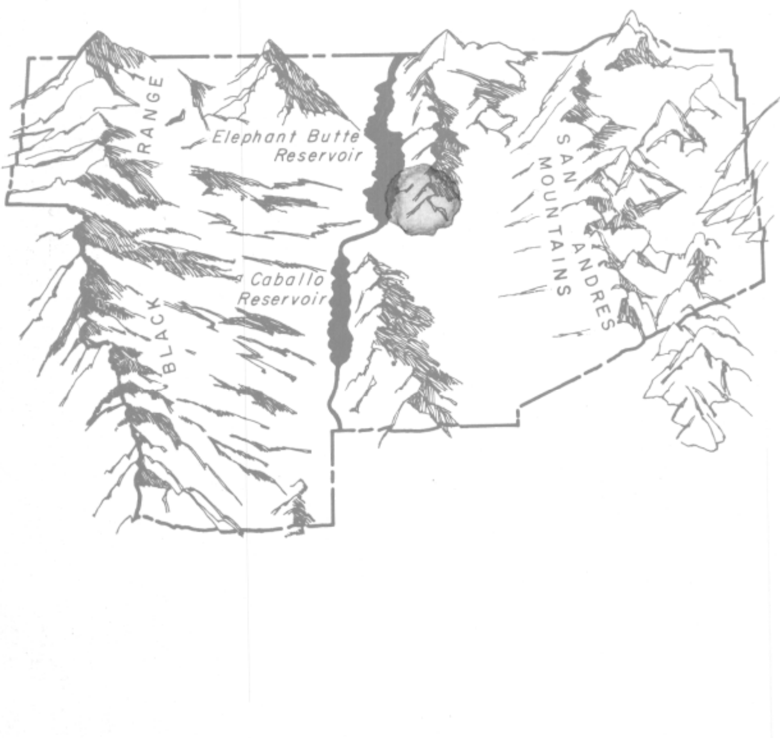
The Geology and Ore Deposits of Sierra County, New Mexico

by GEORGE TOWNSEND HARLEY



BULLETIN 10 1934

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New Mexico State Bureau of Mines and Mineral Resources

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The Geology and Ore Deposits of Sierra County, New Mexico

By

G. TOWNSEND HARLEY

INTRODUCTION

Sierra County, one of the smaller counties of New Mexico, has been its third largest producer of mineral wealth. All of the ore bodies so far exploited have been of small to moderate size, although some of them have been phenomenally rich. To those who are interested in seeking out and operating small mining properties, the potential mineral wealth of this area is still a matter of great interest.

The field work for this report was begun July 1, 1931. During July and August a general survey was made of the county, and most of the mining districts were examined in such detail as the time and condition of the mines permitted. A topographic map of the Hillsboro district was made and the areal geology worked out. It was planned to complete the preparation of the report during the winter months and to have it ready for the printer in the summer of 1932. In the meantime, however, due to depressed conditions in the metal market, many of the larger base-metal mines in the southwestern Urited States greatly curtailed production or suspended operations completely. This encouraged many individuals and small operating units to take up in an energetic manner the search for placer and lode gold deposits, or to attempt to find base-metal deposits containing gold in sufficient quantity to make operation profitable in spite of existing low prices. The result was that many of the mines in the county that were inaccessible in 1931 had been or were being sampled or prepared for operating in the spring of 1932. It was necessary, therefore, during July, 1932, and on several occasions thereafter, to revisit the different mining camps in the county and to include much additional material with that already gathered.

PURPOSE AND SCOPE OF REPORT

This bulletin has been prepared primarily for the use and information of prospectors, owners and operators of mining property in Sierra County, and as a guide to those non-residents of the county who are seeking an outlet for funds through the development of the metallic resources of the region. To this end technical phraseology and the presentation of the highly scientific aspects of the geology of the county have been minimized, and the evidence gathered in the field, as shown by surface outcrops and the portions of veins exposed underground, has been emphasized.

Throughout Sierra County, most of the small properties and many of the larger ones have been inactive for many years, and their workings have caved and have become inaccessible. Many of the owners, as well as others who were once familiar with these old workings, are no longer in the county, and the claims have declined until claim and location monuments, and the notices that were once in them, can no longer be found in the field. Where old records of production are still available or reports by reputable engineers have been read, it has been possible in a measure to picture the conditions that existed in the veins when these old mines were active, but on the whole, the details of production and the value of the ore shipped have become clouded and in many instances are quite out of line with the evidence obtainable at surface. It is not contemplated by the State Bureau of Mines that much actual sampling of the veins shall be done by the geologist investigating ore deposits in the State for Bureau publications, and he is constrained to gather the figures as to the value of the ore from whatever source is available, and to use proper judgment in utilizing them.

In those camps now active, most of the smaller holdings have operated in the past two or three years under a whole series of new claim and company names, and the original and often historic names have been lost sight of completely. Only the more important properties, as the Rattlesnake, Bonanza, Lady Franklin, Silver Monument, U. S. Treasury and several others, have" held to their original names. The report has been prepared very largely on the evidence found on surface, secured without regard for property lines, and supplemented by the study of practically all of the openings accessible to the writer during his several visits to the county.

The first part of the report includes a description of the rocks and the geological history of the county, a discussion of the ore bodies and their mineralogy, and a brief review of practical points involved in the search for ore and the economical exploitation of this mineral wealth. The second part is given to a detailed description of the vein systems and other modes of occurrence of the ore in each of the mining districts within the county, and to the descriptions of most of the mines that were open at the time of visit, and which contributed something to the store of knowledge regarding these veins.

While the material of this bulletin may be regarded as a basis on which to locate and plan future work in the ore deposits of the region, such work should not be prosecuted over long periods of time except under sound technical direction. In the long run it is always the most economical procedure to secure the services of an experienced and reputable mining engineer or mining geologist at frequent and stated intervals, and to rely upon his judgment and advice regarding the future possibilities of the mine, the quantity and value of the ore blocked out, the best campaign for future development, and the advisability of expenditures for plant and equipment.

ACKNOWLEDGMENTS

It is impossible to make adequate note of the assistance rendered by all those encountered during the field work, but grateful acknowledgment is here tendered for the uniform consideration, courtesy and help which the writer received from everyone with whom he came in contact in Sierra County. Special acknowledgment is due to Messrs. Ed James and Charles Hullinger of Chloride, Max Hiltscher and W. D. Slease of Hillsboro, T. B. Everheart of Socorro, D. M. Miller of Lake Valley, and Silas Call of Kingston, who gave generously of their time in conducting the writer through the districts and who supplied much valuable information that has been incorporated in this bulletin. Others who assisted the writer in the field or supplied valuable information are Messrs. W. H. Bucher, Geo. T. Meyers, and Max Kahler, all of Hillsboro, and T. C. Parker of Willow Springs.

The writer also desires to thank those who, without special interest in this report, have been of material assistance in advising him on technical matters, on the arrangement of the report, and in reading and criticizing parts of the original draft of the manuscript. Particular mention in this respect should be made of Dr. C. E. Needham of the faculty of the New Mexico School of Mines.

The drawings contained in this report were prepared by G. H. Wells, who also assisted the writer during the summer of 1931, when the topography and geology of the Hillsboro area were mapped.

PART I. GENERAL FEATURES

GEOGRAPHY

LOCATION

Sierra County is situated in the southwestern part of New Mexico. It is bounded on the east by the New Mexico Principal Meridian, and on the west the crest of the Black Range is the irregular boundary line. The north boundary line is the line between Tps. 9 and 10 S., while on the south the boundary line is the south line of T. 17 S., extending west from the New Mexico Principal Meridian to R. 4 W., thence south along this line to T. 19 S., thence west to the center of R. 8 W., where it connects with the western boundary of the county. The area of the County is approximately 3,118 square miles. It is bounded on the north by Socorro and Catron counties, on the east by Socorro County, on the south by Dona Ana and Luna counties, and on the west by Grant and Catron counties. The population in 1930 was 5,184.

CULTURE

The principal towns are Hillsboro, the county seat, with a population of 200, and Hot Springs with 1,300 inhabitants. Hot Springs, in the valley of the Rio Grande, is a thriving health resort and a distributing point for supplies to miners, ranchers and farmers in this section of the State. The nearest railroad point to Hot Springs is Engle, 26 miles east-northeast, a station on the Albuquerque-El Paso line of the Atchison, Topeka & Santa Fe railway. Lake Valley in the southern part of the county is the terminus of a branch line from the little station of Nutt in Luna County, on the Rincon-Deming-Silver City branch line of the Santa Fe, and is the distributing point for the southwestern part of the county, including Hillsboro and Kingston.

The Elephant Butte dam across the Rio Grande northeast of Hot Springs has impounded the water of the Elephant Butte reservoir. This reservoir, when full, forms a lake 2 to 4 miles wide and 30 miles long, extending to the north beyond the north boundary of the county. At the reservoir one may enjoy excellent fishing, swimming, boating, and camping. Most of the lake and the bordering land have been set aside as a game refuge, where migratory birds may find a haven on their flights to and from the north. In the wide Rio Grande valley and along the small streams tributary to the river, quail and doves abound, while in the Black Range wild turkey, deer, and bear are hunted successfully. This latter area, indeed, constitutes one of the best game regions remaining in the United States.

There are few other towns within the county. Monticello in the northern part is a small farming community, and Fairview' in the northwest part is in a cattle-raising area. Chloride,

The Fairview post office is now known as Winston.

once a thriving mining town, is now nearly abandoned. From north to south along the eastern slope of the Black Range are Chloride, Hermosa, Kingston, Hillsboro, and Lake Valley, all of them important camps during the early history of mining in the county, but which, with the closing of the mines, now exhibit mere remnants of their former activity.

MINING DISTRICTS

The chief mining districts in Sierra County, with their principal metals, are given in the following list. The most important metals are indicated by italics. An index map of the county. Plate III. shows the location of these districts.

Mining Districts in Sierra County and Their Chief Metals

District	Metals
Taylor Creek	*Tin*
Black Range (Chloride)	*Gold, silver,* copper
Apache (Chloride)	*Gold, silver, copper,* lead, zinc
Palomas (Hermosa)	*Silver, lead,* copper, zinc
Kingston (Black Range)	*Silver,* lead, copper, manganese, zinc
Tierra Blanca (Bromide No. 1)	Silver, gold, lead, zinc
Carpenter	*Lead, zinc,* gold, silver
Cuchillo Negro	*Lead, zinc,* copper, iron
Las Animas (Hillsboro)	*Gold, silver, copper,* lead, vanadium, iron, manganese
Lake Valley	*Silver, manganese,* lead, flux
Macho	*Lead,* silver, gold, zinc
San Mateo Mountains	Gold, silver, copper
Mud Springs Mountains (Hot Springs)	Copper, manganese, silver
Fra Cristobal (Armendaris Grant)	Prospects only
Caballos (Palomas Gap)	*Lead, vanadium,* copper
Pittsburg (Shandon)	Gold placers, copper, gold, silver, manganese
Derry	Manganese

In this report, ore deposits in the county that are valuable chiefly for their manganese content and deposits of the various non-metallic minerals are not considered in detail. Some of these have been described in other reports of the State Bureau of Mines and Mineral Resources.[1a]

CLIMATE AND VEGETATION

The altitude of Sierra County ranges from 4,100 feet above sea level in the Rio Grande valley at the south boundary of the county to 10,100 feet in the western part. The valley bottom at

is Wells, E. H., Manganese in New Mexico: N. Mex. Sch. of Mines, Min. Res. Survey Bull. 2, 1918.

Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 4, 1928.

Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features : N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 7, 1933.

the northern end of the county has an elevation of 4,420 feet. This great range in altitude and the abrupt topographic changes cause a wide variety of climatic conditions and types of vegetation.

In the valley proper and on the plains and bolsons, the climate is warm and dry, and the average temperature is about 60° F. Extremes of cold are unknown, but for short periods during the summer months the temperature may be quite high. The average annual rainfall in this part 'of the country is about 10 inches, the greater precipitation occurring from July to October. During this period violent thunder showers of short duration frequently fill the arroyos and washes, and may prevent traffic on the highways for several hours at a time. Light snowfalls are of rare occurrence. In the spring and sometimes in the fall strong winds from the southwest carry an enormous burden of sand and dust, and are relatively important agents of scour and fill in the areas of alluvial deposits and along the river flood plains.

In the mountainous portions of the county considerably more rain and snow falls, and the average temperature is lower. The first snowfall may occur in November on the higher parts, and from then until April or May a blanket usually covers most of the high peaks and ridges.

The following table summarizes climatological data[2] obtained at United States Weather Bureau stations in Sierra County.

Climatological Data for Sierra County

Station	Elevation, Feet	Mean Annual Ppt., Inches	Period of Maximum Ppt.	Days per Year with 0.01 Inches or more Ppt.	Average Amount Snowfall, Inches	Mean Annual Temp., Deg. F.	Mean Annual Maximum Temp., Deg. F.	Mean Annual Minimum Temp., Deg. F.
Chloride	6500	15.40	July-Sept.	60	15.7			
Hermosa	7200	17.79	July-Oct.	59	30.1	48.8	64.8	32.7
Kingston	6500	17.34	July-Oct.	54	24.2			
Hillsboro	5236	12.21	July-Oct.	46	10.4	58.0	73.1	43.0
Lake Valley	5412	13.25	July-Oct.	57	15.0			
Elephant Butte Dam	5265	10.08	July-Sept.	35	5.0	59.6	73.8	45.3

In the flood plain of the Rio Grande, cottonwoods, willows and other similar small trees and shrubs abound. The slopes and plains bordering the valley bottoms support little vegetation other than greasewood, mesquite, and numerous varieties of cactus. On the bolsons and plains above the river, range grasses of various kinds grow in sufficient quantity to support a thriving cattle industry. In the foothills and on the lower mountain slopes, scrub oak and cedar appear, and the range grasses are abundant. The higher mountain slopes have excellent stands of

[2] U. S. Dept. of Agriculture, Weather Bureau, Climatic Summary of the United States Sec. 29, Southern New Mexico, (To 1930, inclusive).

yellow pine, cedar, juniper, and other less valuable woods. In these parts timber has been cut in the past for mining and building purposes and for fuel. It is reported that the mining area near Hillsboro was at one time thickly covered with an excellent growth of yellow pine, which was cut off for use as mine timber and for fuel under the boilers ; now only an occasional rotted stump gives mute evidence of the former forests of the region.

But little farming in the Rio Grande valley is attempted in the northern part of the county, either around the lake or immediately below the dam. Slowly, however, these bottom lands are being reclaimed, and the population is growing. In the southern part, just above the little town of Derry, the highly cultivated area of the Elephant Butte project commences. Cattle raising on the higher plains and foothills is the main industry of the region.

PHYSIOGRAPHIC FEATURES

DRAINAGE

The only permanent stream in Sierra County is the Rio Grande, which flows southward through the east-central part. From the north border to Elephant Butte dam, a distance of 24 miles, it forms the Elephant Butte reservoir of the Lower Rio Grande Conservancy Project. Below the dam the stream bends west and flows in this direction for nearly 6 miles. It then flows south to the southern border of the county near the town of Derry. Throughout its course it is situated to the west of the Fra Crisobal Range and of the Sierra Caballos.

Along the eastern border of the county and east of the Fra Cristobal and Caballos ranges is the broad desert valley named the Jornada del Muerto, or "Journey of the Dead," because of the dangers experienced by travelers crossing these waterless plains before the advent of the railroad. At the south end of the Fra Cristobal Range near Elephant Butte dam, at Palomas Gap, and again at the southern end of the Sierra Caballos, the western rim of the Jornada is being dissected by the lateral tributaries of the Rio Grande.

The present valley bottom of the Rio Grande varies in width from 2 to 4 miles. In the spring the melting snows in the mountains of northern New Mexico and southern Colorado furnish an abundant supply of water, which is caught and stored in the reservoir. Since the building of the dam, the danger from periodic floods in the spring and summer months has been practically eliminated, and in the lower valley the amount of water flowing may be closely controlled at all times.

The western part of the county is drained by a number of eastward-flowing tributaries of the Rio Grande. From north to south the important ones are Alamosa River, which drains territory to the north through Canada Alamosa near Monticello ; Rio Cuchillo, which heads in the Black Range north and west of Chloride and Fairview ; Palomas River and Arroyo Seco originating near Hermosa ; Animas Creek, Rio Percha, and Tierra Blanca Creek, which drain the area north and south of Kingston and Hillsboro ; and Berenda Creek, heading • west of Lake Valley. Most of the streams are fed by permanent springs along their upper courses on the slopes of the Black Range. These waters flow at the surface for varying distances but eventually sink into the sand and gravel. The underground flow can usually be tapped at a moderate depth below surface as the streams approach the Rio Grande. During times of heavy precipitation vigorous sheet and stream erosion occurs.

MOUNTAINS

The general trend of the mountain ranges is north and south. East of the Rio Grande, the Fra Cristobal and Caballos ranges, 20 and 27 miles long respectively, make a practically continuous range of mountains from the north bcundary of the county to its southern boundary. Just west of Hot Springs are the Mud Springs Mountains, about 6 miles in length. The San Mateo Mountainsr although mainly in Socorro County, have their southern termination about 10 miles within the northern boundary of Sierra County. In the western part of the county a series of block-faulted ranges begins near the north boundary northeast of Fairview and extends southward to Hillsboro and beyond to Lake Valley. In this series are included the Sierra Cuchillo, Animas Hills, and Lake Valley Hills. Still farther west, on a due north-south line through Chloride, Hermosa and Kingston, is the eastern escarpment of the Black Range. These mountains form a part of the Continental Divide. They extend beyond the county to the north and south and have a total length of nearly 100 miles. Among the highest peaks are Lookout Mountain and Hagen's Peak near Chloride, Diamond and Reed's peaks near Hermosa, and Hillsboro and Sawyer's peaks near Kingston. The elevatiohs of these peaks range from 9,000 to 10,100 feet. The south end of the range and also the entire range have been called the Mimbres Range in a number of official publications, but these mountains are called the Black Range throughout this report.

In general, three types of mountain structure are represented in the region, and according to Gordon[3] they may be classed as :

(1) The tilted mountain whose primary feature is due to the displacement of a crustal block; (2) that due to the upthrust of a granitic core; and (3) that resulting from the accumulation of volcanic material. The first two are usually modified by igneous activity resulting in extensive accumulations of volcanic products and by intrusions. The modifications

[3]Lindgren, Waldemar, Graton, L. C. and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 65, p. 220. 1910.

effected by erosion in all these types have been extensive, resulting in the removal of vast deposits of the lavas from large areas. In general the volcanic activity seems to have been subsequent to the disturbances which primarily outlined the mountain, but in some places it evidently accompanied these disturbances.

To the first or faulted-block type belong several ranges, among them the * Cristobal, Caballos, and Cuchillo, though in all of these the present relief has been accentuated by vast outflows of lava which erosion has carved into a system of rugged peaks and deep canyons.

Of the second type are the Black and Mimbres (Black) ranges, in which the uplifted strata slope away on both sides from a central mass of granite. At present, however, the most prominent features of the ranges are due to the piling up of vast deposits of volcanic material. In this type the removal of either limb by erosion would produce a mountain apparently indistinguishable from a monocline, but the competency of erosion to bring about this result is questioned.

In the third type the mountain is constructed wholly of volcanic material. Of this type the most prominent examples are the San Mateo Mountains, which occupy a position intermediate between the Magdalena and the Black Ranges. These mountains consist almost entirely, so far as the exposed portions are concerned, of rhyolites and their associated volcanic products.

A number of small isolated hills which rise out of the bolsons and mesas have not been named in the above classification. These are (1) remnants of partly eroded basaltic flews, (2) remnants of extensive flows of Tertiary lavas, or (3) the outcrops of small tilted blocks of sediments which have not yet been planed off by erosion. The low hills west of Hot Springs are an example of tilted fault blocks, and at several places in the Jornada and west of the Rio Grande, remnants of basaltic and of Tertiary lava flows make up a noticeable feature of the terrane. As to form, it may be said in general that those hills having conical or irregular outline are composed of remnants of basalt or other lava ; while those which are markedly lenticular and regular in outline, having one steep face and a more gently sloping opposite side, are of the faulted-block variety.

BOLSON PLAINS

Slightly more than half of Sierra County is floored with detrital material of Tertiary to Recent age in the form of talus, alluvial fans and lacustrine deposits. In general this valley fill may be divided into three main areas ; the Jornada del Muerto, the present Rio Grande valley, and the irregular area lying to the east of the Black Range and west of the Sierra 'Cuchillo and the Animas Hills. The last-named area is in reality three separate small plains connected with one another by short, narrow valleys. All these plains have been classed as bolson plains, although this classification has not gone undisputed. Quoting from Gordon:[4]

As defined by Hill[5] and further elaborated by Tight,[6] the bolson is

[4]Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 221.

[5] Hill, R. T., U. S. Geol. Survey Topographic Atlas, folio 3, p. 8, 1900.

[6]Tight, W. C., Am. Geologist, Vol. 36, pp. 271-284, 1905.

a plain formed by the more or less complete filling of an intermontane basin with detritus derived from adjacent eminences. "Along the margins of these plains are talus hills and fans of boulders and other wash deposits brought down by freshets, while scattered over the interior may be deposits of lacustral origin." The bolson is therefore a constructional plain and is genetically a type of gradation plain. As shown by Tight, the essential feature of the bolson is that the plain is bordered by mountain forms or plateau escarpments that have supplied the detritus with which it is floored. The definition therefore does not concern itself so much with the formation of the original trough or basin as with the conditions which produce a greater contribution of material than pre-existing drainage can remove. A more or less completely closed basin is, therefore, an essential feature of a bolson plain.

The Jornada del Muerto is a nearly level detrital valley plain 10 to 20 miles in width extending from the latitude of Socorro in Socorro County, through Sierra County to Las Cruces in Dona Ana County, and bounded on the east by the San Andres Range, and on the west by the Caballos and Fra Cristobal ranges. Lee[7] states that the altitude of the plain at its north end is about 4,700 feet and at its south end 4,250 feet. There is thus a difference in elevation of 450 feet in 100 miles of length, or an average gradient of 4.5 feet to the mile. According to Gordon:[8]

> The sedimentary rocks exposed in the mountain slopes on either side dip toward the axis of the valley, apparently forming a syncline, and the relations have been described as such in various papers.[9] It is doubtful if the structure of the region is as simple as this. In the interior the plain is covered with detritus to a depth of at least several hundred feet, no wells having penetrated its full thickness. Various facts point to the inference that this was formerly the course of the Rio Grande and that, as in other parts of the main valley, the underlying strata have been subjected to block faulting, though no indications of this appear through the heavy covering of detritus.

In the course of the field work which forms the basis for this report, several trips were made through the Jornada between Rincon and Engle, and at a later date the northern end of the plain was inspected. The following observations are believed to be of some significance in connection with the problem. There are several outcrops of lava flows and tuffs in the southern part of the county, which dip in an easterly direction at about the same angle as the older sedimentary beds exposed on the east flank of the Sierra Caballos. However, if a normal sequence of beds lies between these two exposures, then the sediments here are of much greater thickness than has been noted in any other part of the region. It is much more probable that the lava exposures have been elevated to their present position by block faulting, and have subsequently been eroded to their present low relief. The second point to be noted is that at the northern end of the plain the topography has departed radically from the typical gentle slopes of a bolson plain. The

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7 Lee, W. T., Water resources of the Rio Grande valley in New Mexico and their development: U. S. Geol. Survey Water-Supply Paper 188, p. 10, 1907.

8 Op. cit. (U. S. G. S. Prof. Paper 68), pp. 221, 222.

9 Keyes, C. Ft., Geology and underground water conditions of the Jornada del Muer'o, N. Mex.: U. S. Geol. Survey Water-Supply Paper 123, p. 26, 1905.

impression is gathered that here are the remnants of old river terraces, which sloped on either side toward the center of the plain and were partly dissected by east-west tributaries, giving an ancient land surface very similar to that of the present Rio Grande valley in the region just to the west. The third feature noted is the presence of a dry playa lake bed in the valley east of Upham, and in general the gentle sloping of the valley floor in all directions toward this lake. To the south these gentle slopes have obliterated all former topography except the lava bluffs, which appear to have been faulted up above the general level of the plain. To the north, older topographic features predominate ; the former river terraces are still visible, although the river and tributary channels are now largely aggraded by the superimposed bolson development, and the terraces have been worn down and rounded off until only remnants are left. These features are believed to support the view of Lee, Gordon and others that the valley is a detrital-filled block-faulted area rather than a synclinal basin ; that it was once the course of the Rio Grande, but that later flows of basalt and possibly some distortion dammed it to the north, thus diverting the river into its present channel ; and that the present bolson topography, which is a recent feature, has become well established in the southern part, but it had not much more than begun to the north, when tributaries developing from the new channel of the Rio Grande cut back through the ranges and inaugurated a new cycle of erosion, which in places is preventing the extension of the true bolson-plain topography.

The valley of the Rio Grande between the southern end of the San Mateo Mountains and the southern end of the county, where it is again restricted in width by outcrops of lava and basalt, is considered to be an alluvial plain. Such plains have been called "gradation plains" by Johnson[10] and "clinoplains" by Herrick." Two types of plains are represented in this area. According to Gordon :[12]

Along the side of the valley resting against the flanks of the mountains is the talus plain, or, as Johnson calls it, the "debris apron." This plain is made up by the confluence of the alluvial fans, together with deposition from sheet-flood erosion along the foot of the bordering mountain slopes. The material composing this plain has been derived from the adjoining heights and its surface has a relatively high grade, the result primarily of the ground absorption of the run-off on meeting the lessened slope of the valley plain.

As stated by Herrick, "in some places the talus plain reaches the bottom, but generally it passes abruptly into the plain of the second type or clinoplain proper." The surface of this plain is but slightly inclined and is broken by arroyos with steep walls and nearly parallel courses, the interstream areas being intersected by an intricate network of small, shallow tributaries. In places this plain also reaches to the bottoms, the

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[10] Johnson, W. D., The High Plains and their utilization : U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 609-741, 1901.

' Herrick, C. L., Clinoplains of the Rio Grande : Am. Geologist, vol. 33, pp. 276-381, 1904. '2

[12] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 222.

bordering bluffs varying in height with the fluctuations in the course of the stream. Along the border of this plain occur parts of a degradational plain formed by the river at some former stage of its existence. A prominent remnant of this plain occurs on the west side of the Rio Grande in the vicinity of Cuchillo, where it has a width of several miles, and in it head many small ravines and arroyos that lead to the river. The inclination of this plain is less than that of the upper plain. Its level varies according to location, but in general it appears to be about 100 to 150 feet below that of the outer plain. Its height above the river bottoms is apparently a little more. Toward the south the alluvial plain laps about the south end of the Mimbres (Black) Range and merges with the great plain which extends westward to the Arizona line.

East of the Black Range and west of the Sierra Cuchillo and the Animas Hills is a series of three small, nearly enclosed basins filled with alluvial material, which in their original condition constituted true bolson plains. The original surface of these plains was covered in many places by flows of basalt and was subsequently dissected by the tributaries of the Rio Grande, which cut deeply into the gravel deposits, leaving remnants here and there in the form of lava-capped buttes. The most northerly of these basins, in reality, is the southern portion of a much more extensive bolson plain in Socorro County.

GEOLOGY

THE ROCKS

GENERAL FEATURES

The rocks of Sierra County include sedimentary, igneous and metamorphic varieties. The sedimentary rocks range in age from Cambrian to Recent, and with the exception of the Triassic and Jurassic, all the intervening periods are represented. The stratigraphy, both generalized and for each mportant mining district, is shown in Plate II. Unconformities at which rocks of certain ages are absent are indicated by breaks in the geologic column. These breaks are all drawn of conventional size, and hence do not accurately represent the time intervals of erosion or non-deposition, which account for a considerable part of total geologic time.

The descriptions of the various rocks found within this region have been abstracted in large part from the more detailed descriptions by Gordon[13] and Darton.[14]

PRE-CAMBRIAN ROCKS

The prevailing pre-Cambrian rock is a coarse red granite in which the individual grains may be as large as a centimeter in diameter. Crystalline schists and granite gneisses are prominent in these rocks in places and are usually enclosed in the granite.

13 Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 1910.

14 Barton, N. H., "Red Beds" and associated formations in New Mexico : U. S. Geol. Survey Bull. 794, 1928.

Associated with the granite are numerous dikes of fine-grained granite, aplite and pegmatite ; other dikes are of a more basic character. Good exposures of fairly fresh granite occur along the western base of the Fra Cristobal Range and the Sierra Caballos and in the Black Range near Kingston. In places the granite is undergoing rapid disintegration to a coarsely granular surface deposit of sedentary arkose. This is particularly true where the exposures have been eroded down to gently sloping surfaces. Near Pittsburg the granite is associated with much more hornblende schist and gneiss. It is cut by numerous acidic and basic dikes and is intersected at short intervals by quartz veins, most of which have a northwest trend. West of Kingston granite outcrops for nearly 12 miles and is but little decomposed or disintegrated. It is cut in different directions by dikes of greenstone, aplite, pegmatite, etc.

SEDIMENTARY ROCKS

CAMBRIAN SYSTEM

Bliss Sandstone.—Lying unconformably upon the eroded and irregular surface of the pre-Cambrian rocks is quartzite or sandstone of Cambrian age. In the type section in the Franklin Mountains north of El Paso, Tex., the formation is known as the Bliss sandstone, but in the Sierra Caballos in Sierra County it was named the Shandon quartzite. The name Bliss has precedence and is used in this report. Near Pittsburg (Shandon) the Bliss sandstone has a thickness of 55 feet. Here the usual basal bed of dark-brown quartzite is missing from the section. In other parts of the range the formation is 1.00 feet or more in thickness. Near Kingston the granite is overlain by 75 feet of dark red quartzite with a 3-foot bed of shale near the middle. In general the basal beds are mostly quartzite, with conglomerate locally present, while the upper beds are softer and finer grained.

Generalized Section of the Bliss Sandstone in the Sierra Caballos

	Feet
Dark ferruginous shales with beds of quartzite above; certain layers fossiliferous	40-80
Massive dark ferruginous quartzite	5-10
White quartzite	0-5
Dark ferruginous quartzite; absent in places	5-10
Unconformity	
Pre-Cambrian coarse red granite with some hornblende schist in places, cut by pegmatite, aplite and basic dikes. Pegmatite dikes grade into quartz veins.	

ORDOVICIAN SYSTEM

The strata of Ordovician age comprise the Lower Ordovician El Paso limestone and the Upper Ordovician Montoya limestone.

El Paso Limestone.—The El Paso limestone in the lower part is somewhat similar to the underlying Bliss sandstone. At the base are alternating thin beds of quartzite and limestone about 15 feet in total thickness. Locally this part of the formation consists of calcareous shales alternating with shaly limestone. Above this transition zone the formation is gray slabby and massive magnesian limestone. The surface of many of the beds is covered with thin reticulating brown deposits of silica, and most of the rock weathers to a pale gray tint, two features that are quite distinctive. The El Paso limestone is between 300 and 400 feet thick in the west face of the Sierra Caballos and 150 to 200 feet thick in the Lake Valley district. In Carbonate Creek in the Kingston district, there is a series of calcareous shales with interbedded limestones 100 feet thick. Overlying this is 300 feet of gray crystalline limestone, the lower part of which may be El Paso limestone. At Hillsboro and at other points along the Black Range, the El Paso limestone was not recognized, although it may be present in places under the exposed beds.

Montoya Limestone.–The Montoya limestone, of latest Ordovician (Richmond) age, lies on the slightly irregular surface of the El Paso limestone and is 200 to 300 feet thick at most of the outcrops. The lower part of the formation consists of dark massive limestone in which are many thin layers of chert. The strata are all hard, and at most places the outcrop is a dark cliff in the mountain side. In the Sierra Caballos the formation outcrops prominently with its usual characteristics. At Lake Valley there are 200 feet of gray hard sandstone at the base overlain by 25 feet or more of cherty limestone of strong Montoya aspect. Near Kingston the base is a gray crystalline limestone, which is apparently not separable from the underlying El Paso limestone, overlain by 30 feet of thin-bedded cherty limestone. A small exposure of Montoya limestone has been found near the southeastern corner of the Hillsboro district, but nothing is known as to its thickness.

SILURIAN SYSTEM

Fusselman Limestone.–Only a small part of Silurian time is represented by the Fusselman limestone, which contains abundant fossils of Lower Silurian (Niagara) age. The formation lies on the Montoya limestone, from which it is separated by a surface of erosional unconformity marked in places by a conglomerate consisting of pebbles of the underlying formation. In most areas two members are present, a lower one 85 feet thick of compact fine-grained gray limestone that weathers nearly white, and an upper one about 50 feet thick of hard dark massive limestone with fossils. In the southern part of the Sierra Caballos the Fusselman limestone shows in a prominent cliff and consists of characteristic dark-colored massive limestone 50 feet thick. The thickness of the Fusselman limestone varies greatly but probably averages between 250 and 300 feet. At Hillsboro and southward pronounced silicification of the upper portion of the limestone bed has formed a highly siliceous drusy rock, often called a "quartzite" or "limestone quartzite." Underlying this siliceous phase of the rock, the limestone in many places is broken, and fragments of the limestone 1 to 6 feet in diameter have been cemented together by calcareous material derived from the rock itself. In some places the breccia includes blocks of white grit or sandstone. The upper silicified member of the Fusselman limestone constitutes the footwall limestone for the ores of the Kingston district and elsewhere, and at the Lookout mine in the Tierra Blanca district the ore occurs in fractures within and near the top of this bed. At Lake Valley there is a bed of quartzite 5 to 10 feet thick near the top of the Silurian formation, which in turn is overlain by 12 feet of pink or red limestone, carrying fossils which indicate its age as Silurian.

DEVON(AN SYSTEM

Percha Shale.–Resting upon the eroded surface of the Fusselman limestone is a black shale formation known as the Percha shale from the type locality in Percha Creek near Kingston. This shale represents late Devonian time, and although accordant in attitude with the overlying and underlying formations, it is separated from them by breaks in sedimentation. It attains a thickness of 250 feet in the Sierra Caballos, 160 feet at Lake Valley, and 200 feet at Hillsboro and Kingston. In most places the lower beds are fissile black shales, and the upper beds, though chiefly gray shale, contain layers of slabby and nodular limestone. These upper beds weather to buff or brown with little or no fissility. The lower black shales contain no fossils, but the upper blue or gray shales near Hillsboro and Kingston 'have an abundant and well-preserved Upper Devonian fauna. In many places the basal portion of the Percha shale is brecciated and altered, presumably by heated siliceous waters, to a fine-grained red to black siliceous rock resembling jasper or flint. The brecciated fragments may be red, gray or black, in a matrix of like substance but of different color. Numerous quartz veinlets and drusy cavities occur in this part of the formation.

MISSISSIPPIAN SYSTEM

Lake Valley Limestone.—Exposures of Lake Valley limestone are widespread in Sierra County, with the typical exposure in the Lake Valley district. Other known occurrences are in the Sierra Caballos, and in the Hillsboro, Kingston and Hermosa districts. At Lake Valley, where the top of the formation is eroded and in part overlain by Tertiary igneous rocks, the thickness is about 210 feet. At this place the lower member, 50 feet thick, is a compact massive gray limestone with nodular chert, which may possibly be Devonian. Above this is 5 feet of coarse crystalline yellowish-white limestone, 20 feet of grayish-blue limestone which is more or less siliceous, 25 feet of blue shale with thin layers of bluish limestone, and at the top a light-colored highly fossiliferous subcrystalline limestone 60 feet thick. In the Sierra Caballos the formation consists of light-colored massive to slabby, mostly coarse-grained limestone from 100 to 200 feet thick. In the canyon north of Kingston and near Hermosa are many exposures of the Lake Valley limestone. The crinoids and other fossils yielded by the Lake Valley limestone indicate that it is of early Mississippian age. The formation rests on the Percha shale without discordant attitude, and is overlain by limestone of Pennsylvanian age without difference in attitude but separated by a break representing a long interval of late Mississippian time.

PENNSYLVANIAN SYSTEM

Magdalena Limestone.–The thick limestone succession of the Magdalena limestone is a prominent feature of the Fra Cristobal, Cuchillo and Black ranges, and in the Sierra Caballos this limestone is the predominant rock, but interbedded sandstone and shale occur in all sections. In Sierra County the Magdalena limestone consists for the most part of massively bedded blue and gray limestone, interstratified with which are thin-bedded limestones and dark blue shales. Here and there a thin bed of sandstone occurs. At Kingston the basal strata consist of about 300 feet of dark blue and gray limestone in thick beds with thin shale partings. The upper portion is also about 300 feet thick and consists chiefly of blue and drab shales interstratified with several limestone strata 15 to 20 feet thick. Two miles east of Hermosa, Palomas Creek has cut a gorge 1,000 feet deep, the walls of which are nearly vertical and consist almost wholly of blue and gray limestone of the Magdalena formation. The lOwer half of the escarpment consists of limestone and shale in about equal amounts ; the upper portion is made up of hard, massively bedded gray limestone. About half way up the cliff a few thin beds of quartzite are interbedded with the limestone. In the Sierra Caballos the formation is represented chiefly by limestone, with some shale beds in the basal part, as at Hermosa. In other parts of the State the Magdalena limestone has been divided into a lower and an upper formation known respectively as the Sandia formation and the Madera limestone, but at no place in Sierra County was it possible to make this division with certainty.

PERMIAN SYSTEM

Abo Sandstone.–The red strata of the Abo sandstone, the basal formation of the Permian, outcrop at several places in Sierra County, the most extensive areas being on the east slopes of the Fra Cristobal, Caballos, and Cuchillo ranges, and in the Black Range from just west of ChlOride to as far south as Kingston. The Abo sandstone lies unconformably upon the Magdalena limestone and consists in the main of slabby sandstone of deep reddish-brown color intercalated with arkosic beds and red sandy shales. In a few places a thin bed of gray earthy limestone has been noted, which according to Darton occurs near the base of the Abo, and which has yielded fossils indicating Permian age. At the base of the Abo in many exposures is a limestone conglomerate, the pebbles of which were derived from the underlying rocks of Magdalena age. The thickness of the formation varies from 400 to 800 feet.

Chupadera Formation.–The Chupadera formation, as described by Darton, [15] includes the rocks of Permian age above the Abo sandstone which were formerly known as the Yeso formation and the San Andres limestone. In places in Sierra County and elsewhere in the State it is not possible to separate these rocks into the two formations. The lower division (Yeso) of the Chupadera formation consists mainly of gypsum, gypsiferous shale, limestone and soft sandstone, which are colored red, pink, yellow and gray. In places a yellow massive sandstone is the top member. Some of the gypsum beds are massive and attain a thickness of as much as 140 feet. The Yeso is from 500 to 1,000 feet thick.

The San Andres limestone, the upper division of the Chupadera formation, consists for the most part of gray sandy limestone in which some Permian fossils are found. The thickness is from 300 to 500 feet. In places gypsum and sandstone beds are intercalated with the limestone. This limestone has a characteristic appearance wherever noted, the surface of many beds within it being cracked, pitted, and roughened, as though a sandy, limy ooze had been laid down in extremely shallow water, and before complete consolidation it had been repeatedly expoSed to the atmosphere with attendant development of a confused mass of shrinkage cracks, ripple marks, rain drop impressions, etc., none of which are now separately distinguishable.

Chupadera strata outcrop along the eastern slopes of the Fra Cristobal, Caballos, and Cuchillo ranges, and they possibly overlie the Abo sandstone along the east front of the Black Range.

CRETACEOUS SYSTEM

So far as known, Triassic, Jurassic and Lower Cretaceous rocks are absent in the county, and Upper Cretaceous rocks directly overlie the Chupadera formation. This hiatus may be due to a long period of non-deposition from Permian to Upper Cretaceous time owing to the elevation of the area above sea level, or to the removal by erosion of sediments that were deposited. The Upper Cretaceous formations consist of the Dakota sandstone, Mancos shale and Mesaverde formation.

Dakota Sandstone.–Outcrops of Dakota sandstone occur in the low foothills along the east slope of the Sierra Caballos and in the southeast flank of the Fra Cristobal Range. The

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15 Dayton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geo!,

thickness of the formation ranges from 80 to 100 feet, and in general it is a hard, massive gray to buff bed of fine-grained sandstone, with locally a bed of conglomerate at the base.

Mancos Shale and Mesaverde Formation.—Overlying the Dakota sandstone wherever it is exposed is the Mancos shale of Colorado age. Its thickness ranges from 900 to 1,300 feet, and in general it consists of dark-gray sandy marine shale, with considerable slabby to shaly sandstone near the top. Lee[16] believes that the coal-bearing beds at the north end of the Sierra Caballos, known as the Engle field, are of Benton (Colorado) age. They are largely sandstones of gray to buff color separated by beds of shaly sandstone and shale. Near the Elephant Butte dam is a small area of what appears to be still later beds consisting of white, brown and red sandstones and conglomerates, which grade upward into brown and chocolate-colored shales and sandy shales. These beds are believed to be of Mesaverde (Montana) age.

TERTIARY SYSTEM

On the northeast flank of the Mud Springs Mountains, the small group of hills west of Hot Springs, is an area in which numerous bones and much petrified wood are reported to have been found. On the southeast flank of the Sierra Cuchillo, apparently similar beds contain petrified wood. These exposures may be of Tertiary age, although no direct evidence to support this opinion is at hand.

Underlying many of the terraces along the Rio Grande, especially in the neighborhood of Hot Springs and from there southward to Rincon, are horizontal or nearly horizontal beds of sand, soft sandstone and conglomerate. The colors of these beds are buff, pink, salmon and red, some of the red beds with thin layers of greenish clay, or spotted with small to large greenish to grayish circular patches. This greenish color may be due to the reduction of the normal red ferric oxide by local accumulations of organic matter or other reducing agents. The writer believes that these beds in part at least are the equivalent of the Santa Fe formation of late Tertiary (Miocene and Pliocene) time, as designated by Hayden in 1869 in the northern part of the State. In Sierra County they heretofore have been generally held to be of Quaternary age.

Near the mountain ranges and abutting against them are alluvial fans and beds of conglomerate and sandstone, which were formed during quiescent periods between the various eruptions of Oligocene time. Lenses of sediments were laid down on the erosion surfaces that developed during breaks in the se-

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ṡ [16]W. T., The Tijeras coal field, Bernalillo County, N. Mex.: U. S. Geol. Survey Bull. 471, p. 571. 1912.

Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 199, 1917.

Lee, W. T., Stratigraphy of the coal fields of north-central New Mexico: Geol. Soc. America Bull., vol. 23, p. 031, 1912.

quence of lava flows, dividing the andesites in this fashion into two or three distinct flows, and setting the rhyolites off from the andesites by a considerable time interval. Finally, following the period of lava flows and in general contemporaneity with the Santa Fe formation in the valley, deposits of arkosic sandstone and conglomerate, detrital products of the erosion of these latest igneous extrusions, began to form as alluvial fans and piedmont plains at the base of the mountain ranges. The basal part of these beds is composed in general of grains and pebbles of rhyolite and rhyolite tuff, with a fine cementing matrix of rhyolitic and tuffaceous material, partly cemented with chalcedony and calcite and in part altered and decomposed to claylike material. The upper portions of the beds are composed largely of andesitic fragments and matrix, and the decomposition products contain more abundant chlorite.

QUATERNARY SYSTEM

Detrital material derived from the wearing down of the adjacent slopes fills the Rio Grande valley to a depth in places of more than 2,000 feet, as shown by well records, and covers the high plains and bolsons to varying depths. Much of this material is gravel, which consists of boulders and pebbles of quartzite, limestone, granite, rhyolite, andesite and basalt, and reflects the character of the immediately surrounding rocky complex. These wash deposits cover the greater part of the Rio Grande valley and the adjacent plains and bolsons. They are coarser along the valley sides, grading to finer material toward the middle of the basins. Below Hot Springs in the Rio Grande valley, the lower part of the horizontal sandy to clayey beds exposed in the terraces may be the equivalent of Santa Fe mail of late Tertiary age. In the higher regions, as in the sides of the valley between Fairview and Hillsboro and at Hermosa and elsewhere, beds of Quaternary age are composed of partly worn boulders and pebbles loosely cemented in a finer matrix of the same material into a firm hard conglomerate. These are known as Palomas gravel, named from the type locality in Palomas Creek. In composition and geologic age these gravels are apparently identical with and form an extension of the top part of those deposits in Arizona which have been named Gila conglomerate by Gilbert. [17] The upper part of the Palomas gravel may be somewhat younger than the latest Gila conglomerate.

Younger than the Palomas gravel are the sand and gravel deposits which form some of the intermediate terraces representing a filling of channels excavated in the older deposits of Santa Fe and Palomas age. In other places these intermediate terraces appear to be merely the older gravel eroded down to a new base level as a result of a former state of equilibrium in the land elevations of the region. Still younger are the present flood-plain

Gilbert, G. K., U. S. Geog. Surveys W. 100th Mer., Vol. 3, p. 590, 1875.

deposits along the bottoms of the Rio Grande and its tributaries. These are composed of unconsolidated wash material, ranging in size from clay and silt to the largest boulders that could be transported during flood seasons by the various streams.

Deposits of Quaternary age are in the main the surface deposits of the bolsons and plains of the county, although here and there Tertiary and older igneous and sedimentary rocks extend through them and are exposed just at the general level of the surrounding surface features. Close to the mountain ranges these older formations have been planed off or truncated to an even surface, which slopes toward the river and tributary bottoms at the same angle as do the Quaternary gravels. These are the pediments studied by Bryan [18] at several places in the Rio Grande Valley. In places in Sierra County they are exposed in areas of several acres to several square miles, or as is more usual, they may be partly or wholly obscured under a mantle of a few inches to a few feet of detrital material. Closer to the river, the flat-lying partly consolidated beds of sand and silt, which have been referred in part at least to Santa Fe age, have been planed off by erosion in a similar manner and now lie at or near the surface of the younger gravels, forming what may be considered as an extension of the true pediments of the higher regions.

TERTIARY AND QUATERNARY LAVAS

Late Cretaceous lava flows of considerable extent occur in the southwest portion of New Mexico, but none were noted within the boundaries of Sierra County that could be definitely classed as of this age, and in accordance with past ideas on this subject the writer has felt constrained to consider these early extrusives as being of early Tertiary, probably Oligocene, age. The extrusive rocks consist of an andesite-latite-rhyolite series, which is largely confined to the mountainous area west of the Rio Grande, but with a few scattered erosional remnants projecting through the Quaternary detritus of the Jornada del Muerto, along the eastern slopes of the Fra Cristobal Range and the Sierra Caballos. The earliest extrusive rock was andesite, with associated tuffs and breccias, closely followed by intrusions and extrusions of latite and latite porphyry. Following these extrusions came a period of quiescence, during which the surface of the lavas was eroded and in many places deeply dissected by streams, with the accumulation locally of considerable thicknesses of sediments over the lower areas of the flows and as fanlike accumulations along their borders. Following this came a series of flows of rhyolites, tuffs and breccias of enormous areal extent and comprising at least half of the original total thickness of Tertiary flow rocks, which in several places

[18] Bryan, Kirk, Pediments developed in basins with through drainage as illustrated by the Socorro area, N. Mex. (abstract) : Geol. Soc. America, Bull., Vol. 43, No. 1, pp. 128, 129. 1932.

along the Black Range appears to have exceeded 4,000 feet. This rhyolitic material in many places filled the old canyons eroded in the surface of the older flows, and as in the canyon of the Rio Cuchill° south of Chloride, it flowed out over the sediments derived from the more basic flows and accumulated in basins on these older surfaces. After the rhyolite was extruded, erosion again profoundly carved and dissected the terrane, until at present the rhyolite exists in extensive areas only over the main massif of the Black Range and the San Mateo Mountains. Over the remainder of the area where these flows extended, only scattered remnants are to be found. In the Hillsboro district only two or three small patches of rhyolite remain, and even the andesite has been deeply eroded and in places cut through, exposing the underlying sediments. Between Kingston and Hillsboro great masses of rhyolite and tuff still cover the faulted blocks of that section, and between Kingston, Tierra Blanca and Lake Valley a persistent layer of obsidian marks the base of the rhyolite series. Rhyolite and basic dikes cut the andesites in many exposures throughout the county, and small sills of rhyolite occur in the andesites and older sediments near Hillsboro, at Tierra Blanca and elsewhere.

The normal andesite of the region is dark colored, fine grained to aphanitic, and at the surface usually appears brownish-gray from weathering. In the fine-grained varieties, white plagioclase and black augite grains are present in about equal proportions, as seen in the hand specimen. Porphyritic varieties show phenocrysts consisting of tabular crystals of plagioclase in a dense groundmass, and under the microscope these are shown to be enclosed in a groundmass of smaller crystals of plagioclase, with hornblende, augite, biotite, orthoclase, magnetite and apatite. A dioritic variety, apparently intrusive into the earlier flows of andesite as small sills and dikes, consist of a dark-colored fine to coarse grained porphyritic rock, in which the larger grains are equally divided between plagioclase and augite. The groundmass is similar to that of the extrusive andesite. Near the base of the series the andesites are brecciated and much altered. Here the rock is of a light greenish-gray color, with blotches of purple or light green representing the breccia fragments. The constituents of these altered andesites are plagioclase and augite in a groundmass composed chiefly of calcite and chlorite, with some epidote, serpentine. magnetite and apatite. The magnetite is often altered to pyrite, and veinlets of calcite, pyrite and epidote, with occasional adularia, are present. This type of rock alteration is known as propylitization and is a characteristic alteration of the andesites throughout the county. Near Hillsboro, on the south slope of Animas Peak, a fairly fresh andesite contains many spherical segregations of epidote which vary in size from half an inch to several inches in diameter. Where the rock is worn away these segregations collect in large numbers on the surface. They are reported to contain about $1.25 per ton in gold, and due to their hardness, the suggestion has been made that they would afford a cheap local source of grinding pebbles. In the fresh rock the epidote segregations are often surrounded by a thin bleached zone, while the center of the segregation may be open textured due to a partial leaching out of some of the earlier constituents, and these open spaces are often lined with minute coatings of iron-stained calcite or silica. It is possible that these segregations have been formed by gases or solutions trapped in the rock while it was solidifying, which later spread from these centers of accumulation to react with the original rock minerals in various ways, with the formation of deuteric minerals, and the partial bleaching and solution of others. Another suggestion has been offered, which states that these segregations were originally fragments of sediments trapped in the molten rock and later altered by propylitizing solutions. The writer leans toward the former view, as he was not able to find evidence of channels along which the solution might have traveled through the rock mass to the segregations. Further, it seems improbable that so many small fragments ofa sediment could be trapped in a rock without some larger partly altered xenoliths having been preserved, and it would also appear that such small fragments would have been completely assimilated in the magma long before the period of deuteric mineralization became effective.

The latites occur as dikes, small sills, and as flows,laid down on the old andesite surface. The original flows were largely if not entirely removed before the rhyolite of the region was poured out, and in many places erosion has again cut so deeply that what were once sills of this rock within the andesite are now found at the present land surface. The latites when fresh are gray rocks somewhat lighter in shade and without the greenish cast that characterizes the fresh andesite. Within the dikes the texture is felsitic to fine grained, although in their deeper portions and close to the intrusive monzonite stocks from which the latites are supposed to be direct offshoots, the texture is coarser and may approach that of a fine to medium grained monzonite. Within the sills the texture is porphyritic, and the rock contains abundant medium-sized to large tabular crystals of feldspar in a felsitic to fine-grained groundmass. The phenocrysts are andesine and are oriented so that the long axes and tabular faces lie parallel to the surfaces of the sills. Most of the phenocrysts are corroded and have rounded outlines, instead of the usual sharply defined angular intersection of faces, giving to the rock a characteristic appearance, and the local name "birds-eye porphyry." The composition of these rocks is similar to that of the monzonite porphyry of the intrusive group.

The following paragraphs describing the rhyolites of the Black Range but applicable to the whole of Sierra County where these rocks outcrop, are quoted from Gordon's description [19] of the Chloride district.

> The rhyolite resting upon the andesite is largely tuffaceous and rarely shows indication of flow structure. Some miles west of Chloride the canyon cuts across an old channel in the andesite tuffs which was subsequently filled by the eruption of rhyolite tuffs. The deposits of rhyolite on this side of the range are far less extensive than those of andesite, and stream erosion has dissected the sheet, leaving only cowlings on the ridges or the filling of old depressions in the surface of the andesite.
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> In this section the rock is found to be notably porphyritic, showing large phenocrysts of corroded and broken quartz crystals along with more numerous but smaller fragments of crystals of orthoclase, plagioclase (andesine), and a few of biotite. The groundmass is glassy, in places spherulitic, and here and there partly crystalline. In some places the phenocrysts predominate over the groundmass, giving the rock in hand specimen a pseudogranular structure.

In surface exposures the rhyolite flows are dark brown in color, while in fresh specimens they vary from deep grayish-purple to light purplish-gray. The breccias are of a lighter shade than the flow rocks, while the tuffs are characteristically cream colored or white. Sericitization of the orthoclase and plagioclase has been the chief alteration of the original constituents, with probably considerable local development of kaolin due to surface weathering. Alteration to an extremely low-grade bentonitic material has occurred in the rhyolite tuffs locally, but no commercial beds of this material have yet been found in the county.

During late Quaternary time large areas of the Quaternary gravels of the region were covered with thick sheets of basalt. Scattered remnants of these flows cap the buttes and mesas at a number of places in the central and eastern parts of the county. The prominent basalt mesa near San Marcial in Socorro County is the largest of these ; it, extends some miles into the northeast part of Sierra County. Other important occurrences are near the Elephant Butte reservoir, on the mesa northeast of Hillsboro, and at several places between Hermosa and Hot Springs.

INTRUSIVE ROCKS

At a number of places in Sierra County, intrusive masses of porphyry have penetrated the earlier rocks in the form of stock-like bodies, sills, and dikes. These rocks are probably of early Tertiary age, younger than the andesite extrusives, older than the rhyolites, and contemporaneous with the latites, which are considered by the writer to be apophyses from the main mass of monzonitic magma. At Kingston a dikelike mass of monzonite porphyry about 400 feet wide cuts the sediments for a considerable distance north and south of the town. Similar outcrops to the south in the Tierra Blanca and Carpenter districts are thought to be parts of the same general mass, although in the Carpenter district the intrusive rock is a granite porphyry rather

[19] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 262.

than a monzonite. In the Sierra Cuchillo a large sill of monzonite porphyry has invaded beds of Magdalena limestone and is exposed for a distance of approximately 9 miles along the western escarpment of this faulted block of sediments. This sill thickens toward the south to almost laccolithic proportions, and as a result of erosion now appears as the crest of the range. At Hillsboro several bodies of intrusive rock have been exposed by erosion. These are intrusive into the lower part of the Tertiary andesitic flows that cover the district. Northeast of the town is a prominent hill composed in large part of a coarse-grained monzonite which grades into a granodiorite along its eastern border. Numerous small, irregular stringers of aplite traverse this intrusion. Approximately a mile east of this cupola is a dike of medium-grained monzonitic rock. Two miles north of these outcrops, in the Copper Flat basin, is an area of intrusive porphyritic monzonite, which is undoubtedly a stock and probably connected at no great depth with the other outcrops in the district. This rock is coarse grained and contains large feldspar crystals, many of which are visibly twinned according to the Carlsbad law. Plagioclase is present in smaller grains but in slightly greater quantity than the orthoclase. Hornblende is the prominent dark mineral with some biotite and augite, and locally quartz. Other accessory minerals are magnetite, apatite and zircon. A small area of porphyry was noted in the west face of the Fra Cristobal Range adjoining one of the faults of that region, and west of Cutter on the east slope of the Sierra Caballos a small mass of similar rock has penetrated the Cretaceous beds. The "porphyrite" of the Lake Valley district is ,considered by the writer to be possibly of monzonitic derivation, and at numerous places in the county small dikes of monzonite and latite suggest the presence at no great depth of other large masses of monzonite or related intrusive rocks.

STRUCTURAL FEATURES

During the period of Tertiary igneous activity and perhaps for a considerable length of time before and after, faulting occurred in the region on a large scale. Lindgren[20] states that this was a period of general continental uplift, which was accompanied by the formation of general north-south breaks in the earth's crust of sufficient magnitude to outline the principal mountain ranges of the county. With the exception of the Black Range and the San Mateo Mountains, all the mountains of Sierra County give the general appearance of being monoclinal blocks with steep fault scarps on the western front and with gentle dip slopes to the east. In the western part of the county the Black Range forms a broad northward-trending anticlinal dome with the strata dipping away on each side. This anticline has been

[20] Lindgren, Waldemar, op. cit. (U. S. G. S. Prof. Paper 68), p. 25.

more or less profoundly disturbed in this simple relationship by the major north-south faulting, which has broken the east limb of the structure into long ribbon-like strips, all of which have been dropped in relation to the west limb. Cross faulting has further modified these long strips into numerous faulted blocks, and the terrane has a mosaic pattern with the individual units variously tilted and elevated, one against the other. The San Mateo range is a huge mass of volcanic rocks in which no sedimentary beds are known to be present. Numerous faulted blocks occur as small outliers, somewhat radially arranged, to the south in this region, but the fault pattern has no strikingly regular. arrangement such as has been noted elsewhere in the county, and it may be due to shrinking and settling of the central mass of t4 range after the extravasation of the lavas from below.

Along the line of faulting which has elevated the Sierra Cuchillo, Animas Hills and the Lake Valley Hills, these masses appear to be true tilted fault blocks with fault scarp facing the west in each case, and general dip slopes ranging from northeast to southeast in direction and from 20° to 30° in inclination. These mountain masses are separated from the Black Range by local bolson deposits, which have filled a series of enclosed basins and have effectively hidden from view the intervening structural relations. Another small tilted fault block is that of the Mud Springs Mountains west of Hot Springs. Here the fault scarp faces south and the dip of the beds average 20° in a direction of N. 20° E. In the eastern part of the county the easterly dip slopes of the Fra Cristobal Range and the Sierra Caballos and the westerly dip slope of the San Andres Mountains in Socorro County match up in such a way as to give the general impression that the Jornada del Muerto, which lies between them, is a broad detrital-filled synclinal valley. The structure cannot be as simple as this, however, for at several places within the Jornada the tops of low tilted fault blocks project through the surrounding bolson deposits.

The Fra Cristobal Range and the Sierra Caballos, which lie from north to south along the east side of the Rio Grande in the east-central portion of the county, are clearly the remains of two elongated domes. The western limbs of these domes have been faulted down, while the east limbs have remained in approximately their original position and now constitute the mountain masses. The down-faulted east limb of the Black Range and the similarly dislocated west limbs of the Fra Cristobal-Caballos masses are believed by the writer to have originally lined up in the formation of a wide, synclinal basin from which the present Cuchillo-Animas Hills-Lake Valley Hills fault blocks have emerged, while the relative sinking of the Rio Grande fault trough was in progress. Faulting along the west limbs of the Fra Cristobal and Caballos domes has been complicated and has involved movements of considerable magnitude.

In front of the Fra Cristobal Range and diagonally across the north end of the Sierra Caballos, a hinge fault appears to have dropped the younger sediments in the Hot Springs region, while elevating a long narrow segment of pre-Cambrian rocks in front of the Fra Cristobal. The movement of this faulted block in the neighborhood of Hot Springs has effected a longitudinal splitting of the sedimentary beds at the north end of the bierra Caballos, and these have been dragged down and under, so that over half of the normal thickness is now concealed from view. At the same time the length of the Caballos dome was shortened by compression with the development of transverse overthrust faulting and folding. This is plainly seen in Palomas Gap, where the northern part of the range has been overthrust onto the central mass, and again in the southern part about opposite Derry, where the southern part has been pushed several hundreds of feet to the north.

The development of the main north-south faulting in this region was accompanied in many places by transverse breaks which served to relieve the various strains set up within the rock masses. It is along these transverse planes of movement that the drainage pattern of Sierra County has been very largely developed.

In addition to the regional dislocation, many of the igneous intrusions by their thrusting action have produced local faulting, usually of rather simple radial pattern. In the Hillsboro district this radial arrangement of the fractures is definitely associated with the intrusive monzonite of the district. In the Macho district the intrusions are radially arranged latite dikes quite similar to the apophysal dikes at Hillsboro. In the Black Range at the Silver Monument mine and near the town of Roundyville, clusters of radially striking veins occur superimposed on the general northward-striking vein system of the region, and these may be the result of unexposed intrusions.

GEOLOGICAL SEQUENCE

The oldest rocks in Sierra County are the pre-Cambrian granites and schists that outcrop near Kingston, in the Mud Springs Mountains, and along the western base of the Fra Cristobal Range and the Sierra Caballos. These rocks underlie the younger formations throughout the county. Resting on their eroded surfaces is the thick sequence of Paleozoic quartzites, shales, and limestones, with some conglomerates and arkoses. It is probable that these sedimentary rocks were deposited over the entire county, although rocks of Mississippian age and earlier have not been identified north of Hermosa in the Black Range or north of the Mud Springs Mountains near Hot Springs. These sediments were not laid down in a continuous succession, for the terrane was subjected to several periodic uplifts, when non-deposition or erosion interrupted the normal succession. The alternating periods of deposition and non-deposition are shown on Plate II. Deposition in Triassic and Jurassic time is not known to have occurred anywhere in Sierra County, and only upper Cretaceous beds remain to represent the Mesozoic period. The alternate elevation and depression of the land surface during Paleozoic and Mesozoic times must have been in the nature of gentle pulsating movements of continental extent, unaccompanied by folding, tilting or fracturing of the strata, because throughout this long interval there is little or no discordance in the attitudes of the beds above and below the various erosion surfaces.

During late Cretaceous or early Tertiary time, possibly as a phase of the Cretaceous igneous activity that is manifest around Silver City in southwest New Mexico, the sediments were warped into long anticlines or domes in the Black, Fra Cristobal and Caballos ranges, with gentle synclines in the Jornada del Muerto and the present Rio Grande valley. Minor folds and irregularities probably developed within this area, as on the east flank of the Black Range, and on the west flanks of the Fra Cristobal and Caballos domes. As the igneous activity of the Silver City area continued and became more extended, these minor folds probably continued to develop, and finally the north-south regional faulting so characteristic of the structural conditions of the present day in Sierra County occurred.

Extrusions of andesite inaugurated the period of igneous activity in Sierra County, probably in early Tertiary (Oligocene) time, when the lavas commenced to well up along the regional fractures at many places, and it is quite probable that at the time of their maximum development they covered the entire county. These andesites were poured out in a succession of flows, and in places there was an interval of time between flows sufficient for erosion and sedimentation to accumulate lenses of detrital material in depressions in the surface of the flow rock and as fans along the edges. Faulting continued along the fractures already developed, and new fractures were opened up. Extravasation of lava from below and the piling up of this material on the surface broke the long segments developed by the regional faulting into typical fault blocks, which settled unequally and were tilted in places. Cooling and shrinking of the lava developed minor fracturing within the blocks.

Further igneous activity consisted of the rise along zones of regional fracture of dikes, sills, laccoliths and stocks of intermediate rocks such as monzonite and granodiorite, but locally these rocks varied in composition between granite porphyry and diorite. These magmas rose through the Paleozoic sediments, or as in the case of the Cuchillo sill-laccolith, they were intruded into and between the beds, and it is believed that most of the intrusions came to rest with their uppermost portions well within the lower part of the andesite flows, or within 1500 to 2000 feet of the land surface at that time. This feature is illustrated at Hillsboro and in the Sierra Cuchillo, but in other districts the andesite, and with it the top of the intrusive mass, has been planed off by erosion down to the Paleozoic sediments. Faulting continued throughout this period along the regional fractures and between the faulted blocks, which were further tilted and dislocated. The pushing up of the intrusive masses arched the overlying beds, and in the overlying and surrounding rocks radial fractures were developed. Arching is not sufficient, however, to account for the volume of intrusive rock that has become emplaced within the sediments, and it is considered more lil:cly that these masses to a large extent worked their way toward the surface by crosscutting and stoping through the sediments, with partial or complete assimilation of the detached blocks.

The next important event in the geological succession was the formation of dikes, small sills, and small surface flows of latite and latite porphyry. These rocks occur close to the known igneous intrusions, largely within the radial system of fractures developed by the intrusives, or, as at two places near Chloride and in the Macho district, the veins occur in radially arranged fractures in the andesite, beneath which intrusive rocks are strongly suspected. The latites have the same mineralogical composition as the intrusive monzonites, and are considered to be apophyses from these main masses and a part of the same magma, introduced from depths through the upper and outer shell of solidified monzonite. The introduction and crystallizing of these latitic rocks was followed by fracturing and movement along the dike walls, with continued movement along the regional faults and those of lesser magnitude. Ore-bearing solutions from the magma chambers were thus able to migrate upward and outward from these intrusive masses, and according to distance from the source of supply, conditions of pressure and temperature, nature of the wall rock or of the intermingling solutions, or as a result of the structural features existing, they formed the copper-gold-silver deposits of the Chloride and Hillsboro districts, the lead-silver and lead-manganese-silver deposits of the Hermosa, Kingston, Lake Valley and Macho districts, or the iron, lead-zinc, copper-silver and other deposits found scattered throughout the county.

Subsequent to the formation of these mineral deposits there was a period of active erosion, during which lenses of detrital material were laid down in low areas on the surface of the andesite flow rocks. Following this interval enormous quantities of rhyolite were poured over the surface, surrounding and completely covering the faulted blocks of older sediments and andesite flows, in some places to depths approaching 2000 feet. Erosion then became active, and throughout Miocene and Pliocene time the material derived from the tearing down of the higher extrusive masses contributed to the building of the gravels, sands and silts of the Santa Fe formation. A moderate amount of movement and adjustment continued along the old fault planes of the region, and a few new breaks were formed, but in general, faulting was much less important in this period than during the previous ones. Some deposition of ore minerals followed the extrusion of the rhyolites, and the resulting deposits are generally found along the walls of rhyolite dikes or in close proximity to them. Tin deposits are found in the rhyolite flows of the Black Range and Sierra Cuchillo, and along dikes of rhyolite are found the silver-copper-gold deposits of the Gray Eagle mine near Kingston, the silver telluride and gold deposits of the Lookout mine in the Tierra Blanca district, and small but high-grade gold veins cutting the earlier deposits in the Chloride, Tierra Blanca and Carpenter districts.

Quaternary time was essentially a period of erosion, during which the projecting fault blocks of the ranges were planed off. Except on the west slope of the Black Range and in the San Mateo Mountains, only remnants of the rhyolite flows, tuffs and breccias are left, capping the tilted fault blocks of the region. In many places erosion has cut deeply into the underlying andesites or has removed them altogether, exposing sediments of Paleozoic age. The debris from this process accumulated over the beds of Santa Fe age in the Jornada del Muerto, the present Rio Grande valley, and in the small bolsons east of the Black Range, and these deposits are known as Palomas gravel. Locally, flows of basalt poured out over the Palomas gravel, remnants of which now cap the buttes and mesas of the county. One of these flows appears to have cut off the Rio Grande in its former course through the Jornado del Muerto and to have diverted it through the old bolson plain west of the Fra Cristobal Range and the Sierra Caballos, where it now flows. Faulting continued, as is shown by the extension of the main fault of the Hillsboro district up through the Tertiary and Quaternary sediments. Faulting of this age may be more general than heretofore recognized, and may well have provided the channels through which the basalt was enabled to pour out quietly over the surface. It is interesting in this connection to note how the remnants of the basalt flows form clusters along the known faults of the region or in areas through which they would pass if extended. General elevation of the entire region during this period is indicated, and the Rio Grande drainage system cut to new depths in the gravels along its course, leaving terraces to mark its cyclic development.

Throughout the region periodic floods continue to build up and tear down the alluvial fans at the base of the mountain ranges, while in the valleys and bolsons, intermittent streams and tributaries continue to carve their way headword. playa deposits are from time to time built up in the interior bolsons, and during the dry seasons the winds continue to shift about the lighter silts and sands in the important process of scour and fill to which much of the present day topography of the region may be attributed.

HISTORY OF MINING IN SIERRA COUNTY

In the two centuries following the discovery of America, the Spanish governors of the newly acquired territory sent numerous expeditions into what is now the southwestern part of the United States. These expeditions were under the guise of spreading Christianity among the Indians, but in reality they were expeditions of conquest and attempts to find treasures that had been reported to exist in the region. They usually included several experienced miners or prospectors in addition to the soldiers and religious men.

What is now Sierra County was found by these early explorers to be a particularly inhospitable region. On the route north along the Rio Grande (then called the Rio del Norte) the last well-established settlements of Indians were left behind about where El Paso now stands, and only small scattered villages were seen, until near San Marcial in Socorro County the pueblos of another tribe, the Piros, were encountered. From there north the valley was thickly inhabited. Onate reported 10,000 to 12,000 inhabitants in pueblos between San Marcial and Socorro.

In the larger pueblos, turquoise, and in a few instances pearls from California (or mother of pearl), were used as ornaments. Silver and copper mines were mentioned by the Spaniards of these early expeditions, which were visited by them, and specimens of the ore were taken back to New Spain. It is noteworthy, however, that although the Indians knew of these occurrences of mineral and were able to direct the explorers to them, no silver or copper implements or ornaments were apparently seen by the travelers. A small amount of gold obtained from placers may have been used by the Indians as ornaments.

It is believed that scouting parties from Coronado's main band penetrated as far east as Sierra County in 1541, and there is detailed record of the journeys into this area of Rodriguez in 1581, of the Espejo expedition in 1582-1583, and of the Onate expeditions and the founding of the Province of New Mexico, 1596-1605. These later explorers traveled northward in each instance through the Rio Grande valley. Interesting relics of these early ventures are to be seen at Hillsboro in the valuable collection of Mr. W. D. Slease, who has a set of six iron spoons and a sixteenth century spur found by him in the neighborhood. As far as is known to the writer, no missions were ever established in Sierra County.

During the period of the early Jesuit missions, some mining and prospecting was probably done in the Southwest by the Indians under the direction of the Jesuit fathers, There is evidence of early attempts to work silver deposits, turquoise was mined, and a small amount of gold was obtained from placers. It is doubtful if much or any of this work was done in Sierra County, although it is possible that the Animas placers and perhaps some of the lead-silver outcrops of the Kingston and Hermosa districts were known.

The Pueblo Indians revolted against the oppressive rule of the Jesuits in 1680, and the Spaniards, together with all friendly Indians, were obliged to abandon the country. On their return some 20 years later it was expressly stipulated by the Indians that the Spaniards would not again engage in mining, and the search for metals languished until the end of the eighteenth century, when the copper deposits at Santa Rita, Grant County, were discovered.

New Mexico was incorporated as a territory of the United States at the close of the Mexican War in 1846. The construction of the Southern Pacific and the Atchison, Topeka & Santa Fe railroads through the Territory in 1879 to 1882 resulted in a large influx of prospectors and miners. This was a period of great excitement and activity, during which nearly all the mining districts of the region were discovered and developed. The early prospectors were particularly interested in silver and to a lesser extent in gold. The ores of the base metals, copper, lead and zinc, were not attractive on account of the high transportation cost and long haul through a hostile Indian country to the smelters. In 1877 placers and gold quartz veins were found near Hillsboro. Discoveries were made in the Hermosa 'and Apache (Chloride) districts in 1879, and in the Kingston and Cuchillo Negro districts in 1880, and during the next few years substantial amounts of silver ore were extracted. The silver deposits at Lake Valley, found in 1878, in a few years yielded a total of 5,000,000 ounces of silver. Many small mills and reduction works were built. Some of them were located without proper regard for sources of supplies and were operated on ores unsuited for the process installed and without benefit of expert metallurgical knowledge. As a consequence, most of these plants were unprofitable and were operated for only brief periods. In addition, the rich silver ores of the outcrops were soon worked out, and this, together with the decline in the price of silver which began in 1885, placed the mining industry of Sierra County in a pronounced state of stagnation during the closing years of the nineteenth century.

About 1901 the El Paso smelter, owned by the Consolidated Kansas City Smelting & Refining Co., was acquired by the American Smelting & Refining Co. and was enlarged to permit treatment of copper ores in addition to lead, silver and gold ores. A renewed interest was aroused in the base metals, especially copper, lead and zinc, and many of the old camps of the county again became active. During the present century a small annual production of metals has been maintained, which has varied considerably from year to year, following the trend of prices. In 1903 gold was discovered in the Pittsburg (Shandon placers) district near the Rio Grande, and from time to time discoveries of small but high-grade lode deposits were made, which spurred prospectors to renew activity for short periods. Mining in the county was not stimulated by the World War but revived moderately during the period of 1920 to 1923.

During the summer of 1931 a discovery of placer gold was made on the east slope of the Sierra Caballos, near Apache Gulch. By early fall, the Lookout mine in the Tierra Blanca district, owned by W. D. Slease of Hillsboro, and the Bonanza mine near Hillsboro had resumed operations, producing Alver-telluride-gold and gold-copper ores respectively. In 1932 and 1933 placer ground near Hillsboro was worked experimentally on a large scale, and the Shandon placers were sampled and equipment installed. During this same period the El Oro mine in the northern end of the Hillsboro district was unwatered and a modern new shaft, power house and 300-ton capacity mill were installed and equipped.

During the winter of 1931-1932, owing to the financial depression and consequent lack of employment, many miners returned to the hills to prospect and lease on a small scale, and in 1933 Sierra County presented a picture of mining activity such as had not been seen since the period immediately following the World War.

The extremely interesting details of the history of this region and of the mining development within it may be gleaned from the following references, from which much of the material here appearing has been taken :

Bolton, H. E., Spanish Exploration in the Southwest, 1542-1706, 1930.
Bancroft, H. H., Arizona and New Mexico, History of Pacific States of North America, vol. 12, 1888.
Prince, L. B., Historical Sketches of New Mexico from the Earliest Records to the American Occupation, New York, 1883.
Jones, F. A., New Mexico Mines and Minerals, Santa Fe, N. Mex., 1904.
Lindgren, Waldemar, Graton L. C. and Gordon, C. H., The Ore Deposits of New Mexico, U. S. Geological Survey Professional Paper 68, 1910.

PRODUCTION

In the late seventies and early eighties, immediately following the discovery of ore in Sierra County, the annual production from this area probably exceeded that of any other county in the State. From 1884 until 1888 the production was in close competition with that of Grant County, and the lead appears to have alternated between these two counties. After 1888 and until 1893 the production of Sierra County remained at a fairly constant level, while that of Grant and Socorro counties steadily increased. Since 1893 the annual production of the county has been nominal, with the exception of the years 1898 and 1899, when it rose considerably due to an increase in the quantity of gold recovered.

Prior to 1884 and for the period 1886-1888, inclusive, official records are not available for the production of Sierra County. Estimates of the production from the time of the first mining until 1904 place the figure at about $19,800,000. From 1904 until 1931, production is officially valued at $1,212,040, making the total value of production to 1931 about. $21,000,000.

In the table in pocket, the recorded production totals $9,594,503, and the estimate for the periods 1877-1883 and for 1886-1888, which is not included, is therefore about $11,400,000, in order to arrive at the grand total of $21,000,000 as shown above. Local differences of opinion exist as to the total production from the various districts within the county, and some of these opinions carry considerable weight. The writer has taken these differences into consideration in the sections covering the individual districts but feels that it is less confusing to rely on the long-accepted estimates rather than to make changes in the total amount that would not exceed $500,000 at the most.

The tables included in this section have been compiled from data given in reports of the Director of the Mint, from annual volumes of "Mineral Resources of the United States," and from a table in Professional Paper 68 of the United States Geological Survey.

Most of the gold mined in Sierra County has come from the placers and gold-quartz veins found near Hillsboro. Large quantities of silver ores were shipped in a few years following 1877 from deposits in the Hermosa, Kingston, Apache and Cuchillo Negro districts, and from the phenomenally rich silver deposits in Lake Valley. The most important period of the gold-silver production in Sierra County was from 1884 to 1900.

As a result of improvements in transportation facilities, such as the introduction of the auto truck, the building of good roads in many parts of the county, railroad connections at two points in the region, and efficient smelting plants at El Paso. Tex., and Douglas, Ariz., a market was provided for base metal ores, and there was a more or less steady increase in the production of copper, lead and zinc ores from 1901 to 1931. During this period the production of gold in the county fell off very markedly, while the production of silver was maintained at a moderate level throughout. The table on page 45 shows the average prices that prevailed for silver, copper, lead and zinc from 1884 to 1931, and upon which the values of Sierra County production have been calculated, as shown in the table of production.

From 1911 to 1931 inclusive, Sierra County shipped 76,013 tons of ore, which may be divided among the several districts in

Prices of Silver, Copper, Lead and Zinc, 1884-1931[a]

Year	Silver, per Ounce	Copper, per Pound	Lead, per Pound	Zinc, per Pound
1884	$1.11	$0.13	$0.037	$0.044
85	1.07	.108	.040	.043
86	.99	.111	.046	.044
87	.98	.138	.045	.046
88	.94	.168	.044	.049
89	94	.135	.039	.05
1890	1.05	.156	.045	.055
91	.99	.128	.043	.05
92	.87	.116	.041	.046
93	.78	.108	.037	.04
94	.63	.095	.033	.035
95	.65	.107	.032	.036
96	.68	.108	.03	.039
97	.60	.12	.036	.041
98	.59	.124	.038	.046
99	.60	.171	.045	.058
1900	.62	.166	.044	.044
01	.60	.167	.043	.041
02	.53	.122	.041	.048
03	.54	.137	.042	.054
04	.58	.128	.043	.051
05	.61	.156	.047	.059
06	.68	.193	.057	.061
07	.66	.20	.053	.059
08	.53	.132	.042	.047
09	.52	.13	.043	.054
1910	.54	.127	.044	.054
11	.53	.125	.045	.057
12	.615	.165	.045	.069
13	.604	.155	.044	.056
14	.553	.133	.039	.051
15	.507	.175	.047	.124
16	.658	.246	.069	.134
17	.824	.273	.086	.102
18	1.00	.247	.071	.091
19	1.12	.186	.053	.073
1920	1.09	.184	.08	.081
21	1.00	.129	.045	.05
22	1.00	.135	.055	.057
23	.82	.131	.07	.068
24	.67	.131	.08	.065
25	.694	.142	.087	.076
26	.624	.14	.08	.075
27	.567	.131	.063	.064
28	.585	.144	.058	.061
29	.533	.176	.063	.066
1930	.385	.130	.050	.048
31	.290	.091	.037	.038

[a] Mineral Resources of the United States annual; Part I, Gold, silver, copper, lead and zinc in New Mexico and Texas.

tons approximately as follows : Chloride, 15,283 (principally from the Silver Monument mine) ; Hermosa, 570; Kingston, 3,675 (largely from the Lady Franklin mine) ; Tierra Blanca-Carpenter, 210 ; Cuchillo Negro, 388 ; Hillsboro, 6,506 ; Lake Valley, 46,261 (42,154 tons of low-grade fluxing and siliceous ores included) ; Macho, 1,640 ; Goldsboro, 30 ; Mud Springs, 20; Caballos, 1,430. On the basis of the contained metals, these ores may be divided in tons as follows : Gold, 1,659 ; silver, 6,042 ; gold-silver-copper, 19,884 ; lead-silver, 4,244; lead-vanadium, 328 ; lead-zinc, 403 ; zinc, 60; manganese, 1,239 ; fluxing material, 21,791 ; and low-grade silica, 20,363.

Since 1931 no official figures are available to show the production of the various metals in the county, but in view of the enormous stocks of non-precious metals accumulated as a result of long-continued overproduction in the face of a declining ability to buy on the part of the consuming public, and to the inability of the small producer to operate steadily during a period of declining prices of the metals, there probably was a notable falling off in the quantities of copper, lead and zinc ores produced in 1932 and 1933. The decline in the price of silver during the greater part of this period probably had a similar effect on the production of ores containing small to moderate amounts of silver, when only those of exceptional richness could have yielded a profit under the existing conditions. However, during the last months of 1933 the price of silver increased to above 40c per ounce, and it was believed in many quarters that before many months elapsed in 1934, silver would be valued at some definite ratio with gold, and that the silver miner would be in a much better position to produce this metal at a profit.

On the other hand, an intensive search for gold ores, gold-silver ores and for base-metal ores containing appreciable amounts of gold, was in progress in 1933, and several small properties made a few shipments. For the remainder of the depression at least, and for as long as the spread between cost of producing gold and the market value is large, whether due to low costs for labor and supplies or to an enhanced price for the metal, a continued increase in the production of gold from Sierra County may be looked for with some confidence.

The embargo on gold was lifted by presidential edict on September 8, 1933, and newly produced gold became a commodity, bought and sold under free marketing conditions at a fluctuating price which was set daily by Federal authority. Following the lifting of the embargo, gold promptly increased in value from $20.67 per troy ounce to $29.10 per ounce, and it rose steadily until on November 14 the price stood at $33.56 per troy ounce. Arrangements had been made whereby the shipper of small lots received payment from the United States Mint almost by return mail, and it was expected that soon the minimum requirement of 2 ounces per shipment would be greatly reduced, thus permitting the prospector to make more frequent shipments and to deal directly with the Mint, where the maximum price is paid.

ORE DEPOSITS

GEOGRAPHIC DISTRIBUTION

The known ore deposits of Sierra County are confined entirely to the mountainous areas. Along the east slope of the Black Range an almost continuous belt of mineralization extends from the northern boundary of the county in a southerly direction to beyond the Tierra Blanca and the Carpenter mining districts. A second group of mineralized areas starts near the northern boundary of the county north of Fairview and continues with several breaks southward through the Sierra Cuchillo, the Hillsboro area, and to the Lake valley end Macho districts. The third belt of mineralization is still less continuous and extends from north to south through the length of the Fra Cristobal Range and Sierra Caballos, probably the only area of any importance being that around Hot Springs and Palomas Gap, south of the Elephant Butte Dam.

GEOLOGIC DISTRIBUTION OF DEPOSITS

In his discussion of the ore deposits of New Mexico, Lindgren[21] classifies them under nine main headings, and his general remarks regarding the deposits of the State apply in large measure to those of Sierra County. Lindgren's classification is as follows: (1) Pre-Cambrian deposits, (2) Contact-metamorphic deposits, (3) Veins connected with intrusive rocks of early Tertiary age, exclusive of replacement veins in limestone, (4) Copper deposits due to oxidizing surface waters, (5) Veins and replacement deposits in limestone, exclusive of contact-metamorphic deposits, (6) Veins connected with volcanic rocks of Tertiary age, (7) Lead and copper veins of doubtful affiliation, (8) Placers, and (9) Copper deposits in sandstone.

No ore deposits are known to exist in Sierra County that are of pre-Cambrian age, nor are there any known to be of later age but localized in the pre-Cambrian complex. The gold of the Pittsburg (Shandon) placers was probably derived from the pre-Cambrian basement of the Sierra Caballos, and is discussed in connection with those deposits.

The iron deposits in the north end of the Sierra Cuchillo are of the contact-metamorphic type, and so also are the lead-zinc deposits and the copper deposits somewhat farther south in the same range.

[21] Lindgren, Waldemar, op. cit. (U. S. G. S. Prof. Paper 6 I. pp. 47-49.

Deposits of Type 3 are known in the county only at Hillsboro, where mineralized veins occur in the monzonite at Copper Flat and are genetically related to it.

The copper deposits due to oxidizing surface waters are represented by the disseminated mineralization in the Copper Flat area near Hillsboro, but the actual amount of enrichment by this agency has been of slight importance. At the Silver Monument mine in the Black Range, enrichment of the ore shoots has occurred, but the mine is not entirely dependent on the material thus enriched for commercial operation.

Veins and replacement deposits in limestone. exclusive of contact-metamorphic deposits, have been the principal source of the metal production of the county. Such deposits occur at Lake Valley, Kingston, Hermosa, Tierra Blanca and Carpenter, with minor mineralization of this nature near the main Hillsboro area and in the Sierra Caballos.

Of the veins connected with volcanic rocks of Tertiary age, the Chloride and Hillsboro districts afford the outstanding examples. Other deposits of this type include the veins in the San Mateo Mountains and in the Macho district, the tin deposits in the Taylor Creek district and in the Sierra Cuchillo, and veins in several areas in the Fra Cristobal Range and the Sierra Caballos.

Lead and copper veins of doubtful origin, according to Lindgren's classification, are not known to occur in the county.

Placers in the Hillsboro area have been derived from the veins connected with the volcanic rocks of Tertiary age. At the Pittsburg (Shandon) placers, the original source of the gold was in veins in the pre-Cambrian complex at the base of the Sierra Caballos. Whether these veins are of pre-Cambrian age or were formed in the pre-Cambrian rocks at some later time is not known. To date no veins have been discovered in this region with a gold content sufficient to warrant development work.

Copper deposits in sandstone, more commonly known as "Red Beds" deposits, occur sporadically along the eastern slope of the Fra Cristobal range, the Sierra Caballos, the Sierra Cuchillo, and throughout the length of the Black Range in Sierra County. Mineralization of this type in the known deposits of Sierra County is insignificant.

Throughout the county, in every case except the Pittsburg (Shandon) placers, the ore deposits are clearly related to the period of Tertiary igneous activity, which was so widespread, not only in New Mexico, but over the entire southwest. Nearly all of the mineral deposits in this region are considered to have been formed by solutions that came from the same magma chamber following the intrusion of the stocks, dikes, sills and flows of monzonite, latite and latite porphyry. Among these are the contact-metamorphic deposits of iron, copper, and lead-zinc ; the veins connected with intrusive rocks of early Tertiary age, which contain principally gold, copper and silver ; veins and replacement deposits in limestone consisting of silver-lead, silver-lead-zinc, silver-lead-manganese, and fluorspar-lead-silver deposits ; and probably also most of the copper deposits in sandstone.

A few veins in the region are known to have been formed following the extrusion of the rhyolitic rocks, and these consist of tin deposits, gold veins carrying minor amounts of copper and silver, and gold-silver veins with associated tellurium and bismuth.

Structural control was of paramount importance in the localization of ore bodies. Faulting and fracturing created the channels through which ore-bearing solutions gained access to the host rock, and even in the case of contact-metamorphic and blanket-replacement types of deposits it can be shown that the localization of mineralization was due to a relatively intricate system of fracturing rather than to simple permeability of the beds and the infiltration of solutions for great distances from the major fractures and bedding planes. Differences in chemical and physical character of the host rock were important in the processes of selective replacement. In many places early solutions deposited silica, calcite or other gangue minerals, sealing off the wall rock and filling the smaller fractures, so that the later ore-bearing solutions were forced to deposit their load in the openings remaining in the wider portions of the veins. This resulted in the formation of many small tortuous ore shoots containing much high-grade material, rather than continuous ore bodies in the veins or beds with possibly a lower metallic content. In places a cover of impervious shale caused the slowing up and stagnation of the mineralizing solutions, with consequent replacement of the underlying favorable beds and precipitation of the ore in the form of irregular blankets.

Beds that dip toward the igneous intrusion were mineralized to a greater extent than those that dip away from these rocks. Anticlinal folds formed traps, which served to concentrate the solutions and precipitate the ore minerals, especially where a bed favorable for replacement was capped by an unfavorable impervious bed. In other instances, as at the Lookout mine near Tierra Blanca and at some of the deposits in the Sierra Cuchillo, gentle folding of brittle beds produced tension cracks at the crest of arches, in which ore minerals were concentrated. In the gold-silver-copper veins in the volcanic rocks, open-space filling in fault planes along the contact between dikes and country rock was almost the only mode of ore deposition. At Copper Flat near Hillsboro and at the junctions of some of the more important veins in the district with cross veins, the pronounced vein characteristics were lost in a general fracturing of the surrounding area, producing stockworks in which the mineralization was much more widespread and general but of considerable lower grade.

MINERALOGY OF SIERRA COUNTY

The ore deposits of Sierra County may be classified according to form into (1) veins or lodes, (2) stockworks closely related to veins, (3) replacement deposits or "blankets " and (4) placers. The first two occur principally in igneous rocks, while the third type is common in the limestone areas, but there are exceptions to both rules. A classification of the ore bodies may also be based chiefly upon the genetic features of the ores and their constituent minerals, dividing them into primary deposits and secondary enrichmant deposits.

The table, in pocket presents an alphabetical list of the ore and gangue minerals occurring in Sierra County. The minerals in the list include two distinct groups, differing in mode of origin. In the first class are included not only those minerals of which the country rocks were originally composed before the ore deposits were formed, but those that have been developed from them by the action of surface waters. These minerals are entirely independent of ore deposition and are marked by an asterisk in the table. Where unreplaced blocks of country rock are enclosed within ore bodies, these minerals might be considered as gangue minerals.

The second class of minerals includes (1) those formed by ascending ore-forming solutions (hypogene minerals), and (2) other minerals derived from them by the action of descending waters (supergene minerals). This group has been arranged in the table, in pocket according to the principal metals contained and the relative temperature at which they were deposited.

Many of the minerals listed in the above tables were not seen by the writer in the field ; some were examined in specimens from private collections, and many are taken from lists compiled by others who have investigated the area. The accompanying table gives the composition of each mineral found in the county, the locality where found, and in many cases the relative abundance of the species.

It is of interest and a matter of great importance to note the manner in which the minerals are grouped in the table, in pocket By far the most important group in variety of minerals contained is that at the top of the table, containing the oxidized minerals that are normally found in the zone of oxidation and leaching at and near the surface. The second largest group in point of variety is that of the primary sulfides, and those that have been found in the county are characteristic and common minerals Of the extreme upper part of the zone of moderate temperature (mesothermal) deposition. It is probable that most of the deposition of primary sulfides in Sierra County occurred under physical conditions of temperature and pressure that were intermediate between those of the true mesothermal and epithermal (low temperature) zones, and this intermediate zone has recently been named the leptothermal zone by Graton. [22] The third and only other group worth consideration is that of the secondary sulfides which are found near water level (present or past) as a result of the deposition of minerals oxidized and dissolved near the surface and carried down by descending surface waters to the zone of reducing conditions, the sulfide-enrichment zone of the table.

Probably half of all Sierra County shipments have contained the minerals of the oxidized zone, and these shipments have included the richest ores of the county. It is estimated that one-fourth of the total shipments was produced from the zone of sulfide enrichment. The remaining one-fourth has come from the primary portions of the veins and deposits, but in no case has mining been prosecuted to such a depth that there has not been a noticeable amount of secondary sulfide minerals in these so-called primary sulfide ores.

PRACTICAL FEATURES OF PROSPECTING AND MINING

To those interested in finding new ore bodies and the successful exploitation of those already discovered in Sierra County, the answers to certain questions are of 'great importarfce. Some of these questions are as follows : Where are the most favorable areas for prospecting? What are the most favorable rocks or horizons in which to prospect? Will ore deposits be found at a definite depth below surface, and is there a chance of finding others at greater depths than those now known? Will there be changes in the size of veins and ore shoots at greater depths? Will the grade or character of ore change with depth due to processes of oxidation, secondary enrichment, or impoverishment of primary bodies? What average costs for mining, milling, overhead expense, etc., may be expected within the county? Do the ore deposits of the region in general warrant the construction of a mill at each mine, or should a district customs plant be erected on a co-operative agreement, and under what conditions is milling a practical solution of local problems? It is unfortunate that at many mines and prospects lack of development does not permit definite answers to many of these questions, but it is possible to discuss most of them in a general way, and to some extent at least the risks and limitations of mining in the area may be noted.

[22] Graton, L. C., The depth-zones in ore deposition, Econ. Geology, Vol. 28, No. 6, p. 513, 1933.

In spite of all the study given to ore deposits, [23] the geologist is as yet unable to do more than speculate as to what is beyond the last visible point in a vein. He does not know the conditions that determine why a certain vein should contain a valuable ore shoot while another is barren. No one knows with certainty the exact source of the metals, or what delicate balance of complex conditions determines their deposition in a certain place. It is certain that there is a genetic connection between most ore bodies and igneous activity, and it is believed on the grounds of field evidence that the solutions which deposited the metals came in large part from the solidifying igneous mass that was intruded into the upper layers of the earth's crust, or from the exhalations from a magmatic reservoir at greater depth, but this opinion has not as yet been completely demonstrated.

In order to have a localization of the ore minerals, it is a prime requisite that the openings must exist in which solutions may migrate and accumulate. Such openings are in general created by faulting and fracturing in the sediments adjacent to igneous intrusions or in the upper parts of the intrusive rocks themselves, due to the forces exerted by later intrusions, settling and shrinking accompanying cooling, or to other causes. It may be accepted, therefore, that favorable areas for prospecting are near centers of igneous activity where considerable faulting and fracturing of either sediments or igneous rocks have occurred. Folding of the beds within these areas into low anticlinal arches creates traps in which the solutions deposit their mineral load, and the presence of such folds is especially significant if the beds favorable for ore deposition are overlain by others that are plastic and impervious, such as shales and shaly limestones. Such favorable areas are indicated at the surface by escarpments, folding, tilting and fracturing of the rocks, abundant vein quartz or calcite, pronounced staining of the rocks, by iron, manganese or copper, the presence of relict sulfide minerals or of oxidized minerals in these leached areas, or an abundance of free gold in the leached outcrops or in the stream gravels below such outcrops. Quartz veins may outcrop boldly, whereas veins with predominating calcite gangue may be depressed at the surface and obscured by rock detritus, so that trenching is necessary to locate and sample them ; likewise, the outcrops of the best portions of a vein may be depressed due to oxidation of the sulfides and breaking down of the vein matter, while the poorer portions may remain projecting conspicuously above the surface. There are extensive areas in the county within the exposures of Paleozoic sediments and Tertiary lavas, the two principal ore bearing horizons, that are without faulting, mineralization, or other evidence of unusual disturbance, and hence of little promise for ore deposits. On the other hand, near the known mining

[23] Ransome, F. L., Geology of the Oatman gold district, Arizona : U. S. Geol. Survey Bull. 743, p. 51, 1923.

centers in the county there are still good chances for locating mineralized extensions of known veins, or for finding veins that lie buried under a mantle of detrital material or of later flow rocks.

All the known silver-lead-manganese deposits in the county are in the Paleozoic sediments, where they have formed largely by replacement of favorable beds in the Silurian limestone just under the Percha (Devonian) shale, in the Lake Valley (Mississippian) limestone under its topmost shaly member, or in the Magdalena (Pennsylvanian) limestone underlying one of the contained shaly members. Considerable ore has been found on that side of an intrusion where the sediments dip toward the igneous rock. Valuable ore deposits are located along the axes at the tops of anticlinal folds, in tension cracks at the tops of such arches, and in larger fractures which may or may not be in conjunction with folding. The contact-metamorphic deposits of lead-zinc and of copper in the Cuchillo Negro district occur in the Magdalena (Pennsylvanian) limestone and are quite similar to the silver-lead-manganese deposits in shape and relation to the enclosing beds. In the igneous rocks ore has been found within the intrusive ones of Tertiary age at Hillsboro as veins and stockworks. In the volcanic areas the older flows of andesite and andesite breccia have been much more productive of gold, copper and silver than have the later rhyolites. Most of the ore in the andesites appears to be of the leptothermal type and is closely associated with the latite and latite-porphyry dikes and sills that penetrated and disturbed the andesites prior to the rhyolite extrusions, and which are considered to be direct offshoots from the deeper monzonite stocks of the region. A few weak veins of the epithermal type containing gold and silver have been found in or associated with the rhyolites, but these rocks are notably lacking in valuable mineral deposits within Sierra County.

Practically all of the ore so far discovered in Sierra County has shown evidence of its presence on the surface by actual assay. There is always the chance, however, that concentrations of secondary sulfides at water level may be found under practically barren leached outcrops. As far as the writer has any knowledge, there is no reason why other concentrations of metals in favorable beds underlying impervious shale members should not be found at greater depth under known ore bodies, especially where fractures cross the formation. It is certain, however, that ore found at deeper horizons will consist entirely of primary minerals, and hence these bodies probably will be of smaller size and materially lower grade than those exploited in the past. In the bonanza type of ore deposits in the lava flows, a few ore shoots have been found that apparently had no surface indications of their presence, or the evidence was of such a nature as to have passed unnoticed. In general, considering the rather small size of the individual ore bodies in this region and their scattered distribution within the veins and beds, it appears doubtful if an operating company of large capitalization, burdened as it would be with overhead and administrative expense and probably oversupplied with plant and equipment for the conditions locally existing, could make an ultimate success of an extensive search for deeper lying ore bodies. On the other hand, prospectors, small groups of individuals, or organized companies with modest capitalization and minimum overhead expense, who confine their efforts largely to surface outcrops, the extension of known ore in place, or to the handling of stope fill and low grade dump ore, have a fair chance for profitable operations in many of these old camps.

Except in the blanket type of replacement deposits in limestone, there has been little mineralization of the wall rock adjacent to veins in the region. At water level in places the secondary sulfides extend beyond the strict limits of the opening, but this has been of minor economic importance. In the primary zone below water level, it is believed that with added depth the fissures will tend to tighten and the quantity of ore will thus decrease with each unit of depth gained, although minable ore may persist in the vein for a considerable distance below the zone of enrichment. Probably there will be a shifting of the proportions of the different metals in the veins as depth increases, copper becoming more important compared to gold and silver.

In general the best ores produced in the county have been from the oxidized zones of the silver-lead and the gold deposits, where silver chloride, native silver, lead carbonate and sulfide, and native gold have predominated. Much oxidized manganese and manganiferous iron ore has also come from this horizon.- At and near the ground-water level secondary sulfide deposits of copper have been characteristic, and deposits of zinc carbonate have been found. These secondary sulfide deposits include important quantities of lead sulfide, native and ruby silver and argentite. Below water level occur the primary ores of the different metals. So far as known, all of these have been of much lower grade than were the ores from the same shoots at higher levels, although in places, if a sufficient tonnage could be developed, the grade is such that these ores could be concentrated profitably. The water level is from 50 to 400 feet below the surface, and primary sulfides may begin to make their appearance anywhere from the surface down, due to incomplete oxidation and secondary enrichment.

A careful survey of current costs in the mining districts of Sierra County was made by the writer while in the field. Later it was decided to increase the scope of the survey, making the figures applicable to operations throughout the State, and to compile them in greater detail for Bulletin 7 of the State Bureau of Mines and Mineral Resources, "The Metal Resources of New

Mexico and Their Economic Features." They are incorporated in Part V of that bulletin under the head of "Economic Features of Prospecting, Mining and Milling," pages 159-172, and only a brief summary is given in this report.

Mining costs range from $1.50 to as high as $10.00 per ton at average-scale operations. The low-cost limit may be obtained when the full width of the vein or deposit is mined as ore, and where all handling is by gravity through ore chutes and adit tunnels. Similar work, which requires hoisting from depths of 100 to 500 feet with small equipment, increases costs to between $2.50 and $3.50 per ton. Sorting ore in stopes or on the surface adds rapidly to the cost of mining, and where only quartz stringers are saved from the vein matter, it may amount to $10.00 per ton or more. In the development of the small mine it is always desirable to keep in ore whenever possible. The small ore body will not pay for much deadwork in the nature of shafts and long adit tunnels, and at the same time yield a profit. If in following the ore, large and valuable bodies are uncovered, there is then ample time in• which to consider a more elaborate plan of development and extraction. Too often the long tunnel or deep shaft driven to intersect a vein not sufficiently developed at shallower levels has resulted in the complete failure of the operation. The cost of reopening and equipping an old mine may range from $100 to $300 per ton of daily capacity. These figures include cleaning out, retimbering and sampling all old workings, laying track, providing drainage, pumping equipment, headframe, hoist, mine surface plant, compressor and all working tools and equipment. They do not provide for new development work or general surface costs. Similar costs for a new mine may range from $250 to $500.

Mill operating costs vary from a low of 50c a ton in a simple amalgamating plant to around $1.00 for amalgamating and tabling combined. The costs of flotation and cyaniding are somewhat higher in small plants, ranging from $1.50 to $3.50 per ton treated. Milling, which is advisable for some ores and essential for others, serves three purposes : (1) It separates waste material from the ore and reduces thereby the transportation and smelting charges, (2) it produces a concentrate that can be profitably marketed where the untreated ore possibly cannot, and (3) it produces from an uncommercial complex ore a number of profitable products. There is danger, however, that at a small property too large a mill will be built, or that a mill will be provided before sufficient ore is blocked out to insure repayment of the money expended and a fair profit from operation. It is helpful to have milling facilities available during the development of a mine, as at least a part of the costs may be paid out of profits derived from treating the ore. The following factors should be considered, however, before deciding to construct a mill : At least 95 per cent of all prospects do not develop enough ore to be classed as mines ; although much reserve tonnage is eventually blocked out, the grade of ore may be much lower than anticipated ; and without adequate figures on tonnages and grade, and on the distribution of oxide and sulfide minerals in the ore, the wrong scale of operation and an incorrect metallurgical treatment scheme may be adopted.

In general it should be obvious that during the development period all possible capital expenditures should be avoided, and this may even extend to making a hand-sorted product for shipment or shipping the ore to a nearby custom mill for treatment. There is a definite relation between the value of an ore and the minimum scale of profitable operation for the plant. For a 25- to 50-ton plant, $12 to $15 ore is about the minimum that can be successfully treated ; for a 75- to 100-ton plant $8 to $10 ore is required ; $6 ore should be treated at the rate of 200 to 300 tons per day ; and $3 to $4 ore can be treated only on a very large scale. In rare cases $5 to $6 ore may be made to pay on a scale of 100 tons per day, and in general the treatment of tailing, stope fills, dumps or pillar ore may constitute an exception to the foregoing. Water in sufficient quantity to insure uninterrupted operation of a milling plant is a serious problem throughout the county, and the requirements of the plant are often not given the proper attention in estimates. Small plants using ordinary milling methods require between 1,000 and 2,000 gallons of water to be in circulation for each ton treated, and only 50 to 75 per cent of this amount may ordinarily be saved for reuse. Finally, the cost of erection of mills, using all new equipment, varies between $600 per ton of daily capacity for simple flotation and amalgamation plants to as high as $1,750 per ton in the case of elaborately equipped all-slime cyanidation plants. The percentage of recovery also varies widely, ranging from 60 to 95 per cent, depending on the method of treatment and the nature of the ore.

Overhead expense may vary from a few cents per ton in the case of the individual operator, to $1.00 per ton in the case of a small company, this latter figure being the safe one to use in preliminary estimates. Haulage of ore, concentrates and supplies between the mine and the railway is an important item in Sierra County, and with auto trucks 10c per ton-mile should be used in estimates for either contract or company-account hauling. Sometimes light supply shipments are taken to the mines free by the freighting contractor or at half rates, but in making estimates this should not be relied upon without definite agreement.

Smelting costs, which vary within wide limits, have been discussed in considerable detail by Lasky and Wootton[24] for New

[24] Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features : N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull 7, pp. 140-158, 1933.

Mexico ores and concentrates. In cases where the smelter requires silica, lime, or iron for fluxing purposes, low-grade ores may be accepted by it without penalties or smelting charges being levied, and the usual rates paid for all recoverable metals. Several old dumps have been treated on this basis. Normally, however, a base smelting charge of $2.50 to $5.00 per ton is imposed, payment is made for recoverable metals based on the current market price with certain reductions, and charges are made for undesirable constituents or other objectionable features of the ore. Metals are not paid for in full amount, deductions being made to take care of metallurgical losses in smelting and refining and for metal handling costs such as refining, marketing, shipping of bullion, interest on capital, and the profit to the smelter. Although the amounts paid vary within wide limits, the following may be considered as typical for Sierra County ores :

Gold—.0l to .05 oz. minimum, pay for 95-100% at $19.00-20.00 per[25]

Silver—.5 to 1.0 oz. minimum, pay for 95% at market price less 3 1/3c.

Lead-3.5 to 5.0% minimum, pay for 90% at market price less 1.5c per lb. Lead not paid for in copper ore smelted in a copper furnace.

Copper-8 lbs. deducted per ton, pay for 95% of remainder at market price less 2 1/2c. (Market price less 3 3/4c in a lead ore.)

Zinc—In a high-grade zinc ore or concentrate usually 75-85% is paid for and smelting charges are high. Zinc in a. copper or lead ore is lost in smelting, adds to smelting difficulties, and as a rule is penalized at the rate of 30c per unit in excess of *5%.*

Penalities are charged for the undesirable constituents in an ore and premiums generally allowed for the desirable fluxing constituents. Some typical premiums and penalties are as follows:

Silica-10e to 12c penalty per unit for total silica or insoluble.

Iron—Paid for at 5c to 6c per unit when silica is penalized.

Manganese—Paid for at 5c to 6c per unit when silica is penalized.

Lime—Paid for at 8c per unit in amounts exceeding 2%.

Sulfur—Copper smelters usually ignore the sulfur content, but lead smelters penalize, and in one case sulfur in excess of 1% was penalized 20c per unit.

Arsenic, Antimony, Bismuth—Allow 1% free of these elements combined and charge for excess at $1.00 per unit, but the penalty varies widely.

Moisture—Allow 12% free and charge 20c per unit in excess. This will affect only flotation concentrates.

Miscellaneous—A charge of 50c per ton may be levied for ore received in sacks. Special sampling charges may be imposed for shipments below a certain minimum number of tons.

Railroad freight charges from the nearest shipping point to the smelter are paid by the smelter and deducted from the amount due the shipper on his ore. Freight rates are determined by the railroads and increase for the same haul with the value of the ore.

An excellent rule to follow and one that is given careful consideration by many experienced mine operators and mining companies when considering new properties, is that after liberal

[25]ee footnote. nave 59.

allowance for the total probable operating and overhead expense has been made, the total net value (smelter returns) of the recoverable metals in the ore should be at least double that amount; and in addition, there should be enough ore blocked out and it should be of such grade that the total cost of the plant can be paid back out of the operating profits in not more than three years, and preferably in one year. If the items of purchase of property, organization of the company, and plant construction costs are added to the foregoing estimate of operating expense to arrive at a total cost of producing the metals in the ore, then the net smelter returns should exceed this probable total cost by at least 50 per cent.

PART II. MINING DISTRICTS[26]

THE BLACK RANGE

LOCATION AND AREA

The Black Range follows the western border of Sierra County, with its crest practically coincident with the county line throughout its entire length, except for a distance of 18 miles at the north, where the county line is on the western slope of the range, 10 miles west of the divide. The general trend of the range is 10c to 15° west of north.

GEOGRAPHY

Elevations along the crest of the Black Range average close to 8,200 feet, although where it crosses the northern boundary line of the county, the Beaverhead highway has been built through a pass near the little hamlet of Fluorine, 7,500 feet above sea level. The highest portion of the range is northwest of Kingston, where Hillsboro Peak has an elevation of about 10,100 feet. The eastern foothills of the range are located along a north-south line which passes through Chloride, Hermosa and Kingston. Drainage is prevailingly to the east, through the drainage systems of Cuchillo, Palomas, Animas, Percha, Tierra Blanca and Berenda creeks, and eventually into the Rio Grande. In the extreme northwestern part of the county, tributaries of the Gila River have their origin, and these streams drain to the west through the Gila and Colorado rivers to the Gulf of California. The entire area of the Black Range in Sierra County is within the Gila National Forest, and except for the lower foothills, where scrub oak and cedar abound, the range is covered with good stands of yellow pine, cedar, juniper, and other less valuable woods. In these parts timber has been cut in the past for mining and building purposes and for fuel, but at present under the supervision of the United States Forest Service, large areas are being reforested by natural processes, and the cutting of timber is closely regulated. Most of the creeks have running water in them the greater part of the year.

GEOLOGY

STRATIFIED ROCKS

As noted on Plate II, the stratigraphic columns of the Chloride, Hermosa, Kingston and Tierra Blanca districts show in one place or another the entire geologic sequence known in the

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Si Throughout Part II, the values given for ores and samples of gold and silver are based on a price of $20.67 per troy ounce for gold and 40e an ounce for silver. The higher Prices for gold and silver which were in effect in the spring of 1934 would appreciably increase the value of these ores and samples. As a result, some of the mines and prospects described in Part II might deserve more favorable consideration than formerly, and certain properties might prove to be more profitable than suggested in the report.

county. From the north border of the county nearly to Kingston, the Magdalena (Pennsylvanian) limestone is a prominent feature of the east face of the range. Here a continuous succession of faulted blocks of this formation, having gentle dips to the east, for the most part, form the foothills. In the Black Range mining district, which extends from the north border of the county to Bear Creek and the old town of Robinson, an isolated block of this limestone, with dip to the east, projects through the Tertiary flows of the region. It is in or near this exposure that the ore in this area has been found, and along the east border of which the old mining camps of Fluorine, Phillipsburg and Grafton were located. From Robinson south the faulted limestone blocks constitute the east foothills of the range. Through this same area, for 6 miles or more south of Chloride, faulted blocks of Permian strata lie to the east of the Pennsylvanian blocks. These consist principally of Abo sandstone of deep red color and subordinately of the Chupadera formation. At Hermosa the Magdalena limestone is much faulted, although displacements are small and dips are very slight. From 6 miles north of Kingston to a point 9 miles south, the entire sequence from the pre-Cambrian granite to the Tertiary flows can be seen, as the east face of the range has been broken by a series of north-striking faults, with a total displacement of 1,000-1,500 feet. Farther south the Paleozoic beds gradually disappear under a cover of Tertiary lavas. Alluvial fans form a prominent feature of the east slope of the Black Range.

INTRUSIVE ROCKS

Intrusive rocks are not observed farther north in the Black Range than Kingston, although their presence may be inferred at Chloride, where in two localities the sedimentary beds are slightly arched, and roughly radial groups of mineralized fractures are found. At the Midnight mine in the Apache (Chloride) district, the vein, which is in limestone, contains abundant contact-metamorphic minerals, indicating igneous rocks not far below. At Hermosa, Gordon [27] believes that igneous rocks lie at no great depth below the ore bodies of that district, and that ore solutions have risen from them to precipitate their mineral load in the Magdalena limestone. A small dike of diabasic rock cuts the Magdalena limestone high up in the north wall at Palomas Creek.

At Kingston a dikelike mass of monzonite porphyry has cut through the Paleozoic sediments. This mass is at least 400 feet wide just west of the town of Kingston, and can be traced two miles to the north and to the south about the same distance. South of Kingston it is more irregular in shape and occupies a considerable area. Although Gordon[28] calls this mass a dike, the

[27]ordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 268.
[28]a. T4 ·ın nif (TT g a C Prof Psarlor AR 1 rt 9g,1

writer is inclined toward the belief, without being able to prove the point, that it is the top of an elongated cupola or small stock, which may enlarge rapidly with depth. Monzonite is present in the Tierra Blanca district as an intrusion cutting Paleozoic sediments.

In the Carpenter mining district the intrusive rock is a granite porphyry, which forms dikes of large size near the mines. About half a mile west of the Grandview mine, an elongated stock of granite porphyry forms a prominent ridge which extends in a northerly direction for nearly 3 miles. North of the mine a dike of granite porphyry 20 feet wide and striking N. 40° W. cuts across the limestone. A few dikes of a diabasic rock are known in the district, but these appear to be much younger than the period of metallization.

Although the proportion of the total surface area occupied by intrusive rocks in the Black Range is very small, there is considerable evidence indicating that much larger bodies of these rocks have come to rest at relatively shallow depths below the present surface, and that the ore deposits of the region formed during the final stages of the solidification of these masses and are closely related to them.

EXTRUSIVE ROCKS

The Black Range, except for its eastern edge, is almost entirely covered with a thick series of Tertiary flow rocks, which in places is as much as 3,000 feet thick. The sequence of these flows is, in general, brecciated andesite, andesite flows, and alternating thin layers of andesitic ash 'and of sedimOnts derived from the andesites in the intervals between the various flows. Within this series of andesites are numerous dikes and sills of latite and latite porphyry. Following the andesites and latites came a thick series of rhyolite flows, tuffs, and breccias, which varied in the order of their occurrence from place to place along the range. Near Kingston and to the north, tuffs and breccias were apparently laid down first upon the andesite. Flows of rhyolite followed, and finally these were covered with thick beds of white rhyolitic ash. South of Kingston and down to Lake Valley, wherever erosion has developed canyons that cut deep into the flow series, it was noted that the first of the rhyolite series is a flow with eutaxitic to finely porphyritic texture, having a glassy obsidian base that varies from 2 to 15 feet in thickness. Following this came an alternation of tuffs, agglomerates and flows, and finally at the top a thick series of flows, these surmounted by a thick bed of white ash. Dikes of rhyolite, possibly the feeders for these flows, cut the andesites. Many of these dikes have a glassy texture, and glassy borders are a characteristic feature. A few basic dikes cutting the flow rocks are considered to be of Quaternary age and associated with the basaltic flow rocks that are intercalated with or cover the Tertiary and Quaternary detrital accumulations of the eastern foothills and the bolson plains.

STRUCTURAL RELATIONS

In broad outline, the main mass of the Black Range takes the form of an anticlinal dome of huge areal extent but with relatively slight upwarping and folding of the strata. The major axis of this dome is apparently about at the crest of the range and has approximately the same trend. Along the eastern border of the dome, faulting took place, most of which appears to be of the normal type, and this limb was broken into many fault blocks. The general pattern of the faulting consists of a series of northerly trending breaks along which the flank of the dome is stepped down as one travels eastward, until finally the last of the blocks disappear beneath the bolson deposits and alluvial fans. Intersecting these main breaks are many transverse faults striking generally east. The high point of the dome appears to coincide with the high topographic point of the range near Hillsboro Peak northwest of Kingston, and along the east 'flank of the dome in this vicinity, faulting has exposed the geologic column to a depth of 600 feet below the top of the pre-Cambrian. To the north and south of Hillsboro Peak the beds dip away from the high point as they do to the east and west, but much more gently. On the western flank of the range less faulting is apparent, as most of this area is covered with rhyolite and rhyolite tuffs and breccias, but in general the flows dip gently to the west.

Figure 6 illustrates the cross section of the fault pattern in Palomas Canyon, where over 1,000 feet of Magdalena (Pennsylvanian) sediments may be seen in the steep walls of the canyon. Beneath this cross section is a heavy line, which indicates the original position of the beds along the line C-C' of Plate I, and shows that the faulting occurred in beds that had first been subjected to compressive stresses and had been slightly warped before the period of fracturing had occurred. In the deeper parts of the section near the eastern edge of the block, Lake Valley (Mississippian) limestone and Percha (Devonian) shale may be present in the creek beds. This same relationship of gentle folding prior to faulting can be seen in several other parts of the Black Range, though not always so clearly and conclusively as in Palomas Canyon.

ORE DEPOSITS

The ore deposits of the Black Range consist of (a) vein deposits in eruptive rocks and (b) replacement deposits in limestone. The vein deposits are principally in andesite, and the ores are gold-silver, gold-silver-copper, copper-silver, and lead-copper-silver ores. Some veins of this type extend into the limestone underneath or adjacent to mineralized blocks of andesite. In places along them contact-metamorphic minerals such as garnet, epidote, calcite, hedenbergite, etc., replace the limestone of the walls, while the economic minerals consist of chalcopyrite, galena, sphalerite and pyrite, and varying amounts of gold and silver. There are also a few veins in the rhyolite, these being fissure fillings in which the gangue minerals are quartz and calcite, the quartz often of the amethystine variety, and the economic minerals consisting of gold, gold-silver, gold-silver tellurides, and gold- and silver-bearing sulphides. The second type of deposit is a replacement, either in fissure or blanket form, in the limestone, with lead-silver, silver-lead-manganese, and silver-lead-zinc mineralization.

Typical vein deposits in eruptive rocks are found in the Chloride district and the area to the north as far as the county line. South of Chloride several of the veins may be traced through the andesite into limestone, and in places in the limestone, as at the Midnight mine, contact metamorphism has taken place. Still farther south the veins are again in andesite, as at the Bald Eagle mine, where they contain lead, zinc and silver minerals. At Hermosa, Kingston, Tierra Blanca and Carpenter, most of the mineralization is of the replacement type, occurring along fractures and as blankets, and consisting of the minerals of lead, silver, manganese and zinc in varying proportions. At the Gray Eagle mine at the southern end of the Kingston district, and at the Lookout mine in the Tierra Blanca district, the ores, which are associated with rhyolite, occur as veins along the contacts of the dikes and the sediments. At the Gray Eagle mine, where silver was the chief metal and copper and gold were of moderate importance, the mineralization was clearly associated with the rhyolitic extrusions. At the Lookout mine, native gold associated with the silver telluride, hessite, and possibly with the gold-silver telluride, calaverite, is found in pockets and stringers along the tops of small folds in close association with a rhyolite dike that expands locally into a small sill between the beds. (See figure 7.)

The workings throughout the region are shallow, no shaft reaching a vertical depth greater than 500 feet, and several adit tunnels reach a similar vertical depth, with lengths of 1,700 feet at the Silver Monument mine in the Chloride district, and of about 2,000 feet at the Lady Franklin mine in the Kingston district. The water level throughout the region varies between 50 and 400 feet from the surface. Little or no prospecting below water level has been done, and at only a very few places have even the main shafts or tunnels penetrated below this level. In the oxidized zone in the various workings, native gold, cerargyrite, cerusite, anglesite, copper carbonates and oxides, and manganese oxides occur. At and near water level native silver, secondary sulfides of copper, silver and lead, and perhaps some secondary gold are found in scattered grains or in concentrated bodies. The primary sulfide ores contain pyrite, chalcopyrite, bornite, tetrahedrite, argentite, galena and sphalerite. Tellurides occur in places, and rhodochrosite is a common gangue mineral. These zones are not sharply differentiated, and in many places primary minerals are unaltered at the surface, while in others, the oxides extend along water courses to the greatest depth explored. In general the zone of secondary enrichment is not sharply defined, the secondary minerals being scattered throughout the veins as residual specks within the oxidized minerals or as thin films coating the primary minerals. These minerals are slightly more abundant near water level. Although insufficient work has been done on the lower levels in the various districts in the Black Range to prove the point definitely, it has been repeatedly noted that the grade of the primary ore is lower than in either the oxidized or the enriched zone, and in the past this lowered metal content has made mining on the deeper levels unattractive. With improved methods of mining and milling and cheaper transportation, it should be possible to reopen some of these older mines and work them at a profit.

HISTORY AND PRODUCTION

Interesting early history of mining in the Black Range is given in Professional Paper 68 of the United States Geological Survey, "The Ore Deposits of New Mexico." Quoting from this report:

> According to F. A. Jones'[29] the discovery of ore in this region is attributed to Harry Pye, a driver in the United States Army, who in 1879, while transporting military supplies, found a piece of float in the canyon near the present site of the Chloride post-office which when assayed was found to carry high values in silver. Later, having fulfilled his freight contract with the Government, Pye with some friends located what is known as the Pye lode. From the character of the silver ore the new camp was named Chloride, and shortly afterwards, in 1880 and 1881, with the incursion of the main body of prospectors, •Fairview was started a few miles to the northeast.
>
> During the early eighties the Apache Indians were committing depredations throughout this western New Mexico country, and in 1881 several prospectors were killed in the Apache district, among them Pye, the discoverer of the district.

On hearing of the Pye discovery, [30] J. M. Smith located the present site of the town of Chloride as a ranch, but he soon converted the ground to a townsite. The important period in the life of the Chloride district was from 1882 to 1893. During this period a large number of prospectors were in the hills searching for pockets of silver chloride along the outcrops of the numerous quartz veins. They mined and shipped from 2 to 30 tons of high-grade silver ore from each of these pockets, which of necessity must have assayed between 150 and 200 ounces of silver per ton to be profitable. The ore was packed out of the hills on the backs of burros, and from Chloride and the other towns in the region it was shipped by mule or bull teams to the smelter at

[29] Jones, F. A., New Mexico mines and minerals, p. 99,

[30] 1904. 3° Conversations with Ed James of Chloride, N. Mex.

Socorro, N. Mex., or to the Argo smelter in Denver, Colo.

A local smelter was erected in 1895-1896, but it ran only a short time. It was designed to treat custom ores too low-grade to ship, but the cost of bringing in fuel was as much as shipping the ore out, and the project was doomed from the first. In addition, the outside smelters at once lowered their treatment charges, and after smelting 300 to 400 tons, from which were produced lead bars and copper matte, the plant was shut down. A second smelter was built south of Fairview, which operated for a short time on ores from the Sierra Cuchillo and from the northern part of the Black Range, but it apparently fared no better than did the one at Chloride.

In rapid succession small hamlets sprang up at the scenes of the various discoveries in the region. They thrived and hummed with activity for a season, but the original buildings are standing only in Chloride and Fairview. Among the towns which disappeared many years ago are Grafton and Roundyville, founded in 1881. Robinson, founded in 1885 and named after a vice-president of the Atchison, Topeka & Santa Fe railroad, is said to have been located as the terminal of a proposed branch line from Engle, a survey for which was actually made. The railroad failed to materialize, and in a short time all buildings and activity had been transferred to Chloride or Fairview. Phillipsburg in the Black Range district near the north county line, and Fluorine just on or over the county line, which date back to 1900 and 1909, were never important centers of activity. In 1931-1933 some interest was revived in all of these camps, including sampling and some actual mining operations.

The original discovery in the Hermosa district is said to have been made in 1879 by Harry W. Elliott, who located two claims there and soon after went to Granite Gap on business. On his return a few weeks later, he found that his claims had been jumped by two prospectors, who were so plausible and congenial that he gave them a quitclaim deed to the property and went on to Kingston, there in a short while to find the Brush Heap mine, in which he made a small fortune. The prospectors remained at Hermosa, and in a short time produced ore worth about $60,000 in silver. A prospector from Leadville, Colo., named Miller appears to have made the first location on what is now the Palomas Chief, one mile down the canyon from the town. Shortly after, other locators settled in Palomas Canyon on the Albatross, Eagle, Embolite, Pelican, Vulture and other claims, and thereafter the activity in the region centered around the town of Palomas in the canyon of that name, while Hermosa, a mile to the west and in a much more pleasant and open location, ceased to grow. When silver decreased in value, Hermosa and Palomas both declined. In 1933 Hermosa was only one of the headquarters of the Ladder ranch, and few of the original buildings remained at Palomas.

Quoting again from "The Ore Deposits of New Mexico" :

According to F. A. Jones, [31] the discovery of silver at Kingston was made in 1880 by a party of prospectors. The two first locations were the Iron King and the Empire. In 1881 the area along the east slope of the mountains from Kingston to Grafton, embracing a belt 50 miles long from north to south and 20 miles wide from east to west, was organized into one mining district called the Black Range district. In this area were a number of mining camps and out of it several districts have been formed.

Named from north to south, the districts into which this old Black Range mining district has been from time to time subdivided, are: The Black Range mining district, which extends from north of the Sierra County line to Bear Creek near the old abandoned town of Robinson; the Apache mining district extending from Bear Creek south to Monument Creek 5 miles south of the town of Chloride ; the Palomas mining district, embracing all territory south of Monument Creek, including Hermosa, as far as North Percha Creek, 6 miles north of Kingston; the Black Range mining district, the second division in the region to bear this name, including the Kingston area from North Percha Creek to South Percha Creek, 3 miles south of the town. The Tierra Blanca district on the east side of the range, and the Carpenter district on the west slope extend the mining region several miles farther to the south.

Production from the entire region has amounted to about $9,080,000 as shown by the following table.

Production from the Black Range Mining Districts

District	Production to 1904	Production, 1904-1931	Total Production
Chloride Region	$ 950,000	$ 50,000	$1,000,000
Hermosa	1,250,000	250,000	1,500,000
Kingston	6,250,000	100,000	6,350,000
Tierra Blanca	5,000	215,000	220,000
Carpenter	5,000	5,000	10,000
	$8,460,000	$620,000	$9,080,000

No estimate was made of the value of the various classes of ore shipped, as much of it was suit by prospectors in lots of a few sacks each from widely scattered workings, and no accurate records of it were available. F. A. Jones [32] has given the figures for production to 1904 for the more important camps in the region, but for the others the writer was dependent upon the estimate of those familiar with the early history of the camps. For the production after 1904, reliance was placed upon the ability of various residents of the district concerned to prorate the value of the county production and the records of shipments made, as listed in the annual Government reports in Mineral Resources of the United States.

[31] New Mexico mines and minerals, p. 94, 1904.

[32]x Op. cit.

TAYLOR CREEK TIN DEPOSITS

LOCATION AND AREA

The writer spent only parts of two days in the Taylor Creek district, and hence much of the information contained in this section was necessarily abstracted from the report by J. M. Hill[33] based on 10 days spent by him in the area. In the present report the map, figure 1, has been adapted from the one in Hill's report. This district is on the western slope of the Black Range, in the extreme northwest corner of Sierra County. Only about one-fourth of the district is within the county limits, the remainder being in Catron County to the north and west, as shown in figure 1. The district is 70 miles in an air line southwest of Magdalena in Socorro County, with which it is connected by the Beaverhead highway. Chloride, 24 miles away, can be reached by trail. There are no towns in the district, and all supplies are shipped in by auto from Magdalena.

GEOGRAPHY

The Taylor Creek district is on the high volcanic plateau of west-central New Mexico, commonly known as the Mogollon Plateau. The average altitude is about 7,400 feet, but Indian Peaks rise sharply to a maximum elevation of 8,328 feet to form a conspiCuous landmark. The drainage in the region is through Beaver Creek, which flows southward to the middle fork of the Gila River. The various feeders of Beaver Creek, as Railroad, Mule, Bear, Kennedy, Corduroy, Squaw, Taylor and Hoyt creeks, have all cut deep box canyons through the lava flows to a depth of 200 to 800 feet. Most of these canyons are dry except during wet seasons, but water can be obtained near the surface and in a few places in shallow pools in the stream beds.

GEOLOGY

Rhyolite, rhyolite tuff and basalt are the chief rocks exposed in the Taylor Creek district. The canyons are floored with recently deposited sand and gravel, and are as much as a mile wide in places. Lindgren [34] believes that the rhyolites in the region are of Middle Tertiary age, and the basalts of very late Tertiary or of Quaternary age. It is probable that the rhyolite of the Taylor Creek area corresponds in general to the lower rhyolite of the Mogollon district as described by Ferguson. [35] These rocks are described in some detail by Hill. The rhyolites are the oldest rocks exposed in the area and are at least 700 feet thick, the base of the series not being exposed. Flow lines are prominent and give an appearance of stratification. In all ex-

[33] Hill, J. M., The Taylor Creek tin deposits. New Mexico: U. S. Geol. Survey Bull. 725, PP. 347-359, 1922.

[34] Lindgren, Waldemar. op. cit. (U. S. G. S. Pro'. Pape m ?9.

[35] Ferguson, H. G., The geology and ore deposits of the Mogollon mining district. N. Mex.: U. S. Geol. Survey Bull. 715, pp. 171-204, 1927.

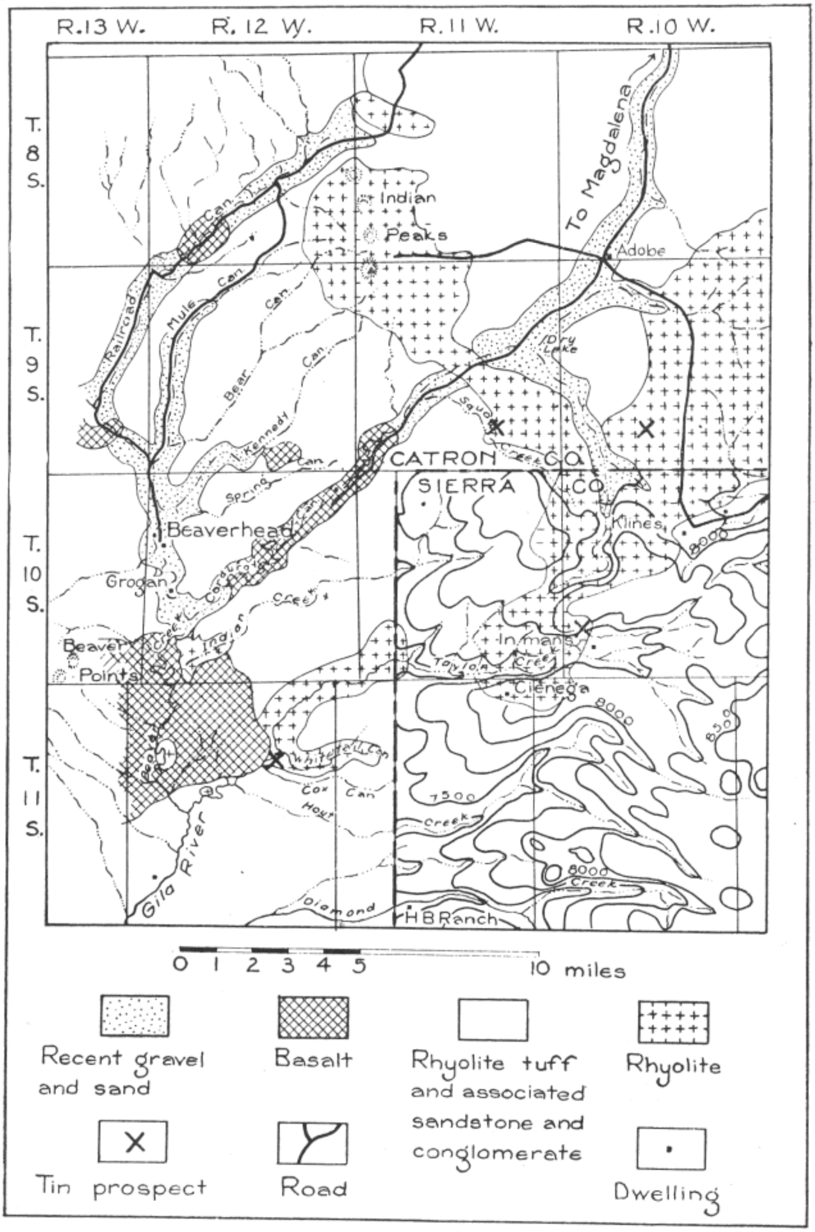

FIGURE 1.—Sketch map of the Taylor Creek tin district. (After J. M. Hill.)

posures this flow banding dips at angles which indicate considerable movement subsequent to the extrusion. Much erosion of the rhyolite is also indicated prior to the laying down of the later tuffs, agglomerates and sandstones. In some places beds of rhyolite stand vertically and are surrounded by horizontal beds of the tuffs and other rocks ; in other places the vertical beds of rhyolite are surrounded by tuff that is itself slightly dipping. In the caves of Taylor Creek, there is evidence that they were formed by the arching of successive rhyolite flows.

White, buff and red sandstones, white rhyolite tuff, and conglomerate composed of purplish rhyolite pebbles overlie the rhyolite flows and are visible over large areas on the surface and in the walls of the canyons.

Small areas of the region are covered by flows of basalt that lie either directly on rhyolite or upon the later tuff series. This rock is a black olivine basalt, which in some exposures is dense and in others vesicular. The material is largely glassy, although generally a few crystals of long, slender plagioclase and other minerals may be seen.

STRUCTURAL RELATIONS

There was apparently much folding and faulting of the rhyolites prior to the deposition of the tuff and sandstone. From Indian Peaks in a south-southeast direction the rhyolite forms a compressed fold about a mile wide, which can apparently be traced as far as the Inman ranch in the southeast corner of the district. In general the tuffs and related rocks are essentially horizontal and have not been disturbed to any considerable extent, except along the flanks of the folded rhyolite, where some movement subsequent to their deposition has taken place along the axis of the fold. The tuff series was deeply eroded before the basalts were extruded, along lines that are parallel to the courses of the present streams in the area. When the basalt was extruded it completely filled a deep canyon along the present Beaver Canyon and sent tongues up the old canyons now known as Railroad, Kennedy, and Corduroy canyons. In places it spilled out over the mesas in thin flows, as between Indian and Taylor creeks. No folding or faulting later than the extrusion of the basalts is known to have occurred.

ORE DEPOSITS

Cassiterite, accompanied by specular hematite, occurs in veinlets in the soft, altered rhyolite at several localities in the district, particularly in the belt of folding which extends between Indian Peaks and Inman's ranch. Another area is in Taylor and Whitetail creeks, in which over 500 feet of older rhyolite and younger tuff and sandstone are visible in the walls of the canyons. The rhyolite is cut by a network of narrow nonpersistent fractures in all of the exposures noted. Where the fracturing is most intense the rhyolite has been kaolinized to a soft white rock. Immediately adjoining the fractures in some places, there are narrow zones in which the white rock has been colored purplish red by iron. Along some of these fractures a mixture of cassiterite and hematite has been found. In numerous specimens gathered by the writer the order of mineralization seems to have been, first, hematite in brilliant black plates and in massive form, followed by a mixture of cassiterite and hematite, and finally scattered plates of hematite over the surface of the earlier minerals. In some places chalcedony has followed the last stage of hematite and forms a thin bluish-white film over the surface of the earlier minerals. The cassiterite is mostly in honey-colored, dark brown or black dense botryoidal masses with colloidal characteristics, but in many places brilliant red crystals of the tin oxide occur in the veins. The hematite is chiefly brilliant black plates which frequently occur in clusters on the vein wall, but in part it is botryoidal. The mineralized fractures are not as a rule completely filled, the coatings on the walls ranging from a sixteenth to an eighth of an inch in thickness. Rarely a fracture as much as an inch in width is almost entirely filled with the mixture of cassiterite and hematite, but such bunches are always small and do not extend far in any direction. Some nuggets of stream tin would indicate that there are a few fractures up to 6 inches in width, as nodular masses of cassiterite evidently built out from one wall to a thickness of 3 inches, have been seen.

Alteration of the rhyolite rarely extends for more than a foot on either side of an individual fracture. Where many closely spaced fractures exist, there may be a greater amount of alteration and mineralization. The altered rhyolite consists essentially of kaolin, which has formed largely from the groundmass of the original rock, and residual quartz. The feldspar phenocrysts in some places have been entirely altered, but at most places the alteration has not been completed and their outlines have been preserved. Next to the fractures the altered rhyolite has become porous for as much as an inch, and is stained a purplish-red color. According to Hill, [70] the material of this character seen under the microscope consists of grains of residual quartz, remnants of feldspar, iron-stained kaolin, small flakes of hematite and cassiterite, and a yellowish-green chlorite. Silicification is absent from practically all of the rocks in the vicinity of the tin-bearing fissures. No sulfide minerals and no topaz, tourmaline, or other fluorine- or boron-bearing minerals were noted in the Taylor Creek deposits.

It is believed by Hill that the fracturing of the rhyolite was caused in part by strains set up in cooling and in part by movements subsequent to the extrusion. The development work shows that fracturing and alteration extend to a depth of 300

[70] Hill, J. M., op. cit. (U. S. G. S. Bull. 725), p. 355.

feet in the rhyolite, and the total depth may be considerably more. The mineralizing vapors or solutions that followed these fractures probably represent the last stage in the cooling of the rhyolite magma. They were apparently not very hot, carried no fluorine, boron or sulphur and very little silica, and were meagre in quantity and weak chemically, as shown by the small amount of wallrock alteration, lack of complete alteration of the feldspars to kaolin, the occurrence of isolated clusters of mineral attached to the walls of the fissures, and by the tendency toward the building of large crystal or botryoidal masses about a relatively few centers of crystallization.

Stream tin occurs in the gravels at various places in the district, principally in Hardcastle, Squaw, Corduroy, Beaver and Taylor creeks. These gravels vary from 50 to 250 feet in width and from 6 to about 15 feet in depth. Water is scarce in most of the canyons, and many large blocks of rhyolite and basalt, which are mixed throughout the gravels, would interfere with placer operations. Systematic sampling of these deposits has been done in but a few places, and it is not yet certain that enough tin •could be recovered from them to make the operation profitable. The admixture of so much hematite is a handicap, as it is hard to separate the two minerals, and a product containing less than 50 per cent tin is hard to market.

HISTORY AND PRODUCTION

Stream tin was discovered in the district in 1918 by J. N. Welch, while prospecting for gold along Taylor Creek. Assays of the heavy black sand he had collected showed no gold but gave returns of 30 per cent tin. Early in 1919 he made locations near the caves on Taylor Creek, and Moliter & Crumley also located nearby ground at about the same time. During the summer of 1919 the New Mexico Tin & Metals Co. of New York city took over these groups of claims, along with several other locations in the upper part of Taylor Creek. In 1919 F. P. Davis and A. D. McDonald located placer ground on lower Taylor Creek and on Squaw Creek, where a small area of rhyolite containing tin veinlets was also located. These men in 1920 found and located the placer and lode claims on Hardcastle Creek in the northeast part of the district. Prior to August, 1920, no prospecting had been done northwest of Corduroy Canyon, and very little had been done except near the mouth of Taylor Creek, on Squaw Creek, Hardcastle Creek, and near the McCarty ranch. Squaw Creek gravels had been tested in a systematic manner, and tests in other gulches had shown the presence of tin. In Taylor Creek, tests had reached only to water level, where there was a large underground flow of water along the valley. The development was confined to the more conspicuous deposits, but nowhere was sufficient work done to prove their commercial possibilities. In 1927, according to reports, five or six holes were drilled with a churn-drill rig to a maximum depth of 260 feet at Hardcastle Creek, north of Taylor Creek and northeast of Squaw Creek. The samples taken ranged in grade from zero to 2.0 per cent tin, with an average grade of about 0.15 per cent. It is also stated that at a later date one or more diamond-drill holes were drilled by other interests, but the results were essentially the same.

Production from the district has been limited to a few hundred pounds of specimens and crude concentrates, and this material has been used only for display or for testing.

DEVELOPMENT

Development in the district has been confined entirely to shallow working, which consists of open cuts, tunnels, pits and shafts. Most of these workings are close to the level of the canyon floors, but some are located along the tops of the cliffs in the rhyolite flow rock.

FUTURE POSSIBILITIES

The tin-bearing veinlets that have been exposed so far are all of small size, discontinuous and of small tin content. Should an area be found containing many closely spaced veinlets, with the cassiterite disseminated for short distances into the wall rock, a fairly large low-grade ore body might be developed. The separation of the cassiterite from hematite, however, might offer a serious handicap to efficient and cheap treatment.

There has not been a great deal of erosion to supply the gravels with tin. The gravels are limited to narrow channels of shallow depth, large boulders in the gravel will present an operating problem, and the development of sufficient water will be costly except in Taylor and lower Beaver creeks.

BLACK RANGE AND APACHE (CHLORIDE) DISTRICTS

LOCATION AND AREA

The Black Range and Apache (Chloride) districts include an area of nearly 350 square miles, extending from above the north boundary of Sierra County southward along the east slope of the Black Range for a distance of 24 miles to Monument Creek, 6 miles south of the town of Chloride. Plate IV is a general map of the district. The maximum width of the mineralized zone is 14 miles. The Black Range mining district continues northward into Catron County nearly 3 miles, while south of the line it terminates at Bear Creek, just north of the old town of Robinson, which is 8 miles south of the county line and 6 miles north of Chloride. At this point the Apache mining district begins and continues for 12 miles to Monument Creek. Fairview and Chloride are the principal towns in the region, being 37 and 40 miles respectively from Hot Springs, the nearest source of supplies. Magdalena, in Socorro County, 90 miles distant, may be reached over fair to good roads during dry weather. The nearest railroad shipping points are Engle, 53 miles from Chloride, and Hatch at a distance of 80 miles. The road to Hatch is much better than the road to Engle, and it probably is preferable when heavy loads of ore are being hauled, in spite of the greater distance.

GEOGRAPHY

The crest of the Black Range, which here is the Continental Divide, constitutes the west boundary of the district. Altitudes along the crest vary from 7,500 to 8,500 feet. The drainage is all carried eastward by tributaries of Cuchillo Creek, which empties into the Rio Grande just north of the town of Hot Springs.

GEOLOGY

SEDIMENTARY ROCKS

Paleozoic formations outcrop continuously along the eastern slope of the Black Range from the southern extremity of the Apache district to a point about opposite the old town of Robinson, where, in general conformity with the Black Range dome, they pitch below the average level of the terrane. A second outcrop of limestone, which is north and west of the main exposure and apparently the top of a long faulted block, extends from a point 3 miles south of the county line to a point a mile north of it. This block lies north of Turkey Creek, and within or adjacent to it are the Great Republic, Keystone and Minnehaha mines. One or two smaller patches of these rocks occur in the district at places where uplift of the tilted fault blocks has been pronounced.

The oldest sedimentary rocks exposed are of Magdalena (Pennsylvanian) age. These rocks outcrop along the western edge of the zone of sedimentary exposures, along the lower portions of some of the fault blocks, and in the isolated areas such as that to the northwest. These beds in general dip to the east, although faulting has so oriented some of the blocks that in small areas they are horizontal or have dips in any direction. Overlying the Magdalena formation is the Abo (Permian) sandstone, which appears at the surface along the eastern edge of the belt of sediments. These strata dip to the east in general conformity with the dip of the underlying Magdalena beds. One or two thin beds of gray limestone are interstratified with the red sandstones, and a yellow sandstone member is conspicuous in places and apparently a persistent feature. Some of the beds are shaly, grading into sandy shales and sandstones ; these may contain thin laminae of greenish-gray shale, or they may be spotted with circular blotches of the same color which vary from a fraction of an inch to several inches in diameter. Just north of Chloride red sandstone, in part gypsiferous, appears to overlie the more normal beds of the Abo formation in a small area, and these may be basal beds of the overlying Chupadera (Permian) formation.

Palomas gravel of Quaternary age abuts against the older sediments low down on the eastern slope of the range, and constitutes part of the bolson deposits that fill the valley to a width of 5 or 6 miles between the Black Range and the Sierra Cuchillo to the east.

EXTRUSIVE ROCKS

The following paragraphs, which give an excellent description of the extrusive andesites of the Black Range, are quoted from Gordon's description[37] of the Chloride district.

> A great thickness of andesite, consisting of flows, tuffs, and breccias, extends all along the top of the Black Range, and except where removed by erosion, reaches down into the valley, being there covered by the Palomas gravel. The higher ridges are capped usually by rhyolite and rhyolite tuffs, deposited evidently on the eroded surface of the andesite. The lower portions of the andesite where revealed by erosion along the bottom of the canyon above Chloride are altered to a grayish-green rock, but at the top of the range the rock is notably fresher and darker in appearance.
>
> The constituents of the altered andesite determinable under the microscope are plagioclase and augite in a groundmass composed mostly of calcite and chlorite, with some epidote and very little serpentine. There is usually a notable amount of magnetite, though it is in many places changed to pyrite. Veinlets composed of calcite, pyrite, epidote, and adularia are abundant.
>
> These propylitic andesites are characteristic of the Black Range region and have a large development along the eastern face of the range. The same alteration has affected the tuffs and breccias, which present a characteristic grayish-green mottled appearance on exposed surfaces and constitute vast deposits over the north end of the range.

A period of erosion intervened between the extrusion of the last of the andesites and the first of the rhyolites, as shown by the presence of rhyolite in the deep erosional channels cut into the andesite tuff west of Chloride, and by the presence of lenses of detrital matter here and there between the top of the andesite and the base of the rhyolite. The rhyolitic material consists largely of tuffs, though some breccia and flow rocks are present. The tuff is notably porphyritic, showing small fragments of crystals of orthoclase and larger phenocrysts of corroded and broken quartz, along with fragments of plagioclase (andesine) and a few of biotite. The groundmass for the most part is glassy, in places with spherulitic development, but here and there it is partly crystalline. In places the phenocrysts predominate over the groundmass, and the rock in hand specimens has a granular appearance. The rhyolite flows are less extensive on the east side of the range than are the andesites. As a result of faulting and stream erosion, rhyolite remains only as cappings on the ridges or as masses filling old depressions in the surface of the andesite.

Remnants of Quaternary basalt occur in the valley to the east of Chloride, this rock forming residual masses capping small buttes and mesas which have been carved out of the original bol-

[37] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 262.

son deposits of Palomas gravel by the later stream action of Cuchillo Creek and its tributaries.

INTRUSIVE ROCKS

Intrusive rocks are not definitely known to be present in the Chloride region. As explained in the section on the Sierra Cuchillo (see page 116), it is thought that the sill of monzonite, which is a prominent feature of that range, continues at least part way under the sediments and flows of the Chloride district, and that it was a part of the Cuchillo mass prior to the faulting that elevated the Sierra Cuchillo to its present elevation. The type of ore deposits in the area tends to bear out this opinion. It is not common to find large or continuous ore bodies that have emanated from a sill, and dikes are rare as offshoots from such intrusions. On the other hand, where some of the veins cut across limestone underlying the andesite, as at the Midnight mine, the limestone walls of the vein show evidence of contact-metamorphic action with the development of such minerals as garnet and epidote. These features suggest that the veins emanated from a mass of hot igneous rock at no great depth.

STRUCTURAL RELATIONS

Faulting has sliced the eastern flank of the Black Range arch or dome into a series of long, narrow blocks, which have in general been lowered with respect to one another from west to east. Cross faulting has divided these narrow strips into blocks of small and unequal dimensions, which have been elevated, lowered and tilted in irregular fashion. The eastward-flowing streams of the area are along those cross breaks for the most part, and they have cut steep gorges; which open out here and there into parks, where the cross break intersects one of the major north-south faults. Near the heads of the streams the flow rocks are thick, and the top of the range has no visible outcrops of sedimentary rocks. Where the faulting has been pronounced, however, erosion has also been deep, and here the various faulted blocks show a base of limestone or Permian "Red Beds," with or without a residual capping of andesite or rhyolite. In places still farther east, blocks have sunk to such an extent that the andesite or rhyolite lies at the level of the valley floor, adjacent to the overlapping Palomas gravels.

ORE DEPOSITS

The chief ore deposits of this area are fissure veins in the andesite. They are filled-fissure veins, with or without replacement of the wallrock. In the rhyolite is found some ore that is believed to be of later age than that in the andesite. Where the veins in andesite pass into limestone in depth, contact-metamorphic minerals are developed for a short distance into the limestone walls, and the ore is usually higher in copper and lower in gold and silver than the average for the district. There are two vein systems, one which trends north-south and the other nearly east-west. In the latter system a roughly radial pattern' is discernible, and in a broad way the character of the ore varies in the two systems. The veins of the north-south system are valuable chiefly for their gold and silver content, with copper occurring sparingly in places. The east-west or radial system, as exemplified in the Silver Monument vein, is valuable chiefly for its silver and copper content. Near Monument Creek, in the extreme southern part of the Apache district, the Bald Eagle group of claims contains vein deposits that are of the galena-sphalerite-pyrite type, with associated silver and gold and chalcopyrite locally present. Although included within the Chloride area, these veins appear to be much more closely associated with the type of ore found in the Hermosa district, 7 miles to the south.

The gold-silver veins in the district occur in a belt 2 to 3 miles wide that extends from the northern boundary of the county to Monument Creek on the south and follows approximately the contact of the limestone and andesite. This belt includes the greater part of the gold-bearing veins, most of which strike due north, although others in this system, such as the Apache and U. S. Treasury veins, strike northwest, and still others strike northeast. These veins have many features common to the epithermal or low-temperature type and range in width from 2 to 8 feet. They are single fissures filled with delicately banded and crustified vein matter, usually with a seam of gouge along one wall, or they are in sheared and broken zones with a seam of gouge usually following one wall of the vein, and the vein matter filling the irregular fractures and spaces in a mass of brecciated wallrock, which passes gradually into the solid ground of the other wall. These veins are persistent, and some of them, such as the Pye lode south of Hagen's Peak and the main or "Great Master" lode in the northern part of the district, may be traced continuously for several miles. The vein filling consists of banded quartz, calcite and locally barite, with which have been deposited pyrite associated with gold and silver, and locally chalcopyrite. Later quartz has filled fractures within the original vein filling and has in part replaced the original calcite. Most of the mines in the region have encountered sulfides at depths varying from 50 to 500 feet below surface, but the great bulk of the ore shipped has been free-milling oxidized ore. In the upper portion of the veins, silver chloride and free gold, and in places oxides and carbonates of copper, have been the valuable minerals. It is reported that native silver, argentite, and chalcocite have been found near water level. In the sulfide zone the ore is lower in metallic content, but within the ore shoots it is considered to be of good milling grade and is said to average $10 to $15 per ton. Ore shoots within the veins are irregular, and although they are 200 to 300 feet in vertical dimension, they are apt to be at short stoping length along the levels. (See footnote, page 59.)

The silver-copper ores occur generally to the west of the main mineralized belt described above and nearer the crest of the range. They are in veins that trend more to the east than those of the other system, although a much greater variation in strike is to be noted here. They are also less persistent than the gold-silver veins, ranging from half a mile to 1^{1}/0 miles in length. Many of them terminate against one of the main north-south faults of the range. This irregular system of veins is concentrated largely around the area which includes the Silver Monument mine at the head of Chloride Creek. It is thought that these veins have been localized over a deep-seated mass of intrusive rock, which in approaching the surface arched and fractured the overlying extrusive rocks and opened channels along which the mineralizing solutions were able to penetrate and deposit their load. They were formed under higher temperature conditions than the north-south system. A similar concentration and arrangement of veins occurs near Roundyville, and these also contain silver-copper ores. The veins carry but a small amount of quartz, being composed principally of bornite, and subordinate chalcopyrite, tetrahedrite and pyrite, which occupy shear zones in the andesite. The minerals have been deposited in these zones, partly as a filling of open fractures but principally as a replacement of the crushed rock along the sides of the fissures. The hanging wall is usually well defined, with fracturing and brecciating gradually diminishing into the footwall. Secondary enrichment of the silver and copper minerals has been of some importance locally, and although primary sulfides are found at surface in the ore shoots, there is a tendency toward a concentration of gold in the upper levels, and an increase of silver-copper content at distances of 200 to 500 feet from surface. At greater depths a somewhat lower grade primary ore prevails in the veins. The ore shoots do not persist for long distances on the levels, but are apt to continue for several hundred feet vertically. They pitch to the east at angles of about 45° as may be seen from the section of the Silver Monument mine, figure 5.

PRODUCTION

The figures on the production from this district can be distributed among the mines only in part, and data on total production from the area are not available locally. Mr. Ed James of Chloride very kindly aided the writer in compiling the accompanying tabulation which, although not complete, may be of interest as an indication of the size of the mines, the value of the ore produced, and the distribution of the mineralization in the district.

Approximate Production of the Apache-Black Range Mining Districts Near Chloride, 1880-1932

Area	Mines	Amount	Type of Ore
Fluorine	Miscellaneous prospects	Small	Gold-silver
Phillipsburg	Occidental Black Mt. (Minnehaha)	$25,000	Gold-silver
	Great Republic	25,000	
	Keystone	5,000	
	Miscellaneous prospects	5,000	
Grafton	Emporia	60,000	Gold-silver
	Ivanhoe	100,000	
	Alaska	Small	
	Miscellaneous prospects	40,000	
Bear, Dry and Mineral Creeks	Readjustor (Mahoning Group)	15,000	Silver-copper-gold
	Dreadnaught	75,000	
Chloride	Wall Street	Small	Gold-silver-copper
	White Mountain	15,000	
	U. S. Treasury	20,000	
	Colossal	75,000	
	Midnight	20,000	
	Silver Monument	415,000	Silver-copper
	New Era	15,000	
Pye Lode	Miscellaneous prospects	Small	Gold-silver
Monument Creek	Bald Eagle (Minnie)	30,000	Gold-silver
	Bald Eagle (lead-zinc)	Small	Lead-zinc-silver
Miscellaneous	(Includes "small" items above)	60,000	Mostly silver-gold
	Total	$1,000,000	

FLUORINE AREA

The Fluorine area is at the northern boundary of the county and in Catron County, the post office of Fluorine being on the Beaverhead highway just north of the county line. The district includes the isolated block of limestone that crops out through the extrusive rocks in this area. The limestone and the surrounding igneous rocks are cut by abundant quartz veins and stringers, some of which carry moderate amounts of gold and a little silver, but the metals seem to be irregularly distributed. In 1931 and 1932 some development work was done in this district. No important shipments have been made. In the autumn of 1933 it was rumored that several of the properties had changed hands and that a renewed activity was pending. The Elephant group of claims is located in this area.

PHILLIPSBURG AREA

The principal mines in the Phillipsburg area include the Occidental, Black Mountain (formerly called the Minnehaha), Great Republic and Keystone. Production from the Occidental and Black Mountain mines has been about $25,000, from the Great Republic about $25,000, from the Keystone $5,000 and small but unlisted amounts from other properties. These mines may have produced ore worth $60,000, which would include all small-lot shipments from the outlying prospects.

BLACK MOUNTAIN GROUP

The Black Mountain (Minnehaha) group of three claims was located in 1881, and is reported to have yielded a small amount of rich ore from a small ore shoot shortly after its discovery. In 1931, Silver City, N. Mex., people acquired the property, and after driving a short tunnel on a cross vein (the Bullion vein) and sinking a winze on it to a depth of 200 feet, from the bottom of which short drifts were run, the property was closed down. No shipments were made during this period. The mineralization consisted of irregular stringers of quartz traversing the fractured zone of the vein, and when the ore was hand sorted it assayed $30 per ton, principally in gold. The main north-south vein, locally called the Minnehaha, was not cut, but drifting along the Bullion cross break for about 200 feet would have encountered it. The old workings on this main vein are said to be caved. The camp is equipped with blacksmith and carpenter shops, a portable compressor, hoist, and bunk and cook houses. It is reported that the owners of this group also bought the Great Republic mine which adjoins the Black Mountain on the same vein system to the south.

GREAT REPUBLIC MINE

The Great Republic mine has been developed to the 400-foot level, but when visited all surface and underground workings were caved and inaccessible. The last work was done in 1923, when a 40-ton capacity tabling and flotation mill was erected. Sulfides were encountered at the 100-foot level, but above this, rich pockets of silver chloride were mined, and it is said that the finest specimens from the district came from a small pocket called the Jewelry Shop on the 175-foot level. A flat fault is said to cut the vein off below the 300-foot level, and it was not found on the 400-foot level. The ore occurs as stringers of quartz with pyrite, gold and silver, in a fractured zone of andesite breccia which has been much propylitized and impregnated with pyrite. It is said that the ore occurs in shoots within the vein, which is 2 to 10 feet wide, and that the mine contains 4,000 tons of this material blocked out, which assays $14 per ton. South of the mine about 1,200 feet, a northeast-striking fault has cut off the vein, and the southern portion of it has been moved 300 feet or more to the east. The northern segment of the vein ends against a block of Magdalena limestone. The vein appears to split between the Republic shaft and this fault, and it is said that the hanging-wall fracture carried mostly silver, while the footwall fracture was richer in gold. It is believed, however, that the footwall fracture carries a later mineralization than the other, which is associated with the period of the rhyolite extrusion.

Residual patches of rhyolite are abundant just to the east of the mine, and some of the rock on the dump is rhyolite, which was said to have come from a dike along the footwall fracture. No evidence of this dike could be found on surface. One carload of ore is reported to have been shipped in 1928.

KEYSTONE PROPERTY

The Keystone property is south of the Great Republic and on the main north-south vein of the district, but due to faulting the vein has been offset somewhat to the east of the line of strike of the Republic portion. It probably produced some high-grade ore from pockets near the surface, and it is said that a considerable quantity of ore is in place on the 100-foot level in a shoot tllat has a stope length of 150 feet. The value of this ore is said to be about $10 a ton, consisting of 2 ounces of silver and the remainder in gold. The property has passed through several ownerships in the course of its history, but is now owned by the U. S. Treasury Mining Co., which has headquarters in Chloride. Mr. Ed James is the manager. The mine has apparently not been actively worked since the early nineties.

GRAFTON AREA

Grafton was at one time a thriving little community with daily stage service to and from Fairview, but now only one or two log cabins and the ruins of a stamp mill and several old mine plants remain to mark its location. The mines described below were among the most important to be worked during the time that Grafton prospered, but many prospects long since forgotten contributed to the total production of this area.

EMPORIA MINE

The Emporia mine is developed by an old shaft sunk on the vein, which strikes north and dips 60° E. The shaft is said to be 120 feet deep, with drifts 150 feet long to the south and about 80 feet to the north. The walls of the vein are andesite breccia, and the fractured vein zone is said to reach a maximum width of 40 feet in one place. Good ore is said to have been mined in the south drift. The vein consists of a gouge-filled hanging-wall seam and two banded and crustified quartz veinlets up to 12 inches wide traversing a zone of brecciated andesite, which is partly silicified and grades into the unbroken footwall. Just above the old shaft, a recent prospect hole has been sunk on a quartz vein that is 20 inches wide and contains gold, silver and copper. This vein is apparently dipping toward the main vein and should connect with it about 50 feet below the surface.

IVANHOE MINE

The Ivanhoe mine is on a vein which strikes northeast and dips southeast, and which must cross the Emporia vein in a draw within 300 feet of the Emporia shaft, although the point of crossing has apparently never been definitely located. The shaft is

380 feet deep, according to report, and there are three levels with 600 feet of lateral workings. Considerable high-grade ore has been won from this mine, but it is said that the bottom level showed an extreme pinching of the vein, athough it could still be followed along its course. One nearly vertical ore shoot had a maximum stope length of over 100 feet. Both walls of the vein consist of andesite breccia. It is said that the first ore found in this mine assayed 17 to 25 ounces gold and over 100 ounces in silver to the ton and about 3$^1/2$ per cent copper. While the mine was yet in the early development stage it was sold to Robert G. Ingersoll, who appeared at the collar of the shaft one day with his engineer and at once completed a deal involving the payment of $60,000 on terms of $10,000 down and the balance in 30 days. The mine is reported to have produced' $100,000, but it never paid a dividend. The main shaft was sunk to a depth of 400 feet, using a hand windlass for hoisting. Lessees on the property are said to have secured much very high grade ore from time to time by close hand sorting. A recent shipment of a few tons of combined Ivanhoe-Emporia gold ore is said to have returned over $200 per ton net.

ALASKA GROUP

The Alaska group of claims is in the old town of Grafton. Over $150,000 is said to have been spent in the equipment and development of this property. A main shaft that was to have tapped the vein at 600 feet depth was started, and the surface plant, consisting of hoist, large boilers, stamps, and much accessory equipment was set up on expensive rock and concrete foundations. The shaft was sunk to '150 feet, and 'a crosscut was driven to the vein, which when cut, flooded the mine with water so rapidly that the miners barely escaped with their lives. Nothing has been done in this shaft since 1883. The property has gone under the names Alaska, Montezuma and Yankee Boy at various times in its history. No shipments other than small lots of high-grade ore from shallow surface workings have ever been made.

OTHER PROPERTIES

Other mines in the vicinity include the Gold Hill, Gold Coin, Little Granite (Mima) and many others. Much ore in small lots has been taken from these prospects from surface cuts and shallow underground workings. Hand sorting of the vein matter has been the rule, and the sorted product in most instances was shipped in sacks which were brought to the main freighting road on the backs of burros.

BEAR, DRY AND MINERAL CREEKS

This part of the district is tributary to the old but long since abandoned towns of Robinson and Roundyville. Such mines as the Readjustor in Rock Cliff Canyon and the Dreadnaught on Mineral Creek are among the better known properties. Some others are the Silver Glance, Mountain Chief, Climax and El Paso. Most of these have produced some silver-copper ore. The Dreadnaught mine is said to have produced ore from one shoot, which was 30 feet long and extended from the surface to a depth of 50 feet, and which ran 100 to 240 ounces silver and $5 in gold to the ton and 18 to 25 per cent copper. The ground here is said to be very hard, and hand-mining methods were costly.

CHLORIDE

The mines in the vicinity of Chloride Creek are a short distance west of the town, where the mineralized belt has been laid bare by the erosion of the main creek and its tributaries. Chloridei is located at the west border of the Palomas gravel, where it overlaps the andesite breccia and tuff or is faulted down against them. West of this belt a faulted block of Abo sandstone has been exposed, and the creek has cut a narrow winding canyon through it. West of the sandstone block is another composed of andesite tuff and breccia, and to the west the creek cuts across block after block of faulted beds, some of which have been elevated sufficiently to show the underlying Magdalena limestone, while others have been relatively lowered until only the upper flows of andesitic material are visible along the creek bed, surmounted by remnants of the later rhyolite tuffs and flows. Cross faulting has localized Chloride Creek, and from the western border of the block of Abo sandstone for a distance of 3 miles up the creek to the west, this fault is mineralized and is known as the Apache vein. It is a shear zone 3 to 5 feet wide with a strike of N. 40° W. and an average dip of nearly 80° SW. The zone is mineralized with small quartz stringers, which fill the main fissure along all fractures and extend out as stringers into the wall-rock. The primary ore minerals are chalcopyrite, argentite, gold and pyrite, and these have been altered to copper carbonates, silver chloride, free gold and limonite in the upper parts of the vein.

NANA MINE

The Nana mine on the Apache vein is on one of the Wall Street group of claims, and has been opened by a tunnel 280 feet long on the vein, which is cut off at the end by one of the main north-south faults of the region. The continuation of the Apache vein has never been sought here, but it is supposed to be offset to the south. The vein averages 3 to 4 feet in width, and for the full width it is said to assay from $4 to $13 per ton in low-grade shoots that may have stoping lengths along the tunnel of 20 feet or more. One high-grade pocket found at the surface assayed $168 per ton, and where it was encountered again in the tunnel, shipments averaged $60 per ton, according to reports.

WHITE MOUNTAIN GROUP

The White Mountain group of four claims is on the Apache vein, or on a vein closely paralleling it, to the southeast of the

Nana workings. The vein is in limestone from which the overlying flow rocks have been eroded. Copper appears to be the predominant metal, although gold and silver are reported. This vein, being at a lower level stratigraphically than those in andesite, shows evidence of contact-metamorphic action, with the development of garnet, epidote and coarse calcite in the wallrock.

U. S. TREASURY MINE

South of the Nana about two miles and at the head of an arroyo tributary to Chloride Creek from the south, is a group of

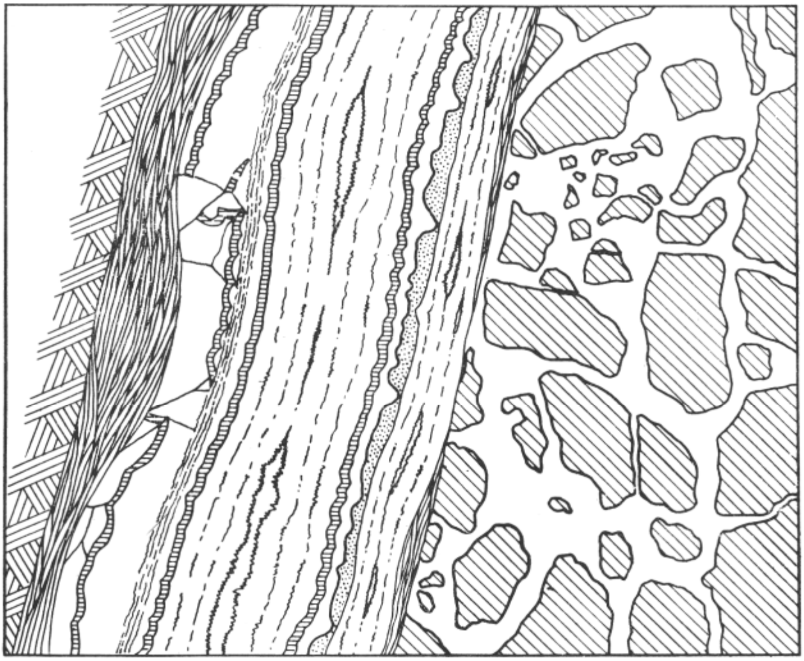

FIGURE 2.—Typical vein structure in the Chloride district. 1, Andesite wallrock; 2, Fault gouge; 3, Brecciated vein quartz; 4, Black mineralized quartz; 5, White banded vein quartz; 6, Silicified andesite; 7, Propylitized andesite; 8, Calcite breccia cement.

claims which includes the U. S. Treasury, Gray Eagle, Whit(Eagle and others, located on a strong vein striking N. 50° W and dipping 65° SW. The vein (see figure 2) consists of an ande site hanging wall, 1 to 12 inches of fault gouge, 6 to 18 inches of banded and crustified quartz, 6 to 18 inches of finely crushed an desite breccia, and 3 to 20 feet of coarsely fractured andesit(which fades gradually into a solid andesite footwall. The frac tured andesite next to the quartz vein is cemented in part will' calcite of probably an early stage, through which stringers of later quartz cut in all directions, but most of the material between the breccia fragments is finely crushed andesite with subordinate calcite, traversed by occasional irregular stringers of vein quartz.

Figure 3 is a composite level map of the workings of the U. S. Treasury shaft. The mine was filled with water to a point a short distance below the 200-foot level when visited, but above that it was partly open for inspection. The shaft is 400 feet

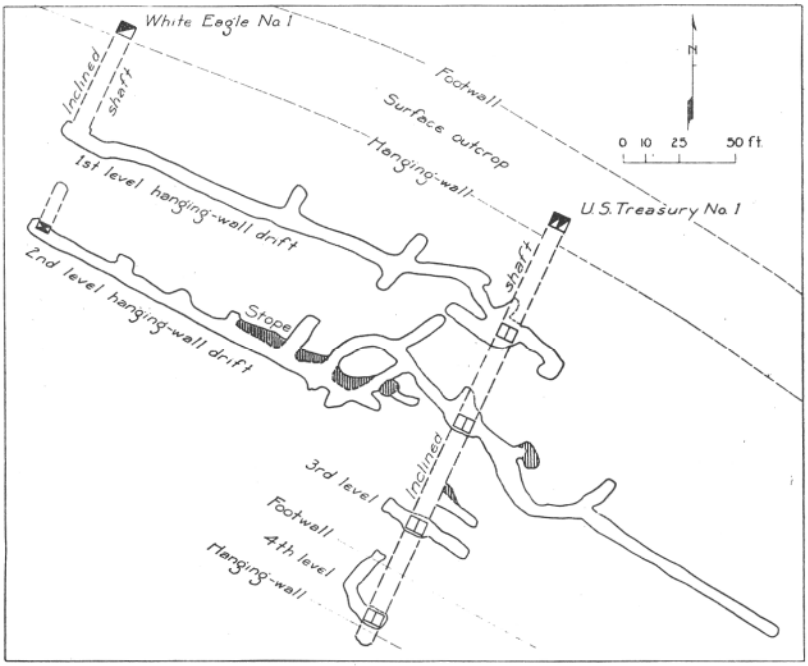

FIGURE 3.—Composite level map of the U. S. Treasury mine.

deep, following the vein down at its inclination of 65°. On all levels the vein is well developed and continuous, and at numerous places on the two upper levels are small open stapes from which shipments have been made in the past. The vein is from 4 to 6 feet wide in most places, but on the lower levels in the shaft it widens to at least 22 feet, and the hanging wall has not yet been determined. The mineralization is principally gold and silver, and the vein is said to average $10 to $16 per ton ; there is said to be a large tonnage of this ore partly developed. On the 400-foot level, where the ore widens, samples taken across the exposed width of the vein (22 feet) are said to average 0.42 ounces gold and 9.8 ounces silver to the ton. There is no development work on this level that would prove a tonnage of ore. On the 100-foot level the writer saw numerous stringers and bunches of vein matter in an oxidized zone of the vein that was said to assay well in silver and gold ; the gold is in the free state, and the silver occurs as the chloride and bromide. The material hand sorted from this vein during the early operations was said to assay as high as 2,200 ounces silver and up to 100 ounces of gold a ton. Many small specimens may be seen on the dump, where sorting was done, which contain specks of free gold and crusts and fillings of silver chloride associated with small amounts of malachite and azurite in a matrix of quartz and massive limonite. According to Gordon, [38] who saw the lower levels of this mine, "The U .S. Treasury vein evidently carries a large amount of low-grade milling ore and under proper management might develop into a paying property."

To the southeast, the Treasury vein leaves the andesite and enters Magdalena limestone, crossing a north-south contact between these two rocks. On the St. Cloud group, ore has been shipped that contains more copper, associated with the gold and silver, than does the ore from, the same vein where it traverses the andesite. The vein here is nearly 20 feet wide and is characterized by a surface outcrop of highly silicified and partly iron stained limestone. The last shipment of ore from the St. Cloud workings issaid to have been made in 1893.

COLOSSAL AND MIDNIGHT MINES

The Colossal and Midnight mines are on the Treasury vein south and east of the St. Cloud workings. The Colossal is reported by Mr. Ed James to have produced $75,000 in gold-silver ores that in some shipments carried as high as 10 per cent copper. At the Midnight mine the vein in the limestone is conspicuous for the presence of contact-metamorphic minerals, including garnet, epidote and calcite, in the wallrock, and for the abundance of copper staining in the upper part of the vein. A mill was erected on this property, but it was in poor condition at the time of the writer's visit. The last shipment of concentrate was made in 1925. In that year it is said that between 4,000 and 5,000 tons of shipping and concentrating ore was taken from the mine. In the past few years the mine workings have caved badly and are mostly inaccessible.

Mills were erected and operated in this part of the district on the U. S. Treasury and Midnight properties, and several smaller plants operated from time to time. Only the Treasury and Midnight mills remained standing in 1932, with part of the milling machinery still in place. On the whole, the mines appear to have been systematically developed, and the plants are of appropriate size in view of the prospects for ore and show evidence of good workmanship and economical construction methods.

[38] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 265.

PYE LODE

The Pye lode is supposed to be the original location of Harry Pye, the discoverer of the district. The lode extends southward from Hagen's Peak, which is about a mile south of the Treasury mine. Radiating from the north, east and south sides of this peak are a number of other veins quite similar to the Pye lode. Near the peak the lode contains some gold and silver associated with pyrite, and to the south for several miles occasional pockets of ore have been found, but on the whole the vein has not proved as productive as some of the others in the district. One reason for this perhaps is that the vein is so isolated that only extremely high grade ore paid to mine, so that nowhere has much more than surface prospecting been done on it.

BALD EAGLE MINE

The Bald Eagle property is located in the extreme southern end of the Apache mining district, and is on both the north and south sides of Monument Creek. North of the creek considerable stoping has been done close to the surface in a prominent quartz vein that outcrops boldly along the top of a low hill. In these stopes, known as the Minnie (Bald Eagle No. 4 and No. 4 Extension) stopes, high-grade ore carrying chloride and bromide of silver with free gold and carbonates of copper has been mined in important amounts, and these stopes are still standing open from the surface down to a moderate depth. South of these stopes the Sheep Creek fault, one of the transverse faults of the district, has offset and shattered the vein, so that its trend is lost in crossing the canyon. To the south, however, prominent veins continue with southeast and with south trends in the andesite. The southerly veins are characterized by a fair amount of quartz gangue and a slight tendency toward higher gold and silver content than in the southeasterly trending veins. In both systems the principal minerals are galena, some sphalerite and pyrite, occasional chalcoyprite, and associated gold and silver. In the upper zones, cerusite, anglesite, azurite, malachite and silver chloride are present in limonite-stained masses of vein rock. In general the hanging-wall of the veins is well defined, but the body of the vein is a brecciated mass of andesite in which filling and replacement by silica and the ore minerals has occurred. The crushed zone fades out gradually, and the footwall is not well defined in the veins of southeast trend, but perhaps a little more in evidence in the north-south veins. Calcite is a more prominent gangue mineral in the southeast-trending veins.

The ores carry from 6 to 45 per cent lead, and from 3 to 8 per cent zinc, while silver varies from one to several ounces and gold from 0.02 to 0.20 ounce per ton. The veins are of good width, averaging 4 to 7 feet, with a high-grade streak from 18 inches to $2^1/_2$ feet.

The mine has been opened by about 400 feet of shaft work, 100 feet of drifting, and over 250 feet of open-cut and tunnel work near the surface. No ore has been blocked out, and there is not sufficient work to determine the value of the property in depth, but practically all work done to date has exposed ore that is of commercial grade. Besides several shipments of lead ore made in the past, it is estimated that 300 tons of ore assaying better than 10 per cent lead is stored on the surface. The ores can be mined from this property under proper conditions at about $3 per ton, and can be concentrated after relatively coarse grinding to save 90 per cent of the metals at a stated cost of $1 to $2 per ton milled. The ratio of concentration is estimated to be about 7 into 1, and it is said that there is probably sufficient water, which will require some development, to keep a 100-ton concentrating plant in steady operation.

SILVER MONUMENT MINE AND VICINITY

The Silver Monument mine is about 10 miles west of Chloride at the head of Chloride Creek. The road from Chloride is in the rocky bed of the creek for the entire distance and requires extensive repairs after each severe storm before it is passable for even light cars. There are other claims in the district, among them the Black Night, which is reported to have more argentite and less bornite in the ore than the Silver Monument, but which otherwise is quite similar. Very little development work has been done at any of these outlying properties.

The Silver Monument mine is located in a fracture zone in andesite which strikes almost due east and dips to the north at about 70°. The vein is from 2 to 8 feet wide. The elevation of the top of the old shaft, which is said to be 350 feet below the crest of the range, is given as 7,650 feet. Along the walls of the veins the andesite has been much propylitized, with later bleaching and alteration due to the action of primary mineralizing solutions and later descending surface waters. The vein consists of a well-defined hanging-wall, along which is a seam of gouge 2 inches to 2 feet thick. The mass of the vein consists of brecciated and altered andesite that merges gradually and indefinitely into the solid andesite footwall. The ore minerals are bornite and chalcopyrite, with which are associated tetrahedrite and argentite. In the upper portions of the vein native silver, cerargyrite, azurite and malachite occur in small to moderate quantities. At greater depth chalcocite, covellite and argentite enrich the primary ore in a zone of indefinite extent, and below the 400-foot level an increasing amount of pyrite appears in the few openings that have been made into the vein. Figure 4 is a composite plan and figure 5 a longitudinal section of the Silver Monument workings. It is clear from the section that the ore occurs in three shoots pitching steeply to the east. The surface outcrops indicate the possible existence of at least three other shoots, upon two of which no

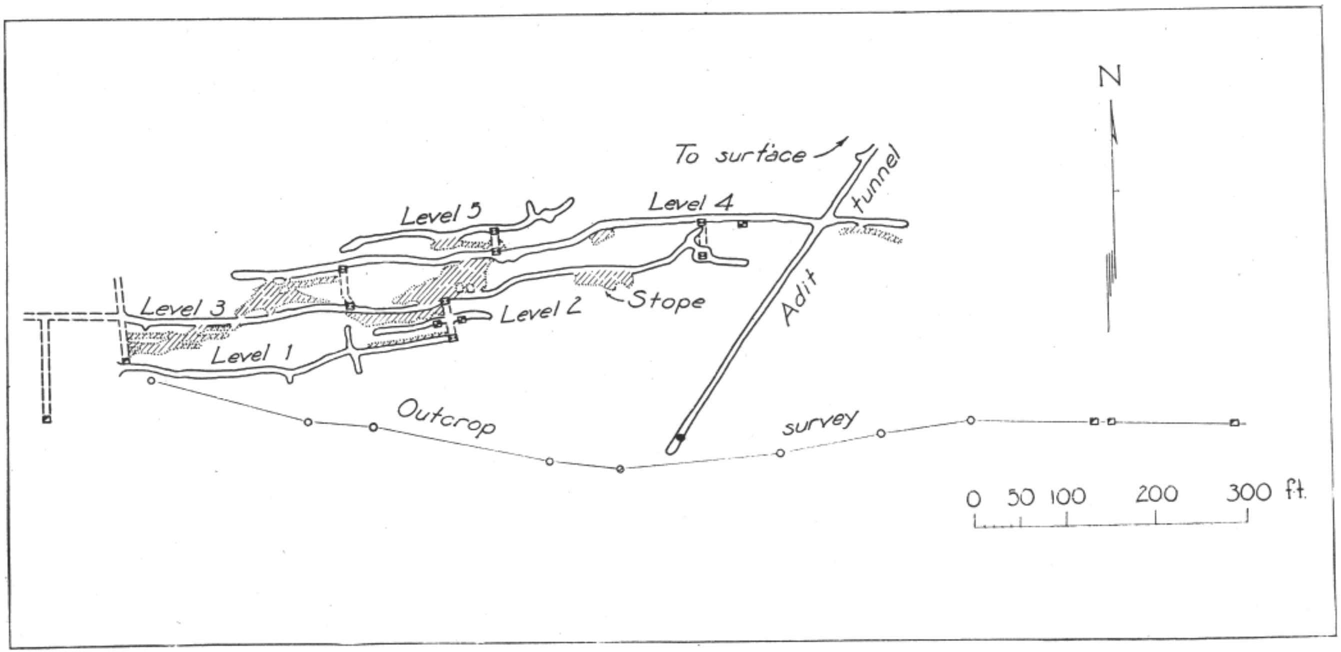

FIGURE 4.—Composite level map of the Silver Monument mine.

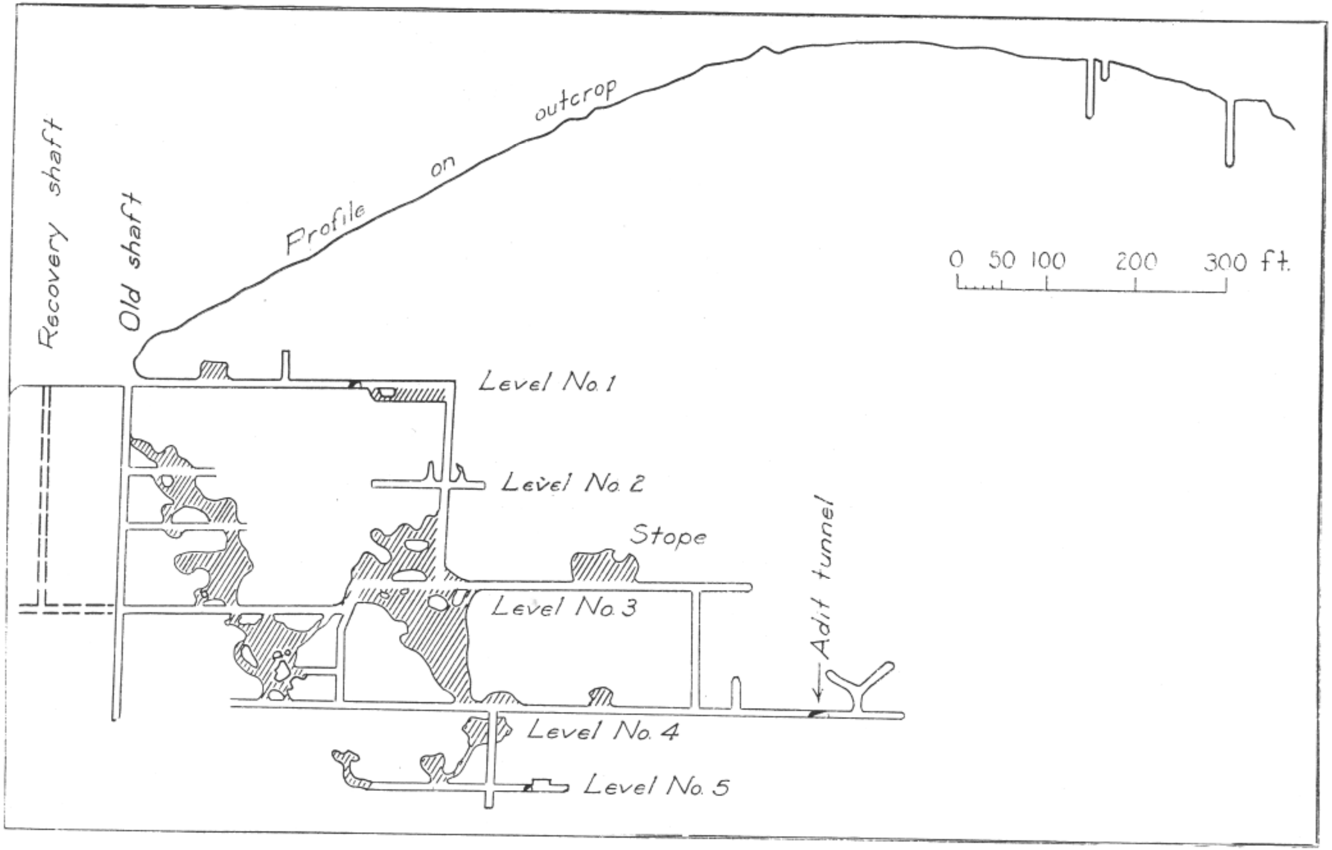

FIGURE 5.—Longitudinal section along vein in Silver Monument mine. Looking north.

work has been done, so that the size and the depth to which these might extend are not predictable.

The workings consist of an old shaft, which extended to the 400-foot level and connected with the various other levels. This has caved, as has a recovery shaft that was sunk alongside, and which connected with the third level. At a later date an adit tunnel, which was driven S. 35° W. for 1,500 feet, cut the vein near the east end of the mine workings and thereafter served as the main working tunnel, all ore being dropped by gravity through chutes.

The property is equipped with machinery for economical mining and with a , modern mill of 100 tons daily capacity, although it does not appear that the ore reserves in the mine at any time warranted the construction of a plant of this size. Apparently the prospects of finding fairly large bodies of moderate to high grade ore in this mine are still good, but it is only by economical operation and the strictest attention to details that these may be made to pay, due to the isolated locality and the difficulty of access.

The New Era mine is on the south side of Chloride Creek, about 1 1/2 miles from the Silver Monument mine. The writer did not visit this mine, which is reported to be under water at 30 feet below the collar of the shaft. It is said to contain fairly large bodies of ore that as shipped contained 17 per cent copper and from 161 to 256 ounces of silver a ton. The vein parallels the Silver Monument vein and is said to average 5 feet in width, and to contain quite similar mineralization. The difficulty en: countered in handling the water was the cause of shutting down. The mine is said to be developed by a 350-foot shaft, having levels at 90, 140, 2U0 and 350 feet.

PALOMAS (HERMOSA) DISTRICT

LOCATION AND AREA

The Palomas district is on the east slope of the Black Range and extends from the southern limit of the Apache District just south of Monument Creek to the northern limit of the Black Range (Kingston) district, which commences at the north fork of Percha creek. Various showings of ore have been discovered throughout the length of the district, and some development work has been done in spite of the difficulty of access to the region. Hermosa is situated on Palomas Creek about 15 miles south of Chloride and about 45 miles west of Engle on the Atchison, Topeka & Santa Fe railway. Good roads extend from Engle, via Elephant Butte dam, and from Hot Springs to the little town of Cuchillo, beyond which travel is by mountain road which for nearly 10 miles is in the bed of Palomas Creek. The main areas of mineralization are at two places in the district, one just north of the town along the trail that leads to Chloride, and the other at the old settlement of Palomas Camp, about a mile east of Hermosa on the north bank of Palomas Creek.

GEOGRAPHY

The altitude at Hermosa is 7,200 feet. Palomas Creek and its tributaries have cut deep canyons in the sedimentary rocks of the region, and just east of the town the main stream has formed cliffs which rise almost vertically to a height of 1,000 feet above the stream bed. The tributaries in general flow north or south, following along the lines of the regional faults that have sliced the east flank of the range into long narrow blocks. Erosion by these streams has formed a cuesta-like topography in the easterly dipping overlying formations along the east bank, while the west bank is more apt to be an easterly dip-slope of the underlying formation.

GEOLOGY

Gordon[39] describes the general geology of the Hermosa region as follows :

Hermosa lies on the western boundary of a belt of sedimentary rocks which have been exposed by the removal of extensive deposits of lavas that once covered the region. On the west are volcanic rocks, chiefly andesite, with scattered patches and embayments of limestone. Igneous rocks, both intrusive and eruptive, occur also within the sedimentary belt. At Hermosa the area of sedimentary rocks is 3 or 4 miles wide. About 2 miles below Palomas camp these beds are terminated abruptly by the Palomas gravel, which abuts directly against the cliff formed by the erosion of the limestone. Along the sides of the valley here the Palomas gravel has been deeply trenched, exposing a thickness of approximately 800 to 900 feet. North of Palomas Creek are several buttes capped with basalt. [40]

At Palomas camp the walls of the canyon are about a thousand feet in height and are composed in large part of massively bedded limestone. In the lower half some shale and quartzite beds alternate with the limestones. At the base of the escarpment is a thick-bedded fine-grained grayish-blue limestone overlain by dark carbonaceous shales. The ores at this camp occur in pockets and shoots in the limestone below the shale. Fossils obtained from the limestone were identified by George H. Girty as forms occurring near the base of the Pennsylvanian series. From this it would appear that the base of the section at Hermosa is to be correlated with the Sandia formation at Magdalena and farther north, indicating a change in the character of the sedimentation toward the south whereby the shales and quartzites give place to limestones.

The strata dip from 20° to 30° N. 62° E. At Palomas camp the general slope of the beds is interrupted by a low arch which pitches to the north. At this point two systems of faults occur, the major faults running N. 38° W., and a series of lesser breaks trending approximately with the dip. One of these, the "Kendall break," contains one of the principal ore deposits of the district.

About 2 miles above Palomas camp, toward the west, the limestone is cut off by andesite tuff. Along the boundary occurs a remnant of an earlier flow of andesite about 600 feet wide, which runs in a nearly north-south direction. On the west side of the mass the surface rock is andesite tuff, showing well-marked stratification planes which bend up abruptly on meeting the old ridge. The south fork of the river on which the town is situated

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[39] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), pp. 266-267.

[40] Just east of the limestone-gravel contact in Palomas Creek, dikes of basaltic rock may be seen, which are perhaps the feeders for the flow remnants noted by Gordon.

cuts through the mass just north of the hotel. North of the stream the greater hardness of the andesite causes it to stand out as a ridge, which decreases in height toward the north and finally disappears under the covering of andesite tuff. Between this ridge of andesite and the limestone to the east is a depression underlain by the Palomas gravel, which here evidently constitutes a filling in a previously eroded valley. The mines of the Antelope group are located in the limestone near the contact with the andesite.

STRUCTURAL RELATIONS

Aside from the regional faults which have sliced the range into long, narrow blocks over such long distances, three major faults having important relations to the ore deposits occur in the limestone section of the Hermosa district. These are named, from east to west, the Palomas Chief, Pelican and Bullfrog. The Palomas Chief and Bullfrog faults are parallel and strike N. 13° E. The Pelican fault, which strikes N. 40° W., cuts the Palomas Chief fault on the south side of the canyon and the Bullfrog fault about half a mile north of the canyon and about five-eighths of a mile to the west of the first intersection. As seen on the sections, figure 6, numerous other faults trend in the same general directons as these three principal breaks. The heavy lines A-B indicate in a general manner the amount of folding and its location in the sedimentary beds prior to the occurrence of faulting. In the lower section of figure 6 a series of eastward-trending breaks, which have also displaced the beds relatively to one another, parallels the course of Palomas Creek.

ORE DEPOSITS

The ore deposits occur principally in the lower part of the Magdalena limestone (Sandia formation) under the bed of dark carbonaceous shale described by Gordon in the above section on the geology of the region. In places, as along the Pelican fault and in the Antelope mine at the western end of the camp, ore occurs in very small quantities above this shale horizon. Below the shale the ore may be in contact with it, but often it is as much as 50 feet below the contact. The three main fractures have been the principal channels along which the solutions have migrated upward, and the ore is in shoots within these fault planes, or in beds and pockets following the bedding planes of the limestone for short distances away from the faults. As shown by figure 6, the principal concentrations of ore have been at places where the limestones were originally arched into low folds, and presumably it has been the trapping of the solution at these points that has caused the abundant precipitation of the metals.

The ores of the district are principally silver-bearing sulphides of lead, copper and iron. The primary ore minerals are galena, chalcopyrite, bornite, sphalerite, and associated silver and gold. Antimony minerals are said to occur locally, but none were seen by the writer. In the primary ore the silver, which has been the principal metal of value in the district, is associated with the galena, chalcopyrite and bornite. Among the secondary

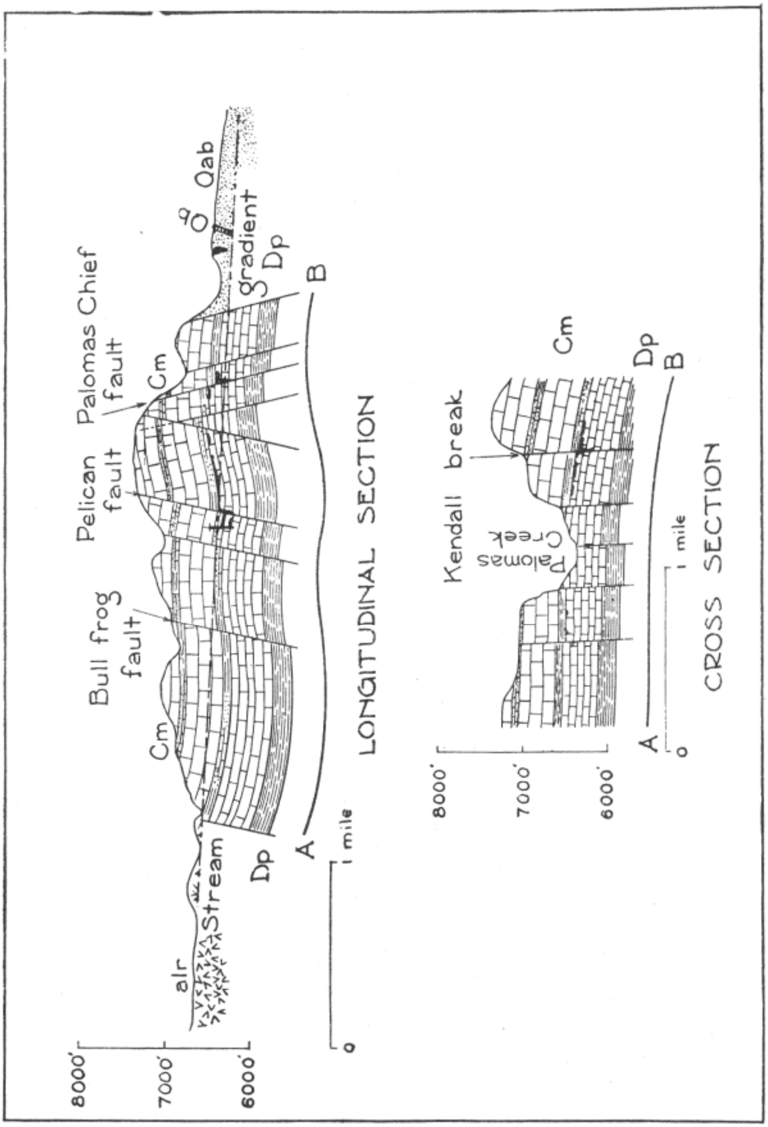


FIGURE 6.—Sections near Hermosa showing structure of the district. Dp. Percha (Devonian) shale; Cm, Magdalena (Pennsylvanian) limestone; alr, Tertiary extrusives; Qab, Palomas gravel; Qb, Quaternary basalt. Areas in black indicate ore bodies and mine workings. Lines A-B show folding of beds before faulting and relation of ore bodies to the arches. (Modified from a private report.)

minerals are silica in boxwork form, anglesite, cerusite, chalcocite, covellite, malachite, azurite, smithsonite, limonite, free gold, native silver, argentite, cerargyrite, bromyrite and embolite. (See footnote, page 59.)

The maximum production from any one shoot has consisted of a few hundred tons of shipping ore, and most of them have yielded from a few tons up to a few carloads.

Near the surface these runs or shoots of ore are oxidized. Solution of the limestone has occurred along the fracture zone, leaving a series of small open chambers in the limestone along one side of the ore shoot. The ore has then been oxidized and leached, with the removal of most of the silver, copper and zinc, and part of the lead, and with the development of a silica boxwork structure and the deposition within it of limonite, anglesite and cerusite. A claylike deposit on the floors of the solution cavities consists of the impurities in the limestone left behind when the latter was dissolved, together with limonite, anglesite, cerusite, fragments of the silica boxwork, and fragments of rock and of the primary vein matter dropped in during the processes of oxidation and leaching. In some places this residue nearly fills the cavity ; in others it is merely a thin coating on the lower walls and on the bottom.

Farther down along the ore shoot and near or at water level, the solution cavities in the limestone have been lined with a crust, often one layer deep, of cubical crystals of galena up to 1 1/2 inches along an edge. Zinc and copper sulfides are not found associated with these large crystals, and the shoot alongside is filled with the silica boxwork, limonite, anglesite, cerusite and residual galena. Native silver is an accompanying mineral, and cerargyrite and other halides of silver may be present. This mode of occurrence of the galena suggests that it has been formed by secondary processes, which have involved its solution in the zone of oxidation, its transportation in some soluble form, possibly as the chloride, and its precipitation as a secondary sulfide from weak solutions in open cavities just above water level and above the point at which the other secondary minerals begin to concentrate.

Below water level in these shoots are the primary sulfides. Here the galena is in small crystals and often approaches steel galena in its fineness. It is associated with primary chalcopyrite, bornite, and sphalerite, and these have been replaced by secondary chalcocite, covellite, argentite, and locally native silver. Solution cavities in the limestone are lacking at this depth.

The ore shipped has been extremely high grade, assaying on an average 250 ounces silver a ton and 40 per cent lead, but this ore was obtained by sorting, as a result of which over 50,000 tons of rock, which assays 10 to 20 ounces of silver, is said to have been left on the dumps of the camp, and from which it is said a screened product containing 30 ounces of silver per ton could be made. In July, 1932, Mr. C. F. Ross was working on a new ore shoot on the Kendall break near the Pelican fault, which he thought might develop into one of the important finds of the district. During the development work, he sorted out underground all visible sulfides and made a product which assayed between 50 and 100 ounces of silver a ton and 35 to 45 per cent lead. Two tons of ore of milling grade was left behind for each ton of shipping ore that was sorted out, and this low-grade material was said to assay 10 ounces of silver, 15 per cent lead, 10 per cent zinc, one per cent copper and a trace in gold.

PRODUCTION

Including shipments made during recent years, the total value of the ore from this district is close to $1,500,000, according to the best estimates locally available to the writer. This production may be approximately divided among the mines of the camp as follows :

Production from the Hermosa District through 1932

Property	Value
Pelican Mine	$1,000,000
Palomas Chief	200,000
Antelope and Ocean Wave	200,000
American Flag, Flagstaff, Wolford, Argonaut, Cliff-L-Embolite, Miscellaneous	100,000
Total	$1,500,000

MINE DESCRIPTIONS

THE ARGONAUT MINE

The Argonaut mine (the one farthest to the east in this district) is in Palomas Canyon. It is opened only by tunnels with a total length of about 1,000 feet. The ore is reported to be similar to that found elsewhere in the district, but the production has been small.

PALOMAS CHIEF PROPERTY

The next property along Palomas Creek to the west of the Argonaut is the Palomas Chief on the north side. This mine is located on the fault of the same name, and at least some of the ore appears to be at the junction of an east-west fracture with the fault, which may be the Kendall break along which so much of the ore in the district has been localized. This property is opened into the face of the cliff by a 2,800-foot tunnel, which followed along the Palomas Chief fault and connected with a shaft 200 feet deep that was sunk from the surface. There is said to be nearly 10,000 feet of workings in this property, most of which were inaccessible, due to caves at the openings of the mine. Very little ore was found in the tunnel along the Palomas Chief fault proper, and nearly all of the ore mined was taken out of the shaft before the long and expensive tunnel was connected with it.

CLIFF-L-EMBOLITE GROUP

South of Palomas Creek at the junction of the Palomas Chief fault and the Pelican fault is a group of claims known as the Cliff-L-Embolite group. There are no shafts on this property, and the workings consist of approximately 4,000 feet of tunnels and drifts. Some high-grade ore has been removed from these workings at the junctions of east-west fractures with the main breaks, but it seems to be the opinion locally that the main junction between the Palomas Chief and Pelican faults has not been sufficiently explored for the indicated possibilities.

PELICAN GROUP

On the north side of the creek along the Pelican fault is the Pelican group of claims, from which the largest production in the district has come. This group consists of four patented claims, which cover the outcrop of the northward-trending Pelican and Bullfrog faults and their intersections with the main cross fracture on the north side of Palomas Creek, known as the Kendall break. Numerous tunnels on these claims extend into the side of the hill at the level of the ore horizon, which is 60 feet or more above the level of the creek. These tunnels have followed the north-south fractures, of which there are a large number between the major breaks, and crosscuts from them prospect all of the east-west breaks that were encountered. Wherever traces of ore were found these were closely followed, and in many places the effort expended in tracing out these tortuous stringers was rewarded by uncovering a shoot or pocket of the typical high-grade ore of the district. Most of these pockets of ore were found at the intersections of the two sets of fractures, and anywhere in a vertical distance of 100 feet, although most of them were found in a bed of limestone about 20 feet under the shale horizon. On the west side of the Pelican fault, the Pelican shaft, with collar 50 feet above the creek level, is 150 feet deep, and its bottom is 164 feet lower than the tunnels of the ore horizon and 120 feet west of the Pelican fault at that elvation. This shaft passed through a bed of shale, and in the underlying limestone it encountered numerous stringers of high-grade ore. The ground here is well fractured, and above the shale the shaft passed through much silicified limestone and stringers of quartz with some showings of lead. It is said that the ground passed through in this shaft was typical of the silicified and fractured rock seen on the surface over the highly productive area east of the Pelican fault. It is probable that where this shaft has penetrated the limestone under the lower shale it is too far away from the Pelican fault and from the intersection of that fault with the Kendall break to be in the best prospecting ground. Should high-grade ore be found in commercial quantities at the lower level, there appears to be no reason why another and perhaps more extensive ore horizon should not exist under the Percha shale, which is estimated to be about 500 feet below the bottom of the Pelican shaft and within reasonable prospecting distance from this level.

OCEAN WAVE AND ANTELOPE GROUPS

The Ocean Wave and Antelope groups of claims are located in the limestone area that borders the andesite at the west side of the district. These properties have been opened by inclined shafts and tunnels driven into the hillside at the level of the creek. The workings could not be inspected on account of caved ground and the presence of water. It is said that the Antelope was an important shipper during the earlier productive history of the camp, and that in these workings there is still considerable ore of moderate to low grade that would be amenable to milling.

AMERICAN FLAG AND FLAGSTAFF PROPERTIES

Along the Bullfrog fault and half a mile south of the Palomas Creek, two properties, the American Flag and the Flagstaff, yielded lead sulfide ores in early days. It is reported that they produced ore worth about $50,000 from a single small surface working and that the ore was taken out of a glory hole under a cave, the total depth of which was only 50 feet.

WOLFORD MINE

To the north of Palomas Creek, and also along the Bullfrog fault, is the Wolford mine, which is close to the trail leading north to Chloride. This mine has a 40-foot shaft and 1,000 feet of tunnels and drifts, from which some high-grade silver ore was mined in early days. Some zinc ore occurs in the oxidized zone, consisting largely of the dry-bone variety of smithsonite, and some lead ore has been produced.

FUTURE POSSIBILITIES

When consideration is given to the total production credited to the Palomas district and to the average grade of ore said to have been shipped, it appears that during the entire production history of the camp about 5,000 tons of ore was freighted out for treatment. In doing this, however, there was left behind 50,000 tons of dump rock and stope fill, which would make an excellent grade of mill ore for an efficiently operated plant of suitable size. Furthermore, the information disclosed in the Pelican shaft is by no means discouraging, and if ore should be found in the lower level from this shaft there is perhaps a reasonable chance of finding ore under the Percha shale at the additional moderate depth of about 500 feet. Prospecting on these lower levels would require a pumping plant. The primary ore in this district seems to be nearly as rich in lead as is any of the oxidized ore. Silver tends to concentrate in the oxidized zone and in the zone of secondary enrichment, but when it is considered that the silver is associated with the primary lead and copper sulfides, and in view of the sorting practice going on today in the district, it seems reasonable to believe that a primary ore containing 25 ounces or more of silver to the ton might be expected from deeper workings. Add to this, 22 per cent lead, 8 per cent zinc, 1 per cent copper, and small amounts of gold, and in spite of the small and scattered nature of the ore bodies, there appears to be a reasonable chance that a small and properly managed exploration campaign might encounter important runs of ore that would make it possible to rehabilitate the camp and to operate the mine at a substantial profit for a moderate period of time.

BLACK RANGE (KINGSTON) DISTRICT

LOCATION AND AREA

The Black Range (Kingston) district is on the east slope of the Black Range between the north and south forks of Percha Creek, and extends from near the crest of the range to a line 11/2 miles east of Kingston. It is about 9 miles long from north to south and 4 miles wide. Kingston is on the middle fork of Percha Creek. Hermosa is about 17 miles to the north, and Hillsboro is nearly 9 miles due east. From Kingston a trail leads over the Black Range to points on the west slope. Early in 1934 construction was under way on the part of U. S. Highway 180 across the Black Range to connect Kingston with San Lorenzo, to which point the highway has been built from the west. The topography of the area is rough and travel is difficult. The altitude just across the main street from the historic old hotel in Kingston is 6,249 feet above sea level. Water is present in the upper reaches of nearly all the streams during the entire year, or it can be found a short distance below the stream beds, and a moderate supply is available for mining operations and camp use in nearly all parts of the district.

GEOLOGY

In the Black Range near Kingston and for approximately 6 miles to the north and south of the town, pre-Cambrian rocks consisting of granite, gneiss and schist have been exposed along the base of a fault scarp through a vertical height of approximately 600 feet. Overlying this core of basement rocks and dipping away to the west from the high point along the fault scarp are Paleozoic sediments, which have a total thickness of 2,200 feet and include formations ranging from Cambrian to Permian. These formations and their approximate thicknesses are as follows: Bliss sandstone, 75 feet ; El Paso limestone, 200 feet ; Montoya limestone, 230 feet; Fusselman limestone, probably 75 feet; Percha shale, 200 feet ; Lake Valley limestone, 200 feet; Magdalena limestone, 600 feet ; Abo sandstone and Tower beds of the Chupadera formation, about 600 feet. With the single exception of the stratigraphic section in the Sierra Caballos on the east side of the Rio Grande, the generalized section in the Kingston area is more nearly complete than any in the county, and it is one of the best Paleozoic sections in the State. The type section of the Percha (Devonian) shale is in this area.

Thick andesitic and rhyolitic tuffs, breccias and flows overlie the Paleozoic rocks. West of the axis they dip gently to the west and are not greatly faulted. To the east of the axis of the range, however, they are much broken by faulting and in general have prevailing dips to the east. The dip of the basal andesite coincides closely with that of the underlying sediments, indicating that the early extrusions had been poured out before much faulting had taken place in the region. On the other hand, the dips of the rhyolitic flows may or may not coincide, depending upon the amount and direction of movement that had occurred before these had been poured out. The sequence, thickness and general character of the various flows, tuffs and breccias is quite similar to that found elsewhere along the east slope of the Black Range.

A monzonite porphyry intrusion cuts the sedimentary rocks west of the town of Kingston. This mass of porphyry is 400 feet wide in the canyon just west of the town and can be traced to the north and south for 2 miles or more in each direction. In general outline the mass resembles a dike of very irregular shape, but in the field the writer gained the impression that it was a small, elongated stock, and that with depth it would increase in size. The monzonite porphyry is very similar in appearance to that of the Hillsboro district, 9 miles to the east, and it is almost certainly of this same general period of activity, if not a part of the same deep-seated magma.

STRUCTURAL RELATIONS

The crest of the Black Range is about 3 miles west of Kingston, and the various sedimentary formations and overlying extrusive rocks west of the crest dip gently to the west and apparently are not faulted. To the east of the crest, the range•presents a fault scarp that has exposed the entire sequence of rocks from the pre-Cambrian basement complex to the last of the rhyolite extrusives. East of this fault scarp the east limb of the original arch is cut by a series of north-south faults, forming many long, narrow slices, all of which have been depressed relative to the west limb of the arch, but which have been tilted and moved among themselves into an intricate pattern of small fault blocks. The faulting occurred after the arching of the range, and it was apparently accompanied and preceded by flows of andesite and the intrusion of the monzonite porphyry. The locus of these flows and intrusions appears to have been where the east flank of the main arch had been further warped into a number of minor folds, which finally developed lines of weakness when compressional stresses were relieved and along which normal faults developed, and it was through these fractures that the first andesitic extrusions reached the surface. In this favorably prepared zone, the later intrusions of granite-porphyry and monzonite porphyry forced their way upward to near the base of the still-heated andesite flows, and in places to within the lower part of the extrusive rock. With the crystallization of these deep-seated masses of porphyry, shrinkage and settling cracks developed, and along these fractures came, first, the mineralizing solutions of the district, and later, as a last stage in the igneous activity, the residual portions of the still-molten body of magma welled up to form the rhyolite dikes of the region, and the extensive rhyolite flows, tuffs and breccias.

Locally, the relationship between the folding of the stratified rocks, the fracturing of these beds, and the intrusion of the porphyritic mass can be seen in the cross canyons, such as the middle fork of Percha Oreek passing through Kingston and in the gulch to the north near the Lady Franklin mine.

ORE DEPOSITS

In the Kingston district the ore occurs in pipes along steeply inclined fracture planes and in beds and pockets in the Fusselman and Montoya limestones below the Percha shale. The ore solutions moved upward along the margins of the igneous intrusions and along related fractures in the limestone farther away from the contacts, and in a large measure they deposited the metals in the tops of the arches that were formed before the period of fracturing and intrusion. The principal deposits are located in a narrow belt on the west side of the main mass of monzonite porphyry. Here the limestone is rather sharply arched in such a manner that ore-bearing solutions traveling upward along the west side of the monzonite were diverted by impervious beds of Percha shale and rose along the underlying beds of eastward-dipping limestone, until they reached the crest of the arch, where the minerals were deposited in bedded or blanket form and in irregular pockets. On the east side of the monzonite, where the sedimentary beds dip to the east, no important deposits of ore are known. The west limb of the arch just described is cut off by a northward-trending fault, which apparently dips steeply to the east at an angle that would cause it to intercept the monzonite mass at a moderate depth below the deepest present workings in the district. Some ore is known in this fault and in the adjacent beds under the shale, but it occurs in minor amounts compared with the ore that formed at the crest of the arch and that came up next to the monzonite porphyry intrusion. The ore occurs in bunches, spaced at somewhat regular intervals of about 50 feet, according to local report, along fractures that strike N. 40° W. and are intersected by another series of minor northeast fractures which usually carry no ore. The largest ore bodies occur where fractures of these two series intersect. Narrow stringers of sulfide ore usually fill the northwest fractures, and by means of these leads, prospecting from one ore body to the next is accomplished. The ore bodies are connected horizontally under the Percha shale along the northwest fractures, the relationship being that of beads spaced at wide intervals along a thread, and they also extend downwards with rapidly diminishing cross section and decreasing value along the intersections of the two series of fractures. Along the strike under the shale, the ore may be continuous from one deposit to the next for as much as 400 feet. In depth, however, the ore generally pinches out in less than 100 feet below the main ore horizon. The ore is not generally in direct contact with the Percha shale, but is separated from it by a thin layer of limestone, through which veinlets of sulfide ore extend. The rocks adjacent to the contact between the Percha shale and the underlying Fusselman limestone have been silicified in a manner very similar to that at Hillsboro and Lake Valley. In some places it is the underlying limestone which has been extensively altered along a zone of very irregular thickness to a white to pink flint breccia, often with crystals of quartz lining the irregular spaces between the breccia fragments. In other places the limestone is apparently unaffected, all the replacement having occurred in the shale, which has been converted into a dark gray to black flint breccia, often with areas of red jasper-like material along the immediate contact. Specks and nodules of pyrite are irregularly distributed within the shale, but none were detected within the limestone. As at Lake Valley and Hillsboro, the silicification and brecciation extend downward along fractures and faults, and where faulting is extensive, the silicification has extended out on both sides of numerous parallel fractures until the whole mass of the rock throughout a wide zone of shearing has been changed into flint breccia, and much of the local structure is thereby concealed. It is reported that this silicified material usually contains small amounts of gold. The rock is locally called "quartzite" in the various districts where it is found. The writer interprets this silicification as the last episode of the intrusion of stocks in the region preceding the introduction of the ore solutions. It is believed that silica-bearing waters rose up along fault planes and pervaded the rocks along an extensive bedding fault that had developed at the contact of the Percha shale and the Fusselman limestone, due to the differential stretching of these beds at the time of their arching. Brecciation along both the fault zone and the bedding fault would provide a favorable zone in which the siliceous solutions could completely replace the limestone and shale fragments and the finer interstitial material, and thus form an impervious rock which the later ore-bearing solutions could not penetrate.

The primary minerals of the district consist of silver-bearing galena and chalcopyrite, sphalerite, pyrite, and the gangue minerals, rhodochrosite, manganiferous calcite and quartz. Alabandite, the sulfide of manganese, has been recognized in specimens from the district, and it is apparently fairly common, although none was seen by the writer. Some argentite (silver sulfide) occurs associated with the other sulfides, and gold in small quantities is generally present in the quartz. The mineralizing solutions converted the host rocks to clay, sericite and residual quartz.

The secondary minerals include anglesite, cerusite, smithsonite, malachite, azurite and cuprite. These are associated with kaolin, limonitic clay residues from limestone, and residual quartz. Free silver formed abundantly and is found in thoroughly leached bodies of clay ; in places cerargyrite, the silver chloride, has been mined. Manganese oxides have formed from the rhodochrosite and manganiferous calcite.

Secondary enrichment has been important in this district. Most of the ore mined has been thus enriched, but several rich shoots are reported to have shown no evidence of enrichment and are considered to be due to local concentrations of primary silver-bearing sulfides.

The ore was introduced primarily along the northwestward-trending fractures in the district in areas of arched limestone where these rocks were overlain by an impervious shale, and the depositing solutions were brought in from below along the contacts of the intrusive masses, or along outlying fractures in the limestone generally parallel to these contacts, which are presumed to have direct connection with the monzonite masses in depth. The minerals were deposited in the limestone by replacement of the wall rock along the fractures. In response to subsequent adjustments in the region, the sedimentary beds were further disturbed. There was developed a new series of northeast fractures, which intersected the northwest ore-bearing series, and the northwest fractures were involved also in this later period of movement. Additional adjustment occurred along the major faults of the region, which were at that time extended through the later rhyolite flows. The development of this second series of fractures and the reopening of the older ones gave surface waters access to the primary ores, and these were oxidized, leached and secondarily enriched, particularly along pipelike channels at the intersections of the northwest and northeast fractures. Enrichment is considerably more advanced where the overlying beds have been eroded and the ore bodies exposed at the surface.

PRODUCTION

The main period of activity in the Kingston district drew to a close with the decline in the price of silver in 1893, and since then mining has been done only occasionally and on a very small scale. Shipments have been limited to small lots of high-grade ores and to a few carloads of moderate to low grade ores, many of them chiefly valuable for their fluxing properties at the smelter. Up to January, 1904, the estimated production as given by F. A. Jones [41] was $6,250,000, most of which was silver. Since 1910 the records show that approximately 3,675 tons Of ore has

[41] New Mexico mines and minerals, 1904.

been shipped from the district in small lots, to which may be attached a value of about $25 per ton, giving a total production during this later period up to January, 1930, of between $90,000 and $100,000, or a total to that date of $6,350,000. The production since 1910 may be divided into lead-copper-silver ores, 590 tons ; lead-zinc ores, 60 tons ; silver and silver-gold ores, 2,025 tons ; and low-grade manganiferous silver ores, 1,000 tons.

MINE DESCRIPTIONS

The workings of the Kingston district are largely caved and could not be entered. The ore deposits are not uniformly distributed throughout the district but are in groups, separated by ground that is barren or only sparsely mineralized. One group of these deposits occurs just west of the monzonite stock and on the north side of Middle Percha Creek, about half a mile above the town. Among these nay be mentioned the Blackeyed Susan, Andy Johnson, Brush Heap, Calamity Jane, Illinois and United States deposits. Nearly a mile north of this group is another in which there are several important ore bodies, such as the Comstock, Black Colt, Kangaroo, Caledonia, Lady Franklin, Superior and Bullion. A little to the west of this latter group are the Iron King, General Jackson, Matchless and Climax properties, while to the north are two groups of claims, active in the early history of the camp, known respectively as the North Percha Camp and as the Mineral Creek Camp. (See Plate V.) South of Kingston in South Percha Creek is the Gray Eagle mine, containing ore of a different period of mineralization. Here the ore is associated with dikes of rhyolite that traverse the limestone, and along which fissure-filling and replacement deposits of silver-gold-copper minerals have formed. This ore has averaged several hundred ounces of silver to the ton in past shipments. It is said that the Gray Eagle has ore blocked out in moderate amount that will assay 15 per cent lead, 11 per cent copper, 18 per cent zinc, and 14 ounces of silver a ton.

In a very general way, the various groups of deposits contain characteristic assemblages of minerals, which may be the result of a zoning of the deposits, dependent upon temperature and pressure conditions at the time of their deposition, which in turn were dependent upon the distance from the source of supply of the mineralizing solutions, or upon the depth below the surface at the time of their formation. In the zone bordering closely on the west side of the monzonite outcrop, the mines named above from the Blackeyed Susan to the Bullion were essentially of the high-grade silver-lead-copper type, with rhodochrosite a prominent gangue mineral in the blanket deposits. Here oxidation had produced large amounts of native silver in ores ranging up to 250 ounces to the ton in silver, with some ore assaying as high as 1,000 ounces silver to the ton. Gold in the ore ranged in value from 50c to $1.20 per ton. Low-grade ore left in the mines, which with slightly increased depth changes rapidly to primary material, may average 5 to 20 ounces silver per ton. It contains a small amount of lead but much manganese oxides, which make it a desirable fluxing material at the smelter. The Lady Franklin and adjacent mines in the early days produced a great deal of high-grade silver ore, and at the present time the Lady Franklin is reported to have nearly 10,000 tons of developed ore which is said to assay 15 ounces silver, $1.20 gold and 25 per cent lime. In addition there are probably 2,500 tons of old stope fill of about the same grade. Alabandite is reported as being a fairly common mineral in the Lady Franklin mine, and in this mine, as well as in others of the district, it may be the source of more of the secondary manganese minerals than is commonly supposed. In the Comstock mine some ore is blocked out which is said to average 10 to 15 ounces per ton in silver and 80c in gold, and in the Kangaroo a considerable amount of 6- to 7-ounce silver ore is reported, all containing considerable quantities of manganese and lime.

The Virginia mine is located on a fault fissure along which the ore occurred in the old North Percha Camp. At this mine the ore is within the fissure and has been partly developed and stoped to a depth of 120 feet. The width of the ore was 4 to 5 feet, and it was said to assay in places 60 ounces in silver and $1 to $2 in gold per ton, and to carry some lead. Silver chloride was a prominent mineral in the surface ores of all of these mines.

In the group of mines just west of Kingston, the Calamity Jane has blocked out a little ore that may average 30 to 40 ounces silver to the ton. This mine has been very little developed along the lower portion of the productive beds. The Illinois and United States mines are reported to have considerable development on the lower levels, with no large quantity of ore in reserve. The Brush Heap and Andy Johnson and the Blackeyed Susan all contain some ore, reported to be 10 to 12 feet wide on the average and to contain slightly more zinc than the average ore of the district.

A short distance to the west of this high-silver group of mines are the Iron King, General Jackson, and closely surrounding claims. The ore of these properties is distinctly of the lead-zinc type and representative assays show 12 to 15 per cent lead, 40 per cent zinc, 4 per cent copper, and 12 ounces of silver a ton.

East of Kingston, along the fault zone which has brought Silurian limestone on the east up into contact with Permian beds on the west, are a few scattered ore deposits, some of which are said to be of excellent grade. To the north of the highway near Armour's ranch are three properties consisting of the Gypsy, Stowe and Picket Springs groups of claims. It is said that the Gypsy produced ore worth $200,000 and that the only known occurrence of ruby silver in the district was in this mine. On the Stowe and Picket Springs claims, it is said that on an old 100-

foot level, 4 feet of ore has been exposed that will assay 60 ounces of silver and $2.50 in gold to the ton. No tonnage of this material appears to have been blocked out.

FUTURE POSSIBILITIES

Water is a problem in all of the mines of the district below a very moderate depth, and it is said that for this reason the mines were restricted to operations on the upper levels. In the few places that the writer was able to visit underground, however, he noted distinct evidence of the dying out of secondary enrichment and oxidation features, even above water level, and it is quite probable that, except for a relatively few small shoots of high-grade primary ore that may extend to some depth, the metal content in general below water level is very close to, if not actually below, an economic limit for this district. (See footnote, page 59.)

A significant fact in regard to past production is that even while high prices prevailed during the World War, only a moderate amount of ore was shipped from this district, principally from the Lady Franklin mine. No doubt other shoots of ore will be found from time to time, many of which have no outcrop on surface, but no scheme of development in this district is indicated except to follow stringers from known bodies in the hope that others will be encountered.

Among the mine operators and geologists who are familiar with the Kingston district are some who are impressed with the possibility of large ore deposits at depths greater than have been reached by past development work. The theory upon which these premises are based appears to be that nearer the intrusions and at greater depths, where higher temperatures and pressures prevailed, contact metamorphism of the limestones would be more pronounced, and large contact deposits of zinc-lead ore might have formed. However, the pre-Cambrian rocks are not far from the surface in the district, and it is doubtful if conditions were conducive to extensive contact-metamorphism above this unfavorable host rock. Furthermore, the original lead-silver solutions of the known productive area were certainly weak, and the value of the ores formed by them was dependent largely on secondary processes. It is difficult for the writer to see, therefore, how these solutions could have formed rich primary ore deposits of another type at such a short distance below the present known ore horizon.

TIERRA BLANCA (BROMIDE NO. 1) DISTRICT

The writer spent two days in the Tierra Blanca district, one of which was at the Lookout mine and its immediate vicinity. Much of the information contained in the following sections has been extracted from Gordon's report, [42] with which has been incorporated verbal information supplied by D. M. Miller of Lake

[42] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 271.

Valley, and the observations of the writer made during his visit to the district.

LOCATION

The Tierra Blanca district is 6 miles south of Kingston, near the heads of Trujillo and Tierra Blanca creeks. It is about 10 miles by road southwest of Hillsboro and is 15 miles northwest of Lake Valley. The hills surrounding this area are covered with a prominent capping of white rhyolite tuff and related rocks, and from this circumstance the name Tierra Blanca has originated. The district is in the rugged foothills on the east slope of the Black Range. Travel is by fair mountain roads and trails.

GEOLOGY AND STRUCTURE

The Tierra Blanca district includes a continuation of the same zone of folding, faulting and intrusion that is prominent in the Kingston district. As at Kingston, the east slope of the range is faulted to such an extent that pre-Cambrian granite is exposed at the base of the main escarpment. Paleozoic limestones form a long, narrow belt along the range east of the granite, although the continuity of this belt is much broken by faulting, and it is covered in many places by the usual series of andesite and rhyolite flows and tuffs. The beds dip to the east and southeast, much as they do at Kingston, and they are cut off in that direction near the mines by an intrusion of monzonite porphyry, which is probably an extension of the intrusion at Kingston. In addition to this stock, several dikes with north to northeast strike cut the sediments, and these grade from monzonite porphyry identical in appearance with the stock through a birdseye porphyry to a fine-grained phase, with the same field relations to the parent mass of monzonite stock as have the dikes in the Hillsboro district.

Overlying the granitic basement rocks to the west, the lower Paleozoic sediments may be seen in places, while at others they are overlain and hidden by andesite, with white rhyolite tuffs capping the hills. Along the eastern foothills many of the faulted blocks are also covered with residual patches of the andesitic and rhyolitic flow rocks, and many buttes and mesas of these rocks constitute prominent features of the landscape. The contact between the latest flow of andesite and the first of the rhyolite flows in the district is an unconformable one that is characterized by a layer of obsidian at the base of the rhyolite flow. This relationship persists in the range all the way from Hermosa to Lake Valley.

Near the ore deposits the Lake Valley limestone has been arched into low folds having their axes parallel to the trend of the range, and along these arches north-south faulting has occurred, which has been accompanied by considerable cross fracturing and the division of the beds into many small fault blocks. The fracturing is generally inclined to the porphyry contacts in such a manner that parallel fractures or faults dip toward the monzonite porphyry masses in depth, and hence they could readily function as channels for ore-bearing solutions concentrated at the walls of the igneous masses or migrating from greater depths along these contact surfaces.

ORE DEPOSITS

Ores of silver and of silver and lead are important in this district. The silver occurs as native silver and as the chloride and bromide in the oxidized portions of the veins, and as the sulfide, argentite, in the zone of secondary enrichment and in the primary zone. It is also in combination with the sulfides of lead and copper. The silver and silver-lead ores occur chiefly as pockets and pipes in limestone underlying the upper shaly beds of Lake Valley limestone (Crinoidal limestone of Lake Valley) along narrow zones bordering the porphyry intrusions in the district. In these zones the ore in the limestone is as much as 150 to 200 feet away from the contact. Fractures in the limestone have been channels along which solutions have traveled upward, and low structural arches under the shale have acted as traps to retain the solutions and permit the precipitation of their mineral load to form the commercial ores.

Gold is found in the top of the Fusselman (Silurian) limestone in a thin bed that has been replaced by silica. This topmost silicified portion of these beds is a persistent feature of the Fusselman limestone, and it is thought to be a brecciated zone caused by differential movement between Fusselman and Percha beds at the time of folding in the region, and prior to'the time of faulting and igneous activity. The silica-bearing solutions are thought to belong to an early stage of the mineralization and to have come up along faults and fractures, replacing the limestone breccia and converting the fragments to flint. Pink and white quartz fills the interstices between the fragments with the formation of many crystal-lined vugs, and small amounts of gold were deposited along with it. The ledge has been reported to assay $8 to $9 per ton in gold in places, but no verification of these figures is at hand, and so far as the writer knows, no shipments have ever been made of this material and no systematic prospecting and sampling of this ground has ever been attempted. (See footnote, page 59.)

Gold mineralization of a later period also occurs in this region, being associated with the rhyolite dikes and flows which were emplaced after the early gold, silver and silver-lead deposits had been formed. This gold occurs in veins along the contact of rhyolite dikes and sills within the limestone. The gold is native and is associated with hessite (silver telluride). The gold-silver telluride, calaverite, which has been reported, was not seen by the writer, but it may be present in parts of the deposit.

PRODUCTION

Several small properties have been worked in this district, but since 1905 very little has been done. Mr. D. M. Miller, manager of the Log Cabin mine, estimated roughly that the Log Cabin mine has produced a total of $75,000 in the past, the Hornet claims not less than $30,000, the L. M. Sly group $2,500, while other mines in .the district such as the Bi-metallic, Silver King, Silver Bell, Victorio and Silver Tail, have produced good to high-grade ores from one or more small stapes at each property. In all, the shipments from this part of the district have probably amounted to about $120,000. Mr. Miller is sponsor for the statement that from one stope in the Silver Tail 10 feet long, 3 feet wide and 4 feet high, a spring-wagon load of sorted ore was shipped, which netted $2,200 in smelter returns. Mr. W. D. Slease of Hillsboro, estimated that the Lookout mine has produced in all approximately $100,000 in high-grade gold-silver ore since its discovery. It has also been unofficially stated that nearly as much ore, but of somewhat lower grade, is now blocked out in the various mines as has been shipped from them in the past. Official reports indicate that around 210 tons of ore was produced from this district between 1911 and 1931 inclusive, most of which came from the Log Cabin mine.

MINE DESCRIPTIONS

LOOKOUT MINE

The Lookout mine, the most northerly mine in the district, is in one of the steep tributary canyons on the south side of Trujillo Creek near its head. The road to the mine follows along the bed of Trujillo Creek, and the last 4 miles to the mine work, ings must be negotiated by trail. Here a rhyolite dike cuts across steeply dipping beds of quartzite, shale and limestone. An offshoot from the dike, which is 20 feet wide, makes out between the quartzite and overlying shale beds for a distance of not more than 75 feet in the form of a sill about 6 feet thick. Development has shown that the quartzite beds under this sill are very slightly arched at fairly regular intervals, the crests of the arches being parallel to the dip, and that the tops of these arches were cracked by tension stresses to a depth of 3 to 5 feet below the contact with the overlying rhyolite. These tension cracks are mineralized with white to amethystine quartz, hessite and free gold, and possibly in places with gold-silver tellurides. Occasional particles of pyrite and slight staining by copper salts were noted. Development of the mine has been principally by a tunnel, which follows near the footwall of the dike just under the sill and at intervals has encountered the ore-bearing fractures. These have been followed by raises of small to moderate size but amply large to have extracted all the ore from the gash veins. Several of these fractures extend to the surface along the hillside and have been followed down with winzes, which in a few instances have connected with raises driven on the same fracture from the tunnel level. Mr. Slease and the writer estimated that there are about 2,400 feet of workings in this mine, of which 1,000 feet consists of raises and winzes on pipes of ore, and from which, Mr. Slease believed, $100,000, or $100 per foot, had been recovered. The material shipped was broken by hand to pieces the size of a walnut and smaller, and only the pieces showing visible tellurides, together with the material too fine to inspect, were saved. Some of these shipments have assayed as

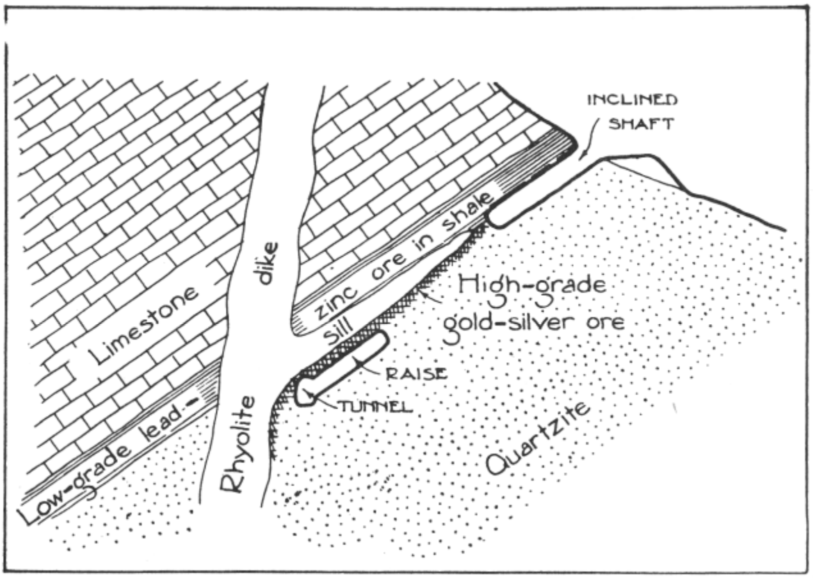


FIGURE 7.—Generalized geologic section in the Lookout mine, Tierra Blanca mining district.

high as $85,000 per ton, while others, in which hessite (silver telluride) has greatly predominated, have assayed as low as $100 per ton. Mr. S. G. Lasky, assistant geologist on the staff of the United States Geological Survey, examined under the microscope polished sections of the rich ore from this mine with the writer, and it was found that the gold was in the free form and later than the silver telluride, and that it traversed the silver telluride in minute veinlets. No trace of gold was observed in any of the samples of the pure hessite examined chemically, but the ratio of the total gold and silver in many of the shipments was close to that of the mineral calaverite, and until quite recently this was considered to be the valuable mineral of the ore. The microchemical determination of hessite, however, with which free gold is associated in varying amounts, explains why some shipments with visible tellurides ran comparatively low in gold.

Due to its inaccessibility and to the high concentration of gold and silver only in very small pipes of ore, it would seem that this mine could best be worked on a small scale similar to past operations, with perhaps a one- or two-drill compressor plant installed, and a small hoist. Future development should look toward finding new fractures by advancing the tunnel on the footwall side of the dike. It would also be well to investigate both walls of the dike somewhat below the level of the tunnel and for considerable distance along both walls.

LOG CABIN MINE

At the Log Cabin mine a gold vein is associated with the silver deposits. The writer did not examine this vein, but from the descriptions it is believed to be of the same age as the Lookout vein and later than the silver ores. The workings are fairly extensive in the underground part of this mine, and it is reported that ore worth at least $50,000 is blocked out and so located that under normal prices for silver and lead it can be extracted and shipped at a moderate profit.

STANDARD METAL MINING & MILLING CO. PROPERTY

The Standard Metal Mining & Milling Co. owns or controls 25 claims in the Tierra Blanca district, and appears to be a reorganization of the old Bi-metallic Mining and Milling Co., including the Midnight, Wausa, and Argus claims, which was effected in 1926. The ore• forms flat-lying deposits in the limestone, which have been cut by later rhyolite dikes. The ores consist of mixed oxides and sulphides of silver, lead and copper, and some gold. For each ounce of gold in the ore there is about 18 ounces of silver. Development is by two shafts 90 and 135 feet deep ; three tunnels 60, 84, and 373 feet long, according to report ; and a moderate-sized plant equipped with drilling machinery and pumping equipment.

It is said by this company that ore has been found through a distance of 300 feet and a width of 22 feet, and that ore reserves consist of 4,500 tons valued at $22 per ton.

CARPENTER DISTRICT

LOCATION AND AREA

The Carpenter district is on the west slope of the Black Range, 6 miles southwest of Kingston. Most of it is in Grant County, and all mining locations to date have been recorded there, but some of the larger working are close to the Sierra County boundary, and ore may be discovered across the county line. For this reason the district is discussed in the present report.

The mines are most easily reached by trail from Kingston, or over fair mountain roads 9 and 11 miles in length from the small hamlets, Sherman and Swartz, on the Mimbres River in Grant County. On the whole, the district is difficult of access. In two localities some important prospects have been developed and some mining has been done, and if provided with suitable transportation facilities, profitable mines might be made of them. One of these is the old Grand View group, located about 7 miles southwest of Kingston, and the other the Grand Central group, 4 miles south-southeast of Grand View camp.

GEOLOGY

The area in and around the Carpenter district is the only part of the Black Range known to the writer where the sediments of the western limb of the arch are exposed to view near its crest. According to Gordon, [43]

> The range is flanked on the west at this point by lower Paleozoic (Ordovician) rocks covered in places by flows of andesites and rhyolites and cut by large dikes of granite porphyry and lesser ones of diabase. In the vicinity of the mines the sedimentary formations consist of blue and white crystalline limestones alternating with beds of quartzite evidently belonging near the base of the Mimbres limestone. Both limestones and quartzites show marked indications of metamorphism, the limestone in places resembling marble. About half a mile west of the Grand View mine these formations are cut on the west by a mass of granite porphyry, which constitutes a prominent ridge running north and south for 2 or 3 miles. A dike of a similar rock 20 feet wide was observed on the trail a short distance north of the mine, cutting across the limestones toward the southeast.
>
> About 2 or 3 miles north of this locality occurs a cliff of limestone seamed with chert closely corresponding in appearance to the Abrigo limestone (Cambrian) described by Ransome [44] in his report on the Bisbee quadrangle, Arizona.
>
> At the Grand View (Mitch-Gray) mine the sedimentary fornlations dip 30° to 35° W. They appear to flatten out somewhat toward the southeast and at the Grand Central (Royal John) locality the dip is not more than 15°.

ORE DEPOSITS

Character of the ores.—At the Grand View camp the ores consist chiefly of galena, with some zinc sulphide and a large amount of iron pyrites in quartz gangue. The ore is of low grade and carries little or no gold or silver. The Grand Central properties show a higher content of zinc, with considerably less of lead and iron sulphides.

Geologic relations.—In both places the ores occur along sheer zones cutting the crystalline limestones. At the Grand View the shear zone is about 30 feet wide and extends N. 53° E. for a distance of 1,000 feet or more. At the Grand Central mines the shear zone is about 25 feet wide and extends nearly due north. The ore is distributed somewhat irregularly along the zone, which appears to dip at a high angle to the east. The openings, which are superficial, are on the east side of a small valley; on the west side the westward-dipping limestones are covered by a flow of rhyolite. The limestone along the vein on the foot-wall side is altered to a hard siliceous rock containing bunches and stringers of ore. No intrusive rocks were observed, but the general relations strongly suggest their presence near at hand.

MINE DESCRIPTIONS

Much of the following information regarding the mining

[43] Gordon, C. II., op. cit. (U. S. G. S. Prof. Paper 68), p. 272.

[44] Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Bisbee folio (No. 112), 1904.

operations in the Carpenter district was told to the writer while in the field with Mr. D. M. Miller of Lake Valley.

In the northern part of the Carpenter district, around what is generally known as the Grand View camp, are a number of small properties, including the Spates or Mineral Mountain, the Teel and others. Near the southern end, in the Grand Central area and along the shear zone between the two camps, are the Perault and the McGee claims, with several smaller holdings surrounding them.

Many of these properties are still prospects, and no ore has been shipped from them except that which has been removed from shallow surface workings to be closely hand sorted and shipped in lots of a few tons each. The properties coming under this classification as to size are the McGee, Perault, Spates, Mitch-Gray and others. In all of these workings some ore was found in irregular bunches and stringers within the shear zone, and further development work would doubtless serve to uncover additional ore of a like nature. It is not known, however, whether excessive development would be required to continue locating new ore pockets to supplant those being worked out. The camp is so isolated that profitable mining on an average grade of ore seems out of the question without large tonnages of this ore being adequately proven prior to operation.

ROYAL JOHN MINE

The Royal John mine, formerly the Grand Central, has been known for many years and has been extensively developed under the management of several different financial groups. It is reported that the late Mr. J. M. Sully and associates obtained an option on the property in 1914, and some drilling was done which served to block out 75,000 tons of lead-zinc ore of milling grade, but the ground was very hard, and comparisons of the estimates of expense and recovery did not warrant a continuance of the option.

A mill was installed on the property by the Monarch Mining & Milling Co. in 1906 and 1907, but it did not operate successfully and was soon shut down. The plant was later taken over by the Black Range Mining Corp., who remodeled and operated it in 1927, but with no better results. In 1928 the Royal John mill and mine were acquired by the Asarco Mining Co., a subsidiary of the American Smelting & Refining Co., and the mill was remodeled into a modern flotation plant of about 200 tons daily capacity. Much development work was done, and a moderate tonnage of ore was milled, but operations were discontinued in 1929. In 1930, A. L. Owen operated the mill for a short time, and he is reported to have produced several hundred tons each of lead and zinc concentrates. It is roughly estimated that this district has produced around 15,000 tons of ore, which has yielded, by various methods of treatment, 30 tons of high-grade lead-copper ore, 750 tons of zinc concentrate, 420 tons of silver-lead concentrate, and 300 tons of lead concentrate.

It is reported that the ore at the Royal John mine occurs in a lens in limestone and that the chief metals are lead and zinc, with subordinate amounts of copper, silver and gold. A considerable tonnage of ore of moderate grade is said to be blocked out.

SIERRA CUCHILLO

CUCHILLO NEGRO DISTRICT

LOCATION AND GEOGRAPHY

The Sierra Cuchillo is located in the northwestern part of Sierra County. It is east of Fairview and extends from the northern border of the county in a southerly direction for 15 miles, where the Rio Cuchillo has cut through it in an easterly direction. (See Plate I.) South of this drainage line a series of low hills extends the range for 12 miles or more in a southerly direction. About 6 miles south of the Rio Cuchillo the Palomas River has cut transversely through these low hills, and at their southern termination the Arroyo Seco makes a wide sweep around them through the Tertiary and Quaternary detrital deposits. Cuchillo Peak, the highest point in the range, has an elevation of auout 7,500 feet and is a short distance south of the hot Springs-Fairview highway, which crosses the range. On the higher le'eis scrub oak and cedar abound. Yellow pines flourished on the northern slopes at one time, but most of these were cut down and utilized during the active days of mining. Three large ranches have headquarters in or sear the Sierra Cuchillo.

GEOLOGY

Commencing at the base of the westward-facing fault scarp of the Sierra Cuchillo, where the rock exposures emerge above the alluvial fans of the interior bolson plain in which Fairview is located, is a poor exposure of limestone about 50 feet thick. This has been doubtfully classed by the writer as Lake Valley (Mississippian). The rock is a light-colored massive to slabby limestone, in which no fossils were observed, nor could the normal unconformity that exists between the Lake Valley and Magdalena strata'be recogniZed. Overlying this bed is a considerable thickness of the Magdalena (Pennsylvanian) limestone. Immediately above the Lake Valley (?) limestone is a bed of dark brown to gray quartzite 100 feet thick, then 18 feet of shaly beds, and then 11 feet of dark brown quartzite. It is believed that these beds are a part of the Sandia (Lower Magdalena) formation recognized farther north in the State. From this point to the top of the ridge the beds are typical of the Magdalena limestone and are 1,070 feet thick in the section measured. They consist of hard massively bedded limestone with a few thin shale partings and contain a typical Pennsylvanian fauna, which includes species of Productus, Spirifer, Fusulina and corals. Additional limestones occur on the dip-slope side of the ridge, which were not measured, but it was estimated that the Magdalena limestone here is not less than 1,500 feet in thickness. On the eastern slope Abo sandstone of Permian age overlies the Magdalena limestone and forms cuestas near the base of the range. At the foot of the

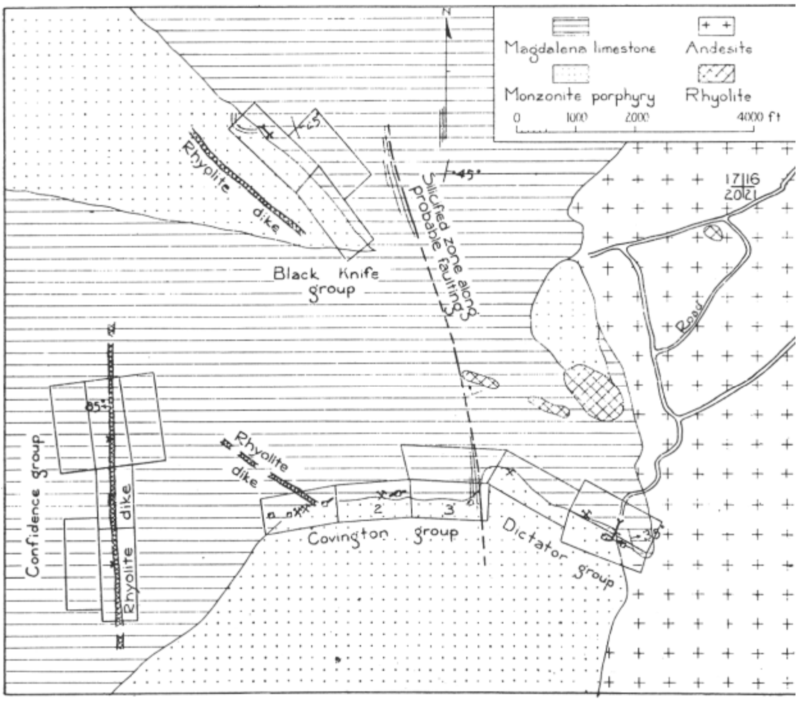


FIGURE 8.—Geologic sketch map of Sierra Cuchillo in the vicinity of Cuchil Mines Co. property. (Modified from a private report.)

western escarpment a small down-faulted block has a low outcrop of Abo sandstone projecting through the detrital material of the alluvial apron. Beds of the Chupadera formation, consisting in the lower part of pink and red shales interbedded with gypsum (Yeso) and in the upper part of limestone (San Andres), are found overlying the Abo sandstone on the east.

Overlying the Chupadera beds for the most part, but in other places apparently resting directly upon beds of Abo or even of Magdalena age, are extrusives of Tertiary age consisting of the usual sequence, from bottom to top, of flows of andesite, latite and rhyolite and related breccias and tuffs. Dikes of the latite and latite porphyry cut the andesite series, and dikes of rhyolite occur at several places cutting limestone. Several small masses of rhyolite in the region (see figure 8) consist of small intrusions, or residual patches left by erosion of flows, or the tops of dikes, only the uppermost irregular parts of which have as yet been bared by erosion.

A large mass of monzonite porphyry, the largest in the county, judged by the extent of its surface exposure, has intruded across and between the beds of Pennsylvanian age in the Sierra Cuchillo. From the northern end of the sedimentary series for a distance of nearly 8 miles along the range, it appears in the western face as a thick sill that separates the Pennsylvanian limestone into an upper and a lower part approximately equal in thickness. At the south end the sill thickens in a short distance to laccolithic proportions, and here it has broken up through the upper beds of the Magdalena formation and the Permian rocks and forms the crest of the range. As a result of its greater resistance to erosion, the monzonite remains as a bold rocky summit and is a prominent landmark for miles around. The sill where exposed at the base has the same dip to the east as the sedimentary strata. The sill-like portion of the monzonite is not everywhere of equal thickness, and near the Black Knife mine in the saddle north of Cuchillo Peak, a depression in the upper surface of the sill has preserved a residual mass of limestone. (See figure 8.) At the base of the sedimentary column and just visible in the bottom of the arroyo for a distance of 150 feet or more, an outcrop of fine to moderate-grained dark gray to greenish-gray basalt was noted. The nature of this occurrence is uncertain, although it is probably a dike.

STRUCTURAL FEATURES

The Sierra Cuchillo is a monoclinal block having the scarp face to the west and a gentle dip slope of approximately 25° to the east. This large faulted block is probably the local expression of a continuous line of breaks along which elevation and tilting has occurred, and which extends from the north end of the county through the Hillsboro and Lake Valley areas to the south. At Palomas River in the southern prolongation of the Sierra Cuchillo, a small block of Magdalena limestone and Abo sandstone projects through the extrusives with dip and strike similar to that of the main mass of the range. Locally, cross-fracturing has occurred in the tilted block along tear faults or planes of adjustment within the block. One of these cross faults marks the course of the Hot Springs-Fairview highway across the range, and several others are known, especially in the southern part of the range where the sill thickens into a laccolith, and where the thickening has caused a series of east-west faults to develop in the limestone above and to some extent below the intrusive rock. It is probable also that the contact between the Abo sandstone and the younger Chupadera beds is marked by a northwest-trending displacement, rather than that the contact is along the face of a cuesta. During the period of faulting the Magdalena rocks both above and below the monzonite sill were gently warped and folded along eastward-trending axes. The extent of this folding is small, the folds being elevated not more than a foot or two at the high points of most of the arches, and the width of the folds is often but a few feet. They may die out along the axis within a few feet, or they may continue without noticeable change for several hundred feet. Bending was sufficient, however, to crack the more brittle beds along the crest of some of these arches, thus creating channels of migration for solutions that were given off from the solidifying magma of the sill.

It is believed that the block faulting and related tear faults and folding, which formed the Sierra Cuchillo, were later than the similar events that outlined and elevated the other ranges in the county. In the Sierra Cuchillo, the Tertiary andesite and latite lie in accordant attitudes over the Paleozoic sediments, indicating that in a large measure at least, block faulting did not occur until after this phase of Tertiary volcanic activity. The sill and laccolith of monzonite porphyry is considered to have been intruded between the period of the andesites and the rhyolites, at a time corresponding to the period of latite porphyry flows, sills and dikes throughout the county. Extreme faulting of the range could not have occurred until after the intrusion of the sill, as it was clearly cut by the main fault and its eastern part elevated to its present position. Near Willow Springs in the Sierra Cuchillo, the latite porphyry within the andesite is very similar megascopically to the underground specimens of monzonite in the Dictator mine, with the exception that in the monzonite, hornblende is the predominating dark mineral, while in the latite porphyry bi,otite is locally more abundant.

ORE DEPOSITS

The ore deposits of the Sierra Cuchillo consist of contact-metamorphic deposits of iron in the extreme northern end of the range, contact-metamorphic deposits of lead and copper in the region of the Hot Springs-Fairview highway, and lead-zinc contact-metamorphic and replacement deposits on the east slopes of the range southeast of Cuchillo Peak. Very little gold and silver occur in these ores, and they are in general a partly oxidized complex mixture of sulfides near the surface.

HISTORY AND PRODUCTION

The deposits in this range were discovered at about the same time as those at Chloride and Fairview, but owing to the presence of hostile Indians in the region, prospecting and development were carried on with difficulty and were often interrupted. Some shipments were made during these times to the Chloride and Fairview smelters from the Rifle Shot, Dictator and Black Knife properties, but this activity did not last long. About 1900, further work was done in the district on the Dictator and Black Knife properties, when several inclined shafts were sunk. This work was done by various lessees. The Black Knife group was formerly owned by C. H. Laidlaw, the original discoverer of the group not being known. In 1917, T. C. Parker, who supplied the writer with much of the following information, entered the district and secured an option on the Black Knife group and adjoining claims, on which he did some development work and from which he shipped three cars of ore. On the Dictator property considerable development work was done by Thomas Scales of Fairview, about 1901 or 1902. In 1902 Parker took an option and lease on the Dictator claims from Frank H. Winston, the owner. Some shipments of oxidized lead and zinc ores were made from the claims just prior to the drop in metal prices in 1921. Work was discontinued in 1921, but Parker again took hold of the property in 1928 under a new option lease, later purchasing both the Black Knife and Dictator groups of claims from Winston, who had previously acquired the Black Knife group from C. H. Laidlaw. The Cuchillo Mines Co. was organized and all of Parker's holdings in the district turned over to it. At Willow Springs, 1.1/9 miles distant from the mine, 160 acres of ranch land, a flowing spring, and all necessary water rights were acquired,And a small mill was erected.

Old figures are not available for the production of ores from the district, but Parker estimates that approximately 1,000 tons was shipped from the Black Knife and Dictator claims prior to 1917. During this early period considerable ore wa§ shipped from the Rifle Shot group and other claims in the region to the smelters at Chloride and Fairview. In 1918 the Black Knife produced 120 tons of ore, 80 tons of which was mined in sinking the 175-fodt shaft. This ore averaged 15 oz. silver, 25 per cent lead, 5.5 per cent copper and 7.7 per cent zinc. In 1920 some small shipments of zinc and lead carbonate ores were made to paint companies, and it is reported that the company was offered a contract for further production of these ores but that the depression in 1921 prevented the consummation of the deal. Other shipments during this period consisted of lead and zinc sulfide ores and some concentrates. Since 1924 shipments from this group have amounted to half a car of dry silver ore from the Black Knife group, one car of lead-silver ore and one car of lead-silver concentrate from the Dictator group, and half a car of lead-zinc-copper-silver concentrate from the same locality. Production figures to date are scarcely a measure of the importance of this district, for it must be remembered that the complex nature of the ores has prevented their easy marketing in the past, and that the mill erected for their beneficiation is essentially a crude concentrator, unable either to make a high recovery or to produce a selective series of products which would command the highest return from the smelters. For the mining that has been done in the district, the following costs are reported as being average; mining $1.75 per ton of ore, hauling $0.50 per ton, and milling $1.50 per ton, making a total operating cost of $3.75 per ton of ore. It cost $7.00 per ton of concentrates for freighting to Engle, the nearest railroad point, and $5.00 per ton to haul freight back to the mine.

MINE DESCRIPTIONS

IRON MOUNTAIN DEPOSITS

North of Fairview about 12 miles are the Iron Mountain contact-metamorphic deposits of iron ore. They are in the northern end of the Sierra Cuchillo and for the most part in Socorro County, although part of the main occurrence and several small detached deposits are in Sierra County. The deposits in Socorro County have been described briefly by S. G. Lasky. [45]

These deposits occur in the Magdalena (Pennsylvanian) limestone and are genetically related to the great sill of monzonite porphyry which is a prominent feature of the Sierra Cuchillo faulted block. This sill separates the Magdalena limestone into an upper and a lower portion, and has slightly arched the overlying beds in a large area. The intrusion has also caused numerous slight folds and much cross fracturing, particularly along the crests of the minor folds. Considerable contact-metamorphism has occurred along these fractures in the tops of the eastward-trending minor folds. The ore minerals are magnetite and hematite, while garnet and partly altered limestone are the gangue minerals. The limestone overlying the ore is altered in places to nearly pure garnet. In places within the ore and occasionally within the overlying garnetized beds, a small amount of copper staining, probably malachite, was noted.

Aside from a few pits and short tunnels, no development work has been done in these deposits, and hence the extension of the ore bodies in depth could not be ascertained. Contact-metamorphic action has been confined largely to the roof of the sill, however, and it is believed with some confidence that the bottoms of the deposits will be confined to the base of the limestone lying above the porphyry intrusion and that it will follow for considerable distances down the general dip of the sedimentary rocks, which here is about 20° NE. As exposed on the surface the main bodies are lens shaped, average 1,200 feet in length, and are 60 to 250 feet wide. The average grade of the ore is reported to be about 45 per cent iron.

VINDICATOR AND WEST CONTACT GROUPS

These claims, about 33 in number, are located for a distance of 7,000 feet along the contact of the porphyry and the overlying limestone northwest of the Black Knife claims, and reach to the

[45] The or- deposi's of Socorro County, N. Mex.: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 8, pp. 138, 139, 1932.

Hot Springs-Fairview highway. Mineralization along the contact consists of sulfides and carbonates of copper, lead and zinc occurring in cross fractures located mainly in the tops of slight folds in the limestone. The ore occurs in bunches and shoots along the contact with the underlying porphyry. The limestone near the ore is garnetized, sometimes completely so, and in some places away from the fractures and veinlets of ore it has been slightly marbleized or recrystallized. Development work consists of a 175-foot shaft sunk on the contact, which here dips 25° slightly north of east, and several other shallow shafts and prospect holes. On the whole, except for the work in the shaft, which disclosed a persistent though small shoot of ore for the full depth, the work done on this property has been insufficient to determine the size and exact mode of occurrence of the important ore shoots.

BLACK KNIFE GROUP

This group of three claims lies southeast of the Vindicator-West Contact claims and near the southern end of the porphyry exposure, as seen on the map, figure 8. The overlying beds of Magdalena limestone strike N. 20° W. and have a dip of 25° NE. The beds are slightly folded, with axes pitching down the dip of the beds, and in many of these folds the top of the arch has been fractured along what appears to be a tension crack. The ore occurs in bunches and shoots within or in close proximity to these cracks. Lead is the chief metal, and subordinate amounts of copper, silver and zinc are present ; the minerals are galena, cerusite, anglesite, azurite, malachite, cerargyrite, sphalerite and smithsonite. The gangue minerals are quartz and calcite, with a small amount of manganese oxides. Occasionally a small amount of fluorspar is noted. Pyrite was an original constituent of the ore, but it has been altered to limonite, which now occupies the original pyrite spaces and has stained the adjacent rock yellow to brown. Along the contact of the limestone and the porphyry, the limestone is greatly silicified. Silica has been deposited in the tension cracks above the ore zone to the surface, and it is an indicator of ore below wherever development work has opened the ground for inspection. Many of these surface occurrences of silicia have not as yet been prospected along the contact. The fractures are nearly vertical and extend at right angles to the strike of the limestone beds. In general the ore shoots are about 2 feet in width and occur from the contact upwards for from 3 feet to as much as 20 feet, with a pitch that follows the dip of the strata.

Development consists of an inclined shaft about 150 feet deep following the dip of the beds. This shaft connects at the bottom with a tunnel from the surface, driven along the strike at the contact of the porphyry and limestone. Half way down the shaft a vertical winze 30 feet deep connects with a crosscut driven from a short winze just below the tunnel level. A second shaft on the contact attains a depth of 175 feet.

DICTATOR AND COVINGTON GROUPS

These groups, consisting of three claims in the Dictator group and four claims in the Covington group, adjoin one another and are situated along the north contact of the limestone and the mass of monzonite porphyry that is known as Cuchillo Peak, as shown on the map, figure 8.

The possibilities of these claims were known to the old prospectors in the region as early as 1880, and shipments were made to the small smelters erected near Chloride and Fairview, but operations did not continue for long, because the complex ores were not easily treated. Further work was done in 1900 by various lessees, who sunk several short shafts along the contact. Among these was Thomas Scales of Fairview, who by means of a shaft 130 feet deep and a connecting tunnel 400 feet long driven on the Dictator claim, exposed a good tonnage of ore. Since 1920 T. C. Parker has had control of these groups, either in his own name or in that of the Cuchillo Mines Co., and has done development work which, though meager in amount, has been well advised and which has exposed an ore zone over 6,000 feet long, following the monzonite and limestone contact. Some of the ore from this development, together with ore derived from stoping in the Dictator ground was shipped as a carefully hand-sorted product to lead and zinc treatment plants, or was concentrated in a small and not especially efficient mill into a high-grade lead-zinc-copper concentrate. In all, probably 300 to 400 tons of ore has been mined from the Dictator-Covington group since 1910.

The workings on the Dictdtor group consist of a shaft 130 feet deep, which is connected by a 100-foot crosscut to an adit tunnel 400 feet long as shown on the map, figure 9. The adit tunnel was driven in a southerly direction for a distance of 320 feet through Magdalena limestone, where it broke into monzonite porphyry at what is considered to be the main contact. Small bunches of ore were encountered in short crosscuts driven along the contact at this place. The main tunnel was continued through 60 feet of only slightly mineralized porphyry and then through a wedge-shaped block of hard blue limestone for a distance of 15 feet. At the farther contact of this block of limestone with the porphyry, the tunnel encountered highly mineralized ground, and considerable stoping was done west of the line of the tunnel, as shown on the map. The crosscut to the east, which connected with the old shaft, exposed within the limestone block some mineralized ground of sufficiently good grade to justify a small amount of stoping. At the extreme end of the tunnel a short winze was sunk and some ore was mined. This are apparently was not all extracted, as the ore shoot seems to continue toward the southeast. In some places on the tunnel level the stopes are

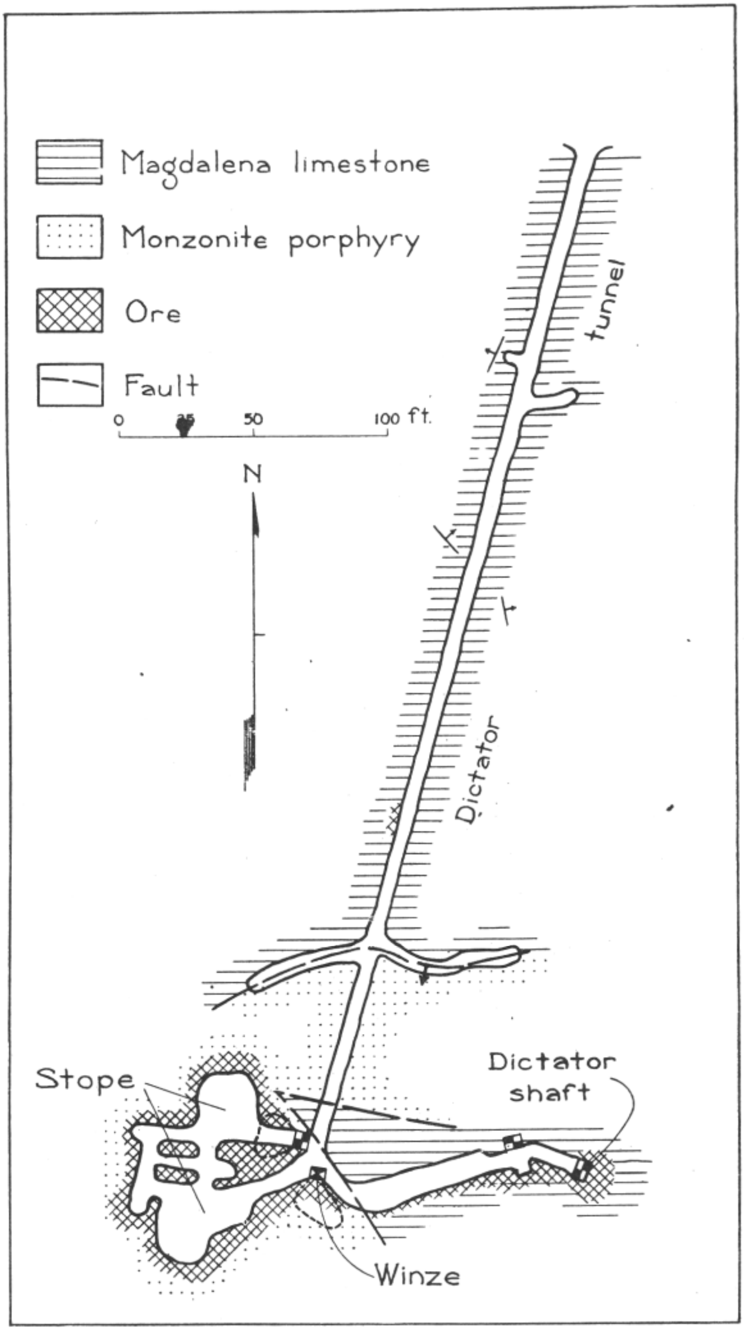


FIGURE 9.—Map of tunnel level in Dictator mine of the Cuchillo Mines Co. (Modified from a private report.)

15 to 20 feet in height, and in practically all places mining has been discontinued with the workings still in a good grade of milling ore.

On the Covington claims development work has been confined largely to the sinking of prospect shafts and to a moderate amount of drifting along the contact of the limestone with the monzonite. On the Covington No. 3 claim, near the east end and adjoining Dictator ground, a 40-foot shaft sunk on the contact cut a heavily epidotized rock stained with iron and manganese the full distance. From the surface to a depth of 20 feet the ore is oxidized, but below this depth grains and bunches of sulfides coated with oxidized material appear. Ore produced from this shaft is reported to have averaged around 6 per cent copper, 6 oz. silver, 14 per cent lead and 15 to 20 per cent zinc. This ore was transported to the mill on pack animals. The ore occurs in a shear zone 10 to 12 feet wide, which strikes N. 15° W. It is estimated that along this zone of shearing the monzonite to the west has been dropped about 100 feet and displaced to the south about 600 feet relative to the block on the east. Erosion of the limestone along the contact has left the monzonite east wall standing as a steep scarp along an arroyo which has cut its way into the shear zone. Near the shaft the surface zone of alteration is as much as 50 feet wide. Northward from the contact this shear zone may be followed through the Magdalena limestone to a point east of the Black Knife- claims as a wide zone of silicification containing some calcite and subordinate fluorite. No development work has been done along this shear zone at places other than the contact of the limestone and monzonite. The bottom of this shaft is in ore, and it is possible that mineralized ore shoots will be encountered at intervals along this shear zone.

On the Covington No. 2 claim a shaft 50 feet deep is located near the east end of the claim. Drifts having a combined length of 25 feet extend N. 80° E. and S. 80° W. from the bottom of the shaft, all in mineralized ground. At the surface in this shaft, partly oxidized lead-zinc ore containing 3 to 6 ounces of silver was mined. In places this ore contained oxidized copper minerals, and where these were present silver rose to as high as 20 ounces per ton. The copper minerals were malachite, azurite and some cuprite in a gangue of limonite and manganese oxides that contained scattered specks of chalcopyrite and chalcocite In the bottom of the shaft, galena, sphalerite and chalcopyrite constitute the usual association, with smaller amounts of oxidized minerals. The contact was apparently not cut in the development work done, although it was closely approached, as indicated by the much-fractured and highly altered appearance of the limestone. Fracturing of the limestone is very pronounced for a distance of 100 to 150 feet from the contact, and the limestone is much altered throughout, being replaced by silica, epidote and garnet. Closer to the contact the fractures and cavities are filled with abundant manganese oxides and limonite, and in the shaft much of the ore is found in a soft, highly decomposed limestone stained with iron and manganese oxides. West of this shaft for 3,000 feet the contact has been exposed by shallow pits and shafts and by short drifts and tunnels. In all openings the ground is impregnated with contact-metamorphic minerals, and ore minerals are present in notable quantities. For the entire distance of over 6,000 feet along the length of these claims the limestone adjacent to the intrusive porphyry is contact-metamorphosed and well mineralized.

CONFIDENCE GROUP

About 3,000 feet west of the Covington ground, and on the west side of the mountain, the Confidence group of six claims has been located in the limestone overlying the porphyry along and adjacent to a northerly trending dike of rhyolite. In one place on the group a 250-foot tunnel, 65 feet of crosscuts and a short winze constitute the development work, and in another place an 80-foot tunnel has been driven and a 50-foot shaft sunk. Seme ledges of magnetite and hematite on this group are similar in appearance to those in the northern end of the mountain. Associated with these are other contact-metamorphic minerals, and in places there are good showings of the sulfides of copper and iron, with accompanying oxidation products such as malachite and chrysocolla.

RIFLE SHOT GROUP

This group of claims includes an area of limestone that underlies the monzonite porphyry sill on the west side of the mountain. The ore occurs along the tops of minor folds in the limestone, in fractures that strike slightly north of east. Oxidized ores shipped to the smelters in Chloride and Fairview in early days are described as being of very high grade. Sulphide ores encountered at some distance from the outcrops down the pitch of the ore shoots are said to contain 10 to 12 per cent copper. It is stated that there are in this group large areas of mineralized ground that have not yet been adequately explored. The extent of the underground workings could not be ascertained.

TIN DEPOSITS

On the east slope of the Sierra Cuchillo and overlooking the valley in which the small village of Monticello is situated, the rocks consist of a thick succession of rhyolite flows, agglomerates and tuffs, dipping gently to the northeast and finally disappearing under the gravel that composes the alluvial fans and degraditional plains on the west side of the Alamosa River. One of these flows consists of flow-banded rhyolite, glassy in places, and having a much crackled appearance which may have been caused from rapid cooling. Surges in the flow caused fracturing of the solidified crust, and molten rhyolite from the interior of the flowing mass welled up through these cracks to form small dikes.

Over large areas the cracks and fractures have been coated with a bluish-white film of chalcedony, and in many of the more open fractures specular hematite and cassiterite have been deposited in a manner quite similar to that of the Taylor Creek tin district. (See pages 69 and 70.) Along the dry washes which lead out of the range and over the gravel deposits, placer tin is found in rounded grains and nuggets that vary in size from one inch or more in diameter down to particles of 80-mesh size. Since the writer's visit to the district late in 1931, T. C. Parker[63] has found an area in which he believes the metal may be present in important amounts. No tin has been produced commercially in this area.

OTHER DEPOSITS

South of the Dictator ground is an old group of three patented claims, two of which are adjacent and the third at some distance from these two, but all located on the contact, which here consists of monzonite porphyry intrusive into andesite breccia. So far as known, no shipments have been made from these claims, and only surface prospect holes have been sunk, but in nearly all of them there are showings of oxidized lead-zinc-copper ore. It is believed that the limestone and monzonite contact is but a short distance below the surface on these claims, and the evidence points to a continuation of the ore-bearing zone of the Dictator ground southward into this property.

FUTURE POSSIBILITIES

On the west side of the Sierra Cuchillo in the Rifle Shot and Confidence groups, and on the east slope in the Black Knife and claims to the north, the ore follows fractures in the tops of the slight arches in the limestone. These arches trend northeast and their axes pitch 25° in the same direction. As far down the pitch as the workings extend, the ore consists of sulfide and oxidized minerals of copper, lead and zinc, and some enrichment has probably accompanied the oxidation. What the grade of unaltered primary ore is and how far down the pitch of the arches it continues must be determined by future development. It would seem, however, that exploration should be limited to following the stringers of ore found at or near the surface, and working them until the cost of development and mining exceeds the net profit from these operations. Extensive prospecting is probably not warranted in this part of the district, but a few shallow prospect holes in the silicified limestone along the crests of arches overlying the monzonite sill and in the silicified zone that trends northwesterly from the Covington claims, would give desirable information.

In the Dictator and Covington claims and along the contact to the south, however, a different type of exploration is war-

[63] Written communication.

ranted. The limestone-monzonite contact is vertical or nearly so, and it may continue without change in attitude to a considerable depth. On the other hand, if the apparently laccolithic mass is nothing more than an enlargement of the top of a sill, the contact may flatten out rapidly at any depth below the present workings to assume the normal dip observed for this sill at other points. If the contact is vertical or dips steeply to a considerable depth, valuable contact-metamorphic ores may have formed along the contact below the present workings, but if the contact flattens a short distance below these workings, the ore deposition may have been confined to the reentrant angle formed by the top surface of the sill and the steep east wall of the protruding laccolithic mass, and therefore may be of only small or moderate importance. Because of the absence of contact-metamorphic minerals in the Dictator tunnel in its first 360 feet, the writer believes that the contact dips steeply for at least several hundred feet, and that this contact should be prospected. At a slightly increased depth below the horizon of the Dictator tunnel, if ore is found, it should be much less oxidized and more amenable to concentration than the ore near the surface.

ANIMAS HILLS

HILLSBORO (LAS ANIMAS) MINING DISTRICT

LOCATION AND GEOGRAPHY

The Hillsboro or Las Animas mining district is in the southwestern part of Sierra County. It is crossed by the Rio Percha, a small river which flows in a winding easterly course through the southern foothills of the Animas Hills. Hillsboro, the county seat, is on the Rio Percha, just southwest of the district, at an elevation of 5,236 feet. It is connected by excellent highways with Kingston 9 miles to the west, Hot Springs 35 miles to the northeast, and Lake Valley 17 miles to the south. Rail shipments to and from the district are handled through Lake Valley. Plate VI is a detailed map of the lode mining portion of the district, covering an area of approximately 16 square miles, while Plate VII is a general map of the placer mining area, which includes 18 square miles of territory to the east of the lode mining ground.

The Animas Hills form part of an almost unbroken chain of hills that includes the Sierra Cuchillo in the northern part of the county and the Lake Valley Hills in the southern part. The Animas Hills are fairly rugged and are more or less circular in outline, surrounding a small erosional area known as Copper Flat, which drains to the eastward and is part of the Rio Percha drainage area. The material eroded from Copper Flat has been laid down as an alluvial fan, which merges with the wide gradational plain and river terraces of the Rio Grande valley. (See Plate I.)

West of the Animas Hills, a small bolson-like valley stretches for 15 miles in a north-south direction between the Animas Hills and the foothills of the Black Range. The Rio Percha heads in the Black Range and flows easterly through a box canyon in the Black Range and through similar canyons carved across the axis of the Animas Hills. Where the river traverses the bolson plain it meanders over a flood plain that reaches a maximum width of half a mile.

GEOLOGY

SEDIMENTARY ROCKS

Montoya Limestone.—The oldest sedimentary rock in the Hillsboro district is the Montoya limestone of Ordovician age, which outcrops in a small area in the southeast part of the district. Apparently it has been faulted into view at this place by minor longitudinal and transverse faults, and nothing is known about its thickness.

Fusselman Limestone.—Above the Montoya is the Fusselman limestone of Silurian age, which crops out along a high ridge east of the highway leading to Hillsboro from Hot Springs. Here it forms a prominent cliff or fault scarp of dark to light gray massive limestone. Much of the limestone has been silicified, and vein quartz deposited from hot solutions is prominent. In many places the escarpment is colored brick red and brown, and resembles the outcrop of an enormous vein of quartz. The thickness of this limestone is about 200 feet, which is more than the Fusselman measures at any other place in the county, and it is quite possible that the lower portion of this exposure belongs to the Montoya limestone of Ordovician age, although the writer was unable to make the separation in the field. The limestone east of the main fault scarp has been silicified, and the topmost member now exposed on the dip slope side of the hill has been altered to silica over such a large area that the exposure is locally known as a "quartzite' or a "limestone quartzite." These upper beds of the Fusselman limestone are very irregular and are much brecciated in places, and near the escarpment parallel faulting and brecciation have occurred over a width of several hundred feet. The surface of the dip slope and the face of the escarpment are strewn with huge boulders of iron-stained vuggy to dense quartz. North of the district, along a northward-trending fault contact, Lower Paleozoic beds, probably Silurian, are in contact with the volcanic rocks of the district, as shown in the northeast corner of the map, Plate VI, but no attempt was made to study them, as they are outside the mineralized area.

Percha Shale.—Overlying the Fusselman limestone and in unconformable contact with it is the Percha shale of Devonian age, which is 200 to 250 feet thick. It consists of a lower greenish-black part barren of fossils, and an upper grayish or light greenish-gray part. The outcrops of the Percha shale are restricted to two or three small residual patches on the dip slope of the Fusselman limestone, and to a larger area about half a mile south of the Rio Percha and about due south of the S. J. Macy vanadium mine. Where this formation overlies the silicified Fusselman limestone, the base is silicified and converted to a form of jasper, probably by the same solutions that silicified the underlying limestone. North of the area mapped, Percha shale is exposed in a faulted block of Paleozoic sediments, but this occurrence was not studied in detail.

Lake Valley Limestone.--The Lake Valley limestone of Mississippian age, occurs in only one place. South of Percha Creek a small patch of it rests unconformably on Percha shale, but only the Crinoidal beds, the topmost of the three beds distinguished at Lake Valley (see page 174) have been found. The absence of the Nodular and Blue limestone may be due to erosion prior to the deposition of the Crinoidal beds. North of the area mapped the Lake Valley limestone overlies the Percha shale with about normal thickness.

Tertiary Gravels and Agglomerates.—Gravels and agglomerates of Tertiary age, showing pronounced stratification and in places interlayered with thin flows of glassy rhyolite, fill the depressions and make the terraces between the Rattlesnake mine and the town of Hillsboro, and along the main fault of the district they lie in contact with the high scarp composed of Ordovician and Silurian limestone.

Palomas Gravel.—On the outskirts of the district Palomas gravel is rather sparingly developed as alluvial fans and as thin coverings over the high terraces. In the arroyos and creek beds recent sediments have accumulated, and in the flood plains of the Percha and the Animas they are quite extensive.

IGNEOUS ROCKS

Andesite Breccia and Andesite.—Resting upon the Lower Paleozoic sediments is a mass of brecciated rock called andesite in this report, although Gordon [47] reports an analysis by George Steiger, showing that it is high enough in potash to be classed as a latite. In part this rock is brecciated and in part it preserves the flow characteristics, but the contact between the two phases is very irregular and indistinct. The impression was gathered in the field that the extrusion occurred in several surges, and that at each surge the cooler portions were cracked and brecciated, but that the last portion to be extruded maintained in part its original massive structure. Under the microscope these later portions of the andesite are seen to vary in texture between a typical flow structure with glassy groundmass, and a microcrystalline trachytic groundmass. The phenocrysts are chiefly plagioclase and augite. In some parts of the field the phenocrysts are easily visible to the naked eye, and on some of the augite cross-sections,

[47] Gordon. C. H., op. cit. (U. S. G. S. Prof. Paper 681, p. 275.

which measure as much as three-quarters of a millimeter across, differential weathering along the basal parting planes has developed a radial design of alternating dull and glistening triangular segments. The plagioclase crystals are white, glistening and striated, and are smaller than the augites, being about half a millimeter in length. In general the rock is dark gray to greenish gray, but where brecciated, and especially along fractures, propylitizing solutions have converted the groundmass in large part to green chlorite. Some of the breccia fragments have a purple color. These andesites vary in thickness, and in places they have been deeply trenched by stream action, but it is probable that originally they averaged 1,500 feet or more in thickness. A period of quiescence and slight erosion appears to have intervened between successive flows of the andesite, as is indicated at two places in the district by the presence of thin beds of sedimentary material composed entirely of fragments of andesite, which occur as irregular lenses filling old erosional depressions on the surface of these flows.

Latite and Latite Porphyry. — These rocks include the "birdseye porphyry" flows, remnants of which cap the hilltops north of the Rattlesnake and Opportunity mines and the hilltop near the Caballero workings ; the radiating dikes of the region with which the mineralization is so closely associated ; and the deeper seated portions of these dikes, which have a distinctly porphyritic appearance and much resemble the monzonite porphyry stocks of the area. They are classed as latites and latite porphyries in order to distinguish them from the more basic rocks which enclose and underlie them, and which have been referred to above as andesites.

In hand specimens the latitic rocks have distinctive appearances. In the dikes at the higher geologic elevations in the southern part of the district, the rock is gray to salmon colored and contains a few sparsely scattered small phenocrysts of flesh-colored feldspar in a dense aphanitic groundmass. Oxidation has altered the rock and stained it with bands of yellow limonite, so that the dikes have a distinctive light yellow color as viewed from a distance, in contrast with the darker colors of the enclosing andesites. Where these dikes have spread out into small sill-like masses within the andesites and where they have formed surface flows, the appearance is different, due to more massive form, greater thickness, protective covering, and consequent slower cooling and crystallization. In these masses the rock is distinctly porphyritic and predominantly brown to gray in color. Phenocrysts consist of white to flesh-colored orthoclase with perfect crystal outlines measuring as much as an inch in length, corroded almond-shaped phenocrysts of white plagioclase from which the name "birdseye porphyry" is derived, numerous small specks and crystals of hornblende, and in some phases a few glistening black books of biotite. The groundmass is dense and stony to extremely fine granular in appearance, and in some places it gives the suggestion of a glassy texture, although for the most part the freshness of the groundmass is clouded by the presence of sericite and chlorite.

The third phase is that of the dikes found at a lower geologic level within the basin of Copper Flat. These dikes, although much altered to sericite and bleached and iron stained, are clearly porphyritic in character and in general have a coarser groundmass than have the dikes at higher levels. They show considerable shearing, and quartz has been deposited within the shear planes, often accompanied by pyrite and chalcopyrite. Throughout the dikes, minute cavities formed by removal of pyrite crystals are visible, and the rock is crossed by bands of yellow, purple, brown and black limonite staining. These dikes are 4 to 40 feet wide; in general they are wider than the first-described type, which with few exceptions have a width of 4 to 8 feet.

Under the microscope these rocks show a decided similarity in composition. The phenocrysts consist of orthoclase, plagioclase close to andesine, and hornblende, with biotite locally prominent, particularly where the rock has taken the form of sills or flows. Many of the orthoclase crystals have perfect outlines and are twinned according to the Carlsbad law. The plagioclase phenocrysts for the most part are corroded and are almond shaped. The groundmass is trachytic with some glass present, and often a flow structure is apparent. Laths of orthoclase predominate in the groundmass, and plagioclase is subordinate. Reds and small books of biotite are numerous. The rock contains some magnetite and in places a small amount of quartz. The feldspars are sericitized more or less completely, and the ferromagnesian minerals are chloritized. Secondary epidoje, calcite, quartz and pyrite are present, especially in areas where these dikes occur in proximity with propylitized andesites.

Monzonite.–Two intrustions of monzonite outcrop in the district. One of these forms a prominent hill about a mile northeast of Hillsboro and near the road leading into Hillsboro from Hot Springs. It is irregular in shape and has a maximum length of about three-quarters of a mile. In the basin of Copper Flat in the central part of the district, another mass of irregular outline occurs, having a length from north to south of a little over a mile and an extreme width of nearly three-quarters of a mile. The top of this mass has been eroded, and it now forms the floor of Copper Flat, as shown on Plate VI. Radiating from this central mass of monzonite are the dikes described in the previous section under "Latite and Latite Porphyry." These dikes in general extend in a southeast direction from the stock.

In hand specimens the monzonite of the central cupola or stock is coarsely porphyritic, with large phenocrysts of orthoclase and plagioclase, and occasionally coarsely megascopic grains of hornblende and augite. The groundmass is medium granular to fine granular, and in it numerous grains of feldspar can be seen. In color the rock varies from gray to light buff or cream color where alteration and staining with iron solutions has progressed very far. In the exposure near Hillsboro the monzonite generally is of finer grain and equigranular, with a slightly greater proportion of the darker minerals present, giving it a darker gray to greenish-gray color ; stringers of aplite cut through it in all directions.

Under the microscope the rock of the central mass is coarsely porphyritic, containing large phenocrysts of orthoclase with perfect crystal outlines, smaller crystals of plagioclase near andesine, and hornblende and augite crystals in subordinate amounts. The groundmass is coarsely to finely equigranular and is composed principally of grains of orthoclase, subordinate plagioclase, and some biotite, magnetite and quartz. Sericite, chlorite, calcite and epidote are the common secondary minerals. In general the phenocrysts and smaller grains of orthoclase are fairly fresh, but the plagioclases are altered to sericite. The dark minerals and the groundmass generally are much altered. The rock of the darker colored cupola is similar to that in Copper Flat except in having a greater proportion of the darker minerals in the groundmass, which in turn have produced a larger amount of chlorite in the outcrops. The eastern part of this exposure is still more basic in appearance, and in places where it is in contact with the Fusselman limestone it contains segregations of almost pure biotite. The eastern differentiate of this cupola is distinctly dioritic in composition.

Basic Dikes.—Near the Sternberg shaft in Copper Flat six dikes, which appear at the surface and in the underground workings, are locally called trap. The rock is dark gray and very fine grained and has a few minute crystals of a dark chloritized mineral and some small altered feldspar. This dike rock is somewhat vesicular, and the vesicles are filled with the hairlike form of cuprite known as chalcotrichite.

Near the west border of the monzonite porphyry cupola in Copper Flat, a typical basalt dike cuts through it in a northeast direction for a short distance and then disappears under surface detritus.

Rhyolite and Rhyolite Tuff.—Residual patches of rhyolite flows and tuffs are all that remain of the immense outpourings of these rocks that once covered this region. One of these is in the northern part of the district and caps a low hill north of Dutch Gulch. It is connected with a rhyolite dike that strikes northeast along the northern border of the monzonite porphyry stock. This dike varies between 8 and 12 feet in width, and it is composed of glass along its walls for a width of 12 to 18 inches. In the southeast part of the district two small patches of this material project through the wash south of the highway, and appear to be directly in contact with Fusselman limestone.

Basalt.–Quaternary basalt in the form of flows is found as residual patches at various places in the district. The largest of these is on the mesa just north of Hillsboro, where basalt about 25 feet thick rests on gravels and agglomerates of Tertiary age. Another nearby residual patch has about the same thickneE, The top of Black Peak consists of basalt 75 feet thick, and on the flanks of the hills at points 1 mile and 1 1/2 miles to the west are two other smaller patches. Black Peak is believed to be the source of the basalt flow in this region, as underground workings in the peak have encountered and passed completely around what appears to be the breccia filling in the throat of the old vent.

STRUCTURAL RELATIONS

The south-central part of the Hillsboro district, which contains the most valuable lode deposits, consists chiefly of extrusive andesites and latites and intrusive monzonite with related dikes. In a drill hole from the bottom level of the Rattlesnake mine, limestone underlying the extrusives was encountered at a depth from the surface of approximately 1,150 feet, and these extrusive rocks may be underlain by limestone in most of the district. At the southeastern corner of the district a faulted block of Fusselman limestone strikes slightly west of north and dips to the east. The original position of the topmost bed of Fusselman limestone along the fault scarp was about 250 feet above the collar of the Rattlesnake shaft, so that there is a difference between the two elevations of the top of the limestone of not less than 1,400 feet, a fair measure of the total throw of the fault. West of this fault the Tertiary agglomerates abut against the limestone and against the andesite to the north, so that relations here are obscured. The monzonite mass near Hillsboro has evidently been intruded along the line of faulting at the point where the fault appears to take a sharp bend to the west. The flat remnant of basalt on the top of the hill showing the monzonite exposure and a similar flat remnant on the mesa north of Hillsboro indicate that all the faulting along this zone was not confined to a single fracture plane, and although no evidence of a fault was found in the Tertiary agglomerates west of the main fault scarp, it is quite clear that there has been a total vertical movement of approximately 250 feet between these two masses of basalt. South of the Rio Percha beyond the limits of the map of the district, the main fault scarp of the Fusselman limestone can be traced for over half a mile through Tertiary agglomerates and Palomas gravel which here make both walls of the break. The zone of faulting is from 12 to 20 feet in width, and it is marked by a slickensided outcrop of silicified, brecciated and iron-stained material that has resisted erosion and now stands as a bold outcrop above the surrounding gravels.

North of the central area proper, faulting is again evident along the contact of the limestone with the andesite. Little is known of the relative positions of the rock masses here, except that in the El Oro workings andesite is the country rock on the bottom level at a depth of 500 feet.

Within the central area a wide zone of shearing is evident along the courses of the dikes and veins, from the Bonanza vein on the west through the Rattlesnake and Opportunity group to the Ready Pay vein on the east. This zone of shearing trends northeast through Copper Flat, where shearing and fracturing are visible in the monzonite floor. North of Dutch Gulch two minor faults and an intervening small patch of monzonite have a linear arrangement in a north-south direction and seem to extend the line of shearing in a general way. It is thought that the horizontal component of the total shearing movement has been greater than the vertical component and that the rocks on the west side have been shifted to the north. Along with this general shearing there may have been a slight hinging action, which has dropped the north end of the east block and raised the south end. The monzonite porphyry intrusion and the many dikes and veins in this area have formed principally in the zone of faulting and shearing.

Another type of movement has been confined to the area of andesite in the central part of the district. When the stock of monzonite porphyry was intruded into the andesites and underlying rocks, it exerted a doming effect on these rocks, and the flanks of this dome dip gently in all directions from the center. The intrusion came in along the zone of northeast shearing, but it added to these fractures by causing additional radiating tension cracks, along which dikes and veins formed just as they did along the shear planes.

GEOLOGICAL SEQUENCE

The geological sequence of the district may be summarized as follows : In late Cretaceous time, when igneous activity had started in the southwest corner of the State and elsewhere in the Colorado Plateau region, gentle warping accompanied by local faulting was taking place in Sierra County, and the present ranges were beginning to take on their general form and outline. At Hillsboro a long fault line supposed to be continuous with similar breaks in the Sierra Cuchillo and in.the Lake Valley Hills had developed, and a large block of sediments had begun to rise along the line now indicated by the fault scarp in the south end of the district, the sheared zone in the central portion, and the minor north-south faulting at the northern end. Erosion accompanied this movement, and the sediments were removed until only patches of Lake Valley limestone and Percha shale were left on the surface of partly eroded Fusselman limestone. In early Tertiary (Oligocene) time, widespread outpourings of lava occurred. These lavas issued from many vents, and in the Hillsboro area the andesites probably found an easy path of emergence at several places along the fault break already formed. The great weight of these superimposed lava flows probably caused a sinking of small blocks of sediments on either side of the main fault. Continued movement relative to the limestone blocks to the south, especially at the point of the projecting angle now occupied by the southern cupola of the monzonite stock, caused a shearing between the two buried blocks and continued the line of original faulting through the newly erupted andesites. This period of activity was followed by a short period of erosion, during which sediments consisting of andesitic detrital material were laid down in a few small areas. Then came the period of intrusion of the monzonite stock and associated monzonite porphyry dikes, porphyritic latite dikes at a higher level, and the local sills and flows of latite porphyry. This period was followed by one during which thick rhyolite flows and tuffs were laid down over the entire region. From the end of Oligocene time to the beginning of the Pleistocene was a period of quiet and of continuous erosion, during which the various fault blocks were undergoing gentle but fairly continuous readjustments of position. It is supposed that the central block at Hillsboro was gently rising at this time. The arched up and fractured central part of this area was eroded away in cycles, following each rise of the central mass, and a large alluvial fan was built out to the east of the range. Pleistocene time was a period of basaltic flows in the region, followed by the formation of Palomas gravels, and these in part were covered by still later flows of basalt. Faulting continued on at least one major plane of movement almost to the end of Pleistocene time, as indicated by the continuation of the fault scarp in Fusselman limestone southward through the gravels south of the Rio Percha.

ORE DEPOSITS

CHARACTER

The ore deposits of the Hillsboro or Las Animas mining district are of four general types as follows : (1) Fissure veins in andesite flows, (2) disseminated deposits in monzonite porphyry, (3) replacement deposits in limestone, and (4) placer gold deposits. (See footnote, page 59.)

Fissure Veins in Andesite Flows.—Most of the production of this district has come from fissure veins in the andesite, and particularly from those in the southern part of the district. It is believed that the source of the veins, as well as the accompanying dikes, is the deep-seated part of the monzonite porphyry stock in Copper Flat. The cupola northeast of Hillsboro and other small masses of monzonite porphyry in the district are considered to be of the same age and to have come from the same deep-seated reservoir.

Within Copper Flat erosion has bared the lower portions of the veins within and adjacent to the stock, and here the important minerals are chalcopyrite, a small amount of bornite, pyrite and accompanying gold and silver. Quartz is the common gangue mineral, and calcite is subordinate. Molybdenite is an accessory vein mineral, and at one place in Copper Flat tetradymite, bismuth telluride, was found in a small shoot in a vein at the surface, accompanied by pyrite and gold. The order of the deposition of these veins minerals, as determined under the microscope and illustrated in figure 10, was quartz, pyrite and gold, followed by chalcopyrite, bornite, quartz and subordinate calcite. Following this mineralization, movement in the veins occurred, and the openings formed were filled with barren quartz in which comb structure is well developed. In most parts of the veins the sequence of ore deposition is obvious.

The veins of this type are continuous over long distances, and are generally 2 to 8 feet between walls, although a few are considerably wider. The more-productive veins accompany dikes of latite. Some of these veins are located on one wall of the dike, while the other wall of the vein is a low-grade seam of gouge, or both walls are of gouge with vein quartz occupying irregular seams and fractures in the dike rock itself. In other veins the dike forms one wall of the vein, along which in the andesite country rock is a zone of brecciated andesite 2 to 4 feet wide, with a seam of gouge either next to the dike or in the andesite on the opposite wall. (See figure 10.) In places irregular stringers and veinlets of mineralized quartz pervade the mass of brecciated andesite, and in others a well-defined vein of quartz and other minerals 2 to 6 inches wide occurs on one of the walls, or at some place between walls. In many places pyrite in fine grains is distributed throughout the andesite or dike rock between the walls, and the rock is much bleached and altered to sericite and kaolin or to chlorite. The andesite adjacent to the veins is propylitized in diminishing amounts for several feet.

Veins of another type occupy fractures or small shear zones in the andesite where latite dikes seem to be absent. This type of vein has so far proved to be of little economic importance. In the shear zone, the mineralized portions of the veins are apt to be discontinuous lenses distributed *en echelon* along the planes of shearing. The vein may follow one shear plane for a short distance and then pinch out, to take up again in a parallel plane that may be from a few inches to 20 feet away in either wall. Normally in this type of deposit, just before the lens pinches out entirely, a careful examination of the walls will show a small stringer of ore, from knife blade dimensions to an inch or more in width, taking off at an angle with the wall, and if this is followed, a new lens is very apt to be picked up. Failure to find the connecting stringers of ore entails crosscutting blindly into the walls at horizontal and vertical intervals. In places numerous cross faults interrupt the continuity of a vein or lens, usually with only a few feet of lateral movement, and close attention to

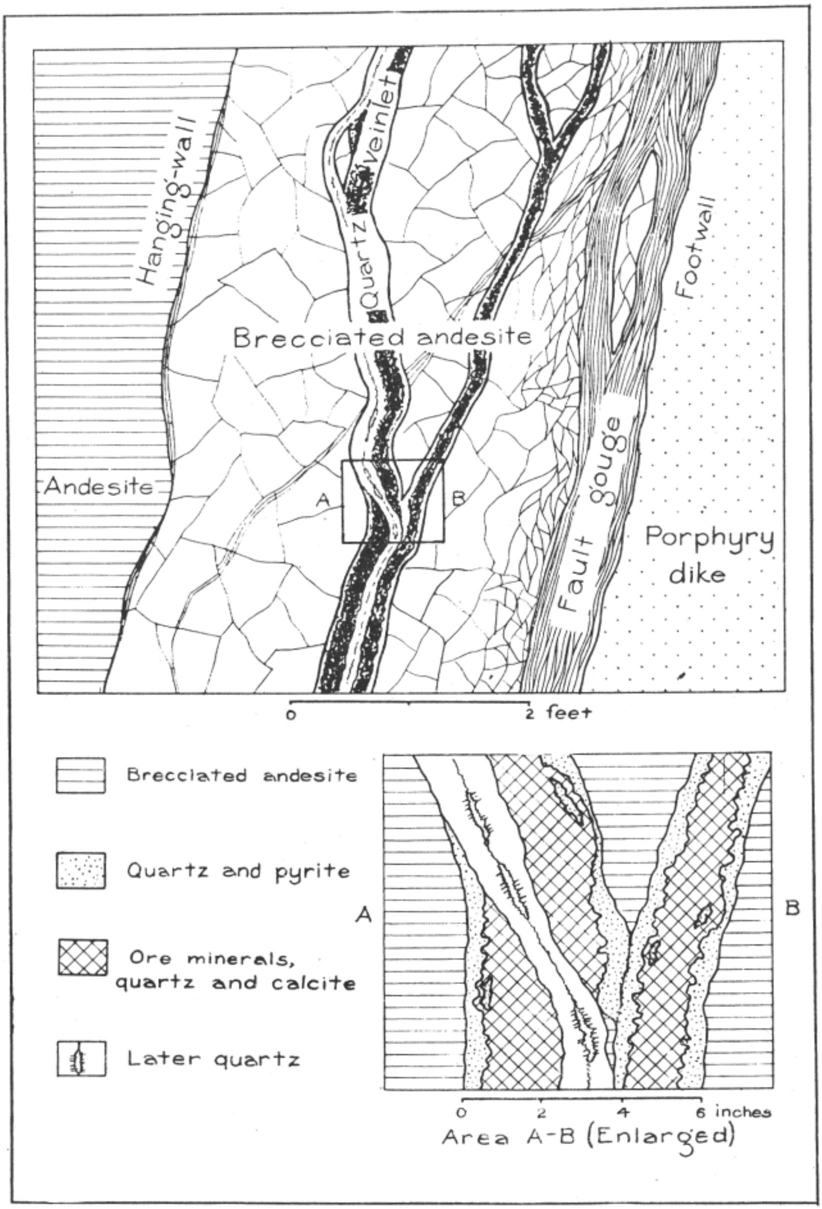


FIGURE 10.—Typical vein structure in the Hillsboro (Las Animas) mining district.

the direction of drag of the fault gouge may determine the direction in which to crosscut.

Within the veins of all types in the andesite, the ore occurs in shoots and pockets. The veins proper pinch and swell at more or less regular intervals, and in general the richer ore is in the narrower parts of the veins. In not a few places the wider parts of the vein have been filled with the early quartz, leaving a central narrow opening continuous with the narrow part of the original opening, and this has been filled with the later ore minerals. The original fracture surfaces were slightly curved. Later shearing has brought concave areas of the walls opposite each other to provide lenticular openings, while convex parts opposite have constricted the openings to a small width. Ore shoots in general are of short length along the drift, but they may extend vertically for several hundred feet. Exceptions to this general statement are the Bonanza, Rattlesnake and Opportunity mines, where several shoots of ore on each vein were so nearly adjacent that they were mined in one stope with a horizontal length of several hundred feet along each vein, but with a somewhat smaller vertical dimension. (See figure 13.)

Disseminated Deposits in Monzonite Porphyry.—The southern nose of the monzonite porphyry stock in Copper Flat near the Sternberg shaft contains a considerable area of sheared and fractured rock in which the oxidized copper minerals, malachite and azurite, are abundantly present, together with limonite and the secondary sulfide, chalcocite. In the Sternberg workings much cuprite, most of which is the variety chalcotrichite, was found in vesicular cavities in basic dikes, and in the wallrock, pyrite and chalcopyrite coated with chalcocite were encountered. Water stands at 60 feet below the collar of the Sternberg shaft and at about the same depth in other short shafts in the district, indicating that erosion within this basin has been operative at a slightly greater rate than has oxidation. In specimens of ore obtained from the dumps of several shafts 50 to 60 feet deep in the flat below the Sternberg shaft, minute specks of pyrite and chalcopyrite are disseminated through partly sericitized monzonite porphyry, and veinlets and small seams of these minerals traverse the rock in all directions. Along the major stringers these primary minerals have been largely converted to chalcocite, while the finer seams and the disseminated specks are coated with only a thin film of this sulfide. At the Chance mine the monozonite has a distinctly granitic aspect, and it is cut by stringers of pegmatite consisting principally of biotite, with quartz, orthoclase, pyrite and chalocopyrite. In the Copper King shaft, 80 feet deep, there are pegmatite stringers of this same type, but the sulfide content is higher and the surrounding rock is replaced with much pyrite and with chalcopyrite which in turn has been partly replaced by chalcocite.

Replacement Deposits in Limestone.—These deposits are largely confined to the southern part of the district and consist there of small, irregular pockets of lead-vanadium-molybdenum ore replacing the Fusselman limestone along bedding planes. Since the deposition of the ores the overlying Percha shale has been entirely eroded away. Much of the primary galena has been oxidized, and the lead is now in the form of anglesite, cerusite, wulfenite and vanadinite. Endlichite, a rare variety of vanadinite in which arsenic replaces the chlorine, occurs in these pockets. Residual patches of galena, coated with concentric shells of anglesite and cerusite, are usually present, even in the most highly oxidized bodies of ore. For the most part the cerusite, vanadinite and wulfenite, together with considerable limonite, form a coating on silica boxwork, and this boxwork, in turn, may enclose residual grains of galena. These rich pockets change abruptly to a low-grade galena-calcite-quartz primary ore of no commercial value. Along the bedding planes several of these oxidized bodies of ore may be connected by small, irregular and often not easily followed stringers of oxidized ore, which may be coated with caliche and honeycombed with solution cavities. In this part of the district much manganese and manganiferous iron ore has been mined from pockets in the limestone.

Placer Gold Deposits.—The gold placer deposits of the district consist for the most part of alluvial fans, the material of which has been derived from the erosion of the Animas Hills, particularly that part which once lay over the area now called Copper Flat. It is estimated that more than 1,000 feet of rock has been eroded from above the present top of the Animas Hills. The upper part of the original range was composed of rhyolite tuffs and flows that probably contained very little gold. The lower parts of the fans consist largely of these rocks, and gold is absent.

The upper parts of the fans are composed of andesite fragments, with pieces of latite and monzonite in subordinate amounts, these being the next lower rocks in the sequence shown in the Animas Hills. It is within this material that the particles of gold and of black sand, much of which contains gold, are found lying on layers of "false bedrock." The principal fan in the district is that formed by the drainage toward the east out of Copper Flat, principally through Grayback Gulch but in part through Dutch Gulch. Erosion to the south on the outside slope of the hills, through Wicks Gulch and down the draws from the Rattlesnake and Opportunity mines, although much less important in quantity of detrital material moved, has nevertheless produced some high-grade placer ground, from which several small fortunes are reported to have been made. The original discovery in the district was made at the placer deposits of Wicks Gulch.

Nuggets of gold worth several dollars each have been found near the heads of the placers, but for the most part flattened grains about the length and width of a grain of wheat and about half as thick represent the upper limit of size. From this size the particles grade down to thin flattened specks of gold so small as to readily escape detection by the unaccustomed eye. Most of the gold near the heads of the fans is coarse and easily recovered, and the exceedingly fine gold becomes relatively more abundant at distances of over a mile from the heads. When recovered by dry methods the particles'of gold may have a gray or a rusty appearance due to a film of caliche or of limonite, but when wet methods have been used they have been cleansed of these films and are a beautiful reddish-golden color. The black sand that is associated with the gold consists in part of magnetite and the other dark and heavy accessory minerals that have formed in the igneous rocks. One of the most important constituents, however, is limonite, derived from the pyrite of the veins by oxidation. The pyrite in the veins carries most of the gold in the district,' and its oxidation and disintegration have liberated the gold. In part, the crystals have been oxidized into pseudomorphs of limonite, which retain the gold. These pseudomorphs are sufficiently abundant in some parts of the placer ground to give the black-sand concentrate, after all free gold particles have been removed, commercial value as a product to be shipped to the smelter for treatment.

SECONDARY ENRICHMENT

Secondary enrichment of the veins in the Hillsboro district is of two types. One of these has resulted in a residual concentration in the oxidized ore of gold and subordinately of other metals, due to the dissolving and removal of the more soluble minerals. The sulfides of iron, copper, silver and zinc have been oxidized with the formation of various soluble sulfates of these metals and of free sulfuric acid, and these products have been carried downward by meteoric waters. Acid-reacting waters have altered the various vein and wallrock minerals, principally to convert the feldspar and sericite to kaolin, and the ferromagnesian minerals to chlorite. These soft, earthy secondary products have been partly removed by the circulating ground water, and as a result, the massive, compact primary ore has been altered to a porous and much lighter ore containing practically all of the original gold. The upper oxidized parts of the veins that were profitably mined in the early history of the camp were the end product of this type of enrichment.

The other type of secondary enrichment has been due to the removal in solution of the copper and silver from the oxidized portions of the veins and their deposition as the secondary sulfides, chalcocite and argentite, which replace the chalcopyrite and pyrite of the primary ore in the zone of precipitating conditions at and near water level. The secondary sulfide minerals form films coating grains of primary sulfide minerals, and fillings in cracks and seams within the grains of these minerals. In places, as along the larger fractures, the secondary sulfides have largely replaced the primary sulfides, only residual grains of the latter now being present within the mass of the new minerals. In other places, as along thin seams and on disseminated grains, it is usual to find only a thin film of secondary minerals coating grains of primary minerals that largely retain their original outline. Copper is the metal most affected by this process, and valuable copper deposits may result from it. Silver is less soluble than copper and more easily precipitated and hence it is usually deposited through a wider vertical zone, and less often forms highly concentrated bodies of ore at water level. Sphalerite is highly soluble, and zinc may migrate farther than either silver or copper ; in part, however, it may remain in the oxidized ore as the carbonate, smithsonite, or as the hydrated silicate, calamine. Lead only occasionally forms the secondary sulfide, being more often oxidized to the sulfate, anglesite, or to the carbonate, cerusite, immediately adjacent to the original galena. This process has been much less important than the gold enrichment in the oxidized portions of the veins.

In veins that outcrop along ridges, where erosion has been slow, free-milling gold in an oxidized and porous gangue has been found and profitably mined to a depth of 500 feet, but where the veins outcrop in arroyos, or at other low points where erosion has been rapid and has outstripped oxidation, sulfides are generally found at or near the surface, and only small, scattered bodies of free-milling gold ore have been worked in these localities. An intermediate condition, giving a better balance between the processes of oxidation and erosion, has been widespread in the district. Under this balance, oxidation has progressed in a normal manner, and the gold has been freed of much of its containing gangue and has been converted largely to the free-milling form. As a cyclic process, following the oxidation of the outcrops and due to periodic changes in the elevation of the land surface caused by continued faulting along old lines of weakness, erosion has followed more or less closely and has kept the completely oxidized zone worn down to a minimum thickness. It is possible that future mining operations near water level in these areas will disclose workable secondary enrichment deposits of copper and silver.

HISTORY AND PRODUCTION

Gold is reported to have been first discovered in the Hillsboro district in 1877 by two prospectors who picked up float on the hillside below what is now called the Opportunity mine. Assays were made of the float rock at an old mill on the Mimbres River, and the returns of $160 per ton in gold and silver caused considerable excitement. In a short time ore was discovered at the Rattlesnake vein, just to the west of the Opportunity. In August, 1877, the first house was built on the present site of the town of Hillsboro.

Placer gold was found in November, 1877, in Rattlesnake and Wicks gulches, and it is reported that during the winter of 1877-78 a miner named George Wells recovered in Wicks Gulch $90,000 in gold dust and nuggets, which he sold in Hillsboro. Placer gold was discovered in the stream beds and the alluvial fans surrounding the mineralized area of the Animas Hills, and hundreds of pits were dug following out the small runs of high-grade material that had accumulated on the first false bedrock. Except for small piles of hand-sorted boulders and an occasional slight depression in the surface of the ground, no evidence remains of the great amount of work that was done during these early years, so effectively have the wind and flood waters filled in and leveled off the workings.

Ore was first mined from lodes in the district in 1877. It amounted to about 5 tons and was hauled to the mill on the Mimbres River. The early production was treated in arrastres that were erected in Hillsboro in 1877. In 1878 the original arrastre in Hillsboro was supplanted by a 10-stamp mill, the foundations of which are still standing.

Work in the camp has been intermittent. Following the first period of important production, which ended in 1893, there was a moderate revival in 1906. Many old properties were opened up and investigated, and some production resulted. During the post-war period from 1918 to 1921, the Rattlesnake and the Opportunity mines were reopened and some development work was done, but only small shipments were made. During 1931-1933, activity was more general and more persistent in the camp, and mining or development work was done in the Bonanza, Opportunity, Sherman, Ready Pay and El Oro properties, while nearly all the other properties in the district were examined. During this later period, placer mining was also carried on. Many individuals were panning or rocking gold from the gravels, but most of the richer runs had already been discovered and removed, and it was only occasionally that such small-scale operations netted the worker more than a bare subsistence. Large-scale placer operations adapted to desert conditions and suited to the recovery of gold from much lower grade gravels than could possibly be handled by hand methods were tried out in Dutch Gulch by two companies.

From 1911 to 1931 inclusive the Hillsboro district produced approximately 6,506 tons of ore, divided as follows : Gold ores, 836 tons ; gold-silver-copper ores, 5,470 tons ; copper ores, 200 tons. The total value of this ore was approximately $150,000.00.

The total production of the camp prior to 1904 has been estimated by F. A. Jones to have a value of $6,750,000. From various local sources the writer gathered information permitting him to make a partial and approximate division of the total production from 1877 to 1931 inclusive into that coming from various individual mines and from restricted parts of the district as shown in the following tabulation. In the preparation of th table Mr. W. H. Bucher of Hillsboro rendered invaluable assi: ance and supplied most of the figures.

Estimated Value of Production of the Hillsboro District, 1877 to 1931, Inclusive

Placers:		
Rattlesnake placers	$ 40,000	
Wicks Gulch	100,000	
Luxemburg	2,000,000	
Miscellaneous	60,000	
Total		$2,200,000
Lode Mines:		
Empire-Bickford	$ 1,000	
Garfield-Butler	40,000	
Bigelow	5,000	
Mary Richmond group	600,000	
Bonanza group	700,000	
Rattlesnake group	1,500,000	
Opportunity group	670,000	
McKinley-Sherman-Caballero	21,000	
Ready Pay mine	10,000	
Wicks group	150,000	
85 Mines	5,000	
Chance-Christmas-Feeder-Extension	6,000	
Sternberg-Copper King group	8,000	
Happy Jack	6,000	
Tripp-Homestake	50,000	
El Oro-Andrews	200,000	
Miscellaneous	728,000	
Total		$4,700,000
Total, placers and lode mines		$6,900,000

MINE DESCRIPTIONS

GENERAL FEATURES OF WORKINGS

Mine workings are fairly extensive in the Hillsboro district, but none of them are deep enough to have encountered serious difficulties from underground water. The deepest shafts in the district are the Richmond, Rattlesnake, Opportunity and El Oro, each of which reaches to approximately 500 feet below the surface. The Bonanza mine, developed by tunnels, has attained a depth of 500 feet under the highest point of the hill.

Development work has consisted chiefly of drifting along the veins on each level, following the high-grade streaks that occur within the veins, and of drifting between the walls of the veins where the ore has pinched out. The ore has been mined, as a rule, by a modified cut-and-fill method of stoping. The high-grade ore has been sorted or cobbed out of each cut made across the back of the stope and transported through stope chutes, and all low-grade material has been left behind as stope fill. If this low-grade material was not sufficient to fill the stopes, they were left open, or the filling was completed with waste rock. Due to the facts that only small amounts of ore were blocked out ahead of stoping operations and that the conditions in which the stoped out areas were left is uncertain, very little is known as to tonnages of ore and stope filling which may be available for future mining operations.

GARFIELD-BUTLER GROUP

The Garfield-Butler group, consisting of three claims, is on the southwest slope of Empire Peak, one of the highest peaks of the Animas Hills, and in the extreme southwest portion of the lode-mining area. The claims, named from southwest to northeast are the Silas, Butler and Garfield. They adjoin end to end, and are located so as to include along their center line a long dike of latite porphyry, on the east or footwall side of which faulting, brecciation and mineralization have occurred. (See figure 11.)

On the Silas claim about 500 feet from the north end line a shaft 140 feet deep has been sunk, and a short drift is reported to extend to the north. The drift was driven in brecciated andesite, but a latite porphyry dike forms the west wall, and there is a seam of gouge on the east or footwall side. The average width of the vein between the dike and the seam of gouge in the andesite is about 4 feet. In places the dike rock is fractured and brecciated, and mineralization extends into the dike. The fractured ground is filled with a network of rusty quartz stringers, in which sulfides are locally abundant. The minerals are pyrite, chalcopyrite, galena and sphalerite ; and secondary limonite, chalcocite, malachite, azurite, and efflorescent coatings of copper and zinc sulfates. Ten tons of ore assaying from $80 to $90 a ton in gold was sorted from the rock broken in the drift, according to report, and the full width of the vein or drift is said to average $10 per ton, principally in gold but with some silver and copper.

Nearly 200 feet from the south end of the Butler claim, there is a 40-foot shaft, from which ore has been stoped along the south side. The vein here is 3 feet wide, and it is reported that the ore mined from the full width of the vein and treated in the Bonanza mill amounted to 40 tons and had a value of $25 to $30 per ton in gold. From a 50-foot shaft sunk on the vein 200 feet farther north, 15 tons of development ore was shipped, which was valued at $18 per ton. Near the middle of the claim a tunnel 350 long has been driven in a northerly direction along the vein. It was planned to continue this tunnel farther to prospect under a fair-sized outcrop of favorable-looking gossan near the top of the hill to the north. In the tunnel just beyond the portal a high-grade streak was encountered, which was followed for 100 feet. It varied in width from an inch to 2 inches and assayed $75 to $80 per ton. In this drift the whole vein is from 3 to 4 feet wide and averages $5 to $6 in value, indicating that the fractured andesite between walls, exclusive of the quartz veinlet, assays about $4 per ton. Beyond this shoot of ore the quartz stringer dwindles in width to a knife-blade seam, but the value of the whole width of vein rises to $6 or $7 per ton.

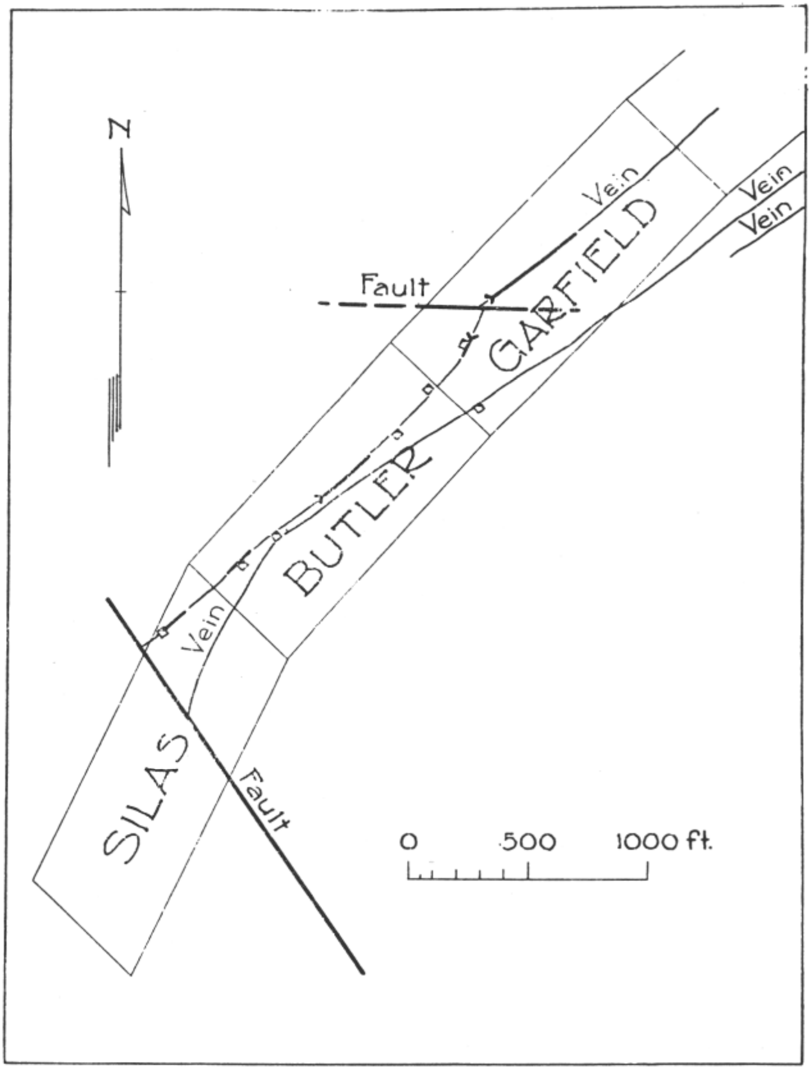


FIGURE 11.—Claim map of the Garfield-Butler group showing vein system and mine workings.

At the northern end of the Butler claim and extending int(
the Garfield claim a small area has been prospected by severa

pits and small open cuts. Several years ago a carload of ore was shipped from these workings, and more recently another carload was shipped. These shipments are said to have had a value of about $40 a ton. The quartz seam within the vein widens to 6 or 8 inches and contains $40 per ton in the valuable metals. The vein here is not over 2 feet wide, and it is entirely within the latite porphyry dike. The average value over the full width of the vein is from $8 to $10.. At the southern end of the Garfield claim is a 60-foot tunnel, driven in a southerly direction toward the pits and cuts just described, from which a 30-foot winze has been sunk. Shipments of $30 ore are reported to have been sent from here to the Bonanza mill. This ore came from an extension of the vein on the Butler claim, but the vein appears to split toward the northeast, and the ground between the two branches is highly kaolinized and slightly mineralized beyond the vein walls. The dike is locally much wider, and there is a 12-inch seam of gouge on the footwall side of the main branch of the vein. The porphyry dike is fractured and brecciated for a width of 4 feet, and along the west or hanging-wall border of this fractured zone is a 2-inch streak of sulfide and oxidized ore, much stained with copper. Barren or slightly mineralized andesite breccia makes up the remainder of the zone, which is said to average $6 in value, with the high-grade portion averaging $40. Just north of this tunnel a fault striking nearly due west displaces the main vein and the split portion slightly to the west. Along the main part of the vein a tunnel 150 feet long has been driven into the hill in a northeast direction. From surface workings above this tunnel, Jose Arelet mined ore in 1878-1879, which is supposed to have netted him $10,000 after treating it in arrastres in Hillsboro. From 1897 until 1900, Robin and Macy drove the tunnel on the vein and stoped out ground above it which was not reached by the Arelet surface workings. They also sunk a winze frdm the tunnel level to a depth of 30 feet, and did considerable underhand stoping at various places along the tunnel. The stopes have a total length of about 150 feet. At a still later date, A. L. Bird of Hillsboro extended this winze to a depth of 60 feet below the tunnel level. At 40 feet he encountered a quartz veinlet which was followed to the northeast for 108 feet, and from which ore worth $4,000 was shipped in two products, one averaging $100 per ton and the other $40 per ton in gold, silver and copper. North of the fault the ground between the two branches of the vein is well kaolinized and mineralized, but the split portion appears to converge and join with the main vein at a point near the end of the tunnel.

BIGELOW GROUP

The Bigelow group, consisting of three full-sized claims end to end, includes two parallel oxidized vein outcrops on the southwest slope of Richmond Mountain at an altitude of 6,000 feet. The westerly outcrop is known as Bigelow No. 1 and as the Frick vein. The easterly outcrop is probably an extension of the Richmond vein that outcrops on the northeast slope of Richmond Mountain. The latter vein is known as the Bigelow No. 2. Both veins strike N. 20° E. and dip 80° NW.

The Bigelow No. 1 vein is developed by a 400-foot tunnel, which is reported to have exposed a mineralized seam the full length with a value of $3 to $80 per ton. Near the mouth of this tunnel a winze 25 feet deep is said to have exposed 12 to 18 inches of $45 ore in the bottom. Bigelow No. 2 vein is partly explored with a tunnel 150 feet long, said to be in good ore, and at the bottom of a 35-foot winze at the end of this tunnel, the vein is reported to be 3 feet wide and to average $19 per ton in free- milling gold.

MARY RICHMOND MINE

This property consists of two full-sized mining claims located end to end, covering the outcrop of the Richmond or Mary Richmond vein on the northeast slope of Richmond Mountain. The dike along which the vein occurs is crossed by several minor faults and it has a number of branches, but it can be traced almost continuously from the monzonite porphyry cupola in Copper Flat to the wash at the southern end of the Garfield-Butler and Bigelow properties at the extreme southwest border of the area. Where the dike and its branches cross the top of the mountain, there is a remnant of a latite flow, which may be a local development of the dike system. In some places within this flow remnant, the course of the dikes may be traced by a fracture or series of parallel fractures that have become leached and iron stained as a result of oxidation ; in other places the flow rock appears to be of different texture and of finer grain along the trend of the dikes ; and in yet other places the writer was unable to detect any evidence that the dike rock was subsequent to the flow or that along the trend of the underlying dikes any planes of weakness had been developed in the flow rock.

The mine has been developed by three tunnels. These consist of an upper tunnel near the crest of the hill and 300 feet long, an intermediate tunnel at the level of the shaft collar, which is 860 feet in length, and a lower tunnel 160 feet below the collar of the shaft and 40 feet above the second level, which is 460 feet long. An inclined shaft follows down on the vein for 500 feet, and from it several levels have been driven. The first level is 100 feet below the collar of the shaft and extends 785 feet to the southwest and 40 feet to the northeast. The second level is 200 feet below the collar and extends 710 feet to the southwest and 200 feet to the northeast. The third level, at a depth of 300 feet, extends 320 feet to the southwest and 185 feet to the northeast. The water level is just below the third level, and the workings below it are flooded, but it is reported that there are two deeper levels totaling 1540 feet in length. The total amount of drifting on the vein in this mine is probably 3,800 feet, exclusive of the three surface tunnels. Figure 12, drawn from descriptions in a private report, shows the lateral development work in this mine. The property at one time had a framed shaft house, blacksmith shop, storehouse and bunkhouse. The machinery consisted of a single-drum steam-driven hoist equipped with cage and cable to hoist 500 feet and a 60-H.P. boiler and accessories. At the present time nothing remains but the bunkhouse and the blacksmith shop.

The vein strikes N. 22° E. and dips 75° to 85° NW. It is from 3 to 8 feet wide and averages 4 feet between walls, and con-

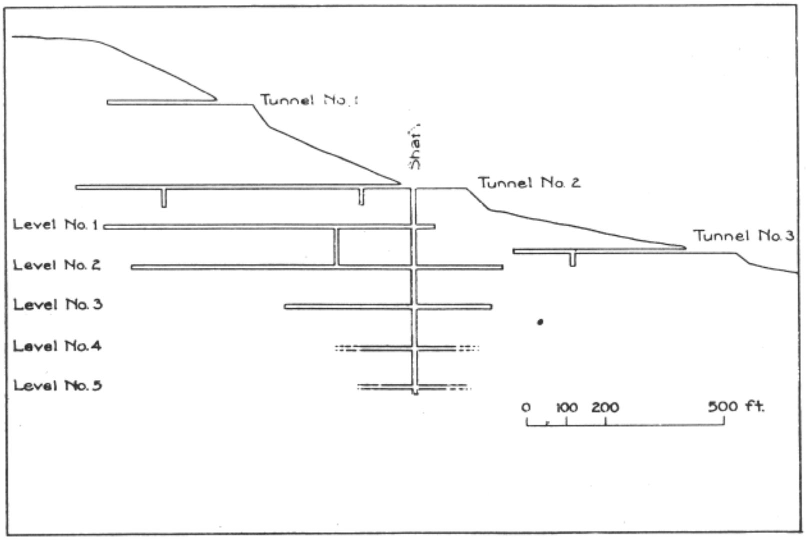


FIGURE 12.—Longitudinal section showing relative location and approximate lengths of levels in the Mary Richmond mine. Stoped areas not indicated.

sists of fractured andesite traversed by stringers of vein matter. In most places the dike makes the hanging-wall of the vein, and the footwall consists of gouge from 1 to 15 inches wide. In places the dike is much fractured and mineralized and constitutes the vein. The primary minerals are pyrite, chalcopyrite, galena and sphalerite. The gold is both free and in the pyrite and chalcopyrite. Calcite occurs in bunches close to the seam of gouge. The andesite wallrock and the fractured andesite within the vein are propylitized, and within or near the vein the feldspars are completely sericitized. Oxidation in the vein above water level has resulted in the loss of sulfide minerals and the formation of silica boxwork and limonite in the sulfide molds, a complete alteration of the sericitized feldspar to kaolin, and thorough bleaching and iron staining of the rock mass within and adjacent to the vein.

Residual sulfides occur in the vein near the surface, even where the vein material appears to be thoroughly leached and oxidized. At greater depths secondary sulfides of copper and silver have been deposited as replacement films and as fillings in minute cracks within the grains of primary pyrite and chalcopyrite. Spurs of the primary vein matter alternating with oxidized material may be found on any level from surface down.

Considerable ore has been mined from Tunnel No. 1. A sample of waste fill from one of these old stopes assayed $4.75 in gold and silver, and in unstoped portions of the tunnel a 12-inch vein that appeared to be well mineralized assayed $5.90 in gold and silver.

Tunnel No. 2 was partly caved a short distance from the portal, and was not inspected beyond the cave. The vein is largely in the fractured dike rock, and it is not oxidized as much as at other places. The sulfide mineralization is strong, however, and the ore is reported to average $12 to $14 per ton. Crosscuts from the main drift have cut small parallel oxidized veinlets in the andesite footwall, but apparently they have not been prospected. Two winzes are said to have been sunk from this tunnel to an average depth of 40 feet on particularly rich portions of the high-grade seam, and in one of them a stringer of ore assaying $181 is reported.

On Level No. 1 from the shaft a horse of latite porphyry causes a split in the vein for almost the entire length of the south drift. Prospecting by crosscuts to the hanging wall seam has exposed ore assaying about $6.50 per ton. The footwall mineralization is stronger, and at 180 feet from the shaft a winze sunk to the 200-foot level is reported to be in a seam of ore 12 inches wide having a value of $22 in gold and a total value of $25.

Tunnel No. 3, the lowest tunnel, has in the back a vein of ore 2 feet wide that is said to assay $11 per ton. This vein starts at a point 100 feet from the portal, but a few feet farther in, the tunnel was caved, and it could not be examined further. At 280 feet from the portal a 30-foot winze is reported to have been put down on a hanging-wall streak 2 feet wide that is said to assay $16 a ton. On the footwall side a streak 18 inches wide assaying $8.60 is reported. The ore 'exposed in this tunnel is said to be sulfide ore that would concentrate without difficulty, although that which the writer saw near the portal was certainly partly oxidized.

Level No. 2 shows no evidence of a horse of waste, the vein here being strong and well defined. The high-grade seam is reported to be 8 inches wide and to assay around $25 ; a hand-sorted shipment from this seam is said to have contained metals worth $48. Level No. 3 exposes an 8-inch streak of ore. It assayed $14 per ton, and from it hand-sorted shipments averaging $35 per ton are reported.

No data are available on the workings below the third level, but reports indicate that the ore is primary and that it probably assays close to $10 per ton. The quantity of this material that had been exposed in the old workings is unknown. Very little information was obtained as to the value of the low-grade material making up the full width of the vein, but assays of old stopE fills, dumps, and a few miscellaneous underground samples indicate that parts of this material might assay about $5 per ton, and that of this total possibly $4 would be due to the gold content

Estimates of tonnages and grade of ore at the Richmond Mine, which were obtained from three different sources, havE been reviewed by the writer, and although they have an extremf variation of more than 100 per cent he has combined and modified them into a table of possible tonnage available for futurE operation, which is given below. The table includes only thE material left in the old workings during the course of the forme] operations, and in no sense does it set a limit on what futurE rinvP1nnment ninrk in fin. min..

Estimate of Ore Reserves at Richmond Mine

	Tons	Gross Value per Ton
High-grade ore in place	8,220	$12.75
Low-grade ore in place	10,000	5.00
Old stope fills available	3,500	4.75
Old dumps already worked over	30,000	3.50
Total possible available ore	51,720	$ 5.35

A mill was put into operation on this property in 1893, and it was destroyed by fire in 1894. Records of shipments during this period total $69,214:73 in value as follows : Ore, 192.75 tons worth $20,259.56; concentrates, 244.49 tons worth $14,016.92; and bullion, 1,899.95 ounces worth $34,938.25. In addition to the above, Mr. Max Kahler, for a number of years the agent for this property, estimates that since 1894 over $40,000 has been received from smelters on numerous small shipments made from surface and various mine workings on the property. Shipments made prior to 1893 bring the total value of the production up to about $600,000.

Estimates of mining and milling costs for this ore vary from $4 per ton for ore in place in the stopes to $2 per ton for reclaiming and milling the ore dumps. In the writer's opinion these are fair assumptions for ore in place, but they would not include the cost of prospecting for and developing new ore, or capital costs, such as rehabilitation of the mine, new construction, overhead, taxes, etc.

BONANZA MINE

The Bonanza mine is in the arroyo east of the Garfield-Butler and Bigelow groups and west of the arroyo in which the Rattlesnake vein is located. The vein has been prospected by three tunnels. The upper tunnel was reported caved and was not visited by the writer. The intermediate tunnel extends cornpletely through the mountain, a distance of 3,500 feet, but is badly caved at a distance of 2,200 feet from the south portal. The lower tunnel is blocked by a cave 1,800 feet from the portal, but it is reported to be approximately 2,000 feet long.

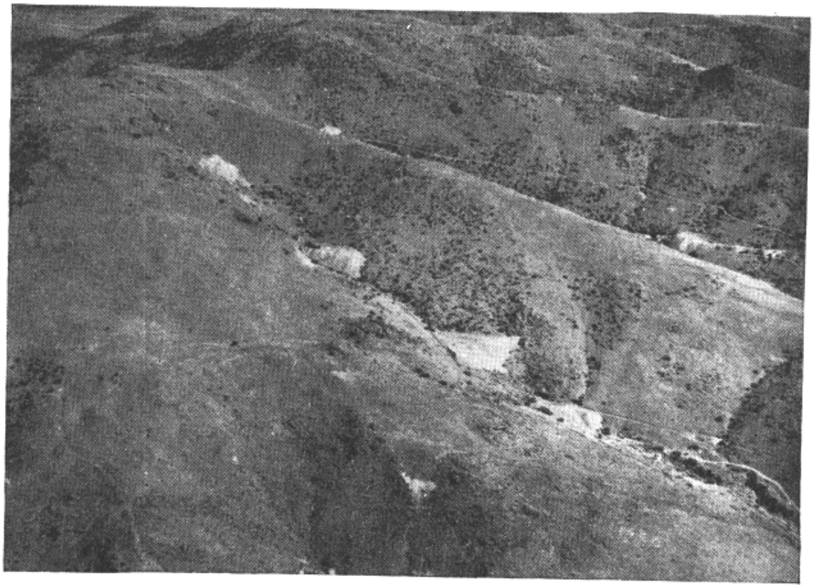
The ore consists of pyrite, chalcopyrite, and small amounts of sphalerite and galena in a gangue of quartz and a little calcite. The sulfides carry gold and silver. As in the other mines of the district, the upper portion of the vein is oxidized and contains free-milling gold. The zone of oxidation and enrichment is not regular, however. Considerable free-gold ore has been mined from the lower tunnel level, and sulfide ores have been shipped from residual patches and upward-projecting spurs of primary ore in the upper and intermediate tunnels. The secondary minerals are chalcocite, argentite, limonite, calcite and silica. In the shallow workings the gold is in limonite and silica box-work in the spaces formerly occupied by pyrite and chalcopyrite. The free gold seen by the writer was quite coarse, and several sacks of hand-sorted sulfide ore gathered during operations in 1931 contained numerous pieces in which broken pyrite crystals were prevented from falling apart by heavy wires of gold. A small amount of bismuth is present, probably as the sulfide.

The Bonanza vein strikes N. 37° E. and dips 80° to 90° NW. In places it consists of a fracture zone 2 to 8 feet wide. In other places the vein more nearly resembles a shear zone of about the same width, and in still other places the ore is localized in lenses arranged *en echelon* in a shear zone as much as 80 feet wide. This shear zone is probably a direct extension of the shearing that is prominent in Copper Flat. The material between walls is fractured and sheared andesite. In places both walls are andesite, the dike being many feet away from the ore. Usually a seam of gouge 1 to 15 inches wide makes the footwall of the vein. In parts of the vein a prominent seam of mineralized quartz varying from one to several inches in width forms the high-grade streak, with minor veinlets of mineralized quartz and disseminated mineralization scattered fortuitously throughout the remainder. In other places the chief quartz seam is absent, and the ore consists of a branching system of thin seams scattered through a fractured zone from 2 to 7 feet wide. In the lower tunnel the main vein averages 3 to 4 feet wide between well-defined walls in the andesite and with the usual gouge-filled fault zone on the footwall. At short intervals thin seams of ore lead out into the footwall of the vein, and occasionally also into the hanging wall. The vein on the upper levels apparently does not project downward into the position of the vein in the lower tunnel, but is in the footwall at a distance of 30 to 40 feet. The stringers of ore making into the walls are possibly connecting links between lenses of ore occupying the shear planes within a wide zone, and it is felt that thorough prospecting of this mine would require numerous crosscuts into both walls at both horizontal and vertical intervals.

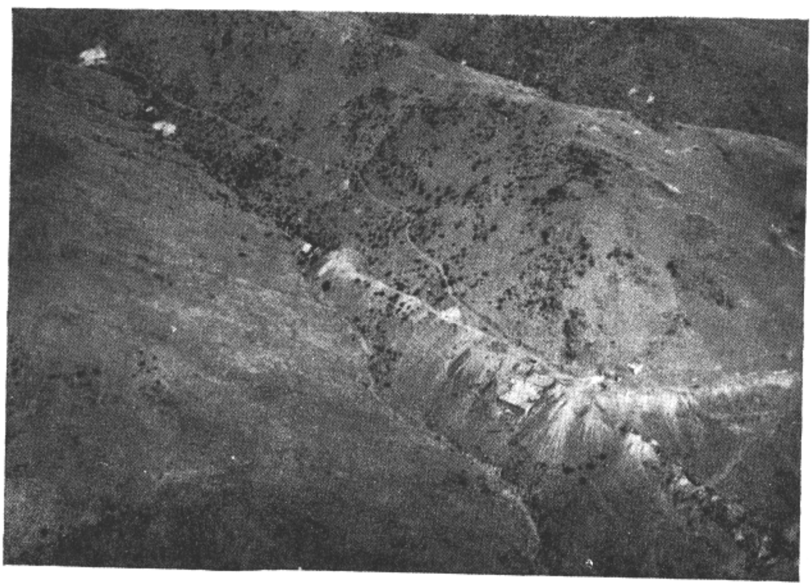
It is reported that at 2,000 feet from the portal in the lower tunnel, the vein or lens that was being followed broke up into several branches that made out into the footwall, and that the main fracture in the breast of the tunnel was barren. At 1,800 feet from the portal, the main drift was also following along a barren streak in the breast, but at this point a stringer of ore making into the footwall was followed by a drift that encountered a parallel lens measuring 12 feet between walls. In this lens was a high-grade seam 2 to 15 inches wide. The remainder of the vein contained considerable pyrite and was said to assay between $5 and $6 per ton, with the high-grade seam assaying up to $80. It is thought that the upper tunnels were driven on this lens of ore. The lens upon which the lower tunnel was driven for 1,800 feet is reported to assay in gold from a few dollars to $75, with silver occurring ounce for ounce with the gold, and to contain from 4 to 5 per cent in copper. The lens is from a fraction of an inch to 4 inches wide. In places the andesite between walls carries up to $7 in gold. At about 1,700 feet from the portal of this tunnel, a small mineralized seam makes off into the hanging wall, and another lens has been opened up that contains a white quartz seam up to 4 inches wide carrying only subordinate sulfides, the value consisting of free gold. Only one vein is visible on the surface of tbis property. Several hundred feet from the portal of the lower tunnel, an 80-foot winze has recently been sunk, and drifting for 100 feet north and the same distance south has disclosed 18 inches of mixed oxide and sulfide ore in the north drift, and a 4-inch streak of sulfide ore in the south drift. At this level the vein appears to be 18 inches wide, but the true hanging-wall probably has not been reached. The seam of gouge that is so persistent on the footwall of the Bonanza vein and is from 1 to 18 inches wide with an average of 6 inches, is reported to assay $6 in gold in many places.

The history of this property is fragmentary, and only partial detailed production figures are available. A mill was constructed in 1904 and began operating in December of that year. From December, 1904, to September, 1905, according to Gordon, [48] the net returns on ores from the Bonanza mine were $7,099.29 from shipping ore, $4,821.02 from concentrates, and $23,801.51 from bullion, making a total for the period of $34,721.82. At first the mill had 10 stamps, but the number was soon increased to 20. The returns from three cars of hand-sorted ore shipped in 1905 gave assay returns as follows : Gold 8.65 ounces, silver 32.3 ounces, copper 14 per cent, iron 15.7 per cent, insoluble 47.47 per cent, and sulphur 16.83 per cent. In 1931 development work was done by the Colorado-New Mexico Gold Mining & Milling

[48] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 276.



A. AERIAL PHOTOGRAPH OF BONANZA VEIN WITH RATTLESNAKE VEIN IN BACKGROUND



B. AERIAL PHOTOGRAPH OF RATTLESNAKE VEIN SHOWING OLD MILLSITE AT SNAKE SHAFT AND OPEN STOPES IN LOWER RIGHT HAND CORNER

Co., which opened up the winze below the tunnel level, drove the north and south drifts, and stoped the back for the full 200 feet to an average height of 30 feet above the level. In 1932 the old mill on the property was remodeled. The new mill consisted of a grizzley, small jaw crusher, automatic disc feeder, a small gyratory crusher, and 10 stamps. The pulp from the stamps was fed into a patented shaking amalgamator, where the free gold was saved, thence to concentrating tables, where the sulfides were recovered and a final tailing product made. It was estimated that the cost of the plant was between $25,000 and $30,000 and that it would handle 25 tons of ore per day. Estimates of costs indicated that mining above the tunnel level and very largely in old stope fills would range between $1.50 and $2 a ton, milling would cost 50c to $1, and overhead expense about 30c, making a total operating cost of between $2.30 and $3.30 per ton mined and treated.

Stoping is reported to have been continuous for many hundreds of feet on each of the tunnel levels in this mine, and in many places to have extended from level to level. It is probable however, that many pillars of low-grade ore were left. The stope fill from these places has been rather carefully sampled, and it is estimated that 25 per cent of the total fill can be screened out to make a mill feed assaying $5 to $20 per ton in gold and 4 to 5 per cent copper in the sulfide form, with an average value said to be considerably in excess of $7 per ton. Dump rock is reported to have assayed between $5 and $6.60 per ton in places. With the exception of the 80-foot winze, 200 feet of drifts, and a stope 30 feet high on this level, the Bonanza vein below the lower tunnel level has not been explored.

Mr. W. H. Bucher of Hillsboro, who handled most of the shipments of bullion from the district through the old Sierra County Bank, of which he was vice-president and cashier, estimates that the total production of the Bonanza vein has been in the neighborhood of $700,000.

RATTLESNAKE (SNAKE) MINE

The Rattlesnake vein is on the south slope of the Animas Hills and 2 miles north of Hillsboro. It outcrops at the north end of the New Year claim and extends slightly east of north through the Rattlesnake, Compromise No. 1, Eureka, Red Mountain, and thence for a mile over the crest of the hill and into Copper Flat, where it disappears at the edge of the monzonite cupola.

The vein is in a strong fracture zone 4 to 40 feet wide in the andesite. South of the main Rattlesnake shaft the vein splits into several branches, which end at the great fault in the southern part of the district. Two of these branches have been extensively worked. North of the Bobtail shaft a latite porphyry dike in the footwall strikes N. 48° E., and on the footwall side of this dike a branch from the main Snake vein extends along

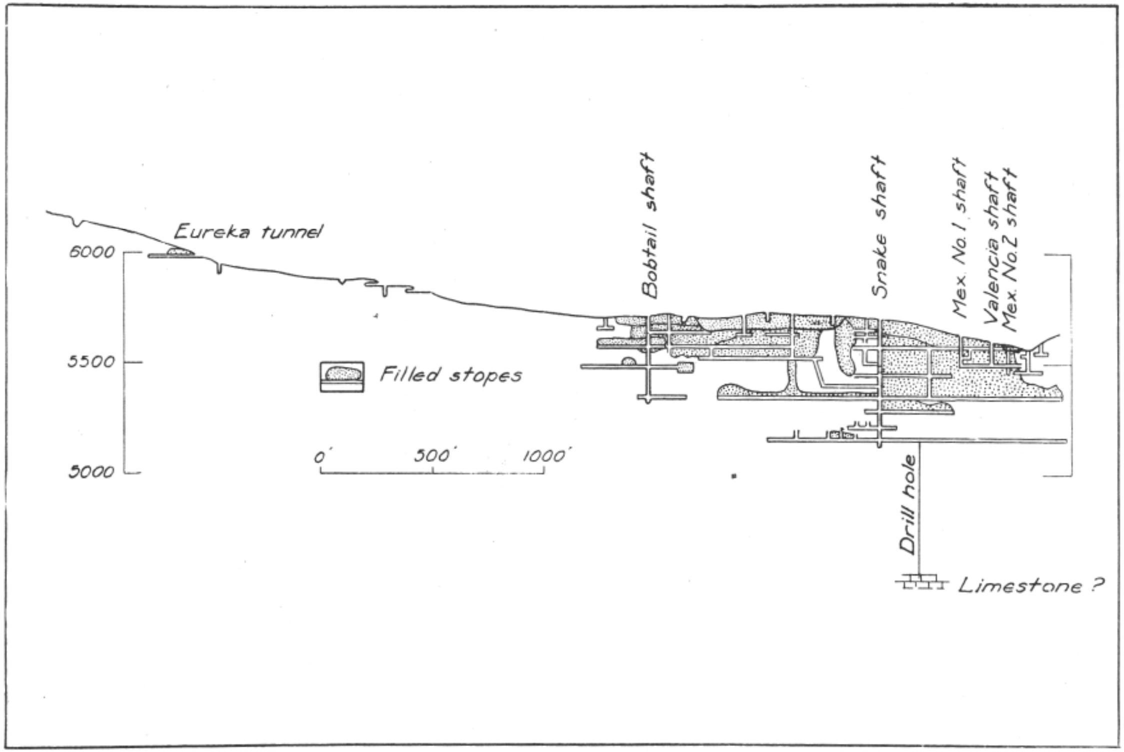


FIGURE 13.—Longitudinal section along Rattlesnake vein, showing old stopes and last development done before shaft and other workings caved. Looking east.

the contact in the andesite. This branch vein is 18 inches wide and carries quartz stringers 1 to 3 inches in width. Pockets of valuable ore occur in these quartz stringers. The whole width of the vein is said to assay $6, with the quartz seams and pockets assaying approximately $70 per ton. Three hundred feet farther north a short surface tunnel in the andesite breccia crosscuts two fractures striking N. 55° E. and N. 60° E. respectively. At the Eureka shaft and tunnel the vein is in a sill of latite porphyry and is much broken up and disturbed. At the portal of the tunnel a latite dike striking northwest has offset the vein on the north side a short distance to the west. The ground here is almost entirely altered to a mass of kaolin over a width of 30 feet. Shearing planes and seams of fault gouge can be traced through this mass along the trend of the vein, and stringers and seams of mineralized quartz are abundant and tend to follow these planes of movement. The full width of this zone is mineralized and contains, according to report, $7.50 per ton. From it a large tonnage of ore was mined in open cuts and in stopes near the surface, and this ore was treated in the local mill with a recovery of $4.50 per ton. Farther north in the tunnel the vein contains higher grade ore along a seam of fault gouge 2 to 4 feet in width. Much low-grade ore is supposed to remain in these workings.

The Snake, Bobtail, and Eureka shafts are caved, and hence no examination could be made of the various underground levels. Figure 13 shows a longitudinal section of the Snake vein adapted from the old maps and from an engineer's map made at the time of the most recent work done in the mine.

Quartz is the most abundant gangue mineral, and it encloses most of the sulfides and gold. The quartz veins occur in shoots from a few feet to 100 feet in length on the strike of the vein, and these are said to vary in width from 1 inch to 12 feet. In one place a width of 30 feet is reported. Often there are two quartz seams in the vein, separated by 12 to 30 feet of country rock. In places the country rock or fractured vein rock carries bunches and stringers of mineralized quartz in sufficient quantity to make the mass of the vein a low-grade milling ore. Irregular bodies of oxidized ore were mined from the surface to the 500-foot level, and sulfide ore was found from surface down, alternating with the oxidized ore.

Estimates of possible reserves in this mine Old their classification, and possible profits from working them are given in the reports of several private investigators. The Snake and Opportunity mines together are reported to have produced a total of $2,170,000 in shipping ore, concentrates and bullion. Of this total the Snake is given credit for $1,500,000. Shipments from the mine consisted of ore that would assay better than $12 per ton, and anything under that figure w as left unmined in the stopes or was hand sorted and the reject used as stope

In places stope fill may have been further enhanced in value by the infiltration of fines from the richer parts of the vein during hand sorting in the stapes, where canvas or boards were not used. One estimate of commercial material remaining in this mine, using a 4-foot width of vein (although it is much wider in places) and 16 cubic feet to the ton as compared with 12 cubic feet in place and 20 cubic feet when broken, is as follows :

Estimate of Ore Reserves of Rattlesnake Mine

	Tons	Value, per Ton	Gross Value
Ore in place (in pillars and unworked parts of vein)	59,707	$8.00	$ 477,656
Stope fill	99,615	5.00	498,075
Ore in surface dumps	17,336	3.38	58,591
Total	176,658	$5.85	$1,034,322

Old shipment records show that 1 ton of hand-sorted ore worth $68 per ton was shipped direct for each 3 tons of $22 ore sent to the mill, making 4 tons of an average grade of $33.50. The part of the vein from which this shipping ore came did not average more than a foot in width. The above estimate of ore in place does not, according to the report from which the figures were obtained, include any probable ore in areas above the lowest level, even though development work has indicated the presence of ore in some such areas, nor does it include any possible ore below the present workings. Such ore, if finally developed, might be expected to average about 4 feet in width and to assay $12 to $14 per ton, assuming the correctness of the figures submitted above.

According to private reports seen by the writer the per-ton cost of mining was $1.04, milling $1.19, hauling $0.24, a total of $2.47. Assuming $2.50 as an average cost of working the ore and fill, thus neglecting all costs of developing new ore reserves, and taking an average of the old mill recovery figures of 75 per cent, there would be a local operating profit in treating the mine fill of $1.25 per ton or $125,000 ; for treating the ore in place $3.50 per ton, or a total of $210,000 ; and for dump ore there is an indicated profit of $15,000, making a total local operating profit on the above reserves of $350,000. Transportation costs to the railroad at Lake Valley when this mine was working were $4.00 per ton ; today they would be $1.70 to $2.00 per ton. Freight to El Paso is $1.00 per ton. In a mill of modern design a concentration ratio of 10 tons of ore into one ton of concentrate may be safely assumed.

KATHERINE VEIN

The Katherine vein is east of the main Rattlesnake vein and is considered to be a split from it near the Bobtail shaft. It has a strike of N. 42° E. A fault, which strikes northwest and passes through the Eureka shaft of the Snake vein, has offset the northern part of the Katherine vein to the west. A shaft said to be 200 feet deep has been sunk on this vein, a moderate amount of underground development work has been done, and some high-grade ore has been shipped with ore from the Snake and Opportunity mines. Fragments of vein matter on the dump, which resemble the quartz of the Snake vein, contain pyrite, chalcopyrite and chalcocite.

85 MINE

This mine is on the northern slope of the mountain in which the Snake mine is located, and it is on the same vein. The 85 claim is an extension of the Red Mountain and adjoins it on the north. The mine is said to have been worked through a shaft sunk to the 400-foot level and to have produced some shipping and milling ores. Another shaft, said to be 80 feet deep, was sunk on an unimportant split from the main vein. The workings are all caved, and only the outcrop of the vein from the Snake through the 85 mine and to the monzonite cupola in Copper Flat was seen by the writer. Calcite is more abundant here than in the vein farther south. Argentite is present in moderate amounts and the gold is associated with chalcopyrite.

OPPORTUNITY MINE

The Opportunity vein, which is east of the Snake vein, takes a direction of N. 10° E. and is nearly vertical. It extends from a point on the Opportunity claim, just north of the monzonite outcrop near Hillsboro, through the Compromise No. 2, the Little King, and thenee over the crest of the mountain to Copper Flat. The Opportunity group of claims is a part of the same group to which the Snake claims belong, and in addition to the claims on which these veins outcrop, others in the group include the Morocco, Quartzite, Morning Star, Moccasin, Morning Glory, Mohawk, Portland, Yankee Girl, and Compromise No. 4.

The main Opportunity shaft and several pits and tunnels are located near the south end of this vein on the shoulder of a low ridge. North of the shaft, stoping from the underground levels has reached to the surface for a distance of several hundred feet along the strike. Farther north, on the Little King claim, the vein splits in a gulch, and the branch trends northeast. Here the dike along which the main Opportunity vein occurs is split, and the branch of the vein follows the branch of the dike. The country rock within the angle made by the split is altered to a soft white mass of sericite and kaolin, which is traveresd in every direction by small stringers of mineralized quartz, forming a low-grade ore body. The dike along the main Opportunity vein averages about 4 feet in width, and the vein, which is in fractured andesite and follows along the west wall of the dike, is about 4 feet wide. A seam of gouge makes the east wall of the vein.

At the main shaft the vein is oxidized to a depth of 250 feet, and the ore is free milling. Near the split in the vein in the arroyo, the ore from the surface down consists of mixed primary sulfides and secondary minerals. The gangue is quartz and subordinate calcite. This portion of the vein has been opened by a small shaft to a depth of 110 feet, and from the shaft drifts about 50 feet long have been driven to the north and to the south on the 50-foot and 110-foot levels. Figure 10 shows two views of the vein in this shaft, and the illustration is typical of practically all the gold-silver-copper veins in the district. Shipments from this shaft have consisted entirely of hand-sorted material that has averaged 2.38 ounces gold, 14 ounces silver and 11.4 per cent copper. Low-grade wall-rock from these workings has assayed 0.23 ounces gold, 1.2 ounces silver, and 1.4 per cent copper. The old stopes worked from the main shaft are reported to be practically continuous for a distance of 1,000 feet along the strike of the vein and down to a depth of 250 feet ; they are reported to have produced a little over $670,000. During 1931 lessees working in surface tunnels south of the main shaft produced a few tons of ore, part of which was worth $16 per ton according to the smelter returns, and the remainder about $6 per ton. It is said that the Opportunity mine stopes are filled with 70,000 tons of sorted material with an average value of $10 per ton.

McKINLEY, SHERMAN AND READY PAY VEINS

The McKinley, Sherman and Ready Pay veins are situated in the order named between the Opportunity vein on the west and the next gulch to the east, known as Ready Pay Gulch. The McKinley vein, also known as the Caballero, has been opened by two tunnels. The lower one, which is 500 feet long, is connected with the upper tunnel and old workings through a raise and some old stopes. The vein is 3 to 4 feet wide and is said to have averaged $7 throughout. The walls of the vein at the lower tunnel level are andesite breccia on the footwall and andesite on the hanging wall. The vein consists of soft and altered andesite and fault gouge, much iron stained and containing the valuable metals in roughly parallel stringers or thin lenses that come in and die out at short intervals throughout the width of the vein. In the face of the tunnel is a massive calcite-quartz-pyrite seam 12 inches wide, which assays $3 to $4 in gold. The oxidized zone of the upper workings is said to have produced ore assaying $50 to $60 per ton, probably after hand sorting, although this was not so stated. The ore is said to occur in shoots 15 to 30 feet long and 10 to 20 feet in height along the vein.

It is said that Martin Conoby, an old resident of the Hillsboro district, made his living for years by mining and sorting the high-grade stringers out of a persistent 18-inch seam of ore in the McKinley vein.

The Sherman vein or "lead" as it is called locally is on the west sidehill above Ready Pay gulch and strikes slightly east of north. It has been opened by 400 feet or more of underground workings, which are now either caved or filled with water. Some stoping has been done on this vein, but the amount is not known. The vein at the surface is a 4-foot fracture zone in andesite, through which small stringers of quartz are irregularly distributed. The dump from these workings is said to consist of 6,000 to 7,000 tons, over 50 per cent of which will pass a 10-mesh opening without further crushing. According to small-scale tests, these fines contain nearly all of the gold and assay $5 per ton. In 1932 this dump was under lease, and the operators were engaged in installing a second-hand Plat-0 table, upon which, they said, laboratory tests indicated that a concentrate worth $100 per ton in free gold and sulfides could be made.

The Ready Pay vein is located in Ready Pay Gulch. Near the south end it is on the west sidehill below the Sherman vein, but about half way to the head of the canyon it crosses the creek bed and then continues up the slope on the east side. The main shaft, old millsite, boiler house and campsite are located in the canyon. The plant is completely dismantled and the shaft is caved, and the mine workings could not be entered. From the surface, however, it could be seen that the vein is a fractured zone in andesite breccia, varying from 10 to 15 feet in width, and that this zone is traversed in all directions by stringers of mineralized quartz. The ore is said to occur within the vein in shoots, one of which was 400 feet long on the levels. Hard lumps of bornite up to 2 inches in diameter were said to,have been found in the vein, which would average $110 in value per ton.

Operations on the property were discontinued in 1908. The plant at that time consisted of a steam-driven hoist and a 30-ton amalgamation and concentration plant. The ore was ground in two Huntington mills and then treated on two plates and two Wilfley tables. The plant handled 24 tons per day for six months, during which time the full width of the vein was mined and treated. The mill heads ran $8 a ton and the tails $2.50, resulting in a saving of about $5.50 a ton. The ratio of concentration was about 12 into 1, and the concentrate assayed about $66 per ton. The direct cost of producing a ton of concentrate is given as $23.50, of which labor accounted for $19.50 and fuel $4.00.

WICKS VEIN

The original discovery of placer gold is said to have been made in Wicks Gulch late in 1877. Wicks Gulch heads in a drainage basin of very small area on the southeast slope of the Animas Hills, and in a short time the source of the placer gold had been located in the Wicks vein, which can be traced along a dike from the highway leading into Hillsboro from Hot Springs, through to the south slope of Black Peak, where it disappears under the basalt capping of that hill. It is probable that workings on the north side of Black Peak are located on the same dike and fracture zone.

The Wicks vein is developed by a shaft 300 feet deep, and by several tunnels and pits. The size of the dump at the main shaft indicates that several hundred feet of underground development work has been done and that considerable ore has been mined. Forty feet east of the main Wicks vein is a parallel vein, on which a shaft 200 feet deep has been sunk. The Wicks vein is said to consist of ,a 3- to 6-inch pay streak containing quartz, pyrite, bornite, chalcopyrite and free gold in a fracture zone averaging 7 feet in width. The pay streak is said to have produced hand-sorted shipping ore .ranging between $50 and $200 per ton in value. The total production is reported to have been around $150,000, and there is estimated to be $25,000 worth of ore of shipping grade blocked out. Only a moderate amount of repair and cleanup work would be required prior to mining this ore. The surface plant has been completely dismantled.

Higher up in the Canyon and on the same dike as the Wicks vein or on a parallel dike, the Morning Glory prospect was operating in 1931-1933 on a small quartz-filled fissure from which a hand-sorted product was being shipped in sacks to the smelter. Other old workings on this vein system include the Black Peak mine, opened by tunnels and shafts on the south slope of Black Peak and on the east side of the long ridge which separates Wicks Gulch and Ready Pay Gulch on the west. Some ore was taken from these workings in years past, but except for sporadic reopening similar to that of the Morning Glory operations, these mines have been idle and are largely caved. On the ridge east of Wicks Gulch some recent work along a well-defined dike uncovered a vein from which small shipments of commercial ore were made.

Some placer mining is conducted in Wicks Gulch from time to time, but most of the placer gold seems to have been recovered from what was at best a very small area of concentration.

CHANCE MINE

The Chance mine, or Cina Mahoney group, is located on the south side of Grayback Gulch along the eastern edge of the andesite area, where it is in contact with the alluvial material, and within a few hundred feet of the extensive placer diggings of Slapjack Hill. The property consists of four claims in the NW.1/4, Sec. 36. The vein occurs in andesite along the wall of a fine-grained latite dike, which strikes N. 55° W. and is approximately vertical. The ore was free milling to a depth of 100 feet below the surface. At this level, the minerals as seen in specimens taken from the dump are predominantly quartz and pyrite, with minor amounts of chalcopyrite and bornite, partly coated with limonite and copper sulfate and in part with thin films of chalcocite. The vein is said to be 3 to 5 feet wide, with a continuous ore seam of

3 to 12 inches averaging $45 in value as hand sorted. The mine was opened through a shaft 900 feet deep, from which drifts in both directions along the vein and 25 to 200 feet in length have been driven at 100-foot intervals.

PETALUMA GROUP

This group of four claims is owned by E. P. Baumann of Hillsboro. It is situated on the north side of Grayback Gulch in the northwest corner of Sec. 36. A dike parallel to and west of the Chance lead crosses the gulch at this point, and an open cut 50 feet long has been made in it. This cut has been widened to 40 feet to crosscut the full width of the dike and its bordering zones of alteration. The dike in the cut is fractured and bleached, and it and the adjacent rocks show much iron staining of brick-red color along fracture planes.

NORTH PERCHA MINING CO. PROPERTY

This property consists of two patented claims, Cincinnati No. 1 and No. 2. They are located northeast of the Chance mine at the old camp of Grayback in Grayback Gulch. A shaft 400 feet deep has been sunk in andesite breccia, but the workings are not extensive. A mill having a daily capacity of 25 to 30 tons was erected on the site, but according to report it was operated intermittently on custom ores from the district and did not handle more than 7 to 10 tons per day. The plant was finally dismantled and the machinery moved away.

SWEETWATER CLAIM

The Sweetwater claim, also known as the Mogul or South Percha, lies on the east slope of Animas Peak. The strike of the vein is N. 75° E. and the dip 65' NW. It is developed by a shaft 115 feet deep, in which 60 feet of water is standing. Several small stopes are reported, and surface dumps are said to assay $9 in gold per ton. About 80 feet northeast of the old shaft a new one has been started following the vein, and at the time the property was visited it was down 16 feet.

FULLERTON AND LITTLE JEWESS PROPERTIES

These properties are owned by Fred Hiltscher of Fullerton, Calif., and are located on the southern and western slopes of Animas Peak. The Fullerton property, on which the Lewellyn tunnel has been driven, is on the south slope of Animas Peak, about one-third of the way up from Grayback Gulch. The country rock is andesite breccia, which has been fractured in a N. 75° E. direction. The Lewellyn tunnel, with a course of N. 40° W. crosscuts this fracture system. If extended about 500 feet it would intersect a vein in Animas Peak which is said to strike N. 60°-70° E. and to originate near the monzonite porphyry mass of Copper Flat. The tunnel is 1180 feet long.

The Little Jewess property is high up on the west slope of

Animas Peak. The workings consists of a tunnel, which crosscuts for 150 feet to a fractured zone in the andesite having a strike of N. 60" E. and dip of 50" NW., and then follows along this zone for a distance of 200 feet. The width of the fractured zone is 2 to 4 feet, and the width of a persistent seam of gouge on the hanging wall side is from 1 to 18 inches. Three shoots of ore were encountered in the gouge along the tunnel in a distance of 200 feet, one of these being 20 feet long and the others each 30 feet long. The value of the gouge seam is said to vary from $2.50 to $52 per ton. A moderate amount of material has been shipped from the three high-grade shoots in the vein. The gangue is calcite and subordinate quartz, and the vein at this elevation is highly altered and oxidized.

REPUBLIC AND WISCONSIN CLAIMS

The Republic and Wisconsin claims are on the north slope of Animas Peak and in Dutch Gulch just south of the road leading to the El Oro property. There is a tunnel on the Republic claim 100 feet long, following a vein which strikes N. 78° E. and dips 65° NW. Latite porphyry makes the hanging wall and andesite breccia the footwall. The vein is 3 to 4 feet wide, and the value for the full width is reported to be from $4 to $5. Stringers of quartz and limonite in a gouge seam within the vein have assayed $16 per ton. These stringers have a width of 6 inches or less.

On the Wisconsin claim a shaft 90 feet deep exposes a vein 4 feet wide, with an 18-inch seam of gouge in the center. The footwall of the vein is latite porphyry and the hanging wall is andesite breccia. Assays from the shaft are said to average about $4 per ton. The vein consists of seams of quartz which are principally within the gouge seam. The vein outcrop has a jaspery appearance, and some of the jasper is said to yield high assays. In places at the surface the copper silicate, chrysocolla, has been found. This vein is considered to be an extension of one of the veins of the El Oro property. At the west end of the Wisconsin claim a fault offsets the vein 50 feet or more. A small pit at this point yielded a few tons of ore, the hand-sorted product from which assayed $20. These claims, formerly owned by Slease and Hiltscher of Hillsboro, have recently been acquired by the El Oro Mines CO.

PROPERTY OF EL ORO MINES CO.

The property of the El Oro Mines Co. is in the northeastern part of the Hillsboro (Las Animas) Mining district. It includes the northern end of Copper Flat, and from there it extends in a northeasterly direction along Dutch Gulch and along the hills on either side of this Gulch to the andesite-limestone contact in the north part of the district. The Republic and Wisconsin claims have recently been acquired by this company, and it is said that the Mary Richmond mine in the southwestern part of the district has also been purchased. The old camp of Andrews was in this part of the district, and several of the old adobe houses in use at the El Oro camp, including the manager's and superintendent's residences, have survived from that period of the camp's activity.

The property covers the northeastern lobe of the monzonite porphyry cupola that extends along the floor of Copper Flat and for a considerable distance through the upper reaches of Dutch Gulch. This area is in• a zone of shearing that is a continuation of the one noted in the Snake and Bonanza mines and in the monzonite porphyry floor in the basin of Copper Flat. The lobe of monzonite porphyry ends at a point a few hundred feet southwest of the El Oro shaft, but a number of latite porphyry dikes continue on down the gulch, and it is along the borders of these dikes and in parallel fractures in the andesite that the veins occur.

The development work consists of a large number of pits, trenches and other shallow workings along the outcrops of the various dikes and fracture zones, from which small shipments of high-grade hand-sorted ore have been made. In addition to theSe shallow workings, several shafts from 75 to 240 feet deep have been sunk on the Golden Rule vein, and from these approximately 1,400 feet of drifting on the vein is said to have been done. Above the 200-foot level all ore is reported to have been stoped from the Golden Rule vein by the early operators. The main shaft of the Golden Rule vein, known as Shaft No. 2 in the reports of the company, is down to the 400-foot level, with slight additional depth for a sump, and from each level drifts have been driven. The total length of these drifts is about 1,700 feet. The longest level to the north from this shaft is the 400-foot level, which is about 430 feet in length, while the longest drift to the south is the 100-foot level, about 230 feet long. This vein, as exposed by the old workings and where it has not been stoped out, is said to average $30 per ton, but it is difficult to accept this figure in view of the average grade of past shipments made from this district.

Southwest of the Golden Rule main shaft and a short distance up the hill from the gulch in which that shaft is located, a new shaft has been sunk by the present owners to a depth of 500 feet in andesite breccia, andesite, and latite porphyry flows. From the bottom level of this shaft a short crosscut has been driven to the northwest, and at about 30 feet from the shaft it encountered broken andesite carrying stringers of pyrite. At 40 feet from the shaft a latite porhpyry dike was cut, which appeared to be dense and barren, and to strike northeast, parallel to the trend of Dutch Gulch. This drift, if extended sufficiently, would cut the Golden Rule vein at a new low level, and at some distance south of the present openings in the vein. A similar crosscut to the southeast, which was open for a distance of 90 feet at the time of the writer's visit, was later driven to 420 feet from the shaft. According to reports issued by the company, it cut at 35 feet a porphyry dike about 12 feet wide that is said to be low-grade ore ; at 80 feet a sulfide stringer ; and at 140 feet a fault zone said to be 8 to 9 feet wide, which has been drifted on for a few feet to the northeast and also to the southwest. From the face of the northeast drift a sample is reported to have assayed $29 per ton, although the width over which this sample was taken was not stated. This fault zone is believed to be the El Oro vein. At 232 feet from the shaft another porphyry dike, which is apparently over 20 feet wide, was encountered, and this is also designated as low-grade ore. At 276 feet from the shaft it is stated that a mineralized zone 45 feet wide was penetrated, and that 18 assays taken in this distance give an arithmetical average of $8.84. At 340 feet an oxidized vein 2 to 3 feet wide is reported, and at 350 feet a vein is said to have been cut that is 10 to 12 feet in width and oxidized, but no assays of these veins were given. At the face of the tunnel it is reported that a sulfide vein containing very rich ore was encountered, but the width and assay returns of this material are not stated. This sulfide vein is located at a point within 5 feet of where the writer's projection of the vein in the saddle on the ridge back of the plant would place it.

At the time of the writer's last visit (Oct. 1, 1933) the new El Oro shaft was the main hoisting shaft. It was equipped with concrete collar, a steel headframe, coarse-crushing plant, belt conveyor and mill. The steel-frame and corrugated-iron power and hoist house was equipped with a hoist, one 350-H.P. Worthington Diesel engine, one 450-H.P. engine of similar make and design, two compressors of 650 cubic feet capacity each, and a complete switchboard. Each engine is direct-connected to an electric generator. The mill was a steel-frame and corrugated-iron building equipped with fine-grinding mills, classifiers, flotation machines and filters, with a rated capacity of 300 tons per day. There is considerable doubt in the writer's mind as to whether an adequate water supply is economically available to keep a 300-ton mill in operation on even a part-time basis in this district. It was understood that the surface plant on this property, as described above, was being built under a contract agreement with an Arizona firm of metallurgical and construction engineers for $150,000, and that with all incidental expenses included, the plant would cost between $175,000 and $200,000. Most of the equipment furnished for this construction was second-hand material, but all said to be in excellent condition.

One of the company officials stated that the new shaft would be put down another 1,000 feet, or until the contact between the andesite, and underlying limestone or monzonite porphyry was cut, in the hope of finding new ore bodies at a greater depth than any discovered heretofore. It was also proposed to continue crosscutting in both directions until all of the 12 parallel veins reported to be present in this area were intersected.

The old camp of Andrews and the neighboring Tripp, Homestake, Freidberg, Buetecke, and other mines, in effect the entire northeast portion of the Hillsboro district north of Copper Flat, produced, according to several independently obtained estimates, only about $260,000 in net smelter and bullion returns up to 1904, when most of the mines in the region became idle. Allowing $25,000 to take care of miscellaneous shipments not included in the above estimate and all minor shipments made subsequently, a total of $285,000 seems to be about the maximum production from this part of the district to date. For many years prior to the organization of the present company the El Oro mines were under water, but these workings were pumped out early in 1932, and operations were resumed. It is understood that at least twice since that time the mine has been allowed to fill up again during temporary shutdowns.

The writer made one visit underground in August, 1932, seeing all workings in the Golden Rule Shaft No. 2, except on one level which was said to be caved, and all the workings in the New El Oro shaft, which included a 500-foot shaft, a northwest crosscut over 40 feet in length, and a southeast crosscut which was over 90 feet in length. Based on these observations the opinion is offered that the surface plant and improvements in progress were larger than justified and that they represented an ill- advised expenditure of money in view of the very small amount of ore actually blocked out in the mine.

The exposed ore bodies in the workings from the Golden Rule Shaft No. 2 and the El Oro shaft were not sampled by the writer, but the mineralization appears to be weak. The geological features, the character of the mineralization, and the results obtained from past mining operations are not encouraging for the existence of large and profitable ore bodies in this area. Some of the recently acquired properties, particularly the Richmond mine (see pages 145-148) are more promising than the El Oro mine proper.

COPPER FLAT CLAIMS

The mineralized area in Copper Flat is held by 20 full.sized mining claims, of which six are patented. This property is owned by Max Hiltscher, for many years a resident of the Hillsboro district.

The area consists primarily of a cupola of monzonite porphyry, which forms the floor of the basin and is in irregular contact with the main andesite country rock of the district on all sides, as shown on Plate VI. The southern end of this mass was apparently more resistant to erosion, as it remains within the basin as a group of low, rounded hills. These hills are composed of a finer grained phase of the monzonite porphyry, which is almost aphanitic in places, and it is believed that they are remnants of the upper portion of the cupola. The rock is very similar in appearance to the latite porphyry dikes that radiate outward from the cupola and that are considered to be direct offshoots from it.

The mineralization within the basin of Copper Flat occurs as (a) veins filling fracture zones in andesite, (b) veins within the monzonite, and (c) deposits of copper in the monzonite. The veins filling fracture zones in the andesite country rock are along the walls of latite or monzonite porphyry dikes, in simple fractures, and in shear zones. They radiate outward from the mass of monzonite porphyry within the basin, and many of them can be traced directly into the important veins that occur on the outer slopes of the Animas Hills, such as the Richmond, Rattlesnake and Opportunity. With the exception of the Richmond, the northern part of the Bonanza workings, and the 85 mine on the north end of the Snake vein, these inside deposits have been of small importance as producers of commercial ore.

The veins within the monzonite mass of Copper Flat are quartz-filled fissures, which contain pyrite, chalcopyrite and gold, but very little silver. One vein, as developed in a surface trench, contains quartz, pyrite, tetradymite (bismuth telluride) and some gold. Molybdenite is sparingly present. These veins are due to a continuation of movement along the principal veins of the district, and a general shrinkage fracturing within the mass of the intrusive after it had solidified but prior to or contemporaneous with the vein-forming period. In general, they are of little importance, although some high-grade shipments have been made from them in the past, mostly as small hand-sorted lots of a few tons each.

The deposits of copper within the southern portion of the igneous mass consist of disseminated primary pyrite and chalcopyrite within the sheared and fractured mass of the monzonite porphyry near the Sternberg shaft. This disseminated ore has been enriched and converted to chalcocite, cuprite, azurite and malachite by oxidation and precipitation processes during the formation of the basin. Molybdenite is present with quartz in seams and stringers, and biotite is locally present with coarse feldspar crystals in small veinlets of pegmatitic appearance, both of these occurrences testifying to a local temperature much above what is considered normal for the formation of the chief ore deposits of the district. Erosion in the basin quickly followed oxidation and secondary enrichment, for within 50 feet of the surface in the prospect workings the secondary sulfides give way to primary pyrite and chalcopyrite.

The Sternberg underground workings have followed along a series of six trap dikes, which outcrop on the surface within a distance of 500 feet. These dikes have amygdaloidal cavities in which cuprite (including the variety, chalcotrichite), some black copper oxide, some native copper, malachite and calcite are present. Along the walls of the dikes, stringers of quartz, pyrite and chalcopyrite make off into the monzonite porphyry along shearing planes trending N. 50° E. The trap dikes strike N. 50" E. and average 4 feet in width. In general the dikes are altered with the formation of much chlorite, and they have a dove-gray color. A few specimens obtained from the dump were vesicular and less altered in appearance and looked much like basalt. It appears probable that these dikes are of the same age as the basalt of the district. Because of their porosity they have easily altered, and they have been impregnated with the copper minerals by circulating ground waters, which have produced secondary enrichment elsewhere in the basin. Along the dike in which the Sternberg shaft and workings have been opened, the west wall is said to be bordered by 4 inches of quartz containing abundant pyrite and molybdenite.

The Sternberg shaft is reported to be 150 feet deep, with a level at 90 feet consisting of 255 feet of drifting in the trap dike and 120 feet of crosscutting. At 175 feet from the shaft, a fault with a strike of N. 50° E. offsets the southern extension of the dike 10 to 15 feet to the southwest. At the time the property was visited the shaft contained water to within 75 feet of the collar, and all the surrounding prospect shafts over 50 feet deep contained some water. The shear zone carrying enriched copper deposits is about 200 feet wide where it is cut by Grayback Gulch, and samples taken in the various open cuts, tunnels and natural exposures along the gulch contain from a trace of gold and 0.3 per cent copper to 0.15 oz. gold a ton, a trace of silver, and 6.55 per cent copper. Hand-sorted material from these old workings assayed 1.01 oz. gold, and 26 to 39 per cent copper, with the reject from sorting assaying 0.52 to 1.3 per cent copper.

FREIDBERG MINE

Northwest of the El Oro mine and on the outward northerly slope of the Animas Hills is the old Freidberg mine, also known as the Brauer group. No shipments have been made from this property, but it is of interest for the reason that the workings have prospected a residual patch of rhyolite flows and tuffs. A shaft 60 feet deep bottoms in a dark shaly material, which is considered to be a sedimentary accumulation on the andesite surface made during the interim between the last andesite flow and the earliest rocks of the rhyolite sequence. Other workings include a tunnel, several crosscuts and two short winzes. All these workings are said to be in rock averaging $1.50 per ton in gold, with some small shoots and patches of $25 ore. It is reported that the grade of the material encountered at the shale contact in the bottom of the shaft is much higher than elsewhere in the workings. At the portal of the tunnel is an obsidian dike 3 feet wide that strikes due east and is nearly vertical ; this dike was cut in one of the crosscuts, where it is said to be 8 feet wide and much fractured and brecciated.

OTHER LODE MINES

Numerous other properties in the district, some with a record of production and others hardly beyond the small prospect stage, surround Copper Flat on the inside slope of the hills to the northwest, west and southwest. Among these is the Buetecke tunnel above the El Oro mine, which is 450 feet long. At the portal this tunnel cuts a wide dike reported to carry $3 to $4 gold, while farther in the hill it penetrates an irregularly fractured mass of andesite, in which metallization is weak and spotty.

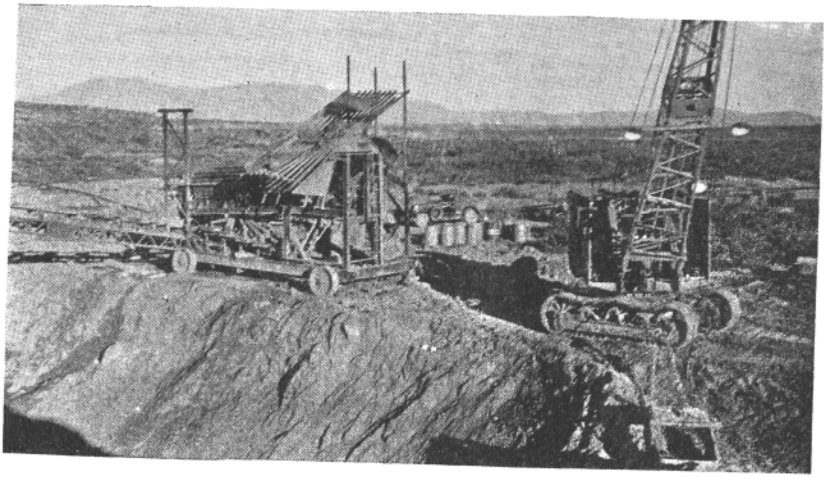
The Tripp and Homestake mines are near the top of the ridge about a mile due west of the El Oro shaft. Each of these mines has been opened extensively by shafts, tunnels and open cuts, and the surface gives evidence that fairly large stopes were mined in the oxidized zone. The combined production of these mines is reported to be about $50,000. The writer did not enter either of these mines, due to the unsafe condition of the workings. It is understood that the El Oro Mines Co. owns both properties.

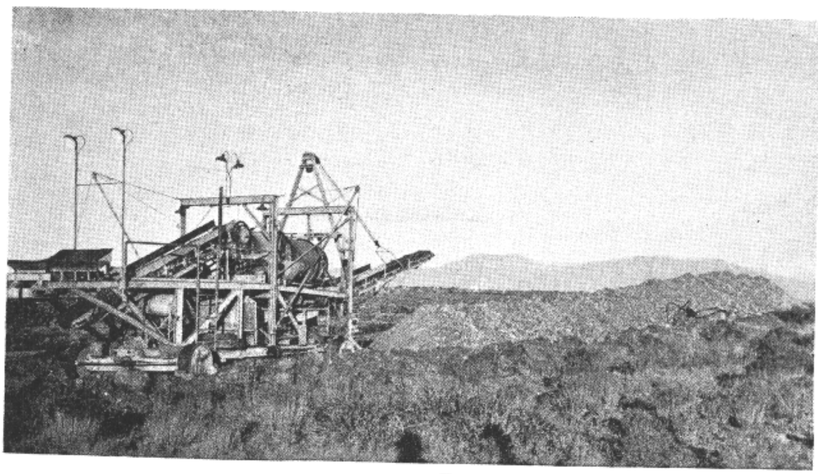
The Empire mine, in the next main draw northwest of the Mary Richmond mine, is on the north slope and near the top of Empire Peak. The production from this mine is given as $1,000. The workings, consisting of pits, tunnels and shafts, have prospected a fracture zone in the andesite that crosses the ridge at the head of one of the tributaries to Grayback Gulch.

ANIMAS (HILLSBORO) PLACERS

Aside from the small placer areas at the foot of Snake Gulch and in Wicks Gulch, both of which are probably almost exhausted, all of the promising placer ground in the Hillsboro district is east of the Animas Hills. These placers are part of an alluvial fan that consists of detrital rock resulting from the erosion of the Animas Hills and Copper Flat. At the present time this fan is being dissected by the drainages of Dutch, Grayback, Hunkidori and Greenhorn gulches.

The basal part of the original fan is composed of fine to coarse fragments of rhyolite derived from the late flows of that material that once covered the Animas Hills. The intermediate part of the fan is composed principally of andesite and latite fragments, and it contains varying amounts of placer gold throughout. The topmost portion of the fan, which is low in gold content, is composed of basalt, andesite and latite fragments. Between the period of deposition of the basal part of the fan and the intermediate part, a period of quiescence or equilibrium must have existed, for just above the basal portion there is a bed of caliche, known as a false bedrock, upon which a large amount of gold has been concentrated. This caliche was formed by the deposition of calcium carbonate from water that rose to





PHOTOGRAPHS OF DRY-LAND GOLD-SAVING MACHINES IN THE HILLSBORO (LAS ANIMAS) PLACER MINING DISTRICT the surface and evaporated there, and since the bed of this material is 2 or more feet in thickness, it indicates a rather prolonged period of neither deposition nor erosion of fan material. At the present time the three streams that built up the fan are degrading it, and where they have cut deep enough to destroy the caliche bed, they have redistributed the gold in irregular runs and lenses farther down the fan. In the course of this reworking, much gold has been carried away, and that remaining has been reduced in size, is in flatter scales, and its fineness has been increased.

Black sand accompanies the gold in varying amounts. It is composed principally of magnetite and of limonite pseudomorphic after pyrite. The pseudomorphs that have been broken and worn down in their migration from the veins to their resting place in the placers are apt to contain but little gold, but the unbroken ones often contain specks or wires of gold. Much of the black-sand concentrate, after separating the free gold particles from it as far as is commercially feasible, would be sufficiently valuable to save and ship to the smelter.

The Luxemburg placers, optioned to the Consolidated Gold Fields of New Mexico, Inc., consist of approximately 500 acres at the apex of the alluvial fan and include the area drained by Grayback, Hunkidori and Greenhorn gulches. These placers include Slapjack and Jones hills, both of which are capped by remnants of the original caliche bedrock. The placer gold is concentrated in runs and boulder chokes above this bedrock, the boulder chokes consisting of accumulations of coarse boulders which have acted as dams to slow up the flood waters over the fan and cause them to drop their load of gold. From Slapjack Hill 10,000 cubic yards of gravel mined by underground methods through a tunnel and treated in a dry concentrator yielded $3.65 per yard in gold over .900 fine. Jones Hill has a similar remnant of the original caliche bed, from above which high-grade gravel has been obtained in underground .workings ; this hill is capped with a thin patch of basalt. The lower ground within the Luxemburg placers, which has been reworked from the original deposits, is said to average better than 40c a yard from the surface to an average depth of 15 feet. (See plate VII.)

In Dutch Gulch north of the Luxemburg ground, placer gold has been recovered from the main gulch and its tributaries as far west as the El Oro property. Over 700 acres of this ground is controlled by the Animas Consolidated Mines Co. This company set up a specially rigged combination screening and washing plant, which is fed by a dragline excavator. It is understood that for one run of 4,000 cubic yards put through the machine the recovery of gold was 43c per yard and that the tailings from the machine ran over 10c, the gold in the tailings being of the same character as that recovered. The operation was conducted in the creek bed, where a false bedrock is 9 to 17 feet below the surface. Water was supplied by one well, which produced 23 gallons per minute with apparently no seasonal variation.

South of the Luxemburg placers the Gold Dust placers, consisting of approximately 1,300 acres, are now under lease to the Placer Syndicate Mining Co. This company is also in control of over 500 acres lying just east of the Luxemburg ground, and these entire holdings include ground drained by all creeks which flow off the east slope of the Animas Hills and from Copper Flat. This company has constructed a 4,000,000-gallon reservoir between Dutch and Grayback gulches, and has installed a 5/8-yard portable shovel, a washing and treating machine mounted on a tractor and consisting of a trommel, four 36-inch Ainlay bowls, and a stacker belt, with a capacity of 1,000 cubic yards a day. Records of runs made with this machine, which have been reported to the writer, indicate that 1,520 cubic yards removed from the bed of Dutch Gulch just east of where the Animas Consolidated machine had worked, yielded 67c per yard in gold, and that a later run of 13,388 cubic yards, during which time the machine was out of the richest ground, produced 23.8c per yard, with the gold paid for on the basis of .927 fine and with gold at $20.67 per ounce. The average recovery from approximately 30,000 cubic yards treated was reported to be 39c a yard.

Grayback and Dutch gulches join in the NW.1/4 Sec. 32, and Dutch and Hunkidori gulches join in the NE.1/4 Sec. 33. It is said that surface samples contain fine gold for 3 miles east of this latter point, and nearly all of the land as far east as this and south to the Rio Percha is held as placer ground.

The water supply in this district is a serious problem, as wells to a depth of 85 feet are pumping less than 100 gallons of water per minute, and it is questionable if a large underground supply is available. The water in the Rio Percha is said to be available in part, but its utilization would involve pumping against a 600-foot head for a distance of over 4 miles.

Costs of handling this placer ground are estimated by several engineers who have examined the deposits, to range between 16c and 20c per yard, depending on the cost of supplying water to the machine. The writer believes that with a normal wage scale, and a developed water supply sufficient to keep a machine of 1000-cubic-yards daily capacity in operation, costs will approximate 25c per yard, which will include all operation and capital charges for the plant, but will hardly take care of royalty payments that may be imposed. On the basis of these costs, it seems hardly probable that commercial ground suitable for large-scale operations will be found east of the east line of Sec. 31. Narrow runs along the creek beds and elsewhere in the low areas may be workable as far east as the east line of Sec. 33.

It is reported that in early days $2,060,000 in placer gold was taken from this field, $2,000,000 of it having come from dry operations on the Luxemburg ground. In *going* over the ground today as far east as the east lines of Secs. 30 and 31, innumerable small piles of coarse boulders and hollow places on the surface nearby may be seen, where screening operations have been conducted in the years past. With the exception of Slapjack and Jones hills, probably all the high-grade placer ground has been removed, and future profitable operations must depend on large-scale production methods applied to ground that probably contains less than 30c per cubic yard.

POSSIBILITIES OF THE DISTRICT

The Hillsboro or Las Animas mining district is considered to be one of the favorable areas in Sierra County in which to conduct campaigns in search of new ore deposits and the downward extension of known superficial deposits.

The lode mines unfortunately are largely caved, and hence it was impossible during the investigation to search for shoots of sulfide ore that might extend belbw water level. At the Opportunity mine such sulfide veins have been found in the draw north-northeast of the old main shaft, where erosion has outstripped weathering processes. The main portion of the vein, which averages 4 feet between walls, assays over a considerable distance between $5 and $7 per ton, while the quartz stringers, which have a combined maximum width of 6 inches, have assayed between $50 and $80 per ton. In a few places the wall-rock beyond the vein proper can be classed as low-grade milling ore. Assuming a 6-inch streak of $75 ore and a 3½-foot width of $6 vein material, the entire vein would be valued at $14.62 per ton. The tonnage of such ore is not known, as no attempt has been made to block out reserves. Other veins of a similar nature are probably present in the district. (See footnote, page 59.)

Within the oxidized zone the veins have been extensively worked for their free-milling gold, and except for small ore shoots in virgin ground, pillars left behind in old stopes, and old stope fill, not a great deal of new ore is to be expected at this horizon. Virgin ground may yield some hand-sorted ore which, on the basis of recent shipment records, should assay about $25 per ton in value, and old stopes in the district may contain relatively large awounts of fill assaying from $4 to $6 per ton, which can probably bk. treated effectively by simple amalgamation, concentration or flotation.

The most favorable places to look for sulfide ores are under known shoots of oxidized ores that have been mined to water level, or at other points along the veins that have been important producers in the past, as the Rattlesnake, Bonanza, Opportunity and others in the southern part of the district. The extensions of these veins into Copper Flat deserve investigation. In the southern part of the monzonite intrusion in Copper Flat, ores of gold and silver in quartz veins and disseminated copper sulfide ores have been mined, and oxidized surface ores of copper have been produced near the Sternberg shaft.

In the limestone in the southern part of the district, ores containing vanadium, molybdenum, lead and manganese have been mined from irregular replacement bodies. These ore bodies have been largely worked out, and although other small pockets may be discovered from time to time, there is no assurance that they can be profitably mined except under the stimulus of extraordinarily high metal prices. At the north end of the district, at the fault contact between the limestone and the andesite, a replacement deposit in the limestone contains gold in moderate amounts. The average ore shipped contained 12 per cent lead and about $8 per ton in gold. This deposit is of interest, and plans have been discussed to sink along the contact until the limestone under the andesite is encountered.

The gold in the placers of the district has come from the eroded parts of the gold lode deposits. The gold has accumulated in alluvial fans, the principal fan heading at the entrance to Copper Flat. Near the head of this fan the gold is coarse and well concentrated, but as distance is gained from the source, commercial values quickly confine themselves to runs of moderate width and length, with poor material between, and the gold rapidly diminishes in size until at a distance of 2 to 3 miles from the head of the fan, the particles are extremely small, and the quantity is definitely below commercial limits except in a few small areas.

Several attempts made in the past to mine the lode and placer deposits of the district have been unprofitable, largely due to one or more of the following causes : (1) A large plant has been erected before actual reserves of ore have been blocked out, and capital funds have been depleted before development started, or the excessive size of the plant has ruined any possibility of mining a small to moderate sized ore body with profit; (2) money has been spent for development at places offering small chances for ultimate success, while more favorable areas have not been explored ; (3) well-conducted campaigns of exploration have been stopped because the companies financing them were looking for larger ore bodies than are characteristic of the district ; and (4) sampling has been inadequate or has been neglected.

LAKE VALLEY HILLS

LAKE VALLEY DISTRICT

LOCATION AND AREA

The Lake Valley district has been described by Clark [49] and by Gordon, [50] who used much of Clark's material. In the present bulletin the writer has utilized considerable information given

[49] Clark, Ellis, The silver mines of Lake Valley, New Mexico: Am. Inst. Min. Eng. Trans Vol. 24, pp. 138-167, 1894.

[50] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), pp. 278-281.

in the reports of Clark and Gordon, but he has included data obtained during his study of the surface geology and the detailed examinations of several small recent underground workings.

The district is in the southwestern part of Sierra County and is about 7 miles from both the western and southern boundaries. This is the only mining district in the county having a direct rail connection, which is by way of the 13-mile branch line out of Nutt, a small station on the Rincon-Deming-Silver City branch of the Atchison, Topeka & Santa Fe railway. The town of Lake Valley owes its present slight activity almost entirely to the fact that this rail connection makes it the distributing and shipping point for nearly the entire southwestern quarter of Sierra County and adjacent parts of Luna and Grant counties. The district is not a large one, the entire known mineral-bearing area being within a rectangle three-quarters of a mile long in a northeasterly direction and half a mile wide. The old Santa Fe trail is reported by Clark[57] to have passed within 6 miles of Lake Valley, and the camp is 15 miles in an air line from the Rio Grande.

GEOGRAPHY

The immediate vicinity of Lake Valley is an area of low hills and basins, which are surrounded by higher peaks and ridges partly enclosing the terrane on three sides but opening to the southeast and south onto the great alluvial plain that extends through the length of the county along the west bank of the Rio Grande and to Deming and beyond. The most prominent topographic features of the region are two rhyolite peaks, Porphyry Hill 1 mile southwest of Lake Valley and the so-called Rhyolite Range 3 miles northwest. Porphyry Hill attains an elevation of 1,000 feet and the Rhyolite Range about 1,500 feet above the town. About a mile to the east is Monument Peak, an isolated knob that overlooks the town from an elevation of 500 feet. This group of hills marks the termination of a short, rapidly dwindling spur which diverges from the main Black Range in a southeasterly direction to disappear under the detrital material of the valley plains bordering the Rio Grande at a point just east of the town. Within the basin a ridge of sedimentary rocks trends northeast with gradually decreasing elevation, until it disappears under the detrital material near the former lake that gave the district its name. Lake Valley lies on the southeast or dip-slope side of this sedimentary ridge. Due to the presence of alternating strata of hard limestones and softer shales, the dip slope of this tilted block has been eroded into a series of alternating troughs and cuestas. Apache Hill, due north of the town, is the high point of the sedimentary ridge, rising to an elevation of more than 700 feet above the mines. Surrounding the ridge and in the erosional troughs on its dip-slope side, alluvial material

[57] Clai.k, Ellis, op. cit., p. 132.

derived from the disintegration and erosion of the higher peaks and slopes has formed flat valley floors that partly obscure the underlying formations. The bed of Berenda Creek takes a northeasterly course through the main valley that lies at the foot of the northwest-facing escarpment of the tilted rocks. (See Plate X.)

The elevation of Lake Valley is given as 5,412 feet above sea level by the United States Weather Bureau. The climate is mild and the rainfall slight, averaging only 13.25 inches per year. Roads leading into the district are open at all times, and outside work can be carried on effectively all the year round.

GEOLOGY

THE ROCKS

The rocks of the Lake Valley area include sedimentary and igneous varieties. The sedimentary rocks range in age from Ordovician to Mississippian, [52] all the intervening periods being represented. The stratigraphy, together with intervals of erosion or non-deposition, is illustrated in Plate II.

El Paso Limestone.—The oldest sedimentary formation showing, in the district, is the El Paso limestone of Lower Ordovician age, visible along the foot of the northwest escarpment of the tilted block of sediments that rises from the Berenda Valley 1 1/2 miles northwest of the town of Lake Valley. In this area the formation is about 150 feet thick and is composed of slabby limestone. Many of the beds are covered with a thin meshlike growth of brown silica, and where exposed they have weathered to a pale-gray color. These two features are distinctive of the El Paso limestone in this region.

Montoya Limestone.—Above the El Paso limestone and lying unconformably upon it is the Montoya limestone of latest Ordovician (Richmond) age, which consists of 20 feet of hard gray sandstone at the base, overlain by 25 feet of cherty limestone. This cherty limestone consists of alternating thin beds of limestone and chert in the upper part and very dark massive limestone below. The lower part of the Montoya limestone contains few fossils, but in the upper cherty layers fossils of the Richmond fauna are relatively abundant.

Fusselman Limestone.—Strata of Middle Silurian (late Niagara) age, known as the Fusselman limestone, rest upon the Montoya beds, and are separated from them by an erosional unconformity. In places the basal part of these beds consists of a conglomerate made up of rounded pebbles of the underlying Montoya limestone in a limestone cement. At Lake Valley the exposures of Silurian limestone are highly silicified and in places much brecciated, especially along the fault scarp on the northwest side of the ridge. Quartz has recemented the fault breccia,

[52] Darton, N. H., op. cit. (U. S. G. S. Bull. 794), p. 326.
Clark, Ellis, op. cit., pp. 139-142.

which in many places is drusy and lined with clear quartz crystals. In the main the quartz is milky and granular, and where the breccia fragments have been replaced by this material the rock is locally called quartzite, which it greatly resembles. Brecciation of the original limestone has extended for some distance from the fault along the top of the beds, and this part of the formation has also been recemented and replaced with silica. Occasional fossils are found, notably one or more species of Favosites that usually have been converted to silica, the original interior open spaces being filled with this material while the walls have been dissolved away. Where erosion has exposed the Fusselrnan limestone, great boulders of the silicified rock are strewn over the surface, and rough, craggy outcrops occur on the dip slopes or project through the shallow detrital material that covers the lower slopes.

Percha Shale.—This formation is 160 feet thick in the Lake Valley district and is separated from the underlying and overlying formations by breaks in sedimentation, although accordant with them in attitude. It consists of a lower part of dark gray to black limonite-stained thin-bedded shale 100 feet thick, and an upper part of greenish-gray shale 60 feet thick, which is fossiliferous in places and contains thin layers of slabby and nodular limestone. The fauna of the upper part occurs principally in the limy beds and is regarded as being of late Devonian age. No fossils have been found in the lower beds, and it is not possible to say what proportion of the entire Devonian system these beds represent. Erosion of the soft shale has formed a valley from 500 to 1,000 feet wide on the dip-slope side of the underlying Fusselman limestone, along the contact of which the highway northward to Hillsboro follows for a distance of about 3 miles. In places the base of the Percha shale has been silicified and converted to a red, jaspery rock containing many vugs lined with clear quartz crystals. It is believed that the same solutions that silicified and replaced the topmost brecciated bed of the Fusselman limestone also replaced and jasperized the lower beds of the Percha shale. At other places the base of the shale member appears to be unaltered, but below it and above the silicified limestone, there is red limestone 12 feet thick, which may be Devonian. In a shaft which was sunk through this formation, nodules of iron pyrite about the size and shape of potatoes were observed near the base of the shale member.

Lake Valley Limestone.—The Lake Valley limestone is 210 feet thick in the local section, and although accordant in attitude with the Percha shale, the two formations are separated by an erosional unconformity. The known Lake Valley ore deposits occur almost exclusively in the Lake Valley limestone. In the district this formation can be divided into three members. [53] At

[53] Clark, Ellis, op. cit., pp. 140-142.

the base is the Nodular limestone, 48 feet thick, which consists of nodules of limestone up to 3 inches in diameter surrounded by a soft limestone matrix. Next above this is the Blue limestone or "Footwall Limestone," so called because it immediately underlies the ore bodies. This member is 24 feet thick, and according to Clark it contains 3 to 5 per cent silica and 45 to 50 per cent lime. It is broken in places by faults, which have been filled with a ferruginous, manganiferous and silver-bearing flint. The upper part of this bed consists of a layer of the same kind of flint 1 to 2 feet thick, which is present in practically the entire area of mining operations. A few nodules of flint are found in some of the layers of the limestone, but these are more like the flint or chert generally distributed throughout the Lower Paleozoic rocks in this region and not at all like the flint of the faults and of the topmost bed. The top member is a shaly limestone called the Crinoidal limestone, which is about 140 feet thick, and which may be further divided into a lower part 90 feet thick, an intermediate part 25 feet in thickness, and an upper part 25 feet thick. This limestone is very siliceous, containing 35 per cent silica and 30 per cent lime. In it are nodules of flint which can be distinguished only with difficulty in weathered-out specimens from the flint nodules of the underlying Blue limestone. This limestone is known in the district as the "Hanging-wall Limestone" because it directly overlies the ore bodies, and as the "Crinoidal Limestone" because of the abundant crinoids found •in it at Lake Valley and elsewhere.

Intrusive Igneous Rocks.—Until recently no cross-cutting intrusive rocks had been observed in the district, but when the writer last visited it (January, 1933), he observed in two recent underground workings igneous rocks that cut across the sedimentary beds and may be parts of dikelike connections with the overlying "Porphyrite" described by Clark. One of these intrusions is almost directly under the old rock house northeast of the Emporia incline. The sediments above it have been domed up into a small, rounded hill of perhaps an acre in extent, from which a large quantity of ore has been mined. It seems probable° that the doming in this area has been caused by the intrusion of a small mass of igneous rock that came to rest at greater depth than the mine openings have penetrated, and that the dikelike mass and also the surface porphyrite are offshoots from it. The other intrusion is in the Daly drift of the Carolina claim, and it also appears to be a direct feeder for the overlying porphyrite mass. These rocks are too greatly altered to be classified definitely, but they are probably monzonite porphyry or a closely related rock.

Tertiary Lavas.—In the vicinity of Lake Valley, as elsewhere in the county, great quantities of lava flowed over the surface in Tertiary times. These flows were mainly andesite in the earlier stages, with rhyolite and rhyolite tuffs following. Latite and latite porphyry occur in the lower andesite as dikes and small sills and as flows of limited extent on the andesite surface. To the southeast of the district near the Lake Valley railroad station the andesite laps gently over the dipping sediments. A fault has caused a slight displacement here, and a small intrusion that looks like fine-grained monzonite in hand specimens is visible in the andesite flows nearby. Northwest of the faulted block of sediments, andesite flows are in contact with Fusselman limestone for over 3 miles along the escarpment. On the southwest side of the sedimentary fault block rhyolite is in contact with the sediments, and to the northwest the higher parts of the Rhyolite Range are uniformly capped with rhyolite flows and tuffs. At the base of the rhyolite flows is a glassy member 3 to 10 feet thick, which is an excellent horizon marker as far north as the Kingston district, A few dikes and' irregular masses of latite or monzonite were noted in this outlying area.

STRUCTURAL RELATIONS

As seen on the map, Plate X, and on the various drawings prepared by Clark [54] and adapted by Gordon, [55] the Lake Valley district consists essentially of a tilted fault block of Ordovician to Mississippian sediments projecting through and entirely surrounded by volcanic flows. The sedimentary fault block within which the known ore deposits of the Lake Valley district occur is elongated in a northeasterly direction, corresponding to the strike of the beds. The strike of these beds is in general N. 45° E., and the dip 15° to 20° SE. Along the northwest escarpment of this block, the El Paso (Ordovician) limestone is in contact with Tertiary andesite. The minimum throw of this fault cannot be less than 625 feet. On the dip slope the topmost beds of the block disappear at an angle of about 20° under andesite flows. Some faulting also has occurred along this border of the block, although it is minor in amount, as is shown in two shallow shafts that begin in andesite and enter the underlying sediments at elevations that would indicate a displacement of 50 feet or less. At the southwest end of the fault block the beds are sharply terminated by a fault trending N. 10° W., along which the rhyolite of Porphyry Hill has been dropped relatively until it is in contact with the sediments. This fault marks the southwest termination of the known ore in the district.

Faulting in the region commenced at the time of the earliest extrusions or even before, and it continued during the whole of Tertiary time, due largely to the weight of the lava flows and the movement of the intrusive magmas. Following the period of andesite extrusions came the period during which the monzonites and latites of the region were intruded. The field relationships

[54] Clark, Ellis, op. cit., pp. 138-167.

[55] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), pp. 278-281.

indicate that the monzonite or latite porphyry was an offshoot from a deep-seated source of supply, probably cutting across the sedimentary beds and the andesite flows as a dike, following some plane weakness. At the contact of the andesite and the eroded surface of the limestone, or at the contact of the Blue limestone with overlying Crinoidal beds, this intrusion formed a sill, which extends for a distance of over a quarter of a mile parallel to the main trend of the ore bodies of the district. About 300 feet north of the northeast end of this intrusion is another area of altered monzonite about 200 feet wide and 600 feet long in a northerly direction, which appears to follow in general the trend of the Columbia fault. Two other patches of igneous rock, classed by Clark and Gordon as andesite, appear in the sedimentary area as residual patches of the surface flows of this material.

Several breaks striking N. 45° E., parallel to the escarpment face of the sedimentary block, and having a throw of a few inches to 5 feet, had an important localizing influence on the ore deposits of the district ; and several minor faults and fractures striking northwesterly, roughly parallel to the Columbia fault, have modified the pattern of the ore bodies as determined by the strike-fault system. In the southwestern part of the district, where the sedimentary rocks have been elevated in relation to the rhyolite of Porphyry Hill, they have been dragged along the fault plane to such an extent that they dip to the south and southeast at angles of 30° or more. They have undergone considerable fracturing and minor folding in this zone. On the dip slope of the sedimentary block the beds are slightly undulating and have been warped and distorted over areas of a few square feet, with only a few inches to a few feet of vertical elevation, but these small dome-like areas have acted as traps for the retention of mineral-bearing solutions and the precipitation of their mineral content.

ORE DEPOSITS

The ore deposits of the Lake Valley district are all of the bedded type. They are confined to the top of the Blue limestone and to the base of the Crinoidal limestone, and are from 3 to 15 feet thick. Where the limestone beds are not contorted, as in the northeastern part of the district, the ore has replaced the base of the Crinoidal limestone, and the hard cherty layer 1 to 2 feet thick at the top of the Blue limestone forms the footwall of the ore deposits. Near the limestone-rhyolite fault contact, however, where the beds have been dragged down by the movement, the brittle chert layer has been much fractured, and the silver-bearing manganese-iron solutions have completely recemented the chert breccia and have formed a siliceous ore. Varying thicknesses of the Crinoidal limestone overlying this chert zone have also been converted to ore by the replacing process. Along this dragged zone, especially in the Bridal Chamber and in the

Twenty-five and Thirty stopes, fracturing and folding of the limestone have been more important than elsewhere, and consequently these stopes reach a maximum height for the district. This difference in the manner of replacement has led some observers to believe that mineralization was due to two distinct types of solutions, an acid or siliceous type in the southern and southwestern part, which formed the Bridal Chamber, Twenty-five Cut and Thirty Stope ore bodies, and a more basic type in the area to the northeast; which formed the ores of the Strieby-Apache-Miles Standish-Virginia stopes and the Black Bird workings. In the area surrounding the Emporia incline the two solutions are supposed to have mingled, with the result that an intermediate type of ore was deposited.

It is thought that the primary ore-forming solutions in the district had their origin in the same deep seated source from which the "Porphyrite" or monzonite porphyry emanated, and that these solutions migrated upward along fractures in the limestone and along the monzonite-limestone contacts, followed the contact between the Blue and Crinoidal limestones over large areas, and from these moved upward again along minor fractures in the Crinoidal limestone. At first the solutions were high in silica and contained small amounts of manganese, iron and silver. The cherty replacement deposits that they formed contained about 75 per cent silica, 3 per cent iron, 6 per cent manganese and 2 to 5 ounces of silver a ton. Later the solutions were higher in calcium carbonate and silver, and during this period they deposited their load of silver and iron- and manganese-bearing calcite in the cracks and fractures formed within the cherty replacement bodies by the gradual elevating and tipping of the fault block within which the ore is found. The primary silver minerals were stephanite, proustite, pyrargyrite, and argentiferous galena locally, while the primary source of the manganese and iron was principally the iron- and manganese-bearing calcite, or ankerite, and the iron and manganese content of the chert beds. Some pyrite was also deposited.

The ore deposits owe their commercial importance entirely to the oxidation, transportation, and secondary precipitation and enrichment of the silver, which has taken place since the sedimentary fault block was elevated and laid bare by the erosion of the overlying extrusive rocks. The primary sulphantimonides of silver have been oxidized and converted to cerargyrite, embolite and native silver. Galena has been converted to cerusite, vanadinite and wulfenite. The ankerite has been converted to manganese oxides, limonite and manganiferous calcite. Calcite, coating cerargyrite and manganese minerals and as veinlets, is a secondary product. The oxidizing solutions have migrated down the dip slope just over or through the chert bed and have formed rich ore along the east-west fractures of the block. Some ore was deposited along fractures extending a short distance into the Blue limestone, and in a few places it occurs in fractures in the roof of Crinoidal limestone, but these deposits have little commercial value. Where the chert has been fractured the ore is siliceous as a rule, but where the chert was undisturbed the solutions filtered through the overlying bed of limestone and replaced it to form the basic ores of the district, in which the lime content is about 35 per cent and silica about 20 per cent. The solutions penetrating the fractured limestones first filled the fractures and spaces with a mixture of manganese oxides, silver minerals, and calcite, and later they dissolved out the fragments of limestone, leaving a coarse boxwork of the original cementing material ; still later these openings were filled by ore and gangue minerals. Where the secondary ore-depositing solutions precipitated their mineral content in fractures in the chert the silica content is as much as 60 per cent, the remainder consisting of limonite, manganese oxides, calcite and silver minerals. In the intermediate ores, as in the Emporia and Thirty-stope workings, the lime content averaged about 30 per cent.

HISTORY AND PRODUCTION [56]

The Lake Valley ore deposits were discovered by George W. Lufkin in August, 1878. News of the discovery soon spread, and a rush for the new camp was shortly under way. The mines were worked almost continuously until August, 1893. The best properties were absorbed within a short time by three companies, named from the groups of mines the Sierra Grande, Sierra Bella and the Sierra Apache. For several years during the later active history of the camp, operations were conducted under the management of the Sierra Grande Co., and after mining in the district ceased, the other properties were acquired by the Sierra Grande Co. The entire mineralized area, except for a few scattered holdings, is owned by this company. In the early eighties the Bridal Chamber, one of the richest single bodies of silver ore ever found, made the Lake Valley district famous.

These ore bodies are in close proximity to the Santa Fe trail and the old lanes of travel along the Rio Grande, and are marked in many places by prominent outcrops of black manganiferous flint. It seems strange that they were not discovered by the Spaniards, who passed and repassed them for nearly 300 years. [57]

No ore is being mined in the district at present. Occasionally in the recent past small shipments of silver ore or fluxing material have left the district, and since 1910 these have amounted to 46,261 tons divided as follows : Silver or silver-gold ores, 2,658 tons ; lead or lead-silver ores from the Emporia incline section of the district, 210 tons ; manganese ore high in manga-

[56] Clark, Ellis, op. cit., pp. 138 and 150.
Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 63), pp. 276-277, and 281-282.

[57] Clark, Ellis, op. cit., p. 138.

nese with some iron and silver and either basic or acid in composition, 1,239 tons ; basic flux material with low silver content and high in manganese, iron and lime, 21,791 tons ; and siliceous furnace material low in silver, manganese, iron and lime, and high in silica, 20,363 tons.

According to Clark,[58] the production of silver in the district from the date of discovery in 1878 to 1893 was as follows:

Production of Silver in the Lake Valley District, 1878-1893

	Ounces
Bridal Chamber	2,500,000
Thirty Stope	1,000,000
Emporia Incline	200,000
Bunkhouse	300,000
Bella Chute	500,000
Twenty-five Cut	200,000
Apache and others	300,000
Total	5,000,000

From 1894 to 1910 no record of the production of this district separated from that of the Sierra County total is available, although it is estimated by persons acquainted with the earlier history of the district that various odd-lot shipments during this time and some few others not included in the above tabulation for 1878-1893 yielded about 500,000 ounces of silver. From 1910 to 1931 the production is reported to have been 46,261 tons, from which it is estimated that approximately 275,000 ounces of silver was recovered. The total silver produced from the time of the discovery of the district to the end of 1931 is therefore in the neighborhood of 5,775,000 ounces.

In 1928-1929 a drilling campaign was undertaken in the district to explore the lower beds of the Lake Valley limestone, particularly at the horizon just above the Percha shale. Several holes were drilled with shot machines, which produced cores about 2 1/2 inches in diameter. In a few places small showings of ore were found at short distances below the known ore horizons, but this ore invariably proved to be only a rapidly diminishing downward projection from the known ore horizon. The top of the Percha shale was barren of ore. One hole near the old Virginia shaft was drilled to a depth of approximately 400 feet and penetrated through the Percha shale into a thin bed of pink limestone, which may be either the bottom of the Percha shale or the top of the Fusselman limestone. Several feet of this limestone was brecciated and showed evidence of having been permeated by hot siliceous waters, but no silver or manganese minerals were noted.

MINE DESCRIPTIONS [59]

The workings in the different parts of the property are most conveniently described under the names of the three companies

[58] Clark, Ellis, op. cit., p. 150.

[59] See footnote, page 59.

originally owning the district, the Grande, Bella and Apache. Figure 14 shows the Grande and Bella workings, which extended from the extreme southwest end of the district to the Columbia fault. The excellent cross sections of the district by Ellis Clark[60] are also well worth reviewing in this connection.

GRANDE WORKINGS

The Grande workings include Twenty-five cut, Twenty-five stope, Thirty stope, $ridal Chamber, and the Carolina workings. This section of the camp produced the major part of the silver shipped from the district, and generally the ore was of higher grade than that obtained elsewhere. Operations were carried on chiefly from the surface by means of open cuts, short inclines and

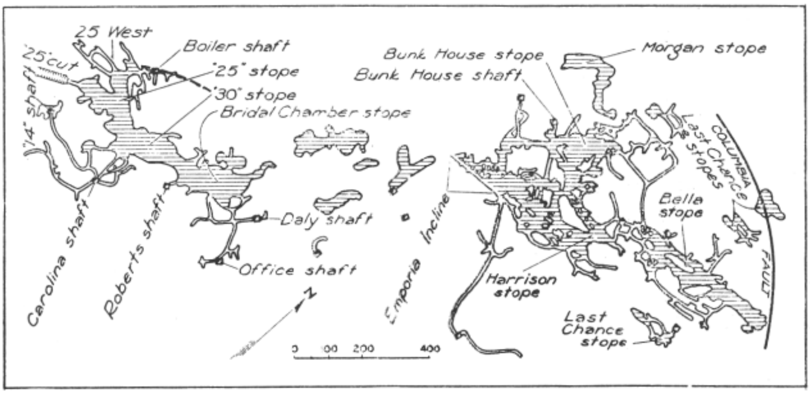


FIGURE 14.—Mine workings in the Grande and Bella sections of the Lake Valley mining district. (After Ellis Clark, Jr.)

shallow shafts, which penetrated to ore bodies lying under a few feet of barren covering. In the extreme southwest end of the district Twenty-five Cut ore was removed from an open cut, which was 50 feet wide, 25 feet deep and 200 feet long, and which was entirely within the Blue limestone. The ore was not especially high grade, and it was very siliceous. In Twenty-five West stope, the ore was found a short distance below the surface within the Blue limestone. North of this stope drifts several hundred feet long explored the contact between the Blue and Nodular beds of limestone without encouraging results. The entrance to Twenty-five stope through Twenty-five Cut tunnel was along the contact between the Blue and Crinoidal limestones, which was here very tight, and although very siliceous it contained only small amounts of secondary silver and manganese minerals. In the roof of Twenty-five West there is a mineralized fissure 2 to 3 feet wide and as long as the stope, which does not

[60] Clark, Ellis, op. cit.

continue into the Blue limestone beneath the stope. No. 14 shaft was sunk 100 feet south of the Twenty-five Cut tunnel and down the dip of the beds from the ore in Twenty-five cut toward the rhyolite contact. This shaft cut the contact of the Crinoidal and Blue limestones at 63 feet below the collar, and manganiferous flint was found in quantity, with occasionally enough silver for assay, but no commercial ore was removed. Secondary processes had not enriched the ground along the dip of the beds this far under the cover of Crinaidal limestone. Farther down the dip of the beds, the Carolina shaft and workings prospected all the beds and contacts of that area, but no enriched ore was found, although much primary mineralized chert was present.

East of Twenty-five stope is Thirty stope, 87 to 125 feet long down the dip and 8 to 37 feet in height. It was in solid ore, which was very siliceous throughout. This ore body lay entirely within the Blue limestone, and except at the outcrop was entirely under a cover of Crinoidal limestone.

The beds dip more steeply in this area than at other places in the district and are sharply folded as a result of being dragged against the rhyolite hanging-wall of the contact fault. Due to this folding and the attendant fracturing of the cherty bed and surrounding limestone, the ore bodies were more massive and more siliceous in composition. A second important essential in the location of these ore bodies was the fortuitous occurrence of these folded and fractured areas just at the line of contact with an overlying bed or cover of Crinoidal limestone. Over the top of Thirty stope there is a large body of manganese-iron flint which does not contain enough silver, except in patches, to warrant shipment at low prices for the metal.

The Boiler shaft, 150 feet north of Twenty-five stope, was sunk on the Boiler Shaft fault, which strikes N. 50° E. and dips locally 80° SE. This shaft is 175 feet deep, and for 80 feet it passed through mud, which filled the fault opening and solution cavities in the limestone alongside. It then cut Nodular limestone of the north wall for 58 feet and was stopped after penetrating 37 feet of the topmost green shale member of the Percha (Devonian) shale. The Nodular limestone was found to be slightly mineralized with pyrite and galena. The limestone-shale contact was barren.

Thirty stope continued eastward along the strike of the beds with greatly diminished dimensions, and merged with the Bridal Chamber across this restricted neck of ore. The extreme eastern edge of Thirty stope and the greater portion of the Bridal Chamber were covered with the porphyrite body shown in Plate X. The Bridal Chamber ore body was a replacement of the Blue limestone. It extended 104 feet down the dip and was 20 feet in maximum thickness, although the average thickness was nearer 7 feet, and it was worked along the strike for a distance of 200 feet. The ore in this body was concentrated within a shallow basin formed by the dragging and folding of the beds along the fault in such a manner as to provide the maximum of favorable conditions for the concentration of an unusually rich body of silver ore. It is said that in the heart of this deposit, several carload shipments were made that ran over 400 ounces of silver to the ton, and that the cerargyrite was so massive that it was sawed from its position in the stope. The greater portion of the ore from here, however, was reported to have assayed between 20 and 30 ounces of silver to the ton.

East of the Bridal Chamber a small deposit of ore was mined from the surface, and a second small deposit was removed from the Daly shaft at a depth of 50 feet. Farther down the dip of the beds no commercial ore was found, although considerable prospecting was done through the Daly, Office and Office No. 2 shafts. Along the contact of the Crinoidal limestone and Blue limestone, an almost continuous layer of the primary manganiferous-ferriferous-silver-bearing chert 1 to 2 feet thick was followed in these workings, but the bed was so far under the cover of Crinoidal limestone that it was not enriched.

BELLA WORKINGS

The Bella workings rank second to the Grande workings, both in the amount and grade of the ore produced. They are northeast of the Grande workings and include such well-known stopes as the Emporia Incline, Bunkhouse, Harrison, Strieby, Bella Chute, and the Last Chance workings. The Emporia Incline ore body, which began as a narrow shoot under a few feet of wash, continued east 400 feet to the bottom of the basin, where the ore was found 150 feet from the surface. This was the deepest place in the district from which ore was mined. The ore shoot then bent sharply toward the northeast, and rose gradually for 250 feet along the Harrison workings. It then turned toward the east to form the Bella shoot, which continued for 450 feet to the Columbia fault. The Incline ore, especially near the head of the incline, contained commercial quantities of lead in the form of ceiusite and galena. It contained a little iron, moderate amounts of manganese, and sufficient silica to make it a neutral ore. The central portion of the Bunkhouse stope contained much cerargyrite, while other portions yielded a basic ore containing some iron, much manganese and a small amount of silica. The eastern part of this stope produced an ore low in silver and silica, but so high in iron and manganese that it made desirable fluxing material.

Comparatively little ore was found in the Strieby, and although much development work was done and the area thoroughly prospected, there are few stopes. The Columbia workings north of the Strieby are close to the surface, and although insignificant amounts of work have been done, it was stated by Clark that a wagon-load of ore from a pocket in this ground yielded $20,000. The Last Chance workings are scattered; two shafts with stopes are located north of the Bella Shoot, one of these being at the contact along the Columbia fault, and the third stope is south of the Bella stope. Manganese ore was found along the contact at a depth of 14 feet. The ore body was opened up in its richest part, where the ore was basic. In the shaft considerable cerargyrite and large percentages of iron and manganese were present in the ore, with little silica. At a distance of 50 feet from the shaft, however, it is reported that the content of silver, iron and manganese had decreased and silica had increased, so that the ore was no longer salable as a basic flux. At 87 feet from the shaft silver was so low and the silica so high that the ore was no longer profitable to mine.

In all the Bella workings, but little folding of the beds is noted, aside from the gentle dip and warpings characteristic of all the beds in this tilted fault block. As a con,equenc,3 of this lack of distortion the iron-manganese-chert layer is but little fractured, and the rich secondary ore has replaced the Crinoidal beds immediately overlying the chert. Some ore occurs in the Blue limestone in this area, but it is where the Crinoidal beds are absent, or because of some purely local features. Minor fracturing of the beds occurred after the introduction of the chert layer and before the deposits were enriched by secondary processes. This is clearly evident in many of the stopes where rich secondary ore ends abruptly against such fractures, while the primary chert layer, which has been displaced a few feet, continues beyond the fracture with only minor enrichment or none at all.

APACHE WORKINGS

Northeast of the Columbia fault considerable work was done along the contact of the Crinoidal and Blue limestones in open cuts and through shallow shafts in what are now called the Apache workings. The ore was close to the surface and under a thin shell of a hanging wall. The production was principally iron-bearing fluxing material, the silver content in general being very low. The workings expose a considerable tonnage of siliceous iron-bearing material containing but a few ounces of silver per ton. Clark notes that on the Bacon claim of the Apache group much money was expended in prospecting the ground, much of which contained abundant iron-flint, but with the exception of float taken from the surface no ore was ever shipped.

FUTURE POSSIBILITIES

Prospecting in the Lake Valley district near the contact of the Blue and Crinoidal limestones should result in the discovery of small pockets and stringers of high-grade silver-bearing ores. With higher prices for silver than have existed for the past four years, quantities of ore may be won from old stope pillars and from the walls of old stopes, and in this manner much ore that was sub-marginal under the low prices may, by careful work, be shipped for its silver content with profit. From time to time, considerable material that would be sub-marginal under almost any price for silver may be shipped profitably as smelter fluxing material, if the fluxing constituents are paid for and the base-treatment charges eliminated. On the whole, however, extensions of the Lake Valley ore deposits are unlikely, either in area or in depth. The known primary deposits of the district, where they have not been enriched, without exception, are below commercial grade. Secondary enriched material has been largely restricted to the beds immediately above and below the primary mineralized layer, and only where the primary layer has been much fractured, has it been greatly increased in value by secondary processes.

MACHO DISTRICT

LOCATION AND AREA

The Macho mining district is about 8 miles southwest of Lake Valley and approximately 13 miles northwest of Nutt, the junction point of the Lake Valley branch line and the Rincon-Silver City branch line of the Atchison, Topeka & Santa Fe railway. The district is a small one, the productive portion being less than a square mile in area, but mineralized veins have been found as much as 3 miles away in a northeasterly direction. Two claims, the Bulldog and the Anniversary, are the only ones having extensive development work, and it is from these that most of the production from this district has come. Seven other claims included in the Bulldog-Anniversary group have only a small amount of development work on them, and there is no record of production other than a few small shipments. All of these claims are owned by Mr. D. M. Miller of Lake Valley. Surrounding them are a few others, apparently still being held by annual assessment work. On some of these claims a considerable footage of work has been done, but no important shipments are known to have been made.

GEOGRAPHY

The immediate vicinity of the Macho district is a basin-like area of low relief converging into one of the dry washes which in this region drain to the southeast and eventually disappear into the alluvium of the plains north of Deming. Surrounding this basin is a group of low, rounded hills not over 100 feet high. Three miles to the west the summit of the Black Range reaches an elevation of 6,500 feet, while slightly west of south Cooks Peak in Luna County, rising to an elevation of over 8,300 feet, is a prominent landmark.

GEOLOGY

The Macho mining district is near the eastern of of the thick lava flows that cover most of the western half of the county. (See Plate I.) The principal rocks of the district are andesite breccia and andesite flows. The low hills surrounding the district are composed principally of andesite flows higher in the series, which are slightly more resistant to erosion than the basal breccias. In places, particularly to the west in the foothills of the Black Range, patches of rhyolite overlie the andesite and tend to form steep cliffs of light buff to pink color, in sharp contrast to the dark brown and purple colors of the andesites. Dikes of latite porphyry cut the lower andesites ; these dikes are generally much weathered and decomposed, and the outcrops in many places are characterized by the conspicuous yellow color of the altered rock, rather than by prominently projecting outcrops. Sedimentary rocks do not appear at the surface in the district, and the nearest outcrops are at Lake Valley and in the Cooks Peak region. A drill hole from the 400-foot level of the Anniversary shaft, which reached a depth of 700 to 800 feet below the surface, may have penetrated Fusselman (Silurian) limestone. No reliable data on this hole appear to be available.

STRUCTURAL RELATIONS

The dikes in this district form a radiating system, the center of which is believed to be a short distance southwest of the Anniversary mine. The Anniversary shaft is on one of the northeastward-trending dikes, and some exploration has been done on adjacent radiating dikes to the east and west of it. Brecciated andesite, suggestive of faulting, occurs generally along one wall of the latite porphyry dikes. Part of this movement is believed to have taken place simultaneously with the intrusion and part later, but before the period of mineralization had ceased. This intrusion of latite porphyry and the fracturing and movement which accompanied and followed it served to break up the andesite, thus affording ready access of mineralizing and altering solutions from below and later oxidizing surface waters from above. The fractured and altered rocks have been easily eroded, with the result that the mineralized area is now a basin.

ORE DEPOSITS

The ore deposits of the Macho district are in veins, occurring between well-defined walls of andesite, in brecciated andesite, and within the latite porphyry dikes. The veins strike northeast ; near the surface they dip steeply or are nearly vertical, but as depth is attained they flatten to the west. In the brecciated andesite the mineralization is principally open-space filling with subordinate replacement of the brecciated material. In the latite the mineralization is almost entirely by replacement, but in places of slight fracturing and brecciation, open-space filling has taken place. The best ore is in the andesite. The veins vary in width from 4 to 6 feet, of which 2 to 4 feet is low-grade replacement ore in latite porphyry dikes, and about 2 feet is high-grade ore in the brecciated andesite of the wall.

The ore minerals of the district are galena, cerusite, anglesite, sphalerite, calamine, vanadinite, wulfenite and pyrite. The gangue is principally quartz, of which some is cherty in appearance and some has a slightly greenish color. Silicification and sericitization of the andesite and latite is the principal form of alteration in the veins. The andesite farther away is propylitized, with the development of abundant chlorite, pyrite, sericite and epidote, and some secondary quartz and calcite.

At the Anniversary vein the hypogene ore mined in the brecciated portion of the vein is reported to contain approximately 15 per cent lead. The low-grade latite-dike portion averages between 3 and 4 per cent lead. The silver content averages 0.6 ounces a ton for each per cent of lead in the ore. Zinc occasionally appears in the analyses of smelter shipments, ranging between 0.4 and 7.2 per cent ; however, only 299 tons shipped to the smelter, out of a total of 1,508 tons for which the writer saw the smelter returns, showed any zinc content, probably because the other shipments were not assayed for zinc. Gold varied from 60c per ton in the low-grade shipments to $1.06 per ton in the higher grade material. In the upper part of the vein vanadinite is rarely observed, but in hand-sorted shipments and concentrates, 1 per cent of V_2O_5 is reported for each 5 per cent of lead. On the lower levels vanadium decreased greatly.

HISTORY AND PRODUCTION

The Macho district was discovered in 1879 or 1880 by prospectors who had come to the region following the discovery of the rich Lake Valley ores a few miles to the north. Pay ore was found at the surface in the Old Dude, or Anniversary vein as it is now called, and some mining was done in 1880. Prior to 1904 considerable ore was produced from this vein, of which no record is now available, but which must have amounted to nearly 1,000 tons, judging from a sketch section made by the writer from verbal descriptions of the workings in the district. (See figure 15.) The mines were idle from 1904 to 1926 except for annual assessment work, a minor amount of prospecting, and possibly some small shipments. In 1926 intensive development work was begun at the vein on the Anniversary claim and was extended into the Bulldog claim lying to the northeast of it. During this period a total of about 1,640 tons of ore was shipped.

Various grades of material shipped have shown a surprisingly uniform relationship between the metals, as is indicated by the table below. The dump ore is a combination of a handsorted product and of screenings that have been jigged in a hand-operated Joplin type of jig. In general, the run-of-mine ore not suited for shipment without sorting was screened throug a 1/4-inch-mesh screen.

Summary of Shipments from the Macho District

Class of Ore	Year	Tons	Zinc, per Cent	Gold, value	Silver, oz. per ton	Lead, per cent	Sulphur, per cent	Insol., per cent
Dump ore and concentrates	1926	495	——	$0.55	4.6	7.7	4.3	67.8
Mine ore (80-foot level)	1927	95	——	0.88	14.5	20.0	6.2	59.2
Mine ore (lower working)	1928	1051	4.1[a]	1.14	15.0	26.1	5.9	52.5

[a] Average of 5 lots only.

The oversize was hand sorted into a shipping product an waste, while the undersize was hand jigged into a shipping pros uct and a waste tailing. The hand-sorted and jigged mated: assayed as shown in the above table, and jig rejects left on a dump assayed 3 per cent lead and amount to between 4,000 an 5,000 tons. Nearly 1,000 tons of screened but not jigged materi; assaying 4.5 per cent lead remains on the dump awaiting trea ment. The remainder of the dump, approximately 5,000 ton consists of waste and partly hand sorted oversize material i about equal quantities. The waste part may average 3 per cei lead, and the oversize and partly sorted material probably ave ages 4 to 5 per cent lead. Some layers of the dump are higl enough in lead to ship direct to the smelter under normal pric(for lead.

Transportation and treatment charges on the ores from th district have varied within the following limits : Trucking $2.(per ton ; freight to El Paso, $1.00 to $1.15 per ton ; and smeltin base rate, $3.50 to $5.00 per ton.

MINE WORKINGS

The Old Dude shaft on the Bulldog claim is about 300 fel north of the main Anniversary shaft. The lowest lateral wor] ings appear to have been on the 100-foot level, although the sha: was sunk to a depth of 300 feet. The Anniversary shaft on ti Anniversary claim lies south-southwest of the Old Dude shot and is 500 feet deep. Both of these shafts are on the same vei: which has a strike of N. 10° E. Levels have been extended 1 the north to connect with the Old Dude shaft on the 100-fo1 and 300-foot levels. South of the shaft, 100-foot, 200-foot, 400-fol and 500-foot levels have been driven. The 100-foot and 200-fol levels south of the shaft yielded ore during the later history (the mine, the stoped areas being shown on the sketch sectio: About 200 feet south of the shaft a barren dike cuts off the vei and no mining has been done south of this point. The 40 foot level south extends 150 feet from the shaft, and at the end this level a diamond-drill station was located, the hole from whit extended to a depth of between 300 and 400 feet, and from ti bottom of which Fusselman limestone breccia is doubtfully reported. This drill hole was apparently not well located, because the Anniversary-Bulldog vein flattens in dip to the west as depth is attained, so that without a crosscut to the west into the hanging wall, a vertical drill hole, such as was reported put down here, would be farther in the footwall at its bottom, 700-800 feet below the collar of the shaft, than is any other prospect opening in the mine. (See sketch cross-section of figure 15.)

Water was standing in the Old Dude and Anniversary shaft at the time the property was visited, and the underground work-

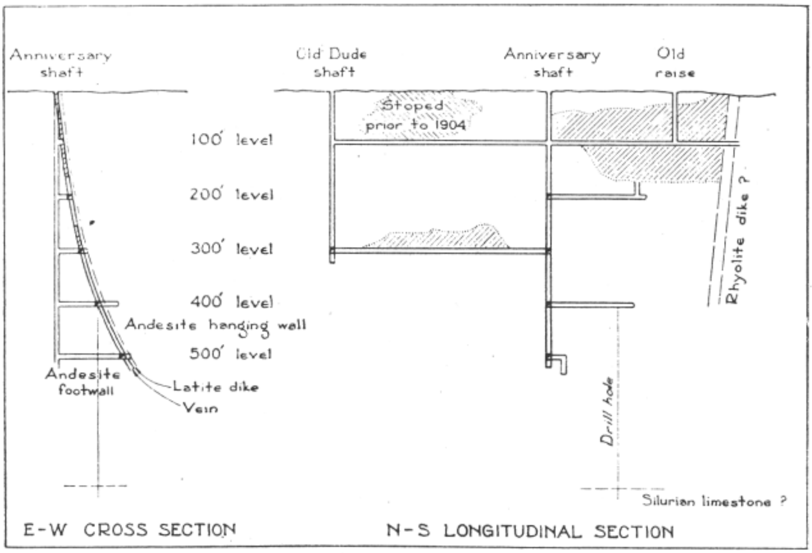


FIGURE 15.—Longitudinal and cross sections in Old Dude vein, Macho mining district.

ings were not inspected. It was estimated that the water was standing at an elevation 60 feet below the collar of the Anniversary shaft. Mr. Miller stated that when the mine is unwatered and working, 50 65 60 gallons per minute must be pumped. This amount is ample to supply a small mill of 50 tons daily capacity or less, but it might diminish with continued pumping.

About 1,200 feet northeast of the main Anniversary shaft, an old shaft 300 to 400 feet deep was sunk in early days on a vein which is near the Bulldog-Anniversary vein and which strikes N. 15° E. The shaft timbers were caved so that entrance could not be effected, but the dump indicates that the workings are in slightly mineralized brecciated andesite adjacent to a latite dike.

No lateral development work is known to have been done from this shaft.

At 1,000 feet northeast of the main shaft and on another of the radiating dikes is an old shaft about which even less information could be gathered. The shaft is perhaps 150 feet deep, and probably little or no lateral work has been done. The dump rock from this shaft indicates that the shaft follows the contact of a latite dike and brecciated andesite wallrock, both of which are well leached and altered. This rock contains considerable manganese oxide, probably psilomelane, which has partly filled the open spaces between the fragments of altered andesite and latite as botryoidal masses. At a later period carbonate-bearing waters penetrated the remaining open spaces and filled them with calcite, so that on fracture faces small spherical shots of black psilomelane appear to be completely embedded in the calcite. No minerals of value were seen on this dump, and no production has been reported from this shaft.

SECONDARY ENRICHMENT

The upper portions of the veins in the district have been partly oxidized and leached by meteoric waters. From the surface to a depth of 60 to 70 feet, pyrite has been completely altered to limonite. The leached outcrops have a rusty cellular appearance, due to the formation of silica boxwork in the space formerly occupied by the pyrite crystals. Manganese oxides and limonite form black to dark brown slaggy coatings in the silica boxwork, botryoidal bunches and stalactites in the open spaces of the vein, and thin films in the fractures of the wall rock. The manganese may have been leached from the minerals of the adjacent rocks or derived from the small amount of manganiferous calcite in the veins. In the oxidized zone the galena has been altered in part to anglesite and cerusite. Most of the sphalerite has been leached, but small amounts of calamine and smithsonite remain in the oxidized ore.

A short distance below water level pyrite occurs in subordinate amounts, and the zinc in the ore ranges from 0.4 to 7.2 per cent. This zinc represents largely the primary sphalerite of the vein, but it includes also a part of the zinc leached from the upper portion of the veins, transferred downward in circulating waters, and redeposited in the reducing zone. Lead shows only a slight relative increase between the 80-foot level and the lower workings (20.0 per cent to 26.1 per cent as shown in the table on page 187), which may be due to an accidental distribution of the metal or to the deposition of a small amount of secondary galena.

POSSIBILITIES OF THE DISTRICT

According to records and estimates, 2,640 tons of ore and concentrates has been shipped from the Macho district in the past and approximately 10,000 tons of material in the dumps may at some future time be sorted or milled at a profit. The veins in most places are 4 to 5 feet wide, but stoping has been confined to a width of 2 or 2 1/2 feet in the richest part. Furthermore, the Anniversary vein may be considered with some degree of assurance to carry moderately profitable ore to a depth of 300 feet, and as only 30 per cent of the ground has been removed from the stopes and development headings within this area, it appears that there may be enough ore on the dumps and in place in the veins to run a 50-ton mill for a period of nearly three years. Development work below the 300-foot level is insufficient to warrant including any ore from this horizon in an estimate of possibilities, but when it is considered that the highest grade ore shipped from the mine was reported from just above the 300-foot level from a stope that is between 200 and 300 feet long, it is reasonable to expect that there may be substantial tonnage of profitable ore below the 300-foot level.

SAN MATEO MOUNTAINS

GOLDSBOROUGH DISTRICT

LOCATION AND GEOGRAPHY

The San Mateo Mountains, which occupy an elliptical area of approximately 800 square miles, are mainly in Socorro County, but the south end extends about 8 miles into Sierra County. The major axis of the ellipse trends southwest and is about 12 miles west of the Elephant Butte reservoir. The range is rugged and travel is difficult. The canyons in their upper reaches are confined between precipitous cliffs, and the courses of the streambeds are broken by sheer falls of as much as 30 feet. In the lower parts of the mountains the valleys are more open, and the low hills between are rounded and gently sloping. South of the main range are several prominent landmarks, consisting of outliers of the more resistant rocks that project through the valley fill as hills and ridges.

GEOLOGY

The San Mateo Mountains consist of volcanic rocks, which in the southern portion show the normal sequence of flows as found elsewhere in the county. These are, from the bottom upward, andesite breccias, flows, and tuffs ; latite flows ; and rhyolite tuffs, flows and breccias. Dikes of rhyolite, latite and basalt are abundant in the lower flows. In the canyon near the Red Rock ranger station a small cropping of a rock resembling gabbro was noted, but its nature was not determined. Older sedimentary rocks were not observed anywhere in this part of the range. No large faults were seen, but the higher cliffs of the range may be due in part to faulting. The volcanic rocks are, however, traversed in all directions by cracks and fractures caused by the settling of the mass and the adjustment between blocks during cooling and shrinking.

ORE DEPOSITS

Gold is the chief metal in the deposits of this area, and the known veins are typically of the Tertiary epithermal type. Silver accompanies the gold in varying proportions, and small amounts of lead and zinc are associated with the gold-silver ores in places. In the lower part of the southwest slope of the range, traces of copper are found in the andesite breccia, and many prospect pits have been dug in these outcrops. So far as known, however, no shipments other than a few sacks of hand-picked ore have ever been made, and within a short distance from the surface the veins pinch to knifeblade seams and disappear.

WORKINGS

The Goldsborough district lies within the southern foothills of the San Mateo Mountains and is about 28 miles from Hot Springs, the nearest town. At the time of the writer's visit only one group of eight claims had the appearance of being held by bona *fide* annual assessment work. These claims were originally located by H. A. Hanley and his associates, who had been grubstaked by N. S. Sweeney, a merchant of Hot Springs. The claims are now held by Mr. Sweeney and some associates. Apparently, none of the claims of the district have been patented.

The area is one of andesite and rhyolite flow rocks, which have a general strike of N. 80° E. and a dip of about 10° SE. The rhyolite has flowed out over a gently undulating and partly dissected surface of andesite, the depressions in which had been partly filled with loosely consolidated beds of detrital material. Rhyolite tuffs and breccias containing coarse quartz crystals and much-broken feldspars are a prominent part of the sequence. These rocks are interbedded with the rhyolite flows and in part overlie them. Erosion since the last of the rhyolite intrusions has again laid bare the underlying andesites and breccias in the canyons and on the low slopes of the foothills. On the claims mentioned the rhyolite is probably at no place over 100 feet thick, although it is much thicker farther to the south, where the flows dip below the floor of the plains and are protected from erosion. On the east side of the property, near one of the shear zones, a shallow prospect pit is said to have penetrated into the andesite, but as this pit and its dump were covered over by the dump from a later shaft, this could not be verified.

Crossing the property with a strike of N. 10° W. is a zone that dips 68° SW. and has a width of 3 to 10 feet, in which the rhyolite is sheared and brecciated and slightly altered. Two hundred feet east of this zone is a second zone with a strike of N. 15° W. and a dip of 81° SW., and similar in nature to the first. Numerous cross fractures in the rhyolite show evidence of slight movement and the subsequent introduction of subordinate vein material.

Along the first of the shear zones noted above are several pits, open cuts and shallow shafts, from which only a few hundred pounds of hand-sorted ore has apparently been shipped. On the second shear zone are two shafts within 15 feet of each other, one 30 feet and the other 65 feet deep, with a crosscut 30 feet long at the bottom trending N. 15° W. along the strike of the shear zone. These workings are all in rhyolite. One hundred feet east of the shafts and near the east side of the property is an open cut 50 feet long, which gains 20 feet in depth in that distance. This open cut has been driven in the rhyolite along a zone of shearing and brecciation that trends S. 25° W. In all workings the walls of the shear zones are well defined and stand without support.

The vein material consists essentially of quartz and pyrite. Near the surface the rhyolite of the shear zones and near the fractures has been flooded with iron-bearing solutions and has been stained bright red and yellow. A slaggy appearing botryoidal form of limonite, almost black in color, lines the spaces between the breccia particles and locally is associated with minute quartz crystals. In places near the surface a small amount o,f silica box-work is associated with the slaggy iron oxide, and weak staining by manganese has occurred. Where the rocks are tight the original quartz-pyrite gangue of the fractures and shear zones appears within 25 feet of the surface, while in the more open channels oxidation extends to depths of 50 to 100 feet. Native gold is reported to have been found in the shear planes during the sinking of the shafts, and pannihgs of surface outcrops are said to show a small amount of gold. Assays of the vein matter vary from a trace to $420 per ton, but only single assays of commercial grade have been obtained in any one place, and there is nowhere an indication of a continuous vein or ore shoot. On the whole, the mineralization of the district is weak.

QUARTZ MOUNTAIN DISTRICT

Quartz Mountain is one of the outliers of more resistant rock projecting through the valley fill about 2 miles from the southern end of the San Mateo MoUntains. The hill is located about 4 miles west of the Red Rock ranger station on the old Monticello road. It attains a height of about 150 feet and is essentially a tilted fault block, the strata of which strike N. 70° E. and dip 15° SE. The base of the block consists of an andesite flow that is visible for just a few feet above the detrital material which laps gently up against the sides of the escarpment. Above this is a rhyolite agglomerate about 70 feet thick, and above this on the north end of the hill is a mass of white silicified rhyolite breccia 50 to 80 feet in thickness. The block is cut off on the west by a fault striking N. 25° W. and dipping 62° SW., which is highly silicified and intensely iron stained through a zone of gouge and breccia that averages 10 to 15 feet in width. Along the north escarpment the displacement has been in an eastward-trending shear zone. A fault with a displacement of approximately 100 feet marks the south side of this zone, and along it the white rhyolite breccia at the top of the hill has been dropped down against the rhyolite agglomerate, while the agglomerate on the north is now in contact with the andesite in the south wall of the fault. The northern end of the hill is strewn with fragments and blocks of the white silicified rhyolite and agglomerate. At the time of the faulting or shortly after, the rocks were silicified along the fault fissures and adjacent to many small fractures formed in the brittle rocks by the faulting. Complete silicification of the rhyolite breccia followed, and the rhyolite agglomerate was partly silicified.

Several shallow pits have been dug in this area, and on the west side of the hill tunnels have crosscut the breccia and gouge of the fault, and a 15-foot shaft has been sunk along the footwall of the fault. Where silicification has been most intense, reported assays indicate that the rock contains $3.00 to $4.00 in gold. Assays from other parts of the hill are said to be lower, and it has been stated that the mass of the silicified material will average between $2.00 and $3.00 to the ton, but these reports were not verified by the writer.

MUD SPRINGS MOUNTAINS

HOT SPRINGS DISTRICT

Six miles north of Las Palomas and about 3 miles west of Hot Springs there is a group of low hills that measures about 4 miles in length in a northwest direction, and about a mile and a half in greatest width. These mountains are called Sierra Cuchillo by Darton, [61] but in the present report, following local usage and that of Gordon, [62] the mountains east of Fairview have been called the Sierra Cuchillo and these hills the Mud Springs Mountains.

The Mud Springs Mountains have been carved out of a tilted fault block, the strata of which strike about N. 55° W. and dip approximately 20° NE. The range is approximately 500 feet high. From bottom to top along the southwest or fault-scarp face of the range, the same Paleozoic sequence that occurs in the Sierra Caballos has been recognized, beginning with a basement of pre-Cambrian granite and ending with the Magdalena (Pennsylvanian) limestone. The northeast or dip slope of the range has been dissected by arroyos and their tributaries, which have

[61]-Darton, N. H., op. cit. (U. S. G. S. Buil. 794), p. 320, Plate 62.
[62]Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 262.

cut into the Magdalena limestone, but in no place, so far as known, have they reached the underlying Mississippian strata. The block is surrounded on all sides by nearly horizontal beds of sediments considered to be of Santa Fe age, which make up the terraces bordering the flood plain of the Rio Grande. These beds consist largely of pink to buff-colored layers of moderately consolidated gravel, sand and silt. Overlying the Santa Fe beds and concealing them except where the terraces have been truncated by the eroding action of the river and its tributaries, is the Palomas gravel of Quaternary age. This formation consists of loose to partly consolidated somewhat-rounded boulders, in places rudely stratified with layers of gravel and sand, and having a predominating gray color which grades into buff in the finer parts.

MINE DESCRIPTIONS

EQUATOR AND IRON REEF GROUP

This group of claims is located on the southwest face of the Mud Springs Mountains, about 6 miles by road from Hot Springs. It is the property of the Fannie G. Villard Estate. Mr. E. Tittman, an attorney in Hillsboro who is handling the affairs of this estate, estimates that ore having a value of about $40,000 in horn silver (cerargyrite) has been shipped from these two claims, and that there is ore on the deeper levels, which after hand sorting will average 35 per cent copper, with small amounts of silver.

MANGANESE (ELLIS CLAIMS)

Northwest of the town of Hot Springs and within a mile of the city limits, manganese oxides occur in nearly horizontal beds of sandstone considered by the writer to be of Santa Fe age. According to Wells, [63] who describes these deposits in detail, the manganese minerals were deposited by spring waters. The bulletin by Wells should be consulted for further details of these deposits.

FRA CRISTOBAL RANGE

ARMENDARIS GRANT

GEOGRAPHY

The Fra Cristobal Range is in the eastern part of Sierra County and east of the Elephant Butte reservoir. The maximum elevation is about 6,600 feet. The Jornada del Muerto bounds the range on the east, and the Albuquerque-El Paso line of the Atchison, Topeka & Santa Fe railway traverses this valley.

The Fra Cristobal Range is within the boundaries of the Armendaris land grant. It is said that this grant from Spain gave the original owners all surface and mineral rights, excepting only gold, silver and mercury, these being reserved by the

[63] Wells, E. H., Manganese in New Mexico: N. Mex. Sch. of Mines, Min. Res. Survey Bull. 2, pp. 61-63, 1918.

Crown. The Vittorio Land & Cattle Co., the owners, had a geological survey made of the grant, and they report that no mineral deposits of interest were found. The following description is based largely on available reports and on observations made from outside the grant.

GEOLOGY

The main Fra Cristobal Range is a fault block of eastward-dipping sedimentary rocks. West of this block is another fault block, which is higher structurally but which has been eroded down until only a low ridge of granite remains. As viewed from

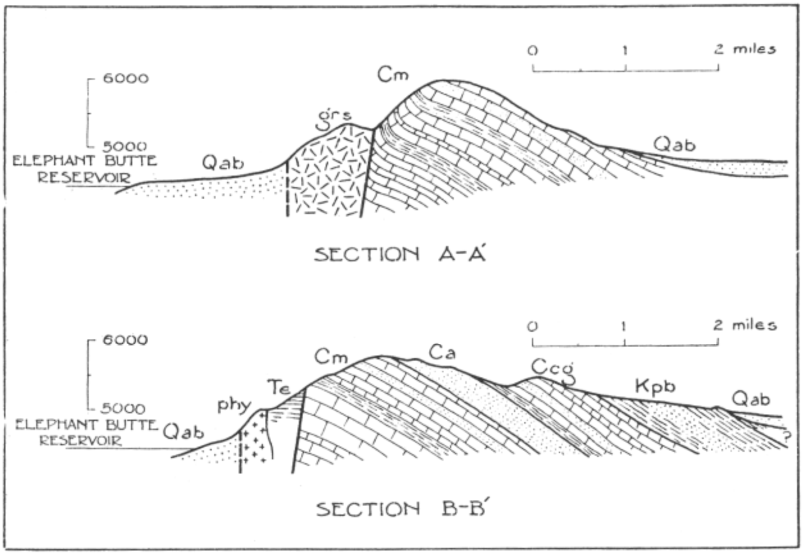


FIGURE 16.—Cross sections in Fra Cristobal Range along sections A-A′ and B-B′ of Plate 1. grs, pre-Cambrian granite; Cm, Magdalena limestone; Ca, Abo sandstone; Ccg, Chupadera formation; Kqb, Cretaceous sediments; Te, Tertiary sediments; Qab, Quaternary sediments; phy, porphyry. (Modified after N. H. Darton.)

the west the sediments of the northern part of the range are partly hidden from view by this granite ridge. Farther south the granite mass decreases in height and disappears under alluvial fans.

Most of the steep westward-facing fault scarp of the range consists of Magdalena limestone. To the east the range presents a long dip slope of Magdalena limestone, upon which near the southeast end of the range are low cuestas of Permian and Cretaceous sedimentary rocks, with here and there a small remnant of lava flows of Tertiary age. At the west base of the range are steep alluvial fans, which coalesce at their bases and merge with the flatter beds of the old bolson plain through which the river has since cut its channel at the base of the range. On the east side of the range, similar fans were built up where canyons cutting back into the dip slopes of the range discharge their loads upon the valley floor. Only the tops of these fans are now visible above the detrital material of the bolson of the Jornada del Muerto, which rises gently toward the range and is slowly burying the outlying cuestas at many points. At the southern end of the range the drainage system of the Rio Grande has worked back into the "Jornada" and is destroying the bolson topography.

Near the south end of the range and west of the main fault scarp, there is a fault striking S. 3° W. and intersecting the main fault. In the angle between these faults, Cretaceous and Tertiary rocks have been faulted down between pre-Cambrian rocks on the west and Paleozoic sediments on the east. A small mass of monzonite porphyry, either a stock or dike, has been intruded along this fault.

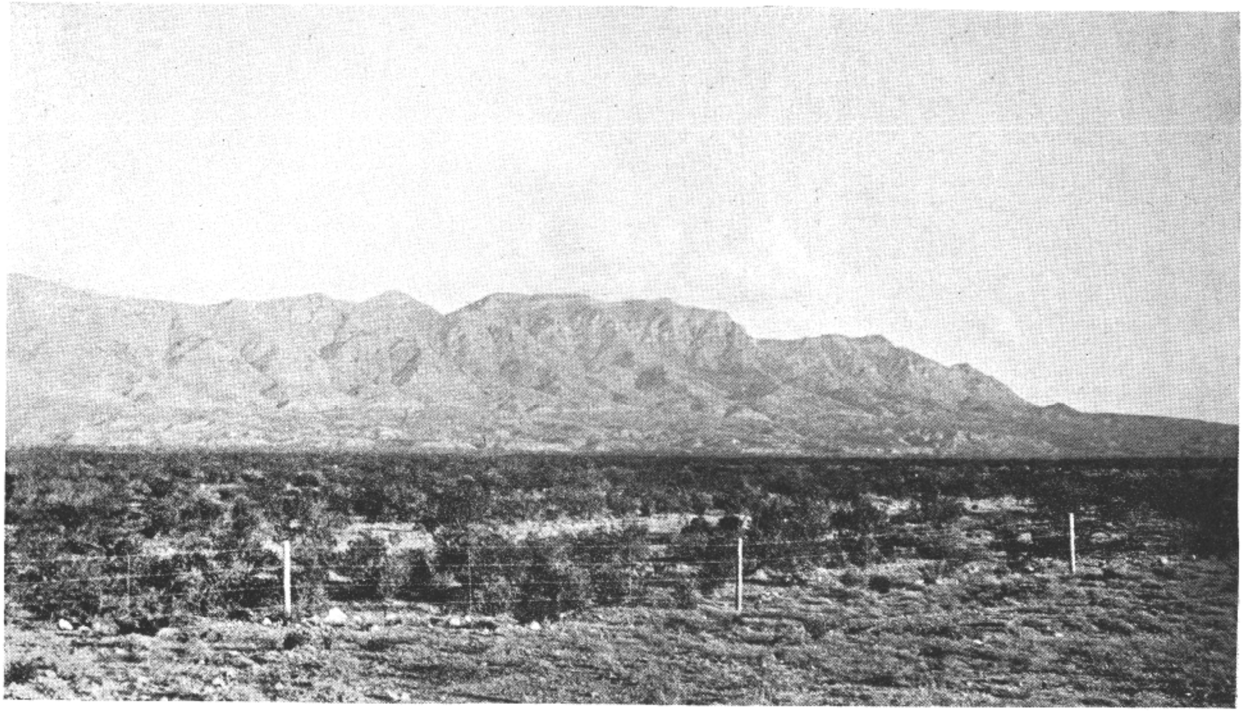
Granite is the chief rock of the pre-Cambrian, but schist is locally prominent, and near the north end of the range diorite containing abundant hornblende is exposed in the bottoms of the arroyos. Pegmatite dikes occur in places, and much vein quartz is present in the fan debris.

The oldest rocks exposed to the east of the main fault belong to the Magdalena formation, and the thickness exposed is approximately 1,000 feet. Lying disconformably upon these limestones is typical red Abo sandstone 400 feet thick, and above it is the Chupadera formation. The Chupadera is divided into 385 feet of Yeso beds consisting of shale, gypsum, sandstone and interbedded thin layers of limestone, and 650 feet of San Andres limestone and sandstone. Cretaceous beds overlie the San Andres limestone.

ORE DEPOSITS

No detailed descriptions of the mineralized outcrops or of the old prospects of the Fra Cristobal Range can be given. Weak mineralization occurs in places, and it is reasonable to believe that in some parts of the area outcrops could be found that would be worth prospecting. Between the Elephant Butte reservoir and the exposures of pre-Cambrian granite, there is a slight possibility of finding placer gold in workable quantities in the dry creek beds or alluvial fans.

High up on the east side of the range several large solution caves in the limestone have been found. Millions of bats inhabit these caves, and from them shipments of guano have been made from time to time. The largest of these caves is visible from the road leading northward out of Engle.



PHOTOGRAPH OF WESTERN FAULT SCARP OF THE SIERRA CABALLOS
Looking east from across the Rio Grande

SIERRA CABALLOS

PALOMAS GAP DISTRICT

LOCATION AND TOPOGRAPHY

The Sierra Caballos is carved out of a prominent easterly dipping faulted block situated east of the Rio Grande valley, and extending from the Elephant Butte dam to the southern end of the county. The west or escarpment face of the range is steep, while on the east or dip-slope side, the slopes are more gentle, varying between 15° and 20°. The maximum elevation is about 10,000 feet.

GEOLOGY

THE ROCKS

Pre-Cambrian Rocks.—The western front of the Sierra Caballos consists in its lower portion of pre-Cambrian rocks, which outcrop for a distance of 15 miles and in places rise precipitously nearly 1,000 feet above the river valley. These rocks consist of granite and smaller amounts of gneiss and schist, all of which are cut by dioritic dikes, pegmatites and quartz veins.

Bliss Sandstone.—The sandstone at the base of the sedimentary section was formerly called the Shandon quartzite, but in this report it is called the Bliss sandstone. (See page 24.) Its thickness varies between 55 and 100 feet, and it can be generally divided into a basal member of dark quartzite and conglomerate 10 feet thick, an intermediate member of white quartzite 4 to 5 feet thick, and an upper member of dark brown and green sandy shale and thin-bedded quartzite 40 to 90 feet thick. Many of the dark strata contain glauconite. In places the beds are highly ferruginous and resemble the Clinton oolitic iron ores of Alabama.

El Paso Limestone.—Limestone of Lower Ordovician age lies unconformably upon the Bliss sandstone, and has a thickness of 300 to 400 feet. It consists of a lower member of massive limestone which outcrops in a high cliff, but on weathering breaks into slabby layers of light gray color, the surfaces showing characteristic brown reticulated chert. Near Palomas Gap the upper portion of this formation is more massive, and in this area it also forms a cliff.

Montoya Limestone.—The Montoya limestone of Upper Ordovician age rests disconformably upon the El Paso limestone. The thickness of these beds is 200 to 300 feet. The lower member, 200 feet thick, consists of dark massive limestone with a thin sandy limestone or sandstone member at its base. In places an upper member, consisting of cherty beds of limestone, is as much as 100 feet thick.

Fusselman Limestone.—In the southern end of the range the Fusselman limestone makes a prominent cliff of dark-colored, massive limestone. It is 50 feet thick as exposed in this region.

Farther north in Palomas Gap and vicinity, faulting has concealed the Fusselman and all other formations below the Magdalena limestone.

Percha Shale.—Above the Silurian beds in the central and southern parts of the range is the Percha shale of Upper Devonian age. This formation outcrops in a slope of moderate inclination, in marked contrast to the cliffs below and above it, and consists of black to gray and greenish-buff shale and thin-bedded sandstone and limestone measuring 200 feet and upward in total thickness. The lower portion of this shale is generally darker in color than the upper portion, which is usually gray to buff. The upper part contains many thin layers of gray limestone.

Lake Valley Limestone.—Above the Percha shale and below the Pennsylvanian rocks is limestone 105 feet thick that corresponds stratigraphically and in general appearance with the Lake Valley limestone of other nearby sections.

Magdalena Limestone—This formation, which is approximately 600 feet in thickness, forms the top of the Sierra Caballos for the entire length of the range. It consists largely of light-colored limestone and a few interbedded shale members. Near the top is a bed of black shale, similar to the shale found in nearly every other exposure of the Magdalena in Sierra County. This shale varies in position from the middle of the section to, near its present top, depending on the amount of erosion that the formation has undergone. It is quite probable that the top of this shale marks the division between what is called the Sandia or lower formation of the Magdalena limestone and the Madera on upper formation in other districts.

Abo Sandstone.—The Magdalena beds are unconformably overlain by the Abo sandstone wherever the contact is visible. The Abo formation is about 800 feet thick, and is composed essentially of red sandstone and red sandy shale, with a few hard layers of pink to buff sandstone. Near the middle of the section is a thin bed of gray sandy to shaly limestone. The Abo beds outcrop for almost the entire length of the range.

Chupadera Formation.—The Abo beds give place abruptly to the overlying gypsum and limestone strata of the Chupadera formation. The basal part of the Chupadera, consisting of the red sandy shales and gypsum beds of the Yeso formation, is of unknown thickness, as these strata form the floor of a flat valley between the Abo and San Andres rocks in this area. The lower part of the San Andres formation, which is the upper member of the Chupadera, consists of alternating beds of limestone and gypsum having a thickness of 250 to 400 feet. Next is 50 to 200 feet of limestone with subordinate beds of gypsum, then 50 feet of sandy shale, and at the top, 25 feet of blue limestone.

Mancos Shale.—The San Andres limestone is cut off by a fault to the east, along which sandstone and shale of upper Cretaceous age, probably Mancos shale, have been brought into position alongside of the Permian beds. These beds outcrop extensively along the east slope of the Sierra Caballos and at the southern end of the Fra Cristobal Range.

Igneous Rock.–Nearly 3 miles west of Cutter, monzonite porphyry projects through beds of Cretaceous age as a low, rounded and weathered hill slightly less than half a mile in diameter. This may be the top of a small cupola or stock. About 12 miles southeast of Cutter and 4 miles northeast of Upham, three outcrops of porphyry, the largest being a mile in length, project through the sands of the Jornada del Muerto as low irregular hills. Approximately 6 miles south of Upham is a group of low hills consisting of rhyolite flows and tuffs, these rocks belonging to the upper part of the Tertiary lava flows that at one time probably completely covered the Sierra Caballos in a series of thin sheets. These flows approximately mark the eastern limits of the vast flows which still cover the western half of the county and extend into Grant County. Faulting and folding have depressed these flows in places, and they have subsequently been buried beneath Quaternary alluvium, and on the tilted fault blocks of the range erosion has completely removed them. Remnants of basaltic flows cap several small buttes and mesas east of the Elephant Butte dam.

STRUCTURAL RELATIONS

In general the Sierra Caballos gives the appearance of being a very large faulted block with the steep escarpment face along the western side and gentle dip slope to the eastward. In detail, however, the dips of the beds diverge slightly, and the range was probably at one time a much-elongated dome, which later was cut by a series of faults parallel to the major axis. The general fault pattern in the Fra Cristobal Range and Sierra Caballos and the relations of the faulted blocks may be seen on the generalized County map, Plate I. The cross sections, figure 16, A-A' and B-B', and figure 17, D-D' and E-E', show additional details of the relations of the blocks to each other. In the Fra Cristobal Range the block of pre-Cambrian granite in front of the sediments is the upthrown side, while along the corresponding fault in the Sierra Caballos the block on the northwest side is the downthrown block. At the north end of the Fra Cristobal range the vertical displacement is 1,000 feet or more. South of Hot Springs the downthrown block has a displacement of approximately 700 feet. The hinge nature of the movement is particularly evident when viewing the Fra Cristobal range from the west side of the Elephant Butte Lake. The block of Magdalena and later sediments on the east side of the fault dips radically to the east and southeast, and the block has a domed appearance as viewed from the west. The Sierra Caballos also shows the domed structure to the east of the main fault scarp. The northern end of the range has been depressed by the movement along the fault east and south of Hot Springs, and the rocks have been broken into four long, narrow slices, by north-south faults, and each slice has been lowered and dragged under, relatively to the one west of it. Upturning of the beds on the east side of these faults is a marked feature, especially near the northern end of the range, where the amount of movement has been greatest. The fault separating the granite and the Paleozoic rocks has a vertical displacement of not less than 600 feet. The upturning of the Paleozoic beds at this point

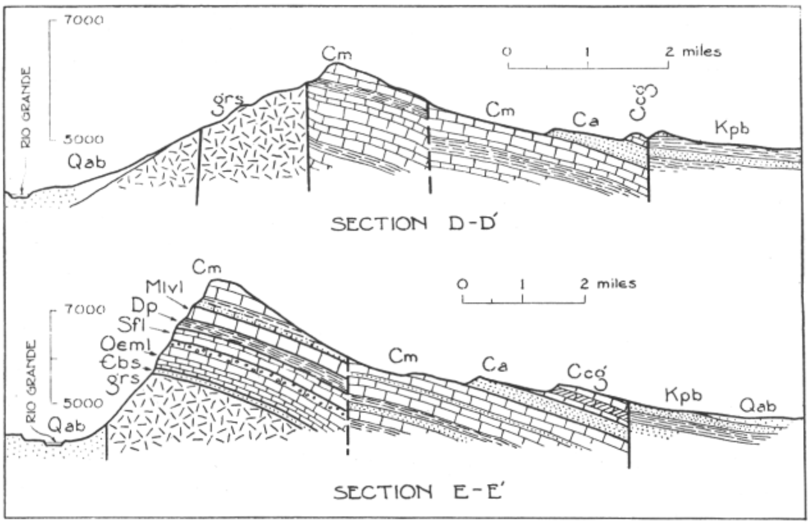


FIGURE 17.—Cross sections in Sierra Caballos along sections D-D' and E-E' of Plate 1. grs, pre-Cambrian granite; Cbs, Bliss sandstone; Oeml, El Paso and Montoya limestones; Sfl, Fusselman limestone; Dp, Percha shale; Mlvl, Lake Valley limestone; Cm, Magdalena limestone; Ca, Abo sandstone; Ccg, Chupadera formation; Kqb, Cretaceous sediments; Qab, Quaternary sediments. (Modified after N. H. Darton.)

has been well illustrated by Darton.[64] Farther east, faulting of the same type has occurred, and at the north end of this break Abo sandstone has been dragged down and under the Magdalena limestone of the west wall. Farther south along this fault, Magdalena limestone is the surface rock on both sides. The displacement decreases in this direction, and the fault ends in a simple monoclinal fold in the Magdalena beds. Along the third fault to the east, the east side has been relatively depressed, with the result that Cretaceous rocks are adjacent to the Abo sandstone and Chupadera formation.

[64] Darton, N. H., op. cit. (U. S. G. S. Bull. 794), Plate 61 b, p. 320.

The structure of the Sierra Caballos is further complicated by transverse overthrust faults. One of these in the northern end of the range shows considerable movement of the overthrust block toward the south. In the southern end of the range near the county line, an overthrust block of Magdalena limestone has moved to the north over Abo beds for a distance of several hundred feet. [65]

ORE DEPOSITS

The ore deposits of the Sierra Caballos are principally fluorspar deposits and lead-vanadium-molybdenum deposits. Most of the fluorspar deposits are in the Magdalena limestone along the face of the range, but one fluorspar vein has been found in the San Andres limestone of the foothills southeast of Palomas Gap. Some of the fluorspar veins contain small amounts of galena. The deposits of lead, vanadium and molybdenum, which are also in the Magdalena limestone, are in and near Palomas Gap on the east side of the range. The Abo sandstone is stained with copper in places, and copper showings have been prospected in the Magdalena limestone along the face of the range. The Shandon placers near the southern end of the range have yielded small amounts of gold.

The lode deposits are almost entirely in true fissure veins, with only a. moderate amount of replacement of the wall rock. With the possible exception of the copper in limestone, the deposits are all of the low-temperature type. There is a gradual transition southward from the deposits of the metallic minerals in and around Palomas Gap through a galena-fluorite type to a fluorite-calcite-silica type at the southern end of the range. All of the veins of this region may be connected with a deep-seated mass of Tertiary intrusive rock, probably monzonitic in character, located near Palomas Gap. This mass has two outcrops, one in the west face of the Fra Cristobal Range, and the other west of Cutter on the east slope of the Sierra Caballos.

The ore minerals are galena, anglesite, cerusite, vanadinite, wulfenite, descloizite, pyromorphite, chalcopyrite, bornite, malachite, azurite, and cuprodescloizite, and small amounts of secondary sulfides and oxides of copper. Fluorite is classed as an ore mineral or a gangue mineral, depending on its abundance and mode of occurrence in the deposits. In most places where fluorite is not the mineral of chief economic importance in the veins, it occurs in such quantity and condition that its utilization as a by-product to be recovered along with the important mineral or minerals is worthy of consideration. Among the gangue minerals are pyrite, silica, calcite, barite, and a little gypsum.

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[65] Johnston, W. D., Jr., Fluorspar in New Mexico, New Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 4, pp. 28-29, 1928.

VANADIUM DEPOSITS

LOCATION

The important deposits of vanadium-bearing ore in the Sierra Caballos are on the eastern slope of the Sierra Caballos and on the north side of Palomas Gap. The nearest station on the Albuquerque-El Paso line of the Atchison, Topeka & Santa Fe railway is Cutter, 12 miles to the east, with which the mines are connected by a good desert road. Water at the mines is sufficient for domestic use only, but large wells have been drilled at Cutter and elsewhere along the railroad.

HISTORY

Vanadium minerals were discovered in this area in 1909, although the veins had been worked for lead for a number of years previously. As in many other districts, the original discoveries of lead were made by prospectors who tried to work the deposits on a small scale and intermittently. One by one, these small holdings were consolidated under the ownership of the Southwestern Lead & Coal Co., and much work was done during 1906-1908 on the Napoleon and Rosa Lee claims, where considerable low-grade galena ore was found. This company purchased the Dewey and White Swan claims from R. Widener in the fall of 1907 for $3,000. Development work on these claims showed much low-grade lead ore, and in addition, much material on the upper levels containing brown hexagonal crystals that were taken for cerusite, lead carbonate. It was not until 1909 that these brown hexagonal crystals were determined to be vanadinite. In that year A. B. Bement of Terre Haute, Ind., a stockholder in the company, took over the property and organized the Vanadium Mines Co. This company did extensive development work on the veins during 1910 and 1911, and experimented with a small mill that was originally designed for a lead concentrator, but the results were not highly successful. Water had to be pumped from wells 4 miles east. The crude vanadinite concentrate was shipped to Cutter, where a plant had been erected in which the concentrates were leached With sulphuric acid to obtain the vanadium sulphate in solution and the lead sulphate as a residue. The pregnant solution was evaporated to dryness and the residue calcined to obtain the vanadium oxides. Leaching was difficult, due to the formation of a coating of lead sulphate over the mineral grains, which protected the inside from further leaching. The plant operated only a short time and produced not more than a few hundred pounds of vanadium oxide before it was finally shut down. During the period of operation in the district much interest was manifested in the venture, and several articles on the geology and operating problems of the region appeared in the technical press.[66]

The third and only other vein of importance is the Red Top, one end of which was originally owned by Ralph Widener and the other end by J. H. Hardin. This vein also was originally prospected for lead by means of a shaft and drifts. The Red Top vein is about three-fourths of a mile south of the Swan and Dewey veins and on the south side of Palomas Gap.

PROPERTY OF THE VANADIUM MINES CO.

The holdings of the Vanadium Mines Co. include two veins. The vein on the north side of the Gap is known as the Dewey, and that on the south side the White Swan. Each vein is developed by a shaft about 400 feet deep, and by nearly 1,000 feet of lateral workings. On the Dewey vein the vein material has been removed for a width of 6 to 12 feet in open cuts and along a drift, and stoping has been done to a height of 30 feet above the drift. The vein is open textured and spongy, and the minerals are all oxidized. At other places in the vein near the surface, the vein matter is predominantly brecciated limestone, which is coated with a thin yellowish-green crust of mixed brown vanadinite and green cuprodescloizite. At the east end of the outcrop, well-developed crystals of vanadinite one-eighth inch or more in diameter have been mined. Many of these crystals are hollow.

The White Swan vein is similar to the Dewey, but it is vertical, and considerable wulfenite is mixed with the vanadinite. The gangue and ore minerals comprise all of those listed above as occurring in the district. The vanadinite is mostly in brown crystals, which are so small as to give a Velvety appearance to cavities lined with them. Under the binocular microscope, they appear as a glistening mass of crystals, radiating in all directions from the irregular surface of the cavities. Many of these cavities are evidently the result of the decomposition of galena. Great numbers of colorless or nearly colorless crystals of vanadinite may be seen under the microscope scattered through the gangue and immediately adjacent wall rock, and some of the unpromising looking material is said to carry moderate amounts of vanadium.

RED TOP VEIN

About three-fourths of a mile south of the White Swan vein, Ralph Widener has located four claims on the Red Top vein,

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[66]Leatherbee, B., Sierra County, N. Mex., Vanadium Deposits: Min. World, Vol. 33, p. 799, Oct. 29, 1910.

Johnson, E. D., The Vanadium Industry in New Mexico: Min. Sci., Vol. 63, p. 259, Mar. 9, 1911.

Larsh, P. A., Caballos Mountain vanadium mines : Geol. and Min. Jour., Vol. 92, p. 118, July 15, 1911.

Allen, C. A., Vanadium deposits in the Caballos Mountains, N. Mex.: Min. and Sei. Press, Vol. 103, pp. 376-378, Sept. 23, 1911.

Clifford, J. O., Vanadium in New Mexico : Caballos Mountain deposit : Min. and Eng. World. Vol. 15, pp. 857-858, Oct. 28, 1911.

Hess, Frank L., Vanadium in the Sierra de los Caballos, N. Mex.: U. S. Geol. Survey Bull. 530, pp. 157-160, 1917.

which from southwest to northeast are named the Gladys, Red Top, Red Top Annex, and Billiken claims. Northeast of this group, J. H. Hardin has a claim called the Owl. The strike of the vein is parallel to the White Swan and the dip is 60° NW. This vein is about feet wide. The vein material consists of brecciated limestone, much disintegrated and cemented with secondary calcite, and white and pink fluorspar. Some galena is scattered through the ore. About a foot of the vein is very spongy and shows the effect of leaching by surface waters, and it is within this portion that crystals of vanadinite occur. The vanadium content of these veins has been estimated at from 1 to 3 per cent, with the latter estimate probably much too high.

GALENA-FLUORITE VEINS

South of the Palomas Gap area and about three-fourths of a mile from the Red Top vein, four well-defined veins in the limestone have yielded a small amount of galena-fluorite ore that was hand sorted or concentrated. These veins are the property of the Southwestern Land & Coal Co., and they were among the first to be worked in the Palomas Gap district. During 1931 these claims were operated by the Great American Co., which was in control of 14 claims in the district. The ore mined was treated by hand jigging to make a galena concentrate; the residue being stored pending the working out of a treatment method for the fluorite. These operations were short lived, however, and the camp is now idle. The property is situated 24 miles from Engle and.14 miles from Cutter, the nearest points on the railroad.

The ore has formed in Magdalena limestone, the strata of which strike N. 50° .W. and dip 15;) NE. The veins have the appearance of being transverse adjustment fractures incident to the major regional faulting of the area. Striations on the walls indicate that the movement was largely horizontal. Bordering the veins in many places there are lenticular fractures in the limestone up to 12 feet long and from one-fourth to 3 inches thick in the widest part, which have a strike of S. 50° W. and dip 75° NW. These are filled with calcite.

The northerly vein of the series, striking N. 75° E. and dipping vertically, varies from 1/4 to 3 feet in width in its productive part, with walls 4 to 6 feet apart. The vein is developed by a tunnel 300 feet long, and two shafts, both of which connect with the tunnel. A third shaft 40 feet deep is located 600 feet east of the portal of the tunnel. The greatest vertical depth thus gained in this vein is 100 feet at the face of the tunnel.

On the tunnel level, small amounts of galena and fluorite were noted in a matrix that was predominantly fault gouge and brecciated limestone recemented with calcite. Above the tunnel level the vein is open textured or spongy, consisting of sugary quartz and yellow fluffy limonite in a fractured matrix of quartz,

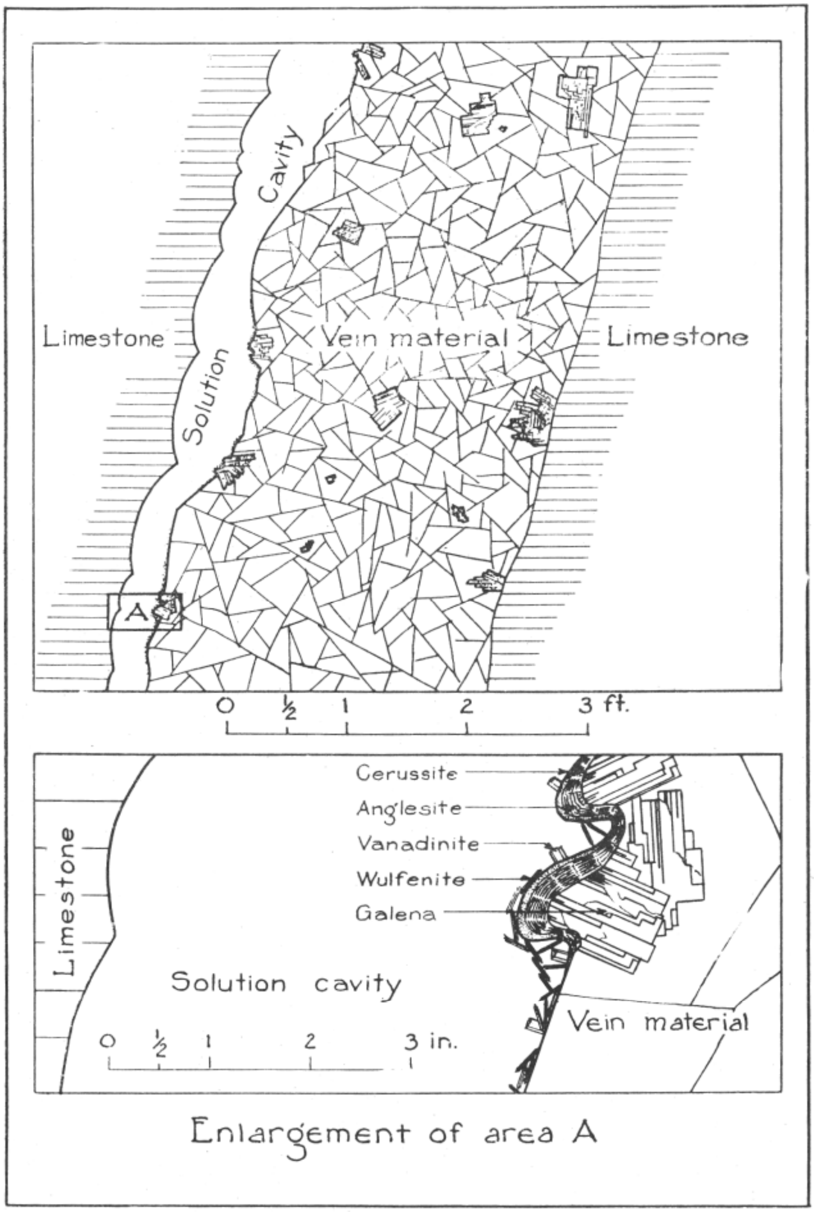

FIGURE 18.—Typical vein structure in the galena-fluorite deposits of the Sierra Caballos.

calcite and fluorite. The ore minerals are galena, anglesite, cerusite, wulfenite, and an occasional vanadinite crystal. In these veins fluorite should be considered as an ore mineral. The gangue minerals are calcite, barite, quartz, limonite, and pyrite. The south wall of the vein has been dissolved by surface waters, and a solution space has been formed, which varies from 1 to 4 feet in width and which stands open down to the 100-foot level. The galena occurs in the vein in single cubic crystals varying in size from one-sixteenth inch to 3 inches across. Aggregates of crystals are uncommon. Within the matrix of the vein these crystals are bright on fractured surfaces and show no evidence of alteration. Where exposed in the solution cavity, however, as shown in figure 18, they are rounded in outline and are covered with a thin layer of anglesite, and a thin outer layer of cerusite. Encrusted on the surface of the cerusite are crystals of wulfenite and scattered crystals of vanadinite. Away from the galena crystals the number of wulfenite crystals rapidly decreases, and on areas of the wall more than 1 foot away from a galena crystal, wulfenite is rarely found.

In the 40-foot shaft to the east of the tunnel the vein is 2 to 4 feet wide, and it is composed of galena, fluorite and calcite. In the bottom of the shaft the galena content of the vein is lower than at the surface. No wulfenite was noted in this shaft or on the dump.

The ore and gangue mineral assemblage in this vein indicates deposition from cool solutions at a great distance from the source, and the coarse crystallinity of the material indicates precipitation from extremely weak solutions. The galena crystals are sparsely distributed throughout the gangue, and the average lead content of the vein is probably not more than 3 per cent. The fluorite content is about 65 per cent. Mr. J. L. Walter, graduate student at the New Mexico School of Mines in 1931-1932, kindly made several qualitative chemical tests on the galena specimens from this vein and from the surrounding shells of anglesite and cerusite, and in none of this material was he able to find a trace of vanadium or molybdenum. It seems probable, therefore, that these minerals were originally dissolved from some remote locality and were carried in soluble form in the percolating surface waters until they came in contact with the lead minerals of these veins, when they formed insoluble compounds that were precipitated on the nearest available surface.

The second vein in the series has a strike of N. 70° E. and is nearly vertical. The walls are 4 feet apart, but the galena-bearing calcite is 18 inches or less in width. This vein is developed by shallow tunnels and shafts, all of which have exposed some galena. Near the western end of the outcrop, considerable copper staining is visible. A cross vein striking N. 44° E. and dipping vertically was encountered in the main tunnel into this vein, which showed 18 inches of fair lead ore. Beyond the cross vein to the west the main vein contains only gouge and fractured limestone. Thin lenses of dark gray to brown shale appear to cut off the veins at the tunnel level, but it is possible that after passing through the shale with greatly restricted width, they will again open out into veins of normal width. In the adjacent wallrock lenticular gashes occur, which are filled with calcite. The cross vein is developed by a raise to the surface and by a winze about 50 feet deep. A small amount of stoping was done at the intersection of the two veins, where the ore appears to have had considerable width. On the surface the cross vein is opened by a tunnel driven to the southwest. The vein here is not well defined, the material driven through being mostly fractured limestone without mineralization other than calcite, and it is questionable if the tunnel had been extended far enough to the south before turning to intersect the vein.

The third and fourth veins in the series appear to be branches from the second vein. They are developed only by a few pits and trenches, and in many places they are covered over with surface debris, so that their relationships could not be determined definitely. These veins are weaker at the surface than the first two and appear to contain less galena. The third vein parallels the second vein in strike and probably intersects the fourth vein about 100 feet west of its most easterly exposure. The fourth vein strikes about east, and appears to intersect the second vein at a point 1,000 feet west of the portal of the main tunnel described above.

COPPER VEINS

Along the west face of the Sierra Caballos, from a point north of Palomas Gap to as far south as Derry, several copper veins outcrop. These veins are chiefly in the basal member of the Bliss sandstone, which is 25 to 50 feet thick. The minerals are chalcopyrite, bornite, chalcocite, cuprite, malachite and azurite in a red hematite matrix. The gangue minerals are quartz and subordinate calcite. In places the veins extend into the upper part of the Bliss sandstone and even into the overlying El Paso limestone. The parts of the veins in the limestone are relatively poorer in copper and higher in their galena-fluorite-barite content. All of the ores in this region are poor in gold and silver. The veins are definitely associated with slight arches in the Bliss sandstone. Only small quantities of copper ore have been mined from these deposits.

MONUMENT MINES CORP. PROPERTY

The Monument Mines Corp. is the present owner of the older Marion Copper Co. holdings, and has 12 claims, five of which are patented. The principal workings are at the Marion and Oohoo mines. The Marion tunnel, over 600 feet long, is 3 miles south-southeast of Palomas Gap at an elevation of approximately 5,000 feet, and is in the Bliss sandstone. The vein followed by the tunnel trends eastward and dips 80° S. The vein is sharply defined on the hanging-wall side, but fades gradually into the footwall. The ore, which is partly oxidized, forms pockets and small bodies in both the hanging-wall and the footwall. The gangue consists of quartz, which is more abundant in the lower part of the vein, and clay gangue. Higher in the vein, calcite and fluorite are present. The ore is said to assay 3 to 11 per cent in copper, and it is reported that past production has had a value of about $100,000.

The Oohoo vein is developed by an incline about 400 feet long, which is now partly inaccessible. The elevation at the portal is about 5,300 feet, and the incline was driven in limestone following the dip of the beds, which is about 25° E. The deposit is in an east-west fissure, but the walls are irregular and some replacement of the wall rock has taken place. The limestone near the tunnel is hard and silicified. It is said that the tunnel has produced considerable oxidized copper ore in the past, and for this locality the gold and silver content of the ore is said to be higher than the average, ranging between $3 and $4 to the ton for the combined metals.

LONE TREE PROSPECT

This property was not visited by the writer. It is south of the Marion at an elevation of about 5,000 feet, and the deposit is reported to be much like the one at the Marion tunnel. Near the tunnel the granite and quartz are cut by a pale brownish-gray porphyritic dike. [67]

CABALLOS MOUNTAIN MINING & LEACHING CO. PROPERTY

This company is reported to own 14 claims 4 miles in an air line northeast of Arrey. The deposits are fissure veins in the basal sediments above the granite contact. The ore is similar in its occurrence to the deposits already described, except in its range of minerals, which here include galena and its oxidation products in addition to the usual copper minerals. Silver is reported in considerable amounts as a constituent of the ore. There are several shallow shafts on the property, the deepest of which is said to be 300 feet, and three tunnels with a combined footage of about 400 feet. The vein on which development work has been done attains a width of 4 feet between the walls, while the mineralized portion consists of veinleth and small bodies distributed somewhat irregularly throughout. A fair road connects the mine with the nearest railroad connection at Hatch, 20 miles distant.

CABALLOS DEVELOPMENT. AND MINING CO. PROPERTY

This property is in the southern extension of the Caballos mining district, and in what is known as the Pittsburg district.

[67] Gordon, C. H., op. cit. (U. S. G. S. Prof. Paper 68), p. 284.

The ore occurrences are similar to those found elsewhere in the range. The ore minerals are chalcopyrite, cuprite, malachite, azurite, galena, anglesite and cerusite, with gold and silver accompanying. The property has been prospected along the outcrop by several pits and short tunnels.

FLUORSPAR-CALCITE-SILICA VEINS

South of the galena-fluorspar veins on both the east and west slopes of the Sierra Caballos, extending approximately from the Marion mine to the southern extremity of the county and beyond, there are a number of veins which are nearly vertical and strike east. These veins, which are valuable mainly for their fluorspar content, have been discussed by Johnston [68] in considerable detail. Some of them contain a small amount of galena, which may in some instances and under the proper price incentive, become of economic importance as a by-product in the recovery of the fluorspar of the veins.

SHANDON (PITTSBURG) PLACERS

LOCATION AND GEOGRAPHY

The Pittsburg district includes the southern part of the Sierra Caballos, in and near Apache Canyon. The district is the southern extension of the Caballos district, and figure 19 shows that portion of it in which the Shandon or Pittsburg placers are located. Pittsburg is a small settlement at the Junction of Apache Canyon and the Rio Grande, and Shandon, five-eighths of a mile to the north, is at the junction of Trujillo Gulch and the river. The Shandon placers are in an area of several-square miles between the foot of the western escarpment of the Sierra Caballos and the Rio Grande at Shandon, and are located chiefly along Trujillo Gulch and its tributaries. Trujillo Gulch is a small, usually dry channel, which heads on the granite pediment at the foot of the mountains and drains due west to the river. Apache Canyon is a much larger valley opening out of the range from the east; it has formed along the course of a pronounced cross-fault. (See Plate I and figure 19.) Gold has been found in two places in Apache Canyon, the first discovery being in Union Gulch, a small gulch which leads out from the upper drainage basin of Trujillo Gulch. The second discovery was made in the summer of 1931, at a point in the main Apache Canyon just below where it empties out onto the alluvial apron which forms the side of the valley. These discoveries have not proved to be important.

GEOLOGY

The Caballos escarpment is a prominent feature of the topography in this part of the range, and the pre-Cambrian gran-

[68] Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 4, 1928.

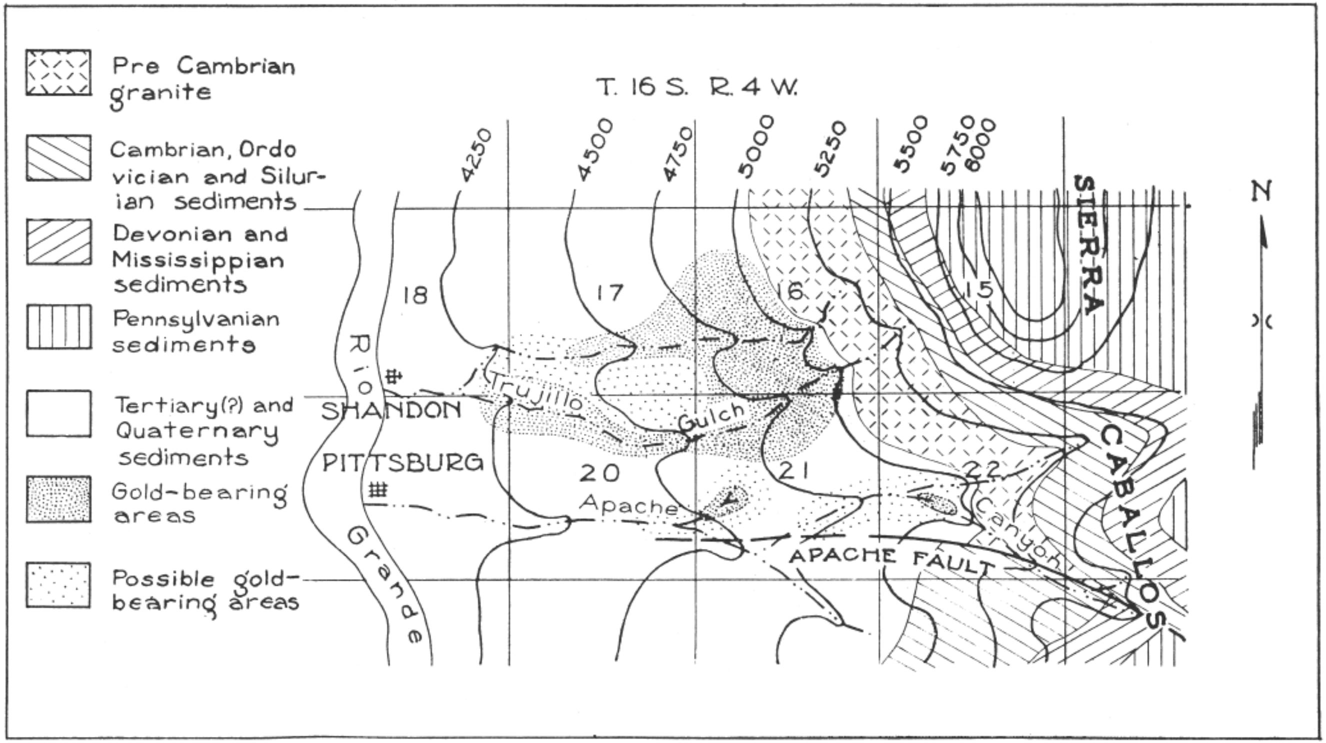

FIGURE 19.—General map of the Pittsburg (Shandon) placer mining district. (After C. H. Gordon.)

ite base is exposed above the alluvial fans of the region for a vertical height of 350 to 500 feet. The total height of the escarpment is between 1,500 and 2,000 feet. The highest point of the range is Timber Peak, which attains an altitude of 10,000 feet. South of Apache Gulch, a small block of Magdalena limestone, dipping 40° N., forms the high ridge along the south side of the canyon. Between the western face of the range and the Rio Grande are alluvial aprons which merge into the valley plains with decided slope to the west and finally terminate in the bluffs of the river channel. The present river valley has been cut in the bottom of an older and wider channel, remnants of which appear as benches along the bluffs and for short distances up the main tributaries. As viewed from a distance, the valley plains give the appearance of having a smooth profile with continuous slope between the foot of the escarpment and the top of the river bluffs. In detail, however, this apparently smooth surface is deeply trenched by steep-sided ravines and arroyos. Near Shandon the original plain surface has been worn down until only a few rounded hills showing above the benches of the first cycle of erosion remain to testify to its former elevation at this point.

The valley plain is composed of Palomas gravel, overlain by a thin covering of more recent alluvial material. The Palomas gravel rests upon a floor of pre-Cambrian granite and schist near the foot of the escarpment.

Flows of Tertiary lavas, consisting of the usual andesite-latite-rhyolite series, have apparently covered the older Pennsylvanian and Permian sediments nearly to the present location of the river. These flows appear to have come from the southeast through Apache Canyon. Residual masses of these rocks project through or underlie the gravels along the base of the escarpment, and a wide sheet farther south has been faulted down against the main mass of the low ridges.

THE PLACERS

The gold-bearing gravels of the district are chiefly in Trujillo Gulch and the area drained by its tributaries. Two small gold-bearing areas are known also in Apache Gulch. The gold found in Union Gulch, a tributary of Apache Gulch, appears to have been derived from the headward erosion of this gulch into the drainage area of Trujillo Gulch. Farther east, in Apache Gulch, is a small area of workable gravel that was derived from a higher source to the south and east of the main area. (See figure 19.)

Gold was probably discovered at Shandon in 1901. The deposits first became known to the public in 1903, when Encarnacion Silva, on one of his trips to Hillsboro to dispose of gold from this area, was induced to tell the location of his workings. A stampede to the district immediately followed. During 1904 'Sierra County produced 1,111 fine ounces of placer gold and in

1905 the production was 2,316 ounces, most of this coming from the Shandon placers. Since 1905 production has been unimportant. For several years a lawsuit involving rights of ownership and other matters interfered with any operations in the district, but this controversy was finally settled, and in the autumn of 1931 the property was under a 20-year lease to Calloway and Burke. At the time of the writer's visit to these workings, they were being sampled by means of pits. Measured quantities of gravel from these pits were being hauled to Trujillo Gulch, and were being treated in a plant consisting of an elevator, trommel, and sluice box 60 feet long by 3 feet wide. When these placers were first worked, water from wells sunk on the bank of the river was forced to the workings by powerful pumps. This equipment had been rehabilitated, and by means of Diesel power, water was being pumped through a 6-inch pipe line to a reservoir on the hill above the placers, from which it was being delivered to the sluices.

The placer gravels of the Shandon district occupy approximately 1,270 acres. One-third of this area is in the gulches that dissect the sloping plain between the mountain escarpment and the river bluffs, and two-thirds is on the terrane between the draws. The terraces are covered to an average depth of 3 to /1 feet with coarse sand, gravel and boulders derived from the decomposition of the granite of the fault scarp. In the, arroyos near the river the gravel is reported to have a depth of 60 to 70 feet, while at the main workings in Trujillo Gulch bedrock is about 7 feet from surface. Near the east end of the area the placer gravels rest on a bedrock of rhyolite and rhyolite tuff, beneath whicn andesite is exposed in places. The gravels immediately above bedrock are impregnated and partially replaced by a mixture of caliche, crystallized calcite, and manganese oxides for a thickness of a fraction of an inch to 3 feet. In places massive slabs of psilomelane have formed, largely by replacement of the gravels ; in other places only interstitial spaces are filled by psilomelane. In places in the gravels caliche with scant manganese is the cementing material, while in others calcite has formed finely crystalline crusts on open channels overlying similar crusts of psilomelane. Near the river the gravel on the hills is low grade to barren, but farther to the east the gold increases. In the gulches near the river the placers- are wide and deep, and a few samples taken near bed rock are reported to be high grade. Farther east in these gulches the gravels are narrow and are not over 9 feet thick. One area worked in Trujillo Gulch near the east side of Sec. 20 was 150 feet long by 75 feet wide and averaged 8 feet deep. The gold-bearing gravels of the arroyo evidently have been reworked and concentrated from the underlying sands and gravels of the alluvial plain, which have been 'eroded away during the dissection of the plains by the arroyos.

The gravel in place has been estimated to contain one-sixth by volume of coarse boulders, one-sixth of cobbles from 1 to 3 inches in diameter, and two-thirds of gold-bearing gravel and sand. In the treatment processes used the sand and gravel are screened out and the gold is separated from them.

Several sets of samples of these gravels have been taken. No details of the methods used were obtained, but it is reported that they represent gravels in place. One set of samples from 684 holes is reported to have varied in gold content from 29c to $18.80 per yard in place. Another set is reported to average $1.00 per yard throughout, with a reported maximum sample of $108.00 per yard, and another sample assaying $28.64 per yard. The lower grade samples on the hills are reported as averaging 8c per yard. Mr. Burke, who conducted the writer over the field, was inclined to accept the $1.00 a yard average valuation for aft gold-bearing gravels on the property, and from measurements of the various pits he thought that they would average 3 feet in thickness on the hills and 6 feet in the gulches.

ORIGIN OF THE GOLD

The gold of the Shandon placers unquestionably has been derived from quartz veins in the pre-Cambrian granites and schists in the lower part of the escarpment of the Sierra Caballos east of Shandon. In this part of the escarpment, quartz and pegmatite veins are much more abundant than elsewhere in the range, and they vary in width from knife-blade seams to several feet. Some of these veins contain gold in quantities varying from a trace to $4.00 per ton, but they are probably too low grade for profitable mining. Supporting this origin for the gold of the placers are the following: (1) The gold varies from coarse to fine, but the particles are uniformly unworn in appearance, indicating that they have traveled only short distances ; and (2) gold occurs in some of the veins in the pre-Cambrian rocks from which the gold-bearing gravels were derived.

At the eastern end of the placer ground next to the granite face of the escarpment, there is little or no gold in the gravels. It is believed that the eroded upper parts of the veins were richer in gold than the remaining lower parts, and that these veins were rapidly eroded and carried down to form a thin veneer of detrital matter over the Tertiary lava flows and sediments. As the veins were eroded down, the average gold content of the detrital material decreased. The recent erosional products from the scarp face have formed a thin, nearly barren covering over the older productive gravels.

POSSIBILITIES OF THE DISTRICT

Although numerous sets of samples have been taken in the district, they do not appear to the writer to have been entirely representative of the area. Most of them have been obtained from the beds of the arroyos where the reworked and enriched portions of the gravels are to be found, and these enriched gravels occupy only about one-third of the area. The value of the thin blanket over the higher two-thirds of the terrane is largely unknown, but it is a question in the writer's mind if the gravels in these areas are of workable grade. There is also a question as to whether the sampling that has been done in the arroyos has been as complete and thorough as it should. Water is available in large amounts, but the placer gravels would be expensive to work, even should careful sampling prove them to be continuous and of fair grade, inasmuch as the 50 per cent of the total yardage believed to be on the hills would almost certainly have to be transported to a permanent central treatment plant located in one of the arroyos, or to one which would be moved from place to place in them as the work progressed.

DERRY MANGANESE DISTRICT

The Derry manganese district [69] is about 6 miles northeast of the town of Derry, and an equal distance southeast of the Shandon placers. Here the range is an anticline in limestone with axis trending north. Manganese occurs for a distance of two miles along the crest of the fold, and it is from this region that the manganese of the Shandon placers was possibly derived by secondary processes. These manganese deposits have not proved to be commercial.

COPPER DEPOSITS IN "RED BEDS"

LOCATION AND GEOLOGY

Outcrops of Permian "Red Beds" are extensive in Sierra County. The larger exposures are on the eastern slopes of the Fra Cristobal Range, Sierra Caballos and Sierra Cuchillo, and almost continuously along the eastern slope of the Black Range from Chloride to the Macho district. These rocks form low cuestas on the dip slopes or are present in tilted fault blocks. They are slightly warped in places and are cut by occasional east-west fractures. "Red Beds" of Triassic and Jurassic age, which are present in other parts of the State, are not known in Sierra County.

The lowest formation of the Permian series is the Abo sandstone, composed principally of red to reddish-brown, coarse to fine sandy, and shaly members, intercalated with beds of yellow to buff sandstone, gray shale, some gypsum, and in places a few thin beds of limestone. The red sandy beds are in part arkosic. Overlying the Abo beds are great thicknesses of variegated gyp-

[69] Wells, E. H., op. cit. (Manganese in New Mexico), p. 64.

sum beds, shale and sandstone of the Yeso or Lower Chupadera formation, and over this the gray San Andres limestone or Upper Chupadera formation.

The problem of the origin of the "Red Beds" has had long consideration by geologists, and differences of opinion still exist as to the source and origin of the sediments and of the red hematitic coloring matter comprising the cementing matrix of the rocks from which they derive their name. [70]

ORE DEPOSITS AND WORKINGS

At many exposures of the "Red Beds" in Sierra County, weak copper mineralization has been found. At a few localities, as in Palomas Gap in the Sierra Caballos, at Chloride, near Hermosa, and near Kingston, the surface showing has been such as to warrant some prospecting, and a few tons of high-grade hand-sorted ore has been shipped. The mineralization has been localized in these beds in several ways ; in fractures cutting across the bedding planes, as nodules replacing the calcareous cement and kaolinized feldspar of the arkosic beds, as replacement of carbonaceous matter such as old tree trunks, twigs, coaly material, etc., and as a replacement of shaly beds. The sulfide minerals include pyrite, chalcopyrite, bornite, covellite and chalcocite ; the oxidized minerals are limonite, hematite, cuprite, melaconite, malachite and azurite ; and the gangue minerals consist of quartz, calcite, barite, gypsum and dolomite. No gold and only small amounts of silver are associated with the copper minerals.

Mineralization is not entirely confined to the red sandstones of the Abo formation, although it is the principal horizon in this respect. The underlying Magdalena limestone, particularly the sandy and shaly members, and the overlying sandy horizons as far up in the geological column as the Cretaceous have been sparsely stained and sporadically mineralized in a manner similar to the mineralization in the Abo beds. The workings at these deposits consist entirely of surface pits and a few short tunnels and shallow shafts.

As these ores consist generally of mixtures of sulfides and oxides or carbonates in a siliceous gangue, the problem of local concentration is a difficult one, and hand sorting and direct shipment to the smelter must be resorted to. The stimulus of a high price for copper is required before they can be profitably shipped. At no place within the county do the ore deposits of this type so

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[70] Tomlinson, C. W., Origin of the "Red Beds" : Jour. Geology, Vol. 24, No. 2, pp. 153-179, No. 3, pp. 238-253, 1916.

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far discovered give promise of ever developing into properties with sufficient tonnage in sight to warrant the erection of even a small treatment plant.

The genesis of the ore deposits of the "Red Beds" type in New Mexico and adjoining states has been the subject of much study and speculation. A selected bibilography [71] is given below for the use of the interested reader.

[71] Austin, W. L., Some New Mexico copper deposits: Proc. Colo. Sci. Soc., Vol. 6, pp. 91-95, 1897.

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Tarr, W. A., Copper in the "Red Beds" of Oklahoma : Econ. Geology, Vol. 5, pp. 221226, 1910.

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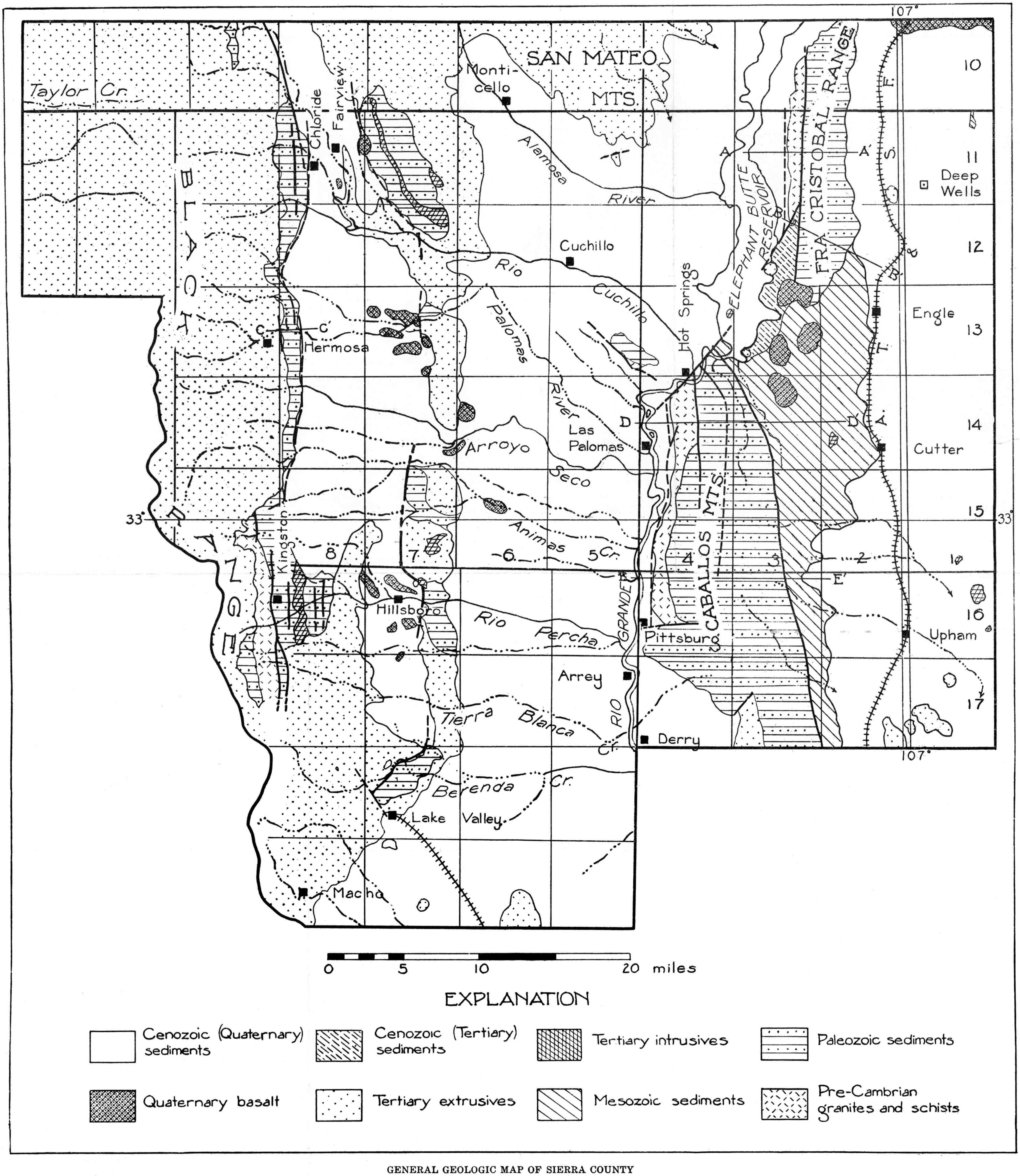
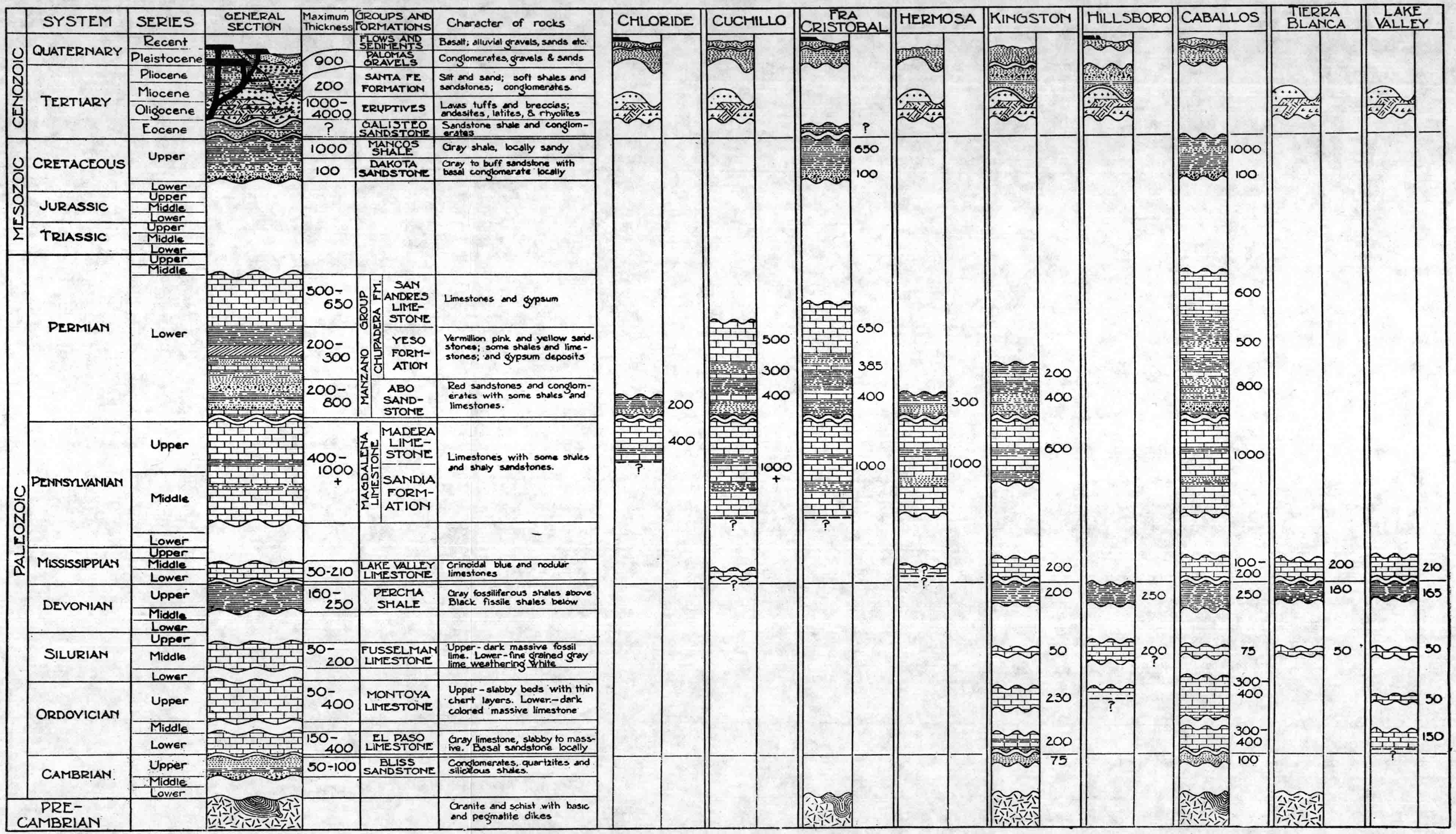
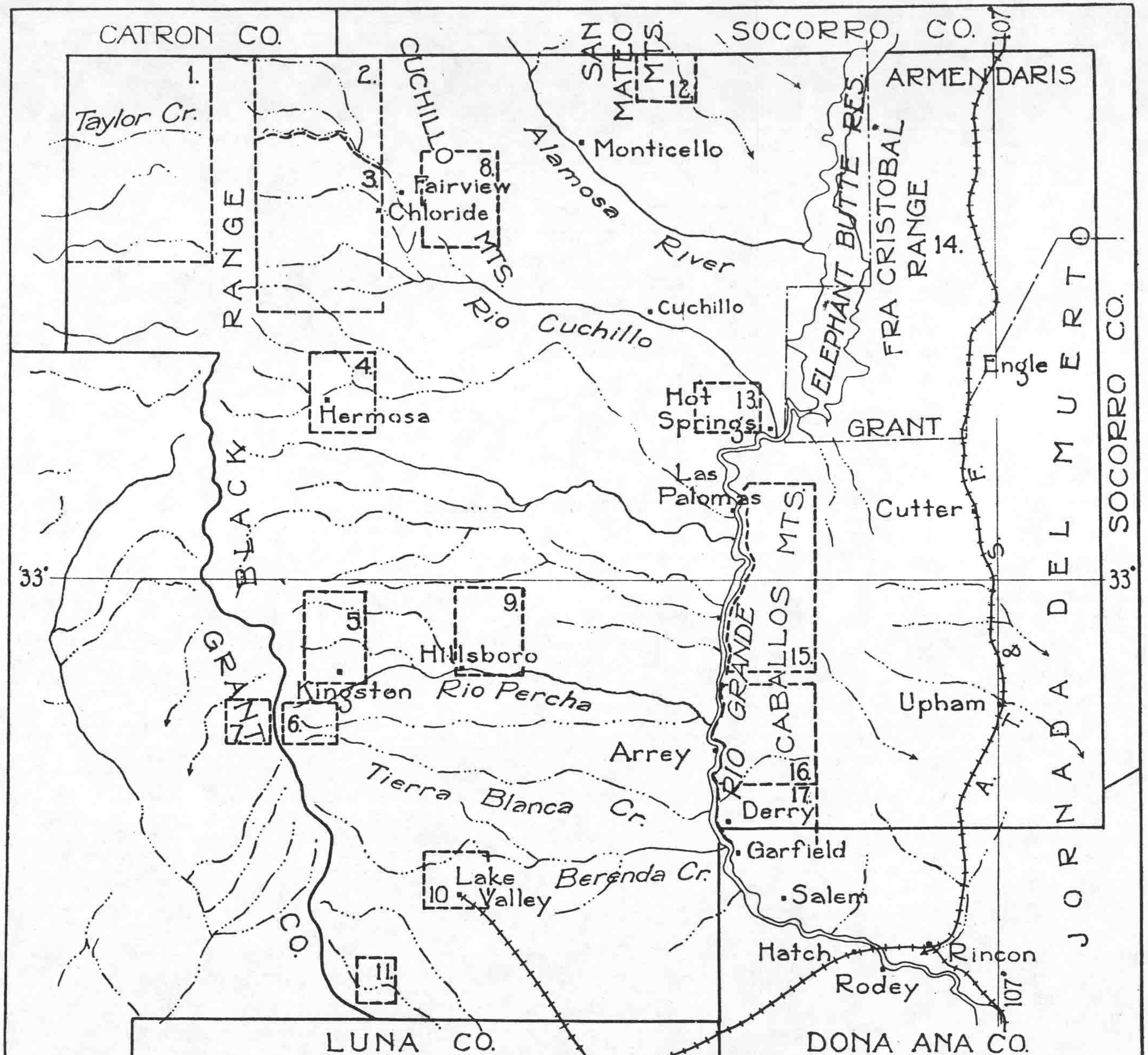


GENERAL GEOLOGIC MAP OF SIERRA COUNTY



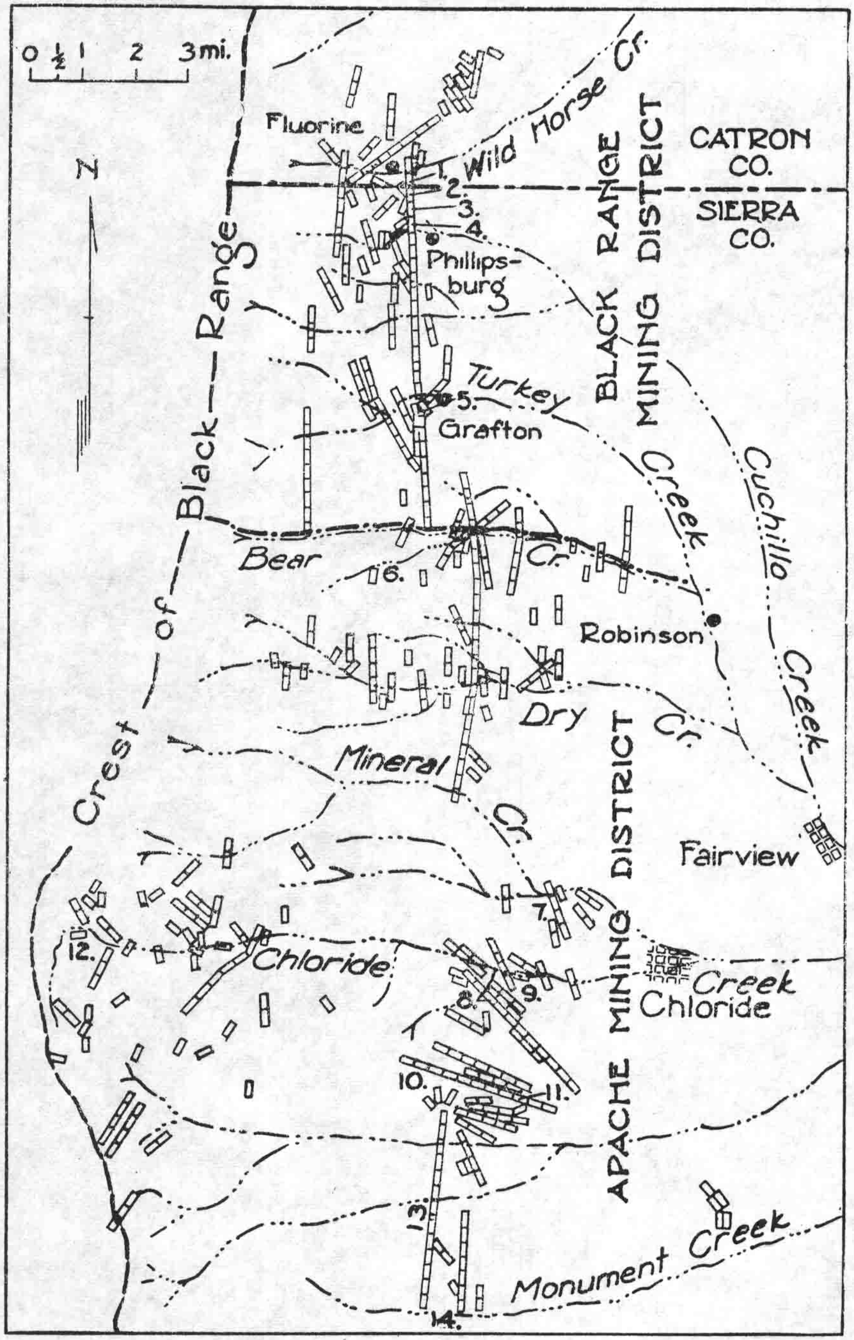
COMPOSITE AND SPECIAL STRATIGRAPHIC SECTIONS IN SIERRA COUNTY



MINING DISTRICTS

1 Taylor Creek
2 Black Range (Chloride)
3 Apache (Chloride)
4 Palomas (Hermosa)
5 Kingston (Black Range)
6 Tierra Blanca (Bromide No. 1)
7 Carpenter
8 Cuchillo Negro
9 Las Animas (Hillsboro)
10 Lake Valley
11 Macho
12 San Mateo Mountains
13 Mud Springs Mountains (Hot Springs)
14 Fra Cristobal Range (Armendaris Grant)
15 Sierra Caballos (Palomas Gap)
16 Pittsburg (Shandon)
17 Derry

INDEX MAP OF SIERRA COUNTY SHOWING LOCATION OF MINING DISTRICTS



MINES

PHILLIPSBURG AREA

1 Occidental
2 Black Mountain (Minnehaha)
3 Great Republic
4 Keystone

GRAFTON AREA

5 Emporia, Ivanhoe, Alaska

BEAR, DRY AND MINERAL CREEKS

6 Readjuster (Mahoning)
7 Dreadnaught

CHLORIDE

8 Wall Street (Nana)
9 White Mountain (Apache)
10 U. S. Treasury, White Eagle, Gray Eagle
11 Colossal, Midnight
12 Silver Monument

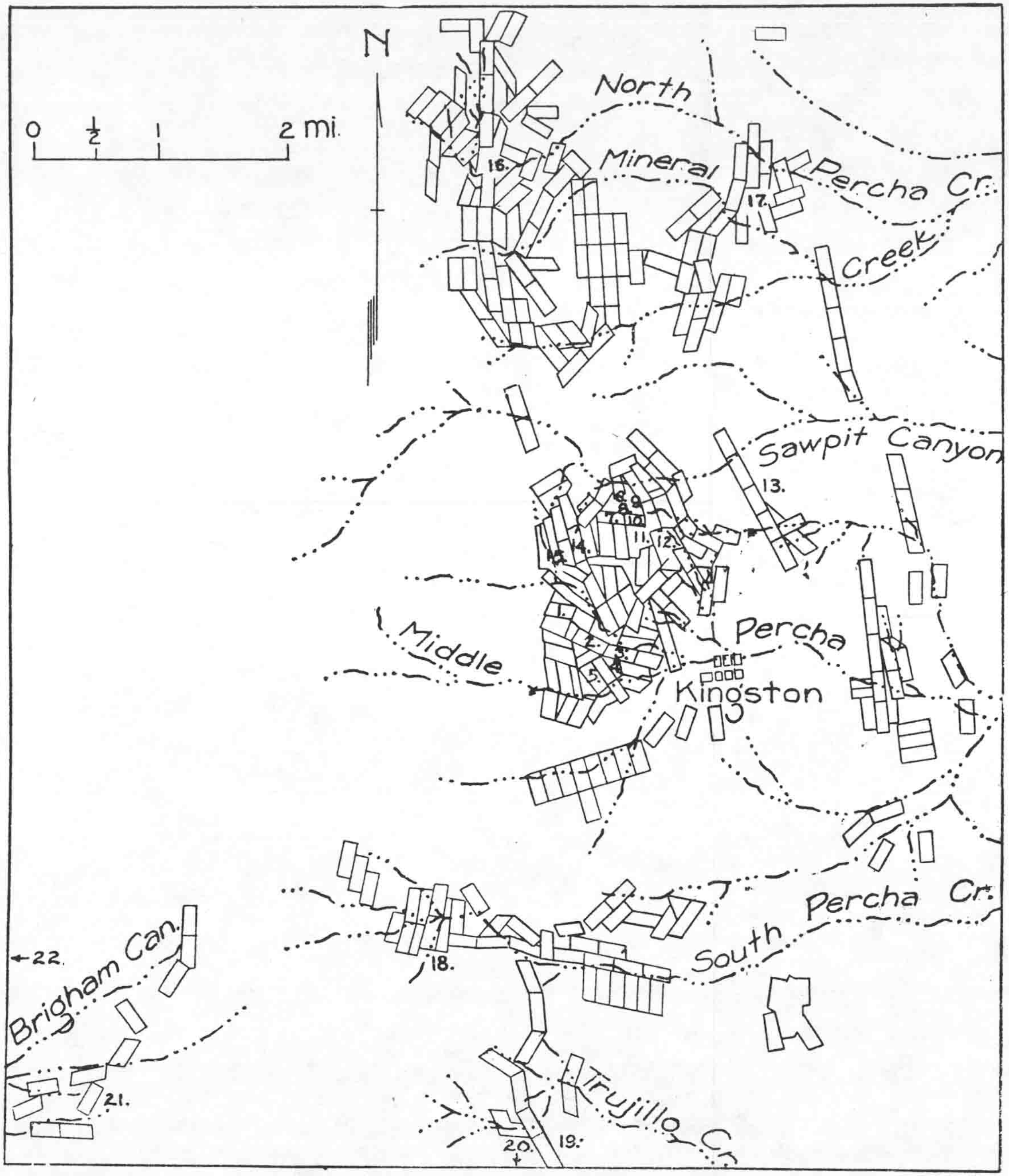
PYE LODE

13 Pye Lode

MONUMENT CREEK

14 Bald Eagle

BLACK RANGE AND APACHE (CHLORIDE) MINING DISTRICTS
SHOWING LOCATION OF PRINCIPAL MINES
(From U. S. G. S. Prof. Paper 68, with slight changes)



MINES

BLACK RANGE (KINGSTON) DISTRICT

LADRONE GULCH CAMP

1 Blackeyed Susan
2 Andy Johnson
3 Brush Heap
4 Calamity Jane
5 United States

LADY FRANKLIN CAMP

6 Comstock
7 Black Colt
8 Kangaroo
9 Caledonia
10 Lady Franklin
11 Superior
12 Bullion
13 Gypsy, Stowe, Picket Springs
14 Iron King
15 General Jackson

NORTH PERCHA CAMP

16 Virginia

MINERAL CREEK CAMP

17 Mineral Creek

SOUTH PERCHA CREEK

18 Gray Eagle

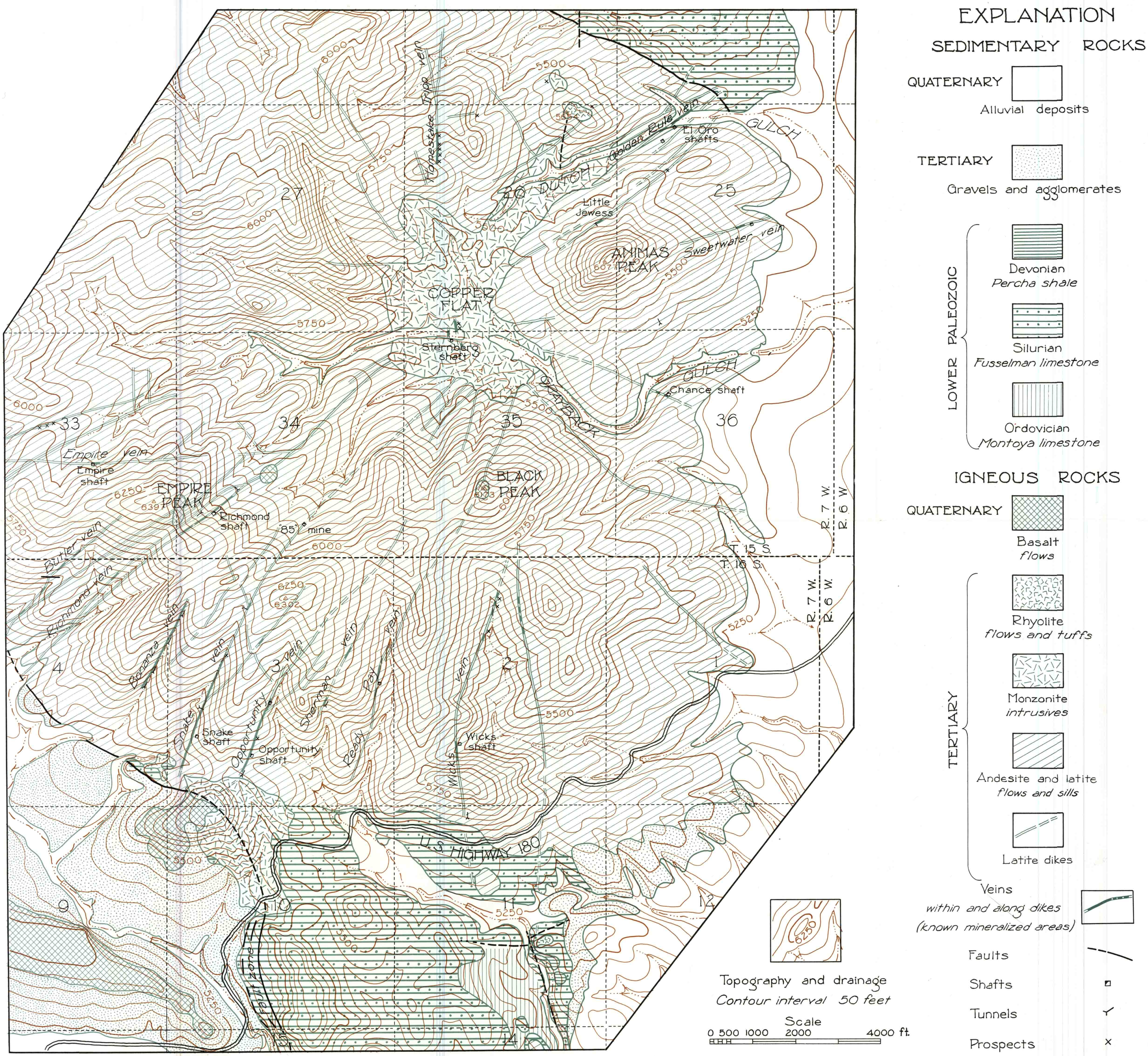
TIERRA BLANCA (BROMIDE NO. 1) DISTRICT

19 Lookout
20 Log Cabin (beyond limit of map)

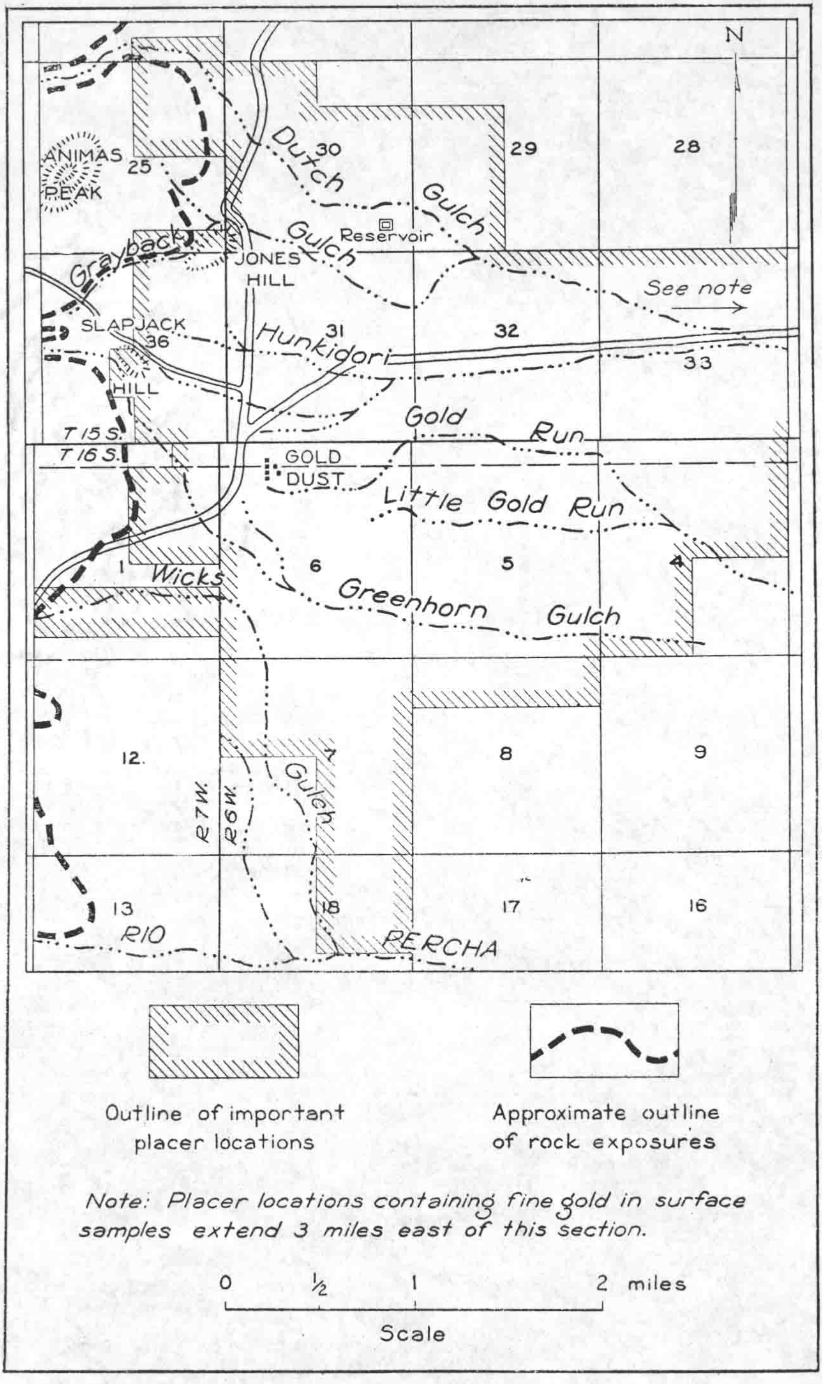
CARPENTER DISTRICT

21 Grand Central
22 Grand View (beyond limit of map)

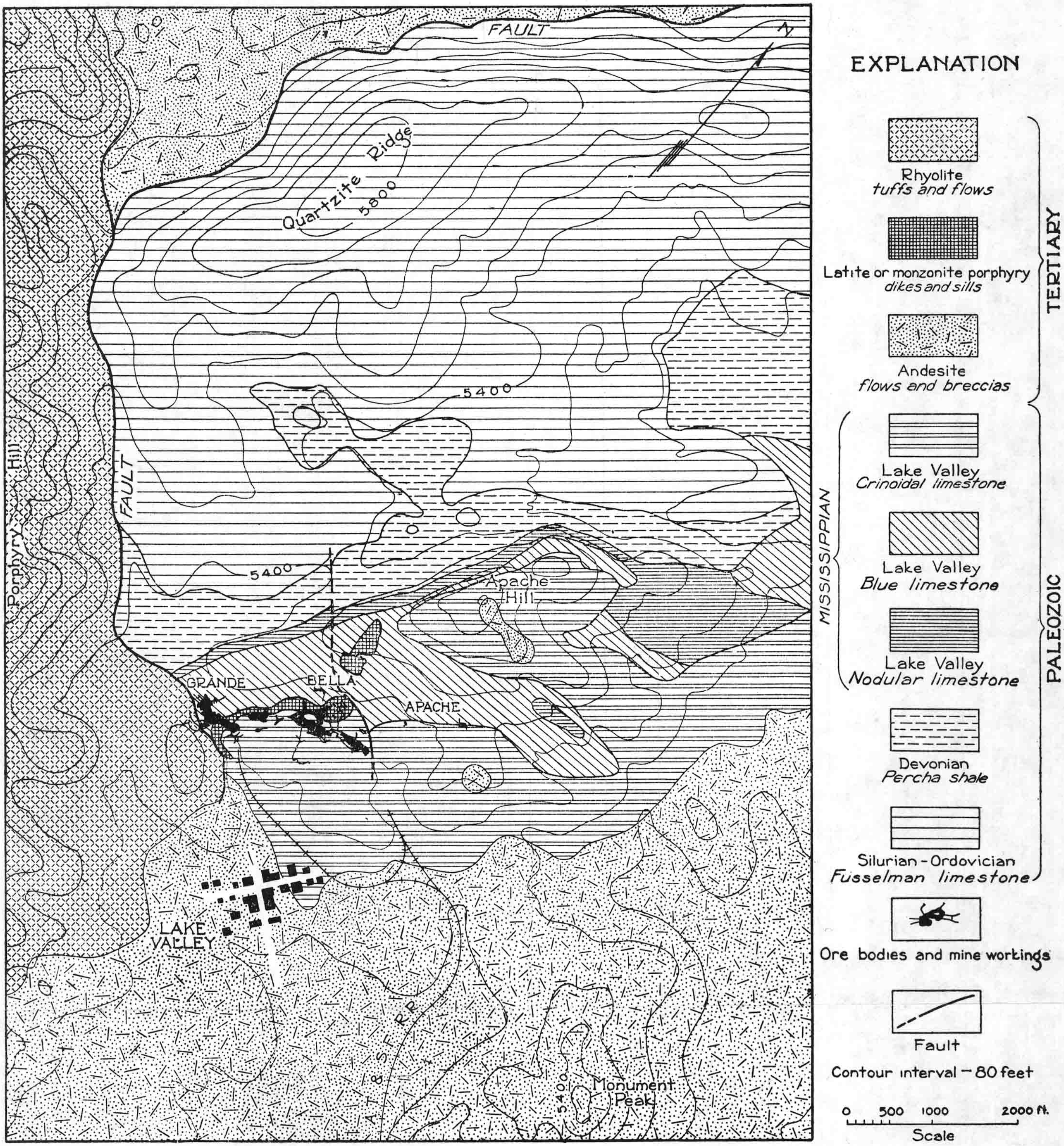
KINGSTON (BLACK RANGE), TIERRA BLANCA (BROMIDE NO. 1), AND CARPENTER MINING DISTRICTS SHOWING LOCATION OF PRINCIPAL MINES
(From U. S. G. S. Prof. Paper 68, with slight changes.)



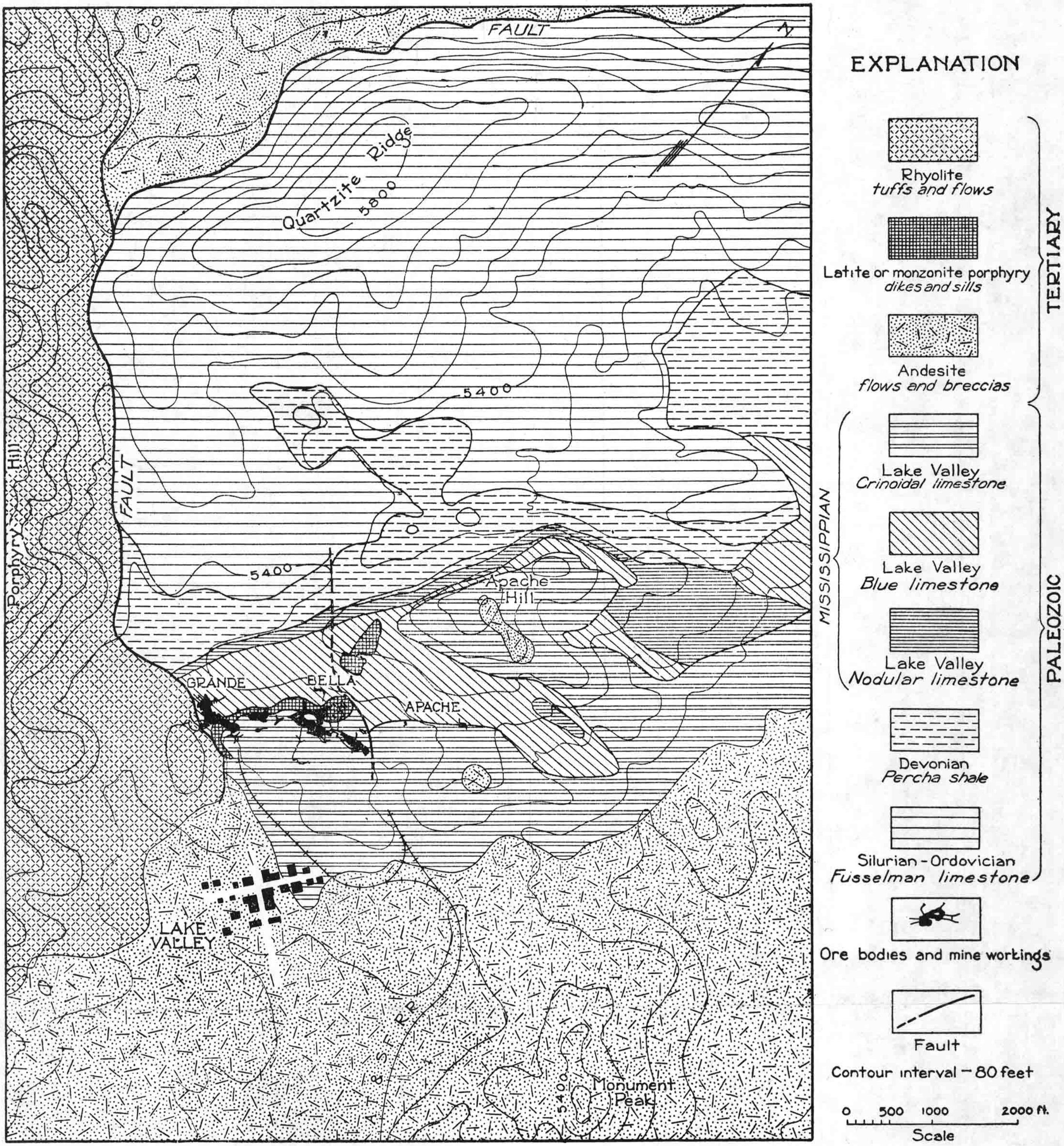
TOPOGRAPHIC AND GEOLOGIC MAP OF THE HILLSBORO (LAS ANIMAS) LODE MINING DISTRICT



GENERAL MAP OF THE HILLSBORO (LAS ANIMAS) PLACER MINING DISTRICT



TOPOGRAPHIC AND GEOLOGIC MAP OF THE LAKE VALLEY MINING DISTRICT
(After Ellis Clark with slight changes.)



TOPOGRAPHIC AND GEOLOGIC MAP OF THE LAKE VALLEY MINING DISTRICT
(After Ellis Clark with slight changes.)

(see page 50)

Minerals of the Ore Deposits of Sierra County[a]

		Ore Minerals								Gangue Minerals			
		Iron	Manganese	Zinc	Lead	Copper	Silver	Gold	Others	Silica	Alumina	CaO,MgO,MnO	Others
Supergene Minerals	Oxidized Zone (Oxysupergene)	Limonite Hematite	Manganite Psilomelane Pyrolusite Wad Mallardite Melanotekite	Goslarite Calamine Smithsonite	Anglesite Cerusite Descloizite Massicot Minium Plumbojarosite Pyromorphite Vanadinite Wulfenite	Azurite Chrysocolla Copper Cuprite Cuprodescloizite Malachite Melaconite	Bromyrite Cerargyrite Embolite Iodyrite Native Silver	Native Gold		Chalcedony Opal Quartz	Kaolin	Aragonite Calcite Talc	Siderite
	Sulfide Enrichment Zone (Sulfo-supergene)	Marcasite			Galena	Chalcocite Chalcopyrite Bornite Covellite	Argentite Native Silver Proustite Pyrargyrite Stephanite	Native Gold			Kaolin	Talc	Siderite
Hypogene Minerals	Low Temperature Zone, 50°-150°C. (Epithermal)	Pyrite				Chalcopyrite	Hessite Argentite Proustite Pyrargyrite Stephanite	Calaverite Native Gold Petzite Sylvanite	Fluorite	Quartz Chalcedony Amethyst	Adularia	Calcite	Barite Fluorite
	Moderate Temperature Zone, 150°-300°C. (Mesothermal)	Pyrite Siderite	Manganocalcite Manganosiderite Rhodochrosite Alabandite Hausmannite	Sphalerite	Galena	Bornite Chalcopyrite Tetrahedrite	Argentite Hessite	Calaverite Native Gold Petzite Sylvanite	Tellurium Tetradymite Fluorite	Quartz		Ankerite	Epidote Barite
	High Temperature Zone, 300°-800°C. (Hypothermal and Pyro-metasomatic)	Magnetite Pyrite Specularite							Cassiterite Molybdenite	Quartz			Epidote Garnet

[a] In the preparation of this table the writer has been guided by a similar one by G. F. Loughlin appearing opposite page 146 in "Geology and Ore Deposits of the Leadville Mining District, Colorado," U. S. Geological Survey Professional Paper 148, 1927.

Minerals Occurring in Sierra County

(see page 50)

*Mineral	Chemical Composition	District or Occurrence
Adularia	$K_2O.Al_2O_3.6SiO_2$	A feldspar occurring in epithermal veins.
Alabandite	MnS	Fairly common in ore deposits of Kingston district, and possibly elsewhere.
*Albite		A feldspar in acid igneous rocks.
Amethyst	SiO_2 with Mn	In epithermal deposits in Chloride and Kingston districts.
*Andesine		A feldspar in intermediate igneous rocks.
Anglesite	$PbSo_4$	Secondary after galena in all lead districts.
Ankerite	$CaCO_3.(Mg,Fe,Mn)CO_3$	Probably with other mangano-carbonates in lead-silver deposits in the county.
*Anorthite		A feldspar in basic igneous rocks.
*Apatite		A common accessory mineral in igneous rocks.
Aragonite	$CaCO_3$	In veins in Chloride and Kingston districts.
Argentite	Ag_2S	Chloride, Hermosa, Kingston, Tierra Blanca, Hillsboro and Lake Valley districts.
*Asbestos		Hydrothermal alteration mineral in limestone at Hillsboro.
*Augite		A ferromagnesian mineral in basic igneous rocks.
Azurite	$2CuCO_3.Cu(OH)_2$	A secondary copper mineral at Chloride, Hillsboro and elsewhere, and in "Red Beds."
Barite	$BaSo_4$	A gangue mineral in the Chloride district and in the Sierra Caballos.
*Biotite		A ferromagnesian mineral in acid and intermediate igneous rocks, and in pegmatite at Hillsboro.
Bornite	Cu_5FeS_4	Chloride, Hermosa, Hillsboro districts, and in Sierra Caballos.
Bromyrite	AgBr	Tierra Blanca district, not common.
*Bytownite (?)		A feldspar in basic igneous rocks.
Calamine	$H_2Zn_2SiO_5$	A secondary mineral in Kingston and Cuchillo Negro districts.
Calaverite (?)	$(Au,Ag)Te_2$	Tierra Blanca district.
Calcite	$CaCO_3$	A common primary or secondary mineral in ore deposits, and the principal mineral of limestone.
Cassiterite	SnO_2	Taylor Creek and Cuchillo Negro districts, and possibly in the San Mateo Mountains.
Cerargyrite	AgCl	Chloride, Hermosa, Kingston, Tierra Blanca, Hillsboro, Lake Valley, and other districts.
Cerusite	$PbCO_3$	Secondary after galena and anglesite in all lead-producing districts.
Chalcedony	SiO_2	A shallow-vein or a secondary mineral, various districts.
Chalcocite	Cu_2S	Secondary copper mineral in all copper-producing districts and in the "Red Beds."
Chalcopyrite	$CuFeS_2$	A primary copper mineral known in all districts except Lake Valley.
*Chlorite		Alteration product of igneous-rock minerals.
Chrysocolla	$CuSiO_3 + 2H_2O$	Secondary mineral in Hillsboro district.
Coal		In Cretaceous beds near Engle.
Copper	Cu	An oxidation product in Hillsboro district.
Covellite	CuS	Associated with chalcocite in many localities.
Cuprite	Cu_2O	In Hillsboro district, variety chalcotrichite, rare.
Cuprodescloizite	$4(Cu,Pb)O.(AsV)_2O_5.H_2O$	Secondary vanadium mineral in Hillsboro and Lake Valley districts and in Sierra Caballos.
*Cyanite		A mineral in schist resulting from regional metamorphism.
Descloizite	$4(Pb,Zn)O.V_2O_5.H_2O$	Secondary vanadium mineral in Hillsboro and Lake Valley districts.
*Dolomite	$CaMg(CO_3)_2$	As a vein mineral in Kingston district, (?) and in dolomitic limestone.
Embolite	Ag(Cl,Br)	In Lake Valley district.
Endlichite	$3Pb_3.(AsV)_2O_8.PbCl_2$	A variety of vanadinite found in Hillsboro and Lake Valley districts.
*Epidote		Product of contact-metamorphic or hydrothermal alteration.
Fluorite	CaF_2	In Sierra Caballos, Hillsboro district, and others.
Galena	PbS	Important at Hermosa and Kingston but present in all districts.
Gold	Au	Chloride, Tierra Blanca, Hillsboro, Shandon and other districts.
Goslarite	$ZnSo_4+7H_2O$	Efflorescent mineral on walls of drifts near zinc deposits.
*Grossularite		Calcium garnet of contact-metamorphic zones.
Gypsum	$CaSO_4.2H_2O$	In "Red Beds" and as a minor gangue mineral in various districts.
Hausmannite	Mn_3O_4	Much manganocalcite may be a mixture of hausmannite and calcite.
*Hedenbergite		A mineral of the contact-metamorphic zone.
Hematite	Fe_2O_3	In leached outcrops and in black sands.
Hessite	Ag_2Te	In Tierra Blanca district.
*Hornblende		In acid to intermediate igneous and metamorphic rocks.
*Ilmenite		An accessory mineral in igneous rocks.
Iodyrite	AgI	Lake Valley district.
*Kaolin		An alteration product of feldspars and other minerals, usually by surface waters.
*Labradorite		A feldspar in basic igneous rocks.
Limonite	$2Fe_2O_3.3H_2O$	An important mineral of leached outcrops over most ore deposits.
Magnetite	Fe_3O_4	In igneous and metamorphic rocks.
Malachite	$CuCO_3.Cu(OH)_2$	Generally distributed in limestone near copper-bearing deposits, and in oxidized portions of copper veins.
Mallardite	$MnSo_4 + 7H_2O$	Lake Valley district, rare.
Manganiferous calcite	$MnCo_3.CaCO_3$	Mixture of manganese carbonate and calcite. See also hausmannite above.
Manganite	$Mn_2O_3.H_2O$	With pyrolusite at Lake Valley and mined as silver ore or as manganese ore.
Manganosiderite	$MnCo_3.FeCO_3$	Mixture of manganese carbonate and siderite.
Marcasite	FeS_2	Hermosa district as a crystalline film on galena.
Massicot	PbO with iron	In limestone in Hillsboro district (?)
Melaconite (tenorite)	CuO	A copper mineral of the oxidized zone, found principally in "Red Beds" deposits in Sierra County.
Melanotekite	$2PbO.Mn_2O_3.2SiO_2$	Rare mineral in Hillsboro district. Iron may replace manganese.
*Microcline		A feldspar in acid igneous rocks.
Minium	Pb_3O_4	In limestone in Hillsboro district, rare.
Molybdenite	MoS_2	Hillsboro district in Copper Flat and other veins.
*Muscovite		Common mica. Widespread in acid igneous rocks and in pegmatite veins.
*Oligoclase		A feldspar in acid igneous rocks.
Opal	$SiO_2.nH_2O$	Upper vein zone, usually in extrusive rocks.
*Orthoclase		A feldspar in acid igneous rocks.
Petzite (?)	$(Ag,Au)_2Te$	Tierra Blanca district.
Plumbojarosite	$PbFe_6(OH)_{12}(So_4)_4$	In leached outcrops over lead-bearing deposits.
Proustite	Ag_3AsS_3	Kingston, Lake Valley and other districts, not common.
Psilomelane	H_4MnO_5	Hermosa, Kingston, Hillsboro, Lake Valley and Hot Springs districts, and Sierra Caballos.
Pyrargyrite	Ag_3SbS_3	Hermosa, Kingston, and Lake Valley districts.
Pyrite	FeS_2	Common in nearly all deposits and districts.
Pyrolusite	MnO_2	Kingston, Hillsboro, Lake Valley, Derry and other districts.
Pyromorphite	$(Pb,Cl)Pb_4P_3O_{12}$	In Sierra Caballos near Palomas Gap.
*Quartz	SiO_2	Common in most rocks and as a vein mineral.
Rhodochrosite	$MnCO_3$	A gangue mineral in Kingston district.
*Rutile		An accessory mineral in igneous rocks.
*Sanidine		A glassy, often transparent, feldspar occurring as phenocrysts in rhyolite.
*Sericite (muscovite)		Fine-grained variety of muscovite, usually an alteration product of feldspar.
Siderite	$FeCO_3$	In the contact-metamorphic area in Sierra Cuchillo.
Silver	Ag	Chloride, Hermosa, Kingston, Tierra Blanca, Hillsboro, Lake Valley and probably other districts.
Smithsonite	$ZnCO_3$	In the Cuchillo Negro, Hermosa, Kingston and other districts.
Specularite	Fe_2O_3	In deep-vein and contact-metamorphic deposits.
Sphalerite	ZnS	Closely associated with galena deposits, particularly in Cuchillo Negro district.
Stephanite	Ag_5SbS_4	Lake Valley district.
Sylvanite (?)	$(Au,Ag)Te_2$	Tierra Blanca district.
*Talc		An alteration product of magnesian silicates.
Tetradymite	$Bi_2(Te,S)_3$	A rare mineral in Hillsboro district.
Tetrahedrite	$4Cu_2S.Sb_2S_3$	Silver Monument mine and probably elsewhere. May grade toward tennantite in composition.
Tellurium (?)	Te	Reported from Hillsboro and Tierra Blanca districts. Very rare.
*Titanite		An accessory mineral in igneous rocks.
*Tourmaline		A mineral of pegmatite dikes in granite or in metamorphic rocks.
*Tremolite		A contact-metamorphic mineral.
Vanadinite	$(Pb,Cl)Pb_4V_3O_{12}$	Hillsboro, Lake Valley and Macho districts and Sierra Caballos.
Wad	MnO_2 with impurities	Kingston, Hillsboro, Lake Valley, Hot Springs, and Derry districts.
Wulfenite	$PbMoO_4$	Associated with vanadinite.
*Zircon		An accessory mineral in igneous rocks.

* Minerals marked as shown are found in igneous, metamorphic or sedimentary rocks, and are not commonly known as constituents of ore deposits.

(see page 44)

Production of Metals in Sierra County, 1884, 1885, 1889-1931

Year	Dry Tons	GOLD[a] Value	SILVER[a] Ounces	SILVER[a] Value	COPPER Pounds	COPPER Value	LEAD Pounds	LEAD Value	ZINC Pounds	ZINC Value	Total Value	No. of Producing Mines
1884	----	$ 19,000	1,000,000	$1,110,000	----	$ ----	----	$ ----	----	$ ----	$1,129,000	
1885	----	118,000	910,854	974,614	----	----	----	----	----	----	1,092,614	
86[b]	----	----	----	----	----	----	----	----	----	----	----	
87[b]	----	----	----	----	----	----	----	----	----	----	----	
88[b]	----	----	----	----	----	----	----	----	----	----	----	
89	----	113,875	634,639	595,561	112,050	15,127	810,474	31,609	----	----	756.172	
1890	----	190,400	671,938	705,535	97,142	15,154	86.159	1,627	----	----	912,716	
91	----	217,213	681,836	675,018	184,615	23,631	14,620	629	----	----	916,491	
92	----	285,000	549,544	478,103	262,517	30,452	142,500	5,843	----	----	799,398	
93	----	329,000	162,791	126,977	272,728	29,455	105,000	3,885	----	----	489,317	
94	----	192,000	77,500	48,825	110,000	10,450	103,334	3,410	----	----	254,685	
95	----	150,000	84,094	54,661	----	----	152,438	4,878	----	----	209,539	
96	----	180,000	129,853	88,300	----	----	----	----	----	----	268,300	
97	----	65,750	75,201	45,121	----	----	----	----	----	----	110,871	
98	----	357,220	87,651	51,714	233,030	28,896	----	----	----	----	437,830	
99	----	377,000	85,478	51,287	----	----	----	----	----	----	428,287	
1900	----	37,991	111,142	68,908	64,757	10,750	2,615,953	115,102	----	----	232,751	
01	----	29,615	227,887	136,732	60,607	10,121	2,580,136	110,948	----	----	287,416	
02	----	21,705	25,114	13,310	56,400	6,881	82,965	8,402	----	----	45.298	
03	----	6,584	7,500	4,050	7,556	1,035	2,596	109	----	----	11,778	
04	1,295	74,596	17,055	9,892	16,700	2,138	----	----	----	----	86,626	
05	3,513	99,042	8,760	5,344	46,664	7,280	----	----	----	----	111,666	
06	3,246	18,048	8,102	5,509	5,995	1,157	----	----	----	----	24,714	6
07	700	8,224	2,250	1,485	5,425	1,085	9,548	506	----	----	11.300	11
08	680	18,018	8,589	4,552	12,874	1,699	6,075	255	----	----	24,524	11
09	4,294	10,450	25,698	13,363	25,838	3,359	49,023	2,108	----	----	29,280	
1910	8,306	11,697	15,778	8,520	2,448	311	11,274	496	----	----	21,024	
11	5,036	27,785	16,487	8,738	5,374	672	28,088	1,264	----	----	88,459	
12	252	4,143	11,236	6,910	8,988	1,483	21,001	945	----	----	13,481	
13	269	857	2,529	1,528	22,568	398	32,685	1,438	----	----	4,221	10
14	98	1,747	3,982	2,202	14,436	1,920	5,743	224	----	----	6,093	8
15	438	2,836	316	160	2,228	390	24,617	1,157	7,492	929	5,472	8
16	935	1,468	2,138	1,407	14,427	3,549	126,609	8,736	7,045	944	16,104	10
17	619	1,801	8,712	7,179	11,828	3,229	80,116	6,890	----	----	19.099	13
18	801	568	18,536	18,536	42,053	10,387	25,915	1,840	----	----	31,331	10
19	4,041	3,948	67,658	75,777	31,661	5,889	49,679	2,633	----	----	88,247	9
1920	6,957	15,896	117,089	127,627	43,826	8,064	84,264	6,741	----	----	158,328	17
21	3,856	1,323	77,366	77,366	1,395	180	40,934	1,842	----	----	80,711	8
22	9,965	2,708	136,842	136,842	38,771	5,234	8,746	481	----	----	145,265	9
23	6,441	6,443	80,814	66,267	61,469	9,036	12,842	899	----	----	82,645	14
24	42	527	1,297	869	3,787	496	4,901	392	----	----	2,284	6
25	2,545	1,825	23,090	16,025	6,300	895	38,930	3,387	----	----	22,132	7
26	19,658	4,592	107,973	67,375	16,680	2,835	298,800	23,904	20,500	1,538	99,744	18
27	1,022	8,621	10,300	5,840	20,496	2,685	123,000	7,749	12,000	768	25,663	14
28	500	3,485	6,754	3,951	5,403	778	146,448	8,494	----	----	16,708	11
29	543	2,883	6,105	3,254	7,989	1,406	133,030	8,381	----	----	15,924	14
1930	11,486	3,638	18,465	7,109	72,700	9,451	400	20	----	----	20,218	10
31	578	6,673	4,500	1,305	21,000	1,911	24,000	888	----	----	10,777	24
Totals	98,116	$3,034,195	6,331,443	$5,913,648	2,030,725	$269,369	8,032,893	$373,112	47,037	$4,179	$9,594,503	

[a] Yearly figures for gold and silver include both lode and placer production.
[b] Figures not available.