section is well exposed naturally, but owing to the rugged nature of the country only parts of the section were studied in detail. Although most of the formations, regarded as wholes, are rather well-individualized units, the precise horizons for the division planes that separate them

PLATE XIII.

PLATE XIII.

TYPICAL HILLSIDE SECTION OF THE TELESCOPE GROUP, FROM A POINT ABOUT 1 MILE NORTH OF PANAMINT TOWNSITE.

Direction of view is west-northwest. The formations exposed, in ascending order, are: a, Upper part of Middle Park formation; b, Mountain Girl conglomerate-quartzite; c, Wildrose formation; d, Sentinel dolomite; e, Radcliff formation; f, Lower part of Redlands dolomitic limestone. The Hanaupah formation is not shown in this view.


a
b
c
d
e
f

are often matters for arbitrary decision. Owing to the rather wide lithologic variation from place to place, and also due to the fact that the section in its entirety was not studied in detail, only the most distinctive characters of each stratigraphic unit will be described. The rocks have nearly all been metamorphosed to a more or less degree but are in marked contrast to the highly metamorphosed gneisses and schists of the complex. Many of the schist formations are, however, just as highly metamorphosed as a few of the rock formations making up the Surprise formation. The strike and dip of the schistose cleavage always coincides with the bedding planes.

The rocks are undeformed and strike N-S with an assumed dip of from 10° to 30° eastward. They are thought to be lower Paleozoic in age, but owing to the absence of diagnostic paleontologic evidence, the age of all formations is open to question.

SOUR DOUTH LIMESTONE.

The Sour Dough limestone overlies the Surprise formation. It is a medium gray, crystalline, impure arenaceous limestone. The rock can not be divided into distinct beds but due to the alternation of gray and white fine limestone bands and still finer ones of ferritic material, it exhibits distinct striping in a broad measure parallel with the planes of stratification. On fractured surfaces it is seen that the gray bands predominate. However, the rock is highly corrugated and frequently shows very complex folding on a minute scale. Sericite is often noted on weathered surfaces.

A notable feature is the frequent occurrence of a contact vein on either the lower or upper contacts of this limestone. They are quartz veins carrying lead-silver ore and in several localities have been productive.

The thickness of the Sour Dough limestone is estimated to be from 50 to 60 feet.

MIDDLE PARK FORMATION.

The Middle Park formation conformably overlies the Sour Dough limestone. Owing to the fact that the overlying Mountain Girl conglomerate-quartzite weathers in high cliffs, the actual upper contact of the Middle Park formation was not seen. It is not unlikely that a disconformity separates these two units. The average thickness of the Middle Park formation is approximately 300 feet.

Several rock types make up the formation and are not greatly unlike those described from the Surprise formation. They are usually fine-grained with quartz and fine biotite flakes the only minerals which can be occasionally identified by the unaided eye. A slaty rock which, in thin section under the microscope proves to be a very fine-textured quartz-biotite schist, generally directly overlies the Sour Dough limestone. It is made up largely of irregular and generally elongated quartz granules moulded in a matrix of biotite and all original sedimentary characters have been destroyed. Other slaty facies also occur. They are usually dark gray to greenish gray in color and upon close inspection usually show indistinct fine striping. Other more massive facies include spotted schists, dark green ottrelite schists, dark gray impure metamorphosed sandstones and quartzites, etc. Where detrital grains are recognized they are always ill-sorted and vary widely in size in a single hand specimen.

MOUNTAIN GIRL CONGLOMERATE-QUARTZITE.

The Mountain Girl conglomerate-quartzite lies stratigraphically above the Middle Park formation and below the Wildrose formation. Although it is a persistent formation, it is not very constant in character from place to place. In its most typical development, in the section exposed about 1 mile north of Panamint townsite, the conglomerate-quartzite forms precipitous cliffs and consists of from 10 to 25 feet of reddish brown quartzite composed of well rounded but generally elongated quartzite pebbles. The pebbles are usually not over 6 inches in diameter but one elongated pebble measured 14 inches in longest diameter. The conglomerate grades into a more or less hard complex metamorphic quartzite containing a few small and scattered pebbles. South of Sentinel Peak the formation is not readily recognized. Here both limestone and quartzite pebbles occur. The total thickness of the formation is probably from 65 to 100 feet.

A microscopic examination of one section of the matrix revealed the presence of rounded to sub-angular allothingenous quartz grains with confused mixtures of sericite, chlorite, ferruginous material, muscovite and biotite as the cementing medium. Both small and large sized grains occur in an ill-sorted haphazard arrangement but in general roughly elongated in one direction. Cataclastic effects are evinced in the shattering and recrystallization of grains and in the undulatory extinction on large and small sized grains alike. From an examination of hand specimens it is evident that the material is undoubtedly arkosic but only a few highly altered feldspar grains were detected under the microscope. Accessory minerals are magnetite, ilmenite, and its alteration products leucoxene and rutile.

WILDROSE FORMATION.

The stratigraphic interval between the Mountain Girl conglomerate-quartzite and the Sentinel dolomite is occupied by the Wildrose formation. The various rock types making up this unit are not greatly dissimilar to those of the Middle Park and Surprise formations. No attempt will be made to describe them in detail or to indicate their general stratigraphic position. The thickness is about 500 feet.

In keeping with the other rock formations of the Telescope group, the rocks of the Wildrose formation have been metamorphosed, although their metamorphic character is not always apparent in the hand specimen. A thin section of an apparently unaltered granular brown limestone showed the presence of muscovite, plagioclase and magnetite as secondary minerals. Where small feldspar crystals can be detected megascopically, the cleavage faces seldom give a full reflection of light at one surface.

A large portion of the formation, at least in the vicinity of the Panamint mining district, is conglomeratic

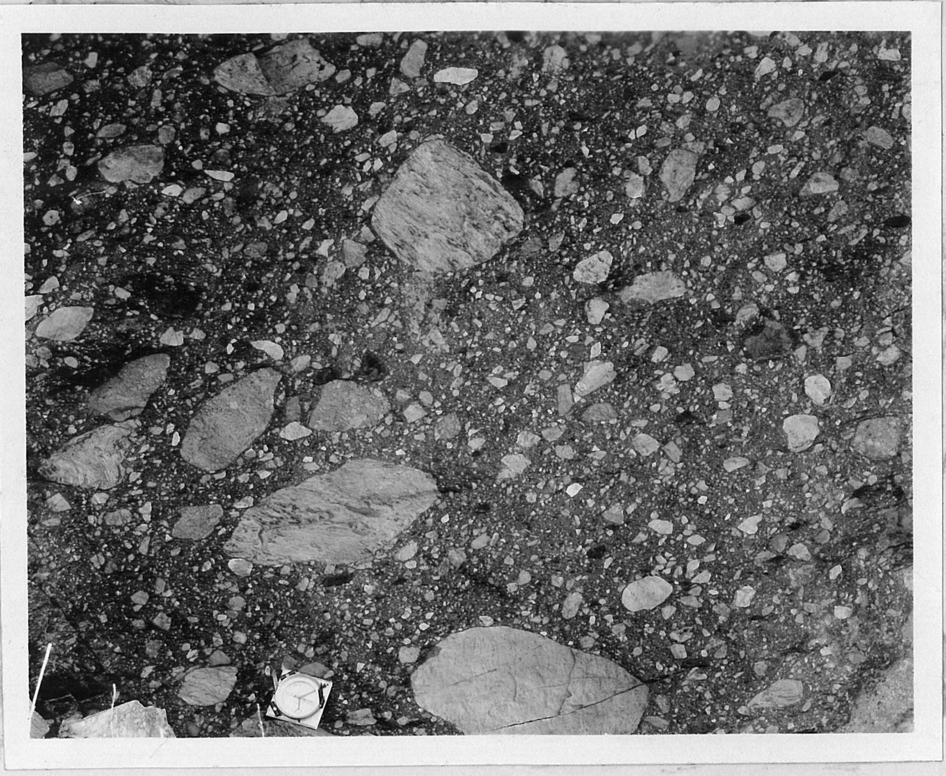
PLATE XIV.

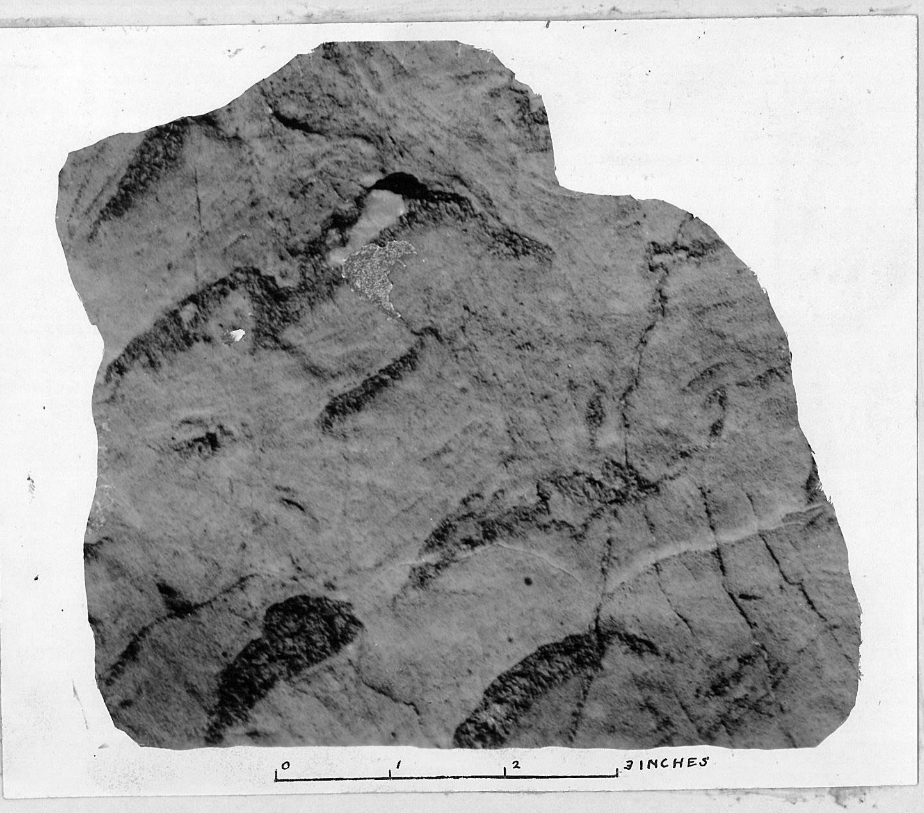
PLATE XIV.

A. DETAILS OF CONGLOMERATE-SCHIST WITHIN THE SURPRISE FORMATION, FROM NEAR THE HEAD OF SURPRISE CANYON.

Most of the fragments are limestone but there are some of quartzite. Many of the limestone boulders are themselves conglomeratic and most of them have been sheared. The matrix is composed of a metamorphic cement, red to brown in color.

B. PHOTOGRAPH OF HAND SPECIMEN OF SENTINEL DOLOMITE, SHOWING THE CHARACTERISTIC IRREGULAR SEGREGATIONS OF COARSELY CRYSTALLINE CARBONATES OR MORE RARELY CHERTY MATERIAL.




0
1
2
3 INCHES

with widely scattered pebbles of quartzite, granite, granite-gneiss, and other foreign rock, which vary in size from a fraction of an inch up to those roughly 4 inches in diameter. The pebbles are generally flattened and elongated, and although well rounded they are not rotund. Several with a triangular outline were noted. Thin sections of apparent granite pebbles showed badly altered orthoclase and albite.

The matrix is dark gray to black in color and may be variously classified as a metamorphosed sandstone, grit or quartzite. In the section analysed, the material was composed essentially of widely scattered allothingenous quartz grains set in an abundant, very complex metamorphic aggregate of sericite, biotite, kaolin, quartz and calcite. Rarely a patch of sericitized and kaolinized feldspar occur. The highly corroded quartz grains are generally rounded to a greater or less degree but the much finer textured grains of the matrix may be round or distinctly angular. Strain shadows on large and small grains alike give unmistakable evidence of pressure. Magnetite and tourmaline are other minerals noted.

Other rocks, generally brown to gray in color, include finely banded biotite schists, crystalline limestone with irregular brown stripes, as well as apparently unaltered sandstones and arenaceous limestones.

SENTINEL DOLOMITE

The Sentinel dolomite lies stratigraphically above the Wildrose formation and below the Radcliff formation.

It is the best horizon marker of the Telescope group of rocks and stands out as a conspicuous white band which can be seen for many miles from a suitable locality. It may properly be regarded as a single bed. The average and rather constant thickness for the region is estimated to be 100 feet.

The Sentinel dolomite is slightly arenaceous and predominantly white in color on both fresh and weathered surfaces. It is usually everywhere characterized by irregular patches or segregations of moderately coarsely crystalline carbonates or more rarely chert. (See Plate XIV, B). Frequently the cherty material has the appearance of vein quartz. More rarely the rock contains irregular but generally parallel stringers of white material which apparently contain a less proportion of dolomite than the rest of the rock. A partial chemical analysis of one specimen of the dolomite gave the following results: CaO -- 30%, MgO -- 21%. The analysis, therefore, closely approximates that of pure dolomite.

RADCLIFF FORMATION.

The Radcliff formation is stratigraphically limited below by the Sentinel dolomite and above by the Redlands dolomitic limestone. Most of the descriptions are based on a study of the section as exposed about 1 mile north of Panamint townsite. Here the greater part of the formation is made up of gray, impure arenaceous limestone, the weathered surfaces of which have been everywhere stained by reddish brown oxide of iron. The corrugated banding of successive layers

PLATE XV.

PLATE XV.

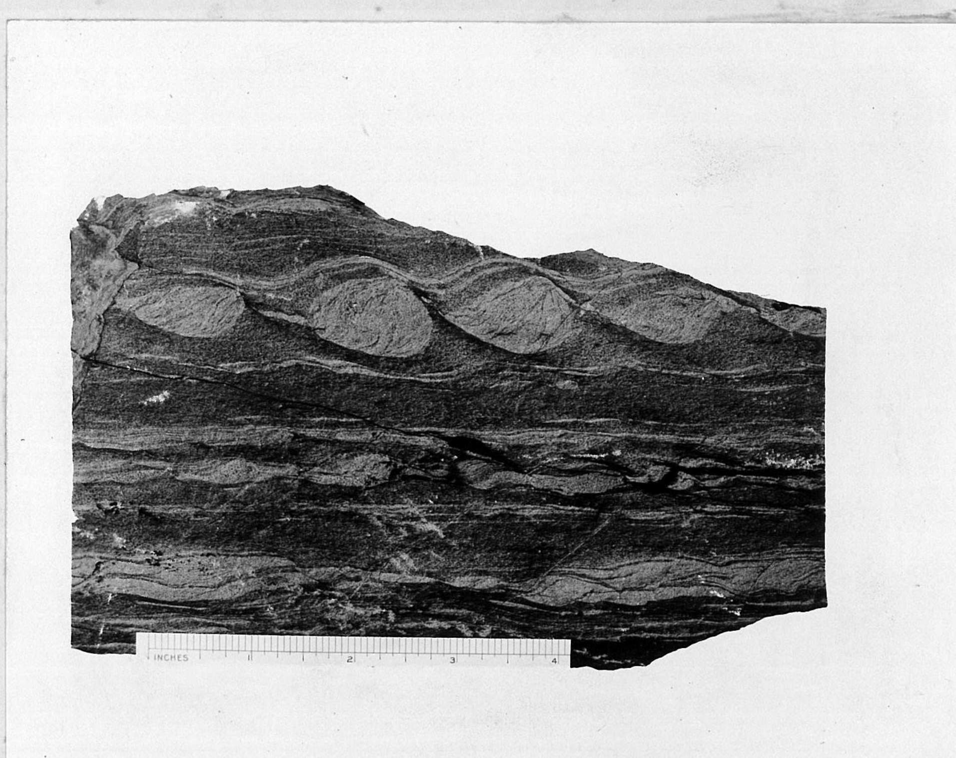
A. TYPICAL RIDGE EXPOSURE OF LIMESTONE IN THE RADCLIFF FORMATION, FROM A POINT ABOUT 1 MILE NORTH OF PANAMINT TOWNSITE.

Corrugated banding well shown, Pyrrhotite is a rather important constituent of this limestone.

B. PHOTOGRAPH OF HAND SPECIMEN FROM HANAUPAH FORMATION, FROM POINT ABOUT 1 MILE SOUTH OF CHARCOAL KILNS, WILDROSE CANYON.

The rock is a slaty schist with light and dark corrugated lenticular bands which probably represent original planes of stratification.

TELESCOPE GROUP.


INCHES 1 2 3 4

is well expressed by fluting, as shown in a typical exposure of this limestone. (See Plate XV, A). The rock weathers into slabs not unlike shale. Muscovite and biotite are frequently seen on weathered surfaces. Near the upper part of the formation in the Panamint district, there is a rather abrupt lithologic change to a dark gray thinly banded lime-silicate rock consisting of alternate layers of siliceous and calcic material. Intercalated gray medium grained sandstones and quartzites also occur as well as some gray and white mottled limestones. In the exposure just west of Porter Peak, the formation is made up of rather similar limestones but the upper part includes very finely striped gray and green shales with typical shaly fracture, as well as other argillaceous rocks. In other localities, white crystalline limestone, arenaceous brown limestone, white sandstones, and dark green phyllites are included in the Radcliff formation. The average thickness is taken at roughly 600 feet.

An interesting feature of the limestone is the rather widespread occurrence of pyrrhotite. It is the oxidation of this mineral which has been instrumental in giving the formation its pronounced reddish brown color. The weathered surfaces of slabs show numerous pits which have resulted from this readily oxidized mineral. Blowpipe tests of many specimens taken across the strike in the exposure about 1 mile north of Panamint townsite, prove the widespread occurrence of this mineral. The mineral is very magnetic.

In connection with the discovery of pyrrhotite, a thorough examination of several thin sections was undertaken. Microscopically, the rocks were found to be rather complex and only a few significant features will be mentioned here. Clearly metamorphism has been more intense than is readily apparent in the hand specimen. In a few sections all traces of the original constituents is lost, and the rock is made up of intricately interlocking and interpenetrating granular aggregates of carbonates, chalcedonic or cryptocrystalline quartz, diopside, muscovite, pyrrhotite, biotite, epidote, zoisite, vesuvianite, chlorite and magnetite in apparent order of abundance. Owing to the fineness of texture and the fact that all the constituents have mutually interpenetrating borders with no sharply defined crystal boundaries, determination of the various individuals was necessarily difficult. The minerals usually occur in fine bands of cryptocrystalline quartz closely intergrown with minute flakes of carbonates, that alternate with layers composed largely of very fine-grained carbonate granules. The banding is also a result of variations in granularity of the carbonate granules of adjacent bands. Pyrrhotite makes its appearance in replacement lenses always following the irregular boundary between siliceous and calcareous layers. Evidence of replacement rests in the concave-convex boundaries as well as in the numerous remnants of quartz, carbonates, and diopside within pyrrhotite lenses.

It is believed that the presence of more abundant and various metamorphic minerals in this formation is due, in part at least, to the impure nature of the original sediment. This has resulted in a more or less complete crystallization of the rock and the production of various lime-bearing silicates by the process of silication. Not unlikely dedolomitization is responsible for the magnesium silicate, diopside. Pyrrhotite has presumably formed during the metamorphism from the original organic material in the rock. It is possible that other members of the Telescope group may show the presence of numerous metamorphic minerals, an inference gathered from the sections which were studied from the Radcliff formation.

Suggestions of fossils were noted in a white granular limestone but the material could not be identified.

REDLANDS DOLOMITIC LIMESTONE.

The Redlands dolomitic limestone lies conformably above the Radcliff formation and below the Hanaupah formation. It is a white crystalline cherty limestone often containing blades of tremolite. Bedding was not recognized. Owing to the limited time spent in the field in studying this formation, the extent of its area is unknown. It is believed that it is a lenticular body but the mapping of the formation was largely a matter of conjecture.

HANAUPAH FORMATION.

The Hanaupah formation conformably overlies the Redlands dolomitic limestone and forms the crest of the range in the vicinity of Telescope Peak. The extent of the area is unknown and the rocks making up the formation were studied in only a few rather widely separated localities. The thickness is about 1500 feet. The rocks are predominantly fine-textured and slaty, and a few of the dominant types will be briefly described.

Perhaps the most conspicuous variety is a fine-textured slaty or flaggy rock which varies in color from light green to dark green or chocolate brown. A photograph of a slab of this material is shown in Plate XV, B. The rock is finely banded with dark green, brown or gray stripes alternating with lighter ones of very similar composition. The thin, lenticular and generally corrugated streaks are assumed to represent original planes of stratification. The number of these wavy overlapping stripes varies widely in a given cross section of a slab. As many as 30 to an inch have been counted in some specimens. The prominent "eye" structure often noted in specimens of this material may have been produced by the squeezing which attended the metamorphism of the rock, but a more likely explanation is that they were originally argillaceous in composition and had been rolled in the form of balls and subsequently elongated into their present shape. The rock has a shaly irregular lumpy fracture following the irregular corrugated banding. Megascopically, the freshly fractured material proves to be a fine-grained quartz-biotite schist with irregular streaks of sericite.

Another similar type is characterized by small oval dark green spots. In this variety the banding is more regular and clearly coincident with the original bedding. Although the material is finely micaceous, megascopic prisms of tourmaline and small cubes of magnetite are scattered through some of the bands.

In another variety green epidotized bands alternate with finer ones of light colored arenaceous and calcareous material. Schistose, medium textured quartz-biotite schists as well as intercalated beds of white to pink quartzite often characterized by concentric bands of reddish brown color, are also included in the Hanaupah formation.

Clearly the rocks were shales and sandstones originally.

DEATH VALLEY FORMATION.

DISTRIBUTION AND GENERAL FEATURES.

The name, Death Valley formation, is given to a considerable number of interbedded limestones, argillites and schists which occupy the eastern versant of the Panamint Range. The field work upon which the present remarks are based was limited to a trip from the divide at the head of Surprise Canyon to the mouth of Johnson Canyon, and a brief examination of the rock formations in several different localities along the base of the range in Death Valley. Naturally no attempt will be made to do more than point out a few distinguishing features of these formations and their general sequence will not be indicated. The interbedding of rocks which do not vary greatly in lithologic details would probably seriously hamper an attempt to separate the Death Valley formation into mappable units, especially if the rocks are non-fossiliferous.

The rocks strike N-S and it is believed that they have a general easterly dip of from 5° to 45°, with a probable average of roughly 25°. Dips up to 45° westward were measured in a few places but it is thought that they are the result of local folding. There is no indication of appreciable faulting. Though in a broad way the rocks apparently have a monoclinal structure, an attempt to approximate the thickness will not be made. A generalization on these points would be little more than a matter of conjecture, owing to the short time devoted to field study of a large area. Although the rocks have not been greatly metamorphosed, there are none that do not show some change.

It was not possible to effect a correlation of the Death Valley formation with other sections in the general region and the age of the rocks is entirely unknown. From their general character, however, a lower Paleozoic age is assumed.

ROCK TYPES.

Calcareous Rocks.

The great bulk of the formation consists of generally thin-bedded calcareous rocks which may often with almost equal propriety be called siliceous impure limestones or calcareous argillites. Some rather pure crystalline limestones also occur and rather heavy bedded varieties are not uncommon. The colors represented are white, gray, brown and intermediate hues. While some limestones are striped with fine bands generally brown in color, others are spotted with fine flakes of muscovite or blotched by ferritic material. One limestone is characterized by segregations of rather coarsely crystalline carbonates, another by siliceous laminations parallel with the bedding. The larger number of them are rather irregularly cherty. Though the bedding and banding is generally regular, it is often corrugated.

The base of the range in the latitude of Gold Hill is composed largely of a hard, light brown, cherty and apparently brecciated limestone. The chert is in irregular masses weathering to a brown color. The rock is silicified to such a degree that only rarely will it effervesce with cold dilute acid. The freshly fractured material frequently shows irregular patches of very coarsely crystalline calcite. The cavities, which have apparently resulted from the brecciation of the rock, have been filled in some places with white finely banded calcium carbonate, probably travertine. The limestone is further characterized by a very rough weathered surface.

Argillaceous Rocks.

In general, the limestones are intercalated with rocks which may variously be called argillites, slates or shales. The general color of the rocks varies from gray to brown or green. They are generally thin-bedded or striped slaty rocks either with or without distinct slaty cleavage or shaly fracture. The banding may be either regular or corrugated. Usually they are irregularly striped in gray, brown or intermediate hues. Ordinarily no minerals are visible to the naked eye but in certain types biotite, sericite, muscovite, magnetite, pyrite and quartz can be identified.

One distinctive rock is characterized by narrow, lenticular and generally corrugated light-colored stripes alternating with wider layers of dark green or chocolate-brown color. A very similar type of rock was described from the Hanaupah formation. At times such stripes have given a moire-effect to a weathered surface of a flag.

Typical sericitic schists also occur. A few pieces of a very greatly metamorphosed biotite-sericite-quartz schist with marked foliation were noted in the fan material but the rock was not found in place.

Other Rocks.

Impure sandstones and quartzites also occur. Near the mouth of Johnson Canyon there is an exposure, possibly several hundred feet thick, of brownish weathered quartzite.

A few diabase dikes and sills were noted in Johnson Canyon and an examination of fan material in various places along the eastern front of the range did not disclose the presence of igneous rocks other than boulders of Little Chief porphyry. However, fragments of sheared granite were noted, not unlike a similar rock of the Panamint metamorphic complex. This rock was not found in place. Also, a few pieces of vesicular basalt were found in the fan material of Johnson Canyon.

IGNEOUS ROCKS.

LITTLE CHIEF PORPHYRY (GRANITE PORPHYRY).

The Little Chief porphyry occurs as a single intrusive body and forms the crest of the range near the head of Surprise Canyon. It is a stock underlying an area of approximately 2 square miles. It is intrusive into the Telescope group and may possibly be founded in part by faults, although this could not be directly ascertained. Beds striking into the granite porphyry have not been deformed. Near the borders the rock becomes somewhat finer in texture. Xenoliths of finer-grained darker material occasionally occur. At the irregular granite contact the alteration has generally resulted in fine-grained dense siliceous rocks with no megascopic minerals present. Where the granite intrudes limestone, it has resulted in a peculiar mottled rock due to ramifying streaks of chalcedony approaching the variety agate. Often chalcedony and limestone are arranged in

PLATE XVI.

PLATE XVI.

LITTLE CHIEF PORPHYRY (GRANITE PORPHYRY),
SURPRISE CANYON, PANAMINT DISTRICT.

IGNEOUS ROCKS.


INCHES
1
2

successive layers around a central nucleus. A piece of float containing diopside was found near the granite porphyry contact. The age of the rock is unknown but indirect evidence points to its being of Mesozoic age. It clearly intrudes the rocks of the Telescope group and the Death Valley formation which are believed to be lower Paleozoic. The rock has not been subjected to metamorphic processes in contrast to all of the other rock bodies, both sedimentary and igneous, in the area under consideration. Furthermore, the veins of the Panamint district appear to have been formed during the late Mesozoic metallogenetic epoch and very probably following the intrusion of the Little Chief porphyry.

It is a massive, medium-grained pink rock whose megascopic constituents are orthoclase, plagioclase and quartz, speckled with small black prisms of hornblende. Although quartz is not a conspicuous mineral to the naked eye, it is rather abundant in the several sections of the material studied under the microscope. Under the microscope the essential minerals of the rock are orthoclase, microcline-perthite, quartz, albite-oligoclase, hornblende and biotite, named in order of apparent abundance. The texture is porphyritic with rather frequent relatively large phenocrysts of microcline-perthite and orthoclase. The intimate interpenetration of quartz and orthoclase with the simultaneous extinction of quartz giving rise to micrographic texture, is a rather conspicuous feature of a considerable part of the sections examined.

The several feldspars are more or less kaolinized. The ferro-magnesium mineral of chief importance is hornblende in relatively small idiomorphic crystals with frequent inclusions of magnetite and more rarely apatite. The pale green, almost colorless hornblende, is a rather unusual mineral of the rock. It is characterized by streaks of brown that have probably resulted from leaching. In addition to apatite and magnetite, other accessories identified are titanite and muscovite.

HORNBLENDE-DIORITE PORPHYRY.

Hornblende-diorite porphyry dikes cut Marvel dolomitic limestone, Surprise formation and the rocks of the Telescope group. The dikes are rather inconspicuous, varying in width from 2 to 15 feet with an average of about 5 feet. They have a general strike of from N-S to NW-SE and dip from 70° to vertical. Many of them are continuous for a distance of nearly a mile. They were intruded subsequent to the folding of the Marvel dolomitic limestone and the Surprise formation. Many of them have been rendered schistose. The dikes are younger than the rocks of the Telescope group but aside from this there is no definite means of determining their age. Only one of these dikes was distinguished in the detail mapping of the Panamint district. This was believed necessary as an aid in the solution of a fault problem in connection with the Wyoming vein.

The color of the freshly fractured rock is olive green. Prisms of hornblende are not always seen, but when present are the only phenocrysts visible to the naked eye. These vary from those of microscopic dimensions up to those a centimeter or more in length. A satisfactory classification of the rock could not be made owing to the presence of abundant decomposition products, the whole rock being too decomposed for accurate study. The groundmass is holocrystalline and consists essentially of hornblende and plagioclase. Examined in thin section under the microscope, it becomes clear that the prevailing green color of the rock has resulted from the epidotization of the feldspar. Phenocrysts of brown hornblende have been almost wholly chloritized and the less abundant aguite has suffered similar alteration. Other secondary minerals in the rock are clinozoisite, biotite, and interstial quartz.

PART III. THE ORE DEPOSITS.

PANAMINT MINING DISTRICT.

SITUATION.

The Panamint district includes a small area in the immediate vicinity of the abandoned town of Panamint and is situated near the head of Surprise Canyon. It is 11 miles northeast of Ballarat, and 36 miles from Trona. A fairly good desert road connects Trona with Panamint. This road crosses Panamint Valley from Trona to the mouth of Surprise Canyon. The so-called Panamint district is a part of the old South Park mining district, under which title the mining claims for the southern part of the Panamint Range from Goler Wash north to William's Canyon are recorded.

Numerous scattered mine workings and prospects occur principally to the west, south and southeast of Panamint. The mines of the district nearly all lie in a belt extending about 9000 feet from east to west and 7000 feet from north to south. The detail geologic map, (Plate 2, in pocket), does not embrace the entire district which extends for some distance south and east of the area mapped.

HISTORY AND PRODUCTION.

To the romantic, few mining districts have a more colorful past than that of Panamint. Its early history is at once interesting and thrilling. Chalfant* states that in 1858 Mormon emigrants found silver ledges in the Panamints and built a small furnace south of the town of Panamint. According to a statement by Dr. S. G. George, appearing in the Panamint News of March, 1875, the first person who recognized the mining possibilities of the Panamint district was a Mr. William Alvord in or about 1860. Dr. George, who was a famous Indian fighter of Inyo County, figured in the first actual mining developments of what was then known as the Telescope mining district. Due to Indian outbreaks, the project was abandoned about the year 1862. In 1873 R. C. Jacobs, R. B. Stewart, W. L. Kennedy and E. P. Raines obtained holdings in the district. Raines interested United States Senator John P. Jones of Nevada in the enterprise. But it was not until United States Senator William Stewart of California, Senator Jones, and Trenor W. Park secured the mining rights on the greater part of the district and organized the Panamint Mining Company, that mining activities of any considerable consequence began. According to a story that has persisted through the years, these rights were procured by purchase from outlaws who previously held and dominated them under some claim, either real or pretended. Numerous

---

* Chalfant, W. A., The Story of Inyo, Chicago, The Author, 1922.

companies were organized, but in later years most of them were consolidated into one general company known as the Surprise Valley Mill and Mining Company. During the next few years the town prospered, supporting a population of about 2500 people, a bank, tri-weekly newspaper and 10 saloons.

A 20 stamp mill and roasting furnace was put into operation in 1875. Some form of pan-amalgamation was employed in the treatment of the ores although the exact process used can not be ascertained. It is likely the Reese River process, consisting of a chloridizing roast preceding grinding and amalgamation in the pans was used as developed at Reese River, near the Comstock Lode at Virginia City, Nevada. This method was not very successful, which is not surprising considering the rebellious nature of the ore. Reduction cost amounted to between $18 to $20 per ton*. The salt used in the treatment was conveniently obtained from Searles Lake while ample wood for fuel was available in the district. Bullion was hauled by 20 mule teams to San Pedro and shipped from there by boat to Swansea, Wales for smelting. Some high grade ore may possibly have been shipped direct to this smelter without previous treatment.

The principal mines developed during this boom period in the district were, in order of importance, Hemlock, Wyoming, and Stewart's Wonder.

---

* Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1875, p. 24, 1877.

The year 1877 marked the close of the boom period in the district, hastened perhaps by the destruction of the mill by fire. According to M r. Fred. Gray, several of the properties located in the southern part of the district were leased late in 1877, to a Mr. Phoebe whose undertakings are said to have been profitable but no record of production is available. At no time has the district been entirely abandoned but in the last half century there has been no production worth mentioning. A 10 stamp mill was operating in 1890.*

In 1923, the interests of S. F. Hopkins, some 40 claims, were acquired by J. V. Lehigh, and sporadic development has been in progress on several of the prospects since that time.

In 1924, A. D. Myers sold one-half interest in the patented claims with the single exception of the Hemlock claim to Messrs. D. D. Corum, W. L. Seeley, and J. M. McLeod. Rebuilding of the road in Surprise Canyon was completed in 1924 at a reported cost of $35,000. In this year an agreement was made with Mr E. G. Lewis which resulted in the organization of the Panamint Mining Company whose holdings comprise some 50 mining claims. In 1925 the driving of a tunnel was started with the expectation of intersecting several veins at a greater depth than had yet

* California Min. Bureau Tenth Ann. Rept., p. 210, 1890.

been attempted in the district. After completing 2310 feet of tunnel, the project was abandoned in 1926. It is believed that some of the claims may have reverted back to one or more of the original organizers of the company.

Recent flotation tests have shown a profitable economic treatment of the ores in the district. According to engineer's reports ample water is available for a 100 ton mill. The district is rather inaccessible and is augmented by the difficulty of building and maintaining a road in the canyon.

There is much conflict in the many more or less indefinite accounts of the extent of production from the several mines in the district but it seems quite safe to say that at least $2,000,000 was realized. Judging from numerous specimens which are found lying about on the different dumps, there is little doubt but that considerable high grade ore was taken out during the active life of the camp. The average assay value of ore delivered to the mill varied from $80 to $100 in silver per ton.* Stetefeldt** has reported high grade ore up to about $900 a ton, and estimated that the average value of ore from pay streaks of the principal mines in the district ranged from $75 to $100 per ton.

---

* Raymond, R. W., op. cit., p. 24, 1877.

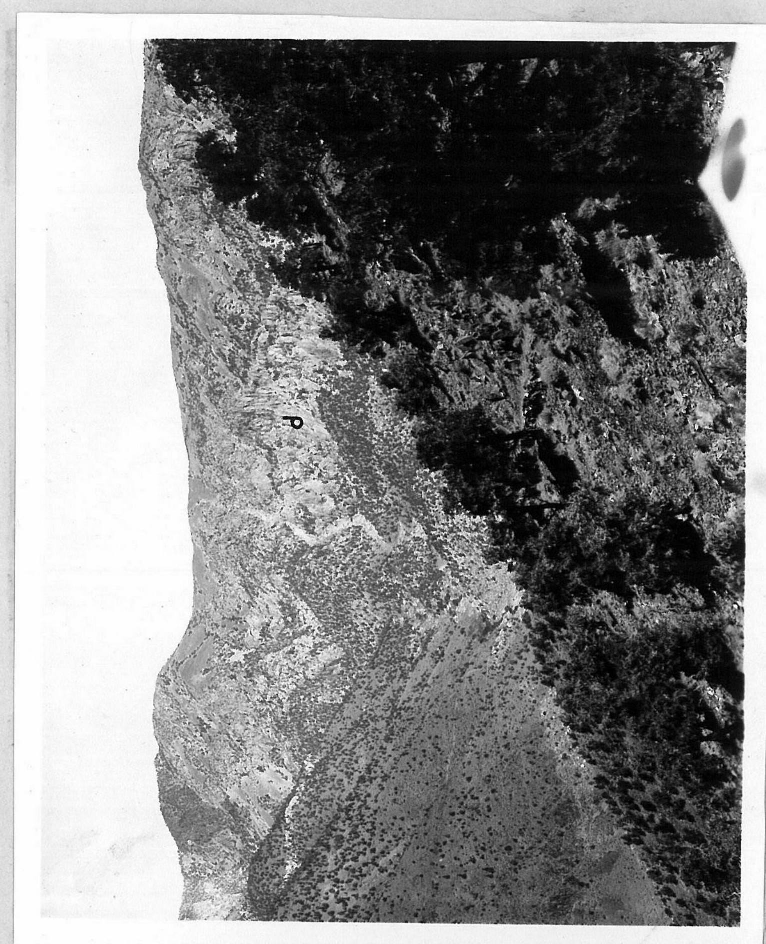
** Raymond, R. W., idem for 1874, p. 37, 1875.

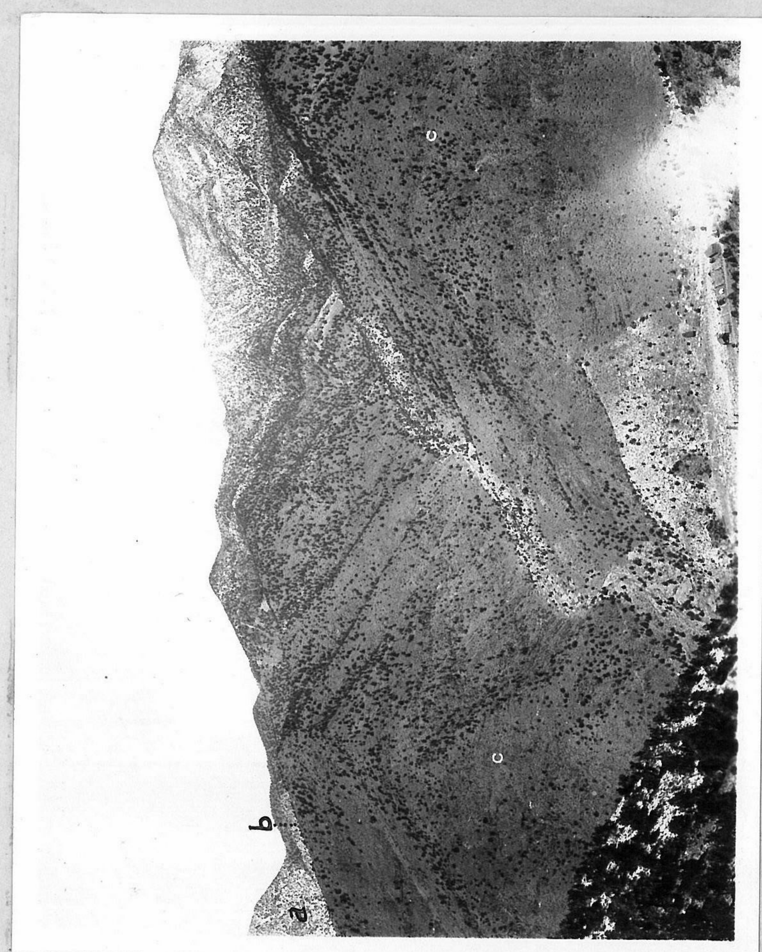
PLATE XVII.

PLATE XVII.

VIEW LOOKING NORTH ACROSS SURPRISE CANYON FROM NEAR WYOMING MINE, PANAMINT DISTRICT.

a, marble of the Panamint metamorphic complex; b, Marvel dolomitic limestone; c, Surprise formation; d, Little Chief porphyry (granite porphyry), here forming the crest of the range. The white band in the background is Sentinel dolomite, a conspicuous marker. Marvel dolomitic limestone occupies the left foreground and Surprise formation the right foreground. Panamint townsite, situated in the lower central part of the left hand view, is 1100 feet below the observer. To the left is Sour Dough Canyon and to the right Water Canyon.





FAULTING.

Evidence of two periods of faulting is recognized in the Panamint district, and classified as, first, - that which accompanied the opening of the mineral-bearing fissures, and second, - post-mineral fissures which dislocate many of the veins of the district. The post-mineral fissures are largely confined to the Marvel dolomitic limestone and many of them are difficult to trace far beyond the limestone-schist contact. Broadly considered the faults of the district present an orderly arrangement in that they trend generally N-NW by S-SE. They are normal faults of small vertical displacement and small horizontal offset. As a rule the dips are high. The vertical element of movement, so far as indicated by striae, was greater than the horizontal element, although the lateral movement was important in a few faults, notably the fault which displaces the vein in the Wyoming mine.

The outcropping of many faults is marked by a large amount of brecciated rock or crushing on fissures which clearly are not faults of large movement. Where the faulted rock is limestone, the fault breccia is likely to be considerable. The width of the finely brecciated rock on the fault in Jacob's Gulch, as measured in a drift of the Camp Bird mine is 10 feet, although the limestone is considerably broken up for twice that distance.

A notable and characteristic feature of the faults is the deposition of travertine in banded layers cementing the actual fault plane or the large and small blocks of limestone or schist which have been torn loose in the faulting. Many of them are in effect veins of travertine. Due to lack of regular bedding planes and horizon markers the positive demonstration of faulting largely depends upon the actual tracing of the brecciated zone.

SILVER-BEARING VEINS.

Distribution, Form and Structure.

The occurrence of numerous, strong, continuous and clean-cut quartz veins is the most interesting feature of the district. They vary considerably in width from mere stringers up to those 25 feet wide and average perhaps 6 feet. The veins that have been more or less productive, lie in an area roughly 6 square miles as indicated on the claim map of the district (see Plate XVIII, in pocket) . The most prominent and productive veins within this area, are the Hemlock, Wyoming and Stewart's Wonder. The outcrops are well exposed naturally and are easily traceable, some for a distance of about a half a mile. From a vantage point with the aid of field glasses many of the veins can be seen for a considerable distance. They traverse both the Surprise formation and the Marvel dolomitic limestone but those in the limestone are more numerous. The veins in the limestone are more readily traceable on the surface and generally do not vary greatly in width from place to place along the strike, as is frequently the case with veins in the Surprise formation. Undoubtedly this is because the limestone

PLATE XIX.

PLATE XIX.

A. LOOKING WEST ACROSS WONDER GULCH, PANAMINT DISTRICT, SHOWING FAULTING OF THE STEWART'S WONDER VEIN.

The vein is outlined by dashed lines. The country rock is the Marvel dolomitic limestone with the overlying Surprise formation in the right background.

B. NEAR VIEW OF THE STEWART'S WONDER AND RAINBOW VEINS AS EXPOSED ON RIDGE JUST EAST OF JACOB'S GULCH.

Rainbow vein (left) dips 40° north and intersects the vertical Stewart's Wonder vein. The principal mass of quartz of each vein is here about 6 feet wide. The continuation of Stewart's Wonder vein west of Jacob's Gulch is outlined by dashed lines. Banding of Rainbow vein also shown. The country rock is the Marvel dolomitic limestone.


Fault
Fault
Fault

was more easily fractured than the schist. The Stewart's Wonder vein splits into three branches as it enters the Surprise formation and is not traceable far beyond the limestone-schist contact. Some wide lenses of quartz are traceable for a short distance on the surface and rapidly pinch out when followed down the dip.

The veins of the Panamint district follow fractures whose strikes vary within rather wide limits but the larger number of them have a general trend of NW-SE and NE-SW. As a rule dips are steep, varying usually from 55° to vertical, although there are several notable exceptions. There is no relation between fissuring and either schistosity or bedding with the exception of a few minor veins occurring in the Surprise formation as well as contact veins which often follow either the upper or lower contacts of the Sour Dough limestone. While the structure of the veins is generally decidedly massive, in places rude indistinct banding was noted but in no way does it resemble the delicate concentric banding of the epithermal deposits.

The contact between quartz and both foot and hanging walls is sharp and seldom accompanied by gouge. In a few instances the veins are attended by many irregular branching stringers which are generally parallel to the major part of the vein.

There is little, if any alteration of the wall rock, and the mineralization never extends into the country rock.

Usually fresh rock adjoins the vein filling, but frequently the limestone has been given a darker color. However, there is no suggestion of dolomitization although rarely will the limestone wall rocks effervesce with cold dilute acid. The Marvel dolomitic limestone itself often corresponds in analysis to that of a true dolomite. Sericitisation of the wall rock was observed in only a few places.

The structure of the ore is massive and the sulphides are irregularly distributed within the quartz, with generally no relation to either the foot or hanging walls of the veins. The ore shoots are small and of pockety character. Quartz druses occur but they are relatively few in number. Many of them appear to be related to planes approximately parallel to the walls. They are unfilled portions of the veins and are always lined with large quartz crystals.

Generally speaking, the veins are rather barren and mineralogically of simple type.

QUARTZ-GALENA-PYRITE VEINS.

Some veins in the district, particularly those occurring in schist north of Surprise Canyon, contain coarse grained galena, with subordinate pyrite, chalcopyrite and zinc blende. Tetrahedrite was observed in a few polished sections. In a few places where the veins have been worked, the ore is valuable chiefly for lead, with subordinate silver. The silver is probably contained in the galena. The order of deposition of the minerals is generally as follows: pyrite, sphalerite, chalcopyrite and galena.

PLATE XX.

PLATE XX.

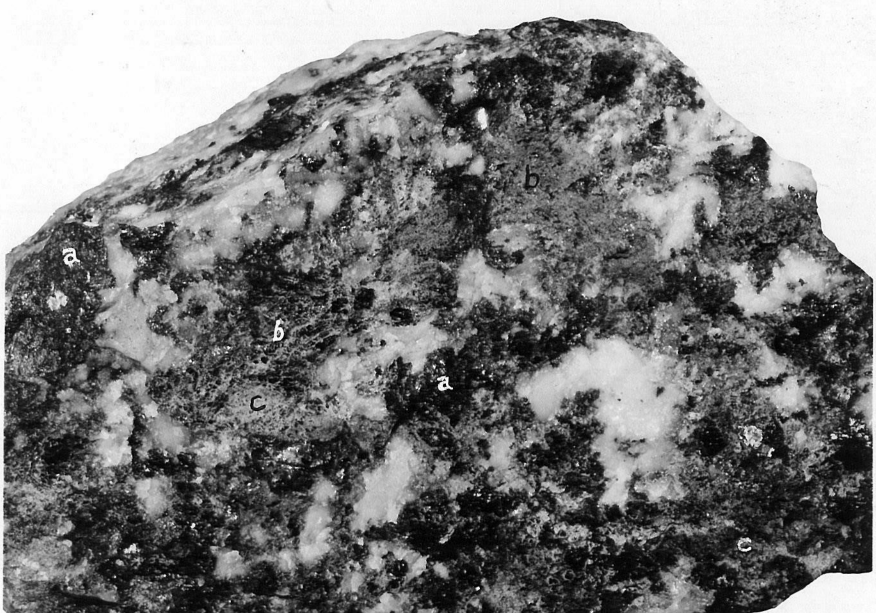
A. TYPICAL HYPOGENE SILVER ORE FROM THE PANAMINT DISTRICT.

Quartz (light), and sulphides, chiefly tetrahedrite, (dark), Wyoming mine.

B. RICH PARTIALLY OXIDIZED ORE FROM THE PANAMINT DISTRICT.

a, tetrahedrite; b, bindheimite; c, malachite. The white is quartz. A specimen from the dump of the Little Molly prospect.

ONE INCH



ONE INCH

MINERALOGY OF THE ORES.

Nonmetallic Minerals.

The principal and almost exclusive vein filling is milk-white sometimes glassy quartz of coarsely crystalline massive texture. The quartz is decidedly of the mesothermal or hypothermal variety. Microscopically, where undeformed after deposition, the quartz has a hypidiomorphic granular texture. This is well shown in Plates XXI, B and XXII, B. Though much of the quartz is undeformed, it may show cataclastic effects from undulatory extinction to granulation of the large grains. The quartz contains very fine inclusions which have often given it an almost kaolinized appearance in ordinary light.

Calcite and possibly ankerite, occur only sparingly as vein minerals and are rarely observed except under high magnification. They replace or fill fractures in quartz. White tabular crystals of barite were observed in one specimen of ore and is contemporaneous with or later than quartz.

Metallic Minerals.

The metallic minerals of undoubted hypogene origin include, in the approximate order of their abundance, tetrahedrite, galena, sphalerite, pyrite and chalcopyrite. In the silver ores of the district, the silver is almost wholly contained chemically bound in the tetrahedrite

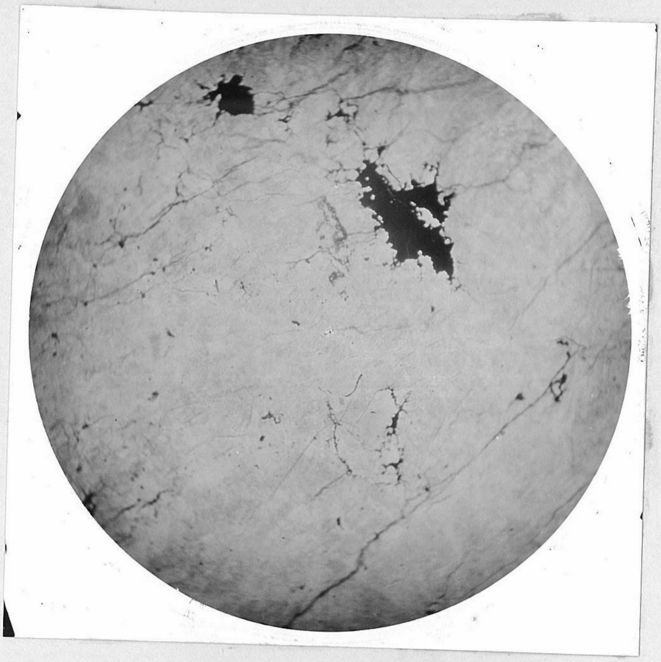
PLATE XXI.

PLATE XXI.

PHOTOMICROGRAPHS OF ORES.

A. Ore from the stope in the Limestone tunnel, Wyoming mine, showing sulphides (black) in part filling open spaces between large undeformed quartz grains, in part filling irregular cracks in fractured quartz, and in part replacing brecciated quartz. The sulphides consist chiefly of tetrahedrite. Some of the small irregular masses and veinlets in quartz have been filled in and replaced by carbonates. Magnified about 20 diameters. Ordinary light.

B. Same as A. Nicols crossed.



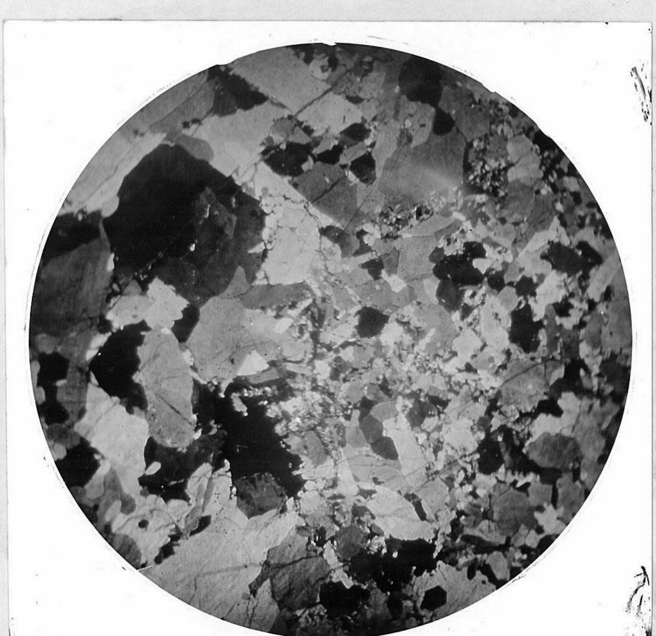


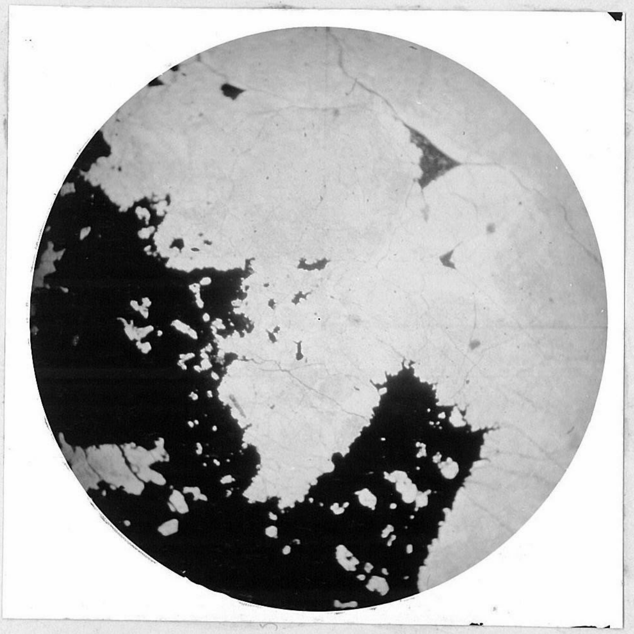
PLATE XXII.

PLATE XXII.

PHOTOMICROGRAPHS OF ORES.

A. Typical sulphide ore from the Panamint district, showing sulphides (black) replacing quartz. The sulphides consist chiefly of tetrahedrite. The triangular space between large quartz grains (shown near the top of the illustration), has been filled by an ore mineral now oxidized. Magnified about 20 diameters. Ordinary light.

B. Same as A. Nicols crossed, showing coarsely granular texture of quartz with partial development of idiomorphic forms.



(freibergite). This is the principal sulphide mineral and is massive, dark gray and with splendent luster on fresh fracture, which becomes metallic upon exposure. The mineral usually gives qualitative reactions for both arsenic and antimony. Rather coarsely cleavable galena and light brown sphalerite are important minerals in the typical ore. Large areas of galena generally contain a number of good sized rounded spots of tetrahedrite. Pyrite and chalcopyrite are rarely seen in the hand specimen, though small grains can usually be found in polished surfaces under the microscope.

PARAGENESIS.

A regular sequence of deposition of the hypogene minerals was difficult to obtain for the various veins in the district as a whole. There appears to have been a slight overlapping but the order generally applying is as follows: pyrite, sphalerite, tetrahedrite and galena. The relations existing between chalcopyrite and the other minerals is largely unknown, owing to the scarcity or absence of this mineral in all the specimens examined. However, chalcopyrite is replaced by galena.

The impression conveyed in a microscopic study of the ores is that the quartz is earlier than all the sulphides. In some instances replacement has taken place around the borders of large idiomorphic quartz grains, in others it has replaced brecciated quartz, and again it may fill open spaces between large undeformed quartz grains.

OXIDATION AND SUPERGENE ENRICHMENT.

The physiographic history of the region indicates that after the formation of the veins they were subject to deep erosion in Tertiary time. There would be, therefore, opportunity for the formation of zones of oxidation and supergene enrichment. Water has not been encountered in any of the mines. The ruggedness of the topography and comparatively sparseness of vegetation favor a quick run-off. The speed of erosion has probably exceeded that of oxidation. Consequently, the zone of oxidation is shallow and irregular and frequently almost unaltered sulphides occur at the surface. Oxidized ores have yielded only a comparatively small part of the total production of the district. The irregularity of the oxidized ores depends more on the permeability of the vein at any particular place than on the depth below the surface. Where the veins have been followed by post-mineral fissures with perhaps shattering of the quartz itself, the degree and extent of oxidation is naturally much greater. The almost entire absence of pyrite in the ores was unfavorable for oxidation and supergene enrichment processes.

The metallic minerals of the oxidized ores include malachite, azurite, anglesite, cerusite, smithsonite, bindheimite and cerargyrite. Bindheimite is a rare constituent of the oxidized ores of a few of the mines in the district. It is soft, ocherous material of a yellow to yellowish-green color. It usually occurs with tetrahedrite, galena and malachite. The mineral has probably resulted from the oxidation of tetrahedrite. Very probably the antimony is furnished by the tetrahedrite and the lead by the galena similar to many of the Idaho occurrences.* Galena oxidizes to anglesite and cerusite. One specimen of ore from the dump of the Little Molly prospect showed nodules of lead sulphide surrounded by dark concentric shells of lead sulphate, which in turn are surrounded by shells of lead carbonate. Sphalerite alters to smithsonite but the latter mineral is nowhere abundant in the Panamint ores. Cerargyrite also occurs very subordinately.

The minerals that strongly suggest deposition by supergene waters are stromeyerite, chalcocite and covellite. In all the specimens examined they are present only in very subordinate amount. Sphalerite is characteristically replaced by incipient veinlets of chalcocite and infrequently bordered by thin coatings of chalcocite. This fact is rarely brought out except under high magnification. Tetrahedrite is also partially replaced by chalcocite in tiny veinlets that frequently rim large and small areas of tetrahedrite along the borders of quartz grains. Covellite

---

* Shannon, Earl V., The Minerals of Idaho, U. S. Nat. Mus. Bull. 131, p. 435, 1926.

forms veinlets in sphalerite but more commonly occurs as small blebs in galena or in veinlets crossing galena areas that appear to follow crystallographic or cleavage directions. The only later rich silver mineral definitely identified is stromeyerite. This mineral replaces tetrahedrite in a complex system of small veinlets and is generally associated with chalcocite.

ORIGIN AND AGE OF THE DEPOSIT.

Although the veins occur along fissures that have been produced by normal faulting, these, as is generally the case, were not structurally important faults and in only one instance show measurable displacement. Owing, however, to the lack of regular bedding planes and horizon markers, some of the fissures along which the veins occur may have suffered more displacement than is at first evident.

A likely explanation of banding is that the veins have been formed by successive small enlargements of the fissures rather than from the subsequent shearing of the veins. A further suggestion of banding has in some cases resulted from included fragments of wall rock.

The ores have been deposited in open spaces in favorable places in the veins, and have not replaced the adjacent wall rocks. Although undoubtedly replacement has taken place in the more minutely shattered country rock, the veins would correspond to the old definition of "true fissure veins". The veins in limestone are interesting in that replacement has been a subordinate factor in their development.

Whereas the veins do vary somewhat in mineral composition, they are all of the same general type and the vein filling was probably contemporaneous over the district as a whole. The evidence afforded by the exposed junction of the Stewart's Wonder and Rainbow veins warrants this conclusion, but other supporting facts are not available.

The mineral deposits are like those that have been generally considered elsewhere to have been deposited by ascending hot waters. The source of the solutions is not known, but it seems most probable that the ores are genetically related to the deeper rock masses that supplied the material for the intrusion of the Little Chief porphyry. Such a relation is suggested but definite proof is not available. The Little Chief porphyry is the only body of an igneous rock in the vicinity of the district. The age of the intrusion is not definitely known but for reasons given elsewhere in this report, a Mesozoic age is assumed. Judging solely from the general character of the veins and their mineral constituents, particularly the massive milk-white coarsely crystalline quartz, the ores were probably formed during the late Mesozoic metallogenetic epoch following the intrusion of the granite porphyry.

√ MINES AND PROSPECTS.

Wyoming Mine. (8,9,10).*

The Wyoming mine is situated on the south

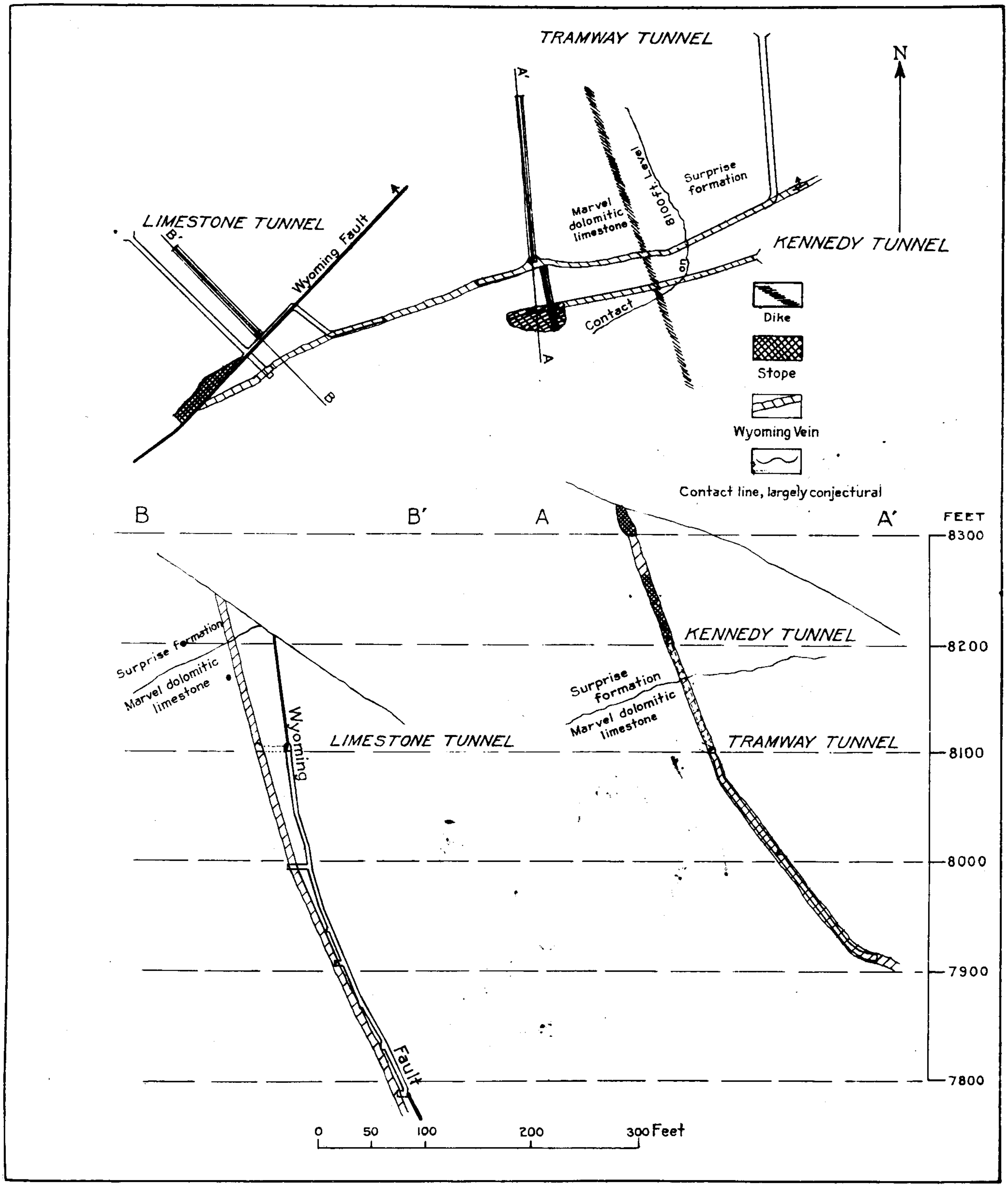
---

* Numbers in parenthesis refer to the detailed geologic map (Plate II, in pocket).

slope of Surprise Canyon on what is known locally as Wyoming Hill. It is at an elevation of 8100 feet, one-half mile south and from 1100 to 1200 feet above Panamint townsite. It is one of the more important mines in the district. Most of the development work in the mine was done during the boom days in the district. The mine is the property of the Panamint Mining Company. Undoubtedly considerable high grade ore was taken from the mine, but production figures are not available. The ore was loaded into buckets near the portal of the Tramway tunnel and sent over a 2600 foot two-cable aerial tramway to the mill and roasting furnace at Panamint. The present company repaired the tramway and it is now in good condition. The total underground workings including tunnels, drifts, raises and winzes (but not including the Lewis tunnel) covers roughly 2500 feet. The mine was exploited from three main adits, Tramway tunnel, Kennedy tunnel, and Limestone tunnel. The plan and sections of the principal workings of the mine are shown in Plate XXIII. Most of the ore removed from this mine, came from two stopes, - one at the end of the Kennedy tunnel and the other located in a drift of the Limestone tunnel. The stopes are from 8 to 15 feet wide, but their extent is not known.

Though there are several veins on the property, the only productive one, is known as the Wyoming. This vein has a fairly straight course and is easily traceable for a distance of over 3500 feet, with a general strike of roughly N. 60° E.

PLATE XXIII



PLAN AND SECTIONS, PRINCIPAL WORKINGS OF WYOMING MINE.

probably relatively large. In keeping with other veins in the district, the Wyoming vein is often rather barren; especially is this true when the country rock is schist. The vein is, however, locally spotted with high grade ore.

In 1925, the present owners started the driving of the Lewis tunnel in an attempt to intersect the Wyoming, and possibly the First Chance and Independence veins with depth. After completing 2310 feet of tunnel, the project was abandoned in 1926. The portal of the tunnel is at an altitude of 7100 feet, 680 feet below the bottom of the winze in the Limestone tunnel. The adit was driven entirely in the Marvel dolomitic limestone and has a bearing of north-south. It was found that the First Chance and Independence veins did not continue to this depth, and only a few small quartz stringers were found in the tunnel. The tunnel intercepted several minor faults, three of them striking N. 35° E. and dipping from 60° to 75° W. Two other faults have approximately the same strike of N. 15° W. and dip from 50° to 70° W. The fault which displaces the Wyoming vein, is encountered 1740 feet from the portal of the tunnel. It has a strike of N. 40° E. and dips westward. A short drift has been run southward following the fault. If the Wyoming vein had not been displaced it would have intersected the tunnel approximately 1500 feet from the portal, assuming that the vein has an average dip of 65°.

The ore-shoots in the district are known to be small and irregularly distributed with no indication as to where they may be found. For this reason a better and less expensive plan of exploring the Wyoming vein with depth, would have been to continue sinking on the vein from the bottoms of either of the two winzes in the mine. In the case of a strong, well-defined fissure traceable on the surface for about 3500 feet, the presumption may be indulged that it will extend an equivalent distance downward. There is therefore some reason for believing that the Wyoming vein extends to the 7100 foot level of the Lewis tunnel, although apparently the vein tends to flatten somewhat with depth.

In order to obtain a better idea of the relations existing between the fault and the vein, a celluloid model was constructed on a scale of 200 feet to the inch. In prospecting for the Wyoming vein, the following suggestions are made. Based on a study of the model, a crosscut driven due east from a point in the tunnel 1530 feet from the portal would intersect the fault at a distance of about 80 feet. The narrow diorite dike which intersects the tunnel 1110 feet from the portal should also be encountered at this point. Drifting along the fault in both directions should be done, in order to determine if possible, the relative displacement of the dike on both sides of the fault. Drifting in both directions from this point might also locate the vein, but if this is not feasible from a mining standpoint owing to the open nature of the fault, the drift should be extended a short distance into the footwall. From here north-south drifts should intersect the vein; the exact length of such drifts will depend upon the average dip of the vein.

Owing to the lack of suitable horizon markers, little could be learned regarding the nature of the fault movement. For this reason no suggestions are offered relative to locating the vein on the hanging wall side of the fault. The evidence bearing on the lateral and vertical components of movement, in so far as indicated by striae and grooves, is rather conflicting, suggesting several movements. However, those inclining about 15° to the south are more prominent. If there have been several movements on this fault, the older striae and grooves are doubtless more or less healed, since travertine is being deposited apparently at a rapid rate in the fault zone.

The ill-advised and unwarrented scheme of development was to continue the driving of the tunnel to the northwest branch of Happy Canyon, a distance of about 2½ miles. According to the survey of the proposed tunnel, the following veins would be intersected at depths ranging from 250 to 1250 feet; Tom Boy, Ida, Rex, California, High View, and Hudson River. A few of these veins are small and not traceable great distances on the surface and some of them may not continue to the depth of the tunnel. There is no reasonable ground upon which to base a conclusion that any considerable amount of workable ore will be found in any of them.

Stewart's Wonder Mine. (4)

The Stewart's Wonder mine, situated on the north side of Surprise Canyon a short distance west of Panamint townsite, includes two patented mining claims, - Challenge and Stewart's Wonder. The property is owned by the Panamint Mining Company. As far as could be learned, all the development work on the property was done during the early days of the camp and includes three tunnels, also several raises, winzes and open cuts on the Stewart's Wonder vein on the east slope of Wonder Gulch aggregating several hundred feet. The workings were not examined in their entirety. It is one of the principal mines of the district but production figures are not available. According to Stetefeldt* some of the ore assayed over $900 a ton (probably largely in silver) and the average ore from a pay streak from an incline assayed $83.24.

The vein as mapped, boldly outcrops for a distance of 2400 feet, but probably extends about 1000 feet west of the area mapped. It ranges from 4 to 8 feet in width and dips from 80° N. to vertical. The country rock is the Marvel dolomitic limestone. The vein splits into three branches as it enters the Surprise formation and can not be traced more than 200 feet beyond the contact.

The west slope of Wonder Gulch has been broken by a number of faults, the more important of which are indicated

---

* Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1875, p. 37, 1877.

on the detailed map of the district. These fissures are so numerous that the limestone in the fault zone is much fractured and crushed. They have cut and displaced the vein into several segments, (see Plate XIX, A), and also resulting in considerable rotation of the vein. West of Wonder Gulch the strike of the vein is N. 70° W. while east of the gulch it strikes N. 64° E. West of the gulch the vein has been badly crushed and at times both walls are followed by faults with more or less brecciation. The faults along the vein are probably an adjustment due to the several cross-fissures.

Hemlock Mine. (11)*

The Hemlock mine, property of A. D. Myers, is situated near the head of Marvel Canyon and about a half a mile south of the area included in the geologic map of the district. Its topographical situation is shown in Plate VI, B. Due to the inaccessibility of a large part of the workings, an examination of the mine was not attempted. It is believed to have been the largest producer in the district although production figures are not available. The Hemlock is connected with the Wyoming mine by a narrow wagon road over which ore was transported to a connecting aerial tramway which delivered it to the mill at Panamint. According to residents in the district, the Hemlock vein is a southwestward continuation of the Kenneth vein. The country rock is the Marvel dolomitic limestone

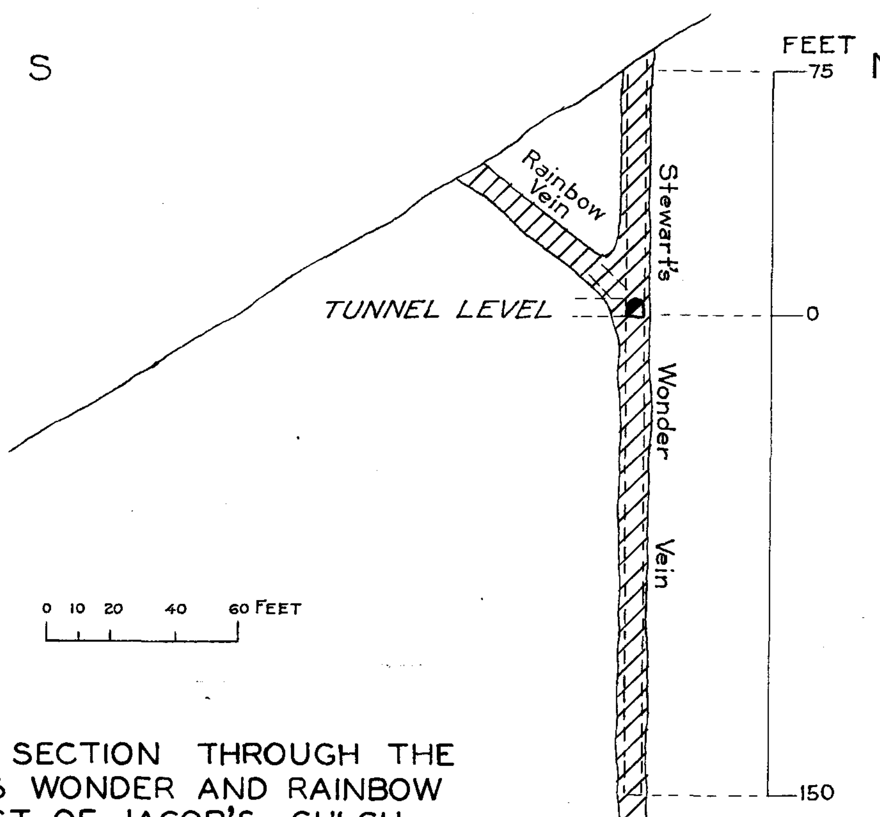
---

* Numbers in parenthesis refer to the reconnaissance geologic map (Plate 1, in pocket).

and the Surprise formation.

Camp Bird Mine. (2, 3)*

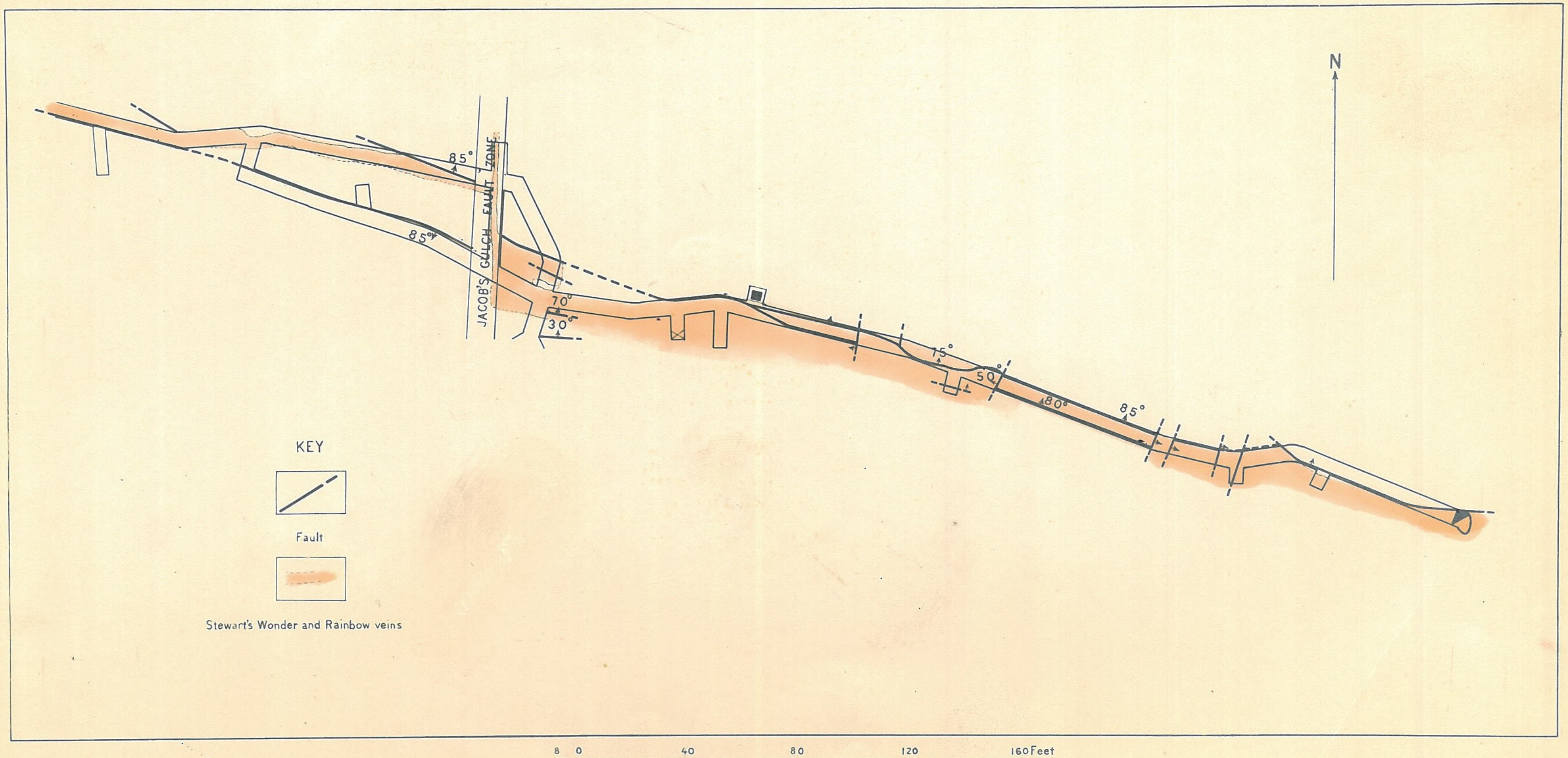
The Camp Bird mine, formerly known as Jacob's Wonder, is situated in Jacob's Gulch, nearly a mile westerly from Panamint townsite. This property is owned by J. V. Lehigh and includes the Camp Bird and Rainbow groups of mining claims, The major part of the development work on the property, was done during the boom days of the camp. The mine is developed by a 150 foot winze and a 75 foot raise on the Stewart's Wonder vein and by several hundred feet of laterals following the junction of the Stewart's Wonder and Rainbow veins. Only limited production is reported to have resulted from the early development work in this mine. The mine has never been satisfac-



GENERAL SECTION THROUGH THE STEWART'S WONDER AND RAINBOW VEINS EAST OF JACOB'S GULCH.

Figure-3.

PLATE XXIV



PLAN MAP OF THE CAMP BIRD MINE

torily sampled and it would be impossible to estimate the average tenor of the ore in the veins. Specimen ore has assayed up to $350 a ton in silver. Screening tests of the dump showed an average of approximately $15 per ton in silver. Very favorable extraction tests have recently been made by the flotation method.

The above mentioned veins very in width from 4 to 10 feet and their outcrops are well pronounced. (See Plate XIX, A, B). The Stewart's Wonder vein strikes N. 75° W. and has a general vertical dip. The rainbow vein dips north from 35°-40° and joins the Stewart's Wonder vein near the portal of the tunnel. An east drift has been run along the junction of these veins for a distance of about 400 feet. The total mass of quartz at the junction is roughly 25 feet wide. The country rock is the Marvel dolomitic limestone.

The Stewart's Wonder vein has been brecciated by post-mineral movement, often along both the footwall and hanging wall, and in places it has been wholly reduced to a white gouge filled with angular fragments of crushed quartz. The fault in Jocob's Gulch has not notably displaced the Stewart's Wonder vein as shown in Plate XXIV.

Little or no ore has been stoped in the mine. The pay streaks are small and not persistent but at several places might be profitably worked.

Bachelor No. 2 Mine. (10)*

The Bachelor No. 2 mine, property of J. V. Lehigh, is about 1 mile east of Panamint townsite and near the head of Surprise Canyon. It is outside the area included in the detailed geologic map of the district. The mine, formerly known as the Sunrise, has been idle since the boom days in the district but reports indicate that a few hundred tons of high grade silver ore was taken out. It is quite evident that the mine has been entirely worked-out.

From a brief examination it would seem that the ore occurred in a brecciated zone between two parallel fissures with well-defined walls which dip in opposite directions and apparently join to the south in a shape not unlike that of a bow of a boat. The country rock is the Marvel dolomitic limestone. Possibly the folding of the limestone may have had considerable to do with the development of the fissuring. All of the ore was found near the surface and under less than 50 feet of cover. The ore was stoped for a distance of about 100 feet. A 50 foot shaft was driven apparently to the intersection of the fissures but it was impossible to study the shaft at the time of my visit.

Revenue Prospect. (11)**

The Revenue prospect, property of J. V. Lehigh,

---

* Numbers in parenthesis refer to the reconnaissance geologic map (Plate 1, in pocket).

** Numbers refer to the detailed geologic map (Plate2).

is situated in Magazine Canyon. Development consists of about 250 feet of drifting on a vein which strikes N. 50° E. and dips 60° NW. It ranges in thickness from a mere stringer to 2½ feet and averages less than a foot. The country rock is the Surprise formation. An insignificant amount of high grade gold ore is reported to have been discovered. Some ore may possibly be encountered at the junction of the Revenue vein with another vein that strikes into it at an acute angle. The relations are shown on the detailed geologic map of the district.

Kenneth Prospect. (12)

The Kenneth prospect, property of J. V. Lehigh, is situated in Magazine Canyon a short distance south of the Revenue prospect. Development consists of about 50 feet of drifting on a vein which strikes nearly north and dips about 55° W. The vein, which crops out in the Surprise formation, varies somewhat in width but averages about 3 feet on the surface. It is generally barren but shows some mineralization locally and a small pocket of silver-lead ore was found near the portal of the tunnel. Post-mineral movement is indicated in several places with both the quartz of the vein and the schist foot and hanging walls more or less brecciated. The striae on some of the gouge surfaces plunge at a low angle to the north. The footwall is at times kaolinized and a thin section of some brecciated material from the hanging wall of the

PLATE XXV.

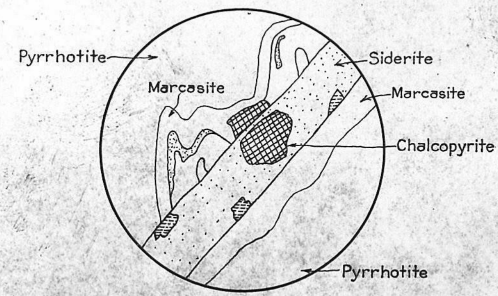
PLATE XXV.

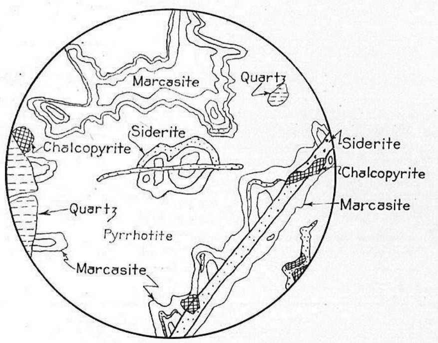
DRAWINGS OF POLISHED SURFACES OF ORES.

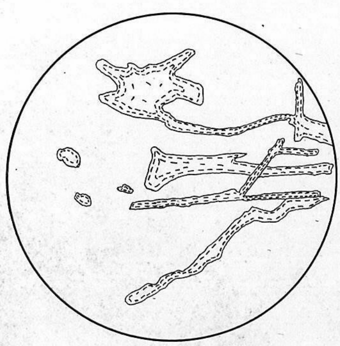
A. Ore from the Kern prospect, showing the relations between pyrrhotite (white), marcasite, chalcopyrite (cross-lined), siderite (dotted) and quartz (broken-lined). Magnified 20 diameters.

B. Ore from the Kern prospect, showing replacement of pyrrhotite by marcasite along fairly definite directi[ons] but often expanding into globular masses built up of concentric shells. Magnified about 20 diameters.

C. Ore from the Kern prospect, showing the relations between pyrrhotite (white), marcasite, chalcopyrite (cross-lined), siderite (dotted), and quartz (broken-lined). Magnified about 60 diameters.


Pyrrhotite
Marcasite
Siderite
Marcasite
Chalcopyrite
Pyrrhotite


Marcasite
Quartz
Siderite
Chalcopyrite
Siderite
Chalcopyrite
Quartz
Marcasite
Pyrrhotite
Marcasite



vein showed the presence of sericite, cryptocrystalline quartz and chlorite, scattered with minute needles which may be rutile.

Kern Prospect.

The Kern prospect, property of Mrs. H.H. Thompson, is situated about a half a mile northeast of Panamint townsite and just outside the area included on the geologic map of the district. There are several quartz veins on the property. The principal one strikes roughly N. 40° W. and dips 25° NE, apparently following the schistosity of the schist. The average width of the vein is 2 feet. It is developed by approximately 300 feet of workings. The country rock is the Surprise formation. The ore has not been successfully concentrated due to the high sulphide content, but according to Robert Warnock, it ranges in tenor from $13 to $17 per ton in gold.

The character of the ore is entirely different from that of other mines in the district. The vein is heavily mineralized and the typical ore composed almost wholly of pyrrhotite, pyrite with subordinate coarsely granular glassy quartz. Pyrrhotite and pyrite impregnate the wall rock for a distance of several inches from the vein. Examination of several specimens of massive pyrrhotite ore in reflected light showed the development of marcasite closely associated with siderite. The marcasite possesses the usual characteristic properties ascribed to this mineral and almost invariably shows concentric rings; but its identity was fixed by the rotation of the plane of polarization of reflected light. The carbonate was identified under the petrographic microscope. It has a high index of refraction and an ashen gray color with distinct absorption, which, according to Winchell* is especially characteristic, although not pronounced. The chemical properties also closely conform to those of siderite.

Siderite appears to be both contemporaneous with and later than marcasite. Though it is often concentric with the marcasite and fills the spaces betwenn successive rings, yet it frequently forms veinlets which cut across the structure of the marcasite. Veinlets of siderite, associated with a few widely scattered grains of quartz, are very often bordered by colloform marcasite, as shown in Plate XXV, A. Again marcasite replaces pyrrhotite along apparent cleavage or crystallographic directions which often expand into more or less globular shaped masses built up of concentric shells (Plate XXV, B).

Chalcopyrite is usually associated with the siderite veinlets and was probably contemporaneous with and earlier than siderite. Occasionally veinlets of siderite,

---

*Winchell, A. N., Elements of Optical Mineralogy, Part II, New York, p. 79, 1927.

usually of such dimensions as to be noticed only under high magnification, cut entirely through grains of chalcopyrite. Chalcopyrite cuts across the structure of the marcasite which fact suggests but does not prove replacement. The relations above mentioned are shown in Plate XXV, C.

Pyrite is replaced by an intricate network of quartz veinlets. However, it is to be regretted that the relations of pyrite to the other minerals in the deposit could not be ascertained with certainty. Gold was not observed in polished sections of the ore. On the assumption that there has been a single generation of quartz, the order of deposition appears to be as follows: pyrite, quartz, pyrrhotite, chalcopyrite, marcasite, and siderite overlapping with the marcasite and the chalcopyrite.

The occurrence of marcasite replacing pyrrhotite and the development of a carbonate, particularly a sideritic carbonate, contemporaneous with and later than marcasite has recently been mentioned by several observers.* The facts seem

---

* Gilbert, G., Oxidation and Enrichment at Ducktown, Tenn., Trans. Am. Inst. Min. and Met. Engs., pp. 998-1023, No. 1318, 1924.

Newhouse, W. H., Paragenesis of Marcasite, Econ. Geology, Vol. XX, pp. 54-66, 1925.

Tolman, Jr., C. F., and Rogers, A. F., Study of the Magmatic Sulfid Ores, p. 40, 1916.

Buddington, A. F., U. S. Geol. Survey Bull. 773, p. 104, 1925. NOTE--Carbonate does not occur in the deposit described by Buddington.

to indicate that the marcasite may have either a supergene or hypogene origin in the several occurrences discussed by Newhouse. The assigning of a hypogene origin for the marcasite was based largely on the fact that quartz was deposited later than marcasite and that supergene sulphide deposition is only rarely accompanied by quartz.

Oxidation products are almost entirely lacking in the ores from the Kern prospect. The sulphides occur at the surface and pyrrhotite has not been noticeably oxidized to limonite. In the silver-bearing veins previously described, the zone of oxidation is shallow and commonly the sulphides occur at the surface. Moreover, there is little indication of supergene enrichment in the silver ores of the district. In the massive sulphide ore from the Kern prospect there is certainly no reason for assuming a supergene origin for the chalcopyrite. It seems improbable, therefore, that marcasite was deposited by supergene solutions and a hypogene origin is favored.

Other Mines and Prospects.

Other mines and prospects in the Panamint district include, -- Anaconda, Grand View, Comstock, Star, Franklin, Omaha, Gold King (1), Last Chance, Leadville, Little Molly (6), First Chance, Little Chief, Ida (7), Independence, Rex, Eureka, Bachelor, Alabama (12),* Hudson River (12).* A little ore has been found in all of them.

---

* Numbers in parenthesis and marked by an asterisk refer to the reconnaissance geologic map (Plate 1, in pocket).

PART IV. THE ORE DEPOSITS --CONT'D

OTHER MINES AND PROSPECTS IN THE RANGE.

NEW DISCOVERY MINE. (3)

The New Discovery mine, is located in Jail Canyon about 2 miles from the mouth of the canyon. This property includes the Gem group of mining claims and the present owner is Robert Warnock. The total production is reported to have been in the neighborhood of $15,000 in gold. The mine was worked from 1888 to 1900 and again from 1911 to 1912. The ore was treated in a 3 stamp mill with an 82% recovery.

Development consists of 4 tunnels, 2 on each side of the canyon, which follow a strong fault fissure striking roughly N. 25° W. and dipping 65° W. The fissure is parallel to the planes of foliation of the sheared granite, country rock. Some distance west of the vein a vertical shaft was sunk 125 feet to water level. On the 75 foot level, a short crosscut to the east intersected the vein. Water is now being pumped from the shaft with a view to further development work. It is not now known how much ore has been stoped in the mine. No satisfactory specimens of ore were collected. The ore is valuable entirely for gold.

BURRO MINE. (2)

The Burro mine is located in Jail Canyon a short distance east of the New Discovery mine. It has been idle for a number of years. The property was not examined but according to a report of the California State Mining Bureau* there are a number of parallel quartz veins with a NW-SE trend which vary in width from 2 to 10 feet. The ore assayed from $2.50 to $25 a ton in gold. Development consists of a 116 foot shaft and a tunnel 200 feet in length.

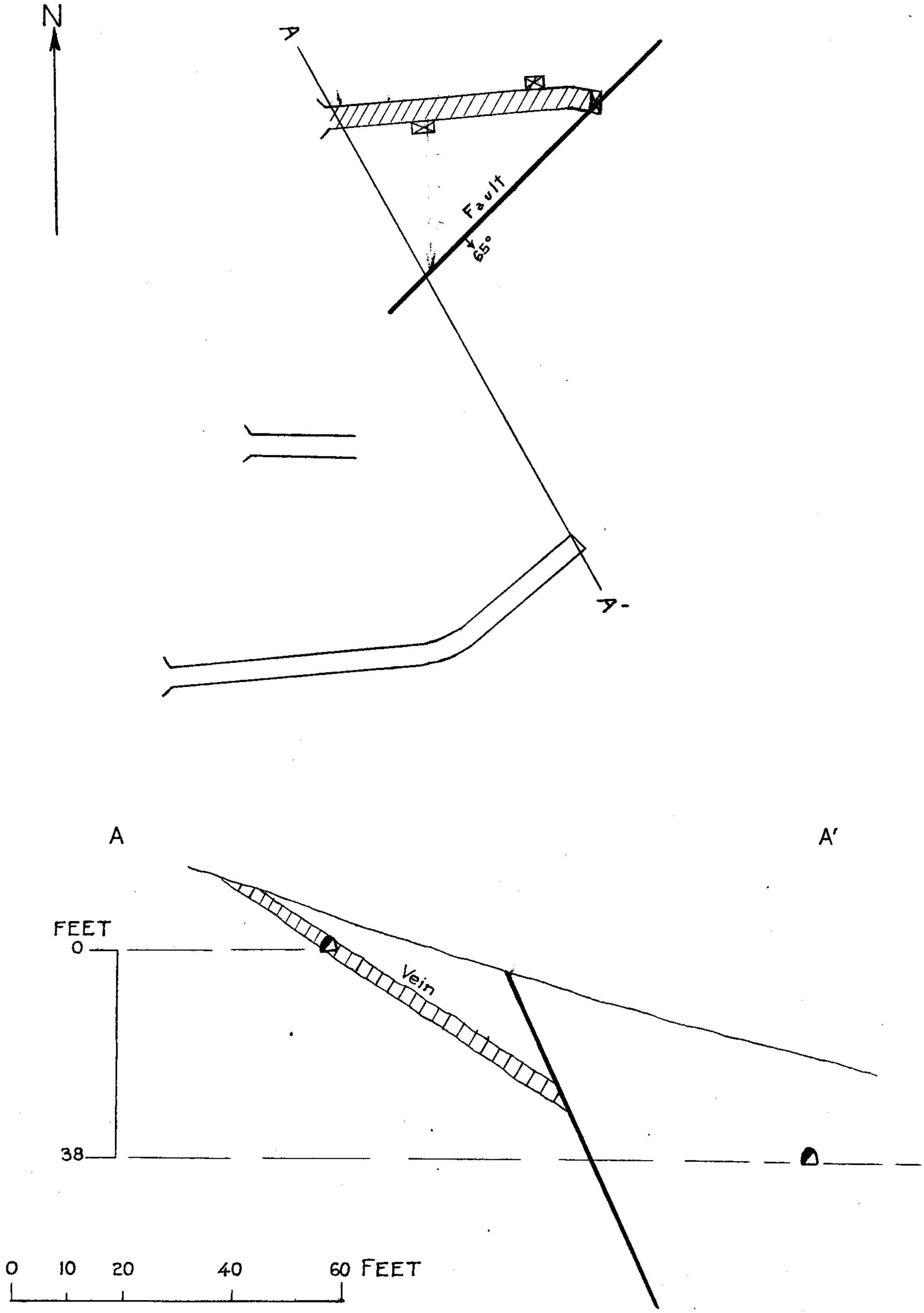
HORN SPOON MINE. (4)

The Horn Spoon mine, property of Christopher Wicht, is situated near the head of Hall Canyon. The elevation of the mine is 7500 feet. The country rock is conglomerate schist. The property is developed by three tunnels, one of which has been run on a fault fissure which dips 35° SE. The vein has been faulted and was not encountered in the other two tunnels. The relations are shown in Plate XXVI. The vein is about 2 feet wide and is reported to average $35 a ton in gold. The vein has been considerably crushed and has a gouge seam on the footwall. The ore is a highly oxidized breccia consisting of fragments of generally dark colored quartz cemented by crusts of secondary quartz. Rather coarse textured gold is the only ore mineral present in the deposit and occurs embedded in masses of limonite.

There are several massive quartz veins on the property but they are in general quite barren.

---

* California Mining Bureau Seventeenth Ann. Rept., p. 281, 1920.



PLAN AND SECTION, HORN SPOON MINE.

MOUNTAIN GIRL MINE. (13)

The Mountain Girl mine, situated at the head of Happy Canyon and about 4 miles in an air line south of Panamint, includes two mining claims, the Mountain Girl and the Mountain Girl Fraction. The original locator and present owner of the property is Harry C. Porter. Several men are now at work developing the property. The mine is at an elevation of about 8000 feet. The owner has realized fair returns selling specimens of coarse gold. The mine is developed by several tunnels, a shaft, and many open cuts and trenches.

There are a number of small quartz veins on the property. The contact between them and the walls is sharp. Rarely these veins follow the jointing of the conglomerate schist, country rock. Post-mineral faults of small displacement offset the veins in many places. The veinlets carrying coarse gold are rarely over 5 inches in width and generally average from 2 to 3 inches. According to the owner, the wider veins are usually barren. They strike from N. 35° E. to N. 50° E. and apparently are branch veins of a main vein which strikes N. 25° E and dips 50° E. The latter is probably a lens and is traceable but a short distance on the surface. The maximum width of the lens is over 30 feet and averages $9 per ton in gold.

A characteristic feature of the deposit, is the occurrence of coarse gold at the junction of calcite stringers with quartz veins. These stringers are rarely over a hairbreadth in thickness but may attain a width of 1/16 of an inch. Usually, they join the vein at an acute angle and apparently are confined to the footwall side. The stringers are seldom traceable into the country rock for a distance of over 2 feet. The general occurrence of coarse gold at the junction of calcite stringers with quartz veins was noted and this suggests a dependent relationship.

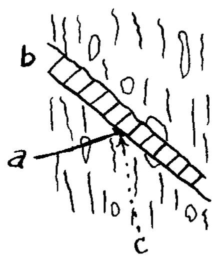


FIGURE 4.— Sketch showing the occurrence of coarse gold at the junction of a calcite stringer with a quartz vein. a, calcite stringer; b, quartz vein; c, gold. The rock is conglomerate schist.

The quartz of the lens is very similar in character to that in the Panamint district, being massive, milk-white and coarsely crystalline; while the quartz of the gold-bearing veinlets is more glassy. Siderite is another nonmetallic mineral of the deposit.

The metallic minerals of hypogene origin include, in the approximate order of their abundance, pyrrhotite, arsenopyrite, chalcopyrite, pyrite, and gold. Commonly pyrrhotite has been metasomatically developed in the wall rocks adjacent to the veins and always as a replacement, either in whole or in part, of quartzite fragments of the country rock.

RADCLIFF MINE. (14)

The Radcliff mine, situated on the south slope of Pleasant Canyon about 5 miles east of Ballarat, was located in 1897 by Messrs. Radcliff and Halbert. The mine is at an elevation of about 7000 feet. It is reported that the ore delivered to the mill averaged about $45 per ton. The property was developed and worked up to the year 1903 when, by reason of bad management, operations ceased. The total production to the end of that year has been locally estimated at between $500,000 and $750,000. The property, now owned by W. D. Clair, includes the following patented claims: Sun Rise, Grover Cleveland, John G. Carlisle, Kentucky Texas, Joker, Joker Extension, Never Give Up, Treasure Vault, W. G. Quartz, and the Cleveland millsite claim. According to various mining engineer's reports there is available a considerable tonnage of ore averaging around $12 per ton. Equipment consists of a 60 ton mill of 20 stamps, cyanide plant, and a 3800 foot two-cable gravity tramway. An attempt was made in 1927 to cyanide the tailings, and, it is stated, was attended with some measure of success. The mine is developed by tunnels run on the veins with several stopes connected through to the surface at different points and a 25 foot vertical shaft; the total workings aggregating about 2400 feet, covering a vertical depth of 500 feet for a horizontal distance of 700 feet. The mine is now being worked by a lessee.

Only a few hours was spent on the property and no attempt was made to thoroughly examine the mine workings, now in large part inaccessible. Apparently, however, several veins have been productive. They have a general strike of E-W and dip south.

The country rock is the Panamint metamorphic complex and may be variously described as a quartz-sericite gneiss, meta-quartzite or conglomerate schist. In the conglomerate facies both quartzite and limestone fragments are represented. Interstratified bands of limestone also are included. The distribution of the veins has not been influenced by any particular type of rock. Bedding when recognized strikes north-south and dips about 35° W.

Both oxidized and sulphide ores have been mined. Apparently the depth of oxidation is not great as the deepest drifting is only 500 feet below the surface of the ridge on which the mine is situated.

The quartz of the veins is a coarse glassy variety and often has a smoky-gray greasy aspect. Microscopically, the quartz is seen to have been greatly strained and crushed to such a degree that in some instances it has been reduced to a cryptocrystalline state. Other nonmetallic minerals of the deposit are siderite and chestnut brown biotite. The biotite and siderite are closely associated with pyrrhotite and clearly contemporaneous in deposition. In one section a remnant of an unreplaced patch of quartz containing a few small grains of microcline was observed.

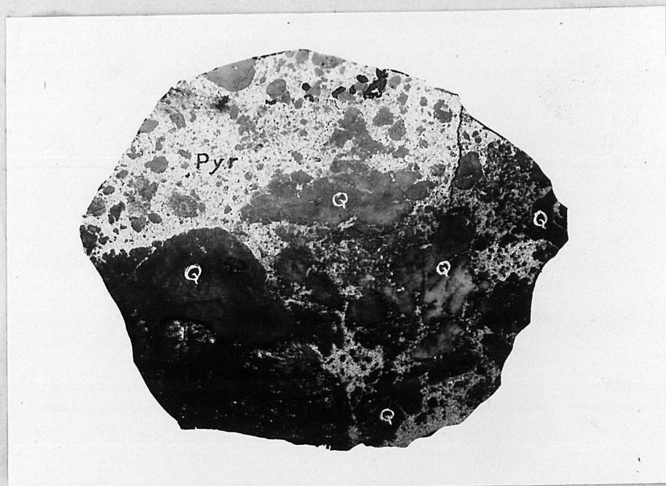
The hypogene ore minerals are pyrrhotite, pyrite, gold, and probably chalcopyrite. The megascopic relation

PLATE XXVII.

PLATE XXVII.

PHOTOGRAPH OF POLISHED SURFACE OF TYPICAL ORE FROM THE RADCLIFF MINE.

Pyrrhotite, (Pyr) light; pyrite, inked black; quartz, (Q), dark; gold, yellow. Natural size.


Pyr
Q
Q
Q
Q
Q
Q

between pyrrhotite, pyrite, gold and quartz is illustrated in Plate XXVII, which is reproduced from a photograph of a polished specimen of ore. Pyrrhotite is the principal sulphide and is always massive. It replaces quartz and pyrite. Pyrrhotite surrounds grains of pyrite and often fills cracks and seams in them and there is, therefore, no doubt that pyrite is older and has been replaced. Pyrite is much less abundant than pyrrhotite and was only observed after specimens of the ore had been polished. Typical sulphide ore is composed largely of pyrrhotite and quartz. The gold fills minute fractures in pyrrhotite or in the quartz and is rather coarse textured. The ore gives a qualitative reaction for nickel but no nickel minerals were observed.

The biotite and pyrrhotite suggest a transition from the mesothermal to the hypothermal group of ore deposits. The age of the deposit can not be accurately stated. The country rock is thought to be of pre-Cambrian age. The deposit is probably generically connected and of the same age as the World Beater porphyry exposed just north of the mine. This rock may have intruded other rocks of the Panamint metamorphic complex but as this could not be definitely proved, it has been provisionally regarded as pre-Cambrian.

WORLD BEATER MINE. (15)

The World Beater mine is situated in Pleasant Canyon approximately 1000 feet northeast of the Radcliff workings. The property was not examined and little could be learned regarding the mine in general. It was discovered in 1896 and worked intermittently until 1908. It is reported to have produced a total of $250,000. The property is developed by several thousand feet of tunnels run on a vein which has an easterly dip. The ore was of good grade. Assays as high as $200 per ton in gold were not uncommon. Equipment includes a 10 stamp mill and cyanide plant although the latter was not put into operation until near the close of the mine's activity. The property, now held by Mrs. H. H. Thompson, comprises 5 claims.

BIG HORN MINE. (16)

The Big Horn mine, formerly known as the Gibraltar is situated on the south side of South Park Canyon about 7 miles southeast of Ballarat. The mine was not examined. Discovery was made in 1907 and development consists of a 70 foot winze and 200 feet of drifting on a vein carrying lead carbonate. Most of the ore was obtained from the winze and 25 carloads is said to have been shipped at a profit.

ANTHONY MINE. (17)

The Anthony mine, situated in Pleasant Canyon about 2½ miles west of the Radcliff, was located in about 1893*

---

* California Mining Bureau Twelfth Ann. Rept., p. 139, 1894.

by C. Anthony. A 5 stamp mill was built in 1895* and operated for a short time. Several gold-bearing quartz veins with a general north-south course have been opened up by a few short tunnels. Production consisted of a few hundred tons of fairly high grade ore. The country rock is crystalline limestone of the Panamint metamorphic complex. The property was not examined.

OTHER MINES AND PROSPECTS.

According to the various reports of the State Mineralogist there are a number of other mines and prospects in the Panamint Range but they were not examined and most of they have been idle for a number of years. A few of them are located on the eastern side of the range but most of them are north of the area covered in the reconnaissance mapping of the range. Small shipments have been made from time to time of gold, silver, antimony and copper ores.

A gold prospect, property of Chris Tyler, is located in Tuber Canyon not far from the foot of the range. The mine was first worked in 1900 and some high grade gold ore is reported to have been found.

Other properties include the Gold Hill mine, Grundy mine, and antimony (stibnite) deposits in Wild Rose Canyon.

---

* California Mining Bureau Thirteenth Ann. Rept., p. 183, 1896.