NEW MEXICO SCHOOL OF MINES

RICHARD H. REECE
President

STATE BUREAU OF MINES AND
MINERAL RESOURCES

JOHN M. KELLY
Director

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by

LAWSON P. ENTWISTLE

SOCORRO, NEW MEXICO
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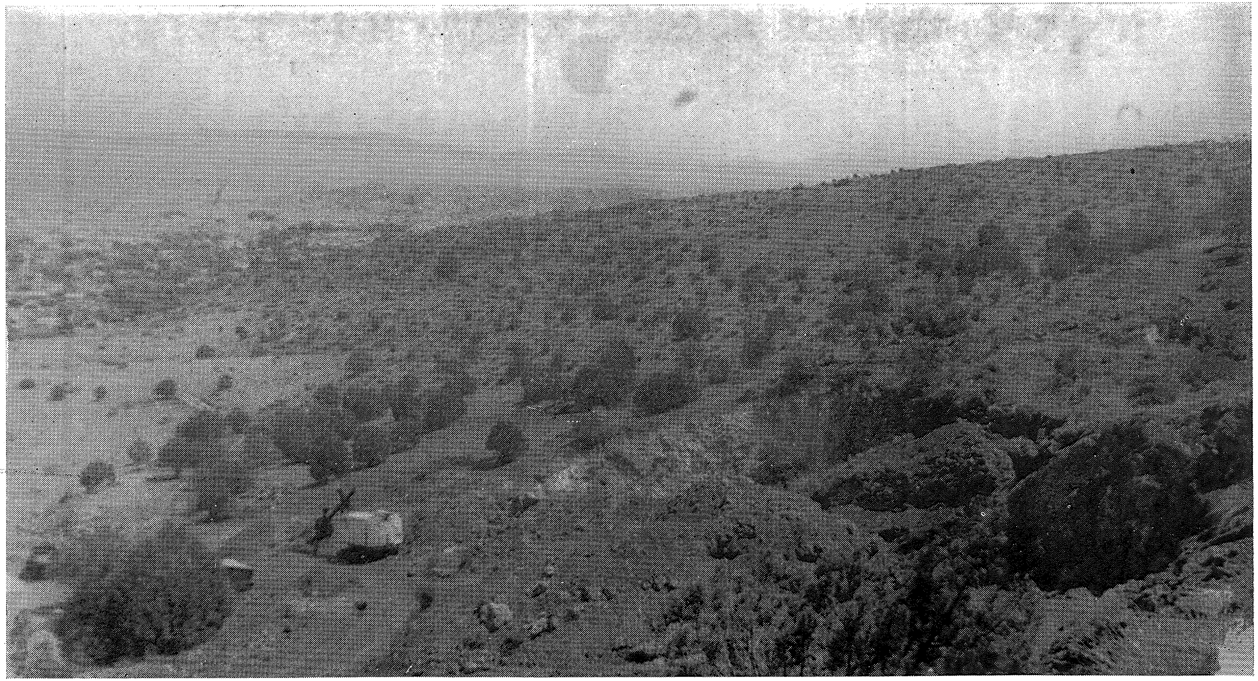

Mining operations, Silver Pick pit, Boston Hill mining district. View looking southeast. Silver City in left background.

CONTENTS

ILLUSTRATIONS

PLATES

FIGURES

ILLUSTRATIONS

PLATES

FIGURES

THE STATE BUREAU OF MINES AND MINERAL RESOURCES

The New Mexico State Bureau of Mines and Mineral Resources, designated as "a department of the New Mexico School of Mines and under the direction of its Board of Regents," was established by the New Mexico Legislature of 1927. Its chief functions are to compile and distribute information regarding mineral industries in the State, through field studies and collections, laboratory and library research, and the publication of the results of such investigations. A full list of the publications of the State Bureau of Mines and Mineral Resources is given on the last pages of this Bulletin, following the index.

Manganiferous Iron-Ore Deposits near Silver City, New Mexico

By

LAWSON P. ENTWISTLE[1]

INTRODUCTION

GENERAL STATEMENT

For many years the potential importance of the manganiferous iron ores at Boston Hill, near Silver City, New Mexico, has been recognized. As recent economic developments have greatly increased the demands for manganese and manganiferous iron ores, these deposits have become of commercial value. Detailed geologic information on the area, with its direct relation to ore localization, is scant; therefore the writer made a survey of the manganiferous iron-ore deposits, and also of the related silver deposits in the Chloride Flat mining district, about one mile north of Boston Hill (see map, Fig. 1). Results of the survey make up the chief part of this report.

A detailed study of a much larger area than that covered in this report is necessary for full comprehension of the broader geologic features. Previous work by competent geologists appears to have correlated adequately the sedimentary rocks and the structural features of the Silver City quadrangle. Many interesting possibilities in the chemistry of the hypogene and supergene ore solutions cannot be presented fully at this time because of limited library facilities and insufficient experimental data.

Field work was started in the summer of 1936, when the writer mapped and studied in considerable detail the surface and underground geology of the most productive part of the Chloride Flat mining district. Field work was then continued intermittently through 1942 in order to complete mapping the Boston Hill mining district and to correlate its geologic features with those at Chloride Flat. Much of the mining at Boston Hill has been near the surface, and many of the deeper workings are now flooded; consequently most of the time was spent mapping and studying the areal geology.

Topography and geology were mapped simultaneously, with transit and stadia. The original field maps were made on a scale of one inch to 200 feet.

The report outlines in a general way the most favorable areas for prospecting, and describes the geologic structures that

[1] Geologist, American Smelting and Refining Company.

have controlled or localized the deposition of the ore minerals. No attempt has been made to show developed ore reserves with indicated tenor of ore, or to discuss metallurgical problems which might arise if selective concentration of the ores should be attempted.

PREVIOUS WORK

In early reports Raymond[1] comments on the discovery and mining of silver ores in the Chloride Flat and Silver Flat[2] mining districts. Graton[3] made a reconnaissance survey of the Chloride Flat mining district during a general survey of the ore deposits of New Mexico. Paige[4] published a study of the structural, stratigraphic, and ore relationships in the Silver City quadrangle, which includes the Central (Hanover, Fierro, Santa Rita, and Bayard), Pinos Altos, Tyrone, Boston Hill, Chloride Flat, Georgetown, and Lone Mountain mining districts.

Before 1916 only silver-bearing manganiferous ores were shipped to smelters for fluxing purposes.[5] In the reports noted above little mention was made of the manganiferous iron ores because until 1916 they were of no manifest economic importance. The first important published data on the Boston Hill mining district are given in a bulletin by Wells,[6] which contains a brief review of the salient features of the rocks, structure, and ore deposits. A few additional notes have been published,[7] and some work was done in the Chloride Flat mining district in 1936.[8] The geology at Boston Hill was summarized in a paper which appeared in 1944.[9] Some new data, collected since the summary appeared, are incorporated herein.

---

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains (1871, p. 286; 1873, p. 311; 1874, pp. 338-339, 342-344; and 1876, pp. 338-339): U. S. Treasury Dept., 1872, 1873, 1874, and 1877.

[2] Silver Flat appears to be the early name for the east and northeast portion of the Boston Hill mining district.

[3] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 18, 26, 38, 63-65, 301-305, 1910.

[4] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), 1916.

[5] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 132, 151, 274, 1910.

[6] Wells, E. H., Manganese in New Mexico: N. Mex. Min. Res. Survey Bull. 2, pp. 39-61, 1918.

[7] Hewett, D. F., and Pardee, J. T., Manganese in western hydrothermal ore deposits: *Ore deposits of the Western States* (Lindgren vol.), pp. 678-679, Am. Inst. Min. Met. Eng., 1933.

Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features: N. Mex. Bur. Mines Bull. 7, pp. 52, 65-66, 1933.

Schmitt, Harrison, Structural associations of certain metalliferous deposits in southwestern United States and northern Mexico: Trans. Am. Inst. Min. Met. Eng., vol. 115, pp. 39-40, 1935.

Umpleby, J. B., Manganiferous iron deposits at Silver City, N. Mex.: Eng. Min. Jour., vol. 104, p. 931, 1917.

[8] Entwistle, L. P., The Chloride Flat mining district, New Mexico: Unpublished thesis, Univ. Ariz. library, 1936.

[9] Entwistle, L. P., Geology of the manganiferous iron-ore deposits at Boston Hill, New Mexico: Am. Inst. Min. Met. Eng., Tech. Pub. 1712, 1944.

ACKNOWLEDGMENTS

In the field the writer was assisted by G. S. Entwistle, D. R. Purvis, and F. S. Cook. The triangulation base in the Chloride Flat mining district was supplied by Harrison Schmitt, consulting mining geologist, Silver City, and was expanded to include the Boston Hill mining district. Dr. Schmitt also read the manuscript critically and gave advice based on his own observations. Analyses were made in the chemical laboratory at the Ground Hog Unit of the American Smelting and Refining Company, Vanadium, New Mexico.

The New Mexico Bureau of Mines and Mineral Resources generously consented to do some of the petrographic and polished-section work, as instruments were not available to the writer. This work was assigned to N. P. Peterson; the results of his analyses are used in this report. The manuscript was edited by S. B. Talmage and Robert L. Bates, of the New Mexico Bureau of Mines and Mineral Resources.

R. I. Kirchman of Silver City furnished maps, churn drilling logs, and historical data on the Silver Spot group of claims. Earle S. Patten, Silver City, assisted with information on the Boston Hill group. The claim map has been taken largely from a map of Silver City compiled by Wm. H. Bard, city engineer.

GEOGRAPHY

LOCATION

The Boston Hill mining district lies at the south extremity of the Silver City Range (see map, Fig. 1). The district, which is a triangular area covering about two square miles, lies in secs. 3 and 4, T. 18 S., R. 14 W., Grant County, New Mexico. It is situated immediately southwest of the town of Silver City (pop. 5,044), the county seat. Silver City was the first town to be incorporated by the Territory of New Mexico, and has been the county seat since December 29, 1871.[10]

A branch line of the Atchison, Topeka, and Santa Fe railway runs from Silver City to Deming, New Mexico, where connections can be made with the main line of the Southern Pacific railroad. Hard-surfaced highways and well-drained gravel roads radiate from Silver City to the main coast-to-coast highways. Plans are

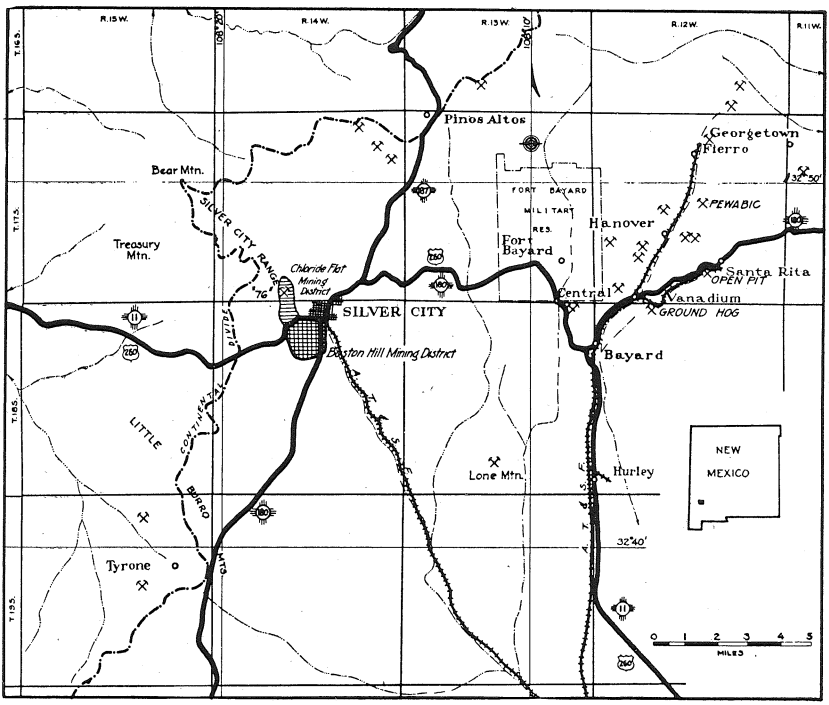

FIGURE 1.—Index map.

[10] Inventory of the county archives of New Mexico, No. 9, Grant County, (Silver City), New Mexico Historical Records Survey, Division of Community Service Programs, Works Projects Administration, Albuquerque, N. Mex., p. 12, Dec. 1941.

under way to build a modern airfield near Silver City. The town is the shopping center for the important mining camps at Santa Rita, Hurley, Vanadium, Hanover, Tyrone, and Mogollon.

CLIMATE AND VEGETATION

The climate in the vicinity of Silver City is, in general, mild. In the summer the temperature rarely reaches 100°F., and the evenings are generally cool. During the winter there are some light snowfalls. Freezing temperatures generally occur from November to April. The heaviest rains fall during July, August, and September; a period of lighter precipitation occurs from December to March.

Climatological data are summarized in the following table.

TABLE 1.

CLIMATOLOGICAL DATA 1933-1943 [a]

Month	Temperature [b]					Precipitation [c]	
	Mean	Mean Highest	Highest	Mean Lowest	Lowest	Total Inches	Snowfall (Inches)
January	39.1	62.4	65	12.5	5	1.10	4.3
February	41.6	65.9	73	13.5	-6	1.59	2.9
March	47.1	72.1	78	21.5	18	1.04	1.3
April	53.3	80.7	86	25.2	18	0.36	0
May	61.2	85.6	90	31.2	28	0.73	0
June	70.0	95.4	101	43.4	38	0.93	0
July	72.6	94.0	98	53.3	49	2.20	0
August	71.3	91.2	96	52.4	49	3.39	0
September	66.1	87.8	90	42.3	34	2.91	0
October	57.1	80.8	88	32.1	27	0.93	0
November	46.9	71.5	75	19.9	9	0.86	0.9
December	42.3	65.7	73	17.0	10	1.45	2.4
						17.49	11.8

a. Collected from Climatological Data, U. S. Dept. Agriculture, Weather Bureau, Albuquerque, New Mexico.

b. Temperatures for station at Fort Bayard, elevation 6,152 ft. Data on temperature at Silver City are incomplete.

c. Precipitation for station at Silver City, elevation 5,937 ft.

On the south slopes of Boston Hill grow bear grass, yucca, cholla and other cacti, and short grass. The denser vegetation on the north slopes includes small piñon trees and bushes.

On the higher mountain ranges north of Silver City are valuable stands of timber. The flatter land to the south is semi-arid and is used for grazing.

TOPOGRAPHY

The general topography of the Silver City Range, of which Boston Hill forms the southern extremity, is described by Paige[11] as follows:

[11] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 2, 1916.

> The range of mountains of moderate relief which trends northwestward from Silver City culminates in Bear Mountain, a peak 8,050 feet high. These mountains are called in this folio the Silver City Range. South of Bear Mountain the range, in a broad way, is asymmetric in form, the western slopes being far steeper than the eastern, which have assumed lower angles in conformity with the dip of the sedimentary rocks that form them. . . The southern part of the mountains is not rugged and merges gradually into the gravel at the south end; the northern part, however, especially in the canyons at the north end, is somewhat rugged.
>
> . . . The mountain masses, whose form is primarily influenced by sedimentary strata, are symmetric. . . Each range is further characterized by a medial valley, more or less deeply incised, which roughly divides it into two parallel ridges. This feature, due to a soft shale, is best shown in the range near Silver City. . .

The Boston Hill mining district lies along an east-trending ridge that forms a hook at the south end of the Silver City Range. The ridge is modified by three small round peaks, the highest of which attains an elevation of 6,300 feet. The slopes are, in general, gentle; but the north and west sides of Boston Hill are slightly steeper than the south and east sides. The east side of Boston Hill is a dip slope on Silurian dolomite. To the south, the slopes on the Lower Paleozoic terrane merge into Quaternary gravels and sands.

The maximum relief is but 300 feet; most of the mining operations are less than 200 feet above the main highways that skirt the district. The low relief facilitates the construction of roads to the several mines.

The drainage from Boston Hill enters San Vicente arroyo, which flows southerly into the Mimbres basin at Deming, New Mexico. The arroyo is dry except during periods of heavy rainfall. The Continental Divide, cutting diagonally through the Silver City quadrangle, is about two miles west of Boston Hill.

The Chloride Flat mining district lies in a medial valley flanked on the west by Lower Paleozoic dolomites and on the east by Carboniferous limestones. The valley was formed by the erosion of soft Devonian shale. (See Plate 2.)

GROUND-WATER LEVEL

In 1940 the water level in the Silver Spot shaft was 40 feet below the collar, at an elevation of about 5,970 feet. In 1944, however, the water had dropped so that it was no longer visible from the surface. The shaft appeared to have caved some distance below the collar, obscuring the present water level. Water has filled a few of the workings off the Silver Spot incline below an elevation of about 5,940 feet. It has not been encountered in any other mines known to the writer.

At Chloride Flat all the mines entered were dry. The deepest were 260 feet vertically below the surface, at an elevation of 6,080 feet.

GEOLOGY

SEDIMENTARY ROCKS

GENERAL STATEMENT

A nearly complete local section of the Paleozoic formations is well exposed in the Boston Hill mining district and surrounding area. The Paleozoic rocks are overlain in places by Cretaceous and Quaternary strata. The sedimentary series, which rests on the pre-Cambrian basement, is broken by several disconformities; but all the rocks, with the exception of a small patch of flat-lying Quaternary limestone, dip about 15° SSE. (See Plate 4.)

TABLE 2.

Generalized section of formations at Boston Hill

		Feet
Quaternary:	Gravels and sand	50±
	Limestone	0-10
	Nonconformity	
Cretaceous:	Colorado formation	800±
	Beartooth quartzite	180
	Disconformity	
Pennsylvanian:	Magdalena formation	89
	Disconformity	
Mississippian:	Lake Valley limestone	325±
	Disconformity	
Devonian:	Percha shale, including sill	456
	Disconformity	
Silurian:	Fusselman dolomite	75
	Disconformity	
Ordovician:	Montoya dolomite	275
	El Paso dolomite	352
	Disconformity (?)	
Cambrian:	Bliss sandstone	180
	Nonconformity	
		2,792±
Pre-Cambrian:	Granite	

All the formations shown in Table 2, except the Quaternary gravels, sands, and limestone, dip southeasterly under gravels or later sills and have been cut by the Silver City intrusion, a roughly circular mass of quartz monzonite porphyry. The gravels, which extend for many miles to the south and west, have been trenched by innumerable steep-walled arroyos.

The Paleozoic section is also exposed east of Santa Rita, and at Lone Mountain, an outlier seven miles southeast of Boston Hill. An uplift in the Hanover area of the Central mining district, about ten miles east of Boston Hill, exposes an altered, broken section of the Lower Paleozoic rocks.

In the Silver City quadrangle the Paleozoic section was beveled by pre-Cretaceous erosion so that the Cretaceous quartzite overlaps all formations from Pennsylvanian to pre-Cambrian. Thus, southeast of Santa Rita the Cretaceous quartzite lies on red shale and purple to gray limestone of Permian age.[12] At the Ground Hog mine in the Bayard area of the Central mining district the Cretaceous quartzite lies on Pennsylvanian limestone and shale. At Treasury Mountain, five miles northwest of Boston Hill, the younger Paleozoic strata have been removed, and the quartzite rests on Silurian dolomite. In the Little Burro Mountains, seven miles to the southwest, all the Paleozoic rocks are absent, and the same quartzite rests on the pre-Cambrian basement.[13]

All the sedimentary rocks at Boston Hill, except those of Quaternary age, have been cut by sills and dikes. In other parts of the Silver City quadrangle, however, sills and dikes of basalt cut Quaternary gravel. Much of the southeast and north parts of the Silver City quadrangle are covered by gravels, sands, tuffs, and flows of Tertiary age, probably Miocene. In the mineralized areas large cross-cutting intrusive masses are common.

CAMBRIAN SYSTEM

BLISS SANDSTONE

The Bliss sandstone, named by Richardson,[14] was originally classified as Cambrian. Paige's work correlated the sandstone found in the Silver City quadrangle with the Bliss as defined by Richardson.[15] More recent work has shown that the rock called Bliss sandstone near Van Horn, Texas, is probably of Ordovician age.[16] Although no concentrated search for fossils was made by the present writer, a few markings which may be annelid borings were found. Paige has reported numerous specimens of *Billingsella coloradoensis*, and fragmentary trilobites.

At Boston Hill the full thickness of the Bliss is not exposed; part has been cut out by faulting or is covered by recent gravels and mantle rock. Where the formation is exposed on the west flank of Boston Hill, it is essentially a pink to red vitreous quartzite; but in an arroyo in the southwest part of the area, where the contact with the overlying El Paso dolomite is well exposed, the top beds are alternating layers of red and green glauconitic sandstone. A thin section of the green sandstone

[12] Spencer, A. C., and Paige, Sidney, Geology of the Santa Rita mining area, New Mexico: U. S. Geol. Survey Bull. 859, pp. 26-28, 1935.

[13] The general relations of the Paleozoic and Cretaceous rocks to the pre-Cambrian basement are well illustrated on Paige's map accompanying the Silver City folio.

[14] Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas: Univ. Tex. Min. Survey Bull. 9, p. 27, 1904.

[15] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 3, 1909.

[16] King, P. B., Older rocks of Van Horn region, Texas: Bull. Am. Assoc. Petrol. Geol., vol. 24, no. 1, pp. 153-156, 1940.

shows it to be composed of rounded grains of quartz, about 0.1 to 0.3 millimeter in diameter, cemented by glauconite which is partly altered to limonite.[17] A little magnetite is dispersed throughout the rock. At and near the Boston Hill fault the Bliss is in many places stained nearly black by introduced manganese oxides.

About two miles to the northwest of Boston Hill, in the Chloride Flat mining district, a section of the Bliss sandstone measured 180 feet. There the base is marked by a one-foot bed of yellowish quartz-pebble conglomerate. The basal conglomerate is overlain by medium-grained to coarse-grained ferruginous and glauconitic quartzite, which becomes limy near the top and appears to grade into the overlying El Paso dolomite. On the Fierro No. 2 claim at Boston Hill, however, the contact between the Bliss and the El Paso is marked by an abrupt change from glauconitic sandstone to gray sandy dolomite.

ORDOVICIAN SYSTEM

EL PASO DOLOMITE

Richardson[18] originally included limestones and dolomites of Lower and Upper Ordovician age in the El Paso dolomite but later restricted the name El Paso to the beds of Lower Ordovician age only.[19]

The El Paso at Boston Hill is essentially a light gray dolomite and magnesian limestone with some white to gray chert. At the base the beds are limy and sandy; the basal magnesian limestone is in most places distinguished by the reddish-brown fucoidal markings described by Paige.[20] The same peculiar markings have been noted by Lindgren[21] in the Longfellow limestone of Ordovician age at Morenci, Arizona. The chert near the base is bedded, but its knotty appearance differentiates it from the smooth banded chert in the middle member of the Montoya dolomite. Near the top of the El Paso formation the chert is in isolated lenses. Gastropods are common among the fossils observed at Boston Hill.

The following section, which is considerably thinner than sections measured in the Chloride Flat mining district, is found on the west flank of Boston Hill.

Montoya dolomite (Upper Ordovician)	
El Paso dolomite (Lower Ordovician):	Feet
10. Dark gray dolomite with irregular nodules of pinkish-white chert and irregular markings of red iron oxide	90

[17] Limonite is used in this report as a general term for mixed hydrous iron oxides. See definition, page 38.

[18] Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas: Univ. Tex. Min. Survey Bull. 9, pp. 29-31, 1904.

[19] Richardson, G. B., Paleozoic formations in trans-Pecos Texas: Am. Jour. Sci., 4th ser., vol. 25, pp. 476, 477-478, 1908. U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 4, 1909.

[20] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 4, 1916.

[21] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona: U. S. Geol. Survey Prof. Paper 43, pp. 62-65, 1905.

9.	Pinkish crystalline dolomite; weathers gray	110
8.	Crystalline dolomite with angular fragments of red chert; weathers light gray	20
7.	Altered dolomite with red iron oxide and calcite	15
6.	Crystalline dolomite with small fossils and gastropods; weathers light gray	40
5.	Crystalline dolomite with white chert; weathers light gray	5
4.	Pinkish dolomite with poorly preserved small fossils; weathers light yellowish-brown	31
3.	Fucoidal beds with six-inch chert bed about four feet above base	6
2.	Light gray crystalline magnesian limestone; weathers yellowish-brown	4
1.	Sandy magnesian limestone in 3- to 12-inch beds; weathers light yellowish-brown; fucoidal markings and sandy layers; knotty white, red, and black chert, increasing in quantity above first five feet	31
		352

Bliss sandstone (Cambrian)

The outcrops of the El Paso dolomite are largely confined to the west flank of Boston Hill, but east of the Fierro fault zone this formation is exposed in a strip extending southwest from the Boston Hill fault to the Apex fault (see map, Plate 3). The narrow band of El Paso dolomite northwest of the Boston Hill fault rapidly expands in areal extent toward Chloride Flat. A section measured in the west outskirts of the Chloride Flat mining district showed the formation to be over 500 feet thick.

Partial analyses of specimens from some of the beds at Boston Hill and elsewhere are given in Table 3.

TABLE 3.

Partial analyses of specimens from the El Paso dolomite

	No. 1	No. 2	No. 3
Insoluble	26.63	4.21	12.09
$CaCO_3$	40.65	50.53	57.37
$MgCO_3$	26.00	41.39	30.54

No. 1—Boston Hill; Bed 1 of measured section above; L. P. Entwistle, analyst.

No. 2—Boston Hill; Bed 9 of measured section above; L. P. Entwistle, analyst.

No. 3—9 miles north of El Paso; W. T. Schaller, analyst. Quoted by Dunham, K. C., The geology of the Organ Mountains: N. Mex. Bur. Mines Bull. 11, p. 45, 1935. Analysis has been recalculated to the carbonate molecule.

MONTOYA DOLOMITE

The Montoya dolomite was first described by Richardson.[22] The formation is here divided into three members: (1) a basal sandy dolomite, the Second Value member, (2) a banded chert

[22] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 4, 1909.

and dolomite, the Par Value member, and (3) a thick-bedded cherty gray dolomite, the Raven member. The names have been taken from the mining claims on which sections of the members were measured.

South of the Boston Hill fault, outcrops of the Montoya are confined largely to two strips, one to the west and the other to the east of the Fierro fault zone (see map, Plate 3). In the northwest corner of the Boston Hill area and northwest of the Boston Hill fault the formations are compressed and only the Par Value member is recognizable. It is probable that in the east part of the area some of the rock mapped as Fusselman dolomite includes part of the Raven member, as the two units are similar lithologically. Only where a red chert bed, which has been used as the division between the Raven member and the Fusselman dolomite, is exposed can an approximate separation be made.

Second Value Member.—The basal member of the Montoya dolomite at Boston Hill consists of deep purplish-gray sandy dolomite that is easily distinguished from the dark-gray dolomite of the underlying El Paso. The sand grains are grouped in worm-like aggregations which in some places simulate filled fossil molds. In a few places the sand is thinly bedded and cross-bedded, and red or black chert fragments are visible. The sand grains are more prominent near the base. Crinoid stems and fossils of reported Galena age[23] are found, especially in the upper part of the member where the sand content diminishes. Although a bed similar to the Second Value member has been recognized in the Organ Mountains,[24] near El Paso, Texas,[25] and at other places,[26] it is locally lenticular. The maximum thickness at Boston Hill as measured on the Second Value claim (see Plate 6), the type locality, is 90 feet.

Par Value Member.—Overlying the Second Value member is a persistent unit composed of alternating bands of red chert and gray dolomite. The proportions are about one-third chert and two-thirds dolomite. This unit, here named the Par Value member of the Montoya dolomite, has been found in many other areas in the southwest part of New Mexico.[27] The base of the Par Value member, which is a very distinctive horizon, was used by Paige as the base of the Montoya dolomite for field mapping in the Silver City quadrangle. The thickness of the member is 65 feet on the Par Value claim (see Plate 6), where it is typically developed.

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[23] Idem, p. 4.
[24] Dunham, K. C., The geology of the Organ Mountains: N. Mex. Bur. Mines Bull. 11, pp. 42-43, 1935.
[25] Richardson, G. B., op. cit., p. 4.
[26] Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, pp. 11-14, 1928.
[27] Idem.

Raven Member.—The upper member of the Montoya dolomite, here named the Raven member from typical exposures on the Raven claim, is essentially a thick-bedded gray dolomite with some red chert. The base is a shell limestone with abundant fossils of Richmond age. The overlying beds are in general non-fossiliferous but in some places contain *Favosites asperi,* colonial corals which protrude in hemispherical masses from the smooth weathered surfaces of the dolomite. The top of the member at Boston Hill is not clearly defined, but fossils of Niagara age were found 15 feet above a bed of nodular chert, only a few inches thick, which is considered here to be the base of the overlying Silurian dolomite. In the Chloride Flat mining district a white chert bed about one foot thick lies in about the same stratigraphic position. The upper part of the Raven member is thick-bedded gray cherty dolomite, which is lithologically similar to the overlying Silurian dolomite. It is therefore possible that in some of the faulted areas the Raven member and the Fusselman (Silurian) dolomite are confused. The thickness measured on the Raven claim (see Plate 6) is 120 feet.

Composite Section and Partial Analyses.—A composite section of the Montoya dolomite found at Boston Hill is as follows.

	Feet	
Fusselman dolomite (Silurian)		
Montoya dolomite (Upper Ordovician)		
Raven member:		
6. Light to dark gray dolomite with a few lenses of white, gray, or red chert; corals common near middle of bed	105	
5. Light gray fossiliferous dolomite; abundant Richmond fauna	15	
		120
Par Value member:		
4. Banded red chert and gray dolomite	65	
		65
Second Value member:		
3. Gray dolomite with lenses of white to black chert; crinoid stems near top	20	
2. Slightly sandy gray dolomite; weathers brownish-gray; carries crinoid stems and small brachiopods	40	
1. Deep-gray to purplish-gray dolomite with chert and sand grains; maximum size of grains two millimeters; black chert at base	30	
		90
		275
El Paso dolomite (Lower Ordovician)		

The following table contains partial analyses from several beds at Boston Hill and other localities.

TABLE 4.

Partial analyses of specimens from the Montoya dolomite

	No. 1[a]	No. 2[a]	No. 3[a]	No. 4	No. 5
Insoluble	40.53	34.0	2.6	8.52	12.66
$CaCO_3$	41.04	34.18	53.36	54.31	55.75
$MgCO_3$	17.96	24.68	37.10	37.17	31.59

No. 1—Boston Hill; Bed 1, Second Value member, of measured section on p. 18; L. P. Entwistle, analyst.

No. 2—Boston Hill; Bed 4, Par Value member, of measured section on p. 18; A. B. Romney, analyst.

No. 3—Boston Hill; Bed 6, Raven member, of measured section on p. 18; A. B. Romney, analyst.

No. 4—8 miles south of Hueco, Texas; W. T. Schaller, analyst. Quoted by Dunham, K. C., The geology of the Organ Mountains: N. Mex. Bur. Mines Bull. 11, p. 45, 1935. Recalculated to the carbonate molecule.

No. 5—3 miles north of El Paso, Texas; W. T. Schaller, analyst. Quoted by Dunham, K. C., idem. Recalculated to the carbonate molecule.

[a] Iron and alumina present; not determined.

SILURIAN SYSTEM

FUSSELMAN DOLOMITE

The Fusselman dolomite was defined by Richardson.[28] At El Paso the formation is nearly 1,000 feet thick and has been divided into two members, of which the lower weathers light colored and the upper weathers darker. The two members have also been found in the ranges along the Rio Grande valley in New Mexico;[29] but at Boston Hill, where the Fusselman is only about 75 feet thick and is uniformly dark-gray and thick-bedded, subdivisions cannot be recognized. The weathered surfaces of the beds in many places show irregular pitting, which is probably caused from the solution, by surface waters, of pentameroid brachiopods common in the formation. At Boston Hill much of the Fusselman dolomite has been affected by mineral-bearing solutions also, and in places the fossils have been replaced by iron and manganese oxides. In these mineralized areas the beds have a spotted appearance.

The Fusselman dolomite crops out along the east part of the district (see map, Plate 3), where much of the formation makes a dip slope. A small outcrop is also found northwest of the Boston Hill fault.

[28] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 4, 1909.

[29] Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, pp. 14, 185-186, 201, 321, 1928.

Partial analyses of the Fusselman are given in Table 5.

TABLE 5.

Partial analyses of specimens from the Fusselman dolomite

	No. 1	No. 2	No. 3	No. 4
Insoluble	0.64	——	——	——
$CaCO_3$	57.25	52.00	51.68	51.13
$MgCO_3$	37.12	38.00	38.44	39.15

No. 1—Boston Hill; average of several specimens; L. P. Entwistle, analyst.

No. 2—San Andres Canyon, San Andres Mountains, N. Mex. Quoted by Darton, N. H., op. cit., p. 186.

No. 3—Franklin Mountains, Texas. Quoted by Richardson, G. B., op. cit., p. 4. Recalculated to carbonate molecule.

No. 4—Hueco Mountains, Texas. Idem.

The Fusselman dolomite is the host rock for much of the manganiferous iron ore found in the Silver Spot group of claims, as well as for the silver ores in the Chloride Flat mining district (see Plate 10, B).

DEVONIAN SYSTEM

PERCHA SHALE

Gordon[30] named the Percha shale after Percha Creek, Sierra County, New Mexico, where outcrops of dark-blue to black shale rest on the eroded surface of the Fusselman dolomite. The general softness of the Percha shale results in topographic depressions, and because several feet of mantle rock cover the area, exposures are found only in arroyos and excavations.

The basal beds of the Percha in the Silver City quadrangle are gray to black fissile shale containing small nodules of pyrite that near the surface have been oxidized to ferric oxide. No fossils have been found in these lower beds. The upper part of the formation consists of red, or red and green, shale with nodules of limestone and sandy limestone. One three-foot bed of gray fossiliferous limestone persists near the top. In the upper 70 feet of the formation excellently preserved fossils of late Devonian age can be collected. Most of the fossils found by the writer have been recognized from descriptions by Kindle.[31]

Along the east slope of Boston Hill and in some areas in the Chloride Flat mining district, isolated patches of brecciated silicified shale up to five feet thick lie on the top of the Fusselman dolomite. The breccia, which is cemented by chalcedonic quartz, is considered here to be a result of local bedding-plane movement along which mineralization took place at a later period.

The red color of the upper beds is probably due to meta-

[30] Gordon, C. H., Lower Paleozoic formations in New Mexico: Am. Jour. Sci., 4th ser., vol. 21, pp. 390-395, 1906.

[31] Kindle, E. M., The Devonian fauna of the Ouray limestone: U. S. Geol. Survey Bull. 391, 1909.

morphism. In the Chloride Flat mining district incipient metamorphism is exhibited in a railroad cut where the shale grades from red along paper-thin shear planes to greenish in the more solid rock. At Bear Mountain the red color is localized along a fault zone. Along the highway between Santa Rita and the Mimbres River, where the upper beds are well exposed in a road cut, the color is yellow brown.

The Percha shale is exposed along Highway 180 (see map, Plate 3), where only the lower part of the formation remains, the upper part having been removed by erosion. Northwest of the Boston Hill fault the shale has been strongly tilted and distorted so that no accurate measurement of thickness could be made. A section measured near the Bremen shaft (see Plate 2) in the Chloride Flat mining district is as follows.

Lake Valley limestone (Lower Mississippian)

Percha shale (Upper Devonian):	Feet
7. Red shale with limestone nodules, highly fossiliferous; in upper 25 feet *Camarotoechia endlichi* and *Schizophoria striatula* var. *australis* are common, but rarely found below. *Spirifer whitneyi* and *Productella* sp. more common in lower part	70
6. Gray massive limestone; zaphrentoid corals abundant	3
5. Red fissile shale and limy shale with reddish sandy limestone nodules; no fossils found	120
4. Gray to black carbonaceous fissile shale	140
3. Sill of diorite porphyry	28
2. Gray to black carbonaceous fissile shale	92
1. Breccia of silicified shale, not persistent	3
	456

Fusselman dolomite (Silurian)

The diorite porphyry sill included in the above section was not found at Boston Hill.

A suite of fossils similar to those found in the upper beds of the Percha shale has been collected and identified by Stoyanow[32] from the Lower Ouray formation and the Martin limestone in Arizona. The exact age of the lower black shale, called by Stevenson the Lower Percha shale,[33] is still somewhat in doubt. Some Middle Devonian strata have been found east of the Rio Grande valley near Canutillo, Texas,[34] although Stevenson[35] believes these beds to be of early late Devonian age. Stainbrook[36] states that the fauna collected in the Sacramento Mountains closely resembles that in the Independence shale (Middle Devonian) of Iowa.

[32] Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, vol. 47, pp. 485-505, 1936.

[33] Stevenson, F. V., Devonian system, *in* Bates, R. L., The oil and gas resources of New Mexico, 2nd ed.: N. Mex. Bur. Mines Bull. 18, p. 22, 1942.

[34] Nelson, L. A., Paleozoic stratigraphy of Franklin mountains, West Texas: Bull. Am. Assoc. Petrol. Geol., vol. 24, no. 1, p. 164, 1940.

[35] Stevenson, F. V., op. cit., pp. 23-24.

[36] Stainbrook, M. A., A Devonian fauna from the Sacramento Mountains near Alamogordo, New Mexico: Jour. Paleon., vol. 9, pp. 709-714, 1935.

MISSISSIPPIAN SYSTEM

LAKE VALLEY LIMESTONE

The original mapping by Paige[37] in the Silver City quadrangle included the Mississippian and Pennsylvanian formations in one group called the Fierro limestone; this term is now obsolete. The name Lake Valley was proposed by Gordon.[38] A subdivision of the Lake Valley was made by Schmitt,[39] who divided the formation into the Lower Blue limestone below and the Hanover limestone above. In more recent work the term Lake Valley has been restricted to beds of Osage age, and the lower beds, of Kinderhook age, have been called Caballero.[40] Inasmuch as the Lake Valley limestone at Boston Hill is not involved in ore deposition, it is not subdivided in this report.

The Lake Valley formation at Boston Hill and in the Chloride Flat mining district is in general a pure limestone. Lenses of oolitic limestone are found at the base in a few places. The overlying beds are pure coarsely crystalline limestone interbedded with shale. Much of this limestone has a fetid odor when freshly broken. The beds are bluish-gray on weathered surfaces. Higher in the formation the Lake Valley is a white crinoidal limestone. White, gray, and red chert lenses are common throughout.

One section measured east of the Chloride Flat mining district is 657 feet thick, but several dikes and faults are present. Probably the true thickness is more nearly half this figure. The upper 100 feet, which is a pure white crystalline limestone, may be the equivalent of the Hanover limestone as defined by Schmitt.[41]

The Lake Valley limestone is found only north of the Boston Hill fault and forms the ridge on the east side of the valley in the Chloride Flat mining district. (See Plates 2 and 3.)

No evidence of manganiferous iron ore in this formation was found near the Boston Hill fault, but the Lake Valley is the principal host rock for many of the zinc-lead deposits in the Central mining district.

PENNSYLVANIAN SYSTEM

MAGDALENA FORMATION

The name Magdalena has become a general term for all sedimentary rocks of Pennsylvanian age in New Mexico. In many of the mining districts of the State the formation has been subdivided, chiefly on a lithologic basis; and an extensive revision of the Pennsylvanian rocks in New Mexico, largely on microfossil evidence, has been made recently by Thompson.[42]

[37] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 5. 1916.
[38] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 229-231, 1910.
[39] Schmitt, Harrison, The Central mining district, New Mexico: Trans. Am. Inst. Min. Met. Eng., vol. 115, p. 188, 1935; The Pewabic mine: Bull. Geol. Soc. America, vol. 50, pp. 780-781, 1939.
[40] Laudon, L. R., and Bowsher, A. L.. Mississippian formations of Sacramento Mountains, New Mexico: Bull. Am. Assoc. Petrol. Geol., vol. 25, no. 12, pp. 2107-2160, 1941.
[41] Schmitt, Harrison, op. cit.
[42] Thompson, M. L., Pennsylvanian system in New Mexico: N. Mex. Bur. Mines Bull. 17, 1942.

As the work of subdivision has not as yet been carried into Grant County, the inclusive term Magdalena is retained in this report.

The base of the Magdalena formation at Boston Hill is marked by 20 feet of shale, which is soft and usually covered by mantle rock. The rest of the formation, about 69 feet in thickness, consists of limestone and shaly limestone. Only a part of the full thickness found in the Silver City quadrangle is present near Silver City. This part is probably equivalent to the Oswaldo formation[43] in the Santa Rita mining district, or the Parting shale and the Middle Blue limestone[44] of the Central mining district.

CRETACEOUS SYSTEM

BEARTOOTH QUARTZITE

The Beartooth quartzite, named by Paige[45] after Beartooth Canyon in the Fort Bayard Military Reservation, overlies the Magdalena formation. Near the base are several sandy quartz-pebble conglomerates that have been cemented to form coarse-grained quartzites. Near the top of the formation are layers of shale and sandy shale. The intervening section is largely vitreous quartzite. All the exposures are on the northwest side of the Boston Hill fault (see map, Plate 3); and, as much of the area is covered by mantle rock, a section cannot be measured accurately. It appears, however, that the formation is about 180 feet thick.

Paige[46] regards the Beartooth quartzite tentatively as Upper Cretaceous in age because of its lithological similarity to the Dakota sandstone. Darton,[47] however, has found near Deming, New Mexico, fossils of Comanchean age in a basal Cretaceous sandstone (Sarten sandstone), which he regards as equivalent to the Beartooth quartzite.[48] Schmitt[49] considers that the Sarten and the Beartooth may be homotaxial equivalents.

COLORADO FORMATION

The lower half of the Colorado formation, exposed north of the Boston Hill fault (see map, Plate 3), consists of gray shales and sandy shales, and the upper half of gray to reddish sandstones and shaly sandstones. A *Gryphaea*-bearing layer found in the Bayard mining area[50] was located about 300 feet above the base of the formation.

The total thickness in the area mapped is approximately 800 feet, although Paige[51] estimates the maximum thickness in

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[43] Spencer, A. C., and Paige, Sidney, Geology of the Santa Rita mining district, New Mexico: U. S. Geol. Survey Bull. 859, pp. 22-26, 1935.

[44] Schmitt, Harrison, op. cit.

[45] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), pp. 5-6, 1916.

[46] Idem.

[47] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Deming folio (no. 207), p. 6, 1917.

[48] Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, pp. 38, 342, 1928.

[49] Schmitt, Harrison, personal communication.

[50] Lasky, S. G., Geology and ore deposits of the Bayard area, Central mining district, New Mexico: U. S. Geol. Survey Bull. 870, pp. 24-25, 1936.

[51] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 6, 1916.

the Silver City quadrangle as 2,000 feet. The lower part of the formation has been correlated with the Benton shale and the upper part with the Mancos shale.[52]

QUATERNARY SYSTEM

The gravels and sands to the south and west of Boston Hill have been studied by Paige,[53] who considers them to be of Pleistocene age and equivalent to the Gila conglomerate. Along the south end of Boston Hill is an area of Quaternary breccia containing angular to subangular fragments of quartz monzonite porphyry, limestone, dolomite, and manganiferous iron ore cemented by caliche (see Plate 5, B).

To the east of Highway 180 and south of Chihuahua Hill (see map, Plate 3) is a small area of flat-lying limestone which contains a few fresh-water fossils. The limestone, up to 10 feet thick, is dirty white in color and wormy in appearance. It lies in a small shallow basin-like depression in the Percha shale. To the east is a low ridge of quartz monzonite porphyry through which has been carved a short narrow canyon that now drains the basin. The presence of fresh-water limestone in this depression suggests that the canyon may be of recent origin and that the limestone may have been formed from sediments trapped in the basin. It has also been suggested that the canyon may have been artificially dammed in prehistoric times, and the water thus trapped used for irrigation by some of the Indian tribes.[54]

IGNEOUS ROCKS

GENERAL STATEMENT

The igneous rocks at Boston Hill and Chloride Flat include rocks of pre-Cambrian and Laramide (?) ages. The pre-Cambrian is composed entirely of granitic rocks. The Laramide (?) igneous rocks include an irregular cross-cutting mass of quartz monzonite porphyry, here referred to as the Silver City intrusion, that cuts rocks as recent as the Colorado formation (Upper Cretaceous); and a number of diorite porphyry sills cut by hornblende diorite porphyry dikes. The sills and dikes intrude only pre-Cretaceous rocks.

The general structural relations of the post-Cambrian igneous rocks in the Silver City quadrangle, and petrographic studies by N. P. Peterson supplemented by those of the writer, suggest that these rocks are more closely related to rocks considered to be of Laramide age than to the Tertiary intrusions and flows of the region. It is possible, however, that a few of the dikes may be of mid-Tertiary age.

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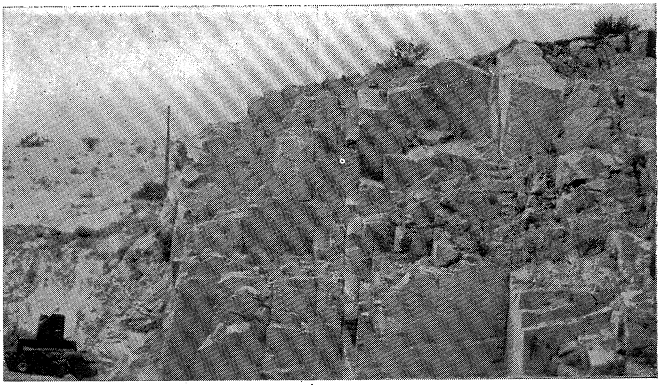
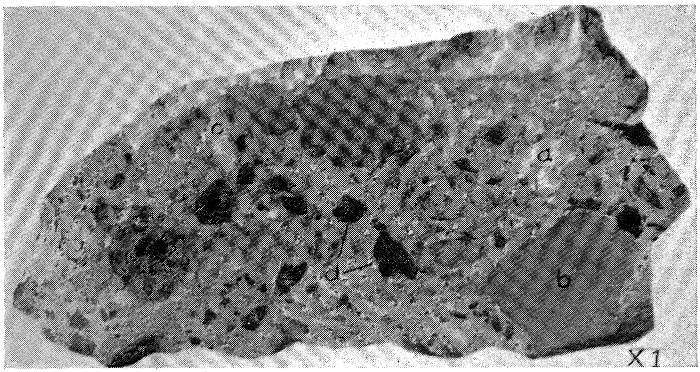
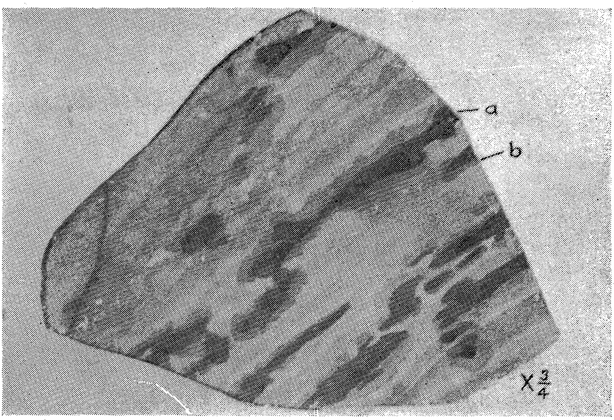
[52] Idem.
[53] Idem, pp. 6-7.
[54] Schmitt, Harrison, personal communication.



A. Exposure of Silver City intrusion (quartz monzonite porphyry) at Grant County courthouse.



B. Quaternary breccia, Iron Plume claim. a, porphyry; b, dolomite; c, shale; d, manganiferous iron ore.



C. Segregation of iron and manganese oxides in dolomite, Naid Queen claim. a, manganese oxide; b, rim of ferric oxide.

PRE-CAMBRIAN

A small area of pinkish pegmatitic granite crops out through recent gravels in the southwest corner of the Boston Hill area (see map, Plate 3). Megascopically the rock appears to comprise pink and white feldspar, quartz, and interstitial muscovite.

According to Peterson, in thin section the rock shows a typical allotriomorphic granitic texture composed of albite, $Ab_{95}An_5$, about 42 per cent of the total section; microperthite, about 25 per cent; quartz, about 31 per cent; and primary muscovite, about two per cent. The plagioclase is partly altered to sericite and is clouded by a light brown limonite stain. The albite twinning is visible in most grains. The microcline in the microperthite is fresh, but the albite intergrowths are altered to sericite. The muscovite is partly recrystallized and has considerable limonite in the altered areas. The average grain size of the rock is from one to three millimeters. Cracks in the section are filled with quartz and specularite. Only one large euhedral grain of magnetite was found in the entire section.

About two miles to the northwest are outcrops of a finer grained prophyritic yellowish-brown pre-Cambrian rock. Peterson's description of a thin section from this locality is as follows.

> This rock shows a porphyritic texture. The groundmass consists of a fine mosaic of nearly equidimensional grains of microcline and quartz averaging about 0.3 millimeter in diameter. About 60 per cent of the groundmass is microcline. There are a few clouded grains which may be albite.
>
> The phenocrysts are anhedral quartz and clusters of microcline. A little biotite occurs as corroded remnants, most commonly associated with the microcline clusters, but also as small plates in the groundmass. The biotite is usually fresh or partly altered to limonite. Magnetite grains, comparable in size to the grains of the groundmass, are scattered sparsely through the section. There are a few grains which measure up to 1.3 millimeters across. A little apatite is associated with the larger magnetite grains.

In view of the above descriptions, and the field occurrences, the rocks are best referred to as sodic granites. Some 20 miles to the east, on the west side of the Mimbres River, the pre-Cambrian rock is a pyroxenite.[55]

LARAMIDE (?) ROCKS

Intrusive rocks in and near the Boston Hill mining district cut formations as recent as Upper Cretaceous. These rocks are classified in previous reports as of Laramide (?) and mid(?)-Tertiary ages. The intrusive rocks at Boston Hill are similar petrographically to the intrusive rocks of Laramide (?) age in the Central mining district. The sills and intrusive masses, such as the Silver City intrusion, are therefore tentatively regarded as of Laramide age.

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[55] Schmitt, Harrison, personal communication.

DIORITE PORPHYRY SILLS

The earliest igneous activity of Laramide (?) age produced several thin sills of diorite porphyry in the Percha shale in the Chloride Flat mining district. A sill of quartz diorite porphyry has been found in the Percha shale in the Hanover mining district.[56] No sills are present at Boston Hill.

The sills found at Chloride Flat are not uniform in appearance along the outcrop. The color is generally gray in the relatively fresh rock, but in places where chloritization and epidotization is strong the rock is greenish; at other places iron oxides stain the rock light yellow-brown. At most exposures the texture is finely porphyritic, but there is a slight tendency toward a glassy groundmass, especially near the contacts with the shale. The rock is somewhat more resistant to erosion than the shale, and the outcrop forms a bench along the hill slope.

Under the microscope the rock shows a fine-grained groundmass set with many phenocrysts of feldspar and hornblende.[57] The phenocrysts average 0.25 millimeter in length and 0.12 millimeter in width. Orthoclase in Carlsbad twins, and plagioclase, about andesine in composition, make up about 30 per cent of the rock. Sericitization has been so strong that only the crystal outlines of most phenocrysts are preserved so that exact determinations of the feldspars are difficult. Brown hornblende phenocrysts averaging 0.25 millimeter in length and 0.08 millimeter in width constitute 25 per cent of the rock. Hornblende phenocrysts up to five millimeters in length have been seen. Strong alteration to chlorite is common, but in some thin sections epidote is the main alteration mineral. Calcite, along cleavage cracks in the hornblende, constitutes about five per cent of the rock and is associated with epidote and chlorite.

Biotite averages about six per cent of the rock but has been completely altered to chlorite. The presence of biotite as an original rock mineral is suggested by the shred-like texture of some of the chlorite.

Apatite, occurring in small needles approximately 0.08 millimeter in length, is the most important accessory mineral and makes up about two per cent of the rock. In the hornblende are inclusions of a brownish transparent mineral with a high index of refraction and high interference colors; although the grains are too small for positive identification, this mineral appears to be titanite. Pyrite cubes, averaging 0.10 millimeter on a side, constitute as high as five per cent of an individual thin section, but an average of all is about one per cent. Some iron oxide dust has been formed from the alteration of the mafic minerals.

The groundmass, which is 30 per cent of the rock, is a fine-

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[56] Spencer, A. C., and Paige, Sidney, Geology of the Santa Rita mining area, New Mexico: U. S. Geol. Survey Bull. 859, p. 18, 1935.

[57] Entwistle, L. P., The Chloride Flat mining district, New Mexico: Unpublished thesis, Univ. of Ariz. library, pp. 31-34, 1938.

grained mat of chlorite and sericite suggesting that feldspar and a ferromagnesian mineral were the original constituents.

Sills of two ages have been studied in the Central mining district.[58] The rock at Chloride Flat is similar to the younger sills, which in the Central district intrude the Colorado formation and are overlain by volcanic rocks regarded as mid-Tertiary in age.

HORNBLENDE DIORITE PORPHYRY DIKES

Dikes, which occupy pre-existing faults, are common in the Boston Hill and Chloride Flat mining districts. At Chloride Flat, where alteration is not intense, the dikes have been determined to be hornblende diorite porphyry. The most striking feature of these dikes is the large well-developed hornblende crystals, many of which attain a length of one centimeter. Hornblende and feldspar phenocrysts are set in a greenish groundmass. Phenocrysts and groundmass are spotted with pistachio-green epidote. In places where alteration is strong, the dikes have been changed to a mass of ferric oxide with kaolinized "eyes" of feldspar.

When studied in thin section[59] the rock is seen to be a porphyry composed of phenocrysts of andesine and hornblende set in a feldspathic groundmass. The total feldspar content is about 60 per cent. Alteration of the feldspar to sericite and "kaolin" is strong. Euhedral hornblende phenocrysts, about 30 per cent of the rock, have been altered to chlorite and epidote. The accessory minerals are apatite, titanite, and zircon. A carbonate constitutes about three per cent and pyrite one per cent of the rock. As much as five per cent of cryptocrystalline quartz has been introduced; it commonly occurs in narrow veinlets cutting all minerals except some of the carbonate.

At Boston Hill two types of porphyry dikes are found. One type, represented by the long dike just west of Highway 180 (see map, Plate 3), is a fine-grained porphyry characterized by strong epidotization; the grain size may be masked by alteration. The second type, common in the workings of the Silver Spot mine, consists of a soft gougy mass of white to red clayey material with kaolinized "eyes" of feldspar. Although the dikes in the Silver Spot mine have a general northerly strike, locally they wind and twist their way through dolomite and ore. The predominance of epidote, chlorite, and ferric oxide in the dikes at Boston Hill suggests that the original rock had a high content of ferromagnesian minerals, and that this rock is similar to the hornblende diorite porphyry dikes found at Chloride Flat.

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[58] Lasky, S. G., Geology and ore deposits of the Bayard area, Central mining district, New Mexico: U. S. Geol. Survey Bull. 870, pp. 26-34, 1936.
Schmitt, Harrison, The Central mining district, New Mexico: Trans. Am. Inst. Min. Met. Eng., vol. 115, pp. 189-192, 1935.
Schmitt, Harrison, The Pewabic mine: Bull. Geol. Soc. America, vol. 50, p. 783, 1939.
Spencer, A. C., and Paige, Sidney, op. cit., pp. 33-35

[59] Entwistle, L. P., op. cit., pp. 34-35.

QUARTZ MONZONITE PORPHYRY

A roughly circular mass of quartz monzonite porphyry, referred to in this report as the Silver City intrusion, has cut all the sedimentary rocks up to and including shales and sandstones of Upper Cretaceous age. The rock exposed in Silver City, especially southwest of the County courthouse (Plates 3 and 5, A), is light colored and porphyritic. Phenocrysts of feldspar, quartz, and hornblende are visible.

Peterson's report on a thin section of the quartz monzonite porphyry is as follows.

About half of the rock consists of phenocrysts of plagioclase, quartz, and hornblende. Plagioclase phenocrysts, which constitute about 31 per cent of the rock, are in nearly euhedral grains that show slightly corroded boundaries and blend into the groundmass. The composition is oligoclase, $Ab_{72}An_{28}$. Although the twinning is still visible in places, the plagioclase is largely altered to sericite and kaolinite. The quartz phenocrysts form about six per cent of the section. They are corroded, presumably by re-

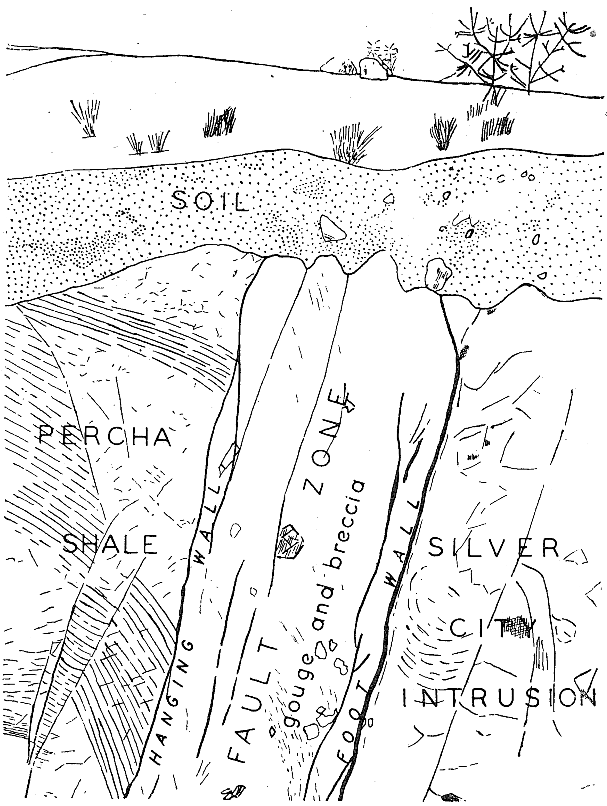

FIGURE 2.—Fault contact between Percha shale and Silver City intrusion at Silver Spot No. 2 shaft. Hanging wall has moved up. Sketch from photograph.

solution, and show rounded embayments and occur as islands in the groundmass. Euhedral hornblende accounts for five per cent of the section and is entirely altered to chlorite, carbonate, and magnetite. The magnetite forms a border of small grains along the original boundaries of the hornblende. The section contains about three per cent biotite, almost entirely altered to chlorite. Other accessory minerals are magnetite in small euhedral grains; apatite, mainly poikilitic, in altered biotite; and a few shreds of muscovite, which may be secondary.

The groundmass, which constitutes 55 per cent of the total section, is a fine-grained aggregate of quartz, plagioclase, and a very fine-grained greenish ferromagnesian mineral. The aggregate is peppered with fine grains of magnetite. The feldspar in the groundmass is largely altered to sericite.

Although no orthoclase was seen by Peterson, Paige[60] reports orthoclase to be a common constituent of the Silver City intrusion. Therefore the rock is considered to be a quartz monzonite porphyry.

The rock is similar to, and may be related to, the intrusive masses found at Lone Mountain, Hanover, and elsewhere in the Silver City quadrangle. The intrusive masses in these localities have been described as granodiorite, quartz monzonite, or quartz monzonite porphyry.

The west boundary of the Silver City intrusion is a fault contact, with the Fusselman dolomite and the Percha shale at the surface on the upthrown side. The faulted contact is well exposed in the Silver Spot No. 2 shaft (Fig. 2) and in a large pit to the southwest of the County courthouse. At the latter locality fragments of Percha shale are found in the breccia, but the wall is Fusselman dolomite. The downthrown side of the fault is to the northeast.

ALTERATION OF THE IGNEOUS ROCKS

All the igneous rocks of Laramide (?) age are slightly to strongly altered. The alteration is most intense in the sills and dikes, but mineralogic changes commonly thought to be the result of the infiltration of hydrothermal solutions are widespread. Sericitization of the feldspar minerals is moderate to strong in all the igneous rocks, including those of pre-Cambrian age. Positive identification of the plagioclase in the diorite porphyry sill has been hampered by strong sericitization. In certain of the dikes the feldspars have been completely changed to sericite, which has also been further altered to "kaolin."

The ferromagnesian minerals—hornblende and biotite, for example—have also been strongly altered. The main products of alteration are chlorite and epidote, which, in some of the dikes, have undergone further alteration to ferric oxide.

The second stage of alteration, from sericite to "kaolin" and from chlorite and epidote to ferric oxide, is believed to be due to circulating meteoric waters.

These mineralogic changes reflect changes in the rock mass.

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[60] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 8, 1916.

The hydrothermal solutions, which have altered the feldspar minerals to sericite and the ferromagnesian minerals to chlorite and epidote, introduced into the original rock mass large quantities of water and potash, and extracted silica. Smaller amounts of iron and sulfur, in the form of pyrite, were added to some of the rocks. The presence of a carbonate associated with the alteration of hornblende in the igneous rocks of Laramide (?) age suggests that the hydrothermal solutions, during some period in their development, contained some carbon dioxide. Some of the carbonate may, however, have been deposited from meteoric waters.

The hydrothermal alteration, especially the formation of epidote, supports the tentative age classification of the rocks involved as Laramide (?), as in the Central mining district it has been found that the more recent mid(?)-Tertiary rocks are "characteristically free of the metamorphic effects, particularly of the development of epidote, that everywhere characterize the earlier granodiorite dikes."[61] The younger igneous rocks in the Central district contain considerable sericite, carbonate, pyrite, and alunite.

STRUCTURE

GENERAL STATEMENT

Because the Boston Hill and Chloride Flat mining districts are small and have few exposures of pre-Cambrian rocks, no discussion of possible pre-Cambrian deformation is warranted. No deformation can be assigned solely to the Paleozoic or Mesozoic era.

Large-scale deformation during Laramide time is common to many of the mining districts in the State, as well as to many throughout the West. The Silver City quadrangle lies within a zone of deformation that, in part, extends eastward to the Rio Grande valley, thence northward into Colorado.[62] The Boston Hill and Chloride Flat mining districts, which are within the Silver City quadrangle, are located on the west limb of a synclinorium; the east limb crops out near Santa Rita. Within the two mining districts local folding is of minor importance; deformation is reflected largely in steep-dipping normal faults.

FOLDING

Folding in the Lower Paleozoic strata is restricted to several minor structural terraces. One occurs in the Fusselman dolomite along the east side of the district near the Lordsburg highway, but the change in dip amounts to only a few degrees and cannot be shown on the cross sections. A similar structural terrace has been formed in the Chloride Flat mining district.[63] East of this

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[61] Spencer, A. C., and Paige, Sidney, Geology of the Santa Rita mining area, New Mexico: U. S. Geol. Survey Bull. 859, p. 41, 1935.

[62] Butler, B. S., Relation of ore deposits of the Southern Rocky Mountains to the Colorado Plateau: Proc. Colorado Sci. Soc., vol. 12, pp. 23-36, 1929.

[63] Entwistle, L. P., The Chloride Flat mining district: Unpublished thesis, Univ. Ariz. library, p. 12, 1938.

district a monoclinal fold has been found in the Mississippian and Pennsylvanian limestones. North of Boston Hill the Colorado shale has in a few places been strongly folded. Outcrops are so scattered that the full extent of the folding cannot be determined. The sedimentary rocks have been dragged locally along some of the larger faults.

FAULTING

The faults within the mineralized area in the Boston Hill mining district can be divided into three groups: (1) those that vary in strike from about north to N. 60° E. and radiate from a nose-like protuberance of the Silver City intrusion, (2) those that strike in a northwesterly direction, and (3) those that strike nearly due west. The faults of the first group are in places cut off by faults of the second and third groups.

FAULTS STRIKING NORTH TO NORTHEAST

Boston Hill fault.—The largest normal fault is the Boston Hill fault, which outlines roughly the north boundary of the mining area at Boston Hill (see map, Plate 3). The fault dips vertically, or steeply to the north; it has an apparent horizontal displacement of about 6,000 feet. The throw near the northeast end of the fault is over 1,000 feet; but as the throw decreases rapidly toward the southwest, the fault must be hinged in that direction. Some of the loss in throw is caused by "horse-tailing," or splitting of the main fault into diverging branches.

The Boston Hill fault cannot be traced directly into the Silver City intrusion because much of the critical area is covered by mantle rock. The peculiar shape of the intrusion in this area and the localization of strong shear in the intrusion along the possible extension of the Boston Hill fault suggest that some of the movement was post-intrusive in age.

The line of the Boston Hill fault has been prospected by many shafts and shallow pits, and ore bodies have been found at places of extreme brecciation. It appears that the Boston Hill fault was one of the main channels for the hypogene mineral-bearing solutions.

Fierro fault zone.—The Fierro fault zone comprises a number of faults that branch off the Boston Hill fault on the Silver Pick and Pennsylvania No. 2 mining claims. The Fierro fault zone strikes southwesterly, and the dips range from 70° NW. to 70° SE. Near the junction of the Boston Hill and Fierro fault zones numerous breaks strike in many directions to produce an area of jumbled sedimentary rocks, all of which have been highly altered and have formed an important ore body. Many of the several strands of the fault zone contain as much as two feet of white gougy material that can be seen where the fault is exposed in mine workings.

The Fierro fault zone is still being prospected, and several important ore bodies have been found. Manganese and iron oxides are found in the El Paso and Montoya dolomites that form the walls of the fault zone or are contained as large broken blocks within it.

Silver Spot fault.—The Silver Spot fault parallels the predominant north-trending structures along the eastern boundary of the Boston Hill district near the contact of the sedimentary rocks with the Silver City intrusion (see map, Plate 3). The strike is about N. 20° E., and the dip ranges from vertical to 70° E. The formations have been dropped about 80 feet on the east side of the fault (see Plate 4). The Silver Spot shaft was sunk near this fault, and some manganiferous iron ore was mined to the east. The location of the quartz-sulfide mineralization cannot be determined as the workings are now flooded. The Silver Spot fault strikes toward the large ore bodies that have been mined from the Silver Spot incline. The fault was not seen underground as the workings appear to be east of its probable continuation.

Adonis fault.—The Adonis fault lies about 600 feet west of the Silver Spot fault. The average strike is N. 4° W. and the dip 78° W. Throughout its entire length the fault is filled with more or less vuggy quartz stained by limonite. That the limonite is probably derived from the oxidation of pyrite is shown by numerous visible cubic casts. None of the many workings along the Adonis fault appears to have reached the sulfide zone, as no sulfide minerals were found on any of the dumps. At the surface, both walls of the Adonis fault are Fusselman dolomite.

FAULTS STRIKING NORTHWEST

The geologic map accompanying Paige's report on the Silver City quadrangle shows faults that cut the post-ore (Tertiary) formations and strike northwest. It cannot be proved at this time that the northwest-striking faults in the Boston Hill mining district are related to mid(?)-Tertiary stresses, but there is a strong suggestion that these faults are younger than those that radiate from the Silver City intrusion. It is known, however, that large post-ore faults in the Central mining district and particularly at the Ground Hog mine[64] strike northeast. Most of these faults are associated with wide pre-mineral northeast-striking fault zones and apparently represent re-opening along pre-existent zones of weakness.

Apex fault.—The Apex fault forms roughly the southwest boundary of the Boston Hill mining district (see map, Plate 3). It strikes northwesterly, and the dip ranges from 62° SW. to 77° NE. so that in places the fault has an apparent reverse movement. The Apex fault has been traced from the south end of

[64] Lasky, S. G., Geology and ore deposits of the Bayard area, Central mining district, New Mexico: U. S. Geol. Survey Bull. 870, pp. 49-54, 111-116, 1936.

the Boston Hill area into the country west of the Chloride Flat mining district, a distance of about two miles. Throughout the length of the fault the walls are characterized by silicification and copper mineralization. In the Boston Hill area the usual grainy character of the Bliss sandstone is in many places masked by silicification; thus the rock appears more like a vitreous quartzite. On the Fierro No. 1 mining claim a shaft has been sunk on some weak copper mineralization along the Apex fault. Parallel to the Apex fault near this shaft are several veins of manganiferous calcite. West of the Fierro No. 3 mining claim an adit explores the fault for a short distance. There it has about 10 feet of soft red clayey gouge containing rolled fragments of limestone. No manganese or iron oxide minerals were seen. West of the Chloride Flat mining district the dolomite walls are silicified for as much as 50 feet on either side of the fault.

In the Boston Hill area the Boston Hill, Fierro, and other northeast-trending faults terminate abruptly at the Apex fault. Although the Apex fault is probably younger than the north- to northeast-striking faults, it cannot with certainty be included in the mid(?)-Tertiary period of faulting. The silicification and copper mineralization of the type found associated with the Apex fault is not known to occur with mid(?)-Tertiary faults.

POST-LARAMIDE FAULTING

Contraband fault.—The Contraband fault, located in the southwest corner of the Boston Hill area, strikes N. 70° W. and dips 53-70° SSW. (see map, Plate 3). For about 1,000 feet the trace of this fault divides Lower Paleozoic formations from Quaternary gravels and sands. The fault is also exposed in a few prospect holes. Continuity of the fault into the Quaternary deposits to the west, where an apparent fault scarp has been formed in the semi-consolidated formations, is suggested.

The Contraband fault can be considered to be of post-Laramide age and is probably related to northwest- to west-trending faults commonly found in mid(?)-Tertiary rocks of the Silver City quadrangle.

ORE DEPOSITS

HISTORY AND PRODUCTION

Much of the early growth of Silver City was influenced by the discovery and mining of "bonanza" silver ores at Chloride Flat.[1] The discovery was made by John Bullard and others in the spring of 1870. Although the United States demonetized silver in 1873, mining in this district enjoyed prosperity until 1893, when the price of silver dropped to 62 cents per ounce.

During the 23 years, 1870-1893, much of the silver was smelted locally in crude adobe furnaces, and much silver bullion was marketed. Some silver was concentrated by the "patio process" and some by amalgamation in rotating barrels. At first the ore was crushed in arrastras, but soon several stamp mills were operating. At Bremen's mill the crushed ore was mixed with salt and then roasted to produce silver chloride. At other mills silver chloride was dissolved in brine and the metal precipitated with metallic copper.

On May 12, 1883, the Silver City, Deming, and Pacific railroad was completed to Silver City; thus transportation of heavy machinery was simplified, and by the next year a smelter was in operation. Although the original intention to build a railroad from Silver City to Mogollon was never realized, a narrow gauge line, called the Silver City, Pinos Altos, and Mogollon railroad, connected the smelter with Pinos Altos via Boston Hill and Chloride Flat. The rails were finally torn up in 1913.

Presumably after the completion of the Silver City, Deming, and Pacific railroad (now part of the Santa Fe system), argentiferous manganese ore was shipped by Wm. Newcomb from Boston Hill[2] as flux to the Silver City, El Paso, and Socorro smelters. By 1904 two smelters were operating in Silver City, and the demand for limy ores to be used as flux in the smelting of copper and lead was great. Even with the low price of silver the mines at Chloride Flat could operate profitably because of the low treatment charges. While the mining of relatively low-grade silver ores was being energetically pushed, Manuel Taylor made two strikes of high-grade ore on the Grand Center claim at Chloride Flat. The first strike was in 1902 and the second in 1906.[3] Although this good fortune encouraged more prospect-

[1] Historical data were collected chiefly from the following sources:

Raymond, R. W., Statistics on mines and mining in the States and Territories west of the Rocky Mountains for 1871, 1873, 1874, and 1876: U. S. Treasury Dept.

Mineral resources of the United States: U. S. Geol. Survey, 1908-24; U. S. Bur. Mines, 1925-31.

Minerals yearbook: U. S. Bur. Mines, 1932-41.

Engineering and Mining Journal.

Mining and Scientific Press.

Jones, F. A., New Mexico mines and minerals, Santa Fe, 1904.

Inventory of the county archives of New Mexico, No. 9, Grant County, (Silver City), New Mexico Historical Records Survey, Division of Community Service Programs, Works Projects Administration, Albuquerque, N. Mex., Dec. 1941.

[2] Wells. E. H., Manganese in New Mexico: N. Mex. Min. Res. Survey Bull. 2, p. 45, 1918.

[3] Bell, Jas. H., personal communication.

ing, no further high-grade deposits were found and the Silver City smelters were finally closed in October, 1907. The mining of silver ore continued at a reduced rate until 1914.

The mining of manganiferous iron ore for use in the steel industry was commenced in 1916 when R. I. Kirchman and associates started work on the Legal Tender and Silver Spot groups. Numerous surface pits were worked all over the Boston Hill mining district, and small tonnages of ore were removed at Chloride Flat. Except during 1921 mines were operated continuously until 1931; 409,145 long tons of manganiferous iron ore was shipped. The Colorado Fuel and Iron Company operated the Silver Spot group under lease, and churn drilled part of the area during 1926 and 1927.

Some silver ore was mined at Chloride Flat from 1921 to 1923. The high lime content and the artificial price of silver set by the Pittman Act allowed mining of 10-ounce ore. During this period the Bohemian Mining Company, operating the Grand Center and Mary Belle claims, shipped approximately $75,000 worth of silver ore. A shipment of lead ore assaying 12 ounces of silver per ton and 16 per cent lead was also made.[4] When government purchases of silver stopped on June 2, 1923, mining ceased.

Until 1934 Boston Hill and Chloride Flat were idle, but after the subsidy of the silver mining industry by the Silver Purchase Proclamation (effective April 24, 1935), interest in the Chloride Flat mining district was renewed. Although in 1935 the Cardinal Gold Mining Company made a geologic examination at Chloride Flat, no ore was mined. In 1937 the H. J. Byron interests of New York started exploration work on the "76" mine, and a few small shipments were made. Work in the area was discontinued when the artificial price was reduced on December 31, 1937. Estimated production of silver ore from Chloride Flat is shown in Table 6.

TABLE 6.

Estimated Production of Silver Ore from Chloride Flat

Period	Short Tons	Estimated Value
1870-1905	100,000	$3,000,000
1905-1914	30,000	200,000
1921-1923	18,000	85,000
1934-1937	1,000	8,000
	149,000	$3,293,000

During 1937 manganiferous iron ores were again shipped to the Pueblo, Colorado, smelter of the Colorado Fuel and Iron Company by the Luck Mining and Construction Company, who

[4] Idem.

leased the Boston Hill group. Nearly all ore mined since 1937 has come from the North and Comanche pits in the Boston Hill group; a small tonnage was mined by the same company at Chloride Flat. Stimulated by wartime demands, production of manganiferous iron ore from Boston Hill reached a new peak in 1943 when about 86,000 long tons was mined. Production of manganiferous iron ore at Boston Hill is given in Table 7.

TABLE 7.

Production of Manganiferous Iron Ore from Boston Hill

Year[a]	Long tons	Grade	
		For flux at copper and lead smelters	
		Mn (per cent)	Fe (per cent)
Before 1904	80,000[b]		
1907	7,000	6	46
1916	16,574	10-35[c]	
1917	15,590	10-35[c]	
1918	32,832	10-35[c]	
1919	12,198	10-35[c]	
1920	19,259	10-35[c]	
1922	28,623	10-35[c]	
1923	6,759	10-35[c]	
1924	23,246	15	
1925	40,848	13	
1926	81,440	10-35[c]	
1927	30,710	10-15	30-38
1928	19,081	10-25	
1929	67,558	8	27
1930	14,427	9.75	26.4
1937	17,861	12	40
1938	5,113	12.7	41.2
1939	31,379	13	38
1940	36,835	13.2	
1941	55,000[b]	13[d]	37[d]
1942	65,000[b]	13[d]	37[d]
1943	86,000[b]	13[d]	37[d]
	793,333		

[a] No production 1908-1915, 1921, 1931-1936.
[b] Estimated tonnage.
[c] Actual grade not reported.
[d] Estimated grade.

MINERALOGY

GENERAL STATEMENT

In order to present clearly and completely the sequence of mineralization, the silver deposits in the Chloride Flat mining district must be considered in conjunction with the manganiferous iron ores at Boston Hill. In the Chloride Flat mining district supergene silver ores of the "bonanza" type accounted for the bulk of the production, although a small tonnage of manganiferous iron ore was mined. At Boston Hill the tonnage and value have been predominantly from the manganiferous iron ores, but some manganiferous silver fluxing ores were mined before 1900.

Probably more hypogene minerals (those formed by ascending solutions) exist at greater depth in both districts than have been found to date; but as the economic importance of the districts is owing to supergene minerals (those formed by descending solutions), most of the mining and exploration have been carried on in the oxidized zone. Some of the hypogene minerals that are resistant to oxidation were found in place near the surface, and others were collected from the dump of the now flooded Silver Spot workings. The minerals from Boston Hill were studied in polished section by N. P. Peterson at the New Mexico Bureau of Mines and Mineral Resources, and those from Chloride Flat were analyzed by the writer at the University of Arizona.

IRON MINERALS

HYPOGENE MINERALS

Hematite (Fe_2O_3).—The micaceous variety of hematite, known as specularite, occurs throughout the Boston Hill district but appears to be more abundant in the eastern and southeastern parts. At many places in the workings off the Silver Spot incline, important amounts of specularite are associated with the red earthy variety of hematite. Specularite is in many specimens associated with magnetite and is considered to be of hypogene origin.

Magnetite ($FeO.Fe_2O_3$).—The magnetic iron oxide, magnetite, occurs in small quantities in all the ores at Boston Hill; but the main concentrations seem to be in the eastern and southeastern parts of the district. Much magnetite can be found on the dump at the Silver Spot shaft, where specimens were seen showing this mineral cut by veinlets of pyrite. Magnetite sand and pebbles are scattered over the surface at Boston Hill.

Pyrite (FeS_2).—Dark brass-yellow cubes of pyrite have been found in the Percha shale in the Chloride Flat mining district and in specimens from the Silver Spot mine at Boston Hill. In the latter locality the mineral shows mutual-boundary relations with quartz, sphalerite, and galena. Cubic and pyritohedral pyrite occur with mesitite, but the relations between the two crystal forms are obscure.

Mesitite ($(Fe,Mg)CO_3$).—The mesitite at Boston Hill is manganiferous. It occurs in small brown and grayish-brown hexagonal-rhombohedral crystals that readily stain brown to purplish black on exposure to air. Although a carbonate, the mineral does not effervesce in contact with dilute hydrochloric acid. Mesitite is the primary mineral of the manganiferous iron-ore deposits. The Silver Spot workings are the only ones that have to date penetrated deep enough to find it. The specimens collected are not entirely free from oxidation; according to Miss Jewell J. Glass[5] of the U. S. Geological Survey,

> The blackish color is unevenly distributed and under the microscope appears to be an opaque [oxidation] staining that is often present in manganese minerals.

Miss Glass gives the Omega index as 1.789, which corresponds to that of mesitite; but as she points out, the index cannot be depended on for exact identification of the carbonates. An analysis made by the writer does, however, agree closely with the mineral mesitite. The following is recalculated after silica, sulfur and iron as pyrite, and water have been omitted:

FeO	17.05 per cent
CaO	1.72 per cent
MgO	30.09 per cent
MnO	4.01 per cent
CO_2	47.08 per cent
Total	99.95 per cent

The above analysis indicates the molecular distribution to be 27.5 per cent siderite, 6.5 per cent rhodochrosite, 63 per cent magnesite, and 3 per cent calcite.

SUPERGENE MINERALS

Goethite ($Fe_2O_3.H_2O$).—Hard, brilliant crystals of dark-brown goethite (?) have been found throughout both mining districts. The crystals, which attain a length of one-half inch, are prismatic and vertically striated. X-ray diffraction studies seem to be necessary for positive identification of goethite.

Hematite (Fe_2O_3).—The iron in the manganiferous iron ore is largely in the form of red earthy hematite, and the pulverulent character of the mineral causes the dry workings to be coated with brownish-red dust. Where mineralization has been only moderate, the host rock (dolomite) is permeated with red iron oxide; but the rock retains much of its original hardness.

Limonite.—Limonite is a general term used to include earthy hydrous iron oxides of uncertain mineral composition. Limonite gossans cap many of the quartz-filled veins along the eastern part of the Boston Hill area. The large number of cubic casts after pyrite, now partly to completely filled by limonite, makes many of the gossans appear to have had about equal amounts of quartz and pyrite. In places leaching has been complete so that a nearly white sponge-like mass of quartz remains. Yellow-brown limonite at the Second Value shaft forms a jacket around veins of pyrolusite. Pseudomorphs of limonite after pyrite are common in certain areas of the Chloride Flat mining district.

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[5] Written communication to N. P. Peterson.

MANGANESE MINERALS

HYPOGENE MINERALS

The source of the supergene manganese oxides is the manganese-bearing carbonate, mesitite, which is described on pages 37-38 under hypogene iron minerals.

SUPERGENE MINERALS

Pyrolusite (MnO_2).—Pyrolusite[6] is the principal manganese ore mineral found at Boston Hill and Chloride Flat. It occurs in radiating fibrous groups of soft black crystals. The best specimens are generally found as narrow veins enclosed by yellow-brown limonite (see Plate 5, C), but the mineral in places occurs in crystal groups surrounded by red hematite. Because much of the mined ore is an intimate mixture of iron and manganese oxides, a sharp separation of the two is difficult.

Manganite ($Mn_2O_3.2H_2O$).—Long black prismatic crystals with vertical striations occur in small bundles at the Iron Spike shaft. The mineral is harder than pyrolusite and gives tests for manganese and water. This mineral may be manganite, but, owing to the variability of physical properties of oxidized manganese minerals, it cannot be surely identified without X-ray and optical studies.[7]

NATIVE GOLD

Gold has been reported in assays of samples from several churn-drill holes on the Silver Spot group, but no specimens containing the metal have been seen by the writer. Minor local concentrations may be due to the oxidation of gold-bearing pyrite. Considering the presence of haloid and manganese minerals in the area, solution and re-deposition of gold is theoretically possible.

SILVER MINERALS

HYPOGENE MINERALS

Argentiferous sulfide minerals, especially galena, are common to many ore deposits in New Mexico, and at Chloride Flat much of the supergene silver ore may have been derived from the oxidation of argentiferous galena. A shipment of lead ore from the Grand Center claim in the Chloride Flat mining district ran 16 per cent lead and 12 ounces of silver per ton; part of the silver probably was in the form of supergene minerals. Galena collected at Chloride Flat assayed 54.96 ounces of silver per ton. A specimen of a one-inch vein from the Silver Spot mine contained 4.54 ounces of silver per ton, 8.45 per cent lead, 0.12 per cent copper, and 23.4 per cent zinc. No silver minerals were visible under the microscope.

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[6] Pyrolusite has been confirmed by X-ray and optical studies by Fleischer, Michael, and Richmond, W. E., The manganese oxide minerals: a preliminary report: Econ. Geol., vol. 38, p. 285, 1943.

[7] Fleischer, Michael and Richmond, W. E., The manganese oxide minerals: a preliminary report: Econ. Geol., vol. 38, pp. 269-286, 1943.

Pearceite ($8Ag_2S.As_2S_3$).—Pearceite is found in narrow veinlets parallel to and cutting the laminations of the gray Percha shale at the "76" mine in the Chloride Flat mining district. Microchemical tests for silver, arsenic, sulfur, and copper were obtained; copper seems to be a common impurity in pearceite.[8] The mineral is only tentatively considered to be of hypogene origin.

SUPERGENE MINERALS

Argentite (Ag_2S).—Argentite occurs sparingly as an alteration product of pearceite. Spongy masses are in some places surrounded by malachite and embolite.

Cerargyrite and embolite ($AgCl$ *and* $Ag(Cl,Br)$).—Cerargyrite and embolite occur in vugs in dolomite and in laminations in shale. Although embolite is more abundant than cerargyrite in specimens from the Bell collection,[9] it is not known whether embolite was more abundant in the deposits as a whole. The embolite is ordinarily in rounded and distorted crystals, commonly cubes, rarely octahedrons. The largest crystals seen were about three millimeters in diameter. The color ranges from yellowish green to gray olive-green, and the luster is waxy. Although the specimens were collected by Mr. Bell over 20 years ago, they still retain the antiseptic "drug-store" odor so aptly described by Burgess.[10]

A property of embolite is its failure to discolor when exposed to light. Chemically prepared silver salts of chlorine, bromine, and iodine discolor rapidly on exposure to sunlight; this property is used in the preparation of photographic film and plates. Luppo-Cramer[11] found, however, that lead nitrate made a silver nitrate solution more stable to light. The work suggests that impurities in embolite may cause it to be unaffected by light.

Silver (Ag).—Native silver is common in the laminations of carbonaceous shale. Plates as large as a silver dollar were found in the workings of the "76" mine at Chloride Flat. Minor quantities of the native metal were also found with argentite and malachite.

COPPER MINERALS

HYPOGENE MINERALS

Chalcopyrite ($CuFeS_2$).—Chalcopyrite was seen in polished sections of specimens from only the Silver Spot mine, where the mineral is associated with sphalerite. The chalcopyrite is in tiny specks more or less aligned with the cleavage directions of sphalerite.

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[8] Van Horn, F. R., A discussion of the formulas of pearceite and polybasite: Am. Jour. Sci., 4th ser., vol. 32, p. 40, 1911.

[9] A collection of beautiful specimens of silver ore from the Chlroide Flat mining district made by Jas. H. Bell, Hanover, New Mexico.

[10] Burgess, J. A., The halogen salts of silver at Wonder, Nevada: Econ. Geol., vol. 12, p. 593, 1917.

[11] Luppo-Cramer, Observations on silver haloid gels: Z. Chem. Ind. Kolloide, vol. 5, pp. 103-104, abstracted by H. Isham, Chem. Abstracts Am. Chem. Soc., vol. 4, pp. 270-271, 1910.

SUPERGENE MINERALS

Chrysocolla ($CuO.SiO_2.2H_2O$).—Chrysocolla was found near the Fierro No. 1 shaft, where it is associated with pyrolusite and hematite as small masses and stringers. The mineral has the common green color and amorphous character.

Covellite (CuS).—Covellite was found in microscopic quantities associated with supergene argentite and hypogene (?) pearceite in ore specimens from the "76" mine at Chloride Flat. The covellite was probably derived from the copper impurity in pearceite. A specimen from the Grand Center mine at Chloride Flat showed a small amount of covellite with anglesite, cerussite, and galena. The hypogene source of the copper here is not known.

Malachite ($CuCO_3.Cu(OH)_2$).—Green malachite occurs in many places in the Chloride Flat mining district but only in very small amounts. Traces of green copper stain at several places in the Boston Hill mining district may be malachite.

LEAD MINERALS

HYPOGENE MINERALS

Galena (PbS).—Galena is the only hypogene lead mineral found at Boston Hill and Chloride Flat. All of the mineral tested was argentiferous (see p. 39). Specimens from the Silver Spot mine show the mineral to be finely disseminated, occurring with sphalerite, pyrite, chalcopyrite, and quartz as veins in dolomite. At Chloride Flat the mineral occurs in coarse-grained aggregates and is associated with barite.

SUPERGENE MINERALS

Anglesite and cerussite ($PbSO_4$ *and* $PbCO_3$).—These minerals occur as oxidation products of galena in the Chloride Flat mining district. Some anglesite is found in layers with adamantine luster, covering kernels of galena; and in places cerussite coats anglesite in concentric bands or in finely crystalline masses.

Beaverite ($CuO.PbO.Fe_2O_3.2SO_3.4H_2O.$)—A canary-yellow mineral found in the Chloride Flat mining district resembles plumbojarosite in physical characteristics but in chemical tests reacts for copper, lead, iron, sulfate radical, and water. The mineral may be beaverite.

Plumbojarosite ($PbO.2Fe_2O_3.4SO_4.6H_2O$).—Plumbojarosite has been identified under the microscope and by micro-chemical tests in specimens from Chloride Flat. The platy character of the mineral is not visible in a hand specimen. The plumbojarosite has a brownish-yellow color somewhat darker than that of the exceptional specimens found at Tombstone, Arizona. Jarosite, hydrous potassium-iron basic sulfate, and natrojarosite, hydrous sodium-iron basic sulfate, may also occur.

ZINC MINERALS

HYPOGENE MINERALS

Sphalerite (ZnS).—Sphalerite, or zinc blende, was found only in specimens collected from the dump of the Silver Spot shaft. The mineral, although in small specks, can be seen to be the light brown variety which presumably has a low iron content. Studies of polished sections by Peterson[12] lead him to believe that sphalerite, galena, pyrite, and quartz were deposited contemporaneously because these minerals show mutual-boundary relations.

Although many of the supergene minerals found at Chloride Flat react micro-chemically for zinc, no sphalerite was found. It seems reasonable to assume, however, that sphalerite was one of the hypogene minerals deposited there.

SUPERGENE MINERALS

Goslarite ($ZnSO_4.7H_2O$).—An efflorescence of delicate white needles of goslarite was found in some of the mine workings at Chloride Flat.

Zincocalcite and monheimite ($(Ca,Zn)CO_3$ *and* $(Fe,Zn)CO_3$). —Some "calcite" from Chloride Flat give micro-chemical tests for zinc. The mineral is considered to be zincocalcite. Red-brown crystals collected in the same area gave strong tests for iron and zinc; this variety may be monheimite. No smithsonite was found.

GANGUE MINERALS

HYPOGENE MINERALS

Barite ($BaSO_4$).—Barite occurs in coarse white blades, which in places are one centimeter wide and 10 to 12 centimeters long. Some of the barite is stained yellowish green by supergene copper minerals. Although the mineral is found in both districts, it is more abundant at Chloride Flat, where it was used as a guide to the supergene silver ores.

Calcite ($CaCO_3$).—Two varieties of hypogene calcite were found. Along the southwest slope of Boston Hill and more or less parallel to the Apex fault, several narrow veins of coarsely crystalline black to chocolate-brown calcite crop out. Notwithstanding its dark color, the mineral is nearly pure; an analysis shows 0.39 per cent manganese oxide, 1.73 per cent ferrous oxide, and no magnesia. The other type of calcite is white and occurs as veins occupying the same faults as narrow dikes. The veins are found on and north of the Fierro No. 4 mining claim (see maps, Plate 2 and 6).

Dolomite ($CaCO_3.MgCO_3$).—A specimen of dolomitic limestone showing a vein of opaque white mineral dolomite in rhombohedral crystals with curved faces was found at the

[12] Personal communication.

Silver Spot mine. The relation of the dolomite to the other vein minerals is obscure.

Quartz (SiO_2).—Vein quartz is common in the eastern part of Boston Hill, where the mineral varies from the white massive variety to coxcomb crystal groups. Polished sections from the Silver Spot mine show quartz of two ages, one in euhedral crystals that lie within, or are replaced by, a later generation. Hand specimens from the same mine show most of the veinlets of quartz and sulfides to be enclosed in a jacket composed of minute crystals of white, milky quartz. Vugs lined with quartz crystals, stained various shades of red and brown by iron oxides, occur in some of the veins.

Under the microscope a narrow vein of quartz and specularite was found in pre-Cambrian granite.

SUPERGENE MINERALS

Actinolite ($CaO.3(Mg,Fe)O.4SiO_2$).—A variety of actinolite called "mountain leather" because of its leathery appearance, was found in a water-course near the bottom of the McEwen incline in the Bremen mine in the Chloride Flat mining district. The supergene origin of the mineral is in doubt.

Calcite ($CaCO_3$).—Supergene calcite is common throughout both mining districts. The mineral fills irregular cracks in the sedimentary rocks and ore minerals. In the workings off the Silver Spot incline much calcite occurs in post-oxidation cracks parallel to the dolomite bedding. Groups of white to pink crystals fill vugs in manganiferous iron ore; the pink coloration is due to the small included particles of hematite.

Quartz (SiO_2).—Crystals of supergene quartz were found coating masses of "mountain leather" collected at Chloride Flat. Stout short hexagonal quartz crystals line vugs in the oxidized ore in the Silver Spot group where many of the quartz crystals are covered by a layer of crystalline calcite.

HYPOGENE MINERALIZATION

SEQUENCE OF DEPOSITION

At least five stages of hypogene mineralization can be recognized within the Boston Hill and Chloride Flat mining districts. (See Fig. 3.) The relations of the several stages are in places obscure; as only the enriched ores have been of economic importance, there has been little incentive to explore the zone containing hypogene minerals alone.

The first period of mineralization appears to have involved specularite and magnetite. Although in many ore deposits these minerals are associated with silicates in a limestone or dolomite

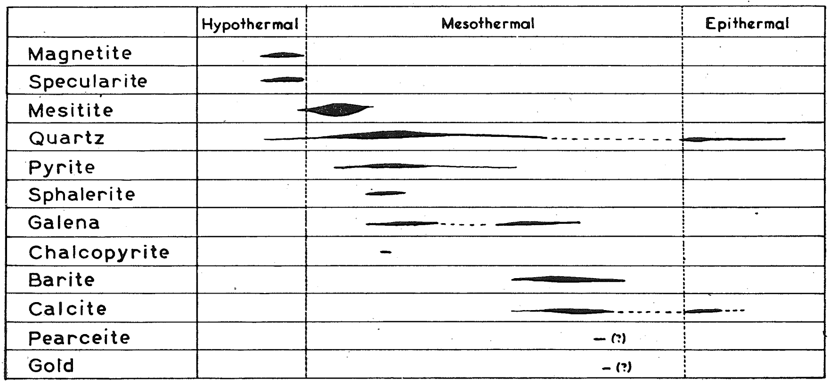

FIGURE 3.—Paragenesis of hypogene minerals.

host rock,[13] at Boston Hill and Chloride Flat silicate minerals have not been found. The lack of silicates may be accounted for by one of four possibilities: first, the deposition of specularite and magnetite took place at about the lowest temperature possible for their formation; second, the deposition of these minerals occurred before silica was available from the hydrothermal alteration of the igneous rocks; third, silica was available only when the temperature was too low for the formation of silicate minerals. The fourth possibility, suggested by Wells,[14] is that the lack of characteristic contact-metamorphic features in certain magnetite-specularite deposits in limestone is due to a sudden release of pressure, liberating ferric chloride and steam from the intrusive mass and depositing iron oxides without appreciably heating the country rock.

The belief that the specularite and magnetite are the earliest minerals is based on the fact that they cut no other minerals. Furthermore, these ferric oxides are commonly associated with the earliest periods of hypogene mineralization.

The second stage of mineralization appears to have involved the deposition of mesitite, the parent mineral of the supergene manganiferous iron-ore deposits; but the relations of this mineral to specularite and magnetite are obscure. Mestite and the ferric oxides are, however, clearly earlier than the quartz-sulfide stage. A change in the kind of iron-bearing mineral deposited has taken place in many ore deposits. Commonly the earliest solutions are oxidizing and they deposit minerals containing iron in the higher valence, but as the temperature and pressure decrease the solutions become charged with carbon dioxide or sulfur dioxide, take on a reducing character, and produce

[13] Butler, B. S., A suggested explanation of the high ferric oxide content of limestone contact zones: Econ. Geol., vol. 18, pp. 398-404, 1923.
[14] Wells, F. G., The origin of the iron ore deposits in the Bull Valley and Iron Springs districts, Utah: Econ. Geol., vol. 33, pp. 477-507, 1938.

ferrous iron-bearing minerals. The order is common, although the intensity of the several stages varies widely. At Leadville, Colorado, for example, the deposition of specularite, magnetite, and silicates was followed by that of manganosiderite.[15] A similar order has occurred at Magdalena, New Mexico.[16]

The deposition of mesitite was extensive, as shown now by the widespread distribution of manganese and iron oxides in the Lower Paleozoic sedimentary rocks at Boston Hill and Chloride Flat. Deposition was, however, concentrated near the Silver City intrusion or along channel-ways leading from it. At Chloride Flat, at a considerable distance from the probable source, only a few bodies have been found that are large enough to mine. The formation of mesitite probably took place under reducing conditions, as previously suggested, as the metals replace lime in certain of the dolomite beds.[17] Clarke[18] states that experimental data show that only ferrous chloride will produce ferrous carbonate in a limestone environment, but that ferric chloride produces ferric hydroxide under the same conditions.

The third period of mineralization involved quartz and sulfides, which are plainly later than magnetite and mesitite. By inference quartz and sulfides are also later than specularite. Some pyrite is found in narrow seams cutting magnetite and mesitite, and in a few places small vugs lined with pyrite crystals are found in mesitite. In one small prospect near the Silver Spot shaft a gossan, probably derived from sulfide minerals, cuts through manganiferous iron ore; and quartz veins, such as the Adonis (see map, Plate 2), cut through manganiferous iron-ore bodies. At the outcrop the quartz veins are iron-stained and show numerous pyrite casts, which in some places are filled with pulverulent limonite. In other places the iron is completely leached, leaving a white cellular mass of quartz.

Quartz-sulfide veins were found in the now flooded workings off the Silver Spot shaft. Specimens collected on the dump show the narrow seams to vary in mineral content; those less than one-half inch in width contain chiefly white milky quartz, rarely pyrite. The quartz appears to have filled open fissures; along the edges of the veins it is massive and milky, but toward the centers it is in the form of minute crystals lining vugs. The wider veins, which rarely exceed two inches in width, have white quartz along the edges in tiny interlocked crystals. Only in a few

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[15] Loughlin, G. F., and Behre, C. H., Jr., Zoning of the ore deposits in and adjoining the Leadville district, Colorado: Econ. Geol., vol. 29, p. 223, 1934.
Emmons, S. F., Irving, J. D., and Loughlin, G. F., Geology and ore deposits of the Leadville mining district, Colorado: U. S. Geol. Survey Prof. Paper 148, pp. 209-219, 1927.

[16] Loughlin, G. F., and Koschmann, A. H., Geology and ore deposits of the Magdalena mining district, New Mexico: U. S. Geol. Survey Prof. Paper 200, pp. 111-113, 1942.

[17] The hypogene carbonate has been found, to date, only where the host rock is dolomite. Certain of the beds in the Lower Paleozoic formations approach limestone in composition. In these beds, if the available lime were in excess of the incoming manganese and iron, ankerite would form. If replacement were complete manganosiderite would then be the hypogene carbonate.

[18] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, pp. 581-582, 1924.

places are sulfides, mostly pyrite, associated with this quartz. In the central portion of the wider veins, quartz, pyrite, sphalerite, and galena are visible to the unaided eye.

Studies by Peterson of sections of specimens from the central portions of several veins led him to conclude that part of the quartz and all the sphalerite, galena, and pyrite were contemporaneous in age. His opinion is based on the mutual-boundary relations between these minerals.[19] Two ages of quartz, however, were recognized, as some euhedral crystals are encased by a later generation. Minute blebs of chalcopyrite are aligned along the crystal faces or grain boundaries of sphalerite. This chalcopyrite may either have separated from a solid solution with sphalerite, or have replaced it.

The field evidence and microscopic studies suggest that during the early stage of the quartz-sulfide period of mineralization the hypogene solutions carried largely silica, which filled or nearly filled many of the narrower fractures in the host rock. In the later stage quartz and sulfides were both being carried in the hypogene solutions, and these minerals were precipitated in the voids left in some of the wider fractures. This paragenesis suggests that precipitation was caused chiefly by changes in temperature and pressure, as the reactive character of the host rock was largely nullified by earlier quartz lining the open fractures. This conclusion would hold true at least for those places in which there was no inter-mineral breaking.

Petrographic studies suggest that the quartz was derived from the alteration of the igneous rocks. Thin sections show that much of the feldspar has been altered to sericite, and the ferromagnesian minerals to chlorite and epidote. These mineralogic changes release silica which can be deposited elsewhere, as quartz veins in near-by rocks, for example. No quantitative measurements were made to determine the approximate amount of quartz introduced into the sedimentary rocks at Boston Hill, but the localization of the quartz veins near the Silver City intrusion and slight silicification of limestone near dike contacts suggest that this quartz was derived from the silica released by the hydrothermal alteration of the igneous rocks. Schmitt, after a careful study of the Pewabic mine in the Hanover mining area, has been able to show convincingly, by many chemical analyses and by roughly quantitative mapping of the degree of alteration, that "the magma need be called upon only to provide metals, halogens, sulphur and water" and concludes that the silica was derived from the hydrothermal alteration of the igneous rocks.[20]

The formation of sericite in the igneous rocks required the addition of water and potash. Schmedeman[21] has discussed

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[19] Although some geologists do not feel that mutual boundaries are full proof of contemporaneity, nevertheless in specimens examined by Peterson there are no examples of any of the minerals cutting each other.

[20] Schmitt, Harrison, The Pewabic mine: Bull. Geol. Soc. America, vol. 50, p. 816, 1939.

[21] Schmedeman, O. C., Notes on the chemistry of ore solutions: Econ. Geol., vol. 33, pp. 801-803, 1938.

this alteration at some length and concludes that when potash is added the mineralizing solutions are then alkaline to faintly acid. The close association of the hydrothermal alteration of the igneous rocks and the sulfide minerals suggests that the alteration was produced by the solutions carrying the sulfide minerals. The mineralizing solutions, if they were faintly acid, would be neutralized quickly in the reactive environment of dolomite and limestone. Such a change, with probable changes in temperature and pressure, would allow precipitation.

The next period of mineralization appears to have produced argentiferous galena and barite. The galena may represent a weak continuation of the earlier sulfide period, being followed by deposition of barite. A polished section of ore from Chloride Flat shows a blade of barite cutting galena. The distribution of barite is widespread, but it is most abundant in Chloride Flat where barite is a common gangue mineral of the supergene silver ores and has been used by the miners as a guide to ore. The areal distribution of argentiferous galena and barite suggests that they were deposited at somewhat lower temperatures and pressures than the quartz and sulfides.

Some minerals cannot be placed with certainty in the scheme of hypogene mineralization. Pearceite has been found only towards the north end of the Chloride Flat mining district, near the outer limit of mineralization. The mineral occurs in a few places in the laminations of the Percha shale and as veinlets cutting the shale. Pearceite may be hypogene and its position in relation to the probable source of mineralization suggests that it was deposited at relatively low temperatures. Manganiferous calcite found in the western part of Boston Hill seems to represent a later period of weak mineralization.

Local silicification and deposition of chalcedonic quartz at the base of the Percha shale is here considered to be of hypogene origin. None of the earlier periods of mineralization appears to have affected the silicified shale or the chalcedonic quartz.

It has not been possible to determine whether the gold reported in assays of sludges from churn-drill holes on the Silver Spot group of claims is hypogene. The gold, which has been reported as occurring along dike contacts cut by the holes, may have been derived from the oxidation of gold-bearing sulfides. All the elements necessary for the transportation and re-deposition of gold[22] are present in the district.

SUPERGENE MINERALIZATION

Through the processes of supergene mineralization the manganiferous-iron bodies at Boston Hill and the silver deposits at Chloride Flat have been made of economic importance. At

[22] Emmons, W. H., The agency of manganese in the superficial alteration and secondary enrichment of gold-deposits in the United States: Trans. Am. Inst. Min. Met. Eng., vol. 40, pp. 3-73, 1912.

Boston Hill the vertical extent of commercial manganiferous iron oxides is dependent on the completeness of oxidation and the consequent enrichment and concentration of the lean hypogene carbonate due to the removal of valueless material. The effective oxidizing power of acid surface waters in the reactive environment of limestone and dolomite is limited to a shallow zone and results in high-grade ore bodies. Most of the mining operations at Boston Hill are within 75 feet of the surface. The mining of silver at Chloride Flat has been confined to rich pockets where supergene silver minerals have been concentrated.

MANGANIFEROUS IRON-ORE DEPOSITS

EXPERIMENTAL DATA

With cold solutions.—Savage[23] performed a number of experiments on manganese carbonate and found that it can be taken into solution by (1) carbonated water, (2) peat solution, or (3) free sulfuric or hydrochloric acid. Distilled water was a poor solvent, and oxygenated water had the least solvent power of any of the solutions. In a solution made acid by excess carbon dioxide the manganese is carried as a bicarbonate. The loss of excess carbon dioxide causes the manganese bicarbonate to split and form unstable manganous hydroxide which remains in solution. With manganese carbonate and manganous hydroxide in unstable equilibrium further transportation can take place. Only after neutralization of the acid carbon dioxide solution can manganese be precipitated. Aeration, in the presence of calcium carbonate, can bring about such neutralization, or even slight alkalinity. The unstable manganous hydroxide oxidizes to a partly dehydrated manganic hydrate (MnO.OH) which in turn readily oxidizes to manganese dioxide. An exchange of the carbonic acid molecule can also take place between manganese bicarbonate and calcium carbonate, after which manganese carbonate is precipitated. Certain thread bacteria materially assist in the precipitation of manganese dioxide under oxidizing conditions.

The experimental work preceding the construction and operation of a water-treatment plant at Brainerd, Minnesota,[24] showed that with solutions containing iron and manganese bicarbonate most of the iron can be precipitated by simple aeration, but manganese will precipitate only if the solution is alkaline. Once oxidation is started the process is catalyzed by manganese dioxide.

Clarke[25] states: "If oxygen and carbon dioxide act together in considerable excess, Fe_2O_3 and MnO_2 will both be formed; but if they act slowly, in small quantities, the oxygen will go to

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[23] Savage, W. S., Solution, transportation and precipitation of manganese: Econ. Geol., vol. 31, pp. 278-297, 1936.

[24] Zapffe, Carl, Catalysis and its bearing on origin of Lake Superior iron-bearing formations: Econ. Geol., vol. 28, p. 764, 1933.

[25] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, p. 542, 1924.

produce Fe_2O_3, and $MnCO_3$ can be generated at the same time." The iron may thus be precipitated separately, and the manganese carbonate can be oxidized later to manganese dioxide.

Metallurgical tests on ore from Boston Hill containing 16.0 per cent manganese, 35.6 per cent iron, and 10.5 per cent silica were made by Davis.[26] One liter of a four per cent sulfur dioxide solution which was agitated at 25°C., with 25 grams of minus 100-mesh ore, resulted in the solution of 97.3 per cent of the manganese in 16 hours.

DeWitt[27] obtained similar results by using sulfurous acid and calcium chloride on manganese carbonate; the reaction suggested is as follows:

$$MnCO_3 + CaCl_2 + H_2SO_3 + O \rightarrow MnCl_2 + CaSo_4 + H_2CO_3.$$

Calcium chloride alone has little solvent power on manganese carbonate.

Dunnington[28] has shown that manganese sulfate plays an important part in the segregation of iron and manganese oxides upon precipitation. Ferrous sulfate, formed by the oxidation of certain sulfide minerals, is a solvent for manganese oxides. Likewise, when ferrous sulfate is in contact with manganese carbonate, under oxidizing conditions, soluble manganese sulfate is again produced and the iron is precipitated as ferric hydroxide. In the presence of calcium carbonate ferrous or ferric sulfate reacts readily, but manganese sulfate reacts only under oxidizing conditions when manganese oxide is precipitated. Thus when iron and manganese sulfates are in contact with calcium carbonate, the iron precipitates easily as ferric hydroxide whereas the manganese remains in solution until oxygen is present.

Moore and Maynard[29] tested the solvent power of several solutions on iron and silica in norite and diabase. Carbonated water and peat solution were found to be the two best solvents; oxygenated and distilled water were poor solvents for iron. They conclude also that in cold natural surface waters high in organic matter the iron is carried largely as ferric oxidized hydrosol.

With hot solutions.—Much has been written on hydrothermal leaching of iron and manganese ores,[30] particularly in connection with the iron-ore deposits of Minnesota and Wisconsin. In Trengove's paper, for example, evidence is cited that rhodochrosite may be altered to manganese oxide by steam at a temperature as low as 170°C. Iron carbonate in isomorphous mixture

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[26] Davis, C. W., Dissolution of various manganese minerals: U. S. Bur. Mines, Rept. Invest. 3024, p. 10, July 1930.

[27] DeWitt, C. C., Leaching ore: U. S. Patent No. 1,835,474, 1931, cited by Dickey, R. M., Manganese in the Montreal mine, Montreal, Wisconsin: Econ. Geol., vol. 33, p. 621, 1938.

[28] Dunnington, F. P., On the formation of deposits of oxides of manganese: Am. Jour. Sci., 3rd ser., vol. 34, p. 176, 1888.

[29] Moore, E. S., and Maynard, J. E., Solution, transportation, and precipitation of iron and silica: Econ. Geol., vol. 24, pp. 272-303, 365-402, 506-527, 1929.

[30] Gruner, J. W., Hydrothermal leaching of iron ores of the Lake Superior type. A modified theory: Econ. Geol., vol. 32, pp. 121-130, 1937.

Trengove, S. A., The hydrothermal oxidation of manganese minerals: Econ. Geol., vol. 31, pp. 29-47, 1936.

with manganese carbonate tends to lower the temperature needed for oxidation. Manganese oxides have been found precipitated directly from emanations of hot springs.[31]

FIELD EVIDENCE

Deposits of manganese and iron oxides have been formed and concentrated by several agencies:[32]

(1) By deposition of manganese and iron oxides from hydrothermal solutions. The temperatures and pressures vary widely. Specularite and magnetite deposits are usually regarded as of high temperature; oxides of manganese and iron have been deposited from hot springs.

(2) By concentration and enrichment by hydrothermal solutions.

(3) By oxidation and enrichment of lean hypogene carbonates by surface waters.

(4) By mechanical and chemical concentration of manganese or iron-bearing sedimentary or igneous rocks by processes of weathering.

(5) By deposition in swampy areas by organic material from manganese and iron content of water.

At Boston Hill hydrothermal solutions have deposited mesitite in certain sedimentary rocks. The vertical extent of commercial manganiferous iron oxides is dependent on the completeness of oxidation, and the consequent enrichment and concentration of the lean hypogene carbonate are due to the removal of valueless material. The small amount of hypogene specularite and magnetite that is present in some of the deposits would not by itself be commercial. Analyses show mesitite to contain about three per cent manganese and 13 per cent iron. The grade of ore mined has varied from eight to 15 per cent manganese and 26 to 41 per cent iron.

In most places the ore is an intimate mixture of iron and manganese oxides, but the probable ratio of enrichment indicates a slight concentration of manganese. Where hematite and pyrolusite have been segregated, the scale has not been large enough to permit selective mining. The removal of magnesia, lime, and carbon dioxide from the hypogene carbonate would produce an ore containing approximately 60 per cent iron and nine per cent manganese. The results of this calculation suggest either that there is a slight segregation of manganese or that some of the hypogene carbonate is higher in manganese and lower in iron than the material analysed.

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[31] Callaghan, Eugene, and Thomas, H. E., Manganese in a thermal spring in west-central Utah: Econ. Geol., vol. 34, pp. 905-920, 1939.

[32] Lindgren, Waldemar, *Mineral Deposits*, 4th ed., pp. 249, 261-282, 293-314, 354-371, 713-716, 737-743, 790-796, 828-831, 871, McGraw-Hill, New York, 1933.

CHARACTER OF SUPERGENE SOLUTIONS

The experimental data reviewed suggest that surface waters, charged with an excess of carbon dioxide and oxygen and filtering through rocks containing mesitite, could produce the deposits at Boston Hill. The iron and manganese carbonate were taken into solution as bicarbonates; but in the presence of a reactive host rock the excess carbon dioxide was used, the solution became alkaline, and ferric and manganese oxides were precipitated simultaneously. Sulfuric acid played only a small part, as the quantity of sulfides available to furnish acid upon oxidation was small. Manganese and iron sulfates on reacting with calcium or magnesium carbonate tend to segregate into deposits of iron and manganese oxide. Some sulfuric acid was present during supergene mineralization, forming minerals such as anglesite, jarosite, and goslarite. Halogen salts were also available as shown by the common "horn silver" minerals at Chloride Flat.

The occurrence of mesitite containing sufficient manganese and iron to have formed the overlying oxidized ore bodies makes it appear that only meteoric waters were necessary for oxidation of the carbonate.

SILVER DEPOSITS

A part of the silver of the supergene silver-ore deposits was derived from pearceite and argentiferous galena. The amount of pearceite originally present seems to have been small. Little ore has been produced from the Percha shale, in which pearceite is present and is somewhat protected from oxidation due to surface waters, and in oxidized areas the visible alteration products of the copper impurity in pearceite are slight. Nor can most of the silver produced at Chloride Flat—probably about 4,000,000 ounces—be readily accounted for by the oxidation of argentiferous galena; more than 75,000 tons of galena would be needed to supply this much silver. Early reports suggest that the silver was accompanied by lead minerals; the addition of litharge in smelting was at first not necessary. Most of the silver seen during the investigation, however, is not accompanied by either lead or copper minerals. It is therefore suggested that some of the silver halides had their source in hypogene argentite.

The presence of much bromine and iodine in many deposits in arid regions has raised the question of the source of these elements.[33] From analyses given by Clarke[34] the rivers draining the Southwest show a larger haloid content than those in other parts of North America. Penrose[35] attributed the relative abundance of silver halides in the Southwest to the formation of closed basins during arid periods in late geologic time. Chlorine, however, has been found in appreciable quantities in gases

[33] Young, J. W., The halogen salts of silver at Wonder, Nevada—Discussion: Econ. Geol. vol. 13, pp. 224-225, 1918.

[34] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, p. 87, 1924.

[35] Penrose, R. A. F., Jr., The superficial alteration of ore deposits: Jour. Geol., vol. 2, pp. 314-317, 1894.

emanating from fumaroles at the Valley of Ten Thousand Smokes, Alaska.[36] Thus a number of possible explanations for the formation of silver halides have been advanced. One or more may have been active near Silver City.

LOCALIZATION OF ORE BODIES

The lean hypogene manganiferous iron-bearing carbonate, mesitite, was localized either in ground well prepared for mineral deposition by strong faulting or in differentially prepared ground where the "mudding up" or the sealing of fractures in shale impounded or decelerated the movement of hypogene solutions. These two types of localization are illustrated in Fig. 4. The exposure of the mineral-bearing ground to surface waters charged with carbon dioxide converted the carbonates to iron and manganese oxides.

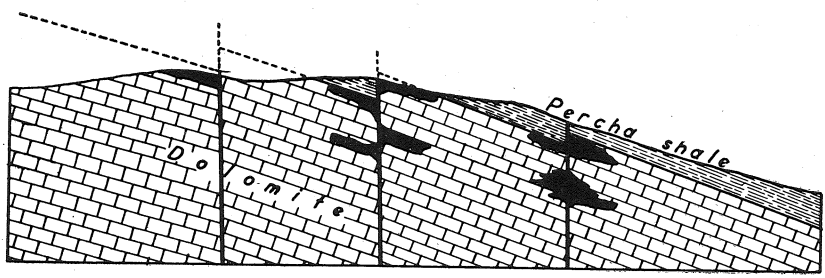


FIGURE 4.—Generalized cross section showing manner of localization of ore bodies. Ore is shown in black.

The first type of localization is exemplified by the ore bodies along the Fierro fault and at its intersection with the Boston Hill fault. At these places the dolomites, which range from the El Paso through the Raven member of the Montoya, have been strongly brecciated and thus made readily susceptible to replacement. Oxidation and enrichment by surface waters have concentrated the iron and manganese in mesitite to oxide-ore. In the Legal Tender group, the fracturing in a wide zone that branches off the Boston Hill fault is less intense than in the vicinity of the Fierro fault; consequently the ore bodies are smaller. So far as known, the ground-water level has not been encountered in any workings in this area.

Along the eastern part of the Boston Hill mining district, ore bodies have been formed by differential ground preparation. Here, as at the Silver Spot group, the ground has been broken by many small faults, but upward movement of hypogene solutions was halted, or at least greatly retarded, by the overlying

[35] Allen, E. T., and Zies, E. G., A chemical study of the fumaroles of the Katmai region: Nat. Geog. Soc., Contr. Tech. Papers, Katmai ser., no. 2, p. 142, 1923.

Percha shale. Where faults with small throws enter the Percha, much of the movement has commonly been absorbed by the soft, fissile shale, producing small folds (see Fig. 5). The loss of movement is well illustrated at Chloride Flat, where many small faults can be mapped on the surface at the base of the shale but only a few of the larger ones, with some loss in throw, traverse the valley (see map, Plate 2). The resulting folds are difficult to find because much of the shale is covered by mantle rock and because many of the folds probably disappear within a short distance.

Shallowness of the ground-water level in the eastern part of the district is apparent from the fact that water stands in some of the Silver Spot workings, the hypogene carbonate has already been encountered, and unoxidized sulfide minerals occur within 150 feet of the surface. Although strata that may contain manganese and iron are present to a depth of about 700 feet, the oxidized portion, constituting the ore, is restricted largely to the relatively thin zone above water level.

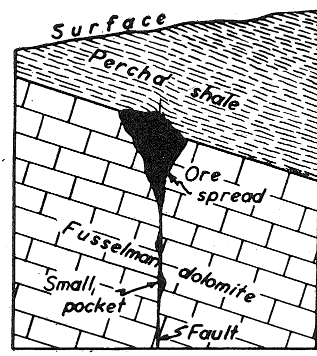


FIGURE 5.—Sketch showing localization of ore at contact between dolomite and shale.

At Chloride Flat the silver deposits are localized at the contact between the Fusselman dolomite and the Percha shale along small fissures or at intersections of fissures. At the contact the ore tends to spread in the dolomite, but some ore penetrates the shale in the shape of a flat arch (see Fig. 5). Silver deposits of this type have been found at Lone Mountain and Georgetown in Grant County; at Kingston, Lake Valley, Hermosa, and Tierra Blanca in Sierra County; at Cooks Peak and Victorio in Luna County; and at Organ in Dona Ana County.

DESCRIPTIONS OF PROPERTIES

The Boston Hill mining district has been extensively prospected by many shallow pits and stopes. Only a few of these will be described, as the type of ground and the mineralization explored by each is similar. Ore bodies have been found in all the Lower Paleozoic dolomites from the El Paso to the Fusselman. Small amounts of manganiferous iron ore have been mined in the Chloride Flat mining district. The descriptions are divided into four sections, namely: (1) the Silver Spot group of claims in the eastern and southeastern parts of the district, (2) the Boston Hill group in the central and western parts, (3) the Legal Tender group in the northeastern part, and (4) the Chloride Flat district.

SILVER SPOT GROUP

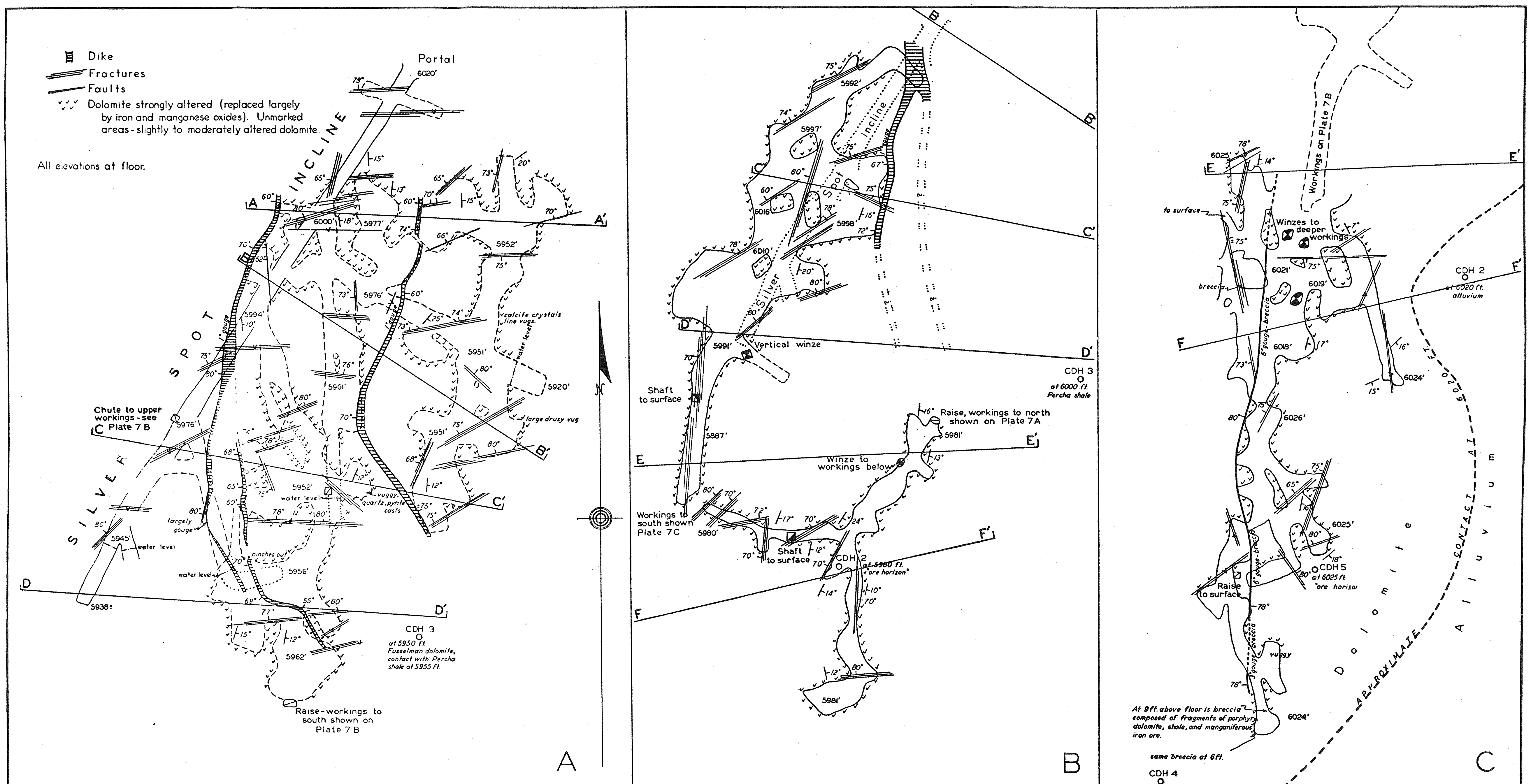
GENERAL STATEMENT

The Silver Spot group of claims, owned by the Silver Spot Corporation, Silver City, New Mexico, consists of the Globe claim which adjoins the Legal Tender claim; 50 acres of patented mineral land in secs. 3 and 10, T. 18 S., R. 14 W.; and contiguous claims forming a reversed L-shaped area located in sec. 9, west of the patented ground (see Plate 6). The greater part of the land lies on the eastern slope of Boston Hill on both sides of Highway 180.

Most of the surface is underlain by Percha shale striking nearly due north and dipping about 15° E. Along the eastern part of the group the shale has been cut off by the Silver City intrusion. West of the highway the shale is cut by a dike, which crops out for nearly 3,000 feet along a northerly strike. A second dike, which has been cut by churn-drill hole No. 17 (Fig. 8), crops out in an arroyo on the Spot No. 4 claim. On the Spot No. 1 and No. 4 claims are two roughly circular patches of flat-lying Quaternary limestone that lie unconformably on the eroded surface of black Percha shale.

Four claims, lying almost entirely in sec. 9, cover the south fringe of Lower Paleozoic formations. The sedimentary terrane is encroached upon by Quaternary breccia containing angular to subangular fragments, as large as several feet in diameter, of igneous and sedimentary rocks and manganiferous iron ore (Plate 5, B). The fragments have been cemented by caliche.

Faults are probably present beneath the mantle rock that covers the Percha shale near Highway 180. The contact between the Percha shale and the Silver City intrusion is obscure except at the Silver Spot No. 2 shaft, where the contact is a well-exposed fault. The gouge strands and the curving of the beds in the



Plan of workings off the Silver Spot incline. Cross sections along lettered lines are shown on Plate 8. Scale, one inch equals approximately 80 feet.

shale indicate that the rocks on the west side have been elevated (Fig. 2).

The Silver Spot fault, which lies largely within the boundaries of the North Extension Volcano and the Mikado claims, enters the Spot No. 1 claim near the Silver Spot shaft. South of the shaft the fault strikes S. 25° W., but near the shaft the strike is S. 8° W. The dip ranges from vertical to 70° E. The fault may merge into the dike west of Highway 180 as the fault can be traced northward for only a short distance, to a point where it becomes covered by mantle rock. The Silver Spot fault has been prospected at many places, and some small bodies of manganiferous iron ore have probably been mined.

On the claims that form the foot of the "L" are several north- to northeast-trending mineralized faults. They appear to terminate abruptly on a fault, striking N. 86° W. and dipping 55-64° N., which may be a strand of the Apex fault.

UNDERGROUND WORKINGS

SILVER SPOT SHAFT

A two-compartment vertical shaft about 150 feet deep near the west side-line of the Spot No. 1 claim is known as the Silver Spot shaft. During the period of examination for this report the water level was within 50 feet of the collar, although in February, 1944, the level had dropped considerably. The shaft is not safe for entry in its present condition. Maps available to the writer from a private report show two levels, the first at 90 feet below the collar and the second at 140 feet (see Fig 6.).

The shaft starts in Percha shale, and at a depth of about 90 feet enters the Fusselman dolomite, which is reported to have been replaced by manganese and iron oxides for 57 feet.[37]

On the first level a cross-cut has been driven to the Silver Spot fault, and drifts explore the fault for a distance of 180 feet along its strike. A parallel drift 80 feet to the east of the Silver Spot fault appears to have explored mineralized dolomite.

The second level has cross-cuts east and west from the shaft. The west cross-cut has reached the Silver Spot fault, along which a drift has been driven for 280 feet. The east cross-cut was driven 200 feet from the shaft and crosses the dike exposed at the surface west of the highway. The repetition of the dike on the level was caused by a west-dipping fault.

Some small ore bodies have been found in the Fusselman dolomite near its contact with the Percha shale, and manganiferous iron ore has been stoped. No figures on the total production are available, but the tonnage was probably small.

Many specimens of hypogene minerals obtained from the dump indicate that the dolomite was irregularly replaced by magnetite and mesitite, and then fractured. Later the cracks were partially filled, first by quartz and then by quartz and

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[37] Kirchman, R. I., personal communication.

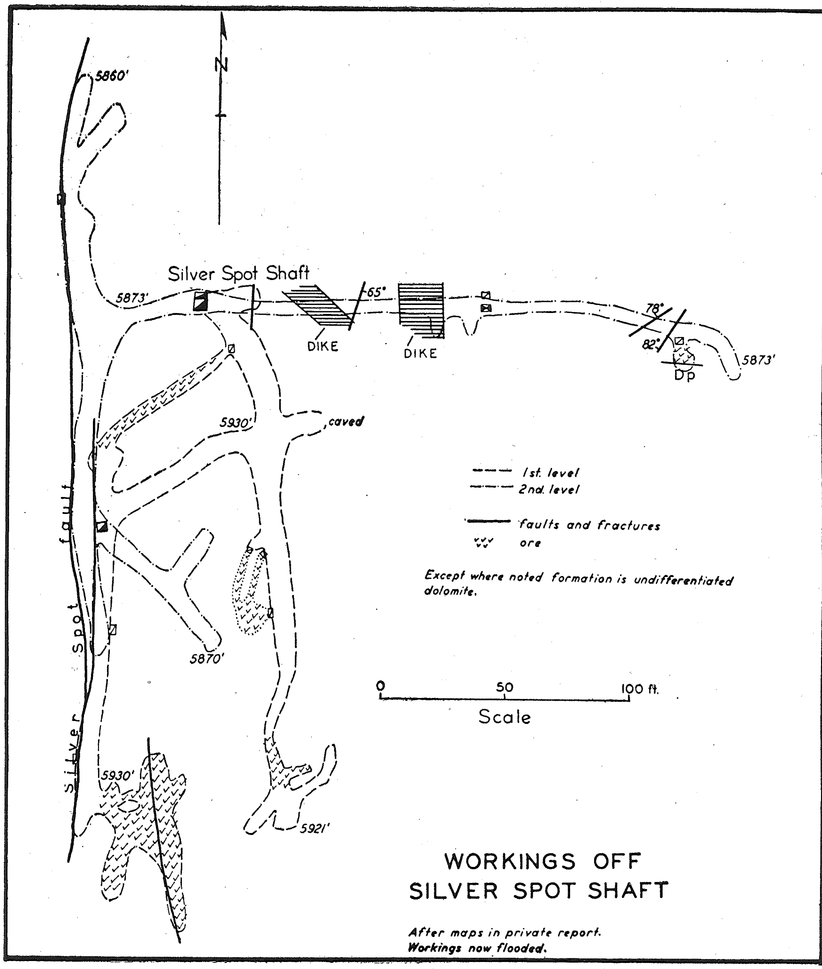


FIGURE 6.—Plan of workings off the Silver Spot shaft.

sulfides. This relationship within the veins is suggested by a narrow band of white quartz that lies against the dolomite. Sphalerite, pyrite, and galena are associated with quartz near the center of the veinlets. The sulfides seem to have been deposited only in seams that had not been previously completely filled by quartz. The above-described occurrence of quartz and sulfides suggests no inter-mineral breaking during the period of deposition of the sulfides.

Although zinc blende and galena have been found, none has ever been shipped. The scattered veins probably do not contain enough lead and zinc to constitute ore even under present wartime conditions. Small specimens of relatively high-grade ore can be found.

SILVER SPOT NO. 2 SHAFT

The Silver Spot No. 2 shaft on the Spot No. 5 claim has been sunk on a fault contact between the Percha shale and the Silver City intrusion (see Fig. 2). The fault strikes N. 10° W. and dips 80° W. The curving of the beds indicates that the fault is reverse. The shaft, now caved, is reported[38] to have followed the contact and at 217 feet to have entered the Fusselman dolomite. An incline was driven upward to the west on the contact between the Percha shale and the Fusselman dolomite. Little or no manganiferous iron ore was mined.

SILVER SPOT INCLINE

The portal of the Silver Spot incline is located near the west side-line of the Spot claim. It was driven S. 30° W. for 450 feet at an average grade of 20 per cent. The bottom is about 115 feet vertically below the surface and 82 feet below the portal. From the main incline are three secondary inclines which enter into stopes or lead to chutes beneath stopes. The secondary inclines give entry only to the area east of the incline. The workings above the main incline can be entered through a chute west of the deepest secondary incline, by way of a raise at the south end of the stopes reached through the intermediate secondary incline, or through workings which come to the surface near the southeast corner of the Mikado claim (Plate 7).

The workings explore an area 1,650 feet long with an average width of 150 feet and a maximum width of about 250 feet. The area outlined by the workings covers about six acres.

The stopes are untimbered rooms averaging about 12 feet high, although some that are elongated along faults may be as high as 50 feet. The largest room may have contained as much as 10,000 tons of ore.

The Silver Spot incline was driven in Fusselman dolomite, which strikes nearly due north and dips 15° E. At 240 feet from the portal a dike cuts obliquely across the incline. The dike here is about eight feet wide, but in other places in the mine it is about two feet wide. It varies in strike from N. 30° W. to N. 20° E., and the dip ranges from 60-80° W. The walls are marked by a one-inch gouge selvage on which are approximately horizontal striations. Workings to the north of the main incline suggest that the dike splits into two parts. It is composed largely of sericite and "kaolin," in which ghosts of feldspar phenocrysts can be seen. In places the rock is strongly stained by ferric oxide. Another dike of similar character is found in the upper secondary incline (Fig. 7) and in adjoining stopes. This is, however, more irregular in dip; and, although horizontal striations on the gouge selvage predominate, in places striations are variable.

The Fusselman dolomite in the workings east of the Silver

[38] Kirchman, R. I., personal communication.

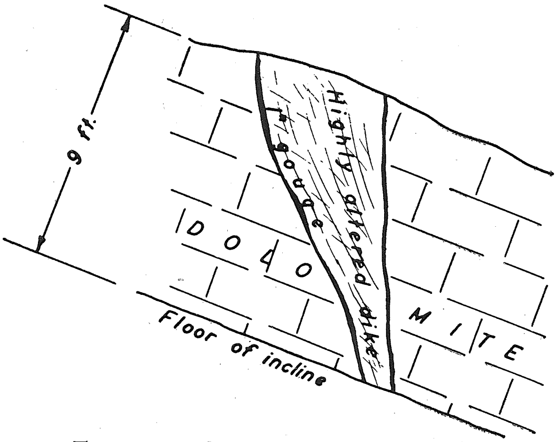


FIGURE 7.—Occurrence of dike in the Silver Spot mine.

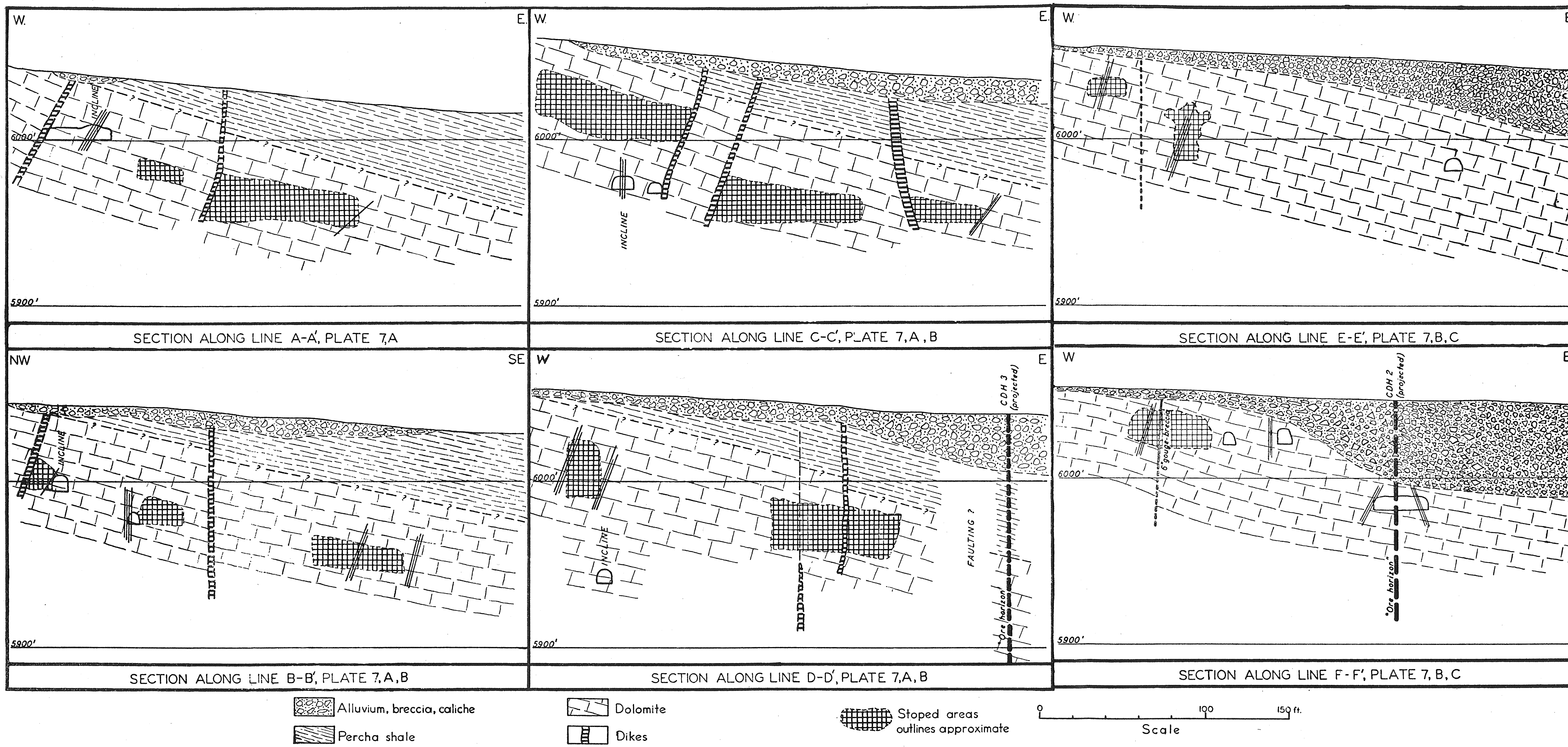
Spot incline has an average dip of 15° E. (Plate 8). The dolomite has been broken by fractures that range in strike from east to N. 70° E. and dip steeply to the north. In the areas where replacement by iron and manganese oxides has been strong the beds have subsided; the resulting cracks, which parallel the bedding, have been filled by calcite. The highly mineralized country is characterized by many vugs, which are in most places partly filled by druses of calcite, quartz, or both. In some places the quartz was massive but is now honeycombed by casts formerly containing cubic pyrite crystals.

The ore is a mixture of hematite, specularite, pyrolusite, and magnetite. Limonite is localized near areas that contained pyrite. In places some limonite remains in the casts, but in other places the cavities contain minute needles of goethite (?). In the workings above and south of the Silver Spot incline (Plate 7, B and C) the ore contains more specularite than in other places in the mine. Here the predominating structures have a north trend; the workings follow, more or less, a north-trending fault that dips steeply east or west.

Most of the stope floors are covered with broken rock, so that it is not possible to determine the strength of mineralization in the floor. The churn drilling, however, suggests that ore may be present at greater depths than those explored by the present workings.

CHURN DRILLING

Twenty-two churn-drill holes, totaling about 4,500 feet of hole, were put down by the Colorado Fuel and Iron Company in 1926-27. On maps made available to the writer the depths and logs of a few holes were missing and the locations of some were not spotted. The term "ore horizon" was used on the logs,



Cross sections through workings off the Silver Spot incline.

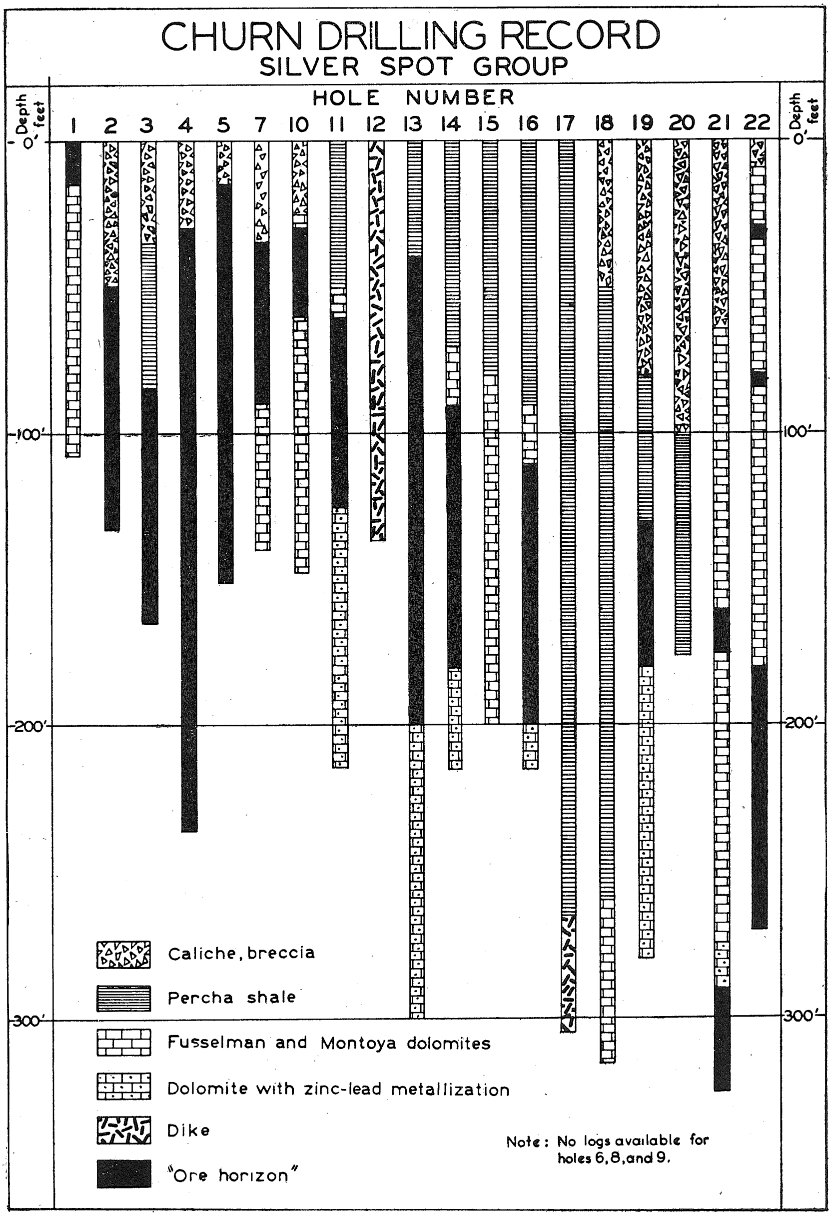


FIGURE 8.—Churn drilling record, Silver Spot group. Locations of drill holes are shown on Plate 3.

but the exact meaning of the term was not defined, and no assays for manganese or iron were shown. The data made available have been assembled graphically in Fig. 8 and in the projection shown on Plate 9. Of the 4,073 feet of hole on which logs have been seen, 1,185 feet was marked "ore horizon."

The churn-drilling program is reported to have blocked out 500,000 tons of ore averaging 9 to 11 per cent manganese, 33 to 35 per cent iron, 0.015 per cent phosphorus, seven per cent silica, and two to three per cent alumina. An additional 1,000,000 tons is considered to be probable ore.[39]

BOSTON HILL GROUP

GENERAL STATEMENT

The Boston Hill group of claims, the largest in the district, covers 579 acres. The claims lie in the central and western parts of the district (see Plate 6). From 1937 to 1944 all ore produced in the district has come from this group, which is being operated under lease by the Luck Mining and Construction Company. In these seven years about 300,000 long tons of manganiferous iron ore, averaging 12 to 13 per cent manganese and 35 to 41 per cent iron, has been shipped to the smelter of the Colorado Fuel and Iron Company at Pueblo, Colorado, where the ore is used as a flux.

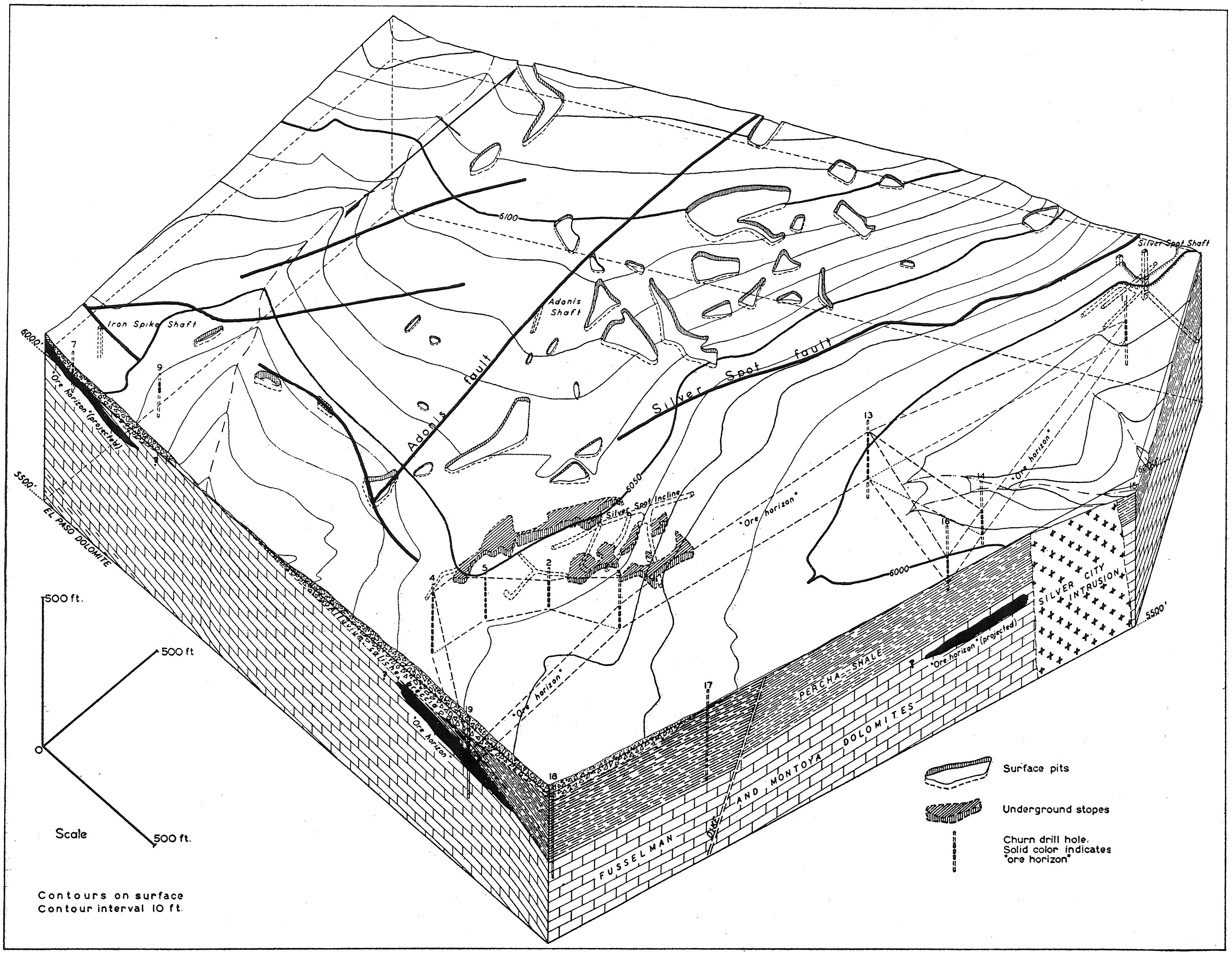
The group covers the apex of the Boston Hill fault for a distance of 4,500 feet, the Apex fault for 2,000 feet, and the Fierro and Adonis faults. The sedimentary rocks exposed south of the Boston Hill fault range from Cambrian to Devonian in age. On the Contraband claim Quaternary alluvium covers the country rock south of the Contraband fault. North of the Boston Hill fault sedimentary rocks as young as Upper Cretaceous in age crop out within the property boundaries.

The rocks are in most places well exposed, but near the Fierro fault a thin mantle of red-brown soil covers the bedrock. On the hill slopes and in the arroyos appreciable quantities of magnetite sand, ranging from fine to coarse, are present.

COMANCHE PIT

The Comanche pit (Plates 2 and 10, A; Fig. 9), 500 feet long by 250 feet wide and over 60 feet deep at the north end, is situated on the Fierro No. 5 claim (Plate 6). In February, 1944, much of the ore shipped from Boston Hill was being mined here. Practically no overburden has to be removed, but material of a grade too low to ship under the existing contract is being sorted out; a large dump of low-grade material has resulted. Some high-grade ore was also being mined on beds dipping eastward under the brow of the pit and about 50 feet below the surface (Fig. 9).

[39] Mineral resources of the United States for 1928: U. S. Geol. Survey, p. 217, 1931.



Stereogram of an area in the southeastern part of the Boston Hill mining district. Boundary is shown on Plate 3 by hachured black line.

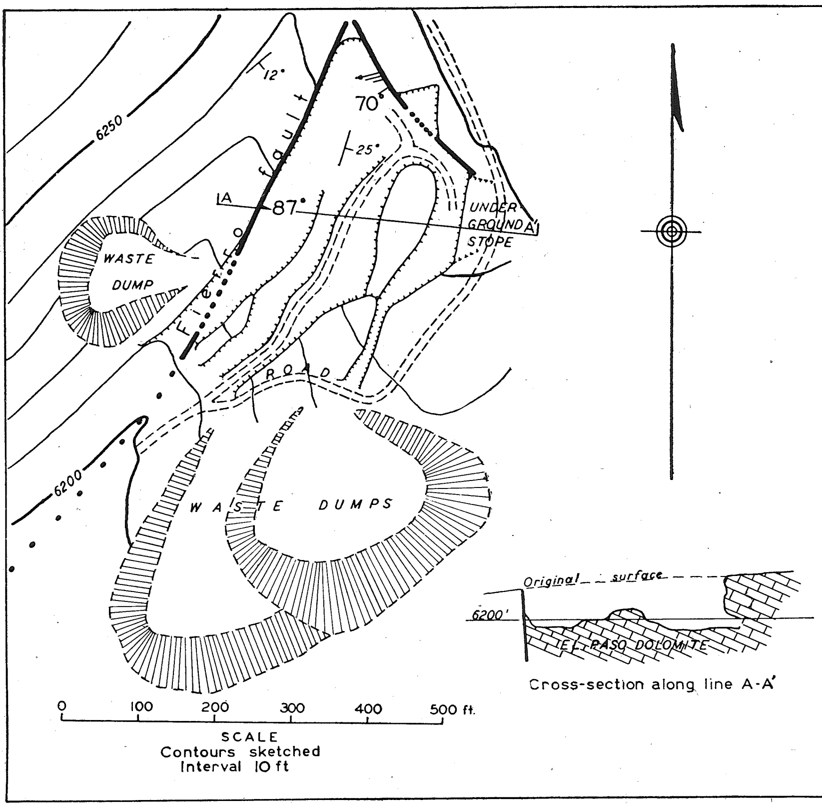


FIGURE 9.—Plan and cross section of the Comanche pit.

Most of the pit is east of a large fault that forms the east boundary of the Fierro fault zone. Locally the fault strikes north and dips 85° E. When seen in February, 1944, the north face of the pit was at a northwest-striking fault, which dips steeply to the southwest and has prominent west-dipping striations. Ore apparently continues northeast of the fault. The rock, which is highly altered, is part of the El Paso dolomite (see map, Plate 2), which has been broken by cracks striking in many directions. The dip of the strata is, however, recognizable. Cross-sections suggest that the Bliss sandstone is about 250 feet below the surface near the south end of the pit.

The ore is composed largely of red hematite and black pyrolusite, closely intermingled. A little magnetite is present, and a few blades of barite were seen at one place. When the ore is blasted, clouds of reddish dust rise that are visible for several miles.

NORTH PIT

The North pit is located largely on the Par Value, Pennsylvania No. 2, Naid Queen, and Silver Pick claims. It is 400 feet long, 150 feet wide, and more than 50 feet deep at the south end (Plate 2 and Fig. 10). The North pit was producing ore in February, 1944.

Along the west side of the pit is a fault that strikes N. 10° W. and dips 55° W. Another fault, striking approximately north and dipping 63° E., is exposed near the east boundary of the pit; this fault appears to be the continuation of the Fierro fault that bounds the west side of the Comanche pit. In the North pit the rock between the faults is part of the Second Value member of the Montoya dolomite, although at the surface the cherty Par Value member was replaced by manganese and iron oxides. Mineralization and breaking have obscured the dip of the bedding. The ore is similar to that seen in the Comanche pit. No barite was noted.

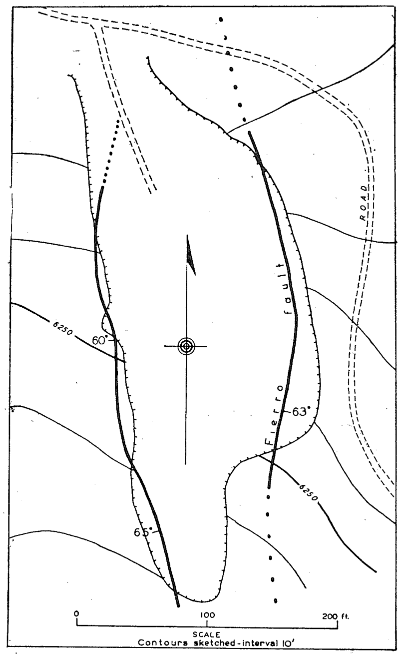


FIGURE 10. Plan of the North pit.

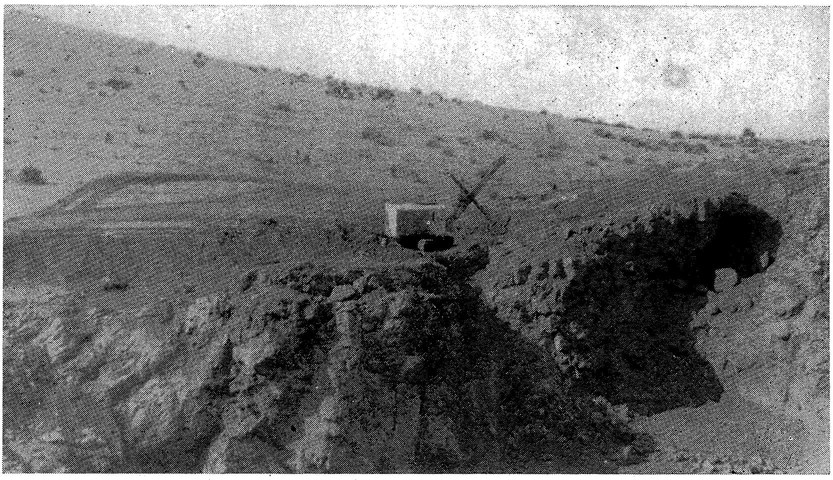
SILVER PICK PIT

The Silver Pick pit (Plates 1 and 2) explores the Boston Hill fault for about 400 feet northeasterly. It attains a maximum width of 170 feet at the northeast end and in places is 40 feet deep. The Boston Hill fault here dips vertically. On the southeast side of the fault the dolomite appears to be part of the Montoya formation; on the northwest side, the rock, strongly altered and bleached, is probably part of the Colorado formation. This pit may be the one mentioned by Wells.[40]

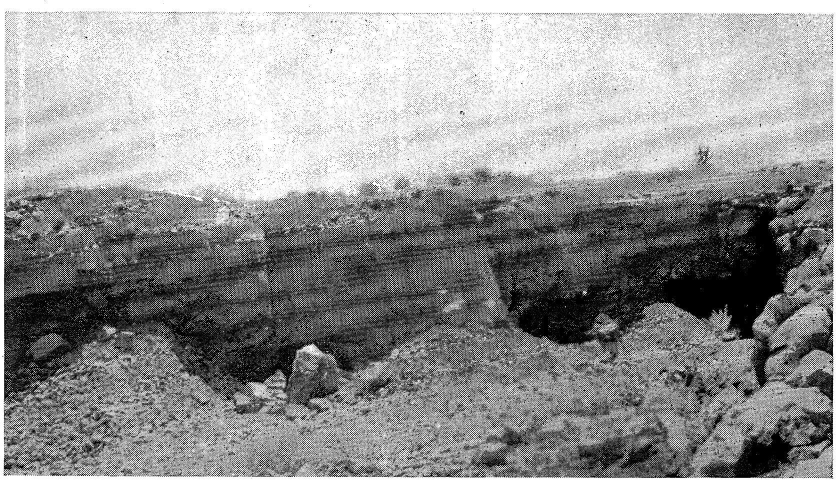
RAVEN MINE

At the southwest end-line of the Raven claim, a small narrow pit along a fault that strikes N. 5° W. and dips nearly vertically is of interest because the cherty Par Value member of the Montoya dolomite has been replaced. The cherty lenses, although cracked and broken, are still visible; but the usual red color has been removed, and the chert is white. Quartz and calcite crystals

[40] Wells, E. H., Manganese in New Mexico: N. Mex. Min. Res. Survey Bull. 2, p. 51, 1918.



A. Stripping operations at Comanche pit, Boston Hill.



B. Bedded replacement in Fusselman dolomite, Globe claim, Boston Hill.

fill fractures both across and parallel to the bedding. The ore is largely red hematite and pyrolusite.

SECOND VALUE SHAFT

About on the center-line 400 feet from the north end-line of the Second Value claim are a few shallow workings and a shaft about 50 feet deep. The material removed from the surface pits is composed largely of yellow-brown limonite cut by veinlets of pyrolusite (see Plate 5, C). The dump from the shaft, however, has much El Paso dolomite which is unaltered to slightly altered. Hematite, limonite, and pyrolusite are cut by supergene calcite. Some barite is present.

FIERRO NO. 1 SHAFT

The Fierro No. 1 shaft is near the southwest side-line of the Fierro No. 1 claim. The shaft, probably nearly 100 feet deep, was sunk on a fault parallel to the Apex fault. The dump contains El Paso dolomite, Bliss sandstone, and pre-Cambrian granite. Magnetite, hematite, and pyrolusite are the iron and manganese minerals found on the dump; but of special interest is the presence of oxidized copper minerals, of which chrysocolla appears to predominate. The copper does not appear to be in commercial quantities.[41]

WORKINGS ALONG THE ADONIS VEIN

The Adonis fault-vein can be followed more or less continuously for 2,000 feet. Most of the outcrop is on the Adonis claim, but the south end of the vein enters the Mikado and Virgin claims (Plate 6). North of the Adonis claim the vein is difficult to follow; but detailed mapping suggests that the vein, or at least a parallel series of veins, strikes towards the Globe and Legal Tender claims. The vein at the north end of the Adonis claim strikes N. 7° E.; where the vein enters the Mikado claim, the strike has gradually turned to N. 7° W. The dip is constant at 78° W.

The vein is composed largely of one to four feet of quartz, which at the surface has many cubic casts from the oxidation and leaching of pyrite. In places the vein breaks into a zone of quartz stringers. The quartz varies in physical character from massive to crystalline and in places banding is suggested by the presence of crystalline coxcombs lining vugs in the massive variety. At the surface the vein cuts through Fusselman dolomite partly to completely replaced by hematite, specularite, pyrolusite, manganite (?), and magnetite.

At the north end of the Adonis claim an inclined shaft has been sunk on the vein to a depth of about 50 feet. Near the southeast side-line of the Adonis claim, about 1,100 feet south of the north shaft, is another inclined shaft probably 100 feet deep. On the south end-line of the Mikado is an additional shallow inclined shaft. Presumably these workings prospected the vein

[41] Wells, E. H., op. cit., p. 44.

for silver ore. The vein in a pit on the Virgin claim is composed of about 18 inches of yellow-brown clayey material. The Adonis vein in the same pit appears to be cut off by a fault that strikes N. 70° W. and dips 72° S. None of the shafts on the Adonis vein could be entered, but they apparently did not reach the sulfide zone as no sulfide minerals were found on the dumps.

MINING METHODS

During the present period of mining activity in the Boston Hill group, all ore has been taken from open pits. The soil overburden is first removed, usually by gasoline shovel (Plates 1 and 10, A). Jackhammers are used to drill deep vertical holes near the face of the pit. The rock is blasted and falls to the bottom of the pit, where it is loaded into trucks by a gasoline power shovel. Where the pit is deep, the ore is broken down by benching. In the Comanche pit, in February, 1944, a high-grade bed was being followed under the east brow, where the ore has to be loaded by hand because of insufficient room for power-shovel operation. As the faces of the pits are advanced and deepened, truck roads are kept open. It is reported[42] that because of this method of handling, ore often is left in the bottom.

LEGAL TENDER GROUP

The Legal Tender mine is located in the northeast corner of the district (see Plate 2). The workings included are those on the Twin Sisters, Rebunel, Globe, and Legal Tender claims (see Plate 6). The mine was worked during and after World War I by R. I. Kirchman and associates[43] and after April, 1924, by the Manganese and Fluorspar Producers Corporation.[44]

Complete records on production from this group are not available, but Wells reports that 37,100 long tons of ore averaging 16 per cent manganese, 35 per cent iron, eight per cent silica, and 0.01 per cent phosphorus, was mined from January 1, 1916, to July 1, 1918. Goodier reports over 200,000 tons averaging 13 per cent manganese, 39 per cent iron, and eight per cent insoluble, mined by the Manganese and Fluorspar Producers Corporation up to about August, 1928.

The rocks which crop out within the boundaries of these claims range from the Second Value member of the Montoya dolomite to the Fusselman dolomite (Plate 2). The main underground workings, covering about two acres of the Legal Tender claim, are largely in the Fusselman dolomite. The workings are entered through an incline, although many other openings throughout the mine connect to the surface. The stoped ground is largely along and to the east of the main entrance.

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42 Patten, E. S., personal communication.
43 Wells, E. H., op. cit., p. 50.
44 Goodier, B. D., Haulage system at the Clan and Seven Sisters mine in Grant County, New Mexico: Colo. Sch. Mines Mag., pp. 23-26, Feb. 1929.

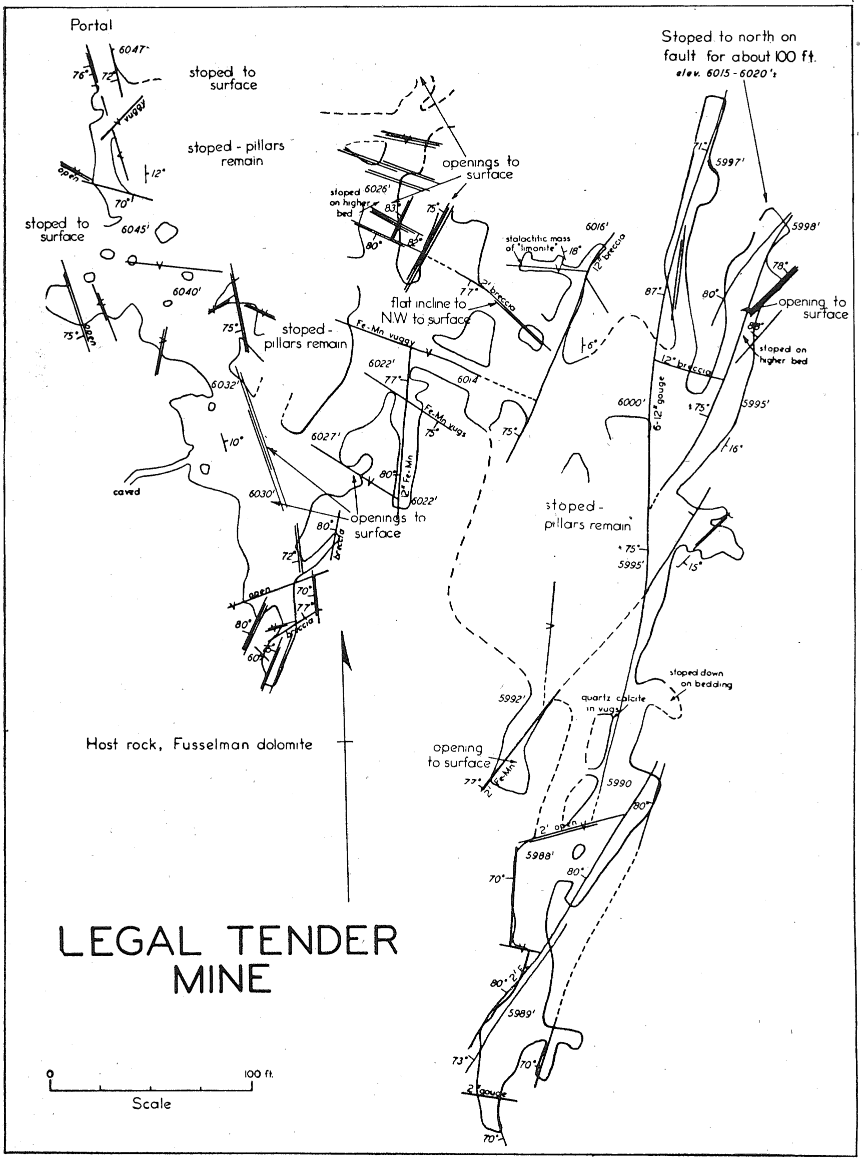

FIGURE 11. Plan of the Legal Tender mine.

The ore body is localized near the base of the Fusselman dolomite (Plate 10, B), which in the west part of the mine has been broken by many steeply dipping, northwest-trending fractures. In the eastern part several faults that range in strike from north to N. 30° E., and in dip from 70-88° W., cut through the formations. One fault contains as much as 12 inches of gouge. The stopes, although following the gentle eastward dip of the dolomite, are elongated parallel to the strike of the faults. Ore has been mined also from beds higher than those shown on the mine plan (Fig. 11). According to Goodier,[45]

> Some [ore bodies] contain only a few tons, others contain as much as 70,000 tons. Some of the fissures have been mined for the full width of the claim but more often the ore bodies are not so long. The height is from a few feet to one hundred feet or more and many times the ore goes to the surface. The width will vary from 3 to 50 feet. Where the mineral-bearing solutions have replaced sections of limestone beds, the height of the ore depends on the thickness of the beds replaced and is from 4 to 15 feet.

The present writer was unable to find any place where tests had been made for deeper ore-bearing beds.

Goodier[46] describes the mining and haulage methods used. The ore was extracted by the room-and-pillar method and was loaded directly into trucks which were driven underground to chutes or to working places. The cost of hauling is reported to have ranged from 12 to 15 cents per ton.

CHLORIDE FLAT DISTRICT

The Silver Cross claim, about 2,500 feet southwest of the Bell shaft (see map, Plate 2), in 1916 shipped 1,132 tons containing 11.7-16 per cent manganese, 34.2-38.7 per cent iron, 12.8-17.1 per cent silica, and 0.047-0.048 per cent phosphorus. Small tonnages have been mined since 1937 from the Chloride Flat mining district.

[45] Goodier, B. D., op cit., p. 23.
[46] Idem.

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Figures in *italic* indicate main references.

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3	Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico; E. H. Wells	1919	Out of print

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5	Gold Mining and Gold Deposits in New Mexico; E. H. Wells and T. P. Wootton, 1932; revised by T. P. Wootton	1940	No charge
6	Carbon Dioxide in New Mexico; E. H. Wells and A. Andreas (Superseded by Circular 9)	1938	Out of print
7	Outlook for Further Ore Discoveries in the Little Hatchet Mountains, New Mexico; S. G. Lasky	1940	Out of print
8	Selected Bibliography on Coal in New Mexico; Robert L. Bates	1943	No charge
9	Carbon Dioxide in New Mexico; Sterling B. Talmage and A. Andreas (Reprinted from Bulletin 18)	1942	No charge

REPORTS OF THE U. S. GEOLOGICAL SURVEY, PREPARED IN COOPERATION WITH THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

U.S.G.S. Bull. 870	Geology and Ore Deposits of the Bayard Area, Central Mining District, New Mexico; Samuel G. Lasky	1936	$0.80
U.S.G.S. Bull. 885	Geology and Ore Deposits of the Lordsburg Mining District, New Mexico; Samuel G. Lasky	1938	1.25
U.S.G.S. Prof. Paper 200	Geology and Ore Deposits of the Magdalena Mining District, New Mexico; G. F. Loughlin and A. H. Koschmann	1942	2.00

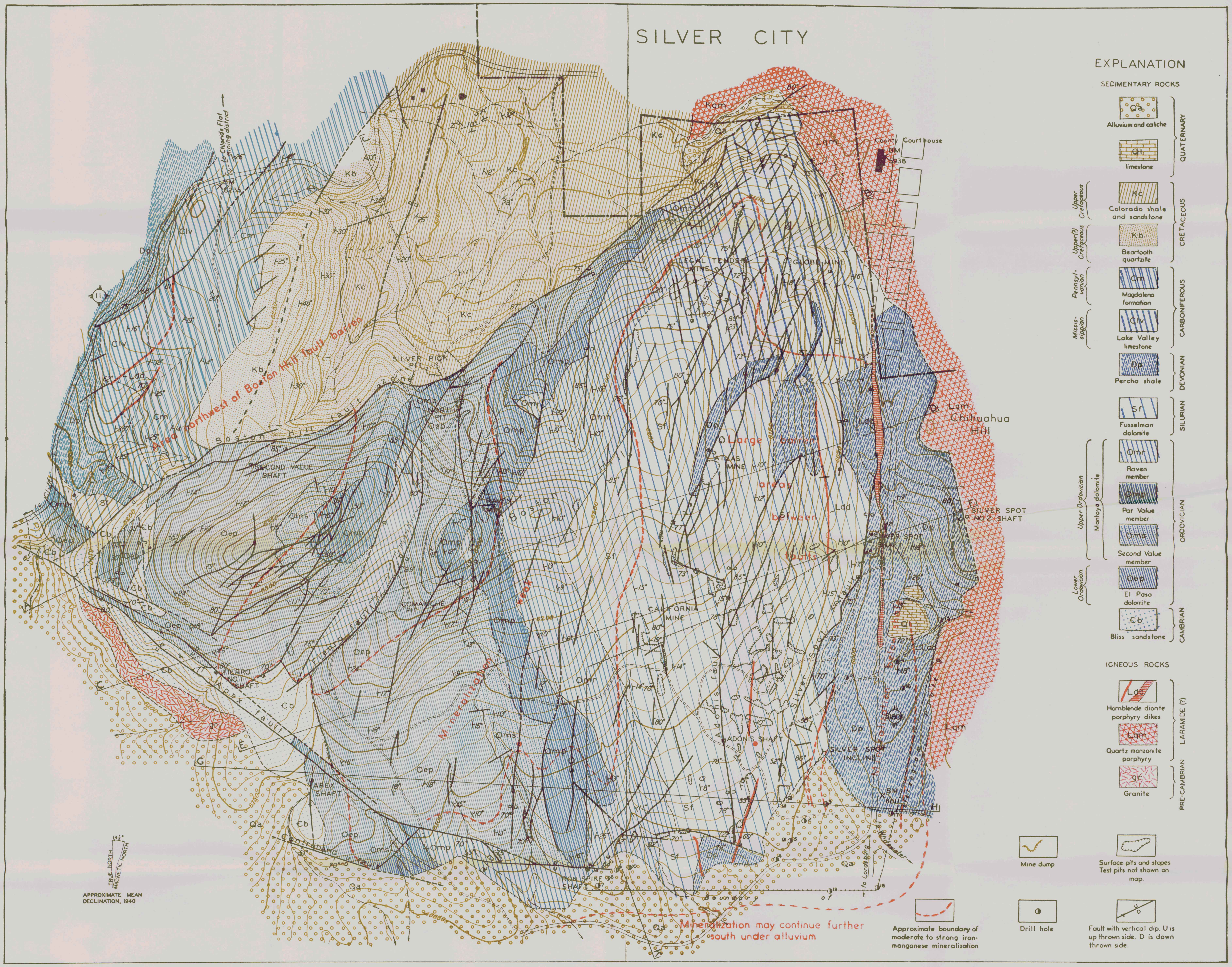
MAPS

Oil and Gas Map of New Mexico; Dean E. Winchester, 1931; revised by Robert L. Bates to July, 1942. (This map is included in Bulletin 18.)	1942	.75 (paper) 1.25 (cloth)
Topographic Map of New Mexico; N. H. Darton. Scale about 8 miles to 1 inch; contour interval 100 meters. U. S. Geological Survey	1925	.75
Geographic Map of New Mexico. Scale 12 miles to 1 inch. General Land Office, Washington, D. C.	1936	.35
A Reconnaissance and Elevation Map of Southeastern New Mexico; Walter B. Lang. Scale 4 miles to 1 inch. U. S. Geological Survey	1943	1.50
Topographic maps of approximately 65 quadrangles in New Mexico and adjacent parts of Arizona and Texas. Scales range from 1,000 feet to 1 inch, to 4 miles to 1 inch. U. S. Geological Survey		.10 each

WELL LOGS

New Mexico	Prices on request

Over 4,500 typed drillers' logs of wells drilled in



Topography by G. S. Entwistle,
D. R. Purvis, F. S. Cook

Geology by L. P. Entwistle

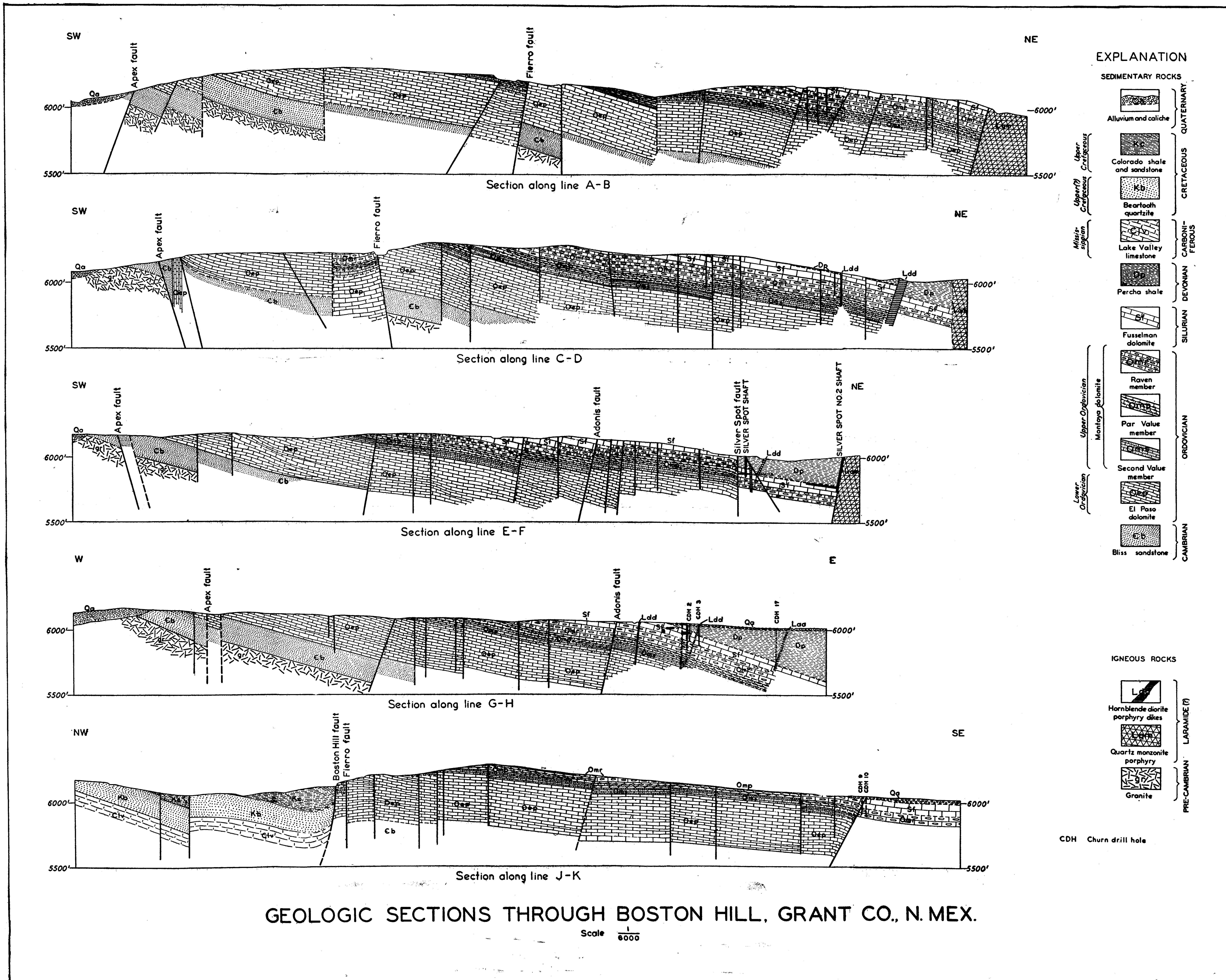
GEOLOGIC MAP OF BOSTON HILL, GRANT CO., N. MEX.

Scale $\frac{1}{6000}$

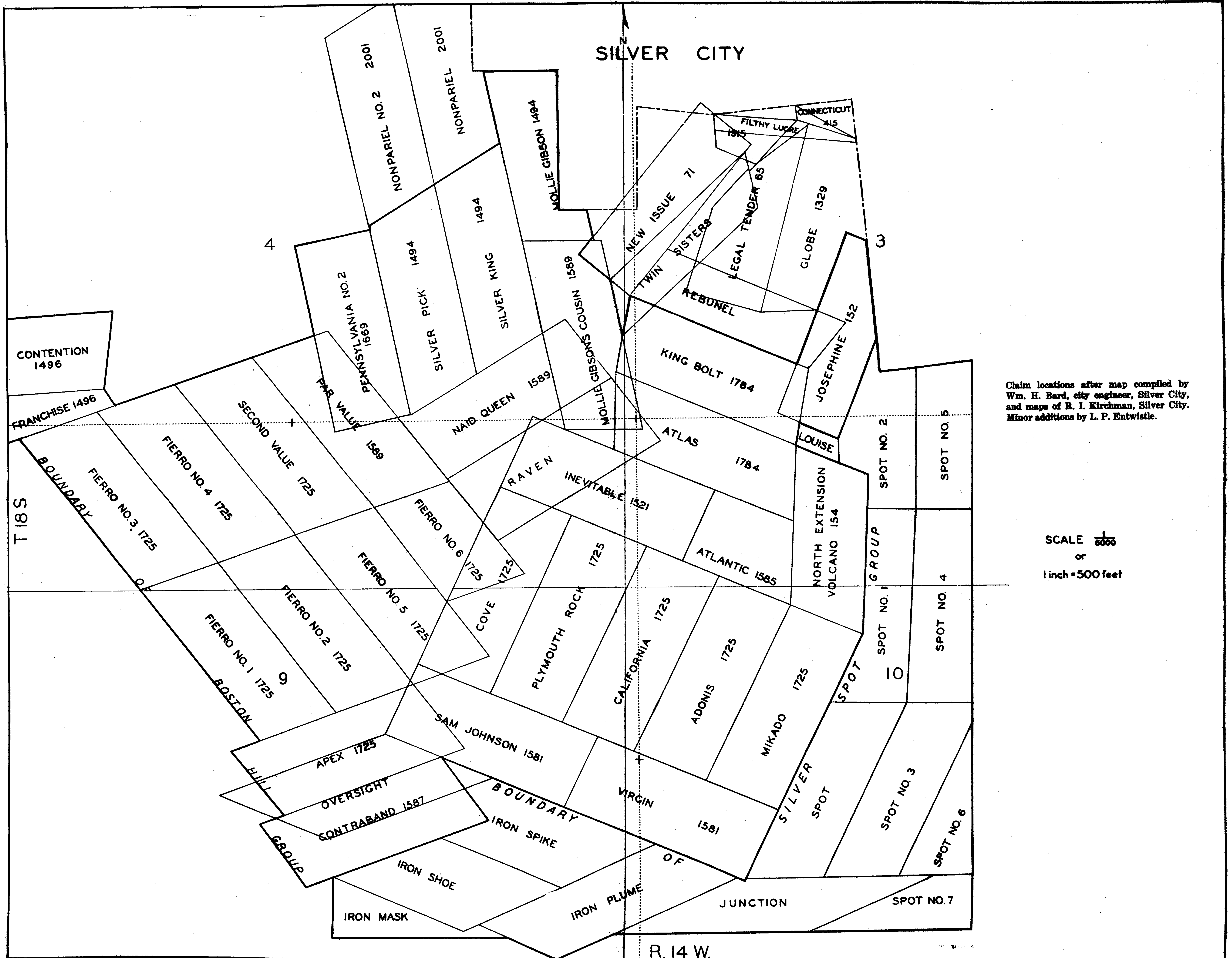
FEET 2500 2000 1500 1000 0 1/4 1/2 MILE

Contour interval 10 feet
Datum is mean sea level
1942

Geologic map of the Boston Hill mining district. Geologic sections along lettered lines are shown on Plate 4.



Geologic sections through Boston Hill mining district. Lines of sections are shown on geologic map, Plate 3. To same scale as Plate 3.



CLAIM MAP OF BOSTON HILL, GRANT CO., N. MEX

Claim map, Boston Hill mining district.