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Fluorspar Resources of New Mexico

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THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

The New Mexico 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 New Mexico Bureau of Mines and Mineral Resources is given on the last pages of this Bulletin.

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PART 1

GEOLOGY AND DESCRIPTION OF THE DEPOSITS

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INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation of fluorspar deposits in New Mexico by the Geological Survey of the United States Department of the Interior was undertaken to stimulate output of fluorspar for war uses, to determine the available reserves, and to supply geological information to war agencies and operators. Many of the data obtained for these purposes are confidential, but those that are not have been assembled in this report to show the progress of investigation and to indicate the work that remains to be done.

In the attempt to encourage new development, priority was given to newly discovered or unproved deposits; thus some of the larger operating properties were not completely investigated. Descriptions of some of these larger properties, therefore, are less detailed than their importance as sources of fluorspar justifies. Some areas, such as the Ladron, San Andres, and Oscura Mountains, were not studied during the present survey, and so little has been written about them that they are not reviewed.

Most of the information in this report was gathered between October 1942 and December 1944. The urgent need for information regarding fluorspar resources, the large number of deposits to be investigated in a short time, and shortages of personnel made it necessary to confine the greater part of the work to studies of small areas along veins and to the preparation of vein and mine maps. For short periods, as many as three field parties employing eight geologists were simultaneously engaged in the

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

work, but usually there were no more than three geologists working on the project.

PREVIOUS INVESTIGATIONS

Previous publications on fluorspar include a review of the deposits of the State by Johnston,[1] studies of the deposits on Fluorite Ridge near Deming by Burchard,[2] and of those near Palomas Gap, Sierra County, by Harley.[3] Fluorspar has been reported by several geologists during their investigations of deposits mined for other products ; references to these reports are made at appropriate places in the text.

ACKNOWLEDGMENTS

The investigation was under the supervision of James S. Williams, Commodity Geologist for Fluorspar, United States Geological Survey. Geologists participating in the field work were Joseph O. Fisher, Robert Smalley, Roy L. Earhart, A. E. Weissenborn, James H. Grunig, Donald A. Warner, Robert D. Trace, and Elliot Gillerman. Special credit should be given to the last two men, who spent several months in assembling data and preparing illustrations for this report.

The assistance of Robert T. Russell and Bettyjean W. Averitt in drafting the illustrations, and of Clyde P. Ross, Helen Duncan, and others in criticizing the manuscript, is much appreciated. Mineral and rock determinations were made by Jewell J. Glass of the Geological Survey. Information was liberally exchanged between the staff of the district office of the Federal Bureau of Mines in Silver City and the Geological Survey's fluorspar party. The owners and operators of the fluorspar properties gave generously of their time and information. Thanks are due also to the New Mexico Bureau of Mines and Mineral Resources for the loan of equipment and for other assistance. Unless otherwise indicated, assays were made by Ira Wright, Silver City, New Mexico.

DISTRIBUTION OF FLUORSPAR DEPOSITS

All the known fluorspar deposits in New Mexico are in mountainous regions (Plate 1). The southwestern region, which is the oldest and the most consistently productive, includes Grant, Luna, Catron, and Hidalgo counties. It is characterized by intense vulcanism of Cretaceous and Tertiary ages. Most of the fluorspar deposits lie within an elliptical area 70 miles long and

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[2] Barton, N. H., and Burchard, E. F., Fluorspar deposits near Deming, New Mexico: U. S. Geol. Survey Bull. 470, 1911.

[3] Harley, G. T., The geology and ore deposits of Sierra County, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 10, 1934.

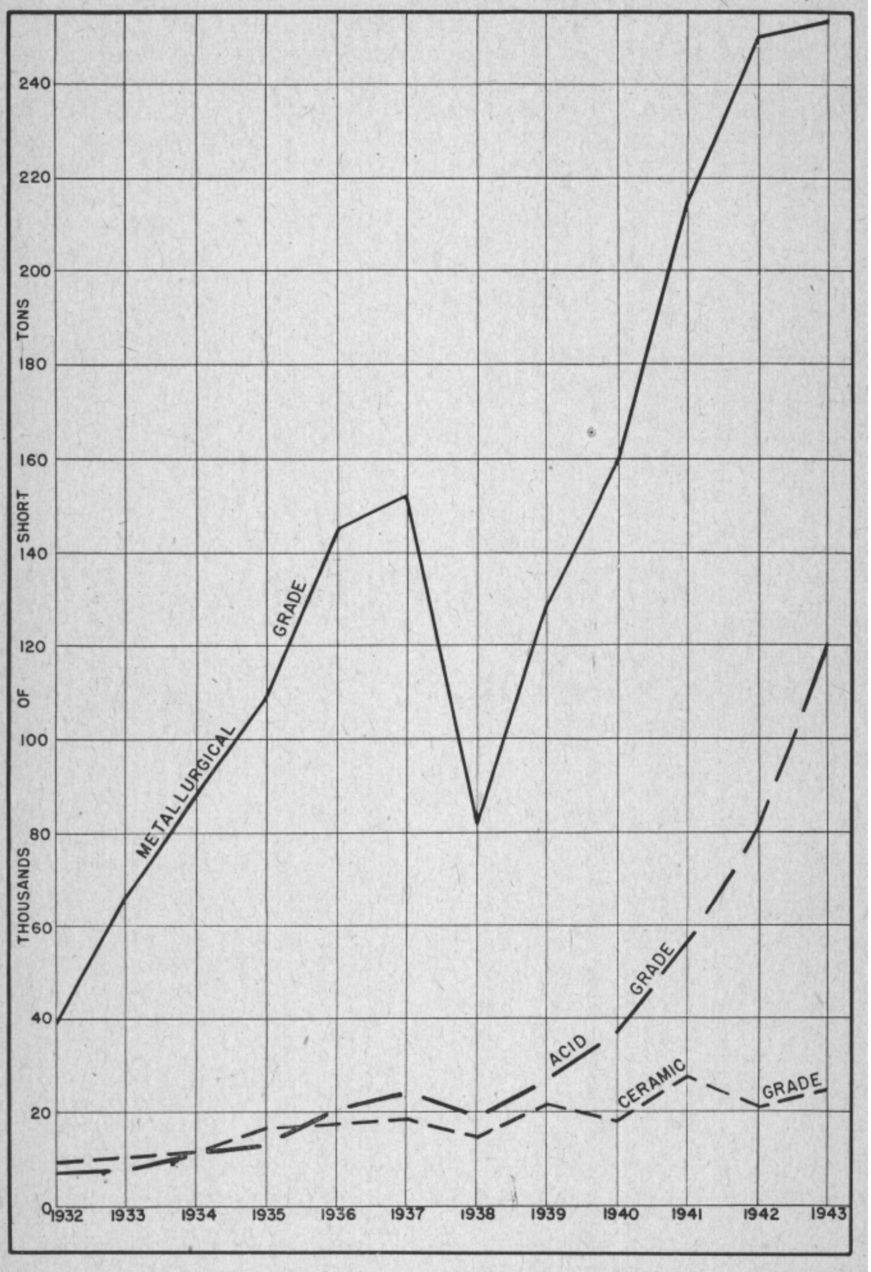

FIGURE 1.—Graph showing the increase in consumption of each of the three grades of fluorspar used in the United States. (Data from Minerals Yearbook, U. S. Bureau of Mines.)

55 miles wide, with the Burro Mountains uplift at its center. The northwestern region includes the deposits within the core of the Zuni Mountains, Valencia County. In recent years this region has become one of the most important sources of fluorspar in the State. The south central region includes Dona Ana, Otero,

TABLE 1. FLUORSPAR MARKETED FROM NEW MEXICO DEPOSITS, 1909-1943[a]

Year	Short tons	Percentage of total U. S. output	Value in dollars	
			Total	Average per ton
1909	710	1.4	$ 3,728	$ 5.25
1910	4,854	7.0	26,250	5.40
1911	4,307	5.0	22,612	5.25
1912	196	0.2	1,176	6.00
1913	5,372	4.7	42,976	8.00
1914	----	--	------	----
1915	485	0.4	3,880	8.00
1916	----	--	------	----
1917	----	--	------	----
1918	3,437	1.3	63,348	18.72
1919	2,346	1.7	37,643	16.05
1920	6,353	3.4	101,460	15.97
1921	3,507	10.0	60,186	17.16
1922	2,180	1.5	30,992	14.22
1923	4,328	3.5	50,861	11.75
1924	2,580	2.0	35,178	13.63
1925	2,639	2.3	40,325	15.28
1926	1,989	1.6	33,058	16.62
1927	2,613	2.3	47,978	18.36
1928	2,589	1.8	50,162	19.38
1929	2,438	1.7	35,682	14.64
1930	2,312	2.6	30,775	13.31
1931	1,026	1.9	13,629	13.28
1932	529	2.1	6,956	13.15
1933	994	1.4	13,250	13.33
1934	2,040	2.4	39,020	19.13
1935	2,726	2.2	39,200[b]	14.38[c]
1936	2,045	1.1	29,837[b]	14.59[d]
1937	3,324	1.9	59,898[b]	18.02[d]
1938	4,066	5.0	71,968[b]	17.70[e]
1939	6,477[f]	3.5	132,408[f]	20.44[f]
1940	7,986[f]	3.4	139,675[f]	17.49[f]
1941	19,089[g]	6.0	355,951[g]	18.65[g]
1942	23,291[g]	6.4	530,025[g]	22.76[g]
1943	37,050[g]	9.1	986,094[g]	26.62[g]
1909-1943	165,878		$3,137,181	$14.76

[a] From annual volumes of Minerals Yearbook for 1937 to 1943, inclusive, U. S. Department of the Interior, Bureau of Mines.

[b] Calculated by multiplying New Mexico's tonnage figures by average value per ton from several states.

[c] New Mexico, Colorado, Nevada, New Hampshire, and Utah.

[d] New Mexico and Nevada.

[e] New Mexico, Nevada, and Arizona.

[f] Includes a small amount from Arizona.

[g] Includes a small amount from Arizona and Texas.

Sierra, Socorro, Lincoln, and Bernalillo counties, in the southern part of the Rio Grande valley. It is characterized by a belt of north-trending valleys between block-faulted mountains, and contains two large intrusive masses—the Gallinas Mountains laccolith in Lincoln County and the Organ Mountains batholith in Dona Ana County. The fluorspar deposits in this region are in sedimentary rocks or in igneous rocks close to their contacts with sedimentary rocks. In the early days of fluorspar mining this region was very important; the fact that little fluorspar came from it during the period 1942 to 1944 is not a measure of its potentialities.

Fluorspar deposits in the north central region, in the upper part of the Rio Grande basin in Taos and Rio Arriba counties, have not been exploited and little has been written regarding them. As they were not visited during 1942-1944 they are not discussed in this report.

SUMMARY OF FLUORSPAR PRODUCTION

In recent years New Mexico has usually ranked fourth among the fluorspar-producing states, its production being exceeded by that of Illinois, Kentucky, and Colorado.

Although the earliest record of fluorspar shipments in New Mexico is for 1909,[4] it is reported [5] that in the 1880's Apolinario Ogas and Pedro Carajal operated the Foster mine 6 miles northeast of Gila, Grant County, and sold fluorspar to the smelters in Silver City. The growth of the industry in the State and the proportion of the country's domestic output supplied by New Mexico are shown in Table 1.

DEFINITIONS OF TERMS

FLUORITE

Fluorite is a mineralogical term that designates naturally formed calcium fluoride, which has the chemical composition CaF_2 and definite physical, chemical, and optical properties.

FLUORSPAR

Fluorspar is the name generally used for ore mined or for mill concentrates that contain the mineral fluorite in noteworthy quantities. It has also been used as a synonym for fluorite, but mineralogists are not in agreement with this use. In this section of the bulletin it is proposed to limit the term fluorite to its mineralogical meaning and to use fluorspar to designate the mineral aggregate mined or studied for its fluorite content. The term fluorspar, therefore, indicates not only the material that is

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[4] U. S. Geol. Survey, Mineral resources of the United States, 1926.
[5] Oral communication from Stephen Villareal, Gila, New Mexico.

sold as ore or the concentrate derived from it, but also the material that is considered of potential economic value by the informed prospector or geologist.

FLUORSPAR ORE

Fluorite-bearing material that can be mined with profit is called fluorspar ore. In the interest of brevity, "ore" is used in this report as synonymous with "fluorspar ore." At the close of 1944, fluorspar in place in New Mexico qualified as ore if it contained at least 35 percent CaF_2, did not contain too high a percentage of undesirable or unseparable impurities, and occurred in bodies sufficiently large and near to market to encourage mining. Low-grade material, containing about 35 percent CaF_2, could be considered ore only if the impurities could be easily removed. The minimum dimensions of an ore body varied with the grade, accessibility, type of operation, and market. Under some conditions, where the ore was of very high grade and the mining largely by hand, veins 18 inches in width could be termed ore bodies, but under most conditions, especially where machinery was used, a minimum width of about 30 inches was necessary for the fluorspar to qualify as ore. The length and downward extent of the deposit also had to be sufficiently great to defray the capital investment as well as the costs of operation.

For several years fluorspar was graded for marketing according to particle size, into the categories of lump, gravel, and ground fluorspar, with various specifications as to the percentage of calcium fluoride and impurities. In recent years emphasis has been placed on the calcium-fluoride content, and fluorspar prepared for sale has been generally classified in three grades : acid, ceramic, and metallurgical. Each of these is further defined by specifications regarding content of CaF_2 and particle size. Immediately before World War II, specifications for acid-grade fluorspar required a minimum of 98 percent calcium fluoride and not more than 1 percent silica. Barite, galena, sphalerite, and iron minerals were allowable only in very small amounts. Specifications for ceramic-grade fluorspar required a minimum of 95 percent calcium fluoride and not more than $2^1/_2$ percent silica, 1 percent calcium carbonate, and 0.12 percent ferric oxide. The fluorspar had to be practically free of lead, zinc, sulfur, iron, or anything that would impair the color of glass or enamel. Ceramic-grade fluorspar was generally ground to 30-mesh or finer and had to be pure white. Specifications for metallurgical-grade fluorspar required a minimum of 85 percent calcium fluoride and not more than 5 percent silica nor more than 0.3 percent sulfur. A common stipulation was that the ore should pass through a 1-inch screen and that the fines should not exceed 15 percent of the minus 60-mesh material.

During the war, owing to the urgent need for fluorspar, specifications for the various grades were lowered by the Office of Price Administration and ceiling prices were set for the various grades. Concentrates having as low as 97 1/2 percent calcium fluoride and as much as 1 1/2 percent silica were classified as acid-grade, and fluorspar of even lower calcium-fluoride content was used in the manufacture of hydrofluoric acid. Approximate specifications for ceramic-grade fluorspar called for a minimum of 95 percent calcium fluoride and not more than 3 percent silica. Approximate specifications for metallurgical-grade at the lowest ceiling price were about 78 percent calcium fluoride and not over 9 percent silica. For fluorspar of metallurgical grade a graduated scale of specifications based on effective units was adopted, but for much of the war period purchasers desiring to buy fluorspar of metallurgical grade with higher specifications than those cited had to obtain special permission from the War Production Board.[6]

GEOLOGY OF FLUORSPAR IN NEW MEXICO

STRATIGRAPHY

The sedimentary and igneous rocks in the fluorspar localities of New Mexico are summarized in Table 2. Further descriptions of the rock units are given in the accounts of the several districts.

TABLE 2. GENERALIZED COLUMNAR SECTION OF ROCKS IN THE FLUORSPAR LOCALITIES OF NEW MEXICO

System	Formation or group	Thickness (feet)	Character of rock
QUATERNARY	Fluviatile and bolson deposits, volcanic rocks		Gravel, sand, and silt, in part consolidated, interbedded with basaltic lapilli and cinders in some localities.
	Unconformity		
TERTIARY	Extrusive, detrital, and older intrusive rocks		Rhyolite, andesite, and latite flows and pyroclastic rocks with intervolcanic conglomerates, sandstones, and siltstones. The older intrusive rocks are chiefly quartz monzonite, monzonite, granodiorite, and syenite and related porphyries, which in Dona Ana and Hidalgo counties were preceded by extensive extrusions of acid, basic, and intermediate rocks.
	?		

[6] For discussion of these wartime specifications and prices, see Office of Price Administration circulars, Maximum Price Regulations 126 dated 11/8/42, 11/30/42, and 4/16/43, and Revised Maximum Price Regulations 126 dated 7/1/43 and 9/16/43.

TABLE 2. GENERALIZED COLUMNAR SECTION OF ROCKS IN THE FLUORSPAR LOCAL] TIES OF NEW MEXICO (CONTINUED)

CRETACEOUS	Late Cretaceous igneous rocks		
	Unconformity		
	Mesaverde group		White, brown, and red sandstones and conglomerates, grading upward into brown sandy shales.
	Mancos shale	900-2000	Dark-gray or brown shale, in places calcareous or sandy; contains many thin sandstone lenses; near Silver City upper part contains interbedded pyroclastic rocks.
	Basal sandstone called:		
	Dakota (?) sandstone in Sierra County	80-100	Hard, gray to buff, massive beds of fine-grained sandstone with locally a bed of conglomerate at the base.
	Sarten sandstone in Luna County	0-300	Light-gray massive quartzitic sandstone with conglomeratic phase at the base.
	Beartooth quartzite in Grant County	90-125	Quartzite with a little interbedded shale and locally a thin conglomerate at the base.
	Unconformity		
PERMIAN	San Andres formation	500	Mostly massive limestones, often cherty and poorly fossiliferous.
	Glorieta sandstone member	300 +	Massive thick-bedded buff sandstone, locally cross-bedded.
	Yeso formation	1000 ±	Light-buff to red siltstone, fine-grained sandstone, and shale.
PERMIAN OR CARBONIFEROUS	Abo sandstone	600-800	Thin-bedded fine- to coarse-grained red and gray sandstone and dark red shale. In Valencia and Lincoln counties there is a basal arkosic conglomerate.
CARBONIFEROUS	Magdalena group	500-1700	Gray cherty limestones and interbedded dark-gray and brown shales (Madera formation), underlain by sandstones, some of which are arkosic, quartzites and shales with interbedded limestones (Sandia formation).
	Lake Valley limestone	100-200	Gray, thin- and thick-bedded limestone with interbedded shale; the upper part is cherty.

TABLE 2. GENERALIZED COLUMNAR SECTION OF ROCKS IN THE FLUORSPAR LOCALITIES OF NEW MEXICO (CONTINUED)

DEVONIAN	Percha shale	150-500	Dark-gray, green, or black fissile shale; in places contains thin sandstones and limestones or bands of limestone concretions.
SILURIAN	Fusselman limestone	50-200	Dark-gray or pink dense limestone with cherty layers near base.
ORDOVICIAN	Montoya limestone	200-350	Light- to dark-gray limestone with minor cherty strata and a thick dense limestone at the base.
	El Paso limestone	300-900	Gray thin- and thick-bedded dolomitic limestone containing many cherty layers.
CAMBRIAN	Bliss sandstone	0-200	Gray to maroon quartzitic sandstones grading into sandy red shale and sandy dark-gray glauconitic limestones.
	Unconformity		
PRE-CAMBRIAN	Granitic complex		Pink medium- to coarse-grained granite, granite gneiss, diorite, and syenite, that contain inclusions of muscovite and biotite schist and are cut by acidic and basic pre-Cambrian dikes.

Age of the Bliss sandstone.—The Bliss sandstone in New Mexico has generally been considered as of Cambrian age, from paleontologic evidence found at three localities—Lone Mountain near Silver City (Plate 1), Apache Canyon in the Sierra Caballos (Figure 14), and the type locality for the formation in the Franklin Mountains a few miles north of El Paso, Texas (Plate 1). From the Lone Mountain specimens E. 0. Ulrich identified *Billingsella coloradoensis* and *Ptychoparia* fragments;[7] from the Apache Canyon collection C. D. Walcott identified *Obolus (Westonia) stoneanus* Whitfield, *Obolus sinoe* Walcott (?), and the following two forms from talus apparently derived from the same horizon: *Plectorthis desmopleura* Meek, and *Lingulella acutangula* Roemer (?);[8] and from the type locality Walcott identified *Lingulepis acuminata, Obolus matinalis (?),* and *Lingulella* fragments.[9] The age of the collections from the first and second localities was determined to be Upper Cambrian and that of the type locality Upper or Middle Cambrian (Upper Cambrian of more recent usage).

Later paleontological work cast doubt on the Cambrian age of the Bliss sandstone at its type locality, and this doubt was heightened by studies in the region of Van Horn, Texas, 120 miles east of El Paso.[10] On Beach

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

[8] Lee, Willis T., Notes on the Lower Paleozoic rocks of central New Mexico: Am. Jour. Sci., 4th Ser., vol. 26, pp. 180-181, 1909.

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

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

Mountain 12 miles north of Van Horn the so-called Bliss sandstone was found to contain Ordovician fossils in addition to the species found in the Franklin Mountains. Those who studied the occurrence correlated it with the Bliss sandstone of the type area and assigned both to the Ordovician. In the present report, however, the Bliss sandstone in New Mexico is considered to be of Cambrian age because of (1) the valid evidence in the Silver City area and in Sierra Caballos, (2) the presence of thick sandstones of known Cambrian age at similar stratigraphic positions in southeastern Arizona,[11] and (3) the striking lithologic and stratigraphic similarity between the Silver City and Sierra Caballos occurrences and outcrops of basal sandstones called the Bliss sandstone in Cooks Peak and in the Mimbres, Florida, Organ, and San Andres Mountains, all of which are within 120 miles of Silver City.

STRUCTURE

Many of the fluorspar deposits occur in areas of deformed rocks into which large masses of igneous rock have been intruded. The intrusions were closely followed by the rise of hot solutions, derived from the same source as the igneous rocks, which made their way along open faults and fractures in which they deposited fluorite and the minerals associated with it. The location of the deposits with respect to the center of the intrusive outcrop depends in part on the distribution of the faults and fractures and in part on the amount of erosion that has taken place, because fluorite is commonly deposited in quantity at some distance from the magmatic source. If the intrusive body has been deeply truncated by erosion, the fluorspar deposits tend to lie at a relatively great distance from the exposed boundary of the intrusive outcrop; in the vicinity of the Organ Mountains this distance is as much as 8 miles. In the Burro and Gallinas Mountains, on the other hand, the fluorspar deposits are closer to the boundary of the intrusive body and this relation suggests that only a small part of the intrusion has been unroofed. In districts where no large intrusive bodies are exposed, the fluorspar deposits may lie directly over unexposed intrusions. The deposits in the Zuni Mountain uplift may belong in this category. The localization of the deposits around such intrusives is further affected by secondary controls, discussed later, which complicate the simple pattern. Some deposits, such as those in the block mountains of the Rio Grande valley, cannot be directly related to igneous masses.

MODES OF OCCURRENCE OF FLUORSPAR DEPOSITS

The fluorspar deposits of New Mexico occur in fissures and fault breccias, and in the cavities and interstices of less fractured rock. Most of the deposits occur in groups of veins or masses, although a few appear to occur singly. The individual deposits

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[11] Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Bisbee folio (no. 112), p. 3, 1904.

may be approximately parallel, as in the Zuni Mountains (Plate 18) ; en echelon, as in the Gila area (Figure 5) ; or in an apparently irregular arrangement, as in the Gallinas Mountains (Plate 12).

SIZE, SHAPE, AND CONTINUITY OF FLUORSPAR DEPOSITS

Within the fissures, breccia zones, and host rock, fluorspar is deposited as veins, either alone or as bodies in veins of other minerals. It also occurs as branching chimneys and irregular masses. The deposits may contain one or more ore bodies, which commonly constitute only a small part of the entire deposit. The ore bodies occur at various places in the deposits, as tabular, lenticular, sheeted, or irregular masses, or as shoots that may overlap, coalesce, or be distinct from one another. A single fissure may contain fluorspar for several thousand feet along its strike, as do those in which the Twenty-one and Twenty-seven veins

TABLE 3. DIMENSIONS OF SINGLE OR EXTENSIVELY COALESCED ORE BODIES IN FLUORSPAR MINES AND MINABLE ROSPECTS

Dimensions	Geologic location: In sedimentary rocks	Geologic location: In igneous rocks
Length		
Number of examples	12	32
Range (feet)	110-1000	60-1000
Average (feet)	425	300
Width		
Number of examples	13	27
Range (feet)	3-15	2- 8
Average (feet)	6.5	4.0
Depth[a]		
Number of examples	12	20
Range (feet)	30-530	20-400
Average (feet)	145	180

[a] In only three mines were the bottoms of the ore bodies determined, and in none was it possible to delimit both top and bottom of an ore body; thus the above figures for depth are probably not entirely representative.

occur in the Zuni Mountains, or a group of veins may extend for several miles, as in the Gila area ; but, as shown in Table 3, the individual ore bodies have relatively small dimensions.

ORIGIN OF FLUORSPAR DEPOSITS

All the fluorspar deposits that have been mined in New Mexico are believed to have a genetic relation to igneous intrusions. The deposits are epigenetic; that is, they were formed later than the rocks in which they occur. Judging from the presence of such gangue minerals as quartz, barite, and calcite, the deposits crystallized from ascending aqueous solutions, acidic in composition, that were derived from the crystallization of deep-seated cooling magmas.[12]

In places these ascending or hypogene solutions had little reacting power, as is indicated by the absence of wall-rock alteration. The resulting deposits, which must have been formed by simple crystallization of the vein minerals in open spaces such as fissures, interstices of fault breccias, and solution cavities, are herein called void-filling bodies. In other places the solutions were more reactive, possibly because of higher temperatures or differences in chemical composition or in the stability of the wall rock. As a result, the rocks with which the solutions came into contact were extensively altered. Finely comminuted rock, such as that in brecciated zones, and chemically unstable minerals such as calcite, the micas, and the feldspars, were replaced by more stable vein minerals, which thus formed replacement bodies. Both replacement and void-filling commonly took place in recurrent stages, and both may have contributed to the formation of a single deposit.

Besides occurring in void fillings and replacement veins, fluorite is formed in minor amounts through other modes of origin. It is found in certain contact-metamorphic deposits, in which limestone at or near the contact of an intrusive body has been replaced chiefly by lime-silicate minerals. An outstanding example of this type of occurrence is the beryllium and tungsten deposits at Iron Mountain, where fluorite is associated with subordinate amounts of specularite, idocrase, chlorite, grossularite, manganese carbonate and silicates, willemite, and chalcedony to form a strikingly banded rock known as "ribbon rock."[13] Fluorite is also reported to have been deposited from sea water[14] at a stage of concentration intermediate between that producing dolomite and that producing gypsum. Fluorine is also found dissolved in certain meteoric waters. No appreciable deposits of fluorite attributable to any of the above modes of origin are to be expected in western New Mexico. Deposits of the evaporite type might be found in the sedimentary rocks of the Permian Basin to the east.

CAUSES OF LOCALIZATION OF FLUORSPAR DEPOSITS

Any change in the temperature, pressure, or chemical composition of mineralizing solutions affects their chemical equi-

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[12] Dunham, K. C., The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 11, p. 139, 1935.

Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, pp. 10, 13, 1928.

[13] Jahns, R. H., Beryllium and tungsten deposits of the Iron Mountain district, Sierra and Socorro counties, New Mexico: U. S. Geol. Survey Bull. 945-C, pp. 52-55, 60, 61, 69, 1944.

[14] Florensky, V. P., Fluorite in the lower Permian of Bashkir S. S. R.: Acad. Sci. U. S. S. R., Comptes rendus, vol. 31, no. 3, pp. 251-254, 1941.

librium and tends to cause deposition of part or all of the dissolved materials where the change takes place. Important changes may be induced by variations in size of the openings and by the physical and chemical composition of the rocks through which the solutions circulate. These controls are the result of (1) the preparation of the ground by fracturing, folding, metamorphism, or solution, (2) the original properties of the country rock, and (3) the order in which the rocks are encountered by the ascending solutions.

PREPARATION OF THE GROUND

The primary factor in the localization of fluorspar deposits is preparation of the ground, as a result of which structural and textural controls are established. The structural features that exert noteworthy control are faults, breccia zones, fractures, and, to a lesser extent, folds. Of these features, faults are by far the most influential, and where breccia zones are present the largest fluorspar bodies generally are deposited. Fractures commonly influence the details in the form of the deposits localized by faults. Control imposed by folds appears to be secondary to that established by faults and fractures.

The most common control exerted by faults is the concentration of fluorspar in lens-like bodies—common features of many mineral veins. This arrangement is attributed to the movement of undulatory walls, by which concave parts of each wall came to be opposite each other, affording open channels for circulation. The Clum East vein and the Spruce Hill No. 1 vein illustrate this condition. Along some faults, notably at the Burro Chief and Greenleaf mines, channels have been formed in brecciated zones at the intersections of branching or cross faults, and large ore bodies have been deposited. At the intersections of faults having less displacement, tight fractures have resulted and branching chimney-like deposits, such as occur at some of the prospects in the Gallinas Mountains, have been formed. A single structure may contain one or more of these types of deposits, or modifications of them. In some areas no controls other than these are apparent, and deposition occurred in a great variety of rocks. In the southwest region of the State, deposits are found in granitic and metamorphic rocks of pre-Cambrian age as well as in intrusive and extrusive rocks of Tertiary and Cretaceous ages, and no relation is shown between the type of rock and the site of the deposit.

In two localities relatively small folds may have had some effect on the localization of fluorspar. One is in the Gonzales prospect, where deposition was chiefly in the highest part of a faulted anticline. The other is in the White Star and Oakland veins, where the widest parts of the deposits coincide with the places where the veins cross an anticline. If the localization of the fluorspar in the crests of these structures is more than a coincidence, it suggests that the rising mineralizing solutions were impounded there by arched impervious rocks.

The ground may also be prepared by metamorphism or solution, as a result of which porous, vuggy, or cavernous voids may be formed. Fluorite may later be deposited in them, as at Iron Mountain and in parts of the Hansonburg mine. The extent of such preparation of ground is closely related to the physical and chemical properties of the rock, which exert a second type of control on the localization of fluorspar.

PROPERTIES OF COUNTRY ROCK

The permeability of the host rock and its susceptibility to alteration are important factors in the control of fluorite deposition. Impermeable rock such as shale may impede the upward migration of the fluids, as they appear to have done in some of the deposits near Hot Springs, where fluorspar is concentrated below shales and thin limestones. Another example is the deposits in the eastern part of Palomas Gap, where fluorspar occurs a short distance stratigraphically below the red shales and flaggy beds of the transition zone between the Magdalena group and the Abo sandstone. Permeable rocks may absorb the solutions and form suitable receptacles for deposition of the contained minerals. Permeability may be expected in arenaceous or other granular rocks, in coarsely crystalline rocks, or along bedding planes.

The chemical composition of the country rock largely determines its susceptibility to alteration. The purer sandstones, dense limestones, and argillaceous rocks are generally not altered. Igneous rocks are ordinarily sufficiently heterogeneous to contain some constituents that can be attacked by fluorine. Dolomitic limestones, however, appear to be more easily altered than igneous rocks; in the vicinity of Hot Springs, dolomitic limestones show more alteration and contain larger fluorspar bodies than the granite a short distance below them.

STRATIGRAPHIC CONTACTS

Throughout western New Mexico many of the fluorspar deposits are located stratigraphically a short distance above or below the contacts of igneous with sedimentary rocks. Sixty-eight deposits are known to be near such contacts. At 35 deposits the distance between the contacts is less than 500 feet; at the others it cannot be determined. Examples of deposits close to the contact are the Blackbird, Blue Jacket, and Gonzales deposits, where a concentration of fluorspar lies just below the contact of the pre-Cambrian rocks with the quartzitic sandstones of the basal Magdalena group. In the deposits near Hot Springs, both impounding by shale and chemical reaction with dolomitic limestone took place a short distance above the granite contact. At Fluorite Ridge the better deposits are in the porphyry just below its contact with argillaceous conglomerates. A similar condition appears to prevail throughout the Zuni Mountains, but it can be demonstrated for only four deposits, the Mirabal, Bonita, Stella Mae, and Spruce Hill deposits, which are only short distances stratigraphically below the contact between the igneous and sedimentary rocks. The other deposits are near the center of the Zuni Mountains uplift, and the sedimentary rocks that once covered them have been removed by erosion. Other examples are cited in the descriptions of the individual deposits.

Replacement bodies are likely to be highly irregular in outline, owing to the variability of the chemical controls, particularly in sedimentary rocks. Large bodies may extend outward from a main vein where it crosses a thick bed or group of beds that were especially susceptible to replacement and were extensively permeated by mineralizing solutions. Such a condition is probably one of the factors that caused the marked irregularities of width in the Universal vein. Narrower bodies may occur along bedding planes where solutions circulated more freely than in the adjoining relatively impervious strata.

AGE OF THE FLUORSPAR DEPOSITS

The fluorspar deposits of New Mexico were not all formed contemporaneously. All those to which an age can be assigned, except the ones at Ojo Caliente in Taos County, are related to the great epoch of vulcanism that took place during late Cretaceous and early Tertiary time. Fluorite veins adjacent to a hot spring at Ojo Caliente are said to have formed since middle or late Tertiary time."

The most definite information as to age of the other deposits is supplied by those in the Pyramid Mountains, Hidalgo County, and in the Organ Mountains and Tonuco Mountain, Dona Ana County. In the Lordsburg district of the Pyramid Mountains fluorite was deposited during the last of six stages of mineralization, all of which were later than a granodiorite intrusion of late Cretaceous or early Tertiary age and earlier than Miocene (?) lavas and associated breccia and tuff that constitute the main part of the mountains." In the Organ Mountains fluorite was deposited

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[15] Lindgren, Waldemar, Graton, L. C. and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 74, 1910.

[16] Lasky, S. G., Geology and ore deposits of the Lordsburg mining district, Hidalgo County, New Mexico: U. S. Geol. Survey Bull. 885, pp. 14-17, 24, 33, 1938.

after the extrusion of early Tertiary lavas and probably after these lavas had been invaded by the quartz monzonite that formed the Organ Mountains batholith.[17] At Tonuco Mountain the fluorspar vein is truncated by an agglomerate belonging to the second period of Tertiary eruptions, which occurred before the Santa Fe erosion cycle, and are therefore of late Oligocene or early Miocene age.[18]

Elsewhere in the State the age relations are less specifically established. In the Zuni Mountains the veins extend into the Abo sandstone (Permian or Carboniferous); in the Sierra Caballos, into the upper Magdalena group (Pennsylvanian); and in the Gallinas Mountains, into the Yeso formation (Permian). In the Mogollon and Pinos Altos Mountains they are in rocks as young as the warped Tertiary extrusive rocks, but are not found in the later, less disturbed Tertiary lava flows. It is very likely that the deposits in Permian or older rocks were formed long after the Permian period—probably in late Cretaceous or early Tertiary time.

PRIMARY MINERALS OF FLUORSPAR DEPOSITS

Fluorite, as previously noted, is the principal mineral of the fluorspar deposits of New Mexico. Only three minerals, quartz, calcite, and barite (Plate 2), are commonly associated with it as gangue minerals. Several other minerals, including galena, sphalerite, and pyrite, are sparingly present. Galena occurs chiefly in those deposits in or near limestones; sphalerite occurs in the Gonzales prospect, where the wall rocks are limestone and granite; pyrite is present in tiny scattered grains in some of the deposits in the Gallinas Mountains. Some of the fluorspar from these mountains also contains the rare mineral bastnäsite, a fluo-carbonate of the cerium metals.[19]

Fluorite, besides being the principal mineral in fluorspar deposits, is a conspicuous gangue mineral in many metalliferous deposits and is associated with helvite in some of the beryllium deposits of the Iron Mountain district.

For complete descriptions of the physical and chemical properties of the minerals mentioned above, the reader is referred to standard works on mineralogy.[20] Only those properties of interest to the prospector or metallurgist are considered in the following paragraphs.

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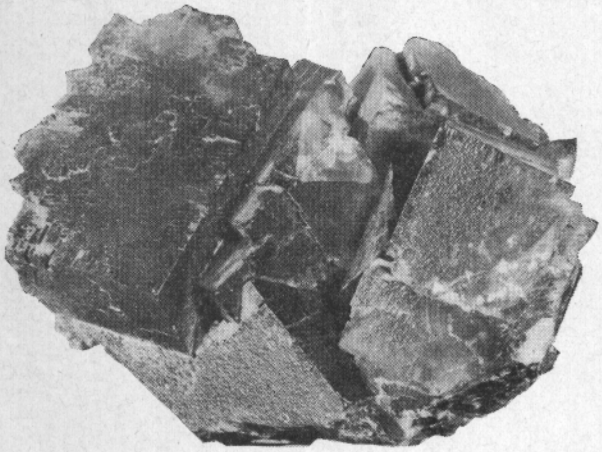
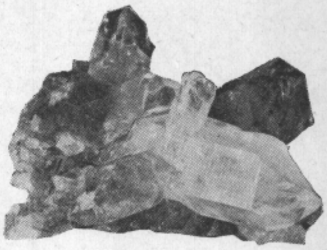
[17] Dunham, K. C., The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 11, p. 139, 1935.

[18] Idem, p. 174, Pl. IX.

[19] Glass, Jewell J., and Smalley, It. G., bastnäsite: Amer. Mineralogist, vol. 30, pp. 601615, 1945.

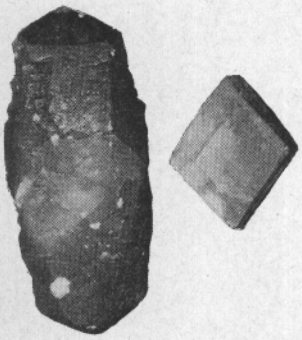
[20] Bayley, W. S., *Descriptive mineralogy:* D. Appleton and Co., New York, 1917. Dana, E. S., *A system of mineralogy,* 6th ed.: John Wiley & Sons, Inc., New York, 1892. Ford, W. E., *Dana's manual of mineralogy:* John Wiley & Sons, Inc., New York, 1929. Kraus, E. H., and Hunt, W. F., *Mineralogy,* 2nd ed.: John Wiley & Sons, Inc., New York, 1928.



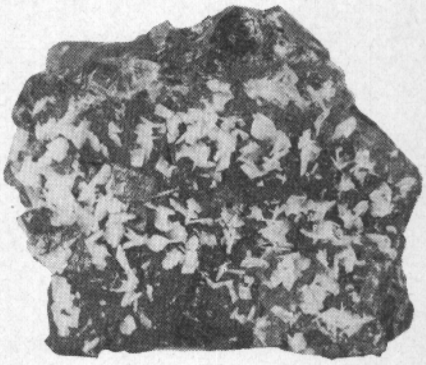


B. Quartz crystals showing striations on one of the prism faces of the large colorless clear crystal.

A. Fluorite cubes. The corner of the middle cube shows incipient separation along an octahedral cleavage plane. The dark tone is due to the purple color. Specimen from the Victory Fluorspar Company mine, Elizabethtown, Illinois.



C. Calcite crystal (left) and cleavage rhomb (right). The crystal is prismatic in habit and has flat pyramidal terminations. Faint lines near the middle of the prism faces are traces of cleavage planes along which the crystal splits to form cleavage rhombs.



D. White barite crystals on purple fluorite. Specimen from the Bill Davis shaft, Mahoning Company, Cave-in-Rock, Illinois.

FLUORITE AND SOME OF THE MINERALS COMMONLY ASSOCIATED WITH IT

FLUORITE

Fluorite, calcium fluoride (CaF_2), is a nonmetallic glassy mineral composed of 51.1 percent of calcium and 48.9 percent of fluorine. It crystallizes in the isometric system, generally in cubes (Plate 2,A), but four-sided double pyramids (octahedra) are not uncommon. A rarer form is the dodecahedron, bounded by 12 four-sided faces. Modifications of the cube, octahedron, and dodecahedron are occasionally observed. In all, 58 crystal forms have been identified.[21] Forms that are not so distinctly crystalline include a fibrous variety that occurs in the fluorspar deposit at Ojo Caliente, and some of the weathered material of the Gallinas Mountains deposits which is so fine-textured as to appear earthy to the unaided eye.

Well-crystallized fluorite has perfect octahedral cleavage. The mineral is brittle and fractures across cleavage planes on uneven, splintery, or conchoidal surfaces. Characteristic colors are blue, purple, and aquamarine, but red, yellow, brown, and violet in various shades or in multicolored patterns are common. Some fluorite is colorless and some white. Colored varieties lose color on continued exposure to strong sunlight, and fade when moderate heat is applied ; the color of light-colored specimens is intensified by the addition of blue under the influence of radium emanations.[22] Transparent or translucent varieties have vitreous lustre ; opaque varieties are glistening to dull.

Fluorite has a hardness of 4.0, and is thus harder than calcite but not so hard as steel or feldspar. It is one of the heavier nonmetallic minerals, having a specific gravity of 3.017 to 3.357[23] with an average of about 3.183. The mineral weighs about 198.5 pounds per cubic foot and has a volume of about 10 cubic feet per ton; however, fluorspar, the ore of fluorite, has a lower specific gravity owing to the inclusion of lighter minerals and to the common presence of voids. Its volume usually ranges from 11 to 12 cubic feet per ton, but may be as much as 16.

Most fluorite is luminescent when heated and glows with a blue or green light, but this color is not related to the color of the original specimen. On heating it also decrepitates, or bursts into small pieces with a crackling noise. Separation of fluorite from gangue minerals by decrepitation, a method applied to ore from the deposits near Hot Springs, is most effective at temperatures between 550° and 650° F.[24] Before the blowpipe fluorite colors the flame reddish yellow, and when heated to 1,387°C.[25] it fuses to an enamel that has an alkaline reaction with turmeric paper.

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[21] Bayley, W. S., op. cit., p. 140.

[22] Idem, p. 141.

[23] Dana, E. S., op. cit., p. 167.

[24] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 39, 1928.

[25] Bayley, W. S., op. cit., p. 140.

Fluorite has a low index of refraction, which for sodium light is 1.4339 to 1.4342.[26] Because of this low refractive index and faint dispersal of light, flawless fluorite is used in certain optical instruments. Fluorite is a nonconductor of electricity. It is highly insoluble in pure water, but is attacked by strong acids and alkaline waters.

Field determinations.—Characteristics that are commonly used to distinguish fluorite in the field are the cubic form of its crystals ; the octahedral cleavage (yielding triangular faces); the hardness (greater than that of a copper cent, calcite, or barite, but less than that of steel or quartz); the specific gravity (greater than that of any of its nonmetallic associates except barite) ; the high degree of insolubility in most acids and water; and the blue, purple, or aquamarine color of some varieties.

Striking fluorite a glancing blow with a pick often produces a momentary blue glow; sparks from siliceous rocks are generally yellow. A simple test for luminescent fluorite is to sift powdered vein material onto hot metal; luminescent fluorite appears as small points of bluish light.

Laboratory tests.—The ability of hydrofluoric acid to etch glass and to dissolve silica is used as a test for fluorine. Proof of the presence of fluorine is ordinarily sufficient to identify fluorite, if the physical characteristics of the specimen are known. A simple test, which is effective if the fluorite is not associated with too much quartz, is made by treating the powdered specimen with concentrated sulfuric acid on a piece of polished glass. After being allowed to stand for at least 5 minutes the mixture is washed off. If fluorine is present in excess of the amount required to combine with the quartz, it will react with the silica in the glass and will produce an etched or frosted surface that is best seen after the glass has been dried.

A more universally applicable test is made by mixing the powdered specimen with 3 or 4 times its volume of potassium bisulfate. A volume of powdered glass equal to that of the specimen should be added if quartz is not associated with the fluorite. The mixture is heated gently in a closed tube that extends far enough above the mixture to permit condensation of the vapors. If fluorine is present, it attacks the glass, forming silicon fluoride (SiF_4), which with water forms hydrofluosilicic acid (H_2SiF_6) with the separation of silicon ($Si0_2$) as a white sublimate. The sublimate is driven up the tube by heating, because of a recombination of the silicon and hydrofluosilicic acid. The presence of $Si0_2$ is proved by breaking the bottom of the tube, gently immersing it in water to wash away the acid, and thus stabilizing the $Si0_2$. The test may be performed conveniently with a beaker instead of a test tube, with a cover glass to catch the sublimate.

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[26] Dana, E. S., op. cit., p. 162.

Mineral separation.[27]—The constituents of a fluorspar deposit and a close approximation of the grade of the fluorspar can be determined by the use of heavy liquids. The procedure is based on the relative specific gravities of the minerals and the liquids by which they are separated. The liquids recommended are bromoform, methylene iodide, and acetone. Chemically pure bromoform has a specific gravity of 2.90. Commercial bromoform serves very satisfactorily, provided its alcohol (4 percent) is completely removed; this can be done by washing it with cold water. The washed commercial bromoform, has a specific gravity of 2.85. Quartz and calcite (specific gravity 2.65 and 2.72, respectively) will float on this liquid, and minerals with specific gravities greater than 2.85, including fluorite, barite, galena, sphalerite, and pyrite (specific gravities: 3.18, 4.5, 7.5, 4.0, 5.0 respectively) will sink. Methylene idoide has a specific gravity of about 3.3 and will therefore float fluorite and allow the barite, galena, sphalerite, and pyrite to sink. Acetone is used to wash the heavy liquids from the mineral grains.

The sample is prepared by crushing the vein material to wheat-sized fragments in a mortar and reducing them to a finer powder by a steel roller and anvil. If the sample is coarse-grained and the minerals are not intimately intergrown, the powder to be tested should be of the size + 100 to – 60 mesh for most efficient handling. If the sample consists of minerals that cannot be separated by grinding to this size, the sample should be ground until all of it passes through an 80-mesh screen. The part retained on a 200-mesh screen is used for the tests, which are made with 10 to 25 grains of material. A large-size separatory funnel is filled one-half to one-third full of bromoform, and the mineral grains are sprinkled slowly into the liquid, which is gently stirred. The grains of specific gravity greater than 2.85 sink and are withdrawn from the bottom of the funnel into a filter-lined large-diameter analytical funnel. Among them are the grains of fluorite. These "heavy" grains are washed carefully with acetone on the filter paper to remove the bromoform. After thorough drying, the "heavy" grains are treated in a separatory funnel, with methylene iodide as the separation medium. Grains with specific gravities greater than 3.3 sink, leaving fluorite and other minerals between the specific gravities 2.85 and 3.3 floating on the surface of the liquid. Although there are many minerals whose specific gravity falls within this range, only a very few are commonly found in fluorspar deposits. A large proportion of these are carbonates such as dolomite, aragonite, and siderite, which can be eliminated by treating with hot hydrochloric acid. The remaining mineral grains whose specific gravities are between 2.85 and 3.3 will closely approximate the

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[27] Abstracted from instructions prepared by J. J. Glass, U. S. Geological Survey.

CaF_2 content of the sample. These grains may be withdrawn from the funnel, washed with acetone, and dried. If quantitative studies are to be made, the separated fractions are weighed and the proportion of each computed.

The procedure may be elaborated by various treatments to separate the constituents further. Among these treatments is the use of solutions having specific gravities different from those of bromoform and methylene iodide. Such solutions are prepared in a wide range of specific gravities by combining either the bromoform or the methylene iodide with acetone, which has a specific gravity of 0.79.

QUARTZ AND OTHER FORMS OF SILICA

Silica, or silicon dioxide ($Si0_2$), occurs in crystalline, cryptocrystalline, and amorphous forms. The most common is the crystalline form, quartz, which crystallizes in the hexagonal system, usually forming prismatic crystals terminated by rhombohedra so developed as to stimulate a hexagonal pyramid. (Plate 2, B.) This form resembles the prismatic form of calcite, but quartz is readily distinguished by its superior hardness and insolubility in dilute hydrochloric acid. Many crystals are greatly distorted, and horizontal striations on the prism faces are common.

The hardness of quartz is 7—distinctly greater than that of steel. It has imperfect cleavage, and breaks along curved or conchoidal faces; this conchoidal fracture, along with its hardness, serves to distinguish quartz readily from the other nonmetallic minerals of fluorspar deposits. The specific gravity of quartz is 2.65. It is generally colorless, white, red, gray, or black. Crystals are transparent to opaque. Granular aggregates of quartz crystals form white (milky), gray, and colorless masses.

The amorphous forms common in the fluorspar deposits are jasper, flint, chert (hornstone), and chalcedony. They are translucent to opaque. Like quartz, they are infusible below 1,470° C., and resist chemical agents except hydrofluoric acid and the alkalies.

CALCITE

Calcite, the carbonate of lime, has the chemical composition $CaCO_3$. It occurs in a great variety of crystalline and amorphous forms. The crystalline varieties belong to the hexagonal system, and are grouped in three types—rhombohedral, prismatic, and scalenohedral. The rhombohedral type tends to be flat and is bounded by oblique parallelograms (Plate 2, C) or combinations of these faces and less dominant scalene triangles. The prismatic type is bounded by elongate parallelograms with flat or steep pyramidal terminations. The scalenohedral or dogtooth type is an elongate tapering crystal bounded by steep scalene triangles that are terminated by others less steeply inclined. Aggregates of calcite crystals are finely to coarsely granular. Fibrous varieties are nodular or stalactitic, and microcrystalline varieties include compact, porous, earthy, and oölitic forms. Calcite is brittle and shatters to form distinctive rhombs (Plate 2, C) produced by its perfect cleavage in three inclined planes.

Calcite has a hardness of 3 and a specific gravity of 2.713 to 2.723. Its lustre is vitreous to earthy; it may be of any color or colorless. In thick transparent fragments the characteristic double refraction is readily discernible. Calcite effervesces briskly in cold dilute acids, including strong vinegar—a property that, together with its hardness and cleavage, distinguishes it from the other minerals commonly occurring in fluorspar veins. Calcite is infusible but colors a flame reddish yellow.

BARITE

Barite (Plate 2, D), sometimes called heavy spar, is a sulfate of barium, with the chemical composition $BaSO_4$. In the fluorspar deposits of New Mexico barite is distinctly crystalline, although massive varieties occur elsewhere. It crystallizes in the orthorhombic system. The crystals are usually tabular or prismatic in habit, but may be very complex. The crystals occur singly or in radiating or crestlike clusters. Basal and prismatic cleavage are perfect and yield six-sided prisms whose faces are oblong or square—a feature that distinguishes barite fragments from those of fluorite (triangular cleavage faces) and calcite (oblique parallelograms). Barite is brittle and has a hardness of 2.5 to 3.5 and a specific gravity of 4.3 to 4.7. This high specific gravity is a distinguishing property of barite. In the fluorspar deposits of New Mexico barite is commonly white or pink and opaque, but elsewhere light-blue, yellow, brown, and red varieties that are transparent to opaque have been reported. Barite is insoluble in acids. It decrepitates and fuses before the blowpipe, coloring the flame yellowish green and yielding a mass that gives an alkaline reaction with litmus paper. Barite, if fused with soda, yields a product that when pulverized and moistened leaves a brown stain on silver.

A table comparing and summarizing the diagnostic characteristics of fluorite, calcite, quartz, and barite follows.

TABLE 4. DIAGNOSTIC CHARACTERISTICS OF FLUORITE, CALCITE, BARITE, AND QUARTZ[a]

Characteristic	Fluorite	Calcite	Quartz	Barite
Chemical Composition	CaF_2	$CaCO_3$	SiO_2	$BaSO_4$
Crystal system	*cubic*	hexagonal	hexagonal	orthorhombic
Common crystal forms	*cubes*, modified cubes, *octahedrons*	*rhombohedral*, long prismatic, *scalenohedral*	*hexagonal prism terminated by pyramidal faces, generally striated horizontally*	*tabular*, prismatic, crested
Other forms	granular, fibrous	granular, fibrous, porous, earthy, oölitic, *stalactitic*	compact	compact, fibrous, reniform
Cleavage	*octahedral*, perfect	*rhombohedral*, perfect	indistinct	*basal*, prismatic, conspicuous
Fracture	flat, conchoidal, inconspicuous	conchoidal	*conchoidal*, conspicuous	uneven
Hardness	*4*	*3*	*7*	2.5 – 3.5
Specific gravity	3.18	2.72	2.65	*4.5*
Common colors	green, blue, purple, white, red, brown, yellow	white or any color	colorless, white, red, black, gray, brown	white, gray, blue, red
Lustre	vitreous	vitreous to earthy	vitreous, waxy, dull	vitreous, pearly
Solubility in HCl	insoluble	*effervesces briskly in cold dilute acid*	insoluble	insoluble
Index of refraction	$n = 1.434$	$\varepsilon = 1.487$ $\omega = 1.659$ *double refraction prominent*	$\varepsilon = 1.5532$ $\omega = 1.5441$	$\alpha = 1.637$ $\beta = 1.638$ $\gamma = 1.649$
Color of flame	reddish yellow	reddish yellow	infusible before the blowpipe	*yellowish green*
Luminescence	generally strongly fluorescent and phosphorescent when heated			

[a] Diagnostic characteristics are *italicized*.

MINOR PRIMARY MINERALS

Bastnäsite.—Bastnäsite, a rare fluocarbonate of the cerium metals, has the approximate chemical formula (Ce, La, Di) 2C309 • (Ce, La, Di) F_3. It was found in specimens of fluorspar from the Gallinas Mountains in October 1943 by Jewell J. Glass of the Federal Geological Survey.[28] In this locality it occurs in thin tabular hexagonal crystals about 4 millimeters wide and seldom more than 1 or 2 millimeters thick. It is thinly laminated and has perfect basal cleavage. The hardness is 4.5 and the specific gravity 4.99. The lustre is vitreous to waxy, and the color is honey yellow. Bastnäsite is soluble in strong sulfuric acid, with effervescence of carbon dioxide and evolution of hydrofluoric acid.

Galena.—Galena, a sulfide of lead (PbS), is the most common of the metallic minerals in the fluorspar deposits. It crystallizes in the isometric system, usually in cubes or octahedra, and has perfect cubic cleavage. It has a metallic lustre, lead-gray color, and dark-gray streak. Its hardness (2.5), lead-gray color, cubic crystals, and specific gravity (7.5) are distinguishing features.

Sphalerite.—Sphalerite, zinc sulfide (ZnS), occurs in distinct crystals and less commonly in microgranular aggregates. Tetrahedra (crystals bounded by four triangular faces) are common but are generally modified by other forms. Sphalerite has a resinous lustre and is colorless, white, brown, black, red, or yellow. The hardness is 3.5 to 4 and the specific gravity 3.9 to 4.2.

Pyrite.—Pyrite, iron disulfide (FeS_2), is a brass-yellow metallic mineral that occurs in cubes, pyritohedra (twelve-sided crystals), and octahedra. The faces of the crystals are often striated. Its hardness (6.5), metallic lustre, and color are diagnostic.

Other primary minerals reported in the fluorspar deposits of New Mexico are chalcopyrite and specularite.29

SECONDARY MINERALS OF FLUORSPAR DEPOSITS

No comprehensive list of secondary minerals of fluorspar deposits was assembled during this investigation. Those which were especially noted include hematite and limonite in the Burro Chief and Red Cloud deposits ; manganese oxides in the Tortugas mine and Good Hope prospect ; azurite, malachite, and chrysocolla in the Burro Chief mine and in some of the deposits in the Gallinas Mountains ; anglesite in the lead-bearing veins of the Sierra Caballos and Oscura Mountains ; and gypsum in the upper part of the Oakland vein and in the breccia beneath the Universal

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[28] Glass, J. J., and Smalley, R. G., Bastnäsite: Amer. Mineralogist, vol. 30, p. 602, 1945.

[29] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 12, 1928.

vein. Vanadinite, descloizite, pyromorphite, cerussite, and cuprodescloizite have been reported from the deposits in the vicinity of Palomas Gap.[30]

WALL-ROCK ALTERATION

The rocks adjoining the fluorspar deposits are commonly altered. In many deposits, notably those in the Sierra Caballos, the walls have been extensively silicified. In many the host rock has been invaded and replaced by fluorite. Some of the deposits in the Burro and Sandia Mountains show sericitization of the walls. In others, kaolin and chlorite have been formed. In the vicinity of the Clum mine the adjoining rocks have been bleached by alteration of biotite. Staining of the walls by oxidized iron is common. Some of these alterations took place at the time the vein was formed and some occurred later. Distinctions of age were not generally made during the examinations.

AIDS TO PROSPECTING

The canny prospector will search for fluorspar in areas close to those where it has already been found, but other localities need not be avoided. The large demand for fluorspar is of relatively recent origin and as a result not all favorable areas have been thoroughly investigated.

Any kind of rock may be host to a fluorspar deposit, but fluorspar probably will not be found in the Santa Fe formation (Miocene and Pliocene), the Gila conglomerate (Pliocene and Pleistocene), the Palomas gravel (Pleistocene), or younger formations. If, as believed, fluorspar veins were formed shortly after the solidification of intrusive rocks, search should be directed to areas where such rocks are exposed or to rocks known to be intruded by them. The quartz monzonite batholith of the Organ Mountains and the intrusive bodies of monzonitic rocks in the Big Burro Mountains and the Cooks Range are typical. In some localities, for example in the Sierra Caballos Range, erosion has not exposed large intrusive bodies, and there is little to guide the prospector except the fact that fluorspar has been found there.

Because of the brittleness of fluorite, high-grade fluorspar veins usually do not crop out conspicuously unless they are on barren slopes. If the fluorspar is siliceous, however, the vein is often indicated by wall-like outcrops of prominent boulders. (See Plates 22, A and 23, A.)

If the vein is not exposed, its presence is sometimes indicated by fragments of vein material in the soil over the eroded vein or in the slope wash or talus below it. Unless the vein is very siliceous,

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[30] Hess, F. L., Vanadium in the Sierra de los Caballos, New Mexico: U. S. Geol. Survey Bull. 530, pp. 157-160, 1913.

these fragments are not often found at a great distance from the parent vein because they disintegrate readily.

Faults that occur within the favorable areas previously noted should be investigated by the fluorspar prospector. Brecciated zones, the intersections of fractures, and other openings along faults are favorable sites for fluorspar deposition. Areas that have been chemically altered by hot springs or other mineralizing solutions may contain fluorspar deposits whose positions may be approximately indicated by zones of unusual discoloration of the rocks.

BERNALILLO COUNTY

GENERAL RELATIONS

The fluorspar deposits of Bernalillo County are in its mountainous eastern part. One group is in the northern part of the Sandia Mountains, 17 miles northeast of Albuquerque and about 2,000 feet higher ; another group is in the Manzanita Mountains, about 16 miles southeast of Albuquerque and 1,300 to 2,000 feet higher (Figure 2). The deposits in the northern group are most easily accessible from the east side of the Sandia Mountains by way of State Route 45, which intersects U. S. Highway 66 thirteen miles east of Albuquerque. The deposits in the southern group are reached most easily from the west by roads leading south from U. S. Highway 66. Rail transportation is supplied by the Atchison, Topeka, and Santa Fe Railway, which passes through Albuquerque. The nearest fluorspar mill is the Zuni Milling Company's flotation mill at Los Lunas, 18 miles south of Albuquerque.

GEOLOGY

The escarpment forming the west faces of the Sandia and Manzanita Mountains is composed chiefly of pre-Cambrian rocks. In the Sandia Mountains these consist mainly of porphyritic gray or pink granite containing muscovite and much hornblende.[31] In the Manzanita Mountains they consist of gneissic granite and syenite. In both areas, these rocks contain large and small inclusions of metamorphic rocks, and the entire complex is cut by dikes of granite and diabase.

The pre-Cambrian rocks were studied in the Coyote Springs area (Figure 2), where the principal rock is flesh-red syenite composed essentially of orthoclase and microcline that have been slightly sericitized.[32] In the vicinity of some faults the syenite is white, as though bleached by solutions circulating along the fault. In general it has a gneissic structure with planes of foliation striking eastward and dipping about 45° S. Inclusions of micaceous schist and gneiss of sedimentary origin are common and range in size from masses a few feet wide and several times as long to huge blocks hundreds of feet in diameter. A large inclusion north of the Blackbird mine in the Coyote Springs area shows gradations from dark-gray quartzitic sandstone at the center to schist at the margins. The planes of schistosity in the

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[31] Ellis, R. W., Geology of the Sandia Mountains: N. Mex. Univ. Bull. 4 (geol. ser. 3), P. 22, 1922.

[32] Determination by J. J. Glass, U. S. Geological Survey.

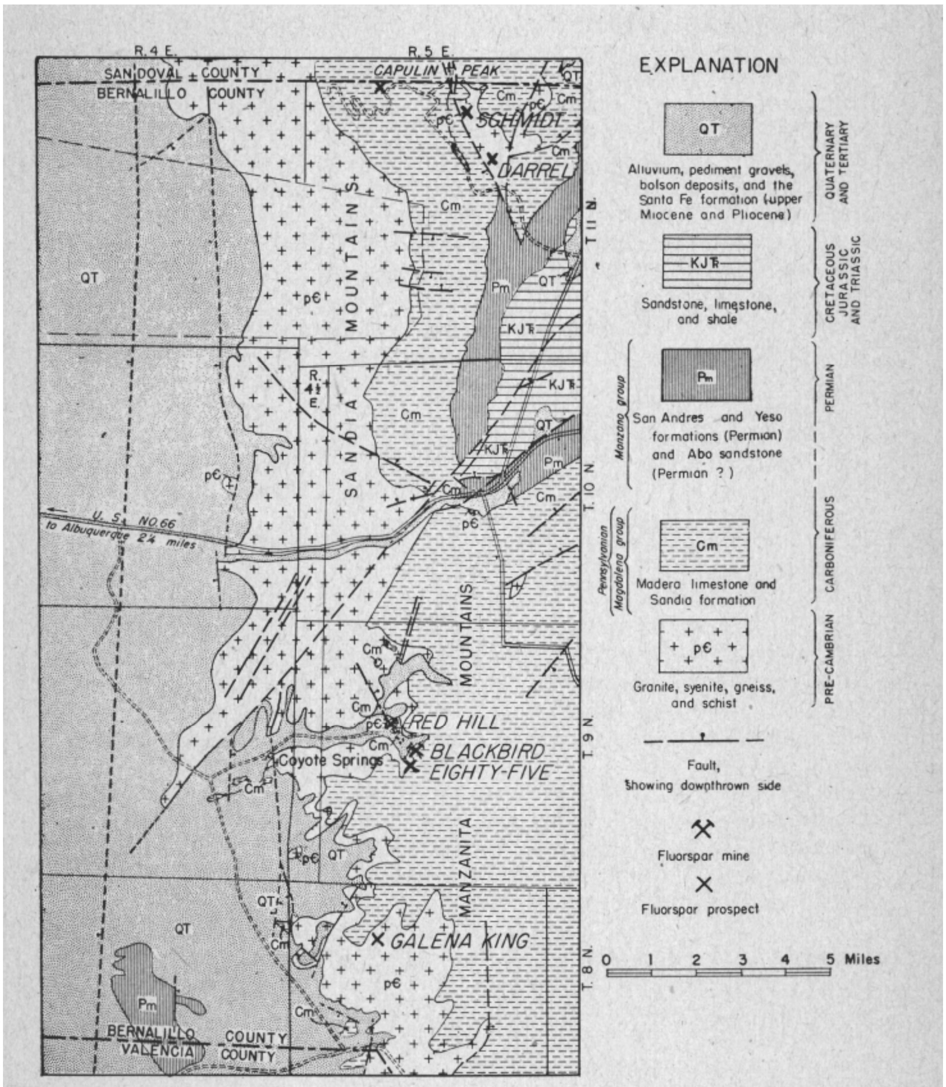

FIGURE 2.—Geologic map showing the approximate locations of fluorspar mines and prospects in the Sandia and Manzanita Mountains, Bernalillo County.

inclusion strike generally N. 65° E. and dip about 75° SSE. A smaller mass of gneiss, also derived from sandstone, is exposed in the escarpment a short distance west of the Blackbird mine. It forms a part of the eroded surface of the pre-Cambrian complex and is unconformably overlain by sedimentary rocks of Paleozoic age. A thinly laminated muscovite schist that was probably originally siltstone or shale lies 350 feet southwest of the shaft of the Blackbird mine.

The syenite near the mine is cut by medium-grained black to dark-red diabase dikes of even texture. They are composed of feldspar and ferromagnesian minerals. The feldspar (labradorite) forms long laths, which are extremely altered to sericitic material, green chlorite, and red iron oxide. Magnetite, most of which has been altered to hematite, and a small amount of ilmenite and secondary quartz are also present.[33] One of the dikes is overlain unconformably by Paleozoic sedimentary rocks.

A dike of dark-brown or black dense microcrystalline basalt, approximately a quarter of a mile south of the Blackbird mine, cuts both the syenite and the overlying Paleozoic rocks and is therefore much younger than the diabase. It was formed before the period of fluorite deposition, however.

The Paleozoic rocks, which were deposited on an unevenly eroded surface of the pre-Cambrian complex, generally form cliffs at the top of the escarpment but also occur near its foot in small scattered outcrops—remnants of down-faulted blocks that are almost completely covered by talus. In the escarpment the Paleozoic rocks commonly dip eastward. The basal beds are of Pennsylvanian age and belong to the Magdalena group.[34] Permian and Mesozoic strata lie above them. Bolson deposits, pediment gravels, and alluvium of late Tertiary and Quaternary ages that occupy the Rio Grande valley overlap the foot of the escarpment. Recent alluvium forms flood plains in the larger canyons (Plate 2). As no known fluorspar deposits in this area occur in sedimentary rocks younger than the Magdalena group, only rocks of this group are described.

The Magdalena group comprises the Sandia formation and the overlying Madera limestone. The Sandia formation consists chiefly of sandstones, siltstones, and shales, with a basal member of conglomerate or limestone that varies in thickness and is locally absent. The average thickness of the formation, as indicated by four sections measured by Read,[35] is 185 feet. East of Coyote Springs the thickness ranges from a few feet to 55 feet.

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[33] Determination by J. J. Glass, U. S. Geological Survey.

[34] 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. 19-20, 1942.

Read, C. B., and others, Geologic map and stratigraphic setions of Permian and Pennsylvanian rocks of parts of San Miguel. Santa Fe, Sandoval, Bernalillo, Torrance, and Valencia counties, north central New Mexico. U. S. Geol. Survey, Oil and Gas Investigations, Prel. Map 21, 1944.

[35] Read, C. B., op. cit.

The Madera limestone is subdivided into a lower sequence of gray cherty limestones and calcareous shales and an upper series of arkosic limestones and sandstones. The sections measured by Read[36] show that the formation has an average thickness of 1,265 feet.

The dominant structural feature in the eastern part of Bernalillo County is an eroded warped homoclinal block that has been faulted on the west and tilted eastward. This block forms the Sandia and Manzanita Mountains. The principal faults are west of the escarpment, trend northward, and are extensively covered by valley fill. Their throw has been estimated by various geologists [37] to range from 4,000 to 8,000 feet. The east-dipping homocline has been fractured by faults that trend principally north, northwest, and northeast (Figure 2). These or later movements tilted the fault blocks in various directions and produced brecciated zones and open fractures. Some of the north-and northwest-trending faults were filled with fluorite and related minerals.

FLUORSPAR DEPOSITS

All the fluorspar deposits are fissure veins or breccia fillings and all except the Capulin Peak deposit are relatively close to the contact of the pre-Cambrian and sedimentary rocks. (See Figure 2.) The Capulin Peak vein is apparently in the Madera limestone, and a fluorspar vein a few hundred feet south of the Eighty-five mine is in the Sandia formation. The other deposits are in pre-Cambrian rocks. The strike of the veins ranges from north to N. 30° W., which approximately corresponds to the general trend of the mountain structure. The veins contain well-crystallized fluorite, with quartz, galena, and barite as gangue minerals. The period of fluorspar deposition was later than early Pennsylvanian.

The mines and prospects in Bernalillo County are listed in Table 5.

The Capulin Peak, Galena King, Schmidt, and Darrel prospects were not visited. The following descriptions of the first two were taken from the references listed in Table 5. The Schmidt and Darrel prospects have not been described in the literature.

CAPULIN PEAK PROSPECT

The Capulin Peak deposit is in the northern part of the Sandia Mountains near the summit of Capulin Peak, approximately 1,000 feet north of the road to Sandia Crest (Figure 2). In

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[36] Read, C. B., idem.

[37] Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico : U. S. Geol. Survey Prof. Paper 68, p. 163, 1910.

Ellis, R. W., op. cit., p. 30.

TABLE 5. FLUORSPAR MINES AND PROSPECTS IN BERNALILLO COUNTY

Name	Approximate location	Reference a
Capulin Peak prospect	NW14, T. 11 N., R. 5 E.	27:118-119; 46: 74
Schmidt prospect[b]	NE14, T. 11 N., R. 5 E.	
Darrel prospect[b]	NEU, T. 11 N., R. 5 E.	
Blackbird mine	Near center of T. 9 N., R. 5 E.	
Red Hill prospect	Near center of sec. 17, T. 9 N., R. 5 E	
Eighty-five prospect	Near center of T. 9 N., R. 5 E.	
Unnamed prospect	Near center of T. 9 N., R. 5 E.	
Galena King prospect	E 1/2 sec. 8 or W1/2 sec. 9, T. 8 N., R. 5 E.	27:119-121; 46:74-75; 30:131-132a

Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

1927 the workings consisted of an inclined shaft about 20 feet deep and small pits dug along fluorspar-bearing veins that occupy faults in limestones of the Magdalena group. The vein in the shaft, which strikes N. 30°W. and dips 60° SW., is 3 feet wide and consists of fault breccia cemented and partly replaced by purple fine-grained 'fluorite. Small pockets of galena occur in the vein. The gangue minerals are barite, quartz, and calcite. The extent of the ore body was not determined.

BLACKBIRD MINE

The Blackbird mine is 14 miles east-southeast of Albuquerque in the south side of Hell Canyon, 3 miles east of Coyote Springs (Figure 2). The main shaft is on the Jay Bird claim, which is one of a group of 10 unpatented claims filed by J. E. Mock, Fred Miller, and others, and operated by them as the Manzano Fluorspar Company. The group, comprising the Blackbird, Jay Bird, Keystone, White Eagle, Little Queen, Virginia, White Hill, Limestone Hill Nos. 1 and 2, and Red Hill claims, was leased to the American Fluorspar Company in January 1943. When the property was visited in August 1943 the workings consisted of a shaft 49 feet deep, a drift 87 feet long on the 42-foot level southeast of the shaft, and some stopes above the drift. The stopes were later extended to the surface and the shaft was deepened. Exposures on other claims in the group have been explored in two shallow shafts and several pits.

The mine is along an approximately vertical fault that cuts the pre-Cambrian rocks and the overlying Sandia formation. It follows the west side of one of the diabase dikes within the pre-Cambrian complex. The mine shaft is at the edge of the valley fill of Hell Canyon, whence the fault can be traced 700 feet S. 32° E. to the rim of the bench 250 feet above the shaft. Beyond these limits, in both directions along the strike, the fault is covered with soil. Fluorspar was deposited along this fault in solid veins where there was little brecciated rock, and as interstitial fillings in the parts of the fault that contained coarse breccia. Some replacement of the rock also took place. This deposit was fractured and in some places brecciated by later faulting.

The vein ranges in thickness from a few inches to 5 feet. At the shaft it is about 2 feet thick. At a place 90 feet south of the shaft it pinches to a few inches, but 80 feet farther south it widens to 2 feet, and immediately above the basal contact of the sedimentary rocks it is 5 feet thick. The ore is a crystalline intergrowth of fluorite with minor percentages of quartz, galena, and barite. The fluorite for the most part is fine-grained, but relatively large crystals are scattered through it. Many small cavities in the ore are lined with euhedral fluorite crystals terminated by octahedral faces or by pyramids coated with tiny cubes in parallel arrangement. The fluorite is green and purple near the surface but is predominantly green underground. Galena occurs in crystalline aggregates up to 1 inch in diameter, and as tiny isolated crystals. Bladed crystals of barite are common along the margins of the ore bodies. Some quartz occurs with the fluorite, but most of the silica indicated by assays is from inclusions of wall rock. Fines from the ore and selected samples show more than 85 percent CaF_2, but run-of-mine ore contains a much lower percentage, the amount depending upon the dilution by waste. Analyses of samples from various parts of the workings are given in Table 6.

TABLE 6. ASSAYS OF ORE FROM THE BLACKBIRD MINE

Assay No.	Description of sample	Chief constituents (percent) CaF_2	SiO_2	$BaSO_4$	$CaCO_3$
1.	Chip sample from face, 87 feet south of shaft on 42-foot level	59.4	18.68	0.59	1.39
2.	Fines from sample No. 2 screened through 60-mesh screen	97.2	1.7	----	----
3.	Chip sample from cut at top of hill sample 5 feet	56.4	26.4	----	----
	525 feet SSE. of shaft; width of				
4.	Do.	59.54	38.67	1.79	0.57

1, 2, 4—Published by permission of the American Fluorspar Co.
3—Sampled by R. G. Smalley, U. S. Geological Survey.

RED HILL PROSPECT

One of the fluorspar prospects in the group of claims leased by the American Fluorspar Company is on the Red Hill claim, 3,375 feet northwest of the Blackbird shaft. The workings include several caved trenches, and a shaft 42 feet deep that exposes a mineralized zone $4^1/_2$ feet wide. In one of the trenches a zone of fluorspar veins and fractured rock 6 feet wide is partly exposed. At the shaft the vein occurs in a vertical fault breccia that strikes N. 43° W. Its southwest wall is clearly defined and is marked by striations pitching from 20° to 35° SE., about parallel with those on the Blackbird fault. The Red Hill fault is in syenite that is flesh-red in the southwest wall but bleached white in the opposite wall. The Sandia formation, which rests upon the syenite, crops out within 40 feet of the shaft.

In the shaft a hanging-wall vein about 10 inches thick and a footwall vein about 8 inches thick, both of high-grade fluorspar, are separated by a brecciated zone 3 feet thick in which the breccia is partly replaced by fluorite. An assay of samples from the hanging-wall and footwall veins showed 73.3 percent CaF_2.[38] A channel sample including the veins and the intervening breccia showed 38.6 percent CaF2.

EIGHTY-FIVE PROSPECT [39]

The Eighty-five prospect is in a small gulch 1,725 feet S. 13° W. of the Blackbird shaft. In 1943 it was operated by J. E. Mock of Albuquerque, who sank an irregularly inclined shaft to a depth of 47 feet and drifted 30 feet southward from the 24-foot level. The workings are in brecciated basalt and syenite along a fault that strikes N. 37° W. and dips 82° NE. The ore occurs irregularly through the breccia in stringers, veinlets, lenses, and mammillary coatings. The mineralized zone is locally as wide as 5 feet. Some of the faces were estimated to contain up to 50 percent CaF_2, although lower values were more common.

About 650 feet south-southeast of the Eighty-five shaft an old shaft marks the site of a former lead mine. The shaft was inaccessible at the time of this investigation, but the dump showed considerable fluorite.

GALENA KING PROSPECT [40]

The Galena King prospect is in the Manzanita Mountains about 5 miles southeast of Coyote Springs (Figure 2). It was opened in 1910 as a lead mine, but several years later one carload, or possibly more, of fluorspar was sold. The deposit was worked

[38] Channel sample collected and assayed by Gordon Macbeth of the American Fluorspar Co.

[39] From unpublished notes by R. G. Smalley, U. S. Geological Survey.

[40] Abstracted from Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, pp. 119-121, 1928.

on two levels approximately 170 feet apart ; and a winze, said to be 150 feet deep, extended below the lower level. Drifts on the two levels totaled 500 to 600 feet in length.

The vein, which is in a northward-striking fault in pre-Cambrian granite gneiss, ranges in width from a few inches to as much as 5 feet; but Ladoo [41] estimated that the average width of fluorspar throughout the workings did not exceed 6 inches. The mineralized zone has a length of about 300 feet.

The fluorspar consists of blue-green euhedral fluorite, with small amounts of galena and barite encrusting fragments of brecciated granite gneiss and filling interstices and small fissures. An assay of hand-sorted ore from the dumps showed 69.69 percent CaF_2, 8.84 percent $Si0_2$, 2.14 percent $CaCO_3$, and 12.75 percent $BaSO_4$.[42]

CATRON COUNTY

GENERAL RELATIONS

Fluorspar has been reported from the southwestern part of Catron County, where it occurs at several places along the west front of the Mogollon Range. Only the deposits near the principal valleys were investigated because those in other parts of the range, even though of high grade, are too inaccessible to be mined. All the fluorspar ore from the county was trucked over U. S. Highway 260 to the railhead at Silver City, 53 miles south of the county line, or to the mill at Gila, 24 miles from this line.

The rocks in southwestern Catron County are chiefly rhyolites, andesites, basaltic andesites, and latites [43] which occur as flows and pyroclastic deposits. The individual units are relatively thin, but the aggregate thickness probably amounts to some thousands of feet. Sandstones and conglomerates are interbedded with some of the extrusive rocks in the vicinity of Mogollon.[44] Small aplite and basalt dikes cut these rocks at a few places. Gravel, sand, and silt, deposited in lake beds and alluvial fans in the valley west of the mountain fronts, are in places several hundred feet thick.

Fluorspar occurs as fissure veins in simple fractures and fault gouge, as interstitial fillings in brecciated rock, and as sheeted deposits in closely spaced joints. Replacement was an important factor in the formation of some parts of the deposits but was of minor significance in others. The fluorspar consists chiefly of fine- to coarse-grained clear fluorite that is white, green,

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41 Ladoo, R. B., Fluorspar, its mining, milling and utilization, with a chapter on cryolite: U. S. Bureau of Mines Bull. 244, p. 131, 1927.

42 Idem, p. 132.

43 Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 42, 193, 1910.

44 Ferguson, H. G., Geology and ore deposits of the Mogollon mining district, New Mexico: U. S. Geol. Survey Bull. 787, pp. 5-1 1927.

purple, or lavender ; microcrystalline translucent white or gray fluorite is found in the Sacaton deposit. The principal gangue mineral is quartz, which was deposited both before and after the fluorite. Calcite, in places manganiferous, is present in some deposits.

FLUORSPAR DEPOSITS

The fluorspar deposits that have been mined or prospected in Catron County are listed in Table 7.

TABLE 7. FLUORSPAR MINES AND PROSPECTS IN CATRON COUNTY

Name	Approximate location	Reference[a]
Huckleberry mine	NE¼ sec. 29, T. 11 S., R. 19 W.	27: 115-116
Lone Star No. 7 prospect	SE¼ sec. 34, T. 11 S., R. 19 W.	
Sacaton mine	SE¼ sec. 28, T. 12 S., R. 18 W.	
Blue Rock prospect	Sec. 29, T. 12 S., R. 18 W.	
Wytcherly prospect[b]	NE¼ sec. 33, T. 12 S., R. 18 W.	
Mogollon mining district	Tps. 10-11 S., R. 19 W.	15

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

HUCKLEBERRY MINE

The Huckleberry mine, formerly known as the Big Spar prospect, is in Little Whitewater Canyon about 4 miles east of Glenwood and 65 miles northwest of Silver City (Figure 3). A Federally constructed access road 4 1/2 miles long connects Glenwood with the mine, ascending approximately 1,370 feet in that distance. The mine is on the north bank of the creek 270 feet above the loading bin at the end of the road.

The deposit was prospected in 1926 by Jessie Campbell, and work was continued intermittently through 1928 by Michael and James Huckleberry. In 1939 Correy and Forbes extended the workings, and between 1940 and 1942 the mine was operated by T. D. Benjovsky and J. W. Penn. It was acquired in 1944 by R. S. Dunbar, who, with C. H. Johnson, mined it until December of that year. The workings consist of an open cut, drifts, and low-angle stopes of the room-and-pillar type (Plate 3).

In 1944 the Federal Bureau of Mines explored the deposit by pneumatic wagon-drill holes, test pits, and underground workings, and the findings were interpreted geologically by R. D. Trace of the Federal Geological Survey. Much of the information in the following discussion is taken from the records of this work.

The predominant rock of the area is a brownish-gray pyroclastic rock of andesitic composition, but a rhyolite sill appears to be the host for much of the ore. Pieces of latitic rock have also been recognized in the ore body.[45] The most prominent structural feature is the Huckleberry fault or fault zone, which, although irregular locally, strikes about N. 25° E. and dips about 25° SE. It consists of a zone as much as 10 feet thick in which the rock segments have moved along many short curved intersecting surfaces that divide the zone into overlapping lenses. Brown gouge ranging from a fraction of an inch to 4 inches in thickness has been developed along these fault surfaces. Slickensides and striations are common. The total displacement along this fault is not known, but movement since fluorspar deposition has been small. The Huckleberry fault zone is broken by at least one northward-striking normal fault of small displacement.

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[45] Petrographic determinations by J. J. Glass, U. S. Geological Survey.

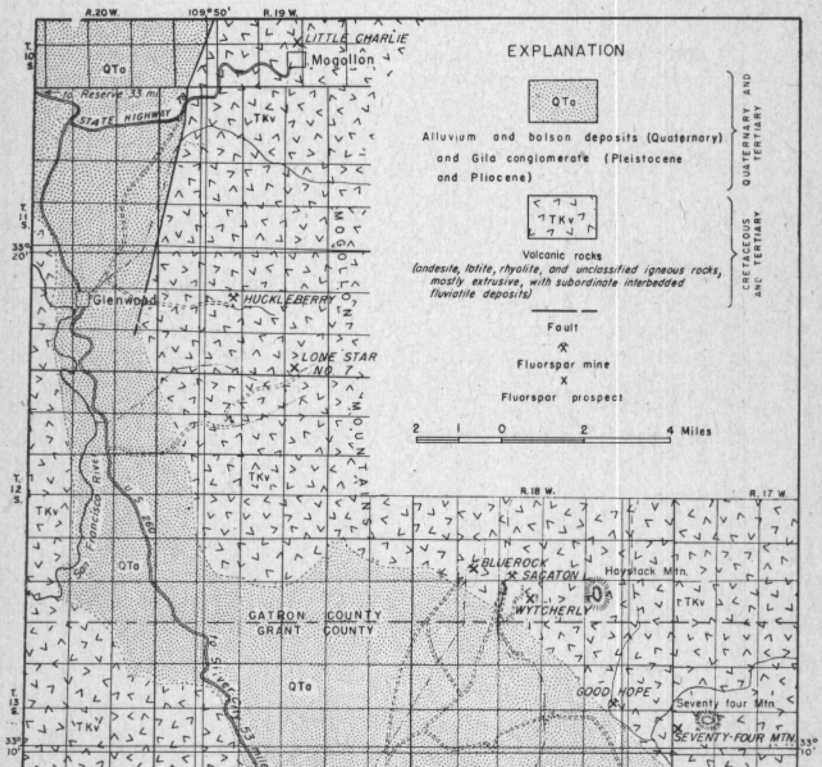

FIGURE 3.—Geologic map of a part of the Mogollon Mountains, Catron and Grant counties.

Most of the fluorspar replaces jointed and brecciated country rock and gouge, or fills closely spaced fractures below and perpendicular to the Huckleberry fault zone. The fluorspar is localized chiefly in the sheeted zone beneath the relatively impervious gouge. The top of the deposit is well defined and is generally richer than the gradational and irregular bottom. A few steeply dipping mineralized fractures cut the fault zone.

The sequence of events in the formation of this deposit appears to be as follows. Steeply dipping northward-striking normal faults developed. These were then truncated by the Huckleberry fault. Ascending solutions filled the fractures but were chiefly impounded below the fault gouge. Fluorspar was deposited by these solutions, replacing the rock and filling openings. Movement was renewed along the northward-striking faults, and northwestward-striking normal faults were formed while the Huckleberry fault was flexed.

The concentration of fluorspar in rhyolite in some parts of the mine suggests that the rhyolite may have been more susceptible to reaction with the mineralizing solutions than the andesite.

The known ore body lies a short distance under the surface of the hillside, except where it is exposed in the open cut, and roughly conforms to the hill slope. The tenor of the ore varies greatly both laterally and vertically. Exploration has revealed an irregularly oval body of indicated and inferred ore approximately 420 feet long, 180 feet wide, and 6 feet in average thickness (Plate 3). About half of this ore has been mined, by methods described on pages 197-198.

White or aquamarine medium-grained fluorite, inclusions of wall rock, and a small amount of quartz are the main constituents of the deposits. The ore is very crumbly, and separation of the high-grade fines from the coarse waste is accomplished by sorting during mining and by classifying through a screen. As a result, a product containing about 58 percent CaF_2 was marketed, although the average CaF_2 content of the ore in place, as computed from sampling by the Federal Bureau of Mines, was 43 percent.

Although the production record of this mine is not complete, it indicates that at least 9,300 tons of ore has been marketed. The limits of the deposit have not been determined.

LONE STAR NO. 7 PROSPECT [46]

The Lone Star No. 7 prospect is about 2 miles southeast of the Huckleberry mine (Figure 3). In 1944 it was owned by F. Menges and Arment Menges of Glenwood and Reserve.

The country rock is fine-grained andesite, some of which is

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[46] From field notes and an unpublished memorandum by R. D. Trace, U. S. Geological Survey.

porphyritic. It is cut by a well-defined fault that trends N. 25°35° W. and dips 60°-70° NE. The footwall is intensely brecciated, and the fragments are cemented with dark-brown and white calcite and green coarse-grained fluorite. This breccia zone, as seen in three short exposures within a distance of 300 feet, is 3 to 6 feet thick. It is poorly exposed for 120 feet beyond the northwesternmost of the three exposures, although vein material from a few inches to 1 foot thick is recognizable.

The fluorite crystallized in the cavities of the breccia, forming irregular veinlets and blebs. A chip sample across a 6-foot face assayed 50 percent CaF_2,[47] but near the southeast end the CaF_2 content was estimated to be as low as 10 percent. The hanging wall, which is only slightly brecciated, is silicified, forming a quartz vein several feet wide that has been prospected for gold.

SACATON MINE

The Sacaton mine is 2 miles west-northwest of Haystack Mountain on the ridge of a spur of the Mogollon Mountain front (Figure 3). It is 1,450 feet (barometric measurement) above the intersection of the access road and U. S. Highway 260, nine airline miles to the southwest, but at least half this difference in altitude is within the last mile to the mine. The deposit is owned by A. H. Alphen, owner of the ranch between the mine and the highway.

Most of the mining was done in open cuts aggregating about 430 feet in length and ranging from 2 to about 20 feet in depth. The main excavation is 230 feet long and trends N. 50° W. From a point near its center a trench and an inclined adit follow a branching vein trending N. 25° W. The trench, which is about 80 feet long, connects the main workings with a parallel trench that extends northwest for about 120 feet. Some 500 feet north of the main workings a cut and tunnel enter the hillside for 50 feet. A similar working is about 1,000 feet northeast of the mine and 350 feet lower. It consists of a caved adit 25 feet long in the east bank of Sacaton Creek.

In the vicinity of the mine the rocks are andesite and a more silicic rock, which occur in alternating bands with a general northwesterly trend. They are cut by several parallel faults that strike N. 50°-60° W., dip from 90° to 60° NE., and in most exposures contain veinlets of 'fluorite. The workings are in two of these faults, which are about 40 feet apart, and in an oblique fault that connects them.

The fluorspar occurs along these faults in branching veins that are of very high grade but are separated by so much altered wall rock that ore shipped from them contained only from 50 to

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[47] Sample collected by F. *J.* Sur and assayed by the U. S. Bureau of Mines.

55 percent CaF_2. The fluorite is chiefly medium- to coarse-grained, and is purple or pale green. A small amount of fine-grained quartz is associated with it. In the northwest end of the northeast trench the fluorspar is microcrystalline, opaque to translucent, white or brown, and resembles that from the Clum mine in Grant County.

The deposit in the cut and tunnel 500 feet north of the main workings consists of numerous veinlets in coarsely brecciated rock along a fault that strikes N. 45° W. and dips 72° NE. Striations plunge 60° NW. The veinlets are too widely spaced to be minable.

The fluorspar in the caved adit in the east bank of Sacaton Creek fills the interstices of a fault breccia and partly replaces the rock fragments, forming a vein 30 inches thick. A chip sample across this exposure assayed 49.6 percent CaF_2 and 40.8 percent SiO_2.

The size of the openings at the main workings indicates that about 400 tons of fluorspar had been mined prior to 1943.

BLUE ROCK PROSPECT

The Blue Rock prospect is 3 miles west-northwest of Haystack Mountain in the canyon of Pine Creek (Figure 3). It is reached from U. S. Highway 260 by leaving the highway 46 miles north of Silver City and following dirt roads and trails north-northwestward through the Alphen ranch and the Gila National Forest for 10 miles. The prospect is on a group of claims owned by J. F. Moore. It was explored by several small pits and cuts.

The country rock is very dark finely porphyritic andesite. In the vicinity of the prospect it is cut by two eastward-trending aplite dikes that are about 650 feet apart and range from 2 to 5 feet in thickness.

The fluorspar forms narrow veins along faults in the coarsely fractured rock. One of these veins trends eastward, and near Pine Creek is in the southern of the aplite dikes. In this locality a brecciated zone several feet wide occurs along the fault and contains fluorspar veinlets for a width of 3 to 6 feet. The deposit is estimated to contain about 35 percent CaF_2 in each of two cuts 50 feet apart. Two north-trending faults arranged en echelon north of this fault contain fluorspar for 200 or 300 feet along their outcrops. The veinlets and breccia fillings occupy from a few to 22 inches of the brecciated zones along these faults. At some places the deposit is solid fluorspar, but along most of the fault it contains a large percentage of unaltered breccia. The vein material is fluorite and quartz. The fluorite is pale green or lavender and is medium-grained.

About 9 tons of hand-sorted ore was mined from the south deposit and sold to the Continental Chemical and Ore Company, which operated a fluorspar mill at Silver City in 1942. The CaF_2 content of this ore averaged 65 percent and ranged from 54.7 to 67.6 percent.[48]

MOGOLLON MINING DISTRICT

The occurrences of fluorspar in the Mogollon mining district were not studied during 1942-1944, but are described by Ferguson[49] whose observations are condensed in the following paragraphs.

The Mogollon or Cooney district is in southwestern Catron County, about 14 miles east of the Arizona line. Silver City, the nearest railroad point, is about 85 miles southeast. The district lies near the western border of the Mogollon Range, which here presents a steep front facing westward toward the valley of the San Francisco River.

The rocks of the district are principally andesite and rhyolite lavas of Tertiary age, with accompanying pyroclastic rocks and subordinate amounts of sandstone and conglomerate. Later gravel, of Pliocene or Pleistocene age, occurs west of the district and is faulted against the older rocks. Small dikes of later (probably Pleistocene) basalt cut the lavas. The Tertiary rocks have been complexly faulted by Tertiary normal faults, and the geologic map shows an intricate mosaic of fault blocks.

The ore deposits of the district are silver-bearing quartz veins and less valuable copper ores. The veins follow closely the earlier faults, and the vein system is therefore complex. Quartz is the principal gangue mineral. Calcite, in part manganiferous, fluorite, and rare adularia are present.

The fluorite, usually from deep to pale green, is abundant in places and is most commonly associated with veins that contain an intergrowth of calcite and drusy quartz. In many veins a rough banding of calcite and fluorite was observed. As a rule the highest fluorite content is in the veins in the west central part of the district. Fluorite is not present in large amounts in or near the silver or copper ore shoots, and nowhere in the mine workings is the proportion of fluorite sufficiently large to constitute a minable fluorspar body.

DONA ANA COUNTY

GENERAL RELATIONS

Fluorspar deposits occur in two parts of Dona Ana County, namely in the northwestern part in mountains bordering the east side of the Rio Grande valley, and in the eastern part in the

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[48] Data supplied by J. 0. Fischer, president, Continental Chemical and Ore Co., through the courtesy of J. F. Moore.

[49] Ferguson, II. G., Geology and ore deposits of the Mogollon mining district, New Mexico: U. S. Geol. Survey Bull. 787, 1927.

San Andres and Organ Mountains (Plate 1). The northwestern deposits include those in the Sierra Caballos north of Hatch and the deposit on Tonuco Mountain, an isolated promontory between Hatch and Las Cruces. The eastern deposits include those on Tortugas Mountain near Las Cruces, a group near Mineral Hill at the south end of the San Andres Mountains, and three deposits on the west and southwest sides of the Organ Mountains (Plate 4).

The deposits that have been actively prospected are near U. S. Highways 80 and 70, which are convenient trucking routes to milling facilities at Deming and El Paso. U. S. Highway 80 parallels the Rio Grande, and U. S. Highway 70, which intersects it at Las Cruces, crosses St. Augustine Pass between the San Andres and Organ Mountains. The Atchison, Topeka, and Santa Fe Railway follows the course of the Rio Grande diagonally across Dona Ana County, and the Southern Pacific Railroad crosses the southern part.

GEOLOGY

In the areas where fluorspar is found the rocks range in age from pre-Cambrian to Quaternary. Only those that are closely related to the fluorspar deposits are described.

Pre-Cambrian rocks are exposed on Tonuco Mountain, in the south end of the San Andres Mountains, and on the west and southwest sides of the Organ. Mountains. On Tonuco Mountain they include a dark-green mica schist cut by pink granite composed of quartz, orthoclase, microcline, and muscovite, with some apatite and tourmaline as accessory minerals.[50] In the San Andres and Organ Mountains the older rocks are biotite and chlorite schists, biotite gneiss, and diorite. They appear to be roof pendants in a huge batholith composed predominantly of gray to pink granite.[51]

Rocks of the Cambrian, Ordovician, Silurian, and Devonian systems are differentiated in some parts of the Organ Mountains, but fluorspar has not been reported in them except as an unimportant gangue mineral in some of the metalliferous deposits.[52] It occurs in significant amounts, however, in Carboniferous and Permian rocks, which include the Lake Valley limestone (Mississippian)., Magdalena group (Pennsylvanian) , Hueco limestone (Permian or Pennsylvanian) in the Organ Mountains, and the Abo sandstone (Permian or Pennsylvanian) in Tonuco and San Andres Mountains. The first three of these formations, which are

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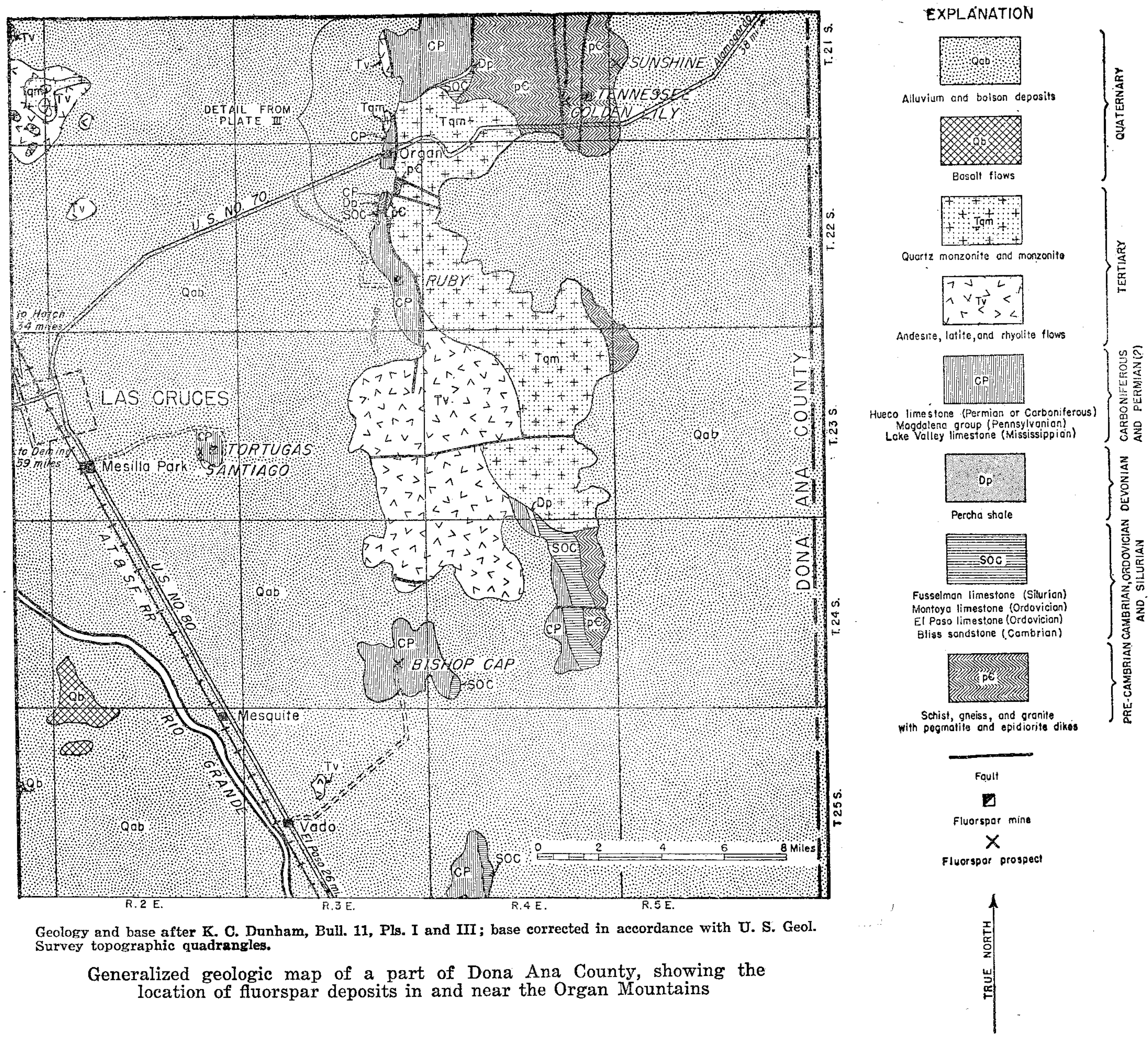
[50] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 66, 1928.

[51] Dunham, K. C., The geology of the- Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 11, pp. 163-164, 1935.

[52] Idem, p. 135.



Geology and base after K. C. Dunham, Bull. 11, Pls. I and III; base corrected in accordance with U. S. Geol. Survey topographic quadrangles.

Generalized geologic map of a part of Dona Ana County, showing the location of fluorspar deposits in and near the Organ Mountains not differentiated on maps of the fluorspar areas, consist chiefly of gray limestones, the younger of which are cherty and interbedded with sandstones and shales. The Abo sandstone, which crops out in the Sierra Caballos and at Tonuco Mountain, consists of thin-bedded fine- to coarse-grained red or gray sandstone with interbedded dark-red or maroon shales. No Mesozoic rocks are present in the vicinity of the deposits.

The oldest Tertiary formations [53] are lavas of acidic, intermediate, and basic composition. They crop out in the southwestern part of the Organ Mountains and consist of rhyolite tuff, thin andesites, and a great thickness of gray to purplish-gray porphyritic. rhyolite. They were invaded first by monzonite and then more extensively by quartz monzonite composed chiefly of feldspar crystals averaging 7 millimeters in length, small amounts of quartz, and a little biotite and hornblende. The quartz monzonite forms the Organ Mountains batholith. Later extrusions in the northwest part of the county formed a thick series chiefly of pyroclastic rocks. This series is composed mostly of rhyolitic tuffs and agglomerates, but interbedded waterlaid sandstones and conglomerates occur near its base. These rocks are exposed at Tonuco Mountain and in the Sierra Caballos. Similar rocks in the Sierra de las Uvas, southwest of Tonuco Mountain, are capped by basalt that is conformable with them and older than basalts known to be Quaternary.[54]

Quaternary rocks are represented by basalt flows, bolson deposits, and river alluvium. No fluorspar deposits have been reported in them.

FLUORSPAR DEPOSITS

Fluorspar is found in rocks of pre-Cambrian, Carboniferous, and early Tertiary ages. The deposits occur in fractures that in most places parallel the main structural axes of the mountains. The larger deposits are in fault breccias, but some minable bodies lie along fractures in which little or no movement took place. The fluorite is generally white or pale green, and the most abundant gangue minerals are quartz, calcite, and barite. The character of the host rock greatly influences the composition of the gangue. In deposits in pre-Cambrian rocks the gangue is predominantly quartz with little or no calcite. In the single deposit reported in rhyolite, the gangue is also siliceous, and no calcite was noted. In deposits in the Magdalena group, however, the gangue contains much calcite and some quartz, the content of quartz ranging from a few percent to percentages equal to that of the calcite. Most of the deposits, regardless of the host rock, contain some barite. The fluorspar was formed chiefly by

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[53] Idem, pp. 169-173.
[54] Idem, p. 173.

replacement, but banded fluorspar veins and drusy fluorite in certain localities indicate that some crystallization took place in open veins and cavities.

The solutions from which the fluorspar deposits were formed probably originated in the depths of the Organ Mountains batholith after the part now exposed had consolidated. Conditions favorable for deposition, however, were not found in the batholith itself but in the early Tertiary lavas, Paleozoic rocks, and pre-Cambrian rocks adjoining it. At least some of the deposition was completed in the northwestern deposits before the deposition of the late Tertiary pyroclastic rocks. Evidence for this conclusion is the presence of fragments of fluorspar from the Tonuco vein in the agglomerate that caps it. According to Dunham,[55] the interval between the batholithic intrusion and the deposition of the pyroclastic rocks occurred in Oligocene or early Miocene time.

The mines and prospects are listed in Table 8.

TABLE 8. FLUORSPAR MINES AND PROSPECTS IN DONA ANA COUNTY

Name	Approximate location	Reference[a]
	Deposits on Tonuco Mountain	
Tonuco mine	Near center S½ sec. 31, T. 19 S., R. 1 W., and N½ sec. 6, T. 20 S., R. 1 W.	12: 263-264 27: 65-72; 30: 124-126
	Deposits on Tortugas Mountain	
Tortugas mine	SW¼ sec. 24, T. 23 S., R. 2 E.	12: 166, 264-265; 14: 35; 27: 75-82; 30: 122-124; 46: 75
Jones vein	SW¼ sec. 24, T. 23 S., R. 2 E.	27: 76
Santiago prospect	SE¼ sec. 24, T. 23 S., R. 2 E.	46: 75
	Deposits in the San Andres and Organ Mountains	
Tennessee mine	SW¼NW¼ sec. 25, T. 21 S., R. 4 E.	
Golden Lily prospect	Sec. 26, T. 21 S., R. 4 E.	
Sunshine prospect	Sec. 19, T. 21 S., R. 5 E.	
Ruby (Hayner) mine	NW¼ sec. 25, T. 22 S., R. 3 E.	12: 126, 228; 27: 63-85; 46: 75-76
Silver Cliff prospect	Sec. 1 (?), T. 23 S., R. 3 E	12: 229
Bishop's Cap prospect	Secs. 25 and 26, T. 24 S., R. 3 E.	27: 12, 85-88, 146, 166, 242; 30: 121-122; 46: 76

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[55] Idem, p. 138.

TONUCO MOUNTAIN DEPOSITS

The Tonuco mine is on Tonuco Mountain, an isolated hill about 800 feet high that lies 2 miles east of the Rio Grande and 20 airline miles north-northwest of Las Cruces (Plate 1) . The Atchison, Topeka, and Santa Fe Railway siding is 1 mile from the mine, and U. S. Highway 85 is on the west side of the river, 21/2 miles west of the mine. The mine is on the Beulah May Nos. 1 and 2 lode claims, which were acquired in 1940 by the Newalpitt Corporation of Pittsburgh, the present owners. The principal deposits are called the Tonuco vein on the No. 1 or north claim, and the Beal vein on the No. 2 or south claim. The workings and deposit were described by Johnston, [56] and, as little ore has been taken from them since his visit, the reader is referred to his account for details of the occurrence. The principal addition to the workings since Johnston's study is a development tunnel driven by the Newalpitt Corporation to cut the Beal vein and its flanking veins about 240 feet below the highest outcrop.

The deposits are in a group of fractures in pre-Cambrian granite and schist. The general trend of the group is N. 35° W., but the individual fractures show a wide variation from this trend. Faulting since vein deposition has brought pre-Cambrian rocks against Tertiary agglomerate on the west and against Permian Abo sandstone on the southwest. At one place near the north end of the deposits, the veins are overlapped by the agglomerate, which contains fragments of fluorspar from the veins.

The fluorspar deposit is a composite vein in a fractured zone that is about 500 feet wide and is exposed for a distance of 3,000 feet. Many of the fractures contain irregularly distributed stringers, veins, or lenses of fluorspar. Breccia fillings or sheeted deposits are found in places where the rock is brecciated or closely jointed. In many of the fractures only narrow short veins were deposited, but in two places on the north claim and three on the south claim the veins have been mined for distances of 100 to 300 feet. The thickness of the ore in these workings ranges from 2 to 25 feet.

The fluorspar consists of intergrown crystals of green fluorite, white barite, interstitial quartz, and partly silicified inclusions of granite and schist. The distribution of these minerals varies greatly; in some places vein material composed mainly of barite and quartz forms large masses that can be sorted out by hand before the ore goes into the bin. Except for scattered high-grade pockets, however, most of the vein contains relatively large proportions of intimately associated barite and silica. The assays in Table 9 show the constituents and indicate the range in grade of the marketed ore.

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[56] Johnston, W. D., Jr., op. cit., pp. 65-72.

TABLE 9. ASSAYS OF ORE FROM THE TONUCO MOUNTAIN DEPOSITS

Assay No.	Description of sample	CaF_2	SiO_2	$BaSO_4$	$CaCO_3$	R_2O_3
	Tonuco vein					
1.	Mill heads	47.33	29.49	17.26	1.03	----
2.	Loading bin at mine	54.92	30.16	10.70	1.42	----
3.	Vein in bottom of winze, width 42 inches	54.08	14.70	26.48	1.83	----
4.	Grab sample of selected ore from upper adit	96.67	1.85	0.93	0.45	----
5.	Shipping concentrates from jig mill	78.52	10.33	9.70	0.50	----
	Beal vein					
6.	Mill head representing 379 tons (141 tons represented in assay for $BaSO_4$)	69.0	----	19.0	----	----
7.	Mill heads representing 60 tons	58.4	28.1	8.2	1.2	3.7
8.	Selected ore, grab sample	97.53	2.28	----	0.31	----

1, 2, 3, 5—Ladoo, R. B., Fluorspar, its mining, milling, and utilization : U. S. Bur. Mines Bull. 244, pp. 124-126, 1927.

4. 8—Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 71, 1928.

6—Data furnished through the courtesy of R. C.' Little, district manager, Newalpitt Corporation.

7—Assay by U. S. Geological Survey.

TORTUGAS MOUNTAIN DEPOSITS

The Tortugas Mountain deposits occur 4 1/2 miles southeast of Las Cruces, on Tortugas Mountain, a mound-shaped hill rising 650 feet above the surrounding valley floor and bounded by steep cliffs on its north and east sides. A graded road from Mesilla Park, 2 miles south of Las Cruces, skirts the north and east sides of the mountain ; trails lead from this road to the deposits, most of which are near the top of the mountain. The principal group of veins, called the Tortugas vein system, includes several intersecting and subparallel veins. The Tortugas mine is in this vein system. About 600 feet east of the Tortugas mine are the workings on the Jones vein, which is oblique to the Tortugas veins and may intersect the northern end of the system. About 800 feet west of the Tortugas mine is a group of veins on the Santiago claims. They were not studied and are not discussed in this report.

Tortugas Mountain, which is composed of limestones and shales of the Magdalena group, is a fault block that has been shattered extensively and tilted westward. The fluorspar veins occur in the fractures caused by this faulting, and trend generally north or northwest. They are predominantly fissure fillings, but include some fillings of fault breccia. The fluorite is aquamarine or white and medium- to coarse-grained. Gangue material includes abundant calcite, some quartz, and inclusions of limestone wall rock some of which are partly silicified. The constituents separate easily, and much of the ore has been jigged to yield a product of ceramic grade.[57]

The deposits were formed chiefly by the filling of open spaces ; replacement played only a minor role. The sequence of deposition began with the crystallization of fluorite and some rhombohedral calcite in the openings formed by faulting. Later an invasion of silica-bearing solutions formed drusy coatings of quartz in cavities and replaced some of the vein calcite and limestone. Reopening of the veins permitted deposition of much scalenohedral calcite, and, in the deepest workings of the Tortugas mine, calcite containing as much as 4.5 percent manganese.

Tortugas mine.—The Tortugas mine is on the east side of the mountain about 500 feet above the end of the access road. The first owners on record were Hayner and Manassee of Las Cruces, who leased the mine from 1919 to 1921 to Charles F. Johnson. Thereafter it was operated successively by Fink, the Hastellite Company of Kalerno, California, and Hayner and Manassee; in 1942 it was acquired by J. K. Stanland.

The principal workings consist of a shaft 532 feet deep, which approximately follows the dip of the vein and from which principal working levels have been driven at depths of 150, 286, and 386 feet. Each of the lower levels is shorter than the one above it (Plate 5) . The veins have been extensively prospected by pits and trenches for distances of 100 feet south and 950 feet north of the mine.

The Tortugas vein lies along an irregularly warped fault whose average strike is N. 7° W. It dips eastward about 70° from the surface to the 150-foot level. Between this level and the 286-foot level the dip steepens and changes to the west but returns to normal a short distance below the 286-foot level. Near the bottom of the shaft the dip steepens to 80° or more but remains east.

Nearly 600 feet north of the shaft the main vein is joined or possibly crossed by a less steeply dipping vein of more northeasterly trend. The north end of the ore body on the three longest levels almost coincides with the junction of these faults, which pitches southward as shown in Plate 5. The south end of the ore body, a little south of the shaft, is irregular but more nearly vertical, so that the ore body tapers downward. North of the junction of the faults fluorspar has been found along the main vein and in other fractures, but only in small, narrow, discontinuous pockets and stringers.

South of the junction, ore has been mined at the surface along the main vein for a distance of 600 feet, but the stopes underground are not so long because of the downward taper of

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[57] Oral communication from Charles F. Johnson, operator of the Tortugas mine.

the ore body and because large pillars have been left in the north half of the stopes above the 386-foot level. The vein pinches to less than minable width in the bottom of the shaft. The widths of the stopes range from 2 to 13 feet and average about 4 feet. The average width, of fluorspar left in pillars and faces is slightly more than 12 inches. With the exception of the blocks of ore in the pillars, the mine has been completely stoped above the 386-foot level.

A branching vein was followed 10 to 30 feet southwest of its junction with the main vein, but the fluorspar pinched to stringers within these workings. The fluorspar is in part frozen to the wall rock and in part traverses fault breccia. In places it is badly fractured and contains fault gouge from a fraction of an inch to several inches thick composed of clay and smaller quantities of fragmental fluorspar. The vein is composed chiefly of bands of coarse-grained fluorite, commonly between bands of prismatic calcite. In places a later generation of calcite encrusts the brecciated fluorspar. When the mine was operated by C. F. Johnson, the ore shipped had the following composition.

TABLE 10. AVERAGE ASSAYS OF ORE AND CONCENTRATES FROM THE TORTUGAS MINE[a]

Description	Chief constituents (percent)		
	CaF_2	$CaCO_3$	SiO_2
Run-of-mine ore	77.41	15.68	6.51
Fluxing spar, obtained by hand-sorting	80.91	13.15	5.64
Ceramic grade, obtained by jigging	93.76	2.50	3.42

[a] Ladoo, R. B., Fluorspar, its mining, milling, and utilization : U. S. Bur. Mines Bull. 244, pp. 122-124, 1927.

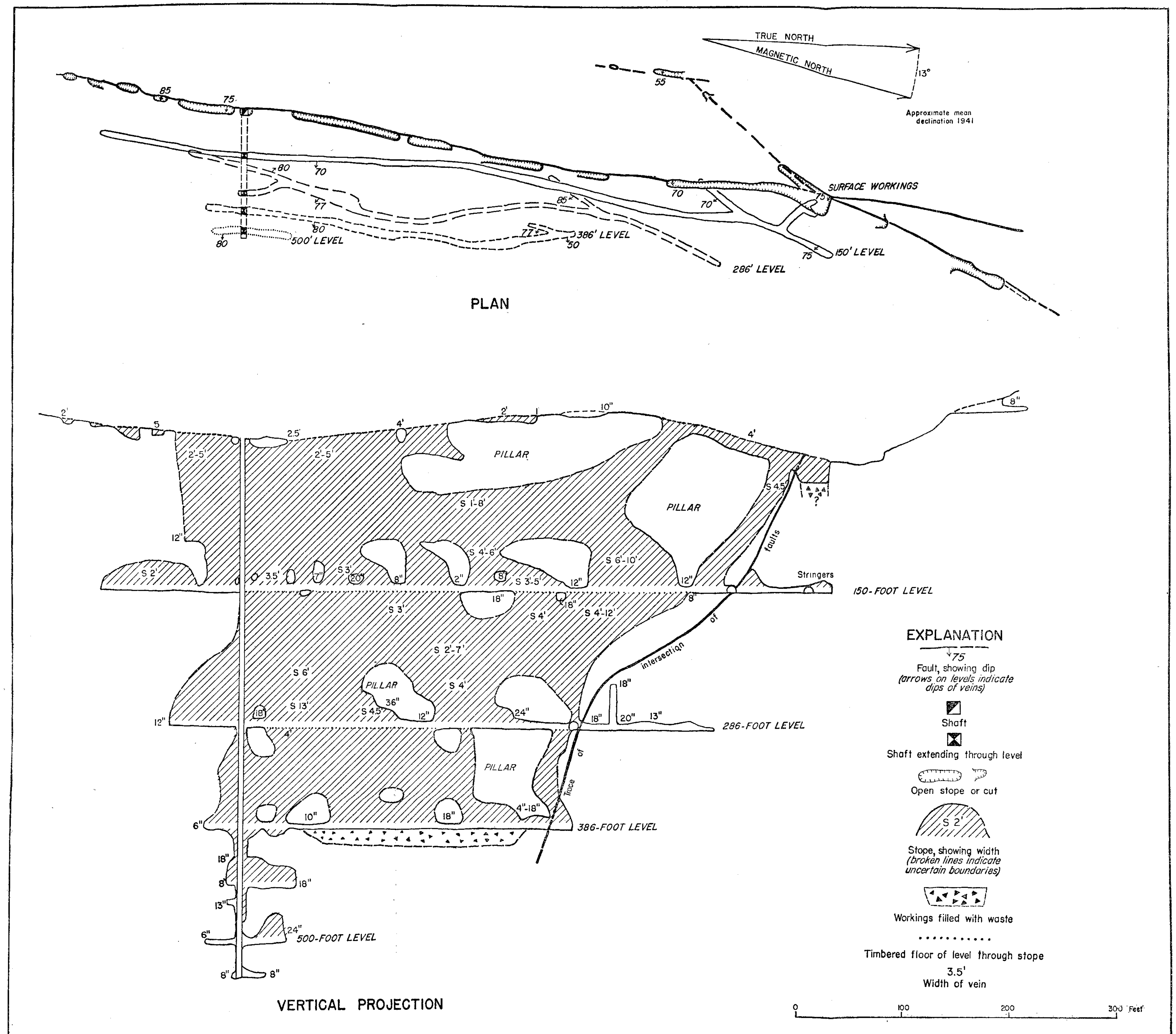
The recorded yield of the mine to 1927 was 15,328 tons.[58] Since then between 3,000 and 5,000 tons has been shipped.

Jones vein.—The workings on the Jones vein are 600 feet east of the Tortugas mine. They consist of a shaft about 40 feet deep, from the northwest side of which small cave-like stopes extend. The workings were made in fault breccia from 3 to 10 feet thick, which was estimated to consist of about one-third rock and gouge and two-thirds fluorite and calcite. Thin veinlets and coatings of quartz are present. The brecciated zone strikes N. 50° W. and can be traced for several hundred feet on the surface by abundant reticulated quartz veins. Stringers and pods of fluorspar are common along this zone, but no large fluorspar bodies were seen.

TENNESSEE MINE

The Tennessee mine is in eastern Dona Ana County at the south end of the San Andres Mountains. It is about 1 1/2 miles

[58] Johnston, W. D., Jr., op. cit., p. 78.



By H. E. Rothrock and J. O. Fisher, 1943

Tortugas mine, Dona Ana County

north of U. S. Highway 70 and is reached by a dirt road that leaves the highway 6.8 miles east of the settlement of Organ (Plate 4) . The mine is on the Tennessee No. 7 claim, which is one of a group of eight unpatented claims filed by Fred E. Leach in January 1942. The workings consist of short adits, trenches, and drifts at 3 localities.

The country rock is pre-Cambrian biotite granite cut by dikes of epidiorite, pegmatite, and aplite.[59] The claims are on an epidiorite dike that strikes N. 55° E., dips 70°-75° NW., and is terminated on the southwest by a prominent north-trending fault. The southeast contact of the dike with the granite is shattered and extensively silicified for a distance of at least a mile northeast of this termination. Within the silicified zone fluorspar occurs in scattered lenses with indefinite boundaries.

The fluorspar is white, dense, and splintery, and consists of fine- to medium-grained very pale-green fluorite with tiny included scattered crystals of quartz some of which are arranged in bands. Gradational boundaries indicate that the fluorspar was formed, in part at least, by replacement of the granite and epidiorite, a process that resulted in bodies irregular in both shape and grade. Stringers and veins of fluorspar alternate with silicified rock and quartz veins in which fluorspar is not megascopically discernible. Manganiferous calcite occupies fractures in the fluorspar, and a small amount of galena and sphalerite occurs in small patches of sulfide and carbonate bodies.

Three localities have been worked for fluorspar. The one farthest southwest contained in 1944 a trench and short adit with a total length of 65 feet. In the southwest end of these workings the fluorspar was 18 inches thick and in the northeast end 42 inches (see assay 1, Table 11). It was reported that 150 tons of ore was taken from this excavation. About 250 feet northeast of the above drift another ore body was opened by a drift 63 feet long and 20 feet below the surface, reached by a short adit. The ore body had a maximum width of 7 feet in the southwest end of the drift. It tapered to stringers northeast within the drift and to a 25-inch vein 40 feet southwest on the surface. The grade of ore obtained by selective mining from this body is shown in assay 2, Table 11. This was F. E. Leach's main working, from which about 200 tons of ore was shipped in 1942 and 50 tons stockpiled in February 1943. Approximately 300 feet northeast of this main working, in the southwest bank of an arroyo, is a third ore body. It was prospected by Leach in 1942 (see assay 3) and was mined in 1943 by P. L. Grattan, who shipped about 600 tons of ore to his mill at Deming (see assay 6). The total recorded

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[59] Dunham, K. C., The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 11, Pl. III, 1935.

yield of the Tennessee mine was approximately 1,000 tons to the end of 1944.

TABLE 11. ASSAYS OF ORE FROM THE TENNESSEE MINE

Assay No.	Description of sample	Chief constituents (percent) CaF_2	SiO_2
1.	Large chip sample across ceiling of adit in southwest working, width 42 inches	48.0	50.2
2.	Grab sample from stock pile of Leach's main working	65.4	31.4
3.	Grab sample from stock pile from northeast working near arroyo	43.9	53.2
4.	Weighted-average assay of sampled shipments from July to December, 1942; total tons 62.6	60.0	----
5.	Average of 3 samples sent to Alloy Metals Mill	63.0	32.0
6.	Shipments of about 600 tons in 1943	52.55	----

1, 2, 3—Sampled by U. S. Geological Survey.
4, 5—Data used through the courtesy of Fred C. Leach.
6—Data supplied by P. L. Grattan.

GOLDEN LILY PROSPECT

The Golden Lily prospect is situated at the south end of the San Andres Mountains about 6 miles east-northeast of Organ (Plate 4). The property includes three claims, the Golden Lily Nos. 1, 2, and 3, owned in 1944 by Henry A. Heuer. A truck trail about 1 mile long connects the property with U. S. Highway 70.

The workings consist of an old adit 75 feet long and about 100 feet above the level of the draw, an adit 345 feet long made by Heuer at a level about 20 feet above the draw, and a shaft about 15 feet deep and 120 feet above the second adit. There are several crosscuts from the adits.

The rock in the vicinity of the prospect is pre-Cambrian granite that contains dikes of aplite,[60] epidiorite,[61] and very coarsely crystalline pegmatite. The old adit was driven along an iron-bearing vein that follows the footwall of an epidiorite dike and shows traces of copper. An aplite dike crops out above and in alinement with the Heuer adit. The area is complexly faulted. Most of the faults trend approximately N. 60° E., but one group trends northward.

Fluorspar is exposed in the mine workings within an area about 150 feet in diameter. In crosscuts in the old adit it is disseminated in the granite on both sides of fractures, forming narrow veins with indefinite boundaries. The end of the Heuer adit intercepted a fractured zone 10 feet wide in altered andesitic rock that has been irregularly replaced by disseminated fluorite. Here there is no fluorite whose origin can be definitely attributed to void-filling processes. Assays 3 and 4, Table 12, are probably representative of the fluorite content of this zone.

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[60] Determination by J. J. Glass, U. S. Geological
[61] Survey. Dunham, K. C., op. cit., Pl. III.

Fluorspar is exposed in the shaft, where a body 6 feet thick was formed in the footwall of a fault. The boundary of the body at the fault is sharp, but the opposite boundary is gradational. Assays 1 and 2 are from, this deposit. In most places in these bodies the fluorite is fine-grained.

TABLE 12. ASSAYS OF SAMPLES FROM THE GOLDEN LILY PROSPECT

Description of samples				Chief constituents (percent)	
Assay No.	Location	Kind	Width (feet)	CaF_2	SiO_2
1.	North face of shaft	chip	5.5	43.6	50.6
2.	South face of shaft	chip	7.0	55.9	37.6
3.	North face of crosscut in Heuer adit	chip	10.0	13.9	73.2
4.	South face of crosscut in Heuer adit	chip	10.0	10.8	80.4
5.	Stockpile	grab	---	24.8	65.4

RUBY MINE

The Ruby claim, together with the Gloria and Line Oak claims, constitutes the fluorspar property sometimes called the Ruby or Hayner prospect or mine. The claims were patented by Frank M. Hayner of Las Cruces. They are 17 miles by road northeast of Las Cruces on the west flank of the Organ Mountains (Plate 4), and are reached by a ranch road that leads south from U. S. Highway 70 at a point $3^{1}/_{4}$ miles west of Organ. The last mile of this road, which rises about 400 feet, was impassable when the mine was examined in 1944.

The mine is in a belt of fractured, mildly distorted, and partly metamorphosed limestone and shale of Carboniferous age." In the vicinity of the mine the dip is generally 50° W. The principal evidences of metamorphism are recrystallization of the limestone and silicification of the limestone and shale along faults and joints. These rocks are in faulted contact with the Orejon andesite of Dunham (Tertiary?) about 1,000 feet east of the principal workings. The andesite forms part of a down-faulted block bounded on the west by the sedimentary rocks and on the east by the quartz monzonite that forms the core of the Organ Mountains.[63]

Fluorspar veins and lenses are numerous in the sedimentary rocks, but only three had been mined prior to 1943. They lie in parallel faults that strike N. 20° E. and dip 55°-70° E. The principal workings are in the middle vein, which can be traced about 600 feet. It has been worked from two levels, 13 feet

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62 Dunham, K. C., The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 11, p. 167, 1935.

63 Idem, P1. II.

apart, from which it was stoped to the surface for a distance of about 80 feet. The upper drift is 120 feet long and the lower one 65 feet. An underhand stope 8 feet deep from the lower drift indicates that the total depth of the ore body is at least 52 feet. The thickness of the vein in the workings ranges from 2 to 6 feet; it decreases northward.

A parallel vein, 80 feet west of the middle vein, has been trenched deeply for a distance of 70 feet. The faces of the trench contain fluorspar from 6 to 20 inches thick. About 300 feet west of this vein an irregular fluorspar deposit in a brecciated zone is exposed in three small pits. The third vein, 450 feet east of the main workings, is exposed in three adits and a deep pit for a distance of 750 feet and through a vertical range of 130 feet.

All the fluorspar deposits contain large proportions of calcite, considerable quartz, and a little barite. The percentage of calcite increases toward the ends of the veins. The fluorite and calcite form relatively pure alternating bands, and also bands in which both minerals are intergrown. Quartz is most commonly associated with inclusions of wall rock, which it has impregnated or encrusted. The barite is usually intergrown with fluorite. The following assays indicate the tenor of the fluorspar in place and after preparation for shipment.

TABLE 13. ASSAYS OF ORE FROM THE RUBY MINE

Assay No.	Description of sample	Chief constituents (percent) CaF_2	$CaCO_3$	SiO_2
1.	Large chip sample across a 3½-foot face in lower level of main workings	41.5	30.8	22.0
2.	Grab sample from loading bin	57.9	26.1	11.6
3.	Selected ore [a]	98.24	1.08	0.64

[a] Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 85, 1928.

Quartz was the first mineral deposited ; it replaced the limestone and formed thin coatings of acicular crystals on the rock fragments. Fluorite and calcite followed, being deposited alternately for the most part, but with some overlapping of the stages of deposition. Barite was contemporaneous with the fluorite.

SILVER CLIFF PROSPECT[64]

The Silver Cliff prospect is situated between Dripping Springs and the mouth of Filmore Canyon, 12 airline miles east of Las Cruces. It is in the thick rhyolite flow that was extruded before the formation of the Organ Mountains batholith. Colorless fluorite and barite are found in a fault breccia that marks

[64] Dunham, K. C., op. cit., p. 229.

the southern continuation of the major fault zone along the northwest side of the mountains. The deposit is of interest because it presents significant evidence regarding the relative age of fluorite deposition and the extrusion of volcanic rocks in the north half of Dona Ana County.

BISHOP'S CAP PROSPECT

The Bishop's Cap fluorspar prospect is 11 miles southeast of Las Cruces at the southern end of the Organ Mountains. It is reached by a truck trail 8.5 miles long from Vado, 15 miles southeast of Las Cruces on U. S. Highway 80 and the Atchison, Topeka, and Santa Fe Railway (Plate 4). In 1944 the prospect was owned by F. A. Burch and B. H. Germer of Las Cruces. Although the deposit was prospected prior to 1927, no ore has been marketed from it. The workings consist of numerous trenches and pits and three short adits on the main vein, and of one adit on a branching vein.

The deposit is described in considerable detail by Johnston.[65] Interest in it as a possible source of fluorspar for the Alloy Metals mill at El Paso resulted in further study in 1944 by R. D. Trace and J. K. Grunig of the Federal Geological Survey, and in sampling in the spring of 1945 by the Federal Bureau of Mines under the direction of F. J. Sur, project engineer. The following information is based on unpublished data gathered during these investigations.

Bishop's Cap is a folded and faulted outlier of the Organ Mountains; several Paleozoic formations are represented in it. The rocks in the vicinity of the prospect, which belong to the Magdalena group,[66] consist chiefly of massive and thin-bedded limestone, in part cherty, and interbedded shale. Near the mine the beds dip about S. 45° W. at an angle of 25° and are cut by faults that are classified in three groups according to their direction and relative age.

The oldest of these groups is represented by a single fault. It has an average strike of N. 15° E., dips 55° ESE., and contains the principal fluorspar bodies. Several faults of slight displacement branching from the east side of this fault strike N. 25°-50° E. and dip 90°-70° SE. ; they constitute the second group, which may have been formed contemporaneously with the fault that strikes N. 15° E. The third group of faults is in an intensely silicified fault zone that strikes N. 85° E. and dips about 65° S. It cuts the north end of the main vein and east of this point merges with the northeast-trending fractures (Plate 6).

All these fault systems contain veins in which some fluorspar is present, but the fluorspar bodies are narrow and extremely

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[65] Johnston, W. D., Jr., op. cit., pp. 85-88.

[66] Dunham, K. C., op. cit., p. 197.

irregular except in the main vein. Fluorspar occurs in this vein for a distance of 1,260 feet, but for 500 feet of this distance the fluorspar is less than 3 feet thick. The remainder of the fluorspar body has an average thickness of 4 feet. The depth to which the deposit extends is not known, but fluorspar occurs in tunnel No. 1 at a point 60 feet below the outcrop. A somewhat greater depth may be inferred from the fact that the difference in altitude between the lowest and highest outcrops of fluorspar is 360 feet.

Fluorite and quartz are concentrated along the footwall, and calcite and barite along the hanging wall. The fluorite is white, green, and in places purple, and is medium- to fine-grained. Silica occurs as jasperoid, white massive cryptocrystalline quartz, and coatings of drusy quartz that were deposited by descending surface waters. The calcite is white, dark brown, or black, and forms coarsely crystalline masses, banded veins, and veinlets. The barite is white and forms bladed aggregates or masses, usually in calcite. The weighted average of 12 composite samples taken by the Bureau of Mines at regular intervals along the vein and in the adits indicates the following composition of the fluorspar body: 43 per cent CaF_2, 25 per cent $Si0_2$, 17 per cent $CaCO_3$, and 6 per cent $BaSO_4$.

Mineral deposition occurred after most of the faulting, and probably in the following order: (1) quartz, chiefly cryptocrystalline, (2) fluorite, probably in part contemporaneous with the quartz, (3) calcite and barite, and (4) finely crystalline drusy quartz.

GRANT COUNTY

GENERAL RELATIONS

Grant County is a generally mountainous area in the southwest part of the State. Its east boundary is the crest of the Mimbres Mountains. The Mogollon Mountains occupy much of its northern half. The Burro Mountains, comprising the Big Burro and Little Burro Mountains, are in the south, and the Pinos Altos Range is between them and the Mogollons. There are rugged mountains in the western part also. The Gila River cuts a deep canyon through the Mogollon Mountains, separates them from the Pinos Altos Mountains on the south, and makes a rugged valley through the Burro Mountains. The southern tip of the county consists chiefly of broad bolsons which are traversed by U. S. Highways 70 and 80 and the Southern Pacific Railroad. Silver City, the county seat, is the railhead for a branch of the Atchison, Topeka, and Santa Fe Railway and is at the intersection of the main highways. Fluorspar from the mines in the county has been shipped by rail to markets out of the State; by truck or rail to the General Chemical Company's flotation mill at Deming, on the Southern Pacific Railroad, 54 miles from

Silver City ; by truck to the Indian Metals mill at Lordsburg, also on the Southern Pacific Railroad ; and by truck to the International Minerals and Chemical Corporation's sink-float mill at Gila, 31 miles northwest of Silver City.

GEOLOGY

In the southern part of Grant County in an area roughly 35 miles long and from 12 to 18 miles wide, pink medium- to coarse-grained pre-Cambrian granite is the principal rock exposed. The planed surface of this granite is overlain by a glauconitic basal sandstone, the Bliss sandstone, which in the Silver City area contains fossils of Upper Cambrian age. [67] This sandstone is overlain by formations representing all the other Paleozoic systems, although some of them are thin.[68] No rocks of early Mesozoic age are present, owing either to removal by erosion or to non-deposition, but late Mesozoic (Cretaceous) time is represented by the basal Beartooth quartzite and the conformably overlying Colorado shale. Although originally extensive and several thousand feet thick, the Colorado shale has been eroded or covered over all the county except the central part. The upper part of this shale contains interbedded fragmental volcanic rocks, which in turn are overlain by volcanic rocks of Tertiary age. These extrusive rocks are cut by large intrusive masses of quartz diorite porphyry in the mountains east of Pinos Altos, and of granodiorite, quartz monzonite, and allied porphyries in the Big Burro Mountains and in the mountains west of Pinos Altos. Concomitant with intrusion and possibly preceding it, the Burro Mountains were elevated, and a broad syncline containing the upturned edges of the sedimentary rocks was formed to the northeast. Major fault systems, one trending northwest parallel with the axis of the syncline and another trending northeast, break the rocks into huge blocks. Many of the faults and associated fractures are filled with narrow dikes, indicating that the tensional movements related to the uplift took place before or during the intrusion.

Primary mineralization occurred after this period of intrusion and faulting, probably in early Tertiary time.[69] The long period of erosion that ensued was terminated by explosive eruptions and lava flows that covered the northeastern part of the county, including some of the mineralized area. The volcanic rocks probably came from vents northeast of Silver City.

This mantle of extrusive rocks extends northwest into the Mogollon Mountains, where a thick series of gently dipping flows caps the mountains. It rests on the Cretaceous (?) or early

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

[68] Paige, Sidney, Copper deposits of the Tyrone district, New Mexico: U. S. Geol. Survey Prof. Paper 122, p. 4, 1922.69

[69] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), p. 14, 1916.

Tertiary extrusive rocks that, near the Gila River, contain the fluorspar deposits. These early extrusive rocks are hydrothermally altered in places, and are more extensively disturbed than the younger rocks. The relationship between these extrusive rocks and those east of Silver City has not been determined. In the western part of the county the mountains in which the Steeple Rock mining district is situated are composed chiefly of extrusive rocks of Cretaceous (?) and Tertiary ages.

The sedimentary rocks are best exposed in the Silver City area, where the sequence shown in Table 14 is present.

FLUORSPAR DEPOSITS

All the known fluorspar deposits in the Burro Mountains are in pre-Cambrian granite (Plate 7). In the Mogollon and northern Pinos Altos Mountains the fluorspar veins are in Cretaceous (?) and Tertiary extrusive rocks. Those near Silver City are in the El Paso limestone (Ordovician) and Bliss sandstone (Upper Cambrian), and probably extend into the underlying pre-Cambrian rocks. The deposits in the north end of Cooks Range are in pre-Cambrian granite, Paleozoic limestones, and Tertiary volcanic rocks.

The fluorspar bodies are found in fissures and fault breccias. Many of them, characterized by comb structure and banding, were formed in open cavities, but the best deposits are those that grade into fault breccia or shattered wall rock and have largely replaced them.

The fluorite shows a wide range of color and crystal size. White and green predominate, red, brown, and blue are common, and yellow fluorspar was obtained from one area in the Lakeview prospect. The texture ranges from microcrystalline to coarse-grained. The chief gangue mineral is quartz, except at the Good Hope mine where the gangue is mostly calcite. Metalliferous minerals were not found in any of the deposits except those in the Burro Chief deposit, which contains patches of oxidized copper minerals.

The fluorspar deposits are described according to the geologic and geographic units in which they occur. These units are the Burro Mountains in the south central part of the county, the Steeple Rock district in the western part near the State boundary, the Mogollon and northern Pinos Altos Mountains in the northern part, the Silver City area, and the northern Cooks Range in the southeastern part (Table 15).

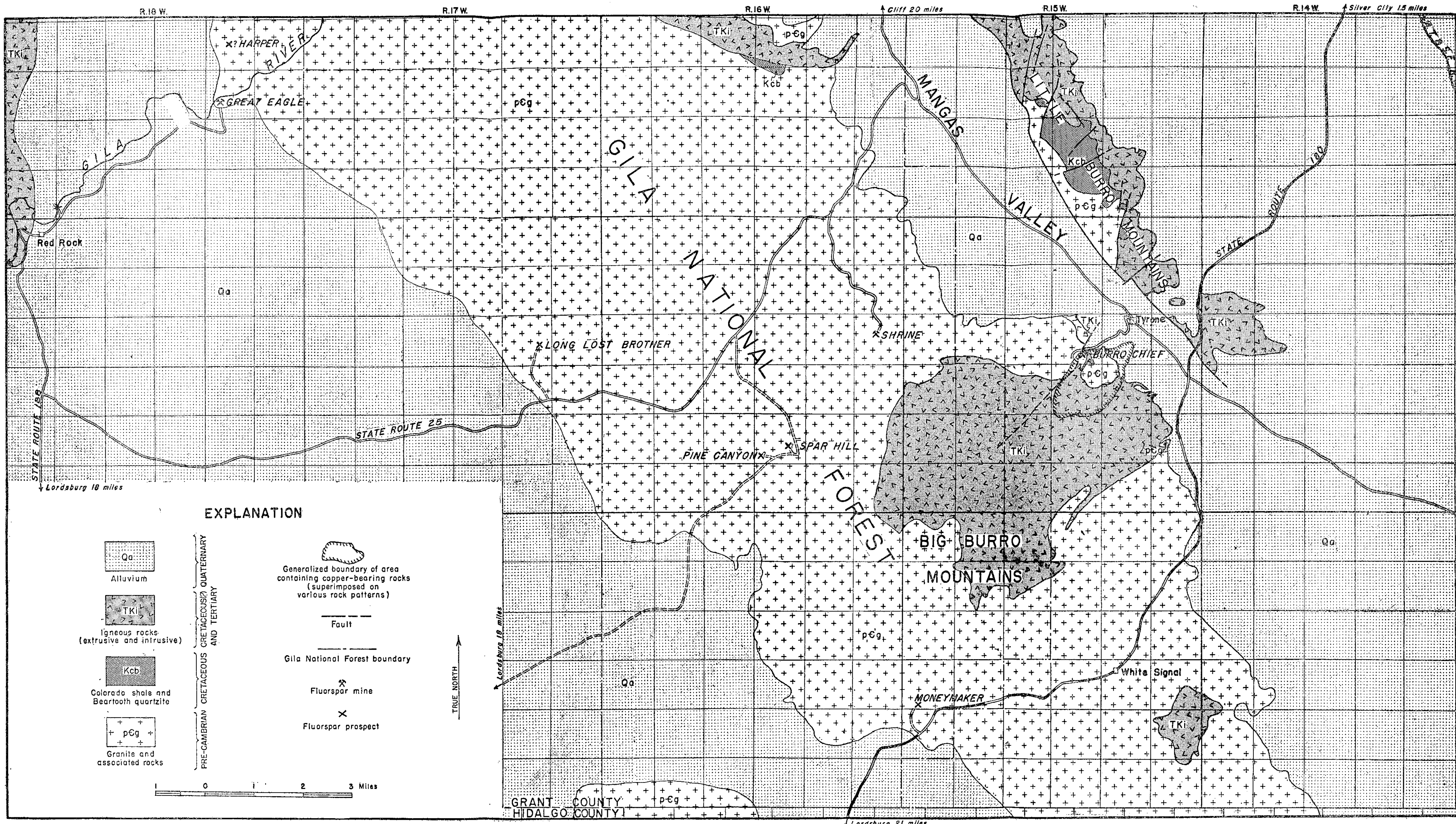
TABLE 14. SEQUENCE OF ROCKS IN THE SILVER CITY AREA [a]

Age	Subdivision		Thickness (feet)	Character of the rocks
QUATERNARY	Recent alluvium and gravel; Pleistocene gravel		1,000 ±	Unconsolidated sand, gravel, and clay in stream beds and bolsons; freshwater limestone; cemented gravel, usually trenched; basalt flows and dikes.
Unconformity				
TERTIARY	Miocene (?)		0-600	Quartz latite flows and dikes; lenses of volcanic sand and tuff.
Unconformity				
EARLY TERTIARY OR LATE CRETACEOUS			0-1675 ±	Granodiorite porphyry dikes and quartz diorite sills.
Unconformity				
UPPER CRETACEOUS	Colorado formation	Mancos shale	130 ± — 450 +	Sandstone with subordinate amounts of shale and limestone.
		Benton shale	190-200	Light to dark shale, locally sandy or calcareous.
UPPER CRETACEOUS (?)	Beartooth quartzite		60-180	Generally vitreous quartzite; in places includes sandstones and limy and shaly beds near the top and conglomeratic beds at the base.
Unconformity				
PERMIAN	Abo redbeds		0-200	Chiefly red shale with thin beds of limestone.
CARBONIFEROUS	Magdalena group	Syrena formation	170-390	Alternating limestone, in part shaly, and shale, in part limy.
		Oswaldo formation	400-430	Thick-bedded shaly fossiliferous limestone containing 20 to 30 feet of basal shale.
	Unconformity			
	Lake Valley limestone		240-450	White crystalline crinoidal limestone with nodules of white chert in the upper part, and massive blue or gray limestone with nodules of black chert and thin interbedded shales in the lower part.

TABLE 14. SEQUENCE OF ROCKS IN THE SILVER CITY AREA [a] (CONCLUDED)

Age	Subdivision	Thickness (feet)	Character of the rocks
UPPER DEVONIAN	Percha shale	100-450	Gray, green, or brown calcareous shale with limestone or layers of limestone nodules in the upper part; black fissile shale, in places pyritiferous, in the lower part.
Unconformity			
SILURIAN	Fusselman limestone	75 ±	Dark gray thick-bedded dolomite.
UPPER ORDOVICIAN	Montoya limestone	180-400	Light gray dolomitic limestone containing pink or red chert, with purplish-gray sandy dolomite at the base.
Unconformity			
LOWER ORDOVICIAN	El Paso limestone	216-478	Blue and gray dolomitic limestone with some white and gray chert; sandy and slabby with knotty chert near the base.
UPPER CAMBRIAN	Bliss sandstone	125-180	Gray to maroon quartzitic and glauconitic ferruginous sandstone with a basal conglomerate and fine-grained dolomitic sandstone near the top.
Unconformity			
PRE-CAMBRIAN			Granite and allied porphyries, gneiss, and schist.

[a] After Lasky, S. G., Geology and ore deposits of the Bayard area, Central mining district, New Mexico : U. S. Geol. Survey Bull. 870, pp. 13-47, 1936 ; Spencer, A. C., and Paige, Sidney, Geology of the Santa Rita mining area, New Mexico: U. S. Geol. Survey Bull. 859, pp. 12-41, 1935; Entwistle, L. P., Manganiferous iron-ore deposits near Silver City, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 19, pp. 13-28, 1944.



Base from Soil Conservation Service quadrangles

Geology from Sidney Paige, U. S. Geol. Survey Folio 199; N. H. Darton, Geologic Map of N. Mex.; Sidney Paige, U. S. Geol. Survey Prof. Paper 122

Generalized geologic map of the Burro Mountains and vicinity, Grant County, showing location of fluorspar deposits

TABLE 15. FLUORSPAR MINES AND PROSPECTS IN GRANT COUNTY

Name	Approximate location	Reference[a]
	Burro Mountains	
Burro Chief mine	S½ sec. 15, N½ sec. 22, T. 19 S., R. 15 W.	27: 109-110; 40; 44: 604-643
Shrine (Osmer) mine	N½ sec. 13, T. 19 S., R. 16 W.	
Long Lost Brother prospect	E½ sec. 14, T. 19 S., R. 17 W.	
Moneymaker prospect	SW¼ sec. 19, T. 20 S., R. 15 W.	
Spar Hill mine	SE¼ sec. 27, T. 19 S., R. 16 W.	
Pine Canyon prospect	SW¼SW¼ sec. 27, T. 19 S., R. 16 W.	
Sid Watson prospect[b]	Not located	
Great Eagle mine	SW¼ sec. 23, T. 18 S., R. 18 W.	27: 105-109; 30: 129; 46: 76
Harper prospect[b]	Sec. 19, T. 18 S., R. 18 W.	
Jack Pot prospect[b]	T. 18 S., R. 18 W.	
Valley Spar prospect	NE¼ sec. 4, T. 22 S., R. 15 W.	
Bounds Ranch prospect[b]	Sec. 8, T. 23 S., R. 15 W.	27: 103-105; 46: 76
Friday prospect	Sec. 22 ?, T. 21 S., R. 16 W.	
	Steeple Rock district	
Mohawk mine	Sec. 27, T. 16 S., R. 21 W.	
Powell (Fork) prospect	Sec. 18, T. 16 S., R. 21 W.	
	Mogollon and northern Pinos Altos Mountains	
	Gila area	
Clum mines	SW¼ sec. 33, T. 14 S., R. 16 W.	
Blue Spar prospects	NW¼ sec. 33, T. 14 S., R. 16 W.	27: 113, 114
Green Spar prospect	SW¼ sec. 28, T. 14 S., R. 16 W.	
Brock Canyon prospect	NE¼ sec. 28, T. 14 S., R. 16 W.	27: 114

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

TABLE 15. FLUORSPAR MINES AND PROSPECTS IN GRANT COUNTY (CONCLUDED)

Name	Approximate location	Reference[a]
Watson Mountain prospect	SE¼ sec. 21, T. 14 S., R. 16 W.	
Last Chance prospect	NE¼ sec. 21, T. 14 S., R. 16 W.	
Foster mine	S½ sec. 32, T. 14 S., R. 16 W.	27: 112-113
Big Spar prospect	NW¼ sec. 32, T. 14 S., R. 16 W.	
Thanksgiving prospect	NW¼ sec. 32, T. 14 S., R. 16 W.	
Victoria prospect	SW¼ sec. 29, T. 14 S., R. 16 W.	
Big Trail (Nut) prospect	NW¼ sec. 29, T. 14 S., R. 16 W.	27: 114
Cedar Hill (Howard) prospect	NW¼ sec. 29, T. 14 S., R. 16 W.	27: 114
	Seventy-four Mountain area	
Good Hope (Rain Creek, Blue Bird) mine	SE¼ sec. 11, T. 13 S., R. 18 W.	27: 114-115; 46: 77
Lakeview prospect	Not located	
Seventy-four Mountain prospect	W½ sec. 18, T. 13 S., R. 17 W.	27: 115
Fairview prospect	Not located	
Rainbow prospect	Not located	
	Silver City area	
Ash Spring Canyon prospect	NW¼ sec. 23, T. 17 S., R. 15 W.	
Cottonwood Canyon prospect[b]	Sec. 7, T. 17 S., R. 15 W.	18: 110-112
	Northern Cooks Range	
White Eagle mine	E½ sec. 34, T. 19 S., R. 9 W.	9: 68; 18: 100-103; 32: 76
Vista and Wagon Tire prospects	S½ sec. 21, T. 19 S., R. 9 W.	
Defense prospect	NE¼ sec. 28, T. 19 S., R. 9 W.	

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

BURRO MOUNTAINS

BURRO CHIEF MINE

The Burro Chief mine is situated on the north side of Copper Mountain, 10 miles southwest of Silver City in the Tyrone mining district. Tyrone, which was an important copper-mining center from 1902 to 1921, is 11/4 miles northeast of the mine. A good graded road 3 miles long connects the mine by way of Tyrone with State Route 180 at a point 9.5 miles from the railhead of the Atchison, Topeka, and Santa Fe Railway at Silver City (Plate 7). The mine is on the Burro Chief and Lode No. 1 patented claims.

The oldest workings are open cuts extending 185 feet southward from the junction of two main veins (Figure 4). From a point on the hillside 200 feet east of this intersection and 122 feet below it, an adit was driven toward a point directly below the junction. Only one mineralized zone was found at the end of the adit, but the junction of the two veins, which is above this point at the surface, was found 100 feet farther south on the adit level. Both veins were mined on the adit level, the west vein for 140 feet and the east vein for 100 feet south of their junction. Most of the ore between the adit level and the surface was removed. About 130 feet south-southwest of the adit is the Chemung No. 1 shaft (Plate 23, B), said to have been sunk in 1906 to a depth of 532 feet. From its 260-foot level, 217 feet below the adit, crosscuts were driven west to the fluorspar vein and east to a copper-bearing vein. By the end of 1944, drifts totaling 230 feet were extended along the fluorspar vein from the end of the crosscut, and stoping between these levels was well under way.

The rocks in the vicinity of the mine include rhyolite [70] of Tertiary (?) age, and granitic rocks of pre-Cambrian age into which the rhyolite was intruded. The deposit is in a fractured zone between two branching faults that belong to the major fault system in the northwest side of the Tyrone copper deposit (Plate 7). One of the branching faults, which forms the footwall of the fluorspar deposit, strikes N. 28° E. and dips 62°-80° SE.; the other fault, which forms the hanging wall, generally dips southeastward but more steeply than the footwall fault. At the surface the faults diverge southward from their junction until they are about 30 feet apart ; then they become parallel and continue so for as far as they have been mapped. On the adit level the junction of the faults is 100 feet south of its position at the surface, and the faults diverge until the fractured area between them is 55 feet wide. Three principal faults are present on the 260-foot level, forming a fractured zone from 18 to 45 feet wide. Their relationship to the faults on the adit level is not definitely established.

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[70] Determination by J. J. Glass, U. S. Geological Survey.

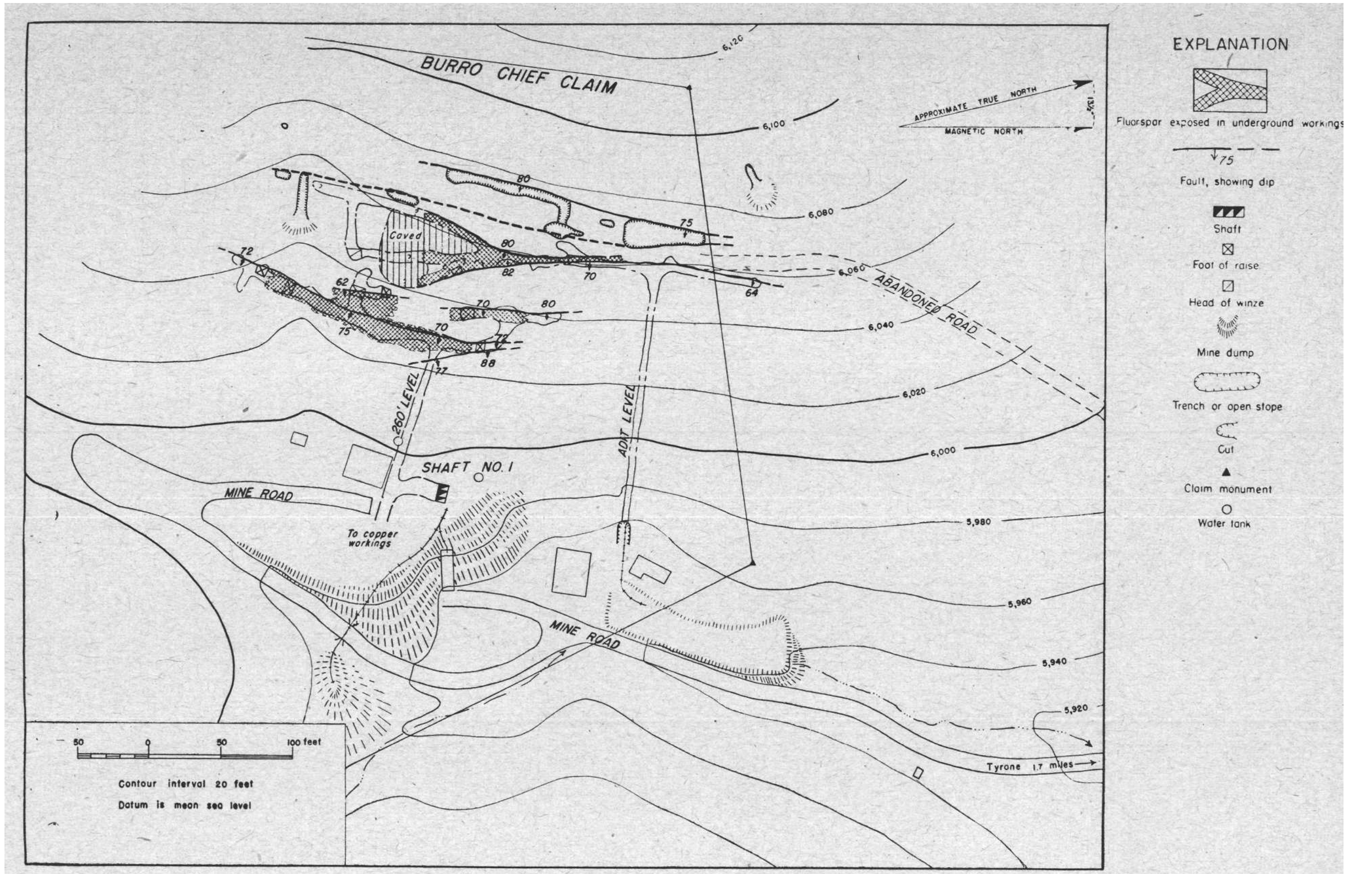

FIGURE 4.—The Burro Chief fluorspar mine, Big Burro Mountains, Grant County.

In many places on the hanging wall, a red gouge from a fraction of an inch to several inches thick causes scaling of the walls in open stopes. Movement occasioned by faulting broke the rock into large masses and small fragments and formed brecciated bodies at many places.

The fractures admitted fluorine-bearing solutions that replaced much of the shattered rock, forming veins of high-grade ore as much as 6 feet thick, and in places brecciated zones of minable ore 26 feet thick, and even thicker masses of lower-grade fluorspar. Some of the larger rock masses were only slightly affected by the solutions and remained as lenticular inclusions or "horses" in the deposit.

The vein material consists of green or purple fine- to coarse-grained 'fluorite, minor proportions of quartz and calcite, partly altered wall rock, and ferruginous clay. Patches of azurite and malachite are present on the footwall on the adit level. Solid veins of high-grade fluorspar are common, but most of the ore consists of hard masses of fluorspar of varying sizes in a soft or friable matrix of fine-grained fluorite, clay, and gangue minerals. The run-of-mine ore during 1943 and 1944 contained from 45 to 65 percent CaF_2, but much higher grades were obtained by selective mining and sorting during the early operations (see assay 10 below). The assays recorded in Table 16 show the CaF_2 content of the veins and of samples of the ore.

The Burro Chief fluorspar vein was first mined for flux for the copper smelters that were operated in the early 1880's.[71] It was acquired in 1913 by the Phelps Dodge Corporation and wag subsequently leased to various operators. By 1928 several cars of metallurgical ore had been shipped.[72] After several years of idleness, mining was resumed in 1937 by Louis L. Osmer and was continued through 1941 by Bacon and Osburn. In 1943 the property was leased by H. E. McCray, by whom it was operated through 1944. Complete records of ore shipments are not available, but partial records indicate that at least 28,500 tons of fluorspar was mined, including the output of 1944.

SHRINE (OSMER) MINE

The workings of the Shrine or Osmer mine lie on both sides of Maverick Gulch, a steep-sided canyon in the rolling hills on the north flank of the Big Burro Mountains. The mine is in sec. 13, T. 19 S., R. 16 W. (Plate 7), but the claims that include the deposit extend into section 14. Tyrone is 5 airline miles east of the mine. Most of the ore has been trucked 24 miles via State Route 25 and U. S. Highway 260 to the Atchison, Topeka, and Santa Fe Railway at Silver City. The mine was worked from

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[71] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico : U. S. Geol. Survey Prof. Paper 68, p. 323, 1910.

[72] Johnston, W. D., Jr., op. cit., p. 110.

TABLE 16. ASSAYS OF ORE FROM THE BURRO CHIEF MINE

Assay No.	Description of sample	Width of sample (feet)	Chief constituents (percent) CaF_2	SiO_2	$CaCO_3$
1.	Sample of 200 pounds of ore taken for metallurgical test from various places in adit level	---	74.0	14.0	---
2.	Sample across back of drift on adit level, 110 feet southwest of adit	12.0	73.5	---	---
3.	Sample across face of stope 20 feet above 260-foot level, 40 feet north of crosscut	4.5	51.3	---	---
4.	Sample across back of drift on 260-foot level, 11 feet northeast of crosscut	8.0	58.1	---	---
5.	Sample across back of drift on 260-foot level, 18 feet southwest of crosscut	3.5	68.0	---	---
6.	Sample across back of drift on 260-foot level, 37 feet southwest of crosscut	6.0	63.1	---	---
7.	Composite of samples 2 to 6	---	65.7	17.8	2.9
8.	Chip sample across back of drift on 260-foot level, 95 feet southwest of crosscut	6.0	54.0	---	---
9.	Chip sample across back of drift on 260-foot level, 120 feet southwest of crosscut	7.5	41.0	---	---
10.	Selected sample from stockpile of metallurgical lump fluorspar	---	96.6	1.7	1.3
11.	Weighted-average grade of about 24,000 tons shipped during 1943 and 1944	---	56.3	---	---

1 and 11—From H. E. McCray.

2 to 7—U. S. Bureau of Mines, sampling by C. H. Johnson, district engineer.

8 and 9—Sampling by R. D. Trace, U. S. Geological Survey, 1945.

10—Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 110, 1928.

1936 to February 1942 by Louis L. Osmer, except for a period in 1940-41 when it was leased to D. F. McCabe. Early in 1942 it was sold to the General Chemical Company, which operated it during the period of this field investigation. L. L. Osmer supplied much of the data for the following description.

The underground workings are chiefly west of Maverick Gulch and prior to acquisition by the General Chemical Company consisted of a shaft 135 feet deep with an adit and drift on the 35-foot level, a few feet above the bed of the gulch, and drifts on the 85- and 135-foot levels. The 35-foot or tram level was stoped to the surface for a distance of about 75 feet west of the shaft. The 85-foot level was stoned eastward under the gulch for a short distance and westward for about 120 feet to a pinch in the vein. Only a small amount of work had been done on the 135-foot level.

The mine is in fine- and coarse-grained pre-Cambrian (?) granite, which is cut by a dike of basic rock trending N. 50° W. and dipping southwest. The dike crops out about 150 feet west of the shaft and was found in the west end of the 85-foot level. The fluorspar is localized in a breccia, a few feet to 14 feet wide, along a fault that strikes N. 75° - 80° W. and dips 60° S. It can be followed in open cuts for about 120 feet west of the gulch and in trenches for about 200 feet east. The fluorspar deposit consists of veins of fluorspar parallel with the fault and separated from it by breccia, manganiferous gouge, or masses of rock. The breccia is partly cemented with fluorspar. Individual veins are as much as 24 inches thick, and the ore body ranges from 3 to 5 feet in thickness. The ore is coarse-grained purple or green fluorite with small proportions of quartz in thin bands and patches. Some of the veins are banded, suggesting that they were formed by crystallization in fissures.

The ore from this mine is of unusually high grade, as indicated by the 1941 and 1942 shipments, which averaged 81.0 and 83.5 percent CaF_2 respectively. The ore marketed from 1936 to February 1942 amounted to 2,865 tons.[73] This volume of shipments was greatly exceeded during 1943 and 1944.

LONG LOST BROTHER PROSPECT [74]

The Long Lost Brother prospect, owned by D. F. McCabe, is in the west foothills of the Burro Mountains, about 1 mile north of the Red Rock-Mangus road (Plate 7).

The prospect exposes a fluorspar deposit in a north-trending fault that cuts gneisses and schists of the pre-Cambrian complex of the Big Burro Mountains. The fault plane, which is nearly vertical, has been traced for about 600 feet. Fault breccia from 4 inches to 4 feet wide has been partly or wholly replaced by fluorite. In the face of a shaft 18 feet deep this breccia is strongly replaced along a band 16 inches thick, which was estimated to contain at least 75 percent CaF_2. In addition to this replacement ore, thin veins of pure green, yellowish-green, and ivory fluorspar traverse the breccia. This fluorspar is coarse-grained, massive or acicular, and in most places banded. Some of the crystal aggregates break into cuneiform masses. The veins are from 4 to 12 inches thick and are composed of very high-grade ore that could be easily sorted from the remainder of the breccia zone.

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[73] Data supplied by H. E. Britt, through the courtesy of L. L. Osmer.

[74] From field notes made by James K. Grunig, U. S. Geological Survey, July 1944.

Northwest of the shaft, across a valley, a northwest-trending fault contains a small amount of fluorite and some psilomelane along its northeast side.

MONEYMAKER PROSPECT[75]

The Moneymaker prospect is situated in Whitehall Canyon, 25 miles southwest of Silver City on a side road about 1 mile north of State Route 180 (Plate 7) . The property comprises four unpatented claims, the Moneymaker Nos. 1 and 2 and the St. Patrick Nos. 1 and 2. They were filed by C. M. Russell and T. M. Russell of Tyrone, who have worked them intermittently since 1939. By 1943, when the property was examined, two shallow shafts and several cuts had been completed.

The deposit is mostly in coarse-grained pre-Cambrian granite along the south side of an aplite dike about 40 feet wide trending N. 65° E. Two bodies of siliceous fluorspar are exposed. One, on the Moneymaker No. 1 claim, is about 400 feet long ; the other, on the St. Patrick No. 1 claim, was opened for a length of 25 feet, but the southwest end had not been reached in 1943. The bodies do not have definite walls and become irregularly leaner away from the middle of the zone. The associated rock is extensively altered. The maximum width of the zone is 6 feet, and the average width of the part estimated to contain 50 percent or more of CaF_2 is 2 feet. Subsequent to the examination on which this discussion is based, Felix Vogel, engineer of the U. S. Bureau of Mines, cut six samples which had an average width of 4 feet and assayed 35 percent CaF_2, 50 percent $Si0_2$, and 4 percent $CaCO_3$. The depths to which the fluorspar bodies are exposed are 40 feet on the Moneymaker claim and 25 feet on the St. Patrick claim. About 300 tons of ore had been sold from this property by May 1944; of this quantity 200 tons showed an average assay content of 50 percent CaF_2, 41 percent $Si0_2$, and 3 percent $CaCO_3$.

SPAR HILL MINE [76]

The Spar Hill mine is on the west flank of the Big Burro Mountains in the Malone mining district. A truck trail 3 miles long connects it with State Route 25 at a point 36 miles from Lordsburg and 25 miles from Silver City. Another road, extending southwest from the mine, reduces the distance to Lordsburg to 27 miles (Plate 7) . The Spar Hill claim was filed by Marshall N. Kuykendall in September 1941, and mining was begun the next year. The workings in February 1944 comprised an inclined shaft to the 40-foot level, a drift on that level following the vein

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[75] Most of this description is taken from field notes made by Joseph Fisher, U. S. Geological Survey, March 1943.

[76] Description chiefly from field notes and an unpublished memorandum made by R. D. Trace, U. S. Geological Survey, February 1944.

southwestward for 90 feet, a crosscut that explored the width of the mineralized zone, and a "glory hole" from which ore was drawn on the 40-foot level.

The deposit is in a wide brecciated zone formed by a fault that strikes N. 53° E. and dips steeply northwest in fine-grained felsic porphyry and granite. On the surface it can be traced for 300 feet southwestward from the shaft. In the crosscut near the end of the drift the zone is 70 feet wide and contains numerous veinlets and pockets of fluorspar, which constitute from 30 to 40 percent of the zone. They are composed of medium-grained transparent gueen fluorite with no appreciable gangue minerals. The chief diluent of the marketed ore is kaolinized wall rock. Hand sorting removed some of this waste, as indicated by the assays in Table 17. Approximately 800 tons of ore was sold to the Indian Metals mill from February 1942 to March 1944.

TABLE 17. ASSAYS OF ORE FROM THE SPAR HILL MINE, 1942-1944[a]

Assay No.	Description of sample	Chief constituents (percent)		
		CaF_2	SiO_2	$CaCO_3$
1.	Small shipment to Gila mill	46.9	42.0	---
2.	Average assay of about half of ore shipped to Indian Metals mill, 1942 to 1944	54.0	37.0	6.9

[a] Data supplied by M. N. Kuykendall.

PINE CANYON PROSPECT [77]

The Pine Canyon deposit is 4 miles northwest of the peak of the Big Burro Mountains and 29 miles by road southwest of Silver City (Plate 7). It is about half a mile west of the Spar Hill prospect. In July 1943 it was owned by Charles F. Johnson.

The country rock is chiefly pre-Cambrian granite. Near the deposit it is cut by several aplite dikes 2 to 7 feet wide that strike N. 30° - 60° E. and dip steeply northwest. The granite is traversed by numerous fissures, most of which are approximately parallel to the dikes and contain stringers and small pockets of fluorspar as much as 2 feet thick. The over-all length and width of the mineralized zone was not determined. Fluorspar also forms isolated groups of crystals disseminated through the granite near the veins. It is medium- to coarse-grained, green, purple, red, or white, and contains no appreciable gangue. Although the fluorspar is very high-grade, the veins and pockets are small and far apart. The over-all grade of the fluorspar and the intervening rock is represented by samples that assayed 27 percent

[77] Description chiefly from an unpublished memorandum by R. H. Earhart, U. S. Geological Survey.

CaF_2. They were taken from a 20-foot trench across one of the zones in which fluorspar is relatively plentiful.[78]

GREAT EAGLE MINE

The Great Eagle mine is $4^1/_2$ miles northeast of Red Rock on the south bank of the Gila River. During 1942-1944 ore was transported by truck for 30 miles southward over State Route 188 to Lordsburg, or for 55 miles over State Route 25 and U. S. Highway 260 to Gila (Plate 7). The property was located in 1911 and worked until 1914 by A. B. Conner of Red Rock.[79] It was idle until 1918 when it was reopened by the Great Eagle Mining Company. A mill was built during the next year and operations were continued until 1921.[80] Mining was resumed in 1939 by the Fluorspar Milling Company, and was continued during the next two years by the Southwestern Mining Company. In October 1943 the property was leased from Mrs. Ruth Spamm, Lampasas, Texas, by D. F. McCabe of Lordsburg, who sold several thousand tons of ore from the old dumps during the succeeding months and was working the mine at the end of 1944.

The workings are along a narrow fault zone that strikes N. 35° W. In 1944 this zone had been trenched and stoped from the surface for a distance of 560 feet. An adit 90 feet below the highest point on the outcrop gave access to the largest of these stopes. An incline from the surface followed the southeast end of the zone to a level about 60 feet below the adit and supplied a working level more than 300 feet long (Plate 8). By the end of 1944 a shaft had been sunk to a depth of 110 feet, or 90 feet below the 60-foot level, and a crosscut to the mineralized zone was being made from the bottom of the shaft.

According to Johnston, [81] the rocks of the area surrounding the Great Eagle mine consist mainly of pink and gray coarse-grained granite, probably of pre-Cambrian age, and a stock-like mass of rhyolite that has been intruded into it. Both granite and rhyolite are cut by thin sills of gray-green diabase. The rhyolite and diabase are probably of Tertiary age. A short distance west of the exposures of Tertiary rocks, a wide fault zone strikes N. 35° W. and crosses the Gila River.

The fluorspar deposits are in irregularly vertical brecciated zones within this fault zone. In the wider parts of the deposit two of more veins are separated by "horses" of partly replaced granite. Toward the ends of the deposit the two veins join, and the fluorspar occurs in a single low-grade vein. In 1944 the average aggregate width of these veins within the known ore

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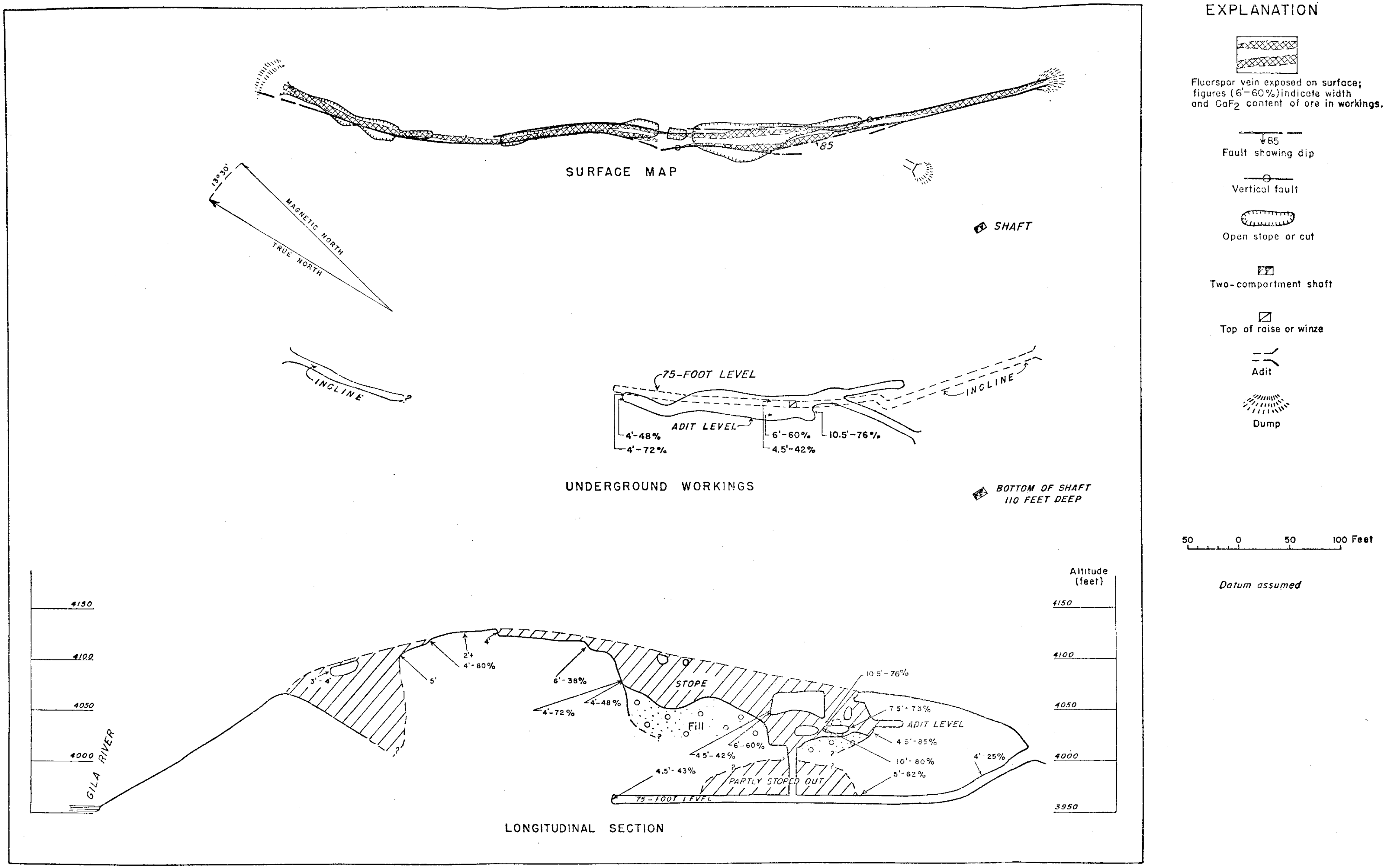
[78] Data furnished by C. F. Johnson.

[79] W. D., Jr., op. cit., p. 109.

[80] Talmage, S. B., and Wootton, T. P., The non-metallic mineral resources of New Mexico and their economic features: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 12, p. 76, 1937.

[81] Johnston, W. D., Jr., op. cit., p. 105.



Compass and tape survey by W. R. Storms, U. S. Bur. Mines, and R. D. Trace, D. A. Warner, and E. Gillerman, U. S. Geol. Survey, 1943-44

Great Eagle mine, Grant County

body was 7 feet. The weighted-average CaF_2 content of the ore was 66 percent, as indicated by seven assays made by the U. S. Geological Survey and Bureau of Mines. The difference in altitude between the highest outcrop and the bottom of the drift is 170 feet. Widths of ore in the drift are slightly less than the average width of the ore body. The over-all length of the deposit is about 600 feet ; the northwest half at the surface contains a mass of low-grade fluorspar about 200 feet long.

The ore body contains coarsely crystalline to microcrystalline fluorite, fine-grained quartz, jasperoid, and inclusions of altered granite. The coarse-grained fluorspar is aquamarine and very high-grade ; the dense microcrystalline fluorspar has a dull lustre and conchoidal fracture, and ranges from reddish-bown to white. A selected sample of the white ore assayed 88.1 percent CaF_2 (see assay 5, Table 18) . This type of fluorspar is generally nodular and has a banded structure. The quartz forms thin bands and small masses of tiny crystals ; lenses of jasperoid contain spherules of fluorite 1 to 3 millimeters in diameter.[82]

TABLE 18. ASSAYS OF ORE FROM THE GREAT EAGLE MINE

Assay No.	Description of sample	Width of sample (feet)	Chief constituents (percent) CaF_2	SiO_2	$CaCO_3$
1.	Surface exposure, southeast face, northwest working	4.0	80.4	18.2	---
2.	Shallow trench, northwest end of main working	6.0	37.9	50.5	---
3.	Face of drift, 410 feet from portal	4.5	42.9	39.2	---
4.	Across ceiling of drift 160 feet from portal	4.0	61.7	27.0	---
5.	Selected sample of white microcrystalline ore	---	88.1	2.5	---
6.	Sample of high-grade vein in upper part of main workings	---	93.0	2.9	---
7.	Average CaF_2 content of 1,983 tons of ore shipped between July 1, 1918, and January 1, 1919	---	91.5	---	---
8.	Average assay by Indian Metals mill of 784 tons of ore from dumps, 1943-1944	---	65.0	30.0	5.0
9.	Average CaF_2 content of 1,206 tons of ore from dumps received at the Gila mill in May 1944	---	53.5	---	---

1 to 5— U. S. Geological Survey.

6, 7—Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 108, 1928.

8, 9—From D. F. McCabe.

[82] Idem, p. 107.

Incomplete records indicate that about 11,700 tons of fluorspar has been marketed, of which 3,800 tons of metallurgical grade was sold during the period 1917-1921, about 1,900 tons from 1931 to 1941, and 6,000 tons of milling ore during 1943-1944.[83]

VALLEY SPAR PROSPECT

The Valley Spar prospect is situated in gently rolling country 17 miles by road north of Separ, a station in Luna County on the Southern Pacific Railroad (Plate 1) . When visited in 1943 the prospect comprised eleven pits and trenches and three shallow shafts. These workings are located on two claims, the Valley Spar Nos. 1 and 2, filed August 12, 1918, by Moses Trimmer. The workings expose a main north-trending vein for a distance of 600 feet, and, at a point 350 feet west of its north end, a subsidiary brecciated zone. Near the middle of the main vein a northwest-trending vein intersects it and is in approximate alinement with the brecciated zone.

The country rock is pre-Cambrian granite ; Tertiary (?) volcanic rocks form the bluffs a short distance to the east. The main vein is a silicified fault gouge and breccia, 1 to 4 feet thick, that has been mined for gold. Veins of purple coarse-grained fluorite, 1 to 18 inches thick, traverse the silicified zone but constitute only a small percentage of it. A wide pit on the subsidary brecciated zone exposes interstitial fillings of fluorite estimated to constitute about 25 percent of a zone $3^1/_2$ feet across. Although a few tons of fluorspar were sold from, the dumps and from ore obtained by selective mining, the ore could not be profitably mined under market conditions that prevailed prior to 1945 and probably could not be recovered profitably as a by-product.

FRIDAY PROSPECT

The Friday prospect is $28^1/_2$ miles by road southwest of Silver City. Of this distance $26^1/_2$ miles is over State Route 180 and the remainder over truck trails south of the highway (Plate 1) . Two claims, the Friday Nos. 1 and 2, were filed on the deposit in May 1944 by Victor Bonnefoy of Albuquerque. The property was visited in August 1944 by R. D. Trace of the U. S. Geological Survey, whose notes form the basis of this description.

On the Friday No. 1 claim six shallow shafts and short stopes expose a fluorspar vein for a distance of 200 feet. The vein is in pre-Cambrian granite[84] that has been faulted, forming a brecciated zone bordered by areas of sheeted structure that strike east and dip 80°-90° N. In these structures stringers and lenses of blue or green medium- to coarse-grained fluorite were deposited. In the brecciated area the fluorite is sufficiently con-

[83] Oral communication from D. F. McCabe.

[84] Darton, N. H., Geologic map of New Mexico: U. S. Geol. Survey, 1928.

centrated to form a vein from $1^1/_2$ to 3 feet thick that is estimated to have an average CaF_2 content of about 30 percent. The workings indicate that the ore bodies are short lenses, 20 to 30 feet long. It is reported that 3,000 tons of ore containing about 50 percent CaF_2 were shipped before Bonnefoy acquired the property.[85]

STEEPLE ROCK DISTRICT

MOHAWK MINE [86]

The Mohawk mine is generally classed with the fluorspar deposits near Duncan, Arizona, the nearest rail outlet. The mine lies in New Mexico, however, $2^1/_2$ miles east of the State line (Plate 1) on Bitter Creek. Ore is hauled $13^1/_2$ miles over a dirt road and thence 12 miles over Arizona State Highway 75 to the Southern Pacific Railroad at Duncan. The property was owned by Robert Gillespie of Casa Grande, Arizona, who leased it to the Southwestern Mineral Company in 1940 and to E. J. Marston in 1944. In January 1944 the mine consisted of a caved stope about 100 feet long and 7 feet wide, in the middle of which was a shaft 80 feet deep. From the 75-foot level in the shaft a drift extended south for 250 feet and north for a little more than 50 feet.

The deposit is in one of the major northwest-trending faults of the area, which at the mine strikes about N. 10° W. and dips 90°-85° E. The wall rock is purple andesite porphyry of Tertiary age. The fault is extensively silicified ; it contains pockets and shoots of fluorspar, and, in the vicinity of the mine, fine-grained disseminated pyrite. The workings accessible in 1943 and 1944 were mainly in the largest of the ore shoots, which is slightly more than 100 feet long and averages 7 feet in width both at the surface and near the bottom of the shaft. In the drifts from the ends of the stope the vein contains too much waste to be mined with profit. Several small pits, dug along the strike of the vein at distances ranging from 100 to 150 feet from the cut, exposed pockets of 'fluorspar 1 to 3 feet wide that were estimated to contain from 40 to 60 percent CaF_2. The ore consists of pale-green fine-grained fluorite associated with fine-grained white quartz.

It has been estimated that 3,000 tons of ore was shipped from the workings, of which 1,850 tons averaging 65 to 70 percent CaF_2 and 30 to 35 percent $Si0_2$, were beneficiated in 1940-41 at the 50-ton flotation mill of the Southwestern Mineral Company. [87]

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[85] Oral communication from Victor Bonnefoy.

[86] This discussion is based on an unpublished memorandum by Roy L. Griggs, 1943, and on field notes by Robert D. Trace, January 1944. U. S. Geological Survey.

[87] Data furnished by Ernest Douglas, Southwestern Mineral Co.

POWELL (FORK) PROSPECT[88]

The Powell or Fork property is 21 miles northeast of Duncan, Arizona, just east of the New Mexico-Arizona line and about 3 miles west of the Mohawk mine (Plate 1). The Bitter Creek road passes a short distance to the south. The prospect, which is on the Fork claim, is owned by Fred Powell of Duncan. He has explored it by a trench 25 feet long and 20 feet deep, a pit 10 feet long and 30 feet deep about 80 feet northwest of the trench, and two shallow pits.

The predominant rock is dark-gray fine-grained basic porphyry that is cut by andesite (?) and rhyolite dikes. All these rocks are probably of Tertiary age. The structure in which the fluorspar occurs is a shattered zone that strikes northwest, paralleling the major faults of the area. Parts of the fault gouge and wall rock have been replaced, and some of the fissures are filled with veins of siliceous fluorspar that range in width from a few inches to 3 feet. The wider parts are small pods of ore irregularly arranged in the fractured zone. The stringers are most numerous in a brecciated zone southwest of the trench, where they constitute as much as 20 percent of the zone. The fluorspar is translucent, green or colorless, chiefly fine-grained, and intimately intermixed with quartz that amounts to about 30 percent of the whole. In some places, however, the fluorspar is coarse-grained and contains relatively little quartz. From March 1942 to January 1943, a total of 127 tons of ore averaging 59 percent CaF_2 was Marketed. Some of this ore contained as much as 41 per cent SiO_2.

MOGOLLON AND NORTHERN PINOS ALTOS MOUNTAINS

The Mogollon and northern Pinos Altos Mountains of Grant County form a southward continuation of the Mogollon Mountains of Catron County, and the fluorspar occurrences are of much the same type as those to the north. The known deposits occur in two localities. One, called the Gila area after the nearby settlement of Gila, occupies the southwest corner of T. 14 S., R. 16 W. It is in the canyon of the Gila River and the mountains to the southeast (Figure 5) . The other, called the Seventy-four Mountain area, is close to the north boundary of the county in the vicinity of Seventy-four Mountain (Figure 3).

The first fluorspar mined in New Mexico came from the Foster mine in the Gila area in the 1880's. Prospecting since then has exposed several veins, from some of which ore was marketed during World War I and intermittently during the ten years that followed. Mining was stimulated by the completion in June 1943 of the fluorspar mill at Gila, and ore from the Clum, Foster,

[88] This description is taken chiefly from an unpublished memorandum by R. D. Trace, U. S. Geological Survey, based on an inspection in April 1944.

and Victoria mines was beneficiated. The average daily output of these mines in 1944 was 50 tons, most of which came from the Clum mines.

GLUM MINES

The Clum mines comprise two deposits, the Clum deposit and the Clum East vein. They are 6 airline miles northeast of the settlement of Gila, in the deeply dissected north end of the Pinos Altos Mountains. The Clum mine is on a ridge about 1,000 feet above the Gila River; the Clum East vein is about 750 feet to the northeast and 300 feet lower, in a gulch tributary to Brushy Canyon (Figure 5). The property comprises a group of six claims, called Spar Nos. 1-6, filed by Marion George of Gila and

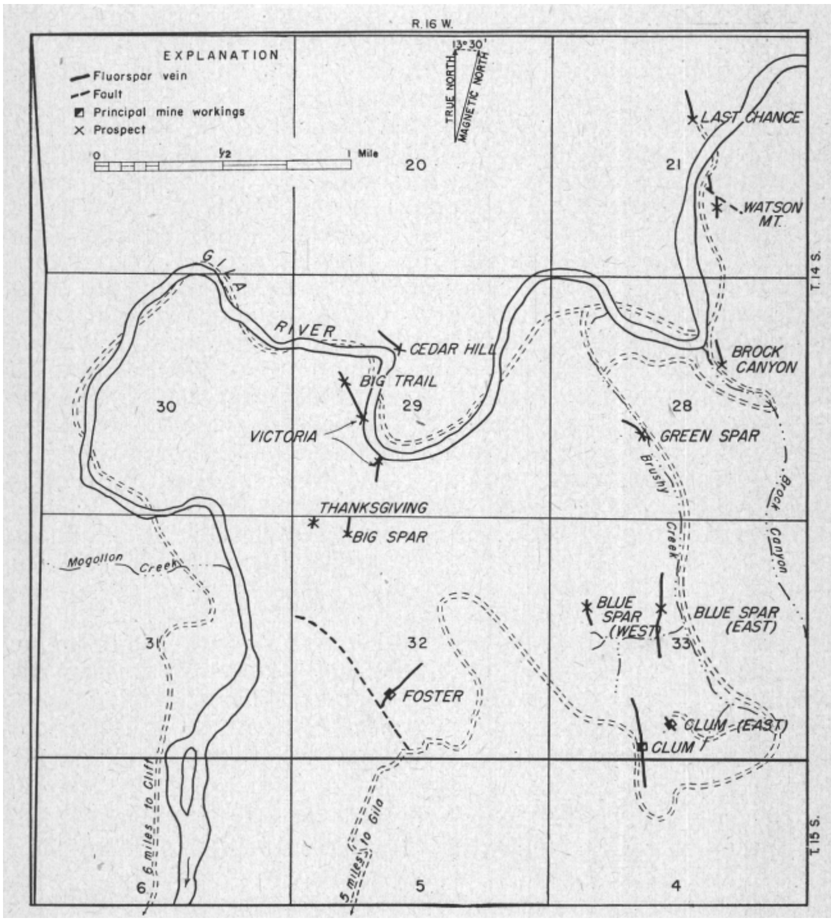

FIGURE 5.—Index map of fluorspar mines and prospects in the Gila

J. G. Hackley of Mangus Springs and leased to the Brown-Johnson Corporation. The access road to the Gila fluorspar area passes both mines.

The workings of the Clum mine are described in Part 2 of this bulletin (pages 198-201) and are illustrated on Plate 24. The Clum East vein has been developed by a shaft 160, feet deep with levels at depths of 60 and 130 feet. Ore was mined from the 60-foot level to the surface on both sides of the shaft for a total distance of about 125 feet, but on the 130-foot level only stringers of fluorspar were found in a drift extending 35 feet northwestward from the shaft.

Trachytic latite occurs both as massive rock and as agglomerate in the vicinity of the Clum mine. The east wall rock of the Clum vein is generally lighter colored than that on the west, owing to bleaching of biotite. South of the mine the latite is darker and the groundmass is more glassy.

The vein occupies a fault that strikes N. 5° W. and dips 70°-80° W. Movement on this fault was greatest along the foot-wall producing a coarsely brecciated zone in which large "horses" of rock are common. This zone is bordered on the west by a sheeted zone formed by fractures that are roughly parallel with the fault. The brecciated zone has been so greatly altered that much of the finer material between the large masses of rock has been reduced to clay. Embedded in this clay and filling crevices in the rock are masses and veins of fluorspar. Some of the veins consist of coarse-grained transparent green fluorite that is coarsely brecciated or forms crusts on rock fragments. A larger proportion, however, is microcrystalline, translucent to opaque, brown, light blue, red, or white, and forms banded or homogeneous cavity fillings and nodules. The chief gangue mineral is quartz, which was deposited contemporaneously with the fluorite, partly replacing wall rock and breccia. No metallic minerals are present. Both replacement and cavity-filling processes contributed to the formation of the vein. The tenor of the ore is shown in Table 19.

At the close of 1944, mining showed that the Clum mine contains two ore bodies, whose limits had not been completely determined. The north ore body, the site of the principal operation, had a maximum known length of 510 feet, on the 160-foot level. The average width of the stopes was 6 feet, and that of the ore left in the faces was $2^1/_2$ feet. A drift 30 feet long north of the shaft at the 260-foot level exposed only a narrow vein, which may be either a lean part of the main vein or a minor vein beneath the main ore shoot, whose northerly pitch may place it beyond the end of this short drift. The south ore body, 325 feet south of the main shaft, is at least 100 feet long on the surface and in 1944 had been stoped to a maximum depth of 30 feet. Its

TABLE 19. ASSAYS OF ORE FROM THE CLUM MINE

Assay No.	Description of sample	Width of sample (feet)	Chief constituents (percent) CaF$_2$	SiO$_2$	CaCO$_3$	R$_2$O$_3$
1.	Average grade of about 3,000 tons shipped to Silver City, Lordsburg, and Deming, 1937-1942	---	70	---	---	---
2.	Average of 2 grab samples from stocks of mined ore	---	61.9	23.5	1.0	7.4
3.	Average of 2 chip samples from stopes above 50-foot level	5	57.1	24.4	1.5	6.7
4.	Weighted-average assay of about 20,000 tons sold to the Gila mill in 1943 and 1944; about 80 percent from the Clum mine and the remainder from the Clum East mine	4,000 Tons ---	52.0	---	---	---

1—Oral communication from M. J. Wallace, operator of the Clum mine in 1942.
2 and 3—Collected by C. H. Johnson, district engineer, U.S. Bureau of Mines.
4—From S. T. Brown, president, Brown-Johnson Corp.

width ranged from 3 to 6 feet. The size and continuity of these bodies in the brecciated zone suggest that exploration of the sheeted zone that adjoins it on the west would be justified.

The first mining operation was in 1937, when several hundred tons of selected ore were taken from the north ore body. After the mine had been closed for a time, it was reopened by M. J. Wallace of Gila in 1942, and mining was continued in 1943 and 1944 by the Brown-Johnson Corporation. The total output through 1944 was about 20,300 tons.

The deposit in the Clum East mine is much smaller than the main ore body of the Clum mine, but otherwise the two are quite similar. The wall rock is trachytic latite, the vein is the product of both replacement and cavity filling in fault breccia, and the ore is chiefly microcrystalline fluorite with minor proportions of coarsely crystalline fluorite in veins and pockets.

The vein occupies a fault that strikes N. 33° W. Near the surface in the main shaft it dips 80° SW., but 75 feet southeast of the shaft the dip is 80° NE. and the vein pinches out. This change or roll of the vein is reflected underground at a point about 80 feet down the shaft, below which the ore body becomes narrower. The roll, with a pitch of about 45° NW., marks the bottom of the ore body in the southeast half of the mine and may do so northwest of the shaft. The northwest pitch of the bottom of the ore explains the absence of ore in the bottom of the shaft and suggests the possibility that this or another ore shoot may be found below the 60-foot level in the northwest end of the vein.

Before the mine was opened late in 1943, the vein had been traced by surface exposures for a distance of 155 feet, and trenching by the U. S. Bureau of Mines had extended the total length to 180 feet. Sampling on the surface showed a 50-foot section of low-grade ore in the north half of the vein. The south half was found to average 7.8 feet in width and to contain 53.6 percent CaF_2. Subsequent mining showed that the low-grade section at the surface was underlain by minable ore.

The ore is composed predominantly of nodules and irregular masses of white, red, or brown fluorite, so finely crystalline that it has a velvety appearance. Tiny quartz grains are distributed through this ore. Assays show that the ore contains from 80 to 81 percent CaF_2 and 6 percent $Si0_2$. Minor amounts of green coarsely crystalline fluorite are embedded in the granular nodules or form veinlets through the breccia. Fluorspar constitutes about one-half of the breccia zone and occurs irregularly through it. Approximately 4,000 tons of ore was sold from this ore body during 1943 and 1944.

BLUE SPAR MINE

The Blue Spar claims, which are about half a mile north of the Clum mines, are in two groups (Figure 5). The west group consists of the Blue Spar Nos. 1 and 2 claims and contains a prospect on the West vein ; the other group, about a quarter of a mile to the east, consists of the Blue Spar Nos. 3 and 4 claims and contains the Blue Spar mine, which is on the East vein. These claims were filed by W. A. Howard of Cliff.

In 1944 the mine consisted of adits totalling 200 feet in length and supplementary workings in opposite sides of a draw on the west side of Brushy Canyon. It is reached by foot trail from the access road in the canyon between 200 and 300 feet below the mine. Numerous trenches and pits and two adits have been made along the vein for 750 feet north and 850 feet south of the mine. These workings were described by Johnston[89] as the Bushy Canyon mine.

In the vicinity of the Blue Spar mine the latite country rock is cut by several north-trending fractures and narrow brecciated zones that contain veins of fluorspar. Only the vein on which the mine is situated has been prospected extensively. It occupies a fault breccia that has an average width of 4 feet and dips steeply both eastward and westward. Fluorspar occurs in the breccia and fault gouge as lenses and pockets that appear to be replacement bodies, and as veins deposited subsequently in open fissures.

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[89] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, pp. 113-114, 1928.

Most of these fissures are next to the walls, although some extend within the brecciated zone. Although the vein is exposed intermittently for a distance of 1,600 feet and over a vertical range of 250 feet, only the small section in the vicinity of the mine has been found to contain ore. The workings suggest that the vein may contain two ore bodies, of which the one south of the draw is the larger. It is about 100 feet long, 30 feet deep, and from 10 to 30 inches wide. Elsewhere the average width of the exposed fluorspar over a considerable distance is 9 inches.

The vein contains coarsely crystalline blue or green fluorite that breaks cleanly from the walls and breccia fragments. The grade of this material is indicated by an assay of two small veins in the south drift of the mine, which showed 91.1 percent CaF_2, 2.6 percent $Si0_2$, 1.8 percent $CaCO_3$, and 4.3 percent $Al_20_3 + Fe_2O_3$.[90]

BLUE SPAR WEST VEIN

The Blue Spar West vein, on Blue Spar Nos. 1 and 2 claims, lies about a quarter of a mile west of the Blue Spar mine. In 1944 it had been explored by a shaft about 30 feet deep and by several shallow exploratory trenches dug by the Federal Bureau of Mines and the operator. The prospect was reached by foot trail about half a mile long from the high ridge on which the access road is situated.

The vein is in a coarsely brecciated zone that strikes N. 6° W. and is vertical. The zone is almost completely mineralized with fluorite and quartz and forms a vein that tapers from a width of 6 feet at the shaft to 4 feet, 2 feet, and 1 foot at points 60, 180, and 195 feet, respectively, south of the shaft. The vein was not found in trenches to the north.

The ore is chiefly microcrystalline gray or reddish-brown siliceous fluorite, but some veinlets, pockets, and crusts of crystalline fluorite occur. Irregularly mixed with the fluorite are gouge and extensively silicified rock fragments. Much of this waste material, which constitutes about 50 percent of the vein, could be eliminated during mining. A small shipment of ore to the Gila mill assayed 61.0 percent CaF_2 and 33.1 percent $Si0_2$.

GREEN SPAR PROSPECT

The Green Spar prospect is $1^1/_4$ miles north of the Clum mine on the steep west side of Brushy Canyon (Figure 5) . It consists of the Green Spar and Big Lode claims, relocated in February 1942 by C. H. Simpson and Lola Simpson. The access road passes down the bottom of the canyon about 100 feet below the claims. The vein has been prospected by an open cut 30 feet long on the outcrop and by a crosscut and drift, aggregating 240 feet in length, at a level 15 feet above the canyon bottom. The

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[90] Idem.

Federal Bureau of Mines trenched and sampled the deposit in 1943.

The country rock is dark-gray trachytic latite that has been largely altered to light gray or buff near eastward-striking fractures or faults. The change in color is due largely to the bleaching of biotite. Some parts of the rock are thickly impregnated with tiny pyrite crystals, whose decomposition in the vicinity of seepages has promoted the formation of alum, probably through processes similar to those described by Hayes [91] near Alum Creek farther up the Gila River. Silicification of the latite along the fractures is common.

Fluorspar occurs in breccia and in the branching fractures of a fault that in its northern part strikes N. 37° W. At a point 190 feet northwest of the open cut a change in strike is associated with an east-trending fault that appears to offset the vein. The brecciated zone dips 65°-80° NE., the southern part being the steeper. Northward, beyond the end of the fluorspar vein, the fault is indicated for several hundred feet by fractures and silicified rock. Southward it is covered beneath a broad talus slope.

Although fluorspar occurs in small amounts along the fault and in the adjoining rocks, it is found in minable width and grade only along the southernmost 70 feet of the vein. Here the vein is from 5 to 6 feet thick, and a channel sample 68 inches long taken across the vein by the Federal Bureau of Mines assayed 45.4 percent CaF_2. The CaF_2 content of the few tons of hand-sorted ore shipped from the cut ranged from 68 to 72 percent.[92] Elsewhere the assays showed from a few to 30 percent CaF_2. The crosscut and drift, 80 feet below the open cut, exposed only stringers of fluorspar.

The ore in the open cut is light green medium- to coarse-grained fluorite with narrow bands and small lenses of fine-grained quartz and inclusions of partly replaced wall rock.

A deposit that is somewhat narrower, but in other respects quite similar to the Green Spar deposit, occurs on Green Spar Nos. 1 and 2 claims, 500 feet to the east on the other side of the canyon. Another fluorspar locality is about 600 feet south of the Green Spar prospect, where there are numerous thin veins of coarse-grained fluorspar. One of these reaches a maximum width of 20 inches for a short distance.

BROCK CANYON PROSPECT

The Brock Canyon deposit is in a promontory at the junction of Brock Canyon and the Gila River (Figure 5). It was owned in 1944 by Clarence Simpson, who filed three claims along

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[91] Hayes, C. W., The Gila River alum deposits : U. S. Geol. Survey Bull. 315, pp. 215-223, 1907.

[92] Oral communication from Jack Wallace, superintendent, Clum mine.

the strike of the vein. The workings at that time consisted of deep trenches into the canyon wall, a shaft about 20 feet deep with drifts at the bottom in the flood plain of the canyon, and two shallow shafts on the extension of the vein in the valley of the Gila River. None of the shafts was accessible at the time of inspection.

The deposit is a fissure vein along a fault that strikes N. 6°14° W., dips 70° W., and contains little gouge or breccia. The vein contains several short narrow lenses of slightly siliceous fluorspar that could be mined only as a small operation under very favorable market conditions.

WATSON MOUNTAIN PROSPECT

The Watson Mountain prospect is on the east bank of the Gila River about $2^1/_4$ miles north of the Clum mine (Figure 5). The access road, which here follows the flood plain of the river, is adjacent to the north opening but is 160 feet below the highest outcrop of the vein. The deposit is included within the Watson Mountain Nos. 1 and 2 claims, filed by Fred Chappel and Dink Chappel. The north opening is an adit that follows the vein southward for 100 feet and then parallels a transverse fault for 40 feet. The north end of the south group of workings is about 100 feet vertically above the face of the adit and 200 feet horizontally south of it. This group of workings consists of trenches and pits having a maximum depth of 20 feet, opened at intervals for 340 feet southward along the vein.

The fluorspar vein occupies a fault zone 1 to 4 feet wide in finely porphyritic andesite. A parallel fault about 300 feet to the east brings agglomeratic andesite into contact with the porphyritic rock. These faults are in approximate alinement with those on the Last Chance prospect, which lies to the north across the Gila River. The main fault of the Watson Mountain deposit is sinuous but has a general northerly trend and dips about 75° W. A coarse fault gouge about 3 feet wide contains the fluorspar veins. In some places there is only one vein, but commonly there are two, one on each wall. Their aggregate thickness ranges from 1 to 3 feet but probably averages slightly less than 2 feet. Between the north and south workings the veins are offset about 100 feet by a fault that strikes N. 35° W. The northern segment was moved westward with respect to the southern. North of the fault the fluorspar is generally thin and irregular, but the south workings within a distance of 300 feet contain two bodies in which the aggregate thickness of the fluorspar veins is about 2 feet.

The fluorspar is composed of coarse-grained green fluorite with a small percentage of quartz, and is estimated to contain from 70 to 80 percent CaF_2. Although considerable waste is unavoidably included with the material mined, much of it can be removed by sorting, as indicated by the fact that a 50-ton lot mined and marketed by the Chappels contained 80 per cent CaF_2.[93]

LAST CHANCE PROSPECT

The Last Chance prospect is in the cliffs on the north bank of the Gila River, across the river from the Watson Mountain mine and at the end of the access road (Figure 5) . A good ford across the Gila is passable for automobiles in all but flood periods. The deposit is within the Last Chance, Poor Devil, and Faun claims, filed in June 1942 by Clarence Simpson, Lola Simpson, Floyd Evans, and Opal Evans. It was later leased to the Brown-Johnson Corporation, which in 1943 drove an adit 304 feet long about 50 feet above the river level. In the early summer of 1943 the Federal Bureau of Mines trenched and sampled the deposit. The topography, geology, and mine workings are shown on Plate 9.

The principal rock in the locality is finely porphyritic andesite that occurs both as massive lava and as flow breccia. A rhyolite dike, which trends N. 50° W. and contains small andesite inclusions near its southwest margin, lies northeast of the deposit. These rocks are probably of Tertiary age. A fault zone bounded by two parallel faults about 150 feet apart, striking N. 25° W. and dipping 75° SW., truncates the dike 400 feet north of the adit portal. The fault zone contains at least one brecciated zone, which in the main workings is parallel with the bordering faults. The fault zone is also traversed by oblique tension fractures that have an average strike of N. 25° E. and a dip of 55° NW. A few of these fractures extend beyond the bordering faults. More than one period of movement is indicated by fault striations, which are vertical on the west bordering fault and plunge 20°-35° southward in the brecciated zone in the main workings. All this movement was pre-mineral.

Fluorspar was deposited chiefly as interstitial fillings in the breccias, but it also occurs in many fractures as coarse-grained high-grade stringers and veins from a fraction of an inch to 6 inches thick. Deposition by replacement was negligible, and the fluorspar breaks freely from the wall rock. Deposition did not completely fill the voids but left many crystal faces with both cubic and octahedral terminations. Most of the octahedral forms resemble those in the Watson Mountain deposits and consist of tiny cubes in parallel arrangement on pyramidal terminations. In the lower parts of the deposit only a little quartz is associated with the fluorite, but in the higher outcrops the veins are extensively silicified.

In most places the stringers are widely separated, but near the top of the bluff a band 10 to 20 feet wide extends obliquely

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[93] Oral communication from Dink Chappel.

from, the southwest to the northeast boundary faults. The band contains numerous veins separated from one another by 6 to 24 inches of andesite and ranging from half an inch to 8 inches in thickness. The veins probably constitute less than 10 percent of the whole band. Concentrations of fluorspar in breccia are rather widely separated, being found in the vicinity of the portal of the adit, in the end of a crosscut 180 feet from the portal, and at the base of the cliff 200 feet above the portal. Outcrops of siliceous fluorspar on top of the bluff northwest of the workings show that the length of the mineralized zone at the surface is 640 feet. Fluorspar occurs over a vertical range of more than 300 feet (Plate 9). The breccias that contain more than 30 percent CaF_2 range in thickness from a few inches to 14 feet, but average 21/2 feet in the adit, 5 feet in the outcrop overhead, and 5 feet in the outcrop at the base of the cliff. Although the *aggregate* tonnage is rather large, that of any one shoot is small. The tenor of these veins is shown in Table 20. Approximately 40 tons of ore was shipped during exploratory work on this prospect.

TABLE 20. ASSAYS OF ORE FROM LAST CHANCE PROSPECT

Assay No.	Description of sample	Width of sample (feet)	Chief constituents (percent) CaF_2	SiO_2
1.	Channel sample diagonally across vein beginning 87 feet from portal	18	33.5	55.8
2.	Weighted averages of samples from vein outcrop above adit	5	31.7	---
3.	Weighted averages of samples from vein under cliff	5	56.0	---
4.	Grab sample from stock bin	--	37.7	55.6
5.	Sample of first 11-ton shipment of hand-sorted ore	--	46.7	---
6.	Sample of second 11-ton shipment of hand-sorted ore	--	37.6	---

1, 4—U. S. Geological Survey.
2, 3—U. S. Bureau of Mines.
5, 6—From S. T. Brown, president, Brown-Johnson Corp.

FOSTER MINE

The Foster mine is the oldest fluorspar mine in New Mexico. Ore produced from it by Apolinario Ogas and Pedro Carajal in the early 1880's was used in the silver-lead smelters at Silver City. The mine is 6 miles northeast of Gila and is the first fluorspar deposit on the access road from Gila to the fluorspar area (Figure 5). The main workings are near the bottom of a west-trending gulch. In 1944 they consisted of an adit 330 feet long, with irregular stopes to the surface, and a winze 45 feet deep from which a small amount of stoping to the adit level had been done (Plate 10). Other workings consisted of two short drifts, three shafts with associated stopes, and several trenches. These workings explored the vein for a distance of about a quarter of a mile northeast of the main adit. In 1944 the property was under lease to D. F. McCabe.

Most of the workings are in trachytic latite, but the highest or most northeasterly are in trachytic agglomerate that dips a few degrees eastward. The deposit ends 180 feet southwest of the adit, at the fault contact between the trachytic latite and the Gila conglomerate. The latter in this locality consists of cobbles and pebbles in a semi-consolidated sandy matrix. Stratification is not apparent in the small exposures near the mine or in road cuts in the vicinity, but in exposures about 1 mile south of the mine finer-textured semi-consolidated conglomerate and underlying coarse-grained sandstone are stratified and have been tilted by faulting. The Gila conglomerate here is similar to and probably contemporaneous with that described in the Gila Valley near Safford, Arizona, which is of late Pliocene and Pleistocene age. [94]

The fluorspar deposit occupies a normal fault of which the average strike is N. 45° E. and the average dip 85° NW. The displacement of the agglomerate indicates a throw of 20 feet and a strike-slip of about 60 feet, with the hanging wall moving southwestward. A zone of moderate brecciation from 3 to 8 feet wide was developed by this movement, and the fissures and interstices of the breccia were filled with fluorite. Recurrent movement opened other fissures, and these were filled with a second generation of fluorite. The vein, therefore, contains both homogeneous fissure veins and heterogeneous breccia impregnations. Both walls of the vein are strong, but a little scaling has developed in the weathered zone near the surface. The average width of the stopes in 1943 was about 3 feet and that of the vein left in the faces was 18 inches. The southwest end of the vein has been dragged southward by a major fault that strikes N. 33° W. and brings the Gila conglomerate into contact with the latite. The northeast end of the vein is in the agglomerate 1,350 feet from this fault and about 435 feet above the main adit. Within this distance three small ore bodies have been mined.

Most of the metallurgical fluorspar is obtained from the fissure veins, which contain coarse-grained clear green fluorite with minor proportions of quartz. Ore from the parts of the vein that contain much breccia is generally of milling grade and can be mined so as to contain from 50 to 70 percent CaF_2. A grab sample from a stock pile accumulated during October 1943

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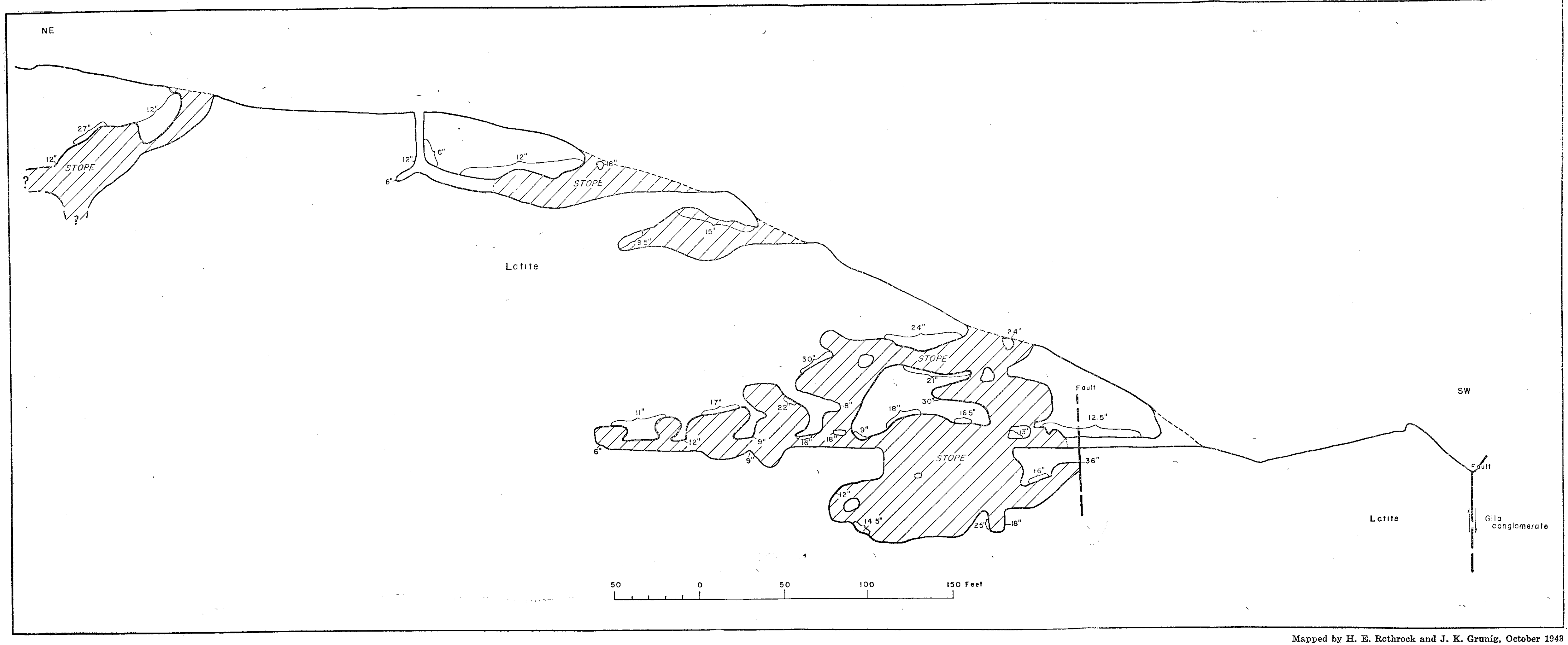
[94] Knechtel, M. M., Geology and ground-water resources of the valley of Gila River and San Simon Creek, Graham County, Arizona : U. S. Geol. Survey Water-Supply Paper 796-F, PP- 196-198, 1938.



Mapped by H. E. Rothrock and J. K. Grunig, October 1943

Vertical section of the Foster mine, Grant County. Figures indicate width of fluorspar assayed 63.5 percent CaF_2 and 24.0 percent SiO_2, and is probably representative of this grade of ore. The total of the shipments of ore from this mine is not known.

BIG SPAR PROSPECT

The Big Spar prospect is situated about three-quarters of a mile north of the Foster mine and in approximate alinement with the Victoria prospect, a quarter of a mile to the north (Figure 5). It is on the Big Spar Nos. 1 and 2 claims, owned by Fred Chappel and Dink Chappel, and is reached by a foot trail that rises about 400 feet from the Gila River, half a mile west of the prospect. An adit 10 feet long, two cuts, and a shallow trench expose the vein for a distance of about 130 feet, with a difference in altitude between the highest and lowest exposures of about 100 feet.

The deposit occupies a fault breccia in latite porphyry. The fault strikes N. 6° - 10°E. and dips 75° - 85° E. Traversing the breccia are two closely spaced discontinuous veins, one commonly on the footwall and the other separated from it for distances as great as 6 feet but averaging about 2 feet. The thickness of each vein ranges from 3 to 24 inches, and their aggregate thickness averages about 18 inches. The fluorspar is siliceous and is estimated to contain from 40 to 80 percent CaF_2. The veins pinch to mere stringers at the north end of the workings.

THANKSGIVING PROSPECT

About 1,000 feet west of the Big Spar prospect are the workings on the Thanksgiving Nos. 1 and 2 claims, owned by H. A. Coffee and Kenneth Coffee of Gila (Figure 5) . The claims are about 500 feet above the Gila River and are reached by foot trail only. Three shallow excavations in fine-grained andesite (?) expose a shattered zone from $2^1/_2$ to 6 feet wide that contains breccia fillings and veinlets of fluorspar. The greatest concentration of fluorspar is in the north trench, where a fault breccia 21/2 feet wide contains an estimated 40 percent CaF_2. In the other two exposures the fluorspar is scattered and does not appear to constitute more than 20 percent of the vein.

VICTORIA PROSPECT

The Victoria prospect is situated in the cliffs on the left bank of the Gila River, about a quarter of a mile north of the Big Spar prospect (Figure 5). It was located in 1939 by Thomas and Edward Gutierrez and was sold to Stephen Villareal and John Barker in 1943. The Victoria Nos. 1 and 2 and Big Trail claims were filed to include several veins. Four small openings have been made on the outcrop of a north-trending vein. One cut near

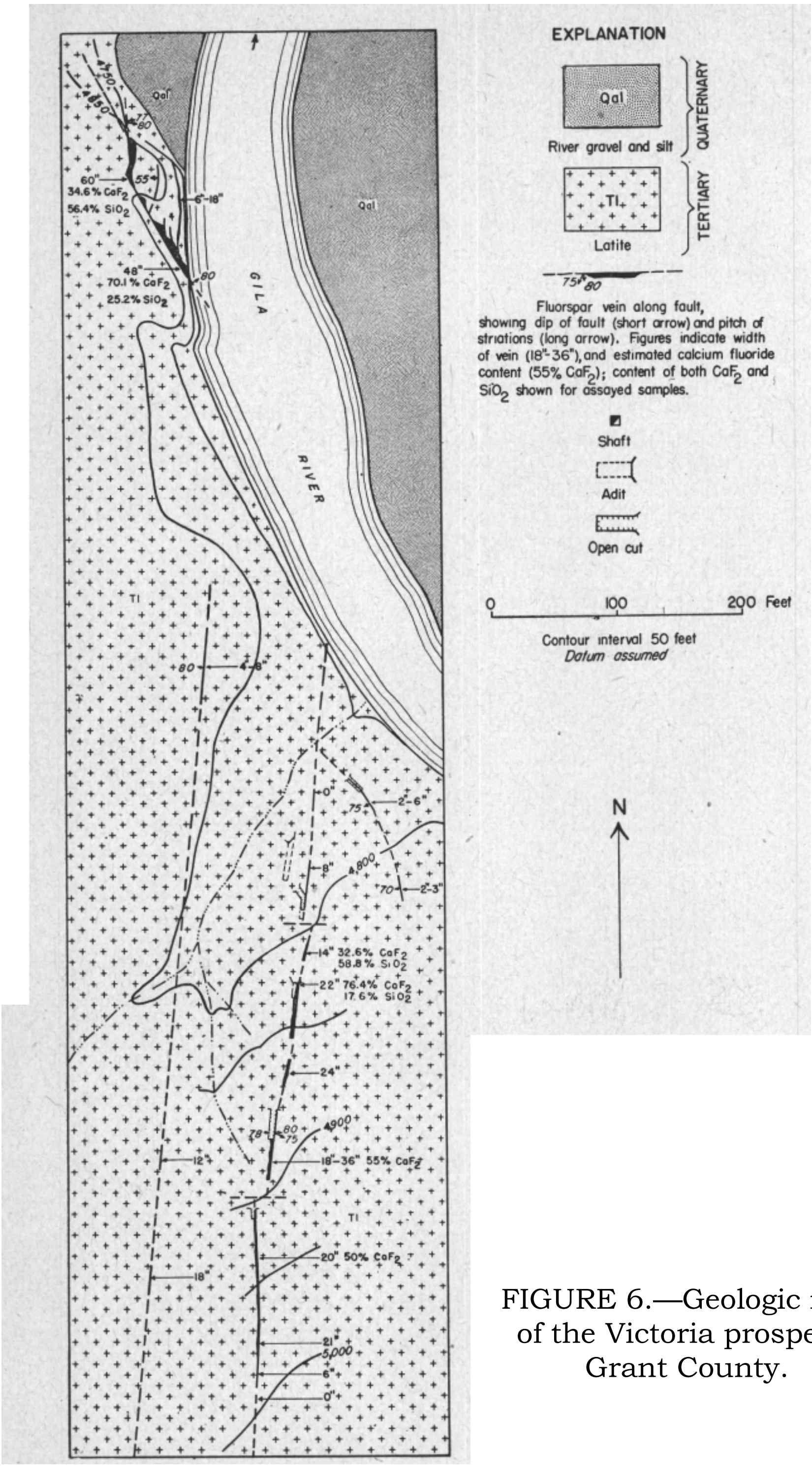


FIGURE 6.—Geologic map of the Victoria prospect, Grant County.

the north end of this vein is on a smaller vein branching southeastward. A shaft 17 feet deep is in a large cut on a northwest trending deposit, 400 feet down the river from the most northerly cut (Figure 6).

The country rock is a dense dark-gray finely porphyritic latite flow that has a glassy to granular matrix containing plagioclase and orthoclase phenocrysts averaging less than 0.1 inch in diameter. A few hundred feet north of the prospect this flow is overlain by an agglomeratic trachyte that is predominantly fine-grained but contains layers of volcanic pellets from 0.1 to 0.3 inch in diameter. It is medium- to thick-bedded and dips about 20° NE.

Four veins are present. The most promising is exposed in a large open cut in a promontory on the west bank of the river. In the floor of the cut a shaft about 7 feet square and 17 feet deep was sunk. As the collar of the shaft is within a few feet of the river's edge, constant pumping is required to de-water it. The vein occupies a wide brecciated zone formed by a fault that strikes N. 30° W., a change of 37° from the general trend of the principal veins on the south end of the property. The breccia, which is on the southwest or foot wall, is thoroughly cemented and partly replaced by fluorspar and forms a vein whose width ranges from a few inches to 5 feet. Several offshoots from this vein penetrate the hanging wall for distances as great as 80 feet. They strike northward, and their thickness ranges from a fraction of an inch to 18 inches. Northwest of the promontory, fractures indicate a continuation of the fault to the Big Trail prospect a few hundred feet distant.

The ore is white or green fine- to medium-grained fluorite with inclusions of brecciated rock and varying proportions of quartz. Assays 3 and 4, Table 21, show the percentages of CaF2 and SiO_2 in samples of the vein, and assay 5 shows the average CaF_2 content of ore shipped during 1944.

In the southern part of the property the chief elements of the structure are two vertical faults that strike N. 7° E. and lie about 100 feet apart. The eastern fault is exposed in the steep hillside south of the river for a distance of 470 feet. The east wall of the fault is well defined and contains striations dipping 70°-75° S. Fault gouge and breccia from a few inches to 3 feet wide separate it from the poorly defined west wall. For a distance of about 350 feet along the fault, siliceous fluorspar occurs irregularly in widths ranging from a few inches to 3 feet. The exposures are separated by covered intervals that are slightly longer than the outcrops and may represent pinches or less siliceous sections in the vein. The highest point on the outcrop is about 200 feet above the river. Assays 1 and 2, Table 21, show the percentages of the chief constituents at two localities on this vein. The western of the two parallel faults contains a siliceous fluorspar vein that in one place is 18 inches thick but elsewhere is narrower. A subsidiary structural feature is a fault that branches southeastward from the north end of the eastern vein. It contains small narrow lenses of fluorspar.

TABLE 21. ASSAYS OF ORE FROM THE VICTORIA PROSPECT

Assay No.	Description of sample	Width of sample (inches)	Chief constituents (percent) CaF_2	SiO_2
1.	Chip sample across second cut on vein south of Gila river	22	76.4	17.6
2.	Chip sample across outcrop between first and second cut on vein south of the river	14	32.6	58.8
3.	Chip sample across brecciated zone west of river at water's edge	48	70.1	25.2
4.	Chip sample across silicified outcrop near top of promontory west of river	60	34.6	56.4
5.[a]	Weighted-average assay of about 600 tons of hand-selected ore taken from the above localities	--	55.0	---

[a] Data furnished by J. Knighton, New Mexico Manganese Co.

During the period January to May 1944, approximately 600 tons of ore was mined from the two principal veins. The ore was transported over a ford at the south vein and a temporary bridge at the north vein, thence by wagon down the river bed to the mouth of Mogollon Creek and from there by truck to Gila.

BIG TRAIL PROSPECT

The northern end of the Big Trail prospect, located on the trail that formerly provided the most direct route into the canyon of the Gila River, is about a quarter of a mile from the wagon road used to haul ore from the Victoria prospect. The Big Trail prospect is the northern continuation of the deposit on the Victoria claims (Figure 5) , and appears to be the one described by Johnston as the Nut prospect.[95] It was relocated in January 1944 by S. L. Villareal and J. L. Barker of Gila.

The south working on the Big Trail claim is a small open cut on a ridge about 650 feet N. 25° W. from the shaft of the Victoria prospect. A zone of fracture within this distance indicates that the north and south deposits are on the same structure, but the fact that only scattered stringers of fluorspar have been found in the intervening ground suggests that this ground is

[95] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School a Mines, State Bur. Mines and Min. Res. Bull. 4, p. 114, 1928.

almost barren. The Big Trail cut, which is 15 feet deep, exposes a faulted siliceous fluorspar vein ranging in thickness from 30 inches at the top to 6 inches at the bottom. The vein strikes N. 35° W. and dips 80° NE. A large chip sample from it assayed 61.5 percent CaF_2 and 31.6 percent SiO_2. A thick non-mineralized gouge along the vein indicates post-mineral faulting. A small cut, 70 feet northwest of the Big Trail cut and 30 feet lower, shows a brecciated vein of siliceous fluorspar 30 inches thick, which was estimated to contain about 35 percent CaF_2. In the draw, about 70 feet northwest of this small cut, another cut shows that the vein pinches to only a few inches in thickness. Scattered veinlets of fluorspar penetrate fragmental trachyte north of the draw, which at this point is close to the contact between the trachyte and the finely porphyritic latite that underlies it. These exposures indicate that vein material containing more than 35 percent CaF_2 is narrow, shallow, and not more than 140 feet long.

CEDAR HILL (HOWARD) PROSPECT

The Cedar Hill or Howard prospect is on the north bank of the Gila River half a mile north of the Victoria mine (Figure 5) . Cedar Hill Nos. 1, 2, and 3 claims, owned by Fred Chappel and Dink Chappel, include the deposit. It is reached by horse trail over the mountains or by poor truck trail up the bed of the Gila River.

The prospect is in a fault breccia several feet wide that strikes N. 45°-50° W., dips 85° SW., and contains veinlets and cavity fillings of quartz and fluorspar. The footwall is a thick flow of finely porphyritic latite overlying latite agglomerate. The same sequence of rocks is in the hanging wall, but the contact is about 70 feet higher. Striations on the footwall pitch 30°-70° SE. Post-mineral faulting has so fractured the vein material and wall rock that the vein is very likely flooded below the level of the river.

Fluorspar can be traced along the fault for a distance of 600 feet, but in the northwest part of the property the exposures are not continuous. The maximum difference in altitude between the highest and lowest exposures is about 180 feet. Three short adits in a cliff at altitudes of about 15, 70, and 140 feet above the river expose vein material 30 to 50 inches, 32 inches, and 34 inches wide, respectively. About 100 feet northwest of the highest adit the vein is exposed in an open cut and is 24 inches wide. Large chip samples from these exposures were assayed with the results shown in Table 22.

About 300 feet northwest of the cut, across a gulch, the vein has been prospected by two open cuts in which fluorspar from 8 to 21 inches thick was exposed. A third cut 50 feet northwest of these was practically barren of fluorspar.

TABLE 22. ASSAYS OF FLUORSPAR FROM THE CEDAR HILL PROSPECT

Assay No.	Location of sample	Width of sample (inches)	Chief constituents (percent) CaF₂	SiO₂
1.	Lowest adit	50	25.3	61.2
2.	Middle adit	32	33.8	54.6
3.	Highest adit	26	35.3	52.0
4.	Cut 100 feet northwest of highest adit	24	56.7	35.2

GOOD HOPE MINE

The Good Hope or Rain Creek mine is situated on the Mogollon Mountain front, 2 miles west of Seventy-four Mountain and about 17 miles by graded dirt road north-northwest of Gila (Figure 3). It is on the east side of the rugged Rain Creek canyon, which is about 300 feet deep and must be crossed to reach the mine. The deposit was owned during World War I by Tabor and Munroe, who named it the Rain Creek mine. Johnston, who examined it in 1927, called it the Blue Bird mine.[96] After World War I the property was acquired by Raymond Barnum and R. B. Springer. During the ensuing years it was leased to various operators, who made two cuts and an open stope along the vein. In the stope they sank a shaft 25 feet deep and extended the level northward by a drift 60 feet long. A tunnel, 123 feet long and 160 feet below the collar of the shaft, was extended toward the vein but failed to reach it by 50 or 60 feet.

The principal rock is a dark-gray or tan latite porphyry[96] with feldspar phenocrysts averaging 1 millimeter in length. The deposit occupies a fault breccia that has an undulating trend but strikes generally N. 5° E. and dips 80° W. The breccia zone is 1 to 10 feet wide, and fissures related to it are irregularly permeated with fluorite, calcite, and quartz. The mineralized breccia is exposed at three localities within a distance of 800 feet along the fault, but only the two southern openings contain ore. The most southerly of these is a cut 40 feet long and 25 feet deep, the south face of which exposes a fluorspar vein 6 inches thick on the footwall, and manganiferous calcite containing a little fluorite 4 feet thick on the hanging wall. The fluorspar forms a solid high-grade vein that widens to 5 feet in the northern end of the cut. The other ore body is exposed 150 feet north of the 5-foot vein by an open stope 55 feet long and about 30 feet deep. Its south end contains a shaft 25 feet deep, and a draft 60 feet long extends from its north end. The vein zone in the open stope contains a few solid siliceous fluorspar veins, ranging in thickness

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[96] Johnston, W. D., Jr., op. cit., pp. 114-115. [97]Idem, p. 114.

from 1 to 12 inches but reported to be as much as 21/2 feet wide, [98] and a zone of brecciated rock and fluorspar several feet wide. The unbroken veins are composed of banded green or purple fluorite, quartz, and white or brown calcite. The brecciated zone contains much calcite, some of which has been leached in these shallow workings, making the ore very porous. The vein in the adit contains narrow fluorspar stringers in a breccia 1 to 2 feet thick.

The abundance of calcite in the Good Hope vein distinguishes it from most of the fluorspar veins in the Mogollon Mountains. Calcite constitutes the major part of the vein north and south of the two principal openings. It is usually gray or brownish black, depending on the content of manganese oxide. The calcite vein in the south face of the south cut assayed 5.1 percent MnO, 65.6 percent $CaCO_3$, 22.9 percent CaF_2, and 2.4 percent SiO_2 and Fe_2O_3.

An assay representative of the siliceous veins showed 73.3 percent CaF_2, 22.8 percent SiO_2, and 1.2 percent $CaCO_3$. The calcareous nature of the brecciated zone is indicated by a 4-foot chip sample, taken across the face of the shaft, which showed 60.3 percent CaF_2, 5.4 percent SiO_2, and 26.8 percent $CaCO_3$. The assay of a grab sample from a stock pile of ore showed 92.65 percent CaF_2, 6.36 percent SiO_2, and 1.05 percent $CaCO_3$, [99] and indicated that a high-grade product could be obtained by careful sorting. It is probable, however, that the ore sold to the mill at Silver City, containing 74 percent CaF_2,[100] is more nearly representative of the shipments as a whole. Reports from several sources indicate that about 1,100 tons of ore has been sold from the mine.

The deposit affords unusual evidence of the successive crystallization of the vein minerals in open cavities. In one exposure this sequence was begun by the deposition of fluorite that only partly filled the fissure. The remaining space was then filled with calcite, after which the fissure was widened and additional bands of quartz, calcite, and fluorite were deposited, though not necessarily in that order. These deposits, as shown in the main workings, were brecciated by post-mineral faulting.

OTHER PROSPECTS

A few tons of fluorspar has been taken from other prospects in the vicinity of Seventy-four Mountain, but the deposits are so inaccessible that operations were not long continued. None of the deposits was visited. A truck-load of very high-grade yellow coarsely crystalline fluorspar was delivered to the Gila mill by

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[98] Idem, p. 115.

[99] Idem, p. 115.

[100] Data furnished through the courtesy of J. O. Fischer, president, Continental Chemical and Ore Co.

Fayette Rice from his Lakeview claims, about 2 miles north of the Good Hope mine on the west side of Rain Creek ; between 200 and 300 tons of fluorspar is reported to have been mined by Oliver Wytcherly and taken by pack train from the veins of the Seventy-four Mountain, Fairview, and Rainbow prospects, all on the west side of the mountain.

SILVER CITY AREA

ASH SPRING CANYON PROSPECT

The Ash Spring Canyon prospect is 6 miles northwest of Silver City on the west side of Ash Spring Canyon near its head (Plate 1) . A private access road leaves the Bear Mountain road at the Continental Divide, three-quarters of a mile southeast of Bear Mountain. The first claims located on this prospect were called the El Carmen and Tularosa, but they were relocated and extended in 1944 by Clara B. Tapia and P. R. Pennington and called the Fluorspar Nos. 1-4. The deposit has been prospected by an adit about 160 feet long, driven to the vein from a point about 150 feet above the canyon bottom, and by a trench, a pit, and a shaft at a level approximately 50 feet above the adit. The extremities of these surface workings are 110 feet apart. One of them is connected with the adit, but the others are only a few feet deep. Most of this work was done in 1943 and 1944 by F. Parks and D. W. Smith.

The workings are in breccia 3 to 6 feet wide along a nearly vertical fault striking N. 65° E. in the El Paso limestone. [1] The adit is approximately 40 feet above the base of the formation. Fragments of Bliss sandstone, which underlies the El Paso limestone, occur in the breccia. The general dip of the strata is N. 35° E. at 15°, but there is considerable variation in the vicinity of the fault. The breccia was partly silicified, and fluorite was later deposited in the crevices and as coatings on the fragments of breccia. The fluorite is aquamarine and coarse-grained, and shows little tendency to replace the breccia. The quantity of fluorite in the ends of the surface workings and in the northeast face of the short drift at the end of the adit is very small; it is greater between these extremities. The assays in Table 23 indicate the tenor of the vein. No ore has been shipped from this deposit.

NORTHERN COOKS RANGE

WHITE EAGLE MINE

The White Eagle mine is $5^{1}/_{2}$ miles north of Cooks Peak in the Cooks Peak mining district (Figure 7) . It is about 32 miles by road from Deming, a shipping and milling point in Luna County ; 9 miles at the mine end of this road was scarcely passable

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[1] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (no. 199), areal geologic map, 1916.

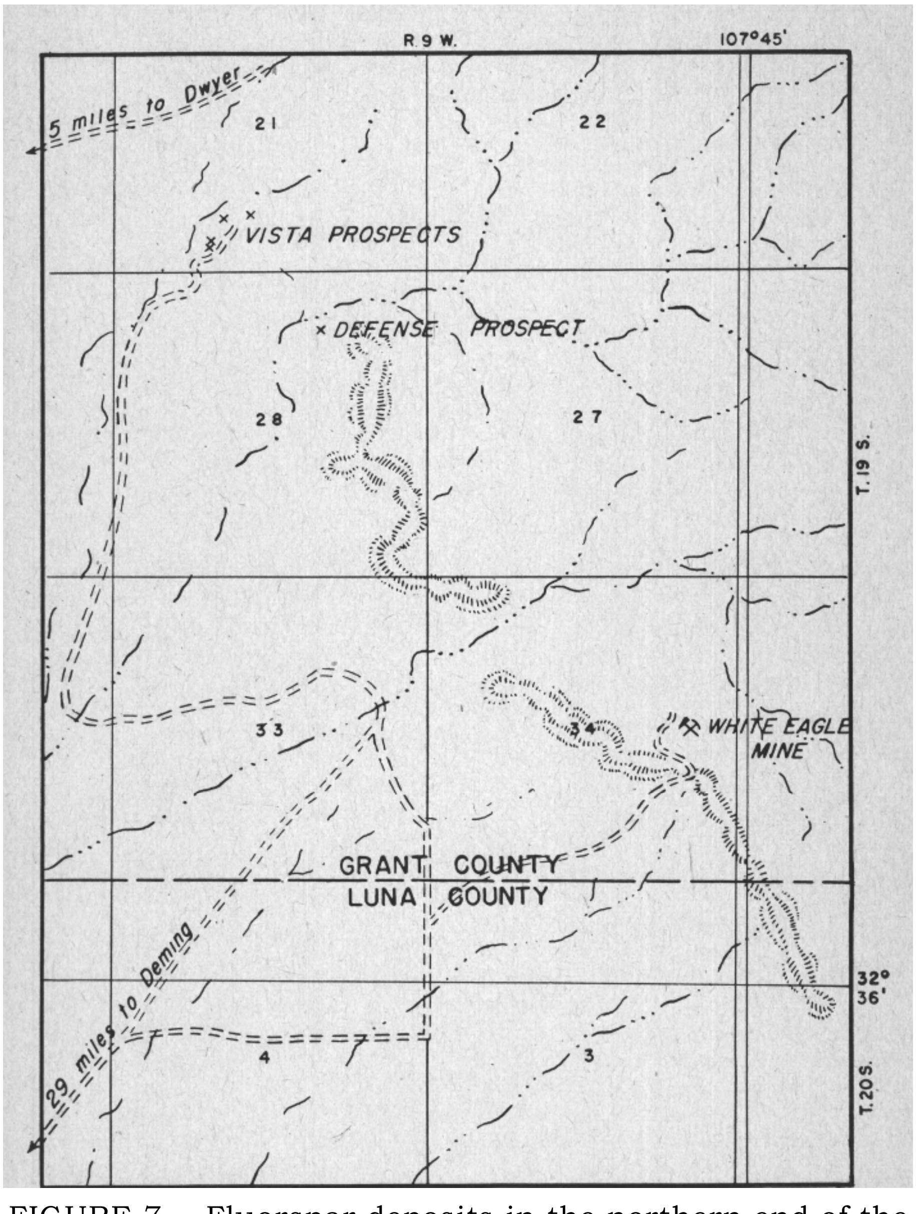

FIGURE 7.—Fluorspar deposits in the northern end of the Cooks Range, Luna and Grant counties.

TABLE 23. ASSAYS OF FLUORSPAR FROM THE ASH SPRING CANYON PROSPECT

Assay No.	Description of sample	Chief constituents (percent)		
		CaF_2	SiO_2	$CaCO_3$
1.	Chip sample from surface trench near center of workings (NE. face of SW. trench) ; width of vein 3 feet -------	25.2	30.1	41.5
2.	Grab sample from muck pile, SW. face of drift, 20 feet from end of adit; width of vein 3 feet --------------------------	19.2	46.1	14.8
3.	Grab sample from stock pile ------	32.3	41.8	12.8

for automobiles in 1944. Spaulding, a siding on the Silver City branch of the Atchison, Topeka, and Santa Fe Railway, is 18 miles southwest of the mine. The property, owned by W. D. Howard, L. H. Duriez, and Alvin White, was leased early in 1944 to D. F. McCabe, who extracted a small amount of ore during that year. The deposit was mined in branching and overlapping stopes for a distance of 700 feet to a maximum, depth of about 175 feet below the highest outcrop.

The deposit occurs principally in a medium-grained pink and gray granite that consists of fractured and partly sericitized orthoclase, abundant partly altered biotite, and some quartz. It is similar to the granite that Darton[2] mapped as pre-Cambrian half a mile south in Luna County. Intruded into it are a pink and gray fine- to medium-grained saccharoidal granite, a dark greenish-gray fine-grained andesite, and a light-gray fine-grained rhyolite porphyry that is probably of Tertiary age.[3] About 300 feet northeast of the mine, a fault marks the boundary of an extensive area covered by dark-red or purple andesitic agglomerate of Tertiary age. Between the agglomerate and the granite-rhyolite group is a wedge of dense gray intensely fractured Paleozoic limestone. The distribution and relationships of these rocks are shown on Plate 11.

The area has been extensively faulted. A normal fault strikes west-northwest and passes about 100 feet northwest of the main workings, bringing Paleozoic limestone against the granite and rhyolite ; it is probably the oldest of the faults. A group of minor nearly vertical fluorspar-bearing faults strike generally N. 55° W. and show little displacement. They cannot be traced in the immediate vicinity of the normal fault, but fluorspar veins in the limestone are in approximate alinement with the mine workings and suggest that these minor faults cut the normal fault. A number of northeast-striking faults show

[2] Darton, N. H., Geology and underground water of Luna County, New Mexico : U. S. Geol. Survey Bull. 618, Pl. I, 1916.

[3] Rock determinations by J. J. Glass, U. S. Geological Survey.

small displacement. One of these offsets the fluorspar veins about 30 feet, crossing them near the intersection of coördinates 4,850 N. and 10,300 E. (Plate 11). This fault strikes N. 22° E., dips 23° NW. and can be traced in the workings to the 113-foot level of the old shaft at the intersection of coordinates 4,940 N. and 10,100 E. A fault 300 feet northeast of the mine is probably the youngest, as the other fractures could not be traced beyond it ; this fault appears to be an extension of the great fault east of Cooks Peak reported by Darton.[4]

The fluorspar veins occupy the irregularly vertical, branching, and overlapping minor faults of the second group mentioned above, and isolated fractures in the limestone northwest of the main veins. The ore bodies have an over-all length of about 850 feet. Throughout this length, except for 150 feet at the southeast end, they have been stoped from the surface to depths of as much as 175 feet. The stopes range from 3 to 15 feet in width, and the ore mined probably averages 4 feet in thickness (Plate 20,A). The average width of the vein left in the pillars and faces at the south end of the workings in 1944 was 31 inches. Core drilling below the northeast end of the vein in 1945 by the Federal Bureau of Mines[4a] showed minable ore below the 113-foot level.

The continuity of the vein is interrupted by tranverse faults. Some of these appear to have been pre-mineral and to have acted as only partial barriers to the formation of the vein, whereas others appear to be post-mineral and to offset the vein. The post-mineral faults dip westward at angles of less than 30°. One, described above, is shown on Plate 11 offsetting the vein near the intersection of coordinates 4,940 N. and 10,000 E. Another was reported in an adit at the level of the old shaft in the north end of the vein,[5] but, as that level was subsequently mined out, the offset was probably small. A third fault of the same group was reported, by D. F. McCabe to cut the vein in the bottom of a shaft 130 feet deep in the south end of the workings.

The ore is white to pale-green massive fluorite cut in places by thin partings of tiny quartz crystals, and containing inclusions of wall rock and scattered veins and lenses of jasperoid. Minor parts of the vein are sufficiently free of impurities to yield fluorspar of metallurgical grade by careful sorting; some fluorspar of this grade is said to have been shipped during the early days of mining. Most of the ore, however, is of milling grade and has been sold to the General Chemical Company's mill at Deming. The following assays indicate the grade of the ore.

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[4] Darton, N. H., op. cit., p. 68.

[4a] Soule, John H., Exploration of the White Eagle fluorspar mine, Cooks Peak mining district, Grant County, N. Mex.: U. S. Bur. Mines Rept. Inv. 3903, July 1946.

[5] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 101, 1928.

TABLE 24. ASSAYS OF ORE FROM THE WHITE EAGLE MINE

Assay No.	Description of sample	Chief constituents (percent) CaF_2	SiO_2	$CaCO_3$
1.	Average analysis of a few carloads of ore shipped in 1918	82.0	12.0	2.0
2.	Average of seven samples taken in various parts of old workings in 1924	87.2	6.8	---
3.	Grab sample from stock pile, 1927	88.3	8.6	2.7
4.	Shipments totaling 1,254 tons made during 1941:		---	---
	a. range	62.0-84.0	---	---
	b. weighted average	72.8	---	---
5.	Sample sent to Alloy Metals mill for analysis, 1943	77.5	---	---

1—From Ira L. Wright.

2 and 3—Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 102, 1928.

4—From W. D. Howard.

5—From H. W. Lust, manager, Alloy Metals Division of Continental Machines, Inc.

Persons familiar with the property estimate that approximately 17,000 tons of ore was shipped prior to 1945.

VISTA AND WAGON TIRE PROSPECTS

The Vista and Wagon Tire prospects are situated 2 miles northwest of the White Eagle mine on the group of claims that includes the Linda Vista Nos. 1, 2, and 3, the Buena Vista Nos. 1, 2, and 3, and the Wagon Tire Nos. 1 to 5 (Figure 7). They are in the rolling country at the north end of Cooks Range and may be reached from the road to the White Eagle mine. The Linda Vista and Buena Vista claims were owned in late 1944 by P. L. Grattan but had been operated for a short time previously by D. F. McCabe. The Wagon Tire claims were owned in 1944 by Baca and Whitehill. Four shafts ranging from 30 to 60 feet in depth, and more than 20 pits, have been dug on vein exposures by former prospectors (Figure 8). These and the Defense prospect were visited in November 1944 by R. D. Trace and Elliot Gillerman of the Geological Survey, on whose notes the descriptions of both areas are based.

The deposits are small, irregularly distributed veins occupying fault breccias from 2 to 4 feet wide in volcanic rocks of Tertiary (?) age. The faults strike in various directions, but the predominant trend is N. 30°-40° W. Variations of as much as 20° from this trend are common. There is likewise little uniformity in the direction or angle of dip. The deposits are scattered over an area half a mile long and a quarter of a mile wide, and only a few of them can be correlated with one another. The fluorspar forms stringers, veins, and pockets ranging from a few inches to 5 feet but averaging between 1 and 2 feet in thickness. In most places inclusions of wall rock and secondary quartz constitute 50 percent or more of the veins. A sample of ore from the most westerly shaft, on the Linda Vista No. 1 claim, assayed 44.5 percent CaF_2.

DEFENSE PROSPECT

The Defense prospect is half a mile southeast of the Vista prospect in an area of pre-Cambrian granite (Figure 7). An adit and two pits expose a brecciated zone that strikes approximately east and is irregularly vertical. It contains siliceous fluorspar in stringers and small pockets that range in thickness from 3 to 15 inches. No minable ore was exposed in these workings.

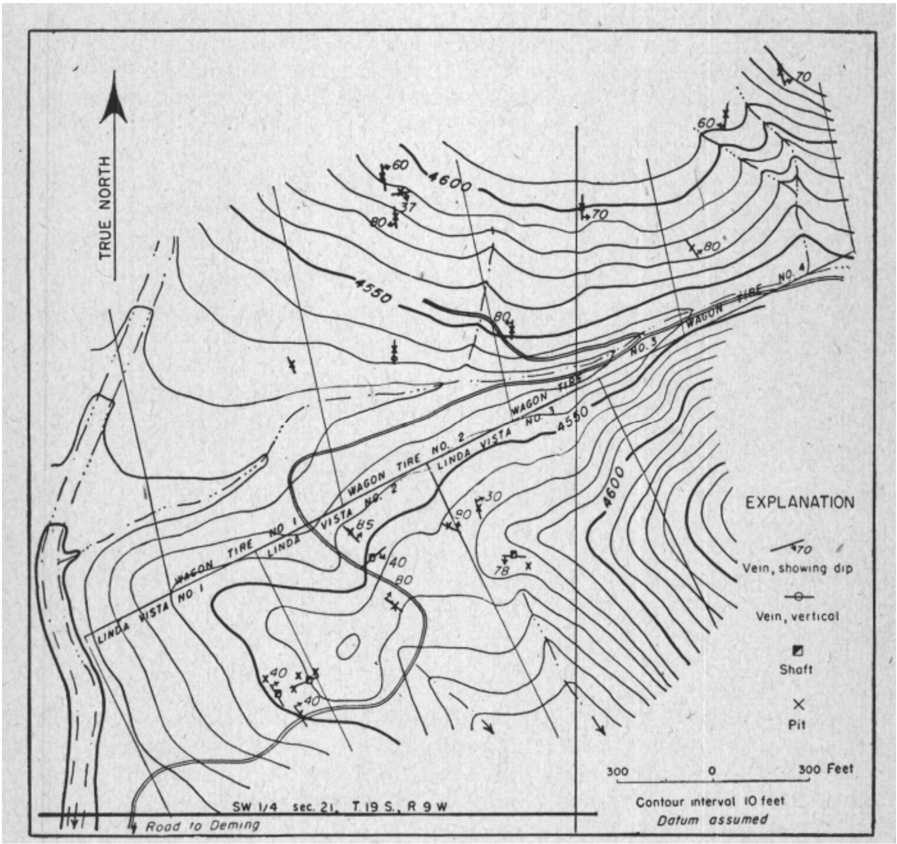

FIGURE 8.—Map of the Vista and Wagon Tire prospects, Grant County.

HIDALGO COUNTY

GENERAL RELATIONS

Fluorspar occurs in the central and northwestern parts of Hidalgo County. The deposits in the central part are in the Pyramid and Animas Mountains ; the only deposits that have been operated commercially are in the Pyramid Mountains, which extend for 20 miles south of Lordsburg. The deposit in the northwestern part of the county is more closely related geologically to the deposits of the Burro Mountains than to the others in Hidalgo County.

All the known deposits are in extrusive and intrusive rocks of late Cretaceous and Tertiary ages. The fluorspar occurs in fissure veins whose walls show little evidence of replacement. The deposits are therefore considered to have crystallized in open spaces from relatively inert solutions. In the Lordsburg mining district, in the northern part of the Pyramid Mountains, fluorite was deposited during the last or sixth stage of hypogene mineralization, which took place before the lava extrusions of the Miocene (?) epoch.[6]

The fluorspar mined in the county is shipped by rail from Animas or Lordsburg or is milled at the Indian Metals flotation mill at Lordsburg.

FLUORSPAR DEPOSITS

The mines and prospects of Hidalgo County are listed in Table 25.

TABLE 25. FLUORSPAR MINES AND PROSPECTS IN HIDALGO COUNTY

Name	Approximate location
Animas mine	SE¼SE¼ sec. 15, T. 25 S., R. 19 W.
Fluorite Group prospects	Sec. 34, T. 23 S., R. 19 W. Secs. 2, 3, T. 24 S., R. 19 W.
Big Nine prospect	Secs. 19, 20, T. 18 S., R. 20 W.
Hoggett prospect	Secs. 31, 32, T. 29 S., R. 18 W.
Lone Star prospect	Secs. 25, 36, T. 23 S., R. 19 W.

ANIMAS MINE[7]

The Animas mine is at the foot of Lightning Rock Mountain on the west side of the Pyramid Mountains. The access road leaves State Route 81 about 17 1/2 miles south of Lordsburg and trends southeastward for 1 1/2 miles to the workings. During

[6] Lasky, S. G., Geology and ore deposits of the Lordsburg mining district, Hidalgo County, New Mexico: U. S. Geol. Survey Bull. 885, p. 41, 1938.

[7] This discussion is based on field notes made by R. D. Trace, U. S. Geological Survey: additional data furnished by D. F. McCabe and I. L. Mosley of Lordsburg.

1942 and 1943 the mine was owned by W. A. Ballard of Animas, New Mexico, and was operated by D. F. McCabe, who sank a shaft to a depth of 300 feet and developed levels at depths of 100, 200, and 300 feet. The work was discontinued in May 1943, after it was found that the ore body became too narrow to mine profitably and exploratory drifts failed to find other bodies.

The workings are in a vein in fine-grained Tertiary (?) porphyry containing white and pink phenocrysts of feldspar. The vein strikes N. 21° W., approximately parallel with the axis of the mountains, and dips 80° SW. It is composed of fluorite, quartz, and black calcite. The fluorite is green and white, medium- to coarse-grained, and intimately associated with fine-grained white quartz. Scattered masses of red to gray cryptocrystalline quartz, and coatings of manganese, are common on the vein material. Most of the ore averaged 63 percent CaF_2, the remaining percentage being about equally divided between $CaCO_3$ and SiO_2.

The one ore body found was 340 feet long on the 100-foot level, over 400 feet long on the 200-foot level, and 30 feet long on the 300-foot level where water was encountered. Its thickness averaged 4 feet but reached a maximum of 10 feet. About 100 tons of ore of metallurgical grade was shipped, and approximately 3,000 tons was beneficiated in the Indian Metals mill at Lordsburg.

FLUORITE GROUP PROSPECTS[8]

The Fluorite Group prospects, known also as the Kneyer mines, are situated at the northwest end of the Pyramid Mountains, about 9 miles south of Lordsburg, and extend across the Lordsburg-Animas highway (Plate 1). The group is composed of 12 unpatented claims, called Fluorite. Nos. 1 to 12, which were filed in 1937 and were owned in 1944 by the Kneyer Mines, Inc., and L. K. Diffenderfer.

The deposit is in a series of fissure veins in Cretaceous basalt.[9] In the vicinity of the highway, on claims Nos. 8 and 9, the veins trend northwestward; but at the northwest end of the group, on claims Nos. 1 and 5, they trend northeastward. They are lenticular and are composed mainly of fluorite, quartz, and calcite, in the proportions indicated by the following weighted assays of about 200 tons of selected ore : 60 percent CaF_2, 30 percent SiO_2 and 8 percent Ca0 (14.3 percent CaCO3).

The most promising localities had been prospected in 1944 by a series of workings of which the most important are described as follows, beginning at the southeast. On Fluorite No. 9 claim a shaft 65 feet deep exposed a vein $3^1/_2$ feet wide at the surface, from which one carload of selected ore containing 93 percent

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[8] Description of the workings is based chiefly on notes made in 1944 by D. A. Warner, U. S. Geological Survey.

[9] Lasky, S. G., op. cit., Pl. 1.

CaF_2 and 17 tons of ore averaging 74 percent CaF_2, were obtained.[10] About a quarter of a mile northwest of this shaft and on Fluorite No. 8 claim, a drift 80 feet long at the 20-foot level was connected with the surface by a shaft and a stope 25 feet long. The vein in the drift is about 4 feet wide, but on the surface it pinches to an average width of 1 foot. The grade of the ore from this body is indicated by assays 5 to 7 in Table 26. About three-quarters of a mile northwest of these workings two shafts were dug on a vein that strikes N. 45° E. The northeast shaft was 35 feet deep. The southwest shaft was in an ore body about 3 1/2 feet wide, which was stoped for a distance of 30 feet to a depth of 28 feet. Two drifts, each about 20 feet long, were driven at the bottom of the stope, one northeast and the other southwest. The ore body pinches to 3 inches at the northeast face and becomes low-grade (30 percent CaF_2) in a 4 1/2-foot vein in the southwest face. The grade of ore taken from this lens is shown by assays 1 to 3 in the table. On Fluorite No. 5 claim, about 1,000 feet southwest of this stope, a small fluorspar body was exposed in two shallow trenches and a shaft 15 feet deep. The widths and estimated grades of the exposures are as follows : 6 inches, 60 percent CaF_2 in the northeast trench ; 12 inches, 75 percent CaF_2 in the shaft 30 feet southwest of the trench ; 22 inches, 30 percent CaF_2 in the pit 50 feet southwest of the shaft. Seven tons of fluorspar mined from this shaft contained 68 percent CaF_2 by assay.

TABLE 26. ASSAYS OF SHIPMENTS OF FLUORSPAR FROM THE FLUORITE GROUP PROSPECTS[a]

Assay No.	Claim No.	Tonnage: Total	Tonnage: Part assayed for gangue minerals	Chief constituents (weighted-average percent): CaF_2	SiO_2	CaO
1.	1	24	--	69	--	--
2.	1	--	14	--	26	1
3.	1	4	--	63	30	4
4.	5	7	--	68	--	--
5.	8	23	--	57	--	--
6.	8	107	--	56	--	--
7.	8	--	24	--	32	11
8.	9	17	--	74	--	--
9.	?	11	--	50	31	13
10.	Total	193	--	60	--	--
11.	Total	--	38	--	30	8

[a] Data supplied by L. K. Diffenderfer.
1, 2, 5 and 9—Shipments to General Chemical Co. mill.
3, 4, 6, 7 and 8—Shipments to Indian Metals mill.

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[10] Reported by L. K. Diffenderfer.

BIG NINE PROSPECT [11]

The Big Nine claim, owned by Thomas Windham of Duncan, Arizona, is in the northwest corner of Hidalgo County in the Steeple Rock mining district. Exploratory work consists of a pit 20 feet deep that exposes a fissure vein of high-grade fluorspar 2 inches wide striking N. 70° W. Other stringers in the granite country rock are sparsely scattered over a broad area about the pit. The veins are too narrow and too widely dispersed to constitute a promising deposit.

HOGGETT PROSPECT

The Hoggett claims are in southern Hidalgo County in the west foothills of the Animas Range about 20 miles southeast of Animas (Plate 1). They were owned in March 1943 by Marlin Hoggett and were worked for manganese for a short time.

About 400 feet east of the manganese mine is a fracture zone that strikes N. 45° E. It is from a few inches to 1 1/2 feet wide, and its crevices are filled with veinlets of fluorspar and quartz. For a distance of about 150 feet the zone averages about 12 inches in width, but tapers to stringers northeast and disappears southwest. Only two or three small excavations had been made in it at the time of investigation. The vein material is medium- to fine-grained and consists of fluorite cut and coated by stringers and druses of quartz.

LONE STAR PROSPECT

The Lone Star group of claims are in the Lordsburg mining district 6 1/2 miles south of Lordsburg, and the main workings are half a mile west of the Lordsburg-Animas highway. The group was visited in May 1943, at which time it was owned by the Indian Metals Company. It originally consisted of the Lone Star and Lone Star Extension Nos. 1 and 2 claims, but other claims, called the Slick-Porter Nos. 1 to 5, were later located to cover the important parts of the older group. The discovery shaft and No. 1 shaft, each about 15 feet deep, were the only significant workings at the time of the visit.

The deposits occur as narrow discontinuous widely spaced veins at the southeast margin of a granodiorite stock of late Cretaceous or early Tertiary age, which has been intruded into Cretaceous basalt.[12] The fluorspar occurs in faults that conform in general with the east-trending faults of the district, and in fissures oblique to them. At the discovery shaft, a vein striking N. 70° W. and dipping 80° S. exposes from 2 to 3 feet of very siliceous vein material that was estimated to contain from 30

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[11] From an unpublished memorandum by R. D. Trace, U. S. Geological Survey, based on an examination made in March 1944.

[12] Lasky, S. G., Geology and ore deposits of the Lordsburg mining district, Hidalgo County, New Mexico : U. S. Geol. Survey Bull. 885, p. 24, 1938.

to 40 percent CaF_2. About 400 feet to the northeast, in shaft No. 1, a brecciated zone 8 feet wide contains several stringers and veins of coarse-grained fluorspar ranging in width from 4 to 24 inches. This zone, which strikes N. 75° E. and dips 60° N., was exposed about 100 feet west of the shaft and 300 feet east of it by trenches that showed only stringers and incrustations of fluorspar. The fluorspar, which is fine- to medium-grained and green or colorless, was formed by replacement of the granodiorite, as at the discovery shaft, and by crystallization in cavities, as at shaft No. 1. Only a few tons of ore has been recovered and shipped to the Indian Metals mill.

LINCOLN COUNTY

GENERAL RELATIONS

Fluorspar has been reported in two areas in Lincoln County, one in the north central and the other in the western part. In the north central area, known as the Gallinas district, important deposits occur in the eastern part of the Gallinas Mountains. In the western area only one deposit, the Julia Ann deposit on Lone Mountain, has been reported. No study of the area surrounding it has been made.

The Gallinas Mountains are in Torrance and Lincoln counties in the central part of the State. The known fluorspar deposits are in the eastern part of the mountains in the vicinity of Red Cloud Canyon (Plate 12). The area is served by U. S. Highway 54 and by the Southern Pacific Railroad, both of which, at Gallinas siding, are $8^1/_2$ miles east of the Red Cloud mine, a landmark of the area. The nearest towns are Carrizozo, 42 miles south; Corona, 9 miles north; and Vaughn, 41 miles northeast of Gallinas siding. The nearest reduction plants are the Alloy Metals flotation mill in El Paso, Texas, about 136 miles to the south, and the Zuni Milling Company's flotation mill in Los Lunas, about 112 miles by rail to the west (Plate 1) .

The Gallinas Mountains are an isolated group of rounded pine-covered peaks, surrounded by rolling plains and low mesas. Valley slopes are steep, although the upland has been worn down to ridges and knobs. Water flows in the valleys only during wet seasons, and the permanent water table is well below the mine workings.

GEOLOGY[13]

The oldest rocks in the area are pre-Cambrian granite and gneiss, which are exposed in three small outcrops in and near Red Cloud Canyon. They are directly overlain by the Abo sand-

[13] Kelley, V. C., Rothrock, H. E., and Smalley, R. G., Geology and ore deposits of the eastern Gallinas Mountains, Lincoln County, New Mexico : U. S. Geol. Survey report in preparation.

stone (Permian or Carboniferous) . The base of the Abo sandstone is conglomeratic and arkosic, and its upper part consists of a series of reddish-brown generally micaceous siltstones and shales. Above the Abo sandstone is the Yeso formation, composed of light-buff to red siltstones and fine-grained sandstones and shales. Capping some of the ridges and peaks are remnants of the Glorieta sandstone member of the San Andres formation (Permian), which is a massive thick-bedded buff sandstone, locally cross-bedded. These rocks were intruded probably during early Tertiary time by fine-grained to aphanitic light-gray syenite porphyry, containing orthoclase phenocrysts averaging 7 millimeters in length. The porphyry occurs chiefly as laccoliths southwest of Red Cloud Canyon and as sills and dikes to the northeast. Later (?) intrusions of fine- to medium-grained light-colored monzonite formed sills and dikes in the north and northeast parts of the area. The youngest intrusive is a monzonite breccia that crops out in five small round areas in sec. 23, T. 1 S., R. 12 E. (Plate 12). The breccia commonly includes, besides monzonite, fragments of dark-brown andesite and smaller amounts of sandstone, syenite porphyry, limestone, and shale.

The east end of the mountains is a much-dissected dome formed by the laccoliths and sills that were emplaced in the sedimentary rocks only a little above the pre-Cambrian basement. The mass is extensively cut by faults, the largest of which trends northwestward, and by fissures that trend in diverse directions. Wide brecciated areas, such as that at the Red Cloud and All American fluorspar deposits, have been formed near the intersections of faults.[14] In the central fractured zone the strata dip erratically, but near the north and east margins of the mountains they dip from 15° to 45° away from the uplift and flatten abruptly in the adjoining foothills.

FLUORSPAR DEPOSITS

The fluorspar deposits occur in the fractured quartzitic sandstones, siltstones, and limestones of the Yeso formation and in the dikes and sills intruded into them. The fluorspar occurs along fractures, brecciated zones, bedding planes, and formational contacts, and as disseminated deposits. Most of the fractures and brecciated zones are included in two groups ; one trends N. 25°-70° E., the other N. 10°-40° W. The disseminated deposits, which adjoin fractures, are represented by the replaced trachyte dike on the Old Hickory prospect and by fluorite-bearing sandstones. The deposits in fractures, along which little movement has taken place, are commonly short, irregular in distribution, and localized at intersections with other fractures. So far

[14] Kelley has tentatively suggested that the Red Cloud fluorspar prospect may be in a breccia pipe, formed in the Yeso formation by the explosive action of magmatic gases.

as known, these deposits have greater depth than lateral extent and in shape resemble branching pipes. The deposits in fault breccias and those disseminated through solid rock generally are larger and more continuous.

Most of the fluorspar is light blue to dark purple. In general the darker these colors are in a fresh exposure, the richer is the grade of the fluorspar. It has a fine-granular texture that is dense on fresh surfaces and coarsely porous where weathered. The deposits are composed chiefly of fluorite, barite, and the siliceous and argillaceous remnants of the host rock, with smaller proportions of calcite, dolomite, and in some deposits bastnäsite, a rare yellow waxy fluocarbonate of cerium, lanthanum, and didymium. Galena, pyrite, chalcocite, celestite, barytocalcite, azurite, malachite, and limonite occur sparingly. The proportions of the chief constituents are shown by the assays of composite samples, made by the Federal Bureau of Mines, representing eleven of the deposits. Each composite sample was made by combining portions of many samples taken from the outcrops, trenches, pits, or underground workings of one deposit. The samples show the following ranges in the percentages of the chief constituents of the ore bodies: CaF_2, 43.8 to 65.7 percent; $Si0_2$, 8.2 to 25.2 percent ; $BaSO_4$, 11.7 to 28.6 percent ; and CaO, 1.0 to 5.5 percent.

Some of the deposits, notably the Red Cloud, show two or more generations of fluorite deposition separated by periods of brecciation. The fluorspar was formed in part by replacement and in part by crystallization in voids of the brecciated zones, fissures, and permeable rocks. The processes have been so obscured by recurrent mineralization that it is difficult to identify the substances that were replaced. It is probable, however, that fluorite was substituted for the arkosic and calcareous material in the sandstones and for most of the constituents of the trachyte. Dense limestone was only slightly replaced by fluorite but was more extensively replaced by barite and bastnäsite. The mineralizing solutions ascended through fractures, all of which were probably produced by the intrusion of the early Tertiary (?) igneous rocks and by subsequent adjustments. The deposits were formed after the intrusion of the laccolith of syenite porphyry and so are of post-early Tertiary (?) age.

GALLINAS DISTRICT

RED CLOUD PROSPECT[16]

The Red Cloud fluorspar prospect (locality 13, Plate 12) is in Red Cloud Canyon, 300 feet east of the shaft of the abandoned Red Cloud mine, which was operated near the turn of the

[16] A large part of the data in this and the following discussions on Lincoln County are based on unpublished reports and field notes by Robert G. Smalley, U. S. Geological Survey. See also : Soule, J. H., Exploration of Gallinas fluorspar deposits, Lincoln County, N. Mex.: U. S. Bur. Mines, Rept. Inv. 3854, April 1946.

TABLE 27. FLUORSPAR PROSPECTS IN LINCOLN COUNTY

Name	Approximate location
Gallinas district	
Red Cloud prospect	NE¼SE¼ sec. 25, T. 1 S., R. 11 E.
Deadwood prospect[a] (copper and fluorspar)	NW¼SE¼ sec. 25, T. 1 S., R. 11 E.
Rio Tinto mine[a] (copper mine with fluorspar in gangue)	NE¼SE¼ sec. 25, T. 1 S., R. 11 E.
Helen S prospect[a]	SW¼SE¼ sec. 24, T. 1 S., R. 11 E.
All American prospect	NW¼NE¼ sec. 23, T. 1 S., R. 11 E.
Conqueror No. 4 prospect	SE¼SE¼ sec. 24, T. 1 S., R. 11 E.
Hilltop prospect	SE¼SE¼ sec. 24, T. 1 S., R. 11 E.
Eagle Nest prospect	NW¼SE¼ sec. 24, T. 1 S., R. 11 E.
Bottleneck prospect	NE¼SE¼ sec. 24, T. 1 S., R. 11 E.
Old Hickory prospect	NW¼SW¼ sec. 19, T. 1 S., R. 12 E.
Congress prospect	NW¼SW¼ sec. 19, T. 1 S., R. 12 E.
Hoosier Girl prospect	NW¼SW¼ sec. 19, T. 1 S., R. 12 E.
Eureka prospect	SW¼SW¼ sec. 19, T. 1 S., R. 12 E.
Summit prospect	SW¼SW¼ sec. 19, T. 1 S., R. 12 E.
Last Chance prospect[a]	NW¼NW¼ sec. 19, T. 1 S., R. 12 E.
Buckhorn prospect[a]	SW¼NW¼ sec. 19, T. 1 S., R. 12 E.
Sky High prospect	NW¼SE¼ sec. 14, T. 1 S., R. 11 E.
Lone Mountain area	
Julia Ann prospect	Sec. 22, T. 6 S., R. 11 E.

[a] Not described in this report.

century for lead, copper, silver, and a little gold. The prospect is partly on the patented Red Cloud claim, owned by C. N. Comstock, and partly on the unpatented Conqueror No. 9 claim, owned by the Continental Engineering Company.

The principal fluorspar outcrop is in a cliff in the east wall of the canyon. For a distance of 30 feet above the stream and for a length of 55 feet the face of this cliff is composed of closely spaced masses of fluorspar in quartzitic sandstone. The operators of the old mine apparently recognized fluorite as a gangue mineral in the metalliferous deposit and in 1921 drove an exploratory drift from the 200-foot level of the copper workings to intersect the fluorspar deposit below this outcrop. The adit was in barren rock and was abandoned about 75 feet short of its objective. In the spring of 1943 J. H. Soule, engineer of the Federal Bureau of Mines, recognized the significance of this deposit and it was included in the program of exploration by the Bureau of Mines and the Geological Survey. Exploration by the Bureau of Mines was chiefly by underground workings, although some trenching and core drilling also were done. The underground work included the sinking of a shaft 110 feet deep with drifts and laterals at the 35-foot and 100-foot levels, and the driving of an adit with laterals at a level a few feet above the collar of the shaft. Two core-drill holes yielded unsatisfactory results owing to the shattered condition of the quartzite and the soft friable earthy character of some of the fluorspar.

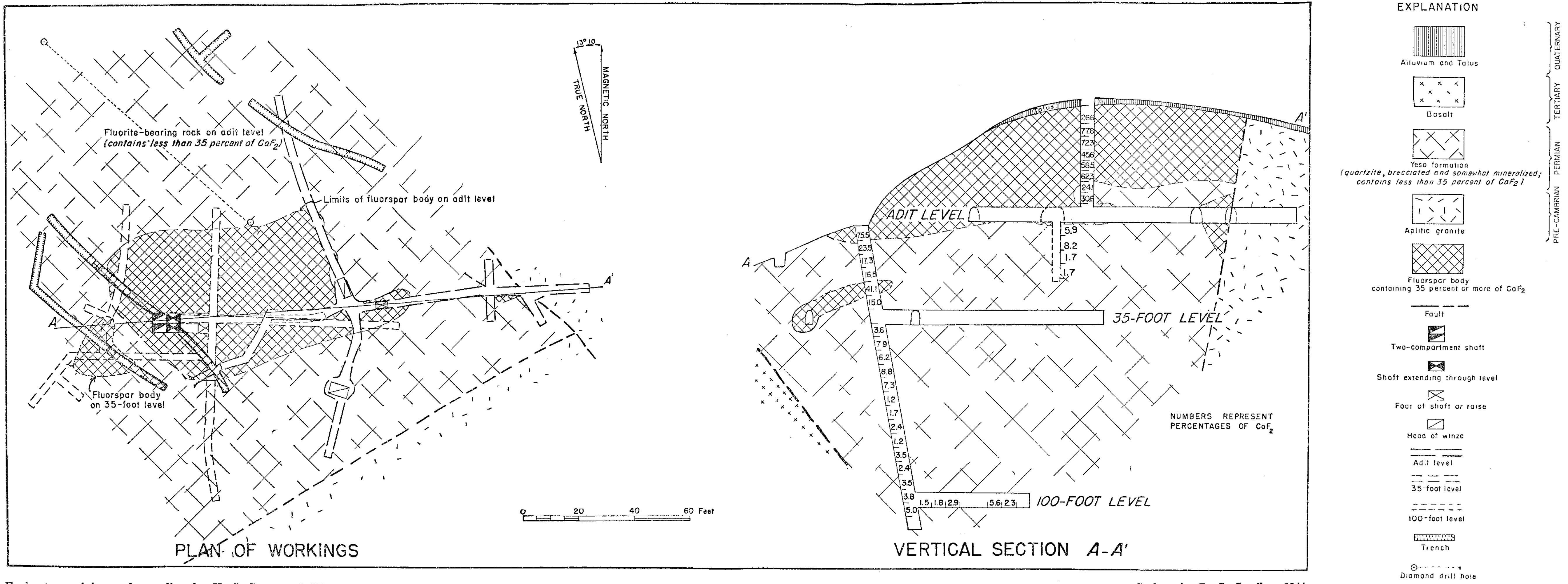
The deposit is in brecciated quartzitic sandstones and silt-stones of the Yeso formation. Although no limestones were found in place, a large limestone boulder was found embedded in ore near the portal of the adit. The brecciated zone lies between two faults or fault zones that intersect at an angle of about 55°. One trends northeastward and brings pre-Cambrian granite and Abo sandstone into contact with the Yeso formation. This fault was not definitely found in the workings, but increased brecciation in the most easterly extremity indicates proximity to a fault. The other fault zone trends north-northwestward and is downthrown on the west. It is exposed in the west end of the workings on the 35-foot level, where a dike of olivine basalt is faulted against quartzitic sandstone. Fractures near the end of the exploratory crosscut in the old mine may belong to this zone. This faulting occurred before the fluorspar body was formed, but post-mineral shattering also took place, as evidenced by open and clay-filled fractures.

The brecciated zone is unevenly mineralized. It generally contains only traces of fluorspar near the faults and in the lower workings, but toward the center of the brecciated area the concentration of fluorite increases to form a lens of ore containing 40 percent or more of CaF_2. This lens is surrounded for a considerable distance by breccia containing much smaller and more irregularly distributed quantities of fluorite. The ore body extends from the surface as a plunging lens that reaches the 35-foot level only in the west end of the workings, near the fault (Plate 13). The lens, which is oval in plan, is 170 feet long and 65 feet wide. Its upper part has apparently been removed by erosion.

The ore is an aggregate of fragments of dense fine-grained purple fluorspar and rock in a soft iron-stained matrix of loosely cemented tiny fluorite crystals, granulated barite, and clay. (See Plate 21, A). Quartz, calcite, barite, bastnäsite, pyrite and limonite, and a smaller proportion of barytocelestite are scattered through the mass. The ore is exceptionally porous, having a specific gravity of 2.0, equivalent to a weight of 16 cubic feet per ton. [17] A composite sample of ore from the outcrop contained 52.1 percent CaF_2, 18.3 percent SiO_2, 17.6 percent $BaSO_4$, and 1.2 percent CaO.

The deposit was formed during more than one period of mineralization. The breccia in what is now the central part of

[17] Gravity determination by the Federal Bureau of Mines.



Exploratory mining and sampling by U. S. Bureau of Mines

Geology by R. G. Smalley, 1944

Red Cloud prospect, Gallinas Mountains, Lincoln County the deposit was first extensively replaced to form dense fine-grained dark-purple fluorspar. Pyrite, barite, and small amounts of calcite were also deposited. Somewhat later the zone was invaded by solutions rich in CO_2, rare earths, and fluorine. From these, bastnäsite was formed in small scattered crystals and the deposit was partly carbonated. The ore body and the surrounding rock were brecciated, and later ascending solutions deposited a new generation of fluorite, accompanied by smaller amounts of barite and minor quantities of bastnäsite and barytocelestite. In the last stage of hydrothermal action, irregular veins, containing chiefly barite with concentrations of later bastnäsite, formed in the porous breccia outside the main body of fluorspar.

In comparatively recent time, downward percolating ground waters leached out some of the clay and perhaps other constituents of the deposit, leaving its upper parts porous and somewhat enriched. The clay has been redeposited in the interstices of the breccia at greater depths and is a prominent component of the shattered rock on the 100-foot level.

ALL AMERICAN PROSPECT

The All American unpatented claim is near the head of Red Cloud Canyon (locality 4, Plate 12). It was owned in 1943 by Vernon Taylor and James Mallery. Fluorspar was discovered here in 1942 in the grading of an access mine road.

The deposit lies in north-dipping rocks consisting predominantly of quartzitic sandstones with minor limestones that are cut by a sill of syenite porphyry and by two intersecting major faults. Joints, small folds, and breccia zones were developed during the intrusion and the adjustments that followed. Fluorine-bearing solutions, admitted through these structures and along formation contacts, reacted with the permeable rock to form stringers of fluorspar in the joints, veins along the faults and formational contacts, pipe-like bodies at the intersections of fractures, and irregular masses in breccia zones. Unbrecciated rock was not noticeably affected by the solutions. Within the exposed mineralized area, which is about 500 feet long and 400 feet wide, the distribution and grade of fluorspar are highly irregular.

The fluorspar is fine-grained, compact or porous, and purple on fresh surfaces. Very small subhedral crystals of fluorite were deposited during the principal stage of mineralization. Later stages are represented by the formation of drusy fluorite in cavities and by the introduction of bastnäsite.

Samples from the ore bodies of better grade, chosen to represent the probable grade of ore that might be sorted from the deposit, assayed 77 to 80 percent CaF_2 and 11 percent $Si0_2$. A composite grab sample, taken by the Federal Bureau of Mines

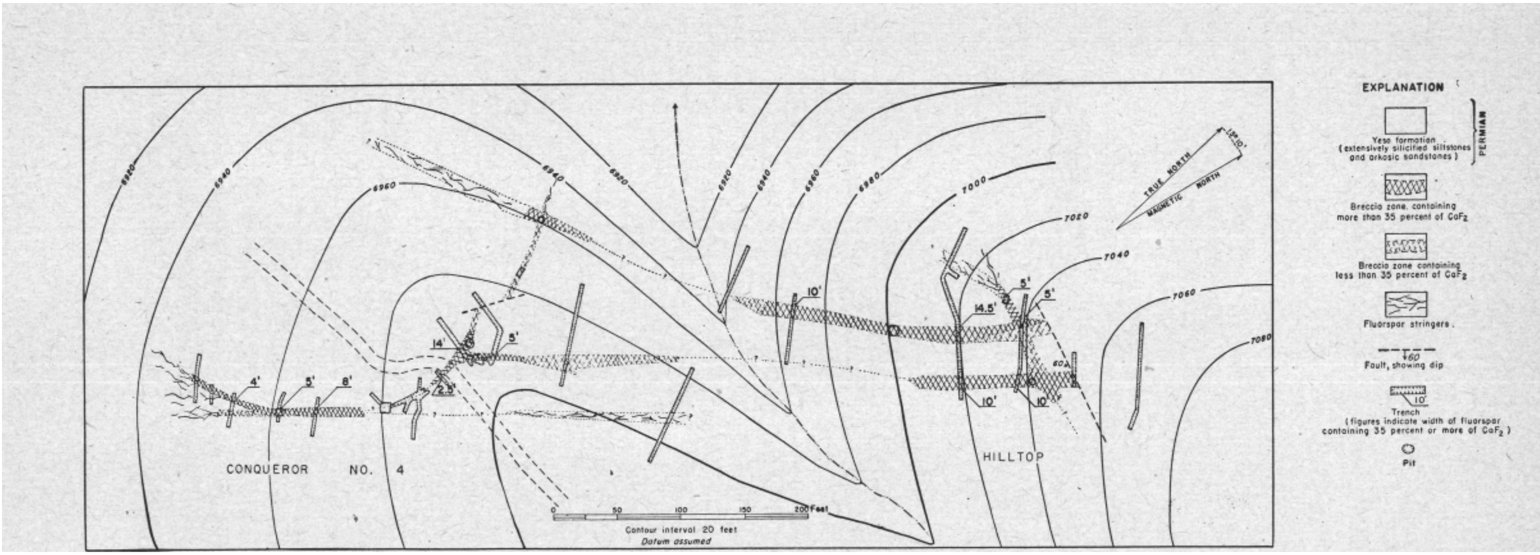


FIGURE 9.—Geologic map of the Conqueror No. 4 and Hilltop deposits, Lincoln County.

from various localities in the deposit, assayed 54.3 percent CaF_2, 23.2 percent SiO_2, 11.5 percent $BaSO_4$, and 1.5 percent CaO.

CONQUEROR NO. 4 AND HILLTOP PROSPECTS

The Conqueror No. 4 and Hilltop deposits consist of a connected series of veins on unpatented claims belonging to the Continental Engineering Company (locality 10, Plate 12). They are on nearly parallel ridges separated by a narrow steep ravine. Quartzitic sandstone and siltstone of the Yeso formation crop out on the ridges, but in the ravine bedrock is covered by a deep mantle of talus.

The ore bodies are contained in a series of fractures and brecciated zones striking N. 45° E. within a zone about 150 feet wide (Figure 9). On the Hilltop claims these fractures are connected by one that strikes N. 70° W. On the Conqueror No. 4 claim the connecting fracture is faulted and curved but has a general strike of N. 15° W. The length of the mineralized ground, as determined by trenching and sampling by the Federal Bureau of Mines, is 650 feet. The ore is widest near the intersections of the fractures, but is not continuous throughout them. Several breccia zones that appear to be favorable hosts for deposition contain very little fluorite. The maximum widths of ore are on the Hilltop claims, where good ore shoots are from 4 to 10 feet wide. On the Conqueror No. 4 claim, ore widths range from 3 to 6 feet. The ore bodies generally end in stringers or low-grade breccia zones. Although the veins can not be traced across the talus-filled ravine between the two exposures, it is probable that they are continuous. Movement along the fractures after mineralization broke the fluorspar into large fragments, which because of weathering now resemble boulders.

The fluorspar in most exposures is fine-grained, compact, and blue or purple on fresh exposures; it is white where weathered. The deposit consists of tiny crystals of fluorite and quartz with larger barite crystals irregularly distributed. The quantity of barite in the deposit ranges from traces to as much as 20 percent. Irregular replacement of barite by fluorite is in part responsible for this variation. The southwest end of the deposit contains scattered clusters of green fluorite crystals up to 1 inch in diameter. The following assays of composite samples from the deposits indicate the character of the ore.

Although the ore bodies are discontinuous, they cover a relatively large area. Their location in an intensely fractured area suggests that they extend to as great depths as any of the larger deposits in the Gallinas district. The difference in altitude between the highest and lowest outcrops of ore is about 90 feet.

TABLE 28. ASSAYS OF COMPOSITE SAMPLES FROM THE CONQUEROR NO. 4 AND HILLTOP PROSPECTS

Prospect	Chief constituents (percent)			
	CaF_2	SiO_2	$BaSO_4$	CaO
Conqueror No. 4	63.4	17.8	14.6	1.6
Hilltop	57.4	20.8	21.2	1.2

Sampling and assaying by the U. S. Bureau of Mines.

EAGLE NEST PROSPECT

The Eagle Nest prospect (locality 7, Plate 12) is about three-quarters of a mile north of the Red Cloud mine on a high southwest-trending spur of Rough Mountain. The deposit, which is on Eagle Nest claim No. 2, filed by the Continental Engineering Company of Carrizozo, has been explored by three shallow pits and a small open cut made by the owners, and by six trenches dug by the Federal Bureau of Mines.

The deposit is in a fault breccia in quartzitic sandstones of the Yeso formation, which dip generally northeastward at angles ranging from 15° to 35°. The fault is nearly vertical and strikes north at the southern end of the deposit and northwest at the northern end. It is mineralized for at least 600 feet along the outcrop, 450 feet of which contains material rich enough to be classified as ore. This deposit may be almost as large as the Old Hickory, probably the largest fluorspar deposit in the Gallinas Mountains. The ore body grades into fluorite-bearing rock of low CaF_2 content at its ends and at some places along its sides. Stringers of fluorspar branch from the main vein, following bedding planes. The thickness of the body is variable and the margins are indefinite in some places. Trenching by the Bureau of Mines indicates an average thickness of 9.5 feet.

The ore is a dense crystalline aggregate of fluorite, barite, and quartz. The groundmass is finely crystalline blue or purple fluorite, through which are scattered short laths and weathered masses of light-pink barite and clusters of medium-grained green fluorite. Near the margin of the vein tiny cubes and pyritohedra of pyrite and of limonite pseudomorphs are common. Minute crystals of bastnäsite occur rarely. The weighted-average CaF_2 content of samples of the outcrop of ore is 60.5 percent, and the proportions of its chief constituents, as determined by an assay of a composite sample made by the Federal Bureau of Mines, are 65.7 percent CaF_2, 13.4 percent SiO_2, 16.4 percent $BaSO_4$, and 1.0 percent CaO.

BOTTLENECK PROSPECT

The Bottleneck prospect (locality 8, Plate 12) is three-quarters of a mile northeast of the Red Cloud mine. A shaft about 25 feet deep, an adit about 30 feet long, and two shallow pits have

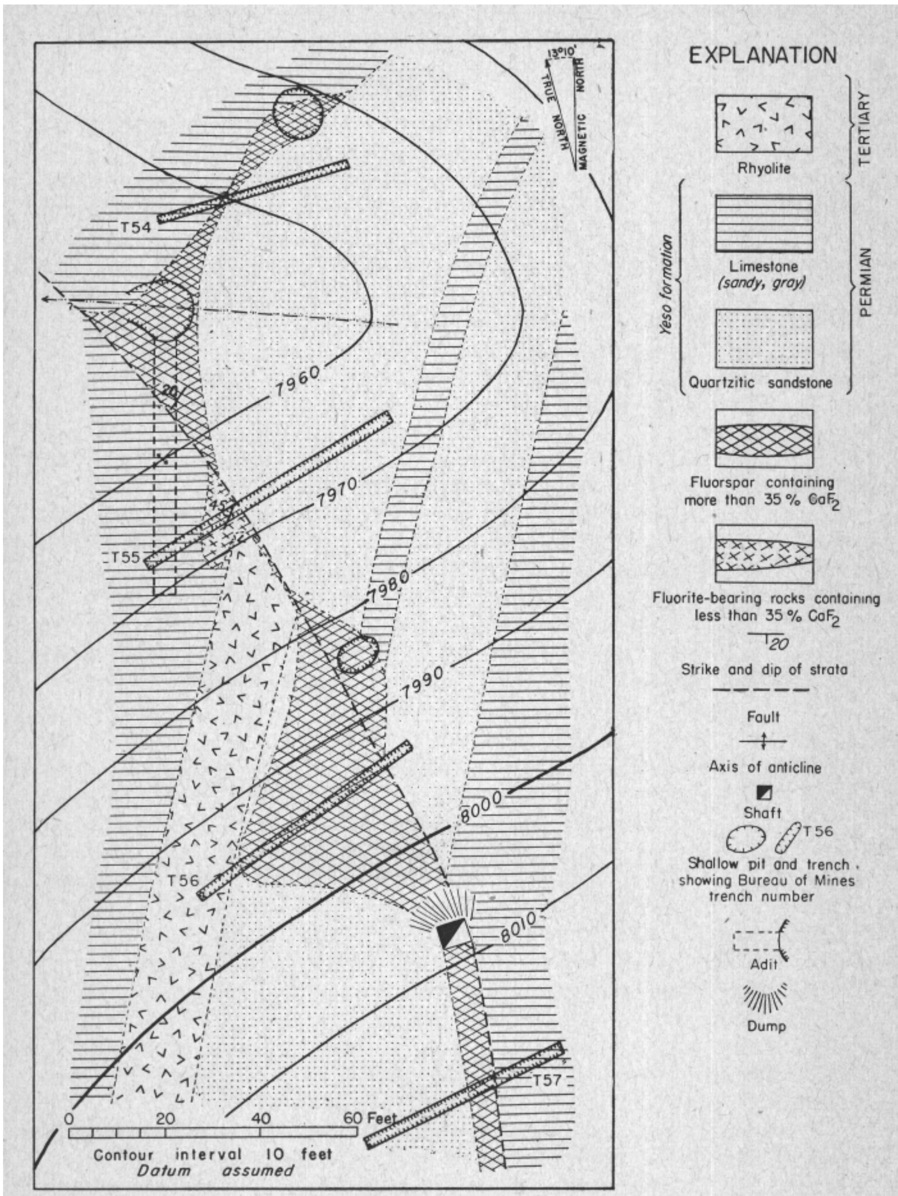


FIGURE 10.—Geologic sketch map of the Bottleneck deposit, Gallinas Mountains, Lincoln County.

been dug by prospectors. The deposit has been further exposed by four trenches made by the Federal Bureau of Mines.

Sandy gray limestones and quartzitic arkosic sandstones of the Yeso formation and a sill of rhyolite (?) porphyry form the country rock. These rocks are folded, faulted, and tilted, but generally strike northeast. The faults trend irregularly north-northwest (Figure 10), and the rocks adjoining them are extensively fractured. In the shaft, fault gouge and fine breccia form a vertical band from 2 to 4 feet thick. The adjoining quartzitic sandstones are coarsely brecciated for much greater widths. The fault breccia and parts of the fractured rocks are partly replaced by fluorite, barite, and quartz, which form bodies that are extremely variable in size, shape, and content of CaF_2. The maximum width exposed, in trench 56, is 40 feet. Although most of the deposit has a low CaF_2 content, the part exposed in this trench averages 51 percent CaF_2. A composite sample of ore from various trenches assayed 47.9 percent CaF_2, 25.2 percent SiO_2, 21.2 percent $BaSO_4$, and 1.3 percent CaO.[18]

The fluorspar appears to have been formed chiefly by replacement of the less resistant constituents of the arkosic sandstones and fault breccia. The limestones have been little mineralized. More than one period of fluorite deposition is indicated by veinlets of fluorite cutting the fluorite-barite aggregate. The porous parts of the deposit contain considerable calcite that was formed during a relatively late stage of deposition.

OLD HICKORY PROSPECT

The Old Hickory prospect (Plate 14) is in the head of a valley northeast of the Red Cloud mine (locality 19, Plate 12). It is on the patented Old Hickory claim, owned by Adele Lehman and Edna Lehman Davis of Alhambra, California. In a search for copper, operators in the early part of the century explored outcrops of fluorspar. The workings consist of a shallow shaft, from the bottom of which an incline cuts across the vein; a shaft about 200 feet deep, with drifts and crosscuts developed at the 100- and 200-foot levels; and an adit, winze, and incline that connect the deep shaft with the surface at a point 45 feet below the collar of the shaft. Several pits were dug by the prospectors, and trenches and core-drill holes were made by the Federal Bureau of Mines in exploring the deposit.

The following description of the prospect is taken chiefly from an unpublished report by Robert G. Smalley, geologist of the U. S. Geological Survey, who participated in the joint investigation conducted by the Survey and the Federal Bureau of Mines.

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[18] Sampling and assays by Federal Bureau of Mines.

The principal rocks are hard fine-grained slightly feldspathic quartzites. They are considerably disturbed by Tertiary intrusives, which are represented by a trachyte dike in the vicinity of the workings. Later movement along this dike shattered it and the adjoining rock and supplied an avenue of access for mineralizing solutions. These solutions replaced a part of the dike and some of the brecciated quartzite, forming a fluorspar vein. At either end of the dike, on the surface, small branching veins of fluorspar follow diverging fractures in the sedimentary rocks, but the veins pinch out or become very thin within short distances. The vein is 180 feet long and averages about 13 feet in thickness. It becomes narrower and shorter with depth, as shown in section A-A', Plate 14. On the 100-foot level a 40-foot drift exposes a vein with an average thickness of 11 feet. On the 200-foot level the average thickness of a lens 65 feet long, between narrow terminations, is 3 feet.

The vein material consists chiefly of a fine-grained dense intergrowth of fluorite, barite, quartz, calcite, and dolomite. The proportions of the chief constituents are shown by the following assay of a composite sample of ore made by the Federal Bureau of Mines from trenches and channels cut in the deposit: CaF_2, 56.0 percent; SiO_2, 15.1 percent ; $BaSO_4$, 15.4 percent; CaO, 2.3 percent.

The sequence of mineralization in this deposit appears to have begun with the deposition of fluorite,' accompanied by crystallization of minor amounts of pink barite. During the later stages of this process, or possibly after it was completed, calcite was formed. Small scattered crystals of galena and coatings of malachite indicate that weak lead and copper mineralization took place subsequent to the principal period of fluorite deposition. Then followed a period of dolomitization, when nearly the entire breccia and some of the adjacent sedimentary rocks were impregnated and partly replaced by calcium and magnesium carbonates. More recently, ground water attacked the more soluble constituents and produced water courses and caves in the rock adjoining the vein. At present these cavities are above the ground-water table, and calcite in the form of dripstone is being deposited in them.

CONGRESS PROSPECT

The Congress prospect (locality 17, Plate 12) is near the top of Rough Mountain. In 1944 it was one of the holdings of the Continental Engineering Company. Two pits near the discovery monument on the Congress claim are along a fault striking N. 20° E. that cuts the Yeso formation, bringing quartzitic sandstone on the east against limestone on the west. The fault is filled with breccia that is about 4 feet wide and is irregularly mineralized with fluorspar similar to that in the Conqueror No. 4 prospect. The vein could not be traced on the surface because of soil cover.

HOOSIER GIRL PROSPECTS

The patented Hoosier Girl claim, owned in 1944 by Edna Lehman Davis of Alhambra, California, is three-quarters of a mile northeast of the Red Cloud mine. Three prospects consist of shallow shafts sunk by miners, and trenches made by the Federal Bureau of Mines in the vicinity of each shaft. Shafts Nos. 1 and 2 (locality 18, Plate 12) are 440 and 300 feet, respectively, west-northwest of the main workings of the Old Hickory prospect. Shaft No. 3 (locality 20, Plate 12) is about 650 feet southwest of Nos. 1 and 2 across a ravine.

All the workings are in the Yeso formation, which here consists of fine-grained quartzitic sandstones with a few interbedded limestones. The surface exposures are measured in a few tens of feet and are associated with intersecting fractures trending approximately north, northeast, and east.

Shaft No. 1 is on the south side of a lenticular fluorspar body that extends for at least 50 feet west-northwest from the shaft and measures 25 feet at its widest point. It was not explored southeastward. The middle of the lens contains an ore body that is roughly circular in plan and about 25 feet in diameter. This body is surrounded by fractured quartzite and limestone that contains stringers, small lenses, and irregular masses of fluorspar. The fluorspar closely resembles that in the Red Cloud deposit. A composite of the samples taken in the ore body was assayed for its chief constituents, which are present in the following proportions : CaF_2, 54.2 percent ; SiO_2 8.2 percent ; $BaSO_4$, 15.0 percent ; and CaO, 4.5 percent. [19] A vein branching from the deposit was followed by trenching for 75 feet south of the shaft. It contains fluorspar in widths ranging from 1 to 5 feet for about 50 feet, and only stringers beyond this section.

Shaft No. 2 is sunk along a small lens or chimney of fluorspar. In the shaft, which is about 20 feet deep, thin-bedded quartzitic sandstone forms the east wall, and thick-bedded brecciated quartzitic sandstone the west wall, of a vertical fault that strikes N. 5° W. The north and south faces of the shaft contain masses of fluorspar and quartzite in about equal proportions. Fluorspar extends a few feet north of the shaft, where it is bounded by a fracture that strikes N. 40° E. The shaft is surrounded on all sides except the east by trenches that are from 10 to 20 feet from it. All the trenches are in barren rock. The deposit, therefore, is restricted on the surface to the immediate vicinity of the intersection of the fractures.

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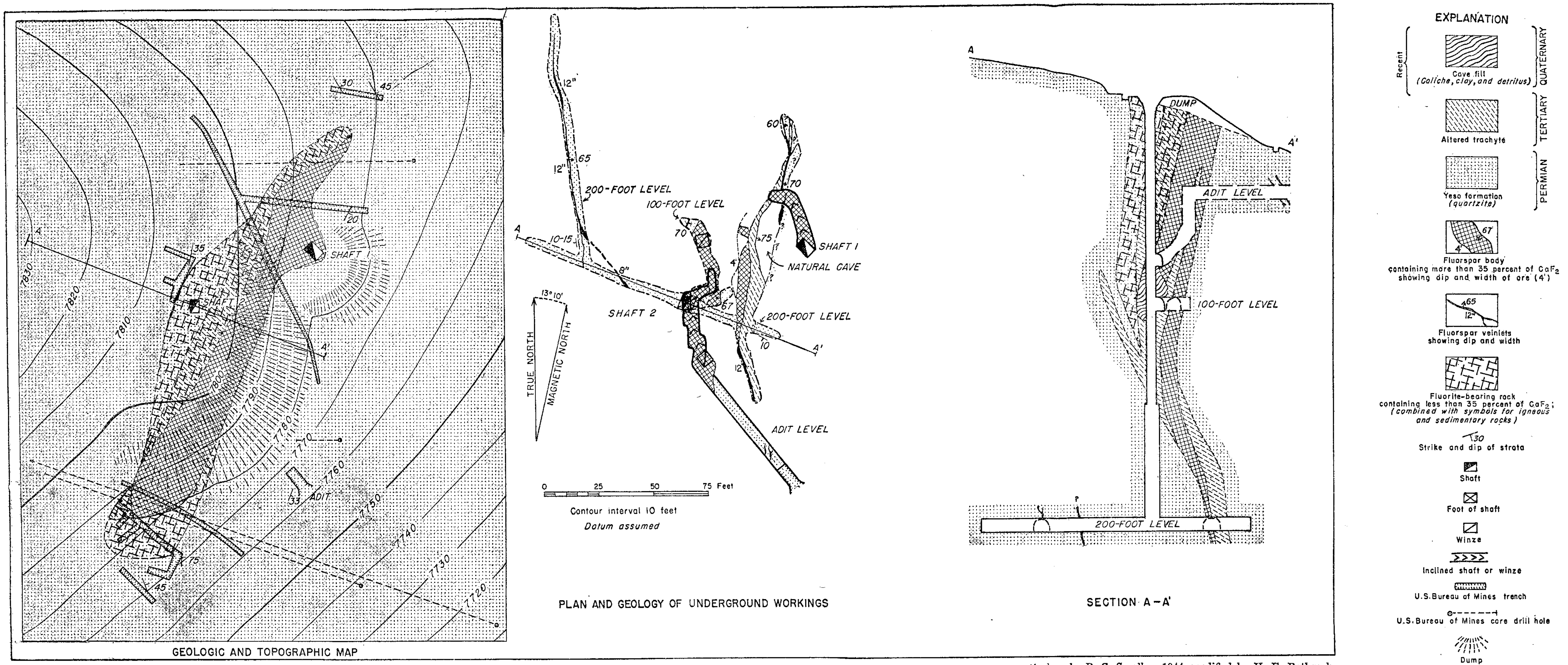
[19] Sampling and assays by the Federal Bureau of Mines.



Old Hickory prospect, Gallinas Mountains, Lincoln County

Geology by R. G. Smalley, 1944, modified by H. E. Rothrock

Shaft No. 3 is sunk along a fluorspar body that is exposed for 30 feet on the surface. Its thickness ranges from a few inches to 6 feet, and it has been followed by the shaft to a depth of about 30 feet. The top and sides of the shaft, which is inclined about 45° in the direction N. 40° W., consist chiefly of fluorspar, much of which is porous because of leaching. The deposit also contains dolomitic rock, travertine, small euhedral calcite crystals, and inclusions of quartzitic sandstone. The walls of the deposit are not definite, but a narrow mineralized zone has been traced for 30 feet north where it is cut by a fault that strikes N. 70° E. The offset segment was not found. A shallow trench 20 feet southwest of the shaft is in barren quartzitic sandstone.

EUREKA PROSPECT

The Eureka prospect is about three-quarters of a mile northeast of the Red Cloud mine (locality 21, Plate 12). It is southeast and across a small ravine from the Old Hickory prospect, and is on the patented Eureka claim. The workings comprise three shafts, an open cut, and an adit; all are connected underground.

The country rock comprises quartzitic sandstones and limestones of the Yeso formation, and a syenite sill. They are tilted eastward away from the laccolith that domed the mountains, but the general structure has been greatly modified by local faulting. The faulted ground contains two veins, one of which contains copper-bearing minerals and the other fluorspar. The adit follows the fluorspar vein for 255 feet in an irregular course that has a general trend of N. 70° W. The vein is in a zone of fault breccia that ranges from 2 to 6 feet in width and dips 90°-65° SW. The breccia is partly replaced by fluorite and other nonmetallic minerals, which form narrow veins of high-grade fluorspar and wider veins of lower-grade material in the breccia. The distribution of these bodies is irregular. Sampling by the Federal Bureau of Mines disclosed six small ore bodies with a total length of 150 feet and an average thickness of 3 feet. The best of these bodies is 43 feet long and 2.4 to 6.7 feet thick. A composite sample from it assayed 43.8 percent CaF_2, 10.8 percent SiO_2, 25.5 percent $BaSO_4$, and 5.5 percent CaO. The fluorspar is porous and consists of tiny crystals of purple fluorite in a mass of small calcite and barite crystals, brecciated rock, and clay.

The copper-bearing vein has been exposed in the open cut and in two shallow shafts. It lies along the contact of quartzitic sandstone with overlying limestone, and in fractures and small porous areas in the limestone. The copper is chiefly in the form of chrysocolla. Fluorite, which was deposited before the copper, and galena are present in minor amounts.

SUMMIT PROSPECT

The Summit prospect (locality 22, Plate 12), is about half a mile northeast of the Red Cloud mine on the crest of a spur of Rough Mountain. The principal working is a pit about 25 feet deep in a zone of fault breccia, in quartzitic sandstone of the Yeso formation. The strike of the zone is not clearly indicated in the shaft, but outcrops of fluorspar a few feet north and 100 feet south of the shaft indicate that at least part of the deposit is a north-striking vein. The fluorspar is 2 feet thick in the northernmost outcrop, at least 4 feet thick in the shaft, and 3 feet thick in the outcrop south of the shaft. The fluorspar resembles that from the Conqueror No. 4 and Hoosier Girl deposits.

SKY HIGH PROSPECT

The unpatented Sky High claim, owned in 1944 by the Continental Engineering Company, is on the road to the lookout on Gallinas Peak (locality 1, Plate 12). The workings consist of a shaft, a caved adit 100 feet north and about 80 feet below the shaft, and a shallow pit 110 feet to the east. The shaft, which was inaccessible at the time of the visit, is said to be 100 feet deep. The presence of fluorspar in the dumps of the shaft and adit, which appear to have been connected, indicates that the workings are along a fluorspar vein, though no outcrops of such a vein could be found. In a small pit 110 feet east of the shaft, a vein of low-grade fluorspar occurs in a breccia zone about 5 feet wide. It strikes north and appears to be a separate deposit from that represented by the shaft and adit.

The ore in the dumps is fine-grained, purple, and slightly leached of some of its gangue minerals. Quartz, barite, and calcite are present in varying proportions. It was estimated that the better specimens of fluorspar contain from 40 to 60 percent CaF_2. The potentialities of the deposit can not be estimated from present exposures.

LONE MOUNTAIN AREA

JULIA ANN PROSPECT

The Julia Ann claim, owned by John W. House of Rodeo, New Mexico, is oh the southwest side of Lone Mountain about 8 miles north of Carrizozo (Plate 1) . It is about half a mile south of the Yellowjacket iron mine. A cut exposes an impure vein of fluorspar approximately 4 feet wide in a brecciated zone that cuts limestone and gypsum of the Yeso formation. The deposit could not be traced on the surface because of soil cover. It appears to have been formed by the incomplete replacement of breccia fragments. Channel samples across the face assayed from 42 to 47 percent CaF2. [20]

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[20] Sampling and assays by the Federal Bureau of Mines.

LUNA COUNTY

GENERAL RELATIONS

The fluorspar deposits of Luna County are in the northern part in the Cooks Range, and in the south central part in the Florida and Little Florida Mountains. In the broad Mimbres Valley between the two fluorspar areas is Deming, to which most of the fluorspar mined in the county is taken. There it is beneficiated in the General Chemical Company's flotation mill or the Grattan flotation mill, or is shipped direct to consumers or brokers. Deming is on the Southern Pacific Railroad and on a branch of the Atchison, Topeka, and Santa Fe Railway with terminals at Silver City and Albuquerque. A network of Federal and State highways and mine roads provides access to most of the deposits (Plate 1).

The Cooks Range and the Florida and Little Florida Mountains consist of rocks of pre-Cambrian, Paleozoic, and Mesozoic ages that were invaded or covered by Tertiary igneous and clastic rocks. The resulting complex was extensively dislocated, by faults, the principal trend of which is northwest. Erosion, which probably has been practically continuous since Pliocene or earlier time, reduced and partly buried the mountains and filled the intervening valleys, forming extensive bolson deposits.

The Cooks Range is the synclinal province east of the Burro Mountains uplift and in this respect is related to the Silver City area. In both areas, moreover, a major fault system trends northwestward ; some of the faults in the Hanover district east of Silver City may be extensions of the main fault on the east side of Cooks Range.

The details of the stratigraphy and structure are presented with the descriptions of the fluorspar localities.

FLUORSPAR DEPOSITS

The fluorspar deposits in the Cooks Range and the Little Florida Mountains are in rocks of Tertiary age or in older rocks into which Tertiary rocks were intruded. 'In the igneous rocks and arenaceous sedimentary rocks the fluorspar bodies are in faults, fissures, and breccias ; in the limestones they follow the bedding and the soluble or permeable parts of the rock, or form veins or stringers in irregular fractures. Examples of both space-filling and replacement deposition may be found. Several stages of fluorspar deposition were accompanied or followed by silicification in varying degrees of completeness. Much of the fluorspar is of especially high grade and consists almost entirely of coarse-grained transparent green fluorite, typically represented in the mines in the southeast end of Fluorite Ridge. Some of it is fine-grained, white, and slightly siliceous. A red or brown fluorspar, generally microcrystalline, was formed by replacement and is stained with iron. Quartz, the chief gangue

TABLE 29. FLUORSPAR MINES AND PROSPECTS IN LUNA COUNTY

Name [a]	Approximate location	Reference [b]
	Cooks Peak district	
Lookout No. 1 prospect	Near SE corner sec. 11, T. 20 S., R. 9 W.	
Bond prospect	NW¼NW¼ sec. 13, T. 20 S., R. 9 W.	
	Fluorite Ridge area (Southeast group)	
Sadler mine (Opening No. 1) (Lower Camp)	Near center NW¼ sec. 18, T. 22 S., R. 8 W.	7:537, 540 27:92-94
Greenleaf mine (Howard mine)	SW¼SW¼NE¼ sec. 18, T. 22 S., R. 8 W.	27:96
San Juan mine	Near center E½NW¼ sec. 18, T. 22 S., R. 8 W.	27:96 7:540-541
Greenleaf No. 4 prospect	SE¼SW¼NE¼ sec. 18, T. 22 S., R. 8 W.	
Lucky mine (Opening No. 2) (Locality No. 2)	250'W. of N¼-corner sec. 18, T. 22 S. R. 8 W.	7:537,538 27:97
Hilltop Spar prospect	Near center NW¼NW¼ sec. 18, T. 22 S., R. 8 W.	
	Fluorite Ridge area (Central group)	
Grattan mine (Opening No. 3) (Locality No. 3) (Upper Camp)	NE¼NW¼ sec. 12, T. 22 S., R. 9 W.	7:538,541-542 27:97-98
Whitehill prospect	700' SE. of Grattan mine.	
Spar No. 2 prospect (Deckert shaft)	S½SW¼ sec. 1, T. 22 S., R. 9 W.	27:98
Grattan State Land mine	SE¼SE¼ sec. 2, T. 22 S., R. 9 W.	
Tip Top prospect	S½ sec. 1 and N½ sec. 12, T. 22 S., R. 9 W.	
	Little Florida Mountains	
Florida mine [c] (Duryea claims) (Spar claims)	Secs. 7 and 8, T. 24 S., R. 7 W.	27:88-91
Price prospect [c]	In the Florida Mountains.	

[a] Names in parentheses are those that appear in other publications or are used locally.

[b] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[c] Not described in this report.

mineral, forms tiny crystals that are intergrown with the fluorite and give the aggregate a white appearance. Quartz also occurs sparingly as jasper veins and drusy cavity fillings that were formed later than the fluorite. Barite was deposited as a late mineral in some veins.

For convenience of description and reference the fluorspar deposits of the county are grouped as follows. The Cooks Peak district includes the old mining area on the north slope of Cooks Peak, a prominent landmark; the district is continuous with the northern Cooks Range of Grant County, discussed on pages 98-103. The Fluorite Ridge area is in the mountains called Fluorite Ridge and Goat Ridge, which lie immediately southwest of the Cooks Range and are in reality a part of it. The deposits in this area have been an important source of fluorspar for many years. The deposits of a third area, the Florida and Little Florida Mountains, were not included in the field investigations and are not described.

COOKS PEAK DISTRICT

No original studies of the geology of the Cooks Peak mining district have been published since the work of C. H. Gordon,[21] from which most of the following description has been taken.

The Cooks Peak district is situated on the north side of Cooks Peak about 20 miles north of Deming. It is best known for its lead-silver-zinc mines, which yielded nearly $4,000,000 worth of metals during the period 1886 to 1927.[22] Cooks Peak (altitude 8,408 feet) is the highest summit on Cooks Range. It is composed of granodiorite porphyry intruded into Paleozoic and Cretaceous strata, remnants of which cover its flanks. The metallic ore-bodies are irregular pipes, kidneys, and pockets in the arched upper part of the Fusselman limestone (Silurian) . They occur just below the Percha shale (Devonian) , which appears to have acted as a deterrent to the rise of the mineralizing solutions. Some offshoots of the main metalliferous bodies contain fluorite at their center. A fluorspar claim, filed by T. N. Bond and called the Lookout No. 1, is about three-quarters of a mile northwest of the site of the furnace for the Gladys mine in the NW1/4 NW1/4 sec. 14, T. 20 S., R. 9 W.; another claim, filed by E. Nickles, is in the bottom of the canyon northeast of the furnace site.

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[21] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico : U. S. Geol. Survey Prof. Paper 68, pp. 287-289, 1910.

[22] Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 7, p. 80, 1933.

LOOKOUT NO. 1 PROSPECT [23]

The Lookout No. 1 prospect is on a ridge high on the flank of Cooks Peak. There are two exposures of fluorspar, one on the crest and the other to the northeast on the side of the ridge. A pit dug in the former exposure contains a fluorspar vein that is 4 feet wide, strikes about N. 50° W., is approximately vertical, and terminates southeastward against a southwest-trending fault or fissure. This vein can be traced for 35 feet northwest of the pit, to a point where it is covered by talus ; it could not be found in a limestone outcrop 75 feet northwest of the pit. The vein material is vuggy and siliceous and is estimated to contain about 50 percent CaF_2. It appears to have been formed by replacement of limestone along intersecting fractures. The fluorspar body seen in the exposure on the side of the ridge also strikes northwest, but dips southwest at the relatively low angle of 15° to 20°; it is interpreted as a replacement deposit along a bedding plane in limestone. The fluorspar in this deposit is irregularly exposed for about 200 feet along the strike. Although the low dip of the deposit makes broad exposures of fluorspar on the slope, the true thickness of the deposit is estimated to be only 2 or 3 feet. The deposit contains distinctly crystalline fluorite and silica minerals in about equal proportions. Some of the fluorite is yellow or green and is edged with purple. Incrustations and botryoidal surfaces of fluorite on fracture walls or rock fragments are common.

FLUORITE RIDGE AREA

Fluorite Ridge comprises an elongate group of barren rugged hills 3$1/4$ miles southwest of the southern end of the Cooks Range, with which it is roughly parallel, and 10 miles north of Deming. It is 4$^1/_2$ miles long and a half mile wide, and its crest is about 900 feet above the adjacent valleys. The fluorspar deposits are in two groups; one, called the Southeast group, is at the southeast end near the base of the ridge, and the other, called the Central group, is about 1$^1/_2$ miles to the northwest, in the higher part of the ridge (Figure 11.) This grouping corresponds with Johnston's designations of Lower and Upper Camp [24] and is used because the camp sites are no longer generally known. The deposits are known by various names both in the literature and in local usage.

The deposits are reached by an access road, constructed by the Federal government, that leaves paved State Highway 26 about 6$1/4$ miles northeast of Deming. There are no springs or

[23] Description from field notes made by James K. Grunig, U. S. Geological Survey, March 1944.

[24] Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Minn. Res. Bull. 4, pp. 92-99, 1928.

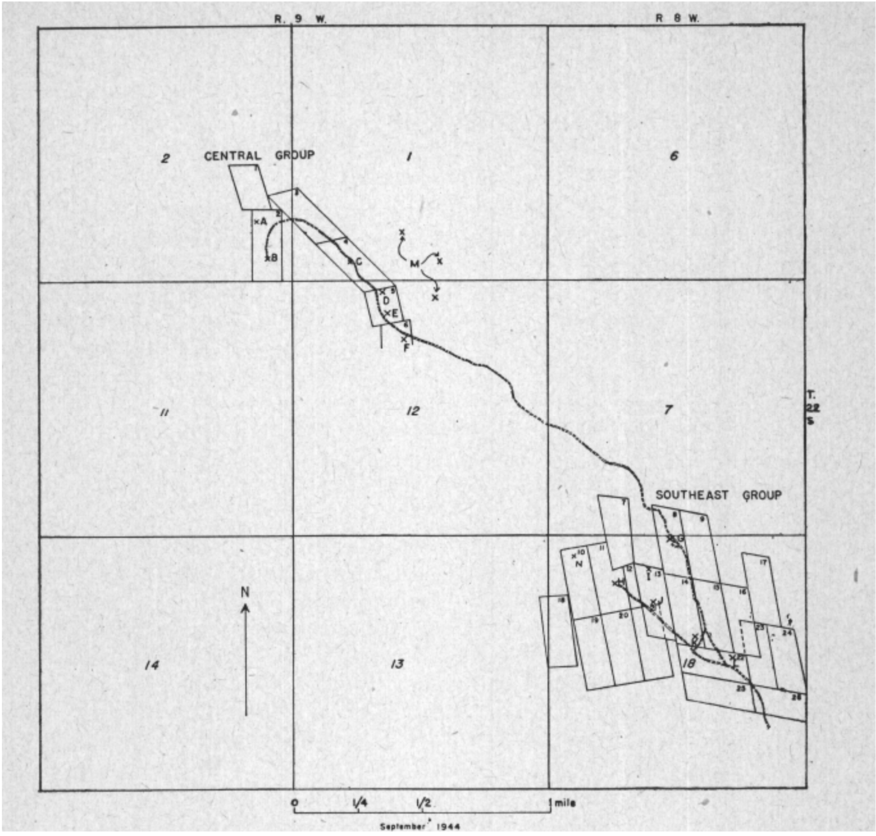

FIGURE 11.-Index map of Fluorite Ridge, Luna County, showing location of fluorspar claims.

MINES AND PROSPECTS

A. Grattan State Land prospect.
B. Grattan State Land mine.
C. Deckert shaft.
D. Grattan mine shaft No. 1.
E. Grattan mine shaft No. 2.
F. Whitehill prospect.
G. Lucky mine.
H. Sadler mine.
I. San Juan mine shaft No. 2.
J. San Juan mine shaft No. 1.
K. Greenleaf mine.
L. Greenleaf No. 4 prospect.
M. Tip Top prospects (approximate locations).
N. Hilltop Spar prospect.

CLAIMS

1. Greenspar No. 1-State lease.
2. Greenspar No. 2-State lease.
3. Spar No. 3.
4. Spar No. 2.
5. Spar No. 1.
6. Dorothy Bell.
7. Williams Brothers No. 2.
8. Lucky.
9. Deer.
10. Susan No. 2.
11. Susan No. 1.
12. Fluorite.
13. San Juan.
14. Greenleaf No. 1.
15. Greenleaf No. 2.
16. Greenleaf No. 3.
17. Valley No. 2.
18. Williams Brothers No. 5.
19. Fern.
20. Sierra.
21. La Purissima.
22. Greenleaf No. 4.
23. Greenleaf No. 5.
24. Valley No. 1.
25. Dorothy No. 1.
26. Dorothy No. 2.

streams in the area, and the permanent water table, reached in the Greenleaf mine at the southeast end of the ridge, is at a depth of about 355 feet.

GEOLOGY

Fluorite Ridge is composed of a stock of monzonite porphyry (Tertiary) intruded into older rocks that cap the eminences and occur as disconnected masses on the sides of the ridge. These older rocks consist of Paleozoic sedimentaries resting on a basement of pre-Cambrian granite and overlain by Lower Cretaceous sandstone. Tertiary clastic and pyroclastic rocks, which surround the ridge and in places extend up the lower slopes, are partly covered by alluvium.

The southeast end of Fluorite Ridge consists of a large block of Paleozoic rocks with a narrow exposure of pre-Cambrian granite at the base. The block is tilted 80° N., and its component strata are exposed in cross section in the steep southeast end of the ridge. Within a distance of 2,500 feet on the east face of this block the following formations, named in ascending order, are exposed : Bliss sandstone (Cambrian) ; El Paso and Montoya limestones (Ordovician) ; Fusselman limestone (Silurian) ; Percha shale (Devonian); and Lake Valley limestone (Mississipian).[25] The Sarten sandstone (Lower Cretaceous) borders the north and west sides of the ridge and caps the highest hill. The central part of the ridge consists chiefly of intrusive monzonite porphyry that includes andesitic phases. At the southeast end of the ridge a series of feldspathic and conglomeratic beds at least 300 feet thick overlies the monzonite porphyry. In several places the contact between the conglomerate and the monzonite porphyry is along faults; elsewhere this contact is obscured by talus. Overlying the conglomeratic beds is a series of agglomerates and flows with minor water-sorted members. The agglomerate is widely exposed on the flanks of the ridge. The presence of monzonite-porphyry fragments in the conglomerate indicates that the monzonite porphyry is the older. The youngest igneous rock is basalt, which forms dikes cutting the conglomerate and older rocks. Darton [26] reports that the dikes occur in the agglomerate and bolson deposits also, and therefore are Quaternary in age. The bolson deposits, which occupy the valleys, consist of a thick series of unconsolidated and semi-consolidated strata composed of irregularly bedded boulders, pebbles, sand, and silt. The bolson deposits around Fluorite Ridge are all of Quaternary age, but the oldest members of the series in the Rio Grande and Gila valleys may have been deposited in late Tertiary time.

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[25] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Derning folio (no. 207), pp. 3-5, 1917. p. 9.

The stratigraphic sequence of rocks in the area is shown in Table 30.

TABLE 30. COLUMNAR SECTION OF ROCKS IN FLUORITE RIDGE [a]

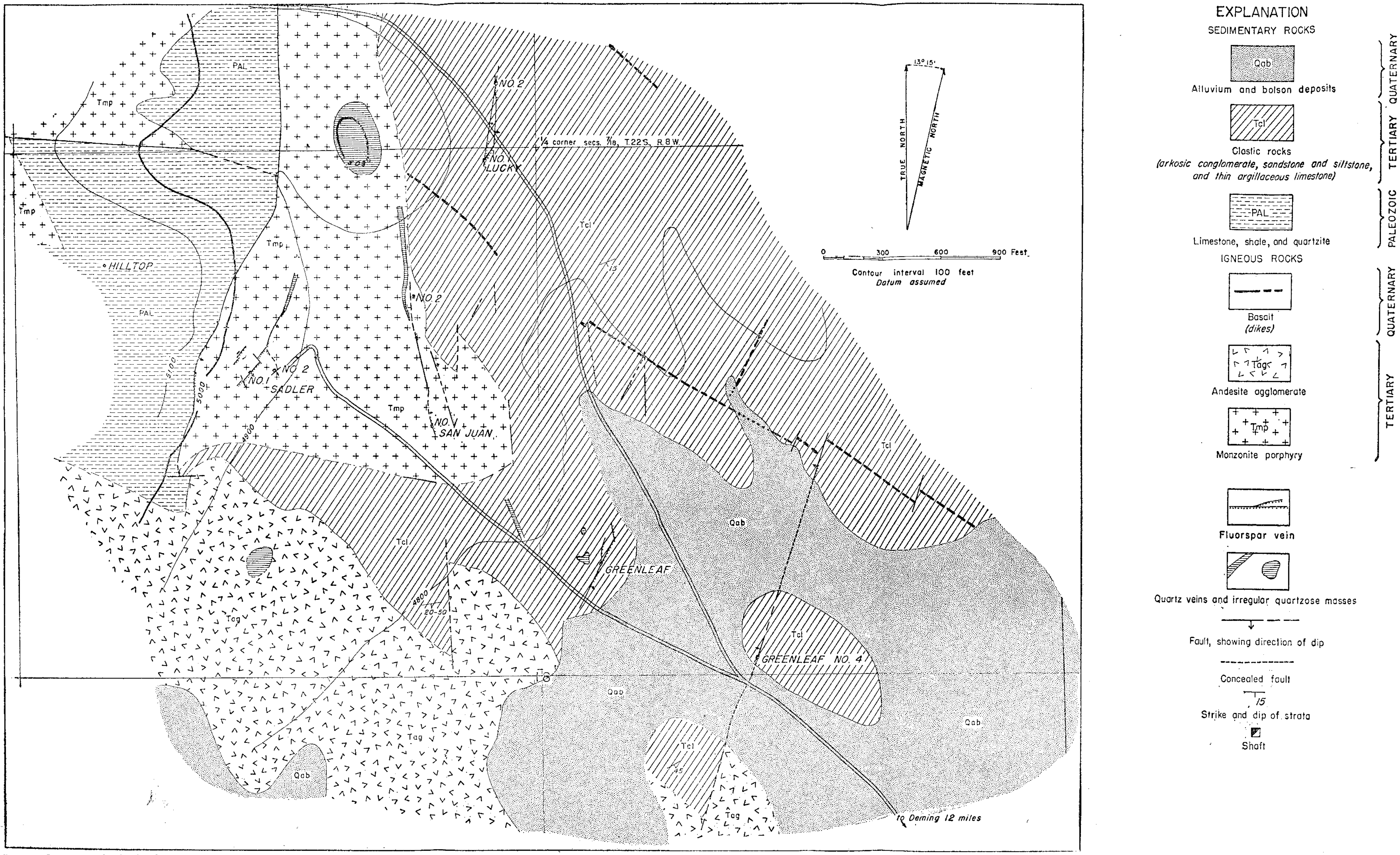
System	Series or group	Formation name and thickness (feet)	Description of rocks
QUATERNARY			Dikes of basalt cutting bolson deposits and older rocks.
		Bolson deposits	Poorly sorted feldspathic gravel, sand, and silt, with subangular boulders of older rocks. At the southeast end of Fluorite Ridge they rest on a thin layer of residual material derived from the underlying Tertiary conglomeratic rocks.
		Unconformity	
TERTIARY		Agglomerate and associated rocks	Irregularly stratified fragmental rocks of volcanic origin, including agglomerate, tuff, volcanic ash; mud and lava flows; and intrusive masses. The agglomerate consists of fragments of dark-gray andesite or latite in a gray or purplish matrix of tuff or volcanic ash.
		Conglomerate and associated rocks	Thick beds of bouldery conglomerate alternating with thinner beds of coarse- and fine-grained pinkish-green and olive-green feldspathic sandstone. The conglomerate has a matrix composed largely of coarse-grained fragments of monzonite porphyry. There are a few thin nodular limestones and limy feldspathic sandstones.
		Unconformity	
		Monzonite porphyry	Greenish-gray monzonite porphyry containing phenocrysts of white striated feldspar, dark-green embayed hornblende, and green biotite in a fine-grained greenish-gray matrix. An andesitic phase occurs near the center of the ridge.
		Unconformity	
CRETACEOUS	Comanche	Sarten sandstone 0 - 300	Light-gray massive quartzitic sandstone with a few interbedded slabby limy strata and a basal conglomerate.
		Unconformity	

TABLE 30. COLUMNAR SECTION OF ROCKS IN FLUORITE RIDGE [a] (CONTINUED)

System	Series or group	Formation name and thickness (feet)	Description of rocks
CARBONIFEROUS	Pennsylvanian	Magdalena group 30-1000	Light-gray massive limestone, partly brecciated, with dark-gray fossiliferous shale and cherty limestone in upper part.
	Mississippian	Lake Valley limestone 200+	Gray limestone, slabby to massive, with interbedded calcareous shale. Top is cherty; basal 100 feet is massive and cliff-forming.
DEVONIAN	Upper Devonian	Percha shale 150±	Dark-gray to black fissile shale.
		Unconformity	
SILURIAN	Niagaran	Fusselman limestone	Dark-gray compact limestone.
ORDOVICIAN	Richmond	Montoya limestone	Light-gray limestone with thin-bedded chert layers at two horizons and dark massive limestone at the base.
		Unconformity	
	Beekmantown	El Paso limestone 400±	Light-gray slabby limestone with some cherty and dolomitic beds. Reddish-brown patches on bedding planes.
		Unconformity	
CAMBRIAN		Bliss sandstone 160±	Gray to brown quartzitic massive sandstone with interbedded slabby sandstone and sandy glauconitic shale. Limy near the top.
		Unconformity	
PRE-CAMBRIAN		Granite	Pinkish massive granite with subordinate darker varieties, gneissic granite, and diorite.

[a] Modified from N. H. Darton's columnar section for the Deming quadrangle, U. S. Geol. Survey Geol. Atlas, Deming folio (no. 207), p. 3, 1917.

The rocks in Fluorite Ridge have been extensively faulted, especially at the southeastern end of the ridge. Arching of the strata was produced primarily by intrusion of the monzonite porphyry. On the southeast end Paleozoic rocks, which strike east and dip 80° N., are discordantly overlain by younger rocks—a condition that probably reflects deformation during pre-Cretaceous time. These rocks are cut by a fault of considerable magnitude that strikes N. 0°-20° E. and dips 65° E., bringing the monzonite porphyry into contact with the Paleozoic rocks (Plate



Base and topography by R. G. Smalley, 1943

Geology by H. E. Rothrock, R. H. Earhart, and J. K. Grunig, 1943-44

Geologic map showing fluorspar deposits at the southeast end of Fluorite Ridge, Luna County

15). The Tertiary rocks east of this fault are cut by numerous faults, which so far as could be determined are normal. Their strike ranges from N. 28° E. to N. 17° W. Many of them contain fluorspar.

All the deposits in Fluorite Ridge are fissure veins except those of the Tip Top and Hilltop Spar prospects, which are fillings in solution cavities in limestone. Mining has been confined to the fissure veins, which occupy faults and fractures and are richest near the intersections of these structures or in areas of great pre-mineral brecciation. The wall rocks include monzonite porphyry, the basalt that cuts it, and the younger eruptive agglomerate. The fluorspar varies considerably in appearance and grade. Much of it is high-grade green transparent coarsely crystalline ore that can be sold as metallurgical-grade fluorspar after simple hand-sorting. The remainder is, white, green, or red, transparent to opaque, and coarse- to fine-grained. Quartz, in small drusy or acicular crystals and in cryptocrystalline masses, is the only conspicuous gangue mineral ; other diluents of the veins are inclusions of wall rock and some clay from altered gouge.

SADLER MINE

All the southeast group of deposits (Table 29) except the Hilltop Spar are near the base of the ridge and are reached by the access road from State Highway 26.

The Sadler mine, on the Susan No. 1 claim, is the oldest fluorspar mine in the Fluorite Ridge area. It was opened by the American Fireman's Mining Company in the summer of 1909,[27] and since then has been operated intermittently by G. M. Sadler, Hayner and Manassee, La Purissima Fluorspar Company, and the General Chemical Company, which acquired it in 1942.

The mine workings consist of trenches, pits, shafts, stopes, and levels made in a group of fluorspar veins that crop out on the southeastern end of Fluorite Ridge. The principal workings are on the two most easterly veins of the group. In the fall of 1943 exploratory levels had been made at depths as great as 180 feet. Mining was done from two shafts. Shaft No. 1 is on a sinuous vein that strikes N. 25° E. and is called No. 1 vein; and shaft No. 2 is 115 feet to the east, on a cross vein called No. 2 vein.

Prior to its acquisition by the General Chemical Company, the Sadler mine had yielded about 32,000 tons of ore,[28] virtually all of which was sold as metallurgical-grade fluorspar.

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[27] Darton, N. H., and Burchard, E. F., Fluorspar near Deming, New Mexico : U. S. Geol. Survey Bull. 470, p. 540, 1911.

[28] Data from Mineral Yearbooks, U. S. Department of the Interior, Bureau of Mines, for the period 1909 to 1938.

All the veins are in monzonite porphyry except one at the faulted contact of the porphyry and the Paleozoic rocks. The veins occur along faults of both large and small displacement and in fractures along which no displacement is apparent. The general trend of the faults is N. 35° E. and the dip is about 70° SE. Striations indicate both horizontal and vertical movement, and chatter marks and plucked and bruised surfaces on the slickensides suggest that some of the faulting was normal. The movements formed brecciated masses and closely spaced sub-parallel fractures, in which the first stage of deposition formed veins of high-grade fluorspar. Recurrent movement shattered these veins, but a later stage of deposition recemented them with fluorite and in some places with considerable quartz. Part of this later movement was across the vein system and it offset segments several feet.

By the fall of 1943 No. 1 vein had been stoped both southwest and northeast of shaft No. 1. The southwest stope is 65 feet long at the surface, 90 feet long on the 100-foot level, and approximately 90 feet long on the 160-foot level. The southwest face of the stope contains a cross fault that offsets the vein 7 or more feet to the northwest. The northeast stope is about 30 feet long and extends from the surface to the 100-foot level. The average width of these stopes is estimated to be about 5 feet. The ore taken from them generally occurs in from one to three veins whose aggregate thickness ranges from 2 to 20 feet. [29]

Developmental and exploratory workings extend beyond the stopes. Southwest of shaft No. 1 the drift from the stope on the 100-foot level follows the drag of the faulted vein westward about 10 feet and thence southwestward for about 45 feet along a shattered vein approximately 3 feet thick. On the 160-foot level the vein was followed to a point 140 feet southwest of the shaft, where a cross fault was encountered. Vein widths in this drift range from 1.5 to 5 feet, and the estimated content of CaF_2 from 50 to 70 percent. The vein is also present on the 180-foot sub-level, where it is 3 feet wide at a point 45 feet southwest of the shaft.

Northeast of shaft No. 1 and the end of the stope, a shallow cut 50 feet long exposes low-grade vein material. The cut contains a shaft about 20 feet deep, inaccessible when visited, which ends at a cross fault. On the 100-foot level northeast of the stope a drift extends for about 40 feet in ore of marginal grade, 3 to 4 feet thick. The face of the drift is in a cross fault.

The workings in No. 1 vein indicate that the ore body rakes southwest and suggest that the bottom and southwest limits of ore have not been reached.

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[29] Johnston, W. D., Jr., Fluorspar in New Mexico : N. M. School of Mines, State Bur. Mines and Min. Res. Bull 4, p. 95, 1928.

About 150 feet northeast of shaft No. 1 a vein, thought to be vein No. 2, joins vein No. 1. The junction is exposed in a deep Y-shaped trench which contains only narrow fluorspar veins.

The No. 2 vein follows an irregular course north and southwest of shaft No. 2 but cannot be traced continuously on the surface. At the 110-foot level a drift follows the vein about 100 feet in a direction S. 10° W. from the shaft and then splits to follow a footwall and a hanging-wall vein, each about 3 feet thick. Much of the ore above this drift has been mined. Near the middle of the drift a winze descends on the vein to the 170-foot level, and a crosscut connects the bottom of the winze with the 180-foot level of vein No. 1. Northward from shaft No. 2 on the 110-foot level a curved drift follows the vein for about 100 feet and exposes ore 4 to 5 feet thick, which is estimated to contain 50 percent CaF_2. The direction and position of the end of this drift indicate that the ore in it connects with that in the intersecting veins north of shaft No. 1.

Several pits and trenches farther up the hill from shaft No. 1 expose fluorspar veins from, 1 to 6 feet thick, but their relations are obscure and their continuity is not demonstrated. A large burrow was made at the contact of the monzonite porphyry and the Paleozoic rocks west of shaft No. 1. There fluorspar is exposed in veins, stringers, pods, and brecciated bodies that are too small to invite further work.

The vein material is composed of coarsely crystalline fluorite and quartz. The fluorite is generally aquamarine, but in crushed zones it ,is white, and where associated with ferruginous silica it is purple or red. The quartz forms drusy coatings, acicular veinlet-fillings, and red or brown cryptocrystalline growths in breccia and cavities. The cavities in places contain abundant cubes and pyritohedra of pyrite. All the varieties of quartz were deposited after the main period of fluorite deposition.

Hand-sorted ore from the upper workings contained 90 percent CaF_2.[30] The veins in the lower workings average considerably less, the estimated CaF_2 content ranging from 50 to 70 percent.

GREENLEAF MINE

The Greenleaf mine is on the flats at the southeast end of Fluorite Ridge, 2,000 feet S. 60° E. from the Sadler mine (Plate 15). The deposit was first worked in 1939 by W. D. Howard of Deming, but from 1940 to the fall of 1944 it was operated by D. F. McCabe of Lordsburg, and since then for a short period by E. J. Marston of Colorado Springs, Colorado.

The data regarding the mine workings have been taken from the field notes and maps of James K. Grunig of the Federal

[30] Darton, N. H., and Burchard, E. F., op. cit., p. 544.

Geological Survey. D. F. McCabe, Hiram. Harrison, and John Harrison also furnished much information.

Tertiary clastic rocks crop out at the mine, but bolson deposits overlap the extensions of the veins. Two isolated masses of cryptocrystalline quartz, shown on Plate 15, form prominent mounds a few feet northwest of the mine. Although the upper workings of the mine are in the clastic rocks, most of the underground workings are in monzonite porphyry, the top of which is at a depth of about 25 feet from the surface on the west side of the vein system and 190 feet on the east side.

The mine is in a major zone consisting of closely spaced intersecting normal faults and fractures ; this zone has a maximum width of 40 feet and a length of about 400 feet. It trends about N. 20° E. The faults constituting it may be grouped in three minor zones, differentiated by their strikes. Numbers are arbitrarily assigned to them and the veins that they contain. Zone No. 1 strikes generally N. 30° E. (range, N. 10°-45° E.) ; it is cut by zone No. 2, which strikes generally N. 10° E. (range, N. 0°-30° E.). The intersection of these two fault zones is in the shaft at the surface, 30 feet north of the shaft at the 167-foot level, 80 feet north at the 190-foot level, and 65 feet north at the 350-foot level. Trenching by the Federal Bureau of Mines, and underground mapping by the Geological Survey, revealed a third zone of faults that strikes about N. 10° W. (range, N. 0°-30° W.) and cuts both the other zones. The downthrow along zone No. 3 is on the north and is about 45 feet. Underground this zone is much warped and appears to be represented by faults that strike N. 9°-26° W. at the 213-foot level, N. 1°-13° W. at the 260-foot level, and N. 18°-29° W. at the 350-foot level at distances of 120 feet, 130 feet, and 140 feet, respectively, northeast of the shaft. North of No. 3 fault zone on the 350-foot level two sub-parallel veins are probably segments of the Nos. 1 and 2 veins that have been offset eastward about 15 feet. The general dip of all the faults is 70°-80° E., but irregularities cause the dip to deviate from, these figures by several degrees ; in some places the faults even dip steeply to the west. Although these faults intersect one another, it is probable that they were formed almost contemporaneously and were modified by later stresses. The fault relations described above were established before the first period of fluorspar deposition, but faulting continued during and after deposition. The resultant of these movements is a throw of 165 feet, as shown by the position of the contact between the clastic rocks and the monzonite porphyry on opposite sides of the major fault zone.

Brecciated masses are common within the major fault zone. Some, the product of the original faulting, were replaced and cemented during early periods of fluorite deposition. Others were formed after the first fluorspar veins had been deposited, and were recemented by later fluorite and quartz.

The dimensions of the ore bodies cannot be determined accurately, because many of the stopes have been filled with waste and others are inaccessible. Detailed mapping, however, shows that the fluorspar ore forms irregularly shaped tabular bodies and shoots having an average length of 60 to 100 feet. The average thickness of the ore bodies is 5 to 6 feet, but several are 15 feet thick ; a maximum thickness of 30 feet is reached in the stope south of the shaft on the 213-foot level.[31] The weighted-average thickness of the ore remaining in the stopes in the summer of 1944 was 3.5 feet, and that in the floor of the 350-foot level was 5 feet. The depth to which the ore bodies extend varies. No. 1 vein pinches at the 40-foot level, but was mined again between the 113- and 192-foot levels and between the 170-and 250-foot levels. No. 2 vein was mined continuously from the surface to the 350-foot level, but the ore bodies were in small shoots above the 167-foot level and in tabular form below.

The ore bodies contain many narrow parts that are left as pillars. It is estimated that these constitute as much as 60 percent of the vein above the 167-foot level, but a much lower percentage in the lower workings. This estimate is corroborated by production figures furnished by D. F. McCabe, who states that about two-thirds of the fluorspar from the mine, mostly of high grade, was taken from below the 200-foot level. Since these levels are close to the lower contact of the clastic rocks with the monzonite porphyry, the difference in size of the ore bodies and in the composition of the ore above and below these levels is believed to be related to the difference in the character of the rocks on either side of the contact. The clastic rocks supplied poorer receptacles for the deposition of the fluorite, probably because they tend to pulverize and to break unevenly, providing channels that are less permeable than those in the more homogeneous and competent igneous rock. Furthermore, the greater amount of silica in the sedimentary rocks tends to make the breccia and gouge formed from them less susceptible to replacement than the feldspar-rich products of faulting in the porphyry. Other evidence in favor of lithologic control of fluorite deposition is the fact that the richest of the other mines in this locality, the Sadler mine, is entirely within the monzonite porphyry, whereas two smaller deposits, the Lucky mine and the Greenleaf No. 4 prospect, are entirely within the Tertiary clastic rocks.

The ore is aquamarine coarsely crystalline fluorite with a small percentage of tiny included quartz crystals and interstitial

[31] Oral communication from Hiram Harrison.

quartz. Some of the fluorite was formed in open spaces and has euhedral crystals terminating in purple bands. This type of ore can be mined and sorted to yield a very high-grade product. A red and green mottled brecciated ore is prominent at the intersections of faults. It was formed by the brecciation of a coarsely crystalline vein, followed by cementation of the mass by fine-grained fluorite and cryptocrystalline red and brown quartz or jasper.

Accurate figures regarding the total yield of the mine are not available, but reliable estimates set the production at about 20,000 tons of ore up to the end of 1942. Of this amount approximately 18,000 tons of milling grade and 9,900 tons of metallurgical grade were sold during 1940-1944.[32]

Mining' methods at the Greenleaf mine are described on pages 201-202.

SAN JUAN MINE

The San Juan mine, owned in 1943 by D. F. McCabe, is situated at the base of Fluorite Ridge about 800 feet east of the Sadler mine (Plate 15). In 1944 the workings consisted of No. 1 shaft, 260 feet deep, near the south end of the deposit ; No. 2 shaft, 620 feet north of No. 1; and at least 24 other excavations, including four pits from 20 to 50 feet deep and shallow cuts and trenches. The underground workings were not studied.

The workings are within the monzonite porphyry except in the northern end a short distance below the surface, where conglomerate forms the east wall of the principal veins. Some of the prospects east of the mine are entirely within the conglomerate. The deposit comprises two veins 50 to 90 feet apart: a west vein that strikes N. 10° W. and dips 65° E., and an east vein that strikes N. 12°-15° W. and dips 65°-85° E. Both shafts are on the west vein. Several small veins trending northeast branch from these two. In addition to the fluorspar veins there are numerous quartz veins that strike in various directions. One of them parallels the north end of the west vein for about 250 feet ; in the north central part of the claim the two veins merge and continue as a quartz vein for at least 200 feet farther. Some of these quartz veins contain barite, which was deposited before the quartz, but barite was not found in the fluorspar veins.

The fluorspar is in narrow veins, small pods, and stringers in fault breccias and fissures. The distance between the walls of the breccias is as great as 7 feet, but the fluorspar commonly occupies only a small fraction of this space. The mineralized zone is composed of medium- to coarse-grained aquamarine or white fluorite with penetrating veinlets of finely crystalline quartz and coatings of acicular quartz around some of the frag-

[32] Data supplied by D. F. McCabe.

ments of rock included in the fluorspar. As most of the work on this deposit has been exploratory or for development, only a small tonnage of ore has been marketed.

GREENLEAF NO. 4 PROSPECT

In the fall of 1942 the Western Mining Corporation sank a shaft on the Greenleaf No. 4 claim, 550 feet southeast of the Greenleaf mine, to an approximate depth of 40 feet (Plate 15). It is entirely in fine-grained Tertiary sandstone and conglomerate. These rocks here dip 5°-10° eastward and are cut by a fault that strikes N. 14° E. and dips 65° W. Within a brecciated zone 1 to 2 feet wide along the fault, stringers and lenses of crystalline fluorspar range from a fraction of an inch to several inches in thickness. The dip of the vein is opposite to that of most of the other veins in this area, but the fault on which the vein occurs is one of the longer dislocations in the area. It can be seen in a shallow pit about 200 feet to the north and again in a small cut 1,150 feet N. 17° E. from the shaft, where there is a similar exposure of fluorspar. One hundred feet northward from this cut the fault offsets a basalt dike for at least 95 feet.

LUCKY MINE

The Lucky mine is in the foothills of Fluorite Ridge, 2,100 feet north-northwest of the Greenleaf mine (Plate 15). A small amount of prospecting was done on it prior to 1910,[33] but most of the ore from the mine has come from a cross vein opened during or shortly after World War I.[34] By 1928 this vein had been stoped for a distance of 75 feet and to a depth of 50 feet,[35] and a shaft had been sunk to a depth of 90 feet. From this shaft several stopes 20 to 40 feet long explored the vein north and south of the shaft. In 1942 the property was acquired by the Western Mining Corporation, which extended the shaft to a depth of 310 feet, excavated drifts 120 feet long on the 174-foot level (vertical distance) and 210 feet long on the 253-foot level, and did a small amount of stoping before abandoning the property in December 1943.

All the workings of the mine are in conglomerates and feldspathic siltstones of Tertiary age. These strata wedge out to the west on the slope of the hill that rises sharply from the mine shaft. The greater part of the hill is monzonite porphyry, but it is capped by a quartzose mass that is probably a silicified sedimentary rock.

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[33] Darton, N. H., and Burchard, E. F., Fluorspar near Deming, New Mexico: U. S. Geol. Survey Bull. 470, pp. 535-536, 1911.

[34] Oral communication from W. C. Siebring, Deming.

[35] Johnston, W. D., Jr., op. cit., p. 97, 1928.

The deposit is at the intersections of three faults that form an acute triangle 400 feet in maximum dimension. The triangle is bounded on the east by a fault striking irregularly north and dipping 65° E., on the west by a fault striking N. 9° E. and dipping 60° E., and on the south by a short cross fault striking N. 30° E. Striations on the west fault pitch southward 60°. The main shaft is at the intersection of the west fault and the cross fault.

Fluorspar occurs in sinuous veins and isolated pods in the brecciated fault zones, which range from 4 to 12 feet in width. The stopes on the cross fault were filled at the time of examination, but Johnston[36] reports that the ore body in the cross fault includes a vein $2^1/_2$ feet thick and two parallel veins 1 foot or slightly less in thickness. Small stopes along the shaft to a depth of 90 feet contain veins that range from a few inches to 24 inches in thickness and are wider in the upper levels than in the lower ones. The drifts at the 174- and 210-foot levels contain no ore south of the shaft, but narrow veins are exposed in the north workings. On the 174-foot level a part of the vein from 20 to 30 feet long is 4 feet thick. On the 210-foot level the vein is about 100 feet long and ranges in thickness from 3 to 30 inches. One or two carloads of metallurgical-grade ore were sorted from a small stope on this vein, and some milling ore was sold to the General Chemical Company's mill at Deming.

A shaft about 40 feet deep was dug during the early years of development at the intersection of the east and west veins in the north end of the deposit. It was inaccessible when visited, but ore in the pillars near the surface appeared to be as much as 14 inches wide.

Fluorspar in the Lucky mine is coarse-grained, white or light green, and semi-transparent. In the upper levels weathering of the brecciated zone has reduced the vein to a crumbly rubble resembling the "gravel spar" of the Kentucky-Illinois fluorspar deposits.

HILLTOP SPAR PROSPECT

The Hilltop Spar prospect is 900 feet northwest of the Sadler mine, near the crest of a hill formed by Paleozoic rocks (Plate 15). When visited by J. K. Grunig in 1944 there was neither road nor trail to it. Ownership was claimed by W. B. Clary of Deming. The workings consisted of a shaft 16 feet deep and shallow cuts in the hillside.

The fluorspar occurs in many small bodies and stringers scattered through a cherty limestone, and as cavity fillings in boxwork with quartz walls. The shaft is along the strike of a series of these fluorspar bodies that can be traced for 70 feet.

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[36] Idem, p. 97.

The sides of the shaft expose a zone of siliceous fluorspar ranging in width from 2 to 16 feet. Although the veinlets and small masses of fluorspar are quite pure, they are so small and irregular in distribution and the adjacent rock contains so much quartz that the prospect has not been developed further.

GRATTAN MINE

The Central group of fluorspar deposits on Fluorite Ridge (Table 29) is about 11/2 miles northwest of the Southeast group; it is served by the same access road and by an old road that enters the area from the south. The earliest records show that the locality was prospected prior to 1910 by G. M. Sadler.[37] From 1934 to 1944 P. L. Grattan of El Paso, Texas, worked the Grattan, Deckert, and Grattan State Land deposits, except for a short period in 1944 when they were controlled by the Edgar J. Marston Company.

The Grattan mine, on Spar No. 1 claim, is on the southwest side of Fluorite Ridge, about 700 feet above the bolson. The principal workings are at shaft No. 1, which in 1943 was 225 feet deep and had several levels both north and south of the shaft to a depth of about 200 feet. North of this shaft deep trenches follow the vein for about 480 feet to shaft No. 2, which was 60 feet deep.

The mine is in a basalt dike that cuts an andesitic phase of the porphyry. The dike branches and varies considerably in direction and thickness but its general trend is N. 40° W. About 270 feet above the mine is the contact of the porphyry with the sedimentary rocks into which it was intruded.

The vein is in a crooked brecciated zone that dips 80° E. and generally follows the east side of the dike. The zone is rather finely brecciated within a few feet of the east wall of the vein, but elsewhere the rock is broken by more or less vertical fractures which on the west side extend as much as 40 feet from the finely brecciated zone. The larger veins of fluorspar occur in the finely brecciated rock, and the adjoining fractured rock contains fluorspar stringers. The deposit has a vertically banded appearance caused by wide strips and irregular masses of dark rock alternating with light fluorspar veins. The veins have been considerably shattered by post-mineral movement and contain many open fractures which increase the hazard of mining.

On the surface the vein has been trenched and stoped almost continuously for 480 feet, but the lengths underground are not so great. The longest ore body underground is at the 200-foot level, where ore was mined for 120 feet north and 160 feet south of shaft No. 1. The ore shoots have an average aggregate thick-

[37] Darton, N. H., and Burchard, E. F., op. cit., p. 541.

ness of 2 to 4 feet. Mining operations indicate that the depth of the ore body exposed at the surface is about 100 feet, whereas that of the body mined from the 200-foot level is at least 70 feet. The vein in the bottom of the shaft at a depth of 225 feet contained only narrow stringers of fluorspar, but when the shaft was deepened to 245 feet in 1945 another body of ore $2^1/_2$ feet thick was exposed.

The vein is composed of coarsely crystalline white or light green fluorite, with intimately associated quartz that forms incrustations on vein walls and around rock fragments. The intervening spaces are filled with fluorite except for scattered vugs some of which are lined with drusy quartz. Deposition of quartz thus took place chiefly before the crystallization of the fluorite, but some quartz was formed later. The grade of the ore mined during 1942-1944 was estimated to average 50-55 percent CaF_2 and 20-25 percent SiO2. [38]

When the mine was in normal operation its output ranged from 5 to 15 tons of ore daily. It is estimated that 12,000 tons of ore had been mined from this deposit by the end of 1944.

The basalt dike was an especially favorable host for the fluorspar because of the open fractures that were formed in it. The best deposits occurred where the strike of the basalt and the fault zone deviated about 30° northward from the general trend. This structural condition may be expected to continue to considerable depth, forming other receptacles favorable for the deposition of ore bodies.

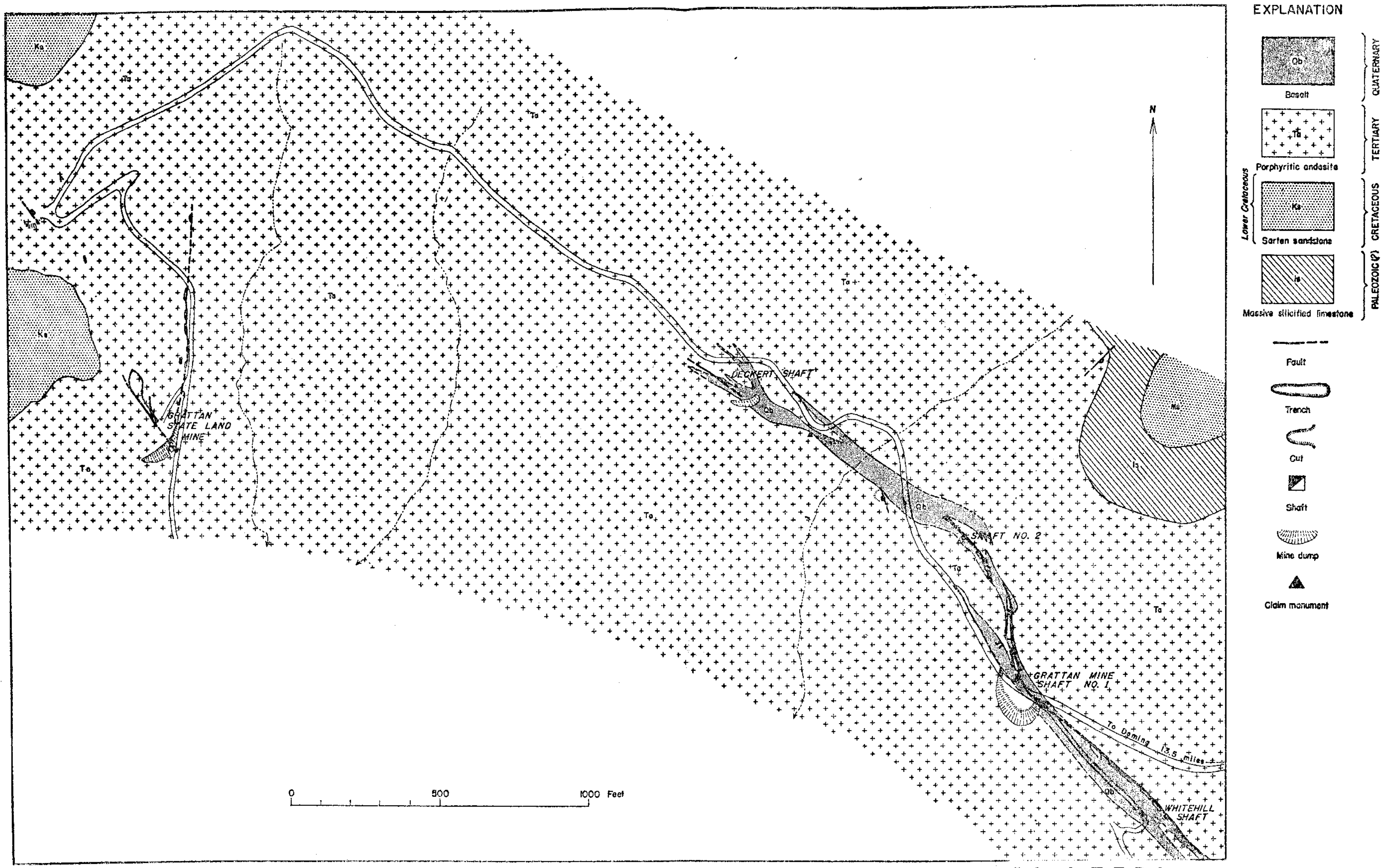
WHITEHILL PROSPECT

The vein of the Grattan mine extends southeastward for about 700 feet, following the basalt dike onto the Dorothy Bell claim, where a shaft called the Whitehill prospect has been sunk (Plate 16). Fluorspar occurs in stringers in the fractured basalt, and in only a few places has an aggregate thickness of more than 12 inches.

SPAR NO. 2 PROSPECT

There are two fluorspar prospects on Spar No. 2 claim, both on the northwest extension of the vein present in the Grattan mine. One, called the Deckert shaft, is 900 feet northwest of shaft No. 2 of the Grattan mine (Plate 16). It is about 30 feet deep and was sunk in a wide shattered zone that strikes N. 45° W. in basalt and porphyritic andesite. The southwest wall of the shaft is in fault gouge 18 inches thick and the remainder is in an intensely brecciated zone 6 feet wide. The breccia contains veinlets and vugs of fluorspar that constitute about 10 percent of its volume. In addition, near the southwest

[38]Oral communication from Lynch Grattan, manager of the Grattan mines and mill.



Base from aerial photographs controlled by plane-table traverse

Geology by H. E. Rothrock, 1944

Geologic map showing fluorspar mines and prospects in the Central group, Fluorite Ridge, Luna County wall of the breccia zone two veins of purple coarsely crystalline fluorspar range from a few inches to 12 inches in thickness.

The other opening is about 650 feet southeast of the Deckert shaft. It is in porphyry and consists of a shaft 25 feet deep and a short drift that could not be entered at the time of inspection. It was described by Johnston[39] as containing an ore body 3 to 5 feet wide composed of horizontal lenses of fluorspar in a matrix of clay, calcite, quartz, and chert breccia, with some basalt and porphyry in the fractured zone.

GRATTAN STATE LAND MINE

The Grattan State Land mine is about 1,700 feet west of the Deckert shaft on Greenspar No. 2 claim, leased from the State (Plate 16). It was visited in February 1944. The deposit is in porphyritic andesite from 100 to 200 feet below the contact of the andesite with the sedimentary rocks into which it was intruded. Development was begun in 1943 at the intersection of a brecciated zone striking northward with fractures striking N. 15° - 25° W. and dipping 75° - 85° W. The breccia is as much as $7^1/_2$ feet wide and contains about 20 percent of interstitial fluorspar. The fractures contain solid veins of fluorspar ranging from a few inches to 3 feet in thickness. A grab sample from the bin assayed 67.5 percent CaF_2, 22.4 percent SiO_2, and 2.5 percent $CaCO_3$. The west wall of the cut follows the principal vein, which was mined for a distance of about 125 feet. A shaft was sunk to a depth of 50 feet and a drift driven northward from the bottom for 85 feet, but no ore bodies were found. It is doubtful that the principal vein was intersected in this drift. By the end of 1943 approximately 2,500 tons of ore had been taken from this deposit.

Northeast of the shaft are several trenches along a subsidiary vein that strikes N. 10° E. and dips 70° - 80° W. A projection of this vein would intersect the main vein about 70 feet south of the shaft in an area that was largely covered with waste at the time of the visit. The fluorspar, which occurs in fissures, is commonly less than 12 inches thick. Numerous veinlets and small lenses of fluorspar have been found on the higher slopes close to the contact of the porphyry and the overlying sedimentary rocks, but none has proved to be minable.

TIP TOP PROSPECT

The fluorspar prospects on the Tip Top claims, owned in 1943 by Mary B. Whitehill of Deming, are on the northeast, east, and south sides of the flat-topped hill that forms the crest of Fluorite Ridge. There are three openings, from 1,000 to 1,200

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[39] Johnston, W. D., Jr., op. cit., p. 99.

feet apart and about 300 feet above the level of the access road at the Grattan mine (Figure 11) . They are reached by foot trails only.

The prospects are in vuggy solution cavities in the limestone where fluorite has been deposited. The process was chiefly one of void-filling by which thin incrustations, botryoidal masses, and rows of fluorite crystals in seams were formed. Drusy quartz then filled the interstices and replaced most of the limestone unaffected by the previous mineralization. The mineralized areas thus contain a large percentage of quartz, and the size of the fluorspar pockets is unpredictable owing to the irregularity of the cavities in which they were formed.

SANDOVAL COUNTY

Fluorspar has been reported[40] in the northern part of the Sandia Mountains, an area where difficulty of access is a serious deterrent to development. The geology of this part of the mountains is similar to that of the remainder of the range, which is described in the section on Bernalillo County, pages 36-39.

The fluorspar occurs as an abundant gangue mineral in the lead-silver-copper veins of the La Luz mine and the Montezuma prospect. The La Luz mine is about 1 mile north of South Sandia Peak in the steep escarpment that forms the west face of the Sandia Mountains. The deposit is a fissure vein 2 to 4 feet thick that strikes about N. 25° W. and dips 75° NE. The ore body is in pre-Cambrian granite close to the contact with the overlying limestone of the Magdalena group.

The Montezuma prospect is about 1 mile north of Placitas, on the west side of Montezuma Mountain near its base. The prospect has been explored for lead-copper ore that occurs in pre-Cambrian schists near their contact with sedimentary rocks.

SIERRA COUNTY

GENERAL RELATIONS

Most of the prospecting and all the mining of fluorspar in Sierra County has been in the Sierra Caballos in the southeastern part, but deposits are known in the northwestern part, in Iron Mountain and Sierra Cuchillo. The deposits in Sierra Caballos are served by U. S. Highway 85, and by the Atchison, Topeka, and Santa Fe Railway, which traverses the Jornada del Muerto east of the range (Plate 1) . The deposits on the east side of the mountains are only a few miles from the railroad. Ore from

[40] Ellis, R. W., Geology of the Sandia Mountains: N. Mex. Univ. Bull. 4 (geol. ser. 3), pp. 42-43, 1922.

those on the west side may be hauled to the railroad at Engle, 19 miles by road east of Hot Springs, or to Hatch, 41 miles south of Hot Springs on U. S. Highway 85. A lateral highway from Hatch, State Route 26 - 27, has been used to haul ore to the flotation mills at Deming, 46 miles distant. The Iron Mountain deposits may be reached from the east by a dirt and gravel road 43 miles long that connects them with U. S. Highway 85, or from the north by a similar road 54 miles long that intersects U. S. Highway 60 west of Magdalena, a railhead of a branch of the Atchison, Topeka, and Santa Fe Railway. The road between Iron Mountain and Hot Springs passes through Sierra Cuchillo and serves as an outlet for that area also. The difficulty of access to the Iron Mountain and Sierra Cuchillo deposits has been a serious deterrent to their development.

GEOLOGY

In Sierra County fluorspar occurs in pre-Cambrian and Paleozoic rocks. Only these and the Tertiary rocks to which the deposits appear to be related are described in this report.

Pre-Cambrian rocks are extensively exposed on the west side of the Sierra Caballos. They consist of muscovite and biotite gneiss and schist cut by granite and granite gneiss. The granite is white to pink, and fine- to medium-grained; the dominant feldspar is microcline, and the chief dark minerals are biotite and magnetite.[41] Dioritic[42] and pegmatitic dikes cut both the igneous and metamorphic rocks.

The oldest Paleozoic formation is the Bliss sandstone, of Cambrian age. It consists of maroon or gray medium-bedded sandstone, dark-gray or black sandy limestone, and brown sandy shale. At the Blue Jacket prospect in the northern Sierra Caballos it is about 120 feet thick, and at the White Star mine it is at least 55 feet thick. Harley [43] reports that its thickness elsewhere in the county ranges from 55 to 100 feet. In the northern part of the mountains the basal beds are commonly light-gray quartzitic sandstone ; the other layers are ferruginous. The limestones are characteristically glauconitic, and the more shaly strata yield *Obolus (Westonia) stoneanus, Obolus sinoe (?), Eoorthis desmopleura,* and *Lingulella acutangulata (?).*[44]

The El Paso limestone, of Ordovician age, overlies the Bliss sandstone. Harley[45] describes this limestone as follows.

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[41] Determinations by J. J. Glass, U. S. Geological Survey.

[42] Harley, G. T., The geology and ore deposits of Sierra County, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 10, p. 197, 1934.

[43] Idem, p. 197.

[44] Darton, N. H., "Red Beds" and associated formations in *New* Mexico: U. S. Geol. Survey Bull. 794, p. 10, 1928.

[45] Harley, G. T., op cit., pp. 24-25.

> The El Paso limestone in the lower part is somewhat similar to the underlying Bliss sandstone. At the base are alternating thin beds of quartzite and limestone about 15 feet in total thickness. Locally this part of the formation consists of calcareous shales alternating with shaly limestone. Above this transition zone the formation is gray slabby and massive magnesian limestone. The surface of many of the beds is covered with thin reticulating brown deposits of silica, and most of the rock weathers to a pale gray tint, two features that are quite distinctive. The El Paso limestone is between 300 and 400 feet thick in the west face of the Sierra Caballos. . . .

The Montoya limestone, of latest Ordovician (Richmond) age, [46] lies unconformably on the El Paso limestone, and is generally gray, cliff-forming, and cherty. It is 200 to 300 feet thick. The Fusselman limestone of Silurian (Niagaran) age normally overlies the Montoya limestone. According to Darton [47] it is absent through faulting north of Palomas Gap in the Sierra Caballos but occurs as a prominent cliff of characteristic dark-colored massive limestone farther south, where it is 50 feet thick.

Above the Fusselman limestone, but separated from it by a break in sedimentation, is the Percha shale of late Devonian age. Harley [48] describes its occurrence in the southern part of the Sierra Caballos as follows.

> This formation outcrops in a slope of moderate inclination, in marked contrast to the cliffs below and above it, and consists of black to gray and greenish-buff shale and thin-bedded sandstone and limestone measuring 200 feet and upward in total thickness. The lower portion of this shale is generally darker in color than the upper portion, which is usually gray to buff. The upper part contains many thin layers of gray limestone.

The Lake Valley limestone, of Mississippian age, is re,ported by Darton [49] to be concordant with the underlying Percha shale and the overlying Magdalena group but to be separated from both by breaks in sedimentation. He describes the Lake Valley as a massive to slabby generally coarse-grained lightcolored limestone, whose thickness ranges from 100 to 200 feet. In the Sierra Caballos the Magdalena group of Pennsylvanian age consists principally of limestone, much of it so thickbedded that it forms prominent cliffs along the west front of the mountains. The lower 400 to 500 feet is characterized by abundant nodular and reticulated chert. Shales that are gray, greenish gray, and black in most of the group but are brown and dark red near its top are interbedded with the limestones. They constitute from 10 to 20 percent of the rocks in the sections of the Magdalena group that were studied. In the Sierra Caballos the group has not been subdivided into the Sandia formation and

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[46] Idem.
[47] Darton, N. H., op. cit., p. 321.
[48] Harley, G. T., op. cit., p. 198.
[49] Darton, N. H., op. cit., pp. 15-16.

Madera limestone, as in areas farther north. Thompson,[50] classifying the Pennsylvanian rocks chiefly by their fusulinid faunas, recognizes four series, the Derry, Des Moines, Missouri, and Virgil, comprising fifteen formations and one undivided group. Johnston[51] states that the Magdalena group has a measured thickness of 1,000 feet at the northern end of the Sierra Caballos ; Darton [52] reports that it is about 600 feet thick in these mountains.

At Iron Mountain the Magdalena group is composed of limestones, quartzites, and shaly beds about 1,400 feet thick. At the base is a vitreous feldspathic sandstone and quartz conglomerate 120 feet thick. Overlying these beds are about 120 feet of light to dark brown shaly strata. The remainder of the group is slabby, to thick-bedded non-magnesian limestone, much of which is cherty. [53]

The Abo sandstone, of Permian or Carboniferous age, is extensively exposed on the east sides of Iron Mountain, Sierra Cuchillo, and Sierra Caballos. It crops out also on the west side of Sierra Caballos in the vicinity of Derry. It consists of dark-red or reddish-brown clayey sandstone and sandy shale, and is reported to be about 800 feet thick and to contain a thin limestone bed near the middle in the Sierra Caballos. [54]

Tertiary volcanic rocks unconformably overlie the sedimentary rocks at Iron Mountain and at the southern end of the Sierra Caballos. At Iron Mountain, according to Jahns,[55] a thick series accumulated in the following order : andesite breccia, andesitic and latitic lavas and tuffs, felsite, and rhyolite with associated pyroclastics. These volcanic rocks are cut by intrusives that are genetically related to the mineral deposits and consist of fine-grained monzonite, porphyritic rhyolite, fine-grained granite and aplite, and reddish-brown felsite. The youngest intrusives are thin dikes of dark-green to black lamprophyre, andesite, and basalt. Remnants of a similar sequence are exposed in the mountains west of the Rio Grande, where extrusions of andesitic rock were closely followed by latite and latite porphyry, and, after a considerable period of quiescence, by extensive flows of rhyolites, tuffs, and breccias.56

Poorly consolidated fluviatile deposits of Tertiary (Miocene and Pliocene) age occur in the Rio Grande valley [57] and in the

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[50] Thompson, M. L., Pennsylvanian system in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull 17, p. 27, 1942.

[51] Johnston, W. D., Jr., op. cit., p. 29.

[52] Darton, N. IL, op. cit., p. 322.

[53] Jahns, R. H., Beryllium and tungsten deposits of the Iron Mountain district, Sierra and Socorro Counties, New Mexico : U. S. Geol. Survey Bull. 945-C, p. 49, 1944.

[54] Darton, N. H., op. cit., p. 322.

[55] Jahns, R. H., op. cit., pp. 50-51.

[56] Harley, G. T., op. cit., p. 31.

Idem, p. 29.

valley west of Iron Mountain.[58] Fluorspar has not been found in these or in younger rocks.

The fluorspar deposits in Sierra County are generally found in mountain blocks that are tilted eastward. The broad features of these mountains were formed before the accumulation of the Tertiary extrusive rocks, which overlap the Paleozoic rocks in the Sierra Caballos and the Cretaceous and Permian rocks on Iron Mountain. In the latter area faulting, fracturing, and tilting, which accompanied Tertiary vulcanism, modified the preexisting structure.[59]

FLUORSPAR DEPOSITS

In Sierra County fluorspar occurs in pre-Cambrian granite, in Paleozoic limestone, sandstone, and shale, and in Tertiary tactite (contact-metamorphosed limestone) . All the deposits except those in the tactite are fissure veins or bedded deposits that have been formed by replacement or space-filling processes. The deposits in tactite were formed by replacement in a zone of contact metamorphism.[60]

The veins and bedded deposits consist chiefly of intimately intergrown aggregates of fluorite, quartz, and calcite, with small proportions of barite and metallic minerals in some deposits. The fluorite is generally fine- to medium-grained and white, but green, blue, and purple fluorite is not uncommon. Quartz is the predominant gangue in deposits in pre-Cambrian rocks and is generally a conspicuous component in all veins. An abundance of calcite is characteristic of deposits in the calcareous Paleozoic rocks. Barite is found in both sedimentary and igneous host rocks in some deposits in the northern part of the Sierra Caballos. Galena is most common in the deposits near Palomas Gap, and occurs as scattered crystals in other localities.

In the contact-metamorphic deposits at Iron Mountain, fluorite occurs in "ribbon rock"—a tactite consisting of minutely crenulated layers, averaging about 0.2 millimeter thick, of magnetite associated in places with specularite alternating with fluorite or silicate minerals or both.[61]

The fluorspar deposits in Sierra County are described under the headings of Sierra Caballos, Iron Mountain, and Sierra Cuchillo (Table 31).

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[58] Jahns, R. H., op. cit., p. 50

[59] Idem, p. 52.

[60] Idem, pp. 52-55.

[61] Idem, p. 55.

TABLE 31. FLUORSPAR MINES AND PROSPECTS IN SIERRA COUNTY

Name	Approximate location	Reference [a]
	Sierra Caballos, Northern group	
White Star mine	NE¼ sec. 15, T. 14 S., R. 4 W.	27:32-40 9: 114-143
Oakland mine	SW¼ sec. 14, T. 14 S., R. 4 W.	27:32-40
Universal mine	SE¼ sec. 22, T. 14 S., R. 4 W.	27:32-40
Tingley prospect	NE¼ sec. 15, T. 14 S., R. 4 W.	
Unnamed prospect	NE¼ sec. 15, T. 14 S., R. 4 W.	
Blue Jacket prospect	SW¼ sec. 15, T. 14 S., R. 4 W.	
Forty-one prospect	NE¼ sec. 22, T. 14 S., R. 4 W.	
	Sierra Caballos, Palomas Gap group	
Dewey prospect [b]	SE¼ sec. 26, T. 14 S., R. 4 W.	20: 203-207
White Swan prospect [b]	NE¼ sec. 35, T. 14 S., R. 4 W.	20: 203-207
Harding prospect	SE¼ sec. 35, T. 14 S., R. 4 W.	27:41
Napoleon-Rosa Lee group	E½ sec. 2, T. 14 S., R. 4 W.	20: 203-207
Cox mine	NE¼ sec. 11, T. 14 S., R. 4 W.	
Imperial prospect	NE¼ sec. 34, T. 14 S., R. 4 W.	
Marion prospect [b]	SE¼ sec. 3, T. 15 S., R. 4 W.	27: 40 20: 207-208
	Sierra Caballos, Southern group	
Fluoride prospect [b]	NW¼ sec. 27, T. 15 S., R. 4 W.	
Lyda K mine	SE¼ sec. 29, T. 16 S., R. 4 W.	27:42-49
Nakaye mine [b]	NW¼ sec. 22, T. 17 S., R. 4. W.	27:49-57 30: 126-127
Alamo prospect	SE¼ sec. 16, T. 17 S., R. 4 W.	
Esperanza prospect [b]	NE¼ sec. 29, T. 17 S., R. 4 W.	27:57-58
Velarde prospect	NW¼ sec. 4, T. 18 S., R. 3 W.	27:61-64
	Iron Mountain district	
Iron Mountain prospects	Sec. 35, T. 9 S., R. 8 W., and sec. 2, T. 10 S., R. 8 W.	25
	Sierra Cuchillo deposits	
Victorio prospect	T. 12 S., R. 7 W.	

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

The Sierra Caballos forms the east side of the Rio Grande valley from Hot Springs in Sierra County to Hatch in Dona Ana County, a distance of about 30 miles. As far as Apache Canyon, 16 miles below Hot Springs, the west side of the mountain is a precipitous escarpment, the crest of which is from 3 to

4 miles east of the river and about 3,000 feet above it. South of Apache Canyon the mountain is lower, and it comes to an end east of Hatch at the junction of the Rio Grande valley and the Jornada del Muerto. Although the escarpment has several large reëntrants, it is cut by only one pass, Palomas Gap, 5 miles south of Hot Springs. From the river the slope rises gradually on large dissected alluvial fans to a band of foothills partly buried in alluvium at the northern and southern ends, and to a steep rock escarpment in the middle. Eastward from the crest of the mountain the slope closely follows the dip of the strata.

All the formations described in the previous section on the geology of Sierra County are represented in the Sierra Caballos except the intrusive silicic Tertiary rocks. The absence of these intrusives is of interest because, in the Organ Mountains to the southeast and in Iron Mountain to the northwest, they are thought to have come from the same source as the mineralizing solutions. If fluorite is closely related to this type of rock, it is reasonable to assume that a similar intrusive, as yet unexposed by erosion, occurs in the vicinity of the Sierra Caballos.

Like many of the north-trending mountains of the south central part of the State, the Sierra Caballos is essentially an eroded fault block of sedimentary and igneous rocks that has been tilted eastward. This general structure is complicated by minor faulting, and by folding that in some localities was intense. Most of the north-trending faults have downthrown sides on the east, and the strata show drag on that side. In the region east of Derry the mountain is described as an anticline.[62] Transverse faults have produced zones of weakness along which Palomas Gap and such valleys as Apache Canyon were formed. In some of these faults fluorite, quartz, calcite, barite, and minerals of copper, lead, vanadium, and certain other metals, were deposited in various combinations.

For convenience of reference and analysis, the deposits in the Sierra Caballos are described in three groups. The Northern group is in that part of the mountains north of Palomas Gap, the Palomas Gap group is in the vicinity of the gap, and the Southern group is to the south.

SIERRA CABALLOS, NORTHERN GROUP

The fluorspar deposits in the northern part of the Sierra Caballos, sometimes called the Hot Springs deposits, form a closely spaced group about 3 miles south-southeast of Hot Springs (Figure 12) . One deposit, the name of which is not known, is on the crest of the mountain ; two, called the Blue

[62] Wells, E. H., Manganese in New Mexico : N. Mex. School of Mines, Min. Res. Survey Bull. 2, p. 64, 1918.

Jacket and Forty-one prospects, are in the foothills ; and the remainder, consisting of the White Star, Tingley, Oakland, Universal, and an unnamed deposit, are on the steep west slope of the mountain approximately 1,000 feet above the town.

The most direct route to these deposits is by a small ferry across the Rio Grande at Hot Springs, and thence up the stony

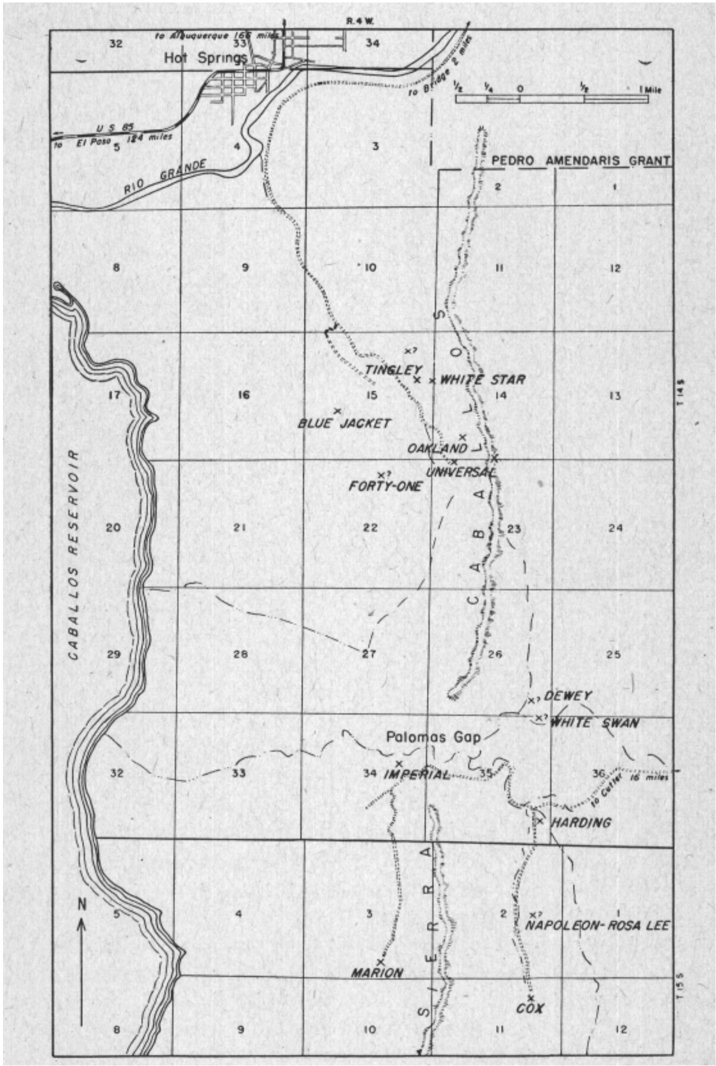

FIGURE 12.—Index map of fluorspar deposits in the northern Sierra Caballos, Sierra County.

bed of an arroyo that passes through the group of claims. Heavy equipment must be taken over a longer route, however, which crosses the Rio Grande on Elephant Butte dam or the bridge just below it and follows a poor truck trail across several arroyos to reach the east terminus of the ferry.

The White Star, Tingley, Oakland, and Universal veins are on a group of 7 patented claims called the Nevada, Tingley, Texas, Montana, Colorado, Arizona, and Illinois claims (Plate 17) , which have been owned since 1924 by Blanchard Hanson of Hot Springs. They were worked intermittently from 1926 to 1934 by Fluorspar Mines of America, Inc., which operated a decrepitation plant at the west end of the Oakland vein for primary separation and completed the beneficiation by tabling in a plant at Hot Springs.[63] The deposits were reopened in 1940 by the United States Fluorspar Company, which constructed a flotation mill nearby on the east side of the Rio Grande. Mining and milling were discontinued in 1942, owing to metallurgical and transportation difficulties. Production records are not in agreement, but they indicate that about 4,500 tons of fluorspar was shipped as a result of these operations prior to 1945.

Because of the urgent need for fluorspar in war industries, the Federal Geological Survey made a preliminary examination of the properties in 1942 and later joined the Federal Bureau of Mines and the Humphreys Gold Corporation, which was subleasing the properties, in a cooperative study. The veins were mapped by the Geological Survey. Samples were taken by the Humphreys Corporation under the supervision of the Bureau of Mines, and assays, metallurgy, and core drilling were done by the Bureau of Mines.

The Blue Jacket prospect is also owned by Blanchard Hanson. The ownership of the other prospects was not determined.

The rocks in the vicinity of the Northern group of deposits are pre-Cambrian granite and Paleozoic limestones, dolomites, sandstones, and shales. Granite crops out near the west end of the White Star vein, at the Blue Jacket prospect, and in the arroyo about half a mile south of the Universal vein. The granite is overlain by the Bliss formation, which, in the southern and western parts of the area, is overlain by dolomites of early Paleozoic age. In the vicinity of the mines, however, the section of rocks between the Bliss sandstone and the Magdalena group, which crops out near the east end of the veins, is not thick enough to include all the formations normally present in this interval. Brecciated and silicified zones indicate that this shortening of the stratigraphic section is due mainly to faulting, but it may also be due to unconformities in the section.

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[63] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, pp. 37-39, 1928.

The Paleozoic formations were not differentiated over the entire area, and the complexity of the structure near the veins where the detailed mapping was done made it impossible to measure accurately the thicknesses of the rock units. The approximate thicknesses in Table 32 are based on measurements made in the vicinity of the White Star vein.

TABLE 32. ROCK UNITS IN THE VICINITY OF THE WHITE STAR VEIN

Description	Thickness (feet)
Gray thick-bedded very cherty cliff-forming limestone	60
Gray medium-bedded cherty limestone interbedded with thin shale beds	90
Brown and black shale and thin-bedded argillaceous limestone interbedded with brown-weathering limestones 1 to 2 feet thick that constitute about 25 percent of the unit	90
White coarse-grained feldspathic sandstone and pebble conglomerate, in some places quartzitic. This is a useful key bed but is missing for at least a quarter of a mile south of the Universal vein	10-20
Gray to brown medium- to thick-bedded dolomitic limestone. The largest ore shoots occur in this group	250
Dark-brown thick-bedded limestone, cut by many thin reticulated veinlets of quartz and containing considerable chert	70
Dark-red to black limy fine-grained thin- to medium-bedded sandstone (Bliss sandstone)	55
Pink coarse-grained granite (pre-Cambrian)	

The deposits in the northern Sierra Caballos occur chiefly in its faulted and folded west flank. The dominant structures in the vicinity of the mines consist of an anticline in the mountain front and a syncline to the west. The axis of the syncline coincides approximately with the arroyo traversed by the trail to the deposits.

The east flank of the anticline dips 20° - 30° E., conforming with the dip of the main mountain mass. The dip of the west flank is commonly less than 45°. It is cut by a major fault that strikes N. 10° W. and dips 70° - 90° W. Very little fluorspar occurs in the part of the flank that lies west of this fault, the only exception being the Tingley prospect, which is in adjacent fractures that also strike N. 10°W. Diverging south-southeastward from the fault are three fracture zones in which the three principal fluorspar veins, the White Star, Oakland, and Universal, were deposited (Plate 17) . The fracture zones can be easily traced up the side of the mountain by the veins that were deposited in them, as high as the series of shales and limestones just above the white sandstone. Here they either branch and die out a short distance to the east, as in the White Star and Oakland veins, or lose their identity among other faults, as in the Universal vein.

The open fractures in which the veins were deposited may extend farther east than their present outcrop suggests. Such extensions might occur in the relatively brittle dolomitic limestones without being reflected in the relatively plastic shales above.

West of the axis of the syncline the dip becomes progressively steeper, and the eastward-dipping rocks are cut by two or more large northwest-trending faults. Half a mile west from the axis the rocks are faulted, and pre-Cambrian granite is in contact with early Paleozoic limestone. The Blue Jacket prospect, and probably the Forty-one also, are on this fault.

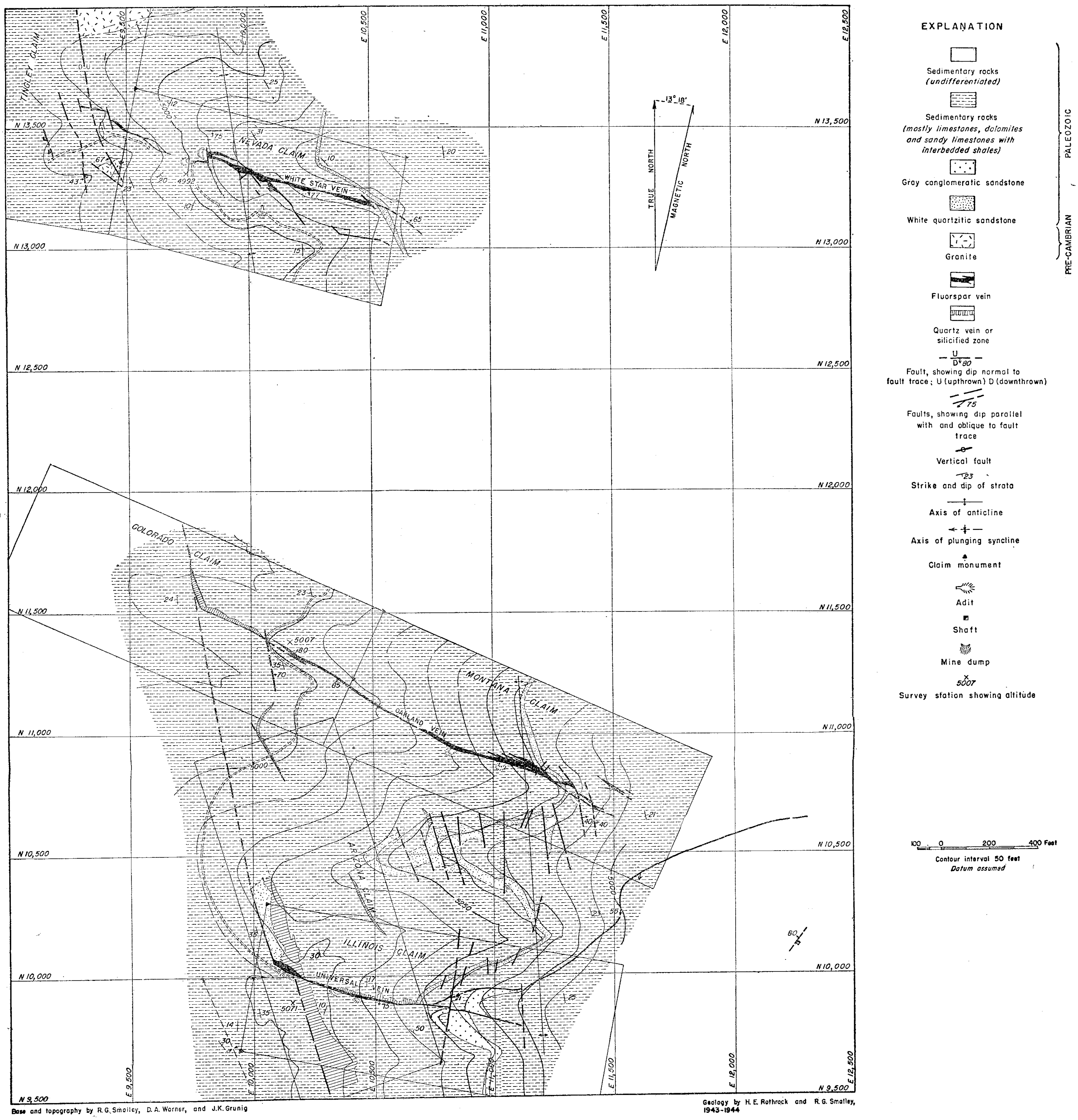
WHITE STAR MINE

The White Star vein, on the Nevada claim, is the north deposit of the Hanson properties in this, area. The workings made by the operators consist of two open cuts, one with exploratory drifts, and an adit and raise 270 feet east of the cuts. The Federal Bureau of Mines dug and sampled twenty trenches, and also sampled other places along the vein. [64]

Fluorspar occurs in a system of fractures that extends for 1,350 feet. Some of the fractures are faults of small displacements, but most of them, where mineralized, are closely spaced fissures or sheeted zones. The principal vein minerals are fluorite, calcite, and quartz ; the wall rock is extensively silicified. The vein minerals are cut by reticulated veinlets of minute quartz crystals, and both vein minerals and wall rock are cut by late calcite veins.

The west end of the White Star vein, which cuts siliceous dolomitic strata, does not contain fluorspar that was minable under the standards of 1944, because of high silica and lime content and the small size of the fluorspar bodies. Near the east end of the vein, however, which is in less siliceous strata, ore is exposed almost continuously for a distance of about 690 feet. The deposit was first mined in an open cut at the west end of this body. The cut followed the vein for 50 feet into the hillside, where the ore ended against a cross fault. An adit driven 50 feet farther along the strike of the vein failed to expose ore. A second cut, which follows a zone of sheeted 'fluorspar for 70 feet, was made 25 feet north of the first one and 30 feet above it. It was started in a solid vein 17.5 feet thick, containing 57.3 per-

[64] Rothrock, H. E., Preliminary report on the White Star, Oakland, and Universal fluorspar veins near Hot Springs, Sierra County, New Mexico: U. S. Geological Survey Strategic Minerals Investigations, Preliminary Report 3-190, Pl. 2, 1945.



Geologic and topographic map of the White Star, Oakland, and Universal veins, near Hot Springs, Sierra County cent CaF_2.[65] A face 50 feet from the beginning of the cut shows that the middle third of the vein is low-grade, owing to incomplete replacement of bands of the vertically jointed limestone. A winze in the floor of the cut leaves the ore 1 foot below the collar. East of the cut on the surface, the vein has several thin low-grade branches trending southeast. These branches and one short section of vein near the raise are too lean to be mined, but elsewhere in the ore body the fluorspar that contains 35 percent or more of CaF_2 has an average width of 8.2 feet and a weighted-average CaF2 content of 42.9 percent. The vein is 4 feet wide at the bottom of the raise, which is level with and 270 feet east of the beginning of the first cut. The east end of the ore body on the surface is at the base of the white quartzitic sandstone that was used as a key bed in mapping the deposits (Plate 17). The possibility that the ore body might extend farther eastward, following the replaceable dolomite down the east side of the anticline, could, be explored readily by core drilling.

The vein material is composed of white crystalline inter-growths of fluorite, quartz, and calcite, with inclusions of partly replaced limestone and dolomite. The proportions of these constituents vary greatly, depending on the completeness of replacement and the degree of silicification. The components are so intimately associated that it is difficult to obtain samples that do not contain substantial amounts of calcite and quartz. The calcite is often in large white rhombohedral crystals. The silica occurs as finely crystalline quartz in veinlets, and as jasperoid in irregular masses. Barite and galena are negligible in most of the vein. A composite of the samples containing not less than 40 percent CaF_2 was assayed by the Federal Bureau of Mines with the following results : CaF_2, 55.06 percent ; SiO_2, 22.04 percent ; $CaCO_3$, 20.35 percent ; $BaSO_4$, 0.20 percent ; and Pb, 0.09 percent.

OAKLAND MINE

The Oakland vein, on the Montana claim, is 2,200 feet south of the White Star vein. The decrepitation plant is located at its west end. The vein was mined in five small open cuts and two short adits, and was extensively trenched and sampled by the Federal Bureau of Mines.66 As shown on Plate 17, the vein consists of a zone of parallel mineralized fractures from 5 to 25 feet wide in the west half and from 10 to 50 feet wide in the east half. The displacement of the rocks could be measured in the eastern part of the vein only, where a throw of about 10 feet was observed in the white quartzitic sandstone. The faulting dies out in the shales and limestones about 200 feet east of the sandstone.

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[65] Sampling and assaying by the Federal Bureau of Mines.

[66] Rothrock, H. E., op. cit., Pl. 3.

The west end of the vein is narrow and siliceous except for small pockets of fluorspar. Eastward the fluorite increases irregularly until it forms an almost continuous ore body near the east end of the vein. Here the fluorspar bodies that are at least 3 feet wide and contain 35 percent or more of CaF_2 aggregate 350 feet in length; they have a weighted-average width of 11.5 feet and a weighted-average CaF_2 content of 50.3 percent. The vein material is widest near the east end of the ore body, where the vein crosses the axis of the anticline and where the shales, now eroded, were only a few feet stratigraphically above. The ore is similar to that in the White Star vein but contains more barite. Parts of the vein contain a high percentage of calcite. Several tons of galena were taken from an adit at the east end of the vein.[67] A composite sample prepared and assayed by the Federal Bureau of Mines from samples that contained at least 40 percent CaF_2 showed the following chief constituents : CaF_2, 53.89 percent ; SiO_2, 21.12 percent ; $CaCO_3$, 18.38 percent ; and $BaSO_4$, 6.50 percent.

The widest part of the exposed ore shoots is near the east end of the vein, about 150 feet west of the contact of the shale and white sandstone. This localization of ore suggests that the fluorspar body may extend farther eastward, following fractures that cut the dolomite and sandstone but do not penetrate the overlying shale.

UNIVERSAL MINE

The Universal mine, on the Illinois claim, is 1,200 feet south of the Oakland mine (Plate 17). The vein has been more extensively mined than either the White Star or Oakland veins. Most of the ore has been taken from two open cuts, but some was recovered during development that consisted of a drift 75 feet long on the level of the largest cut, a shaft 100 feet deep from the same level, and a drift 340 feet long at a level 80 feet below the collar of the shaft. Exploratory work by the Federal Bureau of Mines and the Humphreys Gold Corporation included trenching and sampling along the vein at intervals of about 50 feet and the drilling of five diamond-drill holes by the Bureau of Mines.

The vein occupies a fissure or zone of fissures about 600 feet long, bounded on the west by the major fault that strikes N. 10° W. The fluorspar cannot be traced much farther east than the outcrop of white quartzitic sandstone that is also near the ends of the White Star and Oakland veins. The south side of the vein is the footwall of a fault that contains gouge and fault breccia several feet thick and extends for a considerable distance east of the fluorspar deposit. This breccia is not mineralized and appears to have been a result of post-mineral movement.

[67] Oral communication from Blanchard Hanson.

The vein is composed of ore throughout most of its surface exposure and underground workings. In cross section it consists of three parts : a hanging-wall layer of quartz several inches wide, a middle vein of fluorite, calcite, and quartz averaging 9 feet in width, and a footwall zone of silicified limestone (jasperoid) ranging in width from a few inches to 30 feet. The boundary between the fluorspar and the quartz is generally sharp, but that between the fluorspar and the jasperoid is gradational. The difference in altitude between the highest and the lowest exposures of ore is 180 feet. This figure appears to represent the depth of the ore body, as cores from diamond-drill holes penetrating 160 to 200 feet below the outcrop of the vein disclosed only silicified breccia where extensions of the vein were expected. The recovery of core in these places ranged from 64 to 91 percent.

The ore, is similar to that in the other veins but contains noteworthy masses of late drusy quartz, lining cavities (Plate 21, B). Its chief constituents are shown by the following assay record of a composite sample made by the Federal Bureau of Mines from grab samples taken from various trenches : CaF_2, 55.2 percent ; SiO_2, 30.10 percent ; $CaCO_3$, 12.60 percent ; and $BaSO_4$, 1.10 percent.

Comparison of the structure and stratigraphy of the Universal vein with that of the other two veins suggests that it may contain ore east of its exposures even though it does not extend to a great depth. In the White Star and Oakland veins the widest part of the fluorspar deposits is near the places where the veins cross the axis of the anticline. This condition is probably due chiefly to the large number of closely spaced fractures at these places. A contributing factor, however, may have been impounding of the mineralizing fluids by the arched impervious shales that overlie the fractured beds. A similar condition may exist at the Universal vein. The anticline crosses the trend of the vein about 500 feet eastward from the east end of the highest cut. Unfortunately this locality has been faulted since the fluorspar was deposited; the effect of the faults on the vein can not be predicted from the known data.

TINGLEY PROSPECT

The Tingley claim adjoins the west end of the Nevada claim (Plate 17). The principal structures are closely spaced faults that strike about N.10° W. and are probably related to the major fault at the west ends of the Oakland and Universal veins. Pre-Cambrian granite is exposed on their upthrown sides, and Bliss sandstone and younger Paleozoic rocks form the remainder of the outcrops. Fractures representing the west end of the White Star vein terminate against some of these faults and cross others. The faults are exposed for 180 feet and contain irregular bodies of siliceous fluorspar that were sampled in four places by the Federal Bureau of Mines with the following results.

TABLE 33. ASSAYS OF SAMPLES FROM THE TINGLEY PROSPECT

Location of sample	Width of sample (feet)	Percent CaF_2
Trench 19, near west end of Nevada claim	6.2	34.9
Pit 55 feet west of trench 19	4.0	34.9
Trench 20, 110 feet west of pit	1.3	24.7
	3.5	8.4
Pit 45 feet west of trench 20	2.3	43.1

Fluorspar occurs sparingly in the northward-trending faults. The best exposure is in the discovery pit at the intersection of coordinates N. 13,460 and E. 9,169, Plate 17. This pit is on two parallel faults 5 feet apart. A calcareous fluorspar vein, ranging from 5 to 20 inches in thickness, fills each fracture.

About 220 feet southeast of the discovery pit a shaft was sunk along a narrow irregular vein that dips 75°, N. 15° E. and contains veinlets of purple fluorspar and calcite and patches of copper carbonates in Bliss sandstone. The shaft is 47 feet deep. From its bottom a crosscut trending N. 15° E. was made, exposing the vein 15 feet from the shaft. At this level the vein contains siliceous fluorspar about 3 inches thick. The footwall is Bliss sandstone. The hanging wall and the rest of the crosscut, which has a total length of 71 feet, is in granite.

UNNAMED PROSPECT NORTH OF THE WHITE STAR VEIN

About a quarter of a mile north of the west end of the White Star vein is a fluorspar deposit described by Jahns [68] as follows.

> A complex group of 6-inch to 7-foot fluorspar veins occurs in coarse-grained pink pre-Cambrian granite on a ridge and south-facing slope. . . . The largest veins appear to trend east-southeast, south-southeast, and south, but are so poorly exposed that little could be determined concerning their average width or individual continuity. The area apparently is one of complex fracturing and faulting. . . .

BLUE JACKET PROSPECT

The Blue Jacket prospect is on the crest of a ridge about three-quarters of a mile west-southwest of the White Star mine (Figure 12). It was owned in 1944 by Maude S. Hanson and Blanchard Hanson of Hot Springs. The main working is an open cut about 90 feet long and 25 feet deep at the face. Thirty

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[68] Jahns, R. H., Fluorspar deposits near Hot Springs, New Mexico: U. S. Geol. Survey unpublished report, p. 9, 1942.

feet to the northwest a smaller cut exposes a subsidiary vein. Several trenches and shallow pits have been dug along the vein northwest of these workings.

The deposit occupies a fault that brings a narrow band of granite and basal Paleozoic rocks to the surface (Figure 13). Movement along the fault formed a brecciated zone as much as 15 feet wide in places. Fluorite, quartz, and barite were deposited in this zone for a distance of several hundred feet. The ore is an aggregate of medium-grained subhedral purple or white

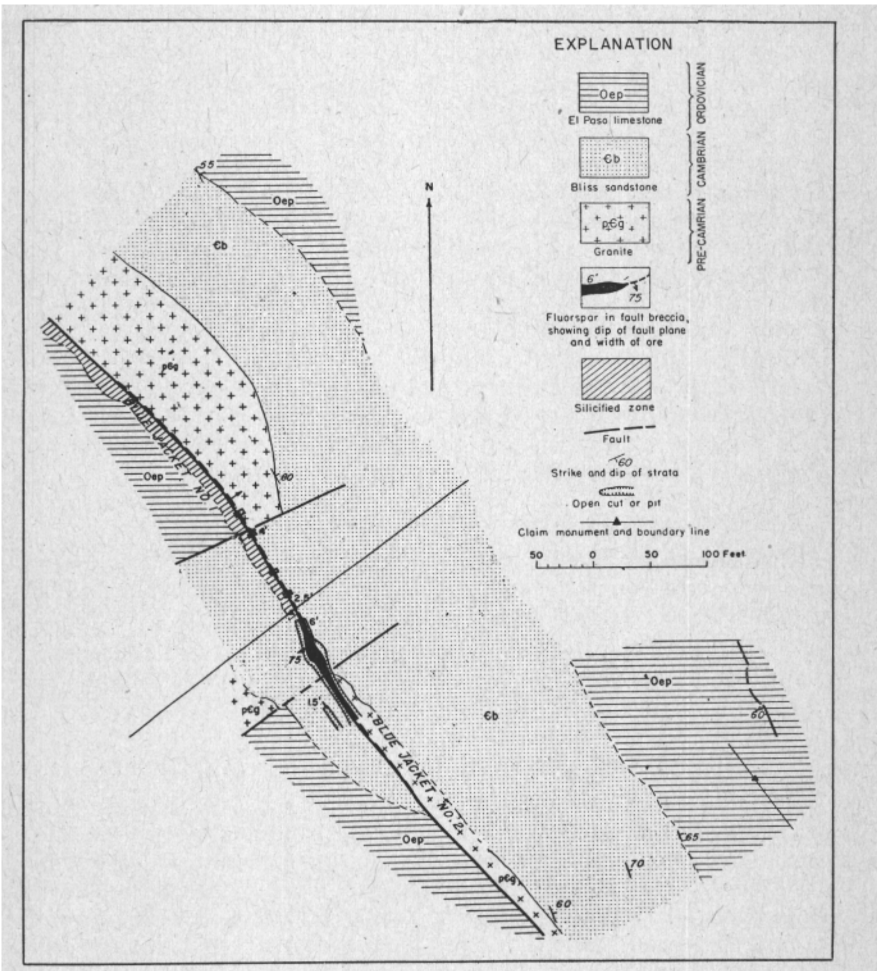

FIGURE 13.—Geologic sketch map of the Blue Jacket prospect, Sierra County.

fluorite, quartz, barite, and rock fragments. The fluorite forms banded incrustations and radiating crystals surrounding pieces of rock or other nuclei. A cluster of barite crystals about 1 inch in diameter forms the nucleus of one nodule of fluorite. Barite is sporadically distributed and probably does not exceed 5 percent of the vein material. In the sedimentary rocks the walls of the vein are irregularly silicified and the ore is more siliceous than in the granite. The quartz in veins in the sedimentary rocks is microcrystalline ; that in the interstices of the granite breccia is drusy. Subhedral crystal forms, banding and incrustation of the vein material, and lack of alteration of the fault breccia indicate that the fluorspar was deposited chiefly from relatively inactive solutions by crystallization in open spaces. Some of the constituent minerals were deposited in the order of quartz, barite, and fluorite, but this may not represent the entire sequence.

At the time of visit the vein was too poorly exposed to warrant an estimate of the over-all grade, but the face of the large cut appeared to contain from 25 to 50 percent CaF_2 near the top and a considerably lower percentage near the bottom. The fluorspar breaks away from the rock so cleanly that a shipping product containing 50 to 60 percent CaF_2 can be made by cobbing. In 1941 between 600 and 1,000 tons of merchantable ore was obtained by this method. [69]

Fissures wide enough to contain minable bodies of high-grade ore are not exposed, and the mineralized insterstitial spaces of the fault breccia constitute too small a proportion of the whole rock to yield a high-grade ore without beneficiation.

FORTY-ONE PROSPECT

The deposit known as the Forty-one prospect is approximately 1 mile southeast of the Blue Jacket prospect. Jahns [70] describes it as follows.

> Several sub-parallel fluorspar veins that trend north occur on the Forty-one claims. .. The veins are fissure fillings in granite, and are crossed by east-trending veins that contain low-grade manganese ore.

SIERRA CABALLOS, PALOMAS GAP GROUP

The fluorspar deposits in the vicinity of Palomas Gap lie on both the east and west sides of the Sierra Caballos, but they are accessible from the east side only. A truck trail about 17 miles long from Cutter, a station on the Atchison, Topeka, and Santa Fe Railway, to Palomas Gap furnishes an outlet for the properties ; an old mine road through Palomas Gap to the Marion mine passes the Imperial prospect.

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[69] Oral communication from Blanchard Hanson.

[70] Jahns, R. H., op. cit., p. 16.

The deposits on the east side of Sierra Caballos are in the first longitudinal valley east of the crest of the mountain. They have been explored in the Dewey, White Swan, Harding, Napoleon-Rosa Lee, and Cox prospects and mines (Figure 12). All the deposits except the Cox were first worked for lead. In 1919 vanadium was recognized in the ore, and subsequently several articles regarding the deposits appeared in technical publications.[71] Fluorite was mentioned in these articles as an important gangue mineral, and subsequently it was mined from the veins on the Harding and Cox properties.

The veins are chiefly in the limestones of the upper Magdalena group. A short distance to the east, the overlying red Abo sandstones and the gypsiferous shales of the Yeso formation are exposed in normal sequence. No igneous rocks are present in the vicinity of the veins, but Hess [72] reports intrusives of diorite and porphyry to the south.

The general dip of the sedimentary rocks is 10°-15° E., but the folding and faulting of the main mountain mass west of the deposits is reflected in subdued form in these rocks. South of Palomas Gap an almost vertical fault separates these gently dipping rocks from those that dip 70° E., near the crest. Two branches from this fault pass an eighth and a quarter of a mile, respectively, north of the Cox mine. Another major fault occurs north of Palomas Gap. It strikes north-northeast, dips west, and is downthrown on the east. Other north-trending faults, [73] some distance from the fluorspar veins, have been mapped in the district.

The veins are along minor fractures that strike northeast and for the most part are nearly vertical. Solution has taken place so extensively along most of the fractures that the ore is either porous or contains watercourses ; in a few places large caves are present. The vanadium- and molybdenum-bearing minerals were formed either contemporaneously with solution in the primary vein or subsequent to it.[74] Fluorite is one of the primary minerals. It is the chief mineral in the Cox vein, but elsewhere it has been considered a gangue mineral. It is sufficiently abundant in the Harding claims, however, to interest the operators, who shipped 30 tons of metallurgical-grade ore from one of the open cuts.[75]

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[71] Hess, F. L., Vanadium in the Sierra de los Caballos, New Mexico : U. S. Geol. Survey Bull. 530, pp. 157-160, 1913 ; Allen, C. A., Vanadium deposits in the Caballo Mountains : Mining and Science Press, vol. 103, pp. 376-378, 1911; Clifford, J. O., Vanadium in New Mexico ; Caballos Mountains deposits : Mining World, vol. 35, pp. 857-858, 1911 ; Larsh, P. A., Caballo Mountain vanadium mines : Eng. and Min. Jour., vol. 92, p. 118, 1911 ; Leatherbee, B., Sierra County, New Mexico, vanadium deposits : Mining World, vol. 33, p. 799, 1910 ; Johnson, E. D., The vanadium industry in New Mexico : Mining Science, vol. 63, p. 259, 1911.

[72] Hess, F. L., op. cit., p. 157.

[73] Harley, G. T., The geology and ore deposits of Sierra County, New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 10, pp. 199-200, 1934.

[74] Idem, p. 206.

[75] Oral communication from Blanchard Hanson.

Most of the veins near the surface are porous aggregates of finely crystalline calcite, fluorite, barite, and quartz. In the brecciated veins small fragments of limestone dilute the fluorspar appreciably, and large pieces of limestone form "horses" that divide the vein. The barite forms scattered crystals and clusters of crystals. Galena is present as single cubes or small aggregates of crystals, which are most plentiful near the walls of the veins. In the veins north of the Cox property the following minerals have also been reported : [76] vanadinite (lead vanadate) , descloizite (vanadate of lead, zinc, and copper), pyromorphite (lead chlorophosphate), anglesite (lead sulfate), cerussite (lead carbonate) , cuprodescloizite (vanadate of lead, zinc, and copper) , limonite (hydrous iron oxide) , pyrite (iron disulfide), and wulfenite (lead molybdate). The vanadinite commonly occurs in the form of brown, fragile, hair-like crystals, lining cavities or bristling from the oxidized surfaces of galena crystals.

The Dewey, White Swan, Harding, Napoleon-Rosa Lee, and Marion prospects were either not visited or not thoroughly investigated by the fluorspar party of the Geological Survey, but notes on the Harding and the Napoleon-Rosa Lee group are included among the descriptions that follow.

HARDING PROSPECT

The main workings of the Harding prospect are about 1 mile southeast of Palomas Gap, at the confluence of several washes (Figure 12), but the claims in the Harding group extend a considerable distance northeast and southwest of these workings. The original filings comprised the Gladys, Red Top, Red Top Annex, and Billiken claims, owned by Ralph Widener, and the Owl claim, owned by J. H. Hardin. They were relocated in 1928 by Blanchard Hanson, who owned them in 1944.

Surface evidences of development consist of two shafts, numerous trenches, and two short adits. The amount of underground development could not be determined because the shafts were inaccessible at the time of inspection.

The veins occupy a fracture zone at least 150 feet wide. They are nearly vertical and strike N. 40° E. A shaft at the northeast end of the workings has been sunk along two of these fractures, each of which contains a fluorspar vein averaging 20 inches in width. Johnston[77] reports that they were exposed in the shaft on the 50-foot level, where each had an average width of 24 inches. He sampled and assayed one of them with the following results : CaF_2, 92.85 percent ; $CaCO_3$, 3.46 percent ; SiO_2, 3.00 percent ; and Al_2O_3 + Fe_2O_3, 0.75 percent. About 220

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[76] Hess, Frank L., op. cit., p. 158 ; Harley, G. T., op. cit., pp. 203-207.

[77] Johnston, W. D., Jr., Fluorspar in New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 41, 1928.

feet southwest of this shaft, another shaft and a group of trenches expose four fluorite-calcite-galena veins. Two of these have been traced across the adjacent wash by trenching and have also been exposed in the next wash to the southwest. These workings indicate that the zone of mineralization has a total length of at least 1,000 feet. On the surface the veins are narrow and contain a large percentage of $CaCO_3$.

NAPOLEON-ROSA LEE GROUP

The Napoleon-Rosa Lee group of claims lies about half a mile south of the Harding group, on both sides of the ridge east of the road to the Cox mine (Figure 12). The claims were owned by the Southwestern Lead and Coal Company in 1906 to 1908, by the Vanadium Mines Company in 1910 and 1911, and by the Great American Company in 1931. The following notes are based on a detailed account by Harley.[78] The ore has formed in Magdalena limestone, the strata of which strike N. 50° W. and dip 15° NE. There are four well-defined veins which have yielded a small amount of galena-fluorite ore that was hand sorted and graded. The northern vein of the series, striking N. 75° E. and dipping vertically, varies from $1^1/_2$ to 3 feet in width in its productive part, with walls 4 to 6 feet apart. In these veins fluorite should be considered as an ore mineral. The gangue minerals are calcite, barite, quartz, limonite, and pyrite. The galena crystals are sparsely distributed throughout the gangue, and the average lead content of the vein is probably not more than 3 percent. The fluorite content is about 65 percent.

COX MINE

The Cox mine is almost 2 miles south of Palomas Gap, in the head of a small valley that is parallel with the mountain and drains northward into Palomas Gap (Figure 12). The deposit extends from the bottom of the valley up both its sides and over the adjoining ridges. It is about 18 miles from Cutter, the nearest railroad station.

The mine, owned by Fulton J. Cox, was operated under lease by R. M. Talbot in 1939 and by the Standard Minerals Corporation in 1942 and 1943. The workings, which consist of several adits and open cuts in the hillsides and of trenches on the ridges, expose the vein for a distance of about 1,000 feet.

On the southwest side of the valley the vein is exposed in an adit 70 feet long near the base of the hill, in two cuts aggregating about 100 feet in length some 250 feet above the valley floor, and in several trenches on the crest of the ridge. On the northeast side of the valley the vein was traced up the hill by several shal-

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[78]Harley, G. T., op. cit., pp. 204-207.

low cuts and adits. The main working was near the top of the hill, where an adit 40 feet long (Plate 20, B) had been excavated early in 1943. This operation was subsequently extended, and 281 tons of ore was mined from it.[79]

The deposit consists of veins in limestones of the Magdalena group that dip about 10° NE. The veins occupy slightly brecciated narrow fault zones that strike N. 50°-75° E. and dip about 75° SSE. On the southwest side of the valley and on the lower part of the opposite side, the exposed vein consists of stringers and lenses of fluorspar ranging in width from a few inches to 24 inches. At the main workings the ore occurs in footwall and hanging-wall veins, which in most places are separated by several feet of fractured rock. Forty feet from the beginning of the drift each of these veins is about 12 inches wide. The footwall vein contains many scattered crystals of galena close to its north margin.

Near the base of the northeast side of the valley and about 200 feet south of the principal vein, a fault breccia contains fluorite and calcite deposits as much as 2 feet wide in some places.

The vein material consists of white medium- to fine-grained compact anhedral fluorite with minute inclusions of quartz. It is associated with limestone and intergrown calcite, which are abundant constituents of the run-of-mine ore. Scattered galena crystals occur in many parts of the vein. The greater part of the ore is of milling grade, but some metallurgical-grade fluorspar was obtained by careful hand-sorting. A total of 705 tons of fluorspar was marketed during the period 1922-1944.[80]

IMPERIAL PROSPECT

The Imperial prospect, owned by Blanchard Hanson, lies on the south side of Palomas Gap about a quarter of a mile west of the crest of the Sierra Caballos. An old mine road through Palomas Gap passes above the property and could readily be made serviceable for transporting ore to the road to Cutter. At the time of the first inspection in 1942 the workings consisted of three small cuts and several pits ; additional work was done late in 1944, and a small amount of ore was marketed.

Paleozoic limestones that crop out in the vicinity are in fault contact with pre-Cambrian granite near the west end of Imperial No. 3 claim. The local structure is complex, owing to the proximity of several faults.

The fluorspar occurs in fissures that strike N. 50°-60° E. but are not in alinement because of small offsets along transverse faults. The fissures can be traced for several hundred feet. The

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[79] Personal communication from Fulton J. Cox.
[80] Personal communication from Fulton I. Cox.

easternmost workings consist of three small cuts in a hillside. The highest cut exposes a vein 7 feet wide, which was estimated to contain about 60 percent fluorite, 30 percent calcite, and 10 percent brecciated limestone. About 15 feet to the northwest, at right angles to the strike of the vein and 10 feet lower, a second cut contains 4 feet of fluorspar. In a third cut, 20 feet farther northwest, the vein is 3 feet wide. Although no brecciated zones could be found between the ends of these cuts, vertical joints striking N. 15° W. are present and may be related to a fault along which the segments of the vein were displaced. About 150 feet southwest of the lowest cut and across the gulch, there is a patch of fluorspar 8 feet in diameter that is not controlled by any apparent structure. It was probably formed by preferential replacement of an especially permeable and alterable part of the limestone. Another opening farther northwest, and thus farther out of structural alinement with the others, exposes 2 feet of ore in a vertical vein striking N. 50° E. A short distance to the west, in the bottom of a gulch, one of the northward-trending faults brings pre-Cambrian granite against the limestones containing the fluorspar. About 500 feet west of the last cut, a west-trending zone of fault breccia in the granite contains fluorspar in stringers and pods that range in width from 3 to 12 inches.

SIERRA CABALLOS, SOUTHERN GROUP

Fluorspar has been reported on the east and west sides of the southern end of the Sierra Caballos. Those on the east side and the least accessible ones on the west side were not visited; only the Lyda K, Alamo, Nakaye, and Velarde deposits (Figure 14) are described in this report. The Nakaye mine it situated in the pre-Cambrian complex and the other deposits are in Paleozoic limestones, generally near the top of the Magdalena group. The rocks south of Apache Canyon are offset westward about 2 miles by faults in the canyon. Farther south the mountain structure is anticlinal, as evidenced by small outcrops of west-dipping Permian rocks in Greens and Woolf er canyons. Parts of the stratigraphic section are repeated by strike faults.

LYDA K MINE

The Lyda K mine, owned by Kinetic Chemicals, Inc., a subsidiary of E. I. DuPont de Nemours and Company, is about a mile southeast of Caballos dam in the foothills of Sierra Caballos (Figure 14). The west end of the workings is about 465 feet above the Rio Grande. A graded road 4 miles long connects the mine by way of the dam with U. S. Highway 85 at a point 22 miles north of Hatch, a station on the Atchison, Topeka,

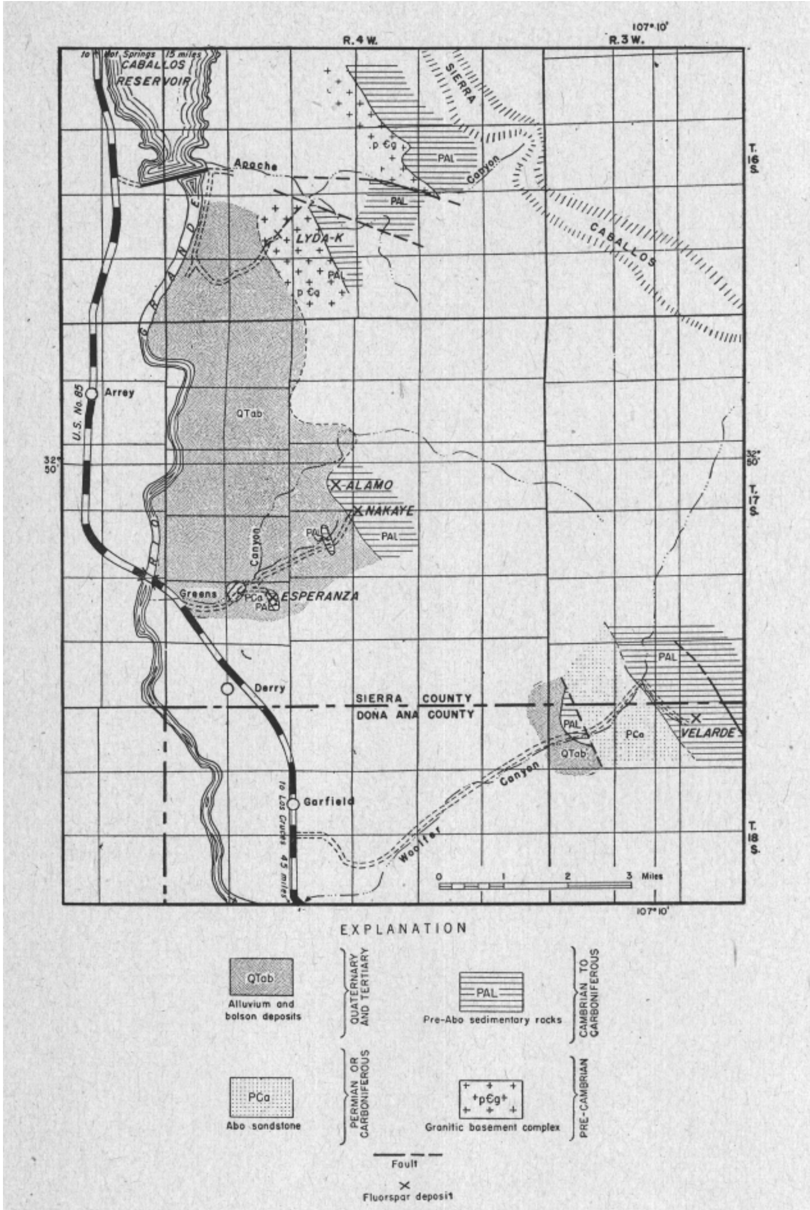

FIGURE 14.—Index and geologic sketch map of fluorspar deposits in the southern Sierra Caballos, Sierra and Dona Ana counties.

and Santa Fe Railway. The workings are described in Part 2 of this bulletin and are shown on Plate 27.

The vein is in pre-Cambrian pink granite and granite gneiss that have inclusions of schist and are cut by many pegmatite dikes containing large crystals of orthoclase. Quartz veins cut both granite and pegmatite. A much altered basic dike parallels the vein in some places. The Bliss sandstone (Cambrian), overlying the granite complex in the escarpment east of the mine, consists of reddish-brown quartzites and indurated sandy shales and is estimated to be at least 100 feet thick. Thick-bedded cherty Paleozoic limestones that appear to lie conformably on the Bliss sandstone form the upper part of the escarpment. The southwest end of the vein disappears beneath bolson gravels.

The vein (Plate 22, A) occupies a fault that strikes N. 48° E. and can be traced from bolson gravels southwest of the mine into Paleozoic limestone about a mile northeast of it. The fault dips irregularly 70°-85° NW., and striations on its walls pitch 30°-45° southwest. The throw along the fault in the escarpment is at least 100 feet. Fault breccia, ranging in width from 1 foot near the northeast end of the deposit to 20 feet on the 120-foot level of shaft No. 3, was formed by this and subsequent movements. The breccia zone and fissures were invaded by fluorine-bearing solutions that deposited a vein of dense anhedral siliceous fluorspar approximately 2,160 feet long. Recurrent movement brecciated the fluorspar and formed fissures in or beside it, providing crevices in which a later generation of purple medium-grained fluorite was deposited. In some places this fluorite forms bands that alternate with paper-thin layers of quartz. Stringers of fine-grained quartz and jasper traverse the fluorspar (Plate 22, B). Subsequently parts of the vein were shattered, and the crevices then formed are either still open or are filled with clay washed in from the thick gouge on the footwall. The vein varies in thickness but averages about 5 feet. It contains fluorspar for its entire length, except for a section about 300 feet long between shafts Nos. 1 and 2, where the rock is almost completely replaced by quartz. Core drilling showed that the vein contains fluorspar at a depth of 280 feet below the surface.[81]

Most of the fluorspar is too siliceous to be marketed without beneficiation, but about 12 percent of the ore mined from the northeast end of the vein was of metallurgical grade. Galena is scattered through parts of the vein. Assays of samples taken from various parts of the mine by the Federal Geological Survey and Kinetic Chemicals, Inc., show the following ranges in the percentages of the chief constituents : CaF_2, 46.2 to 82.7 percent ; SiO_2, 15.8 to 37.2 percent ; $CaCO_3$, 0.3 to 2.1 percent.

[81] Communication from Joseph L. Gillson, Development Department, E. I. Du Pont de Nemours and Co.

ALAMO PROSPECT

The Alamo prospect is $3^1/_2$ airline miles northeast of Derry (Figure 14). It is reached by a truck trail that follows the bed of Greens Canyon for about 2 miles and then mounts the south bank of the canyon and traverses the ridges of a large dissected alluvial fan for $1^1/_2$ miles to the cliffs and knobs of bedrock that form the foothills of the Sierra Caballos. The Alamo claims are a short distance to the north; the Nakaye mine is in the cliffs to the southeast.

A claim was filed on the Alamo deposit on March 1, 1930, by C. B. Hanson, B. D. Luchini, and G. J. Lara. The principal development was during the period 1930 to 1934, when about 3,000 tons of ore is reported to have been marketed. The workings consist of a pit about 20 feet deep, several trenches, and a shaft about 50 feet deep from which drifts extend for an undetermined distance along the vein.

All the workings are in limestones, dolomites, and shales of Paleozoic age. Johnston [82] identified the limestone at the collar of the shaft as belonging to the Magdalena group. The fluorspar veins occupy fractures that strike northeast and northwest. Other fractures trend north, approximately parallel to the longitudinal axis of the range ; none of those examined contains fluorspar, although calcite, siderite, and manganese oxide of the psilomelane type are present.

The shaft was inaccessible at the time of visit, but the vein, partly masked by travertine, could be seen in the walls. The vein consists of a zone of brecciated limestone about 5 feet wide that has been impregnated and partly replaced by fluorite. The footwall is smooth, strikes N. 65° W., and dips about 75° NE. The hanging wall is broken and irregular, and the boundary of the vein on that side is indefinite. Fragments of fluorspar on the dump are composed of white subhedral fluorite, calcite, and quartz, and are slightly porous.

The pit, which is about 1,500 feet northwest of the shaft, follows an almost vertical unbrecciated vein that strikes N. 65° E. and ranges in width from 6 to 18 inches. On the northwest wall of the vein a wide band of gouge contains barite and is stained by manganese oxide. A few tons of cobbed ore near the excavation were estimated to contain about 50 percent CaF_2.

VELARDE PROSPECT

The Velarde prospect is 6 miles east-northeast of Garfield (Figure 14). It is accessible by a truck trail up the bed of Woolf er Canyon. The deposit is included in a group of eleven unpatented claims—the Velarde Nos. 1 to 7, Tonel Nos. 1 and 2,

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[82] Johnston, W. D., Jr., op. cit., p. 50, Fig. 12.

Mountain, and Canyon claims—which were owned in 1944 by Juan Velarde of Garfield. They were prospected in 1928 by the New Mexico Fluorspar Corporation and are described under that title by Johnston.[83]

When the deposit was visited in December 1942 the only exploratory workings that had been completed consisted of two trenches across the vein, an adit about 15 feet long, and several small pits.

The claims are in limestone of the Magdalena group, part of a down-faulted block of Paleozoic rocks that has been tilted westward at an angle of about 45°. This block includes the Abo sandstone, erosional remnants of which form the hills beginning 800 feet west of the workings. About 350 feet stratigraphically below the contact of the Abo sandstone with the Magdalena group, a bed of silicified limestone forms a conspicuous band. It strikes N. 30° - 60° W. and dips 40° - 50° SW. In the bold escarpment about a mile east of the workings the rocks dip eastward at angles ranging from 10° to 20°. Between the deposit and the escarpment a fault or fault zone roughly parallels the axis of the mountain and forms a boundary of the downfaulted block.

The principal fluorspar deposits in the Velarde claims are veins and a few replacement bodies in the bed of silicified limestone. The veins are narrow, range widely in direction and length, and constitute only a small part of the silicified outcrop. Some occupy joint planes at right angles to the bedding. They are composed of subhedral white, purple, or green fluorite, and of calcite and crystalline quartz, all of which form interstitial fillings in brecciated parts of the silicified limestone and line geode-like cavities. In these occurrences the fluorspar is banded or forms incrustations on the surfaces of the rock. Only in small, widely separated localities is the pattern of fluorspar bodies sufficiently dense to interest the prospector.

IRON MOUNTAIN DISTRICT

The Iron Mountain district, in northwest Sierra County (Plate 1) , is known chiefly for its deposits of iron, which were worked as early as 1880, and for its beryllium and tungsten ores. The latter were first recognized in 1941[84] and were extensively explored in 1942 and 1943 by the Federal Geological Survey and Bureau of Mines. ' During the 1942-43 investigation fluorite was found as a constituent of contact-metamorphic "ribbon rock."[85] The following descriptions are taken from reports of these operations.

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[83] Idem, pp. 61-64.

[84] Strock, L. W., A new helvite locality, a possible beryllium deposit : Econ. Geology, vol. 36, no. 7, pp. 748-751, 1941.

[85] Jahns, It. H., Beryllium and tungsten deposits of the Iron Mountain district, Sierra and Socorro counties, New Mexico : U. S. Geol. Survey Bull. 945-C, p. 54, 1944.

Iron Mountain is a long, narrow, north-trending block composed of Paleozoic sedimentary rocks and Tertiary extrusive rocks ; it has been extensively faulted along its west side and tilted eastward. It was invaded and partly metamorphosed during Miocene (?) time by large masses along dikes of monzonite, porphyritic rhyolite, and fine-grained granite and aplite. In some areas the metamorphism involved merely simple recrystallization, but in the areas of more intense alteration calcic silicates, iron minerals, and such rare minerals as helvite were introduced, forming light-colored iron-poor granulite and dark-colored iron-rich tactite. Fluorite occurs in the tactite only. The tactite includes a massive variety and a variety called "ribbon rock." In the massive tactite, which consists mainly of coarsely crystalline magnetite and andradite garnet, fluorite is commonly a minor and inconspicuous constituent. This rock forms bodies that range in size from very small lenses to masses containing millions of tons. In the "ribbon rock", which has a finely laminated structure, fluorite is a more conspicuous constituent, forming thin layers or ellipsoidal pods. The rock forms thick lenses, pipe-like bodies, and thin tabular sheets, the length and breadth of which are measurable in tens of feet.

The investigation by the Federal Geological Survey and Federal Bureau of Mines did not systematically determine the fluorite content of the tactite, as exploration was chiefly directed to the occurrence of beryllium and tungsten. Examination under the microscope of five samples of massive tactite by Jahns [86] shows a fluorite content ranging from a trace to 52 percent, with an average of 12 percent. Similar determinations on "ribbon rock" tactite show a fluorite content ranging from 5 to 34 percent and averaging 16 percent.87

A composite sample (No. 2501) was taken by the Federal Bureau of Mines by collecting random specimens of tactite from outcrops of deposits near the north end and on the west slope of Iron Mountain. It was assayed at the Rolla Laboratory of the Bureau with the following results. [87]

The reserves of ore of which these assays and analyses are representative are not accurately known, but Jahns estimates that there are 1,500 tons of minable beryllium-bearing ore in the deposits of the west slope and between 80,000 and 150,000 tons of indicated and inferred ore in the deposits near the north end of the mountain[88].

Current knowledge and conditions do not justify exploitation of these deposits for their fluorite content, but the best of the

[86] Jahns, R. H., "Ribbon rock," an unusual beryllium-bearing tactite : Econ. Geology, vol. 39, no. 3, p. 178, 1944.

[87] Idem, p. 185.

[88] Idem, p. 68.

TABLE 34. ASSAY OF COMPOSITE SAMPLE OF FLUORITE-BEARING ROCK FROM IRON MOUNTAIN, NEW MEXICO

Constituent	Percent	Constituent	Percent
BeO	0.25	Mn	2.85
CaO	30.20	Fe	12.70
MgO	1.82	Zn	1.80
SiO_2	10.80	F	18.90 [a]
Al_2O_3	18.03	S	0.15

[a] This percentage, if all the fluorine is in the form of CaF_2, is equivalent to 38.83 percent CaF_2.

assays are sufficiently encouraging to warrant consideration of the area as a possible source of by-product fluorspar, whenever market conditions justify the mining and beneficiation of the ore for its other constituents.

DEPOSITS IN THE SIERRA CUCHILLO

Reports of fluorspar deposits in the Sierra Cuchillo Range in northwestern Sierra County have been received from time to time, but most of them were not investigated in the present program because the remoteness and inaccessibility of the area made it unlikely that the deposits would be of service to war industry.

VICTORIO PROSPECT

One of the more promising deposits is on the Victorio claim, about 2 miles east of the settlement of Chise, which is in Cuchillo Canyon 8 miles downstream (southeast) from Winston. The road from Winston is chiefly in the bed of Rio Cuchillo, and is very rough. It ends three-quarters of a mile from the deposit, which is south of the river on the north side of a tributary valley. The total distance from the prospect to U. S. Highway 85, at a point 9 miles north of Hot Springs, is about 42 miles. Development of the deposit in 1943 consisted of a shaft about 40 feet deep and two trenches having a total length of about 75 feet.

The deposit is a vein in limestones of the Magdalena (?) group which dip 15°, S. 80° E. The strike of the vein is N. 25° E., and the dip is almost vertical. The walls contain much jasper, formed by silicification of the limestone. The fluorspar body occurs in a brecciated part of the vein, and consists of anhedral and subhedral fluorite and finely crystalline quartz, filling the interstices of the breccia. At the top of the shaft, which was inaccessible at the time of the visit, the vein is 3 to 3$^1/_2$ feet wide. Less than 20 feet to the southwest, the brecciated zone grades into a zone of sheeted fractures, and the vein splits into several interlacing stringers. In the trenches northeast of the shaft, the vein contains a few rock inclusions and averages 18 inches in width for a distance of about 40 feet. A second trench, slightly offset from the first, exposes fluorspar for 45 feet, but only in widths ranging from 6 to 18 inches. A stock pile at the shaft contained several tons of fluorspar roughly estimated to contain 60 percent CaF_2.

SOCORRO COUNTY

GENERAL RELATIONS

Fluorspar occurs at three localities in Socorro County—in the north central, southeastern, and central parts. The first locality is in the Sierra Ladrones, the second in the San Andres and Oscura Mountains, and the third in the hills on the east side of the Rio Grande near Socorro (Plate 1) . These localities are served by U. S. Highway 85 and a branch of the Atchison, Topeka, and Santa Fe Railway, which traverse the Rio Grande Valley, and, in the Tularosa Valley farther east, by U. S. Highway 54 and the Southern Pacific Railroad. The fluorspar mills at Los Lunas, Deming, and El Paso may be reached by these routes.

Only the deposits near Socorro and in the Oscura Mountains were visited by the fluorspar party of the Geological Survey. Some of the others are described in the literature; references to these descriptions are given in Table 35.

Fluorspar occurs as fissure and breccia fillings in pre-Cambrian granite, Paleozoic sedimentary rocks, and Tertiary volcanic rocks, and as incrustations in cavernous parts of the limestone of the Magdalena group. In most of the deposits studied the fluorite is a gangue mineral of lead and copper ores. In some of these deposits fluorite is abundant, but it is generally associated with large proportions of other gangue minerals, chiefly quartz and barite. The same association occurs in deposits where metallic minerals are scarce. The difficulty of separating barite from fluorite and quartz has been a discouraging factor in the development of the deposits. Although fluorspar occurs in rocks of several ages, there is no evidence that fluorite mineralization occurred before the Tertiary period ; and the presence of fluorite in Tertiary lavas in the Joyita prospect [89] fixes the age as later than these flows and suggests a similar age for the other deposits.

FLUORSPAR DEPOSITS

The deposits in Socorro County that have been prospected are listed in Table 35.

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[89] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull 4, p. 126, 1928.

TABLE 35. FLUORSPAR PROSPECTS IN SOCORRO COUNTY

Name	Approximate location	Reference [a]
	Socorro area	
Gonzales prospect	E½ sec. 2, T. 3 S., R. 1 E.	
La Bonita prospect	Sec. 11 or 12, T. 3 S., R. 1 E.	
Martinez prospect	E½ sec. 12, T. 3 S., R. 1 E.	
Joyita prospect [b]	T. 1 N., R. 1 E.	27: 125-127
Dewey prospect [b]	Location unknown	27: 127-128 34: 61, 62
	Sierra Ladrones	
Juan Torres prospect [b]	Sec. 18, T. 2 N., R. 2 W.	27: 124, 125 34: 89
	Oscura Mountains	
Hansonburg mine	Sec. 1, T. 6 S., R. 5 E.	27: 123, 124 34: 63-71
	San Andres Mountains	
Mockingbird Gap prospect [b]	SE¼ sec. 32, T. 9 S., R. 5 E.	34: 80, 81
Lava Gap prospect [b]	SE¼ sec. 9, T. 10 S., R. 5 E.	27: 121-122
Salinas Peak prospect [b]	T. 12 S., R. 4 E.	
Cave Spar prospect [b]	Sec. 15, T. 14 S., R. 4 E.	

[a] Numerals in column 3 are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages on which the article appears.

[b] Not described in this report.

GONZALES PROSPECT

The Gonzales prospect is 5 miles by airline and 12 miles by road east of Socorro, in the foothills that border the alluvial terraces of the Rio Grande valley (Figure 15) . The property is reached by crossing the river on a bridge 4 miles north of Socorro and following a trail that leads to the south and east for 8 miles, chiefly over sand and gravel. The deposit is on the Gonzales Nos. 1 and 2 claims, leased from the State in August 1942 by P. Innebichler and others. In the spring of 1943 it was subleased by the Humphreys Gold Corporation, which sampled the deposits in cooperation with the Federal Bureau of Mines.

The deposit occupies a fault in the west flank of an anticline whose axis strikes N. 15°-20° W. The fault parallels the axis and dips about 70° W. Its upthrown (east) side exposes a narrow band of pink coarse-grained pre-Cambrian granite about 1,800 feet long and 200 feet across at its widest part. The surrounding rocks belong to the Magdalena group.[90] East of the fault the rocks above the granite consist of thin-bedded limestones, sand-

[90] Darton, N. H., Geologic map of New Mexico : U. S. Geol. Survey, 1928.

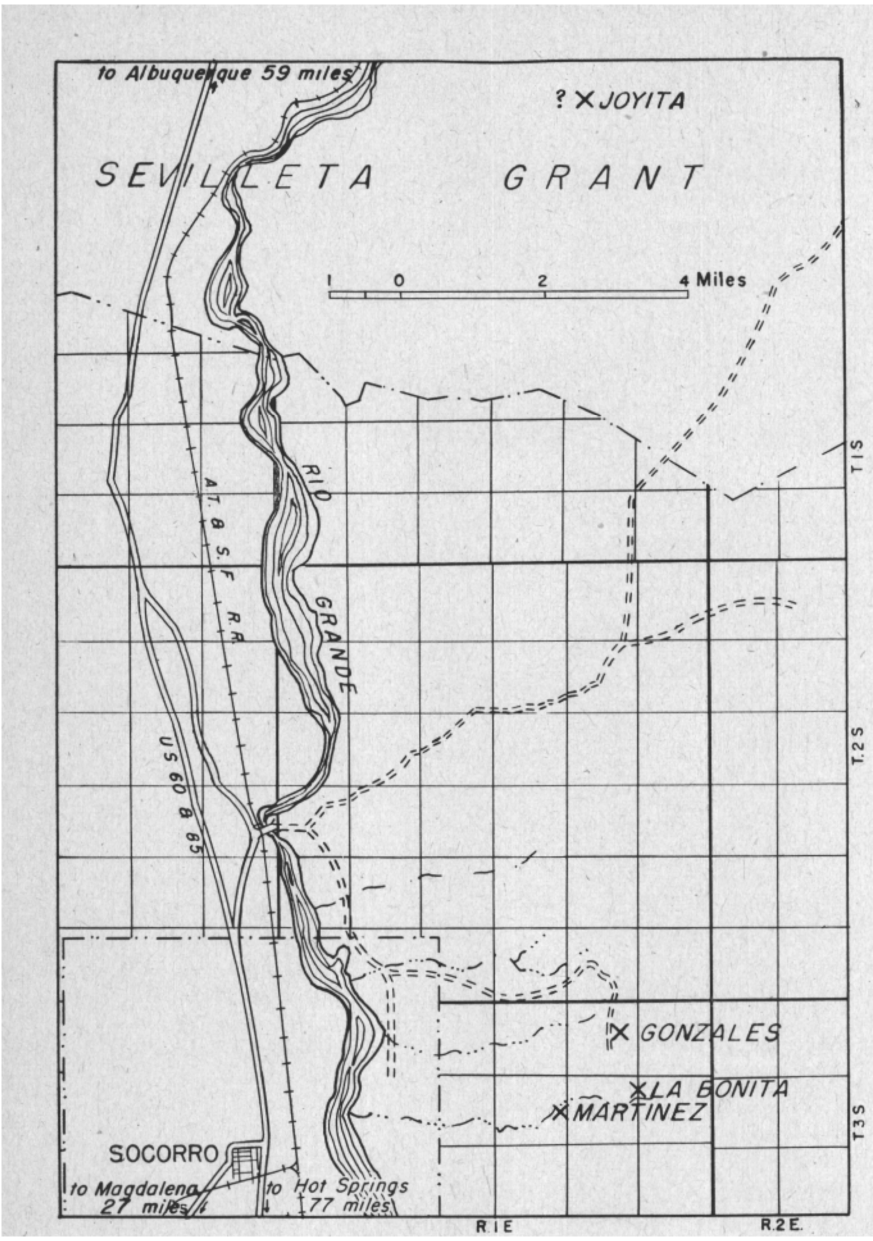


FIGURE 15.—Index map showing location of fluorspar prospects (X) near Socorro.

stones, and red, brown, or gray shales, and have an aggregate thickness of about 100 feet. Above them are several thick beds of coarse-grained gray sandstone with intercalated thin beds of limestone and shale. These beds, which have a total thickness of about 500 feet, belong to the Sandia formation of the Magdalena group. West of the fault the oldest beds consist chiefly of coarse-grained to conglomeratic sandstone and probably represent the upper part of the Sandia formation. Above them are cherty limestones of undetermined thickness that belong to the Madera limestone of the Magdalena group.

The fault is sinuous, and in the areas of greatest deviation from the general trend, the adjacent downthrown rocks are greatly shattered. Elsewhere the sedimentary rocks generally exhibit drag and are brecciated along a zone several feet wide adjoining the fault. Within the granite outcrop the fault is prominently marked by a ridge of silicified granite (Plate 23, A) that forms the footwall of the fluorspar vein. Near the ends of the granite outcrop the evidences of deposition of fluorite and silica almost disappear, and the extensions of the fault in the sedimentary rocks are chiefly indicated by discordances in the strike and dip of the strata. In some places in the sedimentary rocks this fault and subsidiary fractures are marked by calcite veins.

The Gonzales fluorspar deposit is exposed only along that part of the fault that borders the granite outcrop. Most of the fluorspar is in the adjoining brecciated sedimentary rocks, although commonly a narrower vein of siliceous fluorspar is frozen to the footwall, and stringers and patches of high-grade fluorspar extend into this wall. The vein varies greatly in thickness ; it contains two shoots, one 240 feet long and the other 280 feet long, in which the width of fluorspar ranges from 3 to 22 feet. Elsewhere the shoots are too narrow or too short to be of commercial interest.

The principal minerals in the vein are fluorite, barite, and quartz. The fluorite and barite occur as large intergrown crystals that cannot be readily separated by current milling methods. The quartz is microcrystalline and is most commonly near the footwall. These minerals occur in percentages that show the following ranges : CaF_2, 15.0 to 65.7 percent ; SiO_2, 9.2 to 50.2 percent ; and $BaSO_4$, 9.9 to 39.5 percent. [91] Galena and sphalerite occur sparingly as scattered crystals.

LA BONITA PROSPECT[92]

The La Bonita unpatented claims, formerly called the Tienaja claims, are 5 miles east of Socorro (Figure 15). They are

[91] Assays by the Federal Bureau of Mines.

[92] Based on field notes and an unpublished report by R. H. Earhart and R. G. Smalley, U. S. Geological Survey.

about three-quarters of a mile south of the Gonzales prospect, to which they are connected by a rough truck trail. The claims were filed by P. Innebichler and others. They were sampled in June 1943 by the lessee, the Humphreys Gold Corporation, as a part of the study of the deposit by the Federal Geological Survey.

. The rocks exposed in the vicinity are pre-Cambrian granite, and sandstones, limestones, and shales of the Magdalena group. The strata are arched into an anticline and are broken by two normal faults, which in the vicinity of the prospect are about 700 feet apart and have a general trend of N. 25° W. and a dip of 60°65° SW. Between these faults the structure is synclinal ; shale and sandstone occupy the bottom of the trough. The upthrown sides of the faults consist of granite, but the greater part of the downthrown sides consists of sedimentary rocks. There is considerable local deviation from the general trend, and both faults are cut by transverse faults that offset the veins from 5 to 25 feet.

For a distance of about 1,100 feet along each of the faults there are short, narrow lenses of fluorspar, only three of which are sufficiently continuous to be of interest. Surface dimensions and assays of two of these lenses are shown in Table 36.[93]

TABLE 36. ASSAYS OF SAMPLES FROM THE LA BONITA VEIN

Sample No.	Width of sample (feet)	Chief constituents (percent) CaF_2	SiO_2	$BaSO_4$
	Shoot A, northwest vein *Length 100 feet* *Approximate average width, 20 inches*			
34	1.6	23.6	19.3	48.9
37	2.0	32.2	29.9	11.9
	Shoot B, southeast vein *Length 150 feet* *Approximate average width, 30 inches*			
41	1.9	14.1	36.6	24.5
44	2.3	32.7	30.5	5.6

No assays were made of Shoot C, southeast vein, which has a length of 85 feet and an approximate average width of 24 inches.

Three types of vein material are recognized. One is corn-posed of medium- to coarse-grained green fluorite, anhedral quartz, and plates of white barite in dense veins frozen to the footwalls. The second type resembles the first except that the gangue minerals are generally absent and the veins are only 4 inches thick or less. The third type contains fine-grained purple

[93] Data furnished by the Humphreys Gold Corporation.

fluorite intercrystallized with barite and quartz. It fills crevices and voids in the fault gouge and breccia, and in the transverse faults ; it appears to represent a second period of fluorite deposition that took place after the gouge, breccia, and transverse faults had been formed. Silicification of the footwalls is much less intense than at the Gonzales prospect. The small size of the fluorspar bodies and the small amount of silicification as compared with the Gonzales prospect suggest that the La Bonita deposit is at or near the local extremity of this type of mineralization.

MARTINEZ PROSPECT

The Martinez prospect, about $1^1/_2$ miles southwest of the Gonzales prospect, was worked for a few weeks in 1943 by Ralph Truman and Henry Howerton, but no ore was marketed. The deposit is a fissure vein of east-northeast trend in sedimentary rocks of the Magdalena group similar to those at the Gonzales prospect. The contact of the sedimentary and granitic rocks is close to the west end of the vein. This deposit is the only one in this locality in which a fluorspar vein cuts rocks of the Magdalena group.

HANSONBURG MINE

Fluorspar occurs in the Hansonburg or McCarthy lead mine, on the steep west-facing escarpment at the north end of the Oscura Mountains. The property on which the mine is situated comprises the unpatented Halstead, Louise, Eva, Prairie Springs, Oscura, and Calcite claims, which in 1943 were owned by F. L. Blanchard of Roswell, New Mexico. The workings extend for several hundred feet along the escarpment; they include about 800 feet of drifts and crosscuts and numerous surface cuts. They were made in the search for lead, which was extracted by dry concentration in a mill erected in 1916.[94] A good truck trail about 6 miles long connects the mill site with U. S. Highway 380, between San Antonio and Carrizozo.

The mine is on one of the major faults that cut the west face of the mountain. The segments formed by the faults are successively lower toward the west, but the strata are generally tilted eastward.[95] In the vicinity of the mine the fault is entirely within limestones and shales of the Magdalena group. A vein was formed along this fault by the irregular deposition of quartz, fluorite, barite, calcite, and galena, followed by a second generation of quartz. The fluorite was deposited in the interstices of silicified fault breccia, near the margins of the vein, and in cavernous openings in the adjoining limestone. The remaining

[94] Johnston, W. D., Jr., op. cit., p. 123.9

[95] Lasky, S. G., The ore deposits of Socorro County, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 8, p. 65, 1932.

openings were partly filled with barite, calcite, quartz, and scattered crystals or crystal clusters of galena. The larger cavities are lined with a network of these minerals and contain many well-formed purple or green euhedral crystals of fluorite that range from half an inch to 2 inches in diameter ; however, the incrustation of fluorspar generally is only a few inches thick, and the cavities in which it occurs are widely scattered along the vein. High-grade ore could be obtained by the careful hand-sorting of ore from these scattered occurrences, but the run-of-mine product would unavoidably contain large percentages of barite, quartz, and calcite.

VALENCIA COUNTY

ZUNI MOUNTAINS

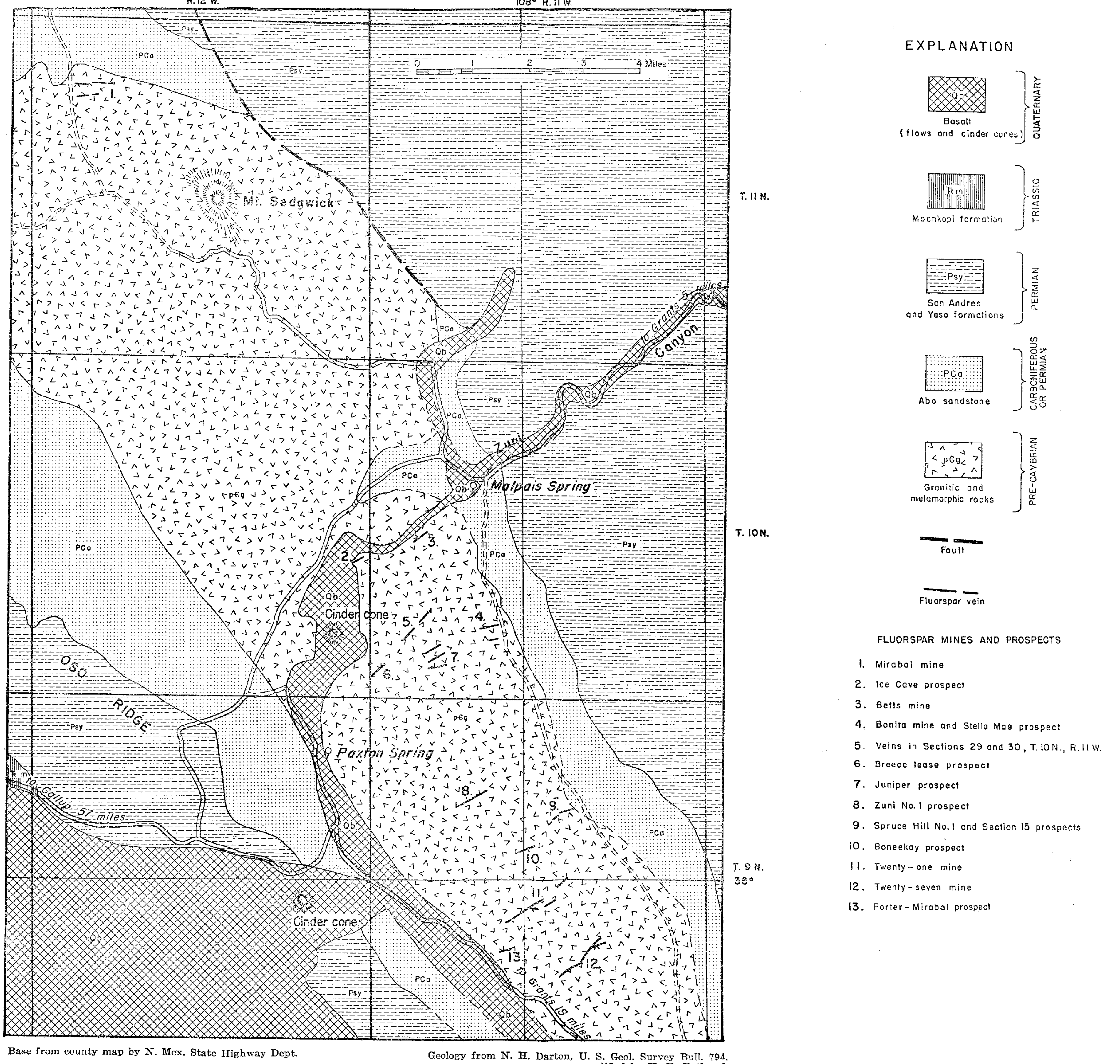
The known fluorspar deposits of Valencia County are in its northwestern part, within an area about 20 miles long and 3 miles wide in the southeastern Zuni Mountains. Their distribution is shown on Plate 18. The northern quarter of the area is rugged, and the snowfall is so heavy as to seriously impede transportation. The terrain in the remainder of the area is characterized by low rounded hills and is accessible throughout the year. The mountains are covered with pine and aspen, from which timber for mining operations can be obtained. There are no permanent streams except the short ones issuing from Paxton Spring, Malpais Spring, and the springs at Ojo Redondo and in Diener Canyon.

The most easily accessible point for shipment by rail is at Grants, a station on the Atchison, Topeka, and Santa Fe Railway. Access roads to the deposits connect with State Routes 53 and 174 from Grants. Mines in the southern part of the mineralized area are about 23 miles from Grants, and the most northerly mine, the Mirabal property, is 26 miles distant by way of Zuni Canyon. Almost all the fluorspar shipped from the mountains was milled during 1942-1944 in the jig mill at Grants, which has since been decommissioned, and in the Zuni Milling Company's flotation mill at Los Lunas, about 75 miles southeast of Grants (Plate 1) .

A detailed geologic study of the fluorspar deposits of the Zuni Mountains, begun in 1944 by E. N. Goddard of the Geological Survey, will be the basis for a future report that will contain descriptions more comprehensive than those which follow.

GEOLOGY

All the mines and prospects are in the pre-Cambrian complex of granitic and metamorphic rocks that forms the core of the Zuni Mountains, but stringers of fluorspar have been reported



Base from county map by N. Mex. State Highway Dept.

Geology from N. H. Darton, U. S. Geol. Survey Bull. 794, modified by H. E. Rothrock

Geologic map of the southeastern part of the Zuni Mountains, Valencia County, showing location of fluorspar deposits in the overlying Permian or Carboniferous sedimentary rocks. No Mesozoic or Tertiary rocks are involved, but Quaternary volcanic rocks undoubtedly cover some of the fluorspar veins.

The pre-Cambrian rocks are chiefly granite. Large areas are gneissic and contain many inclusions of schist. The granite is cut by scattered dikes, which Goddard has identified as quartz monzonite gneiss, gneissic aplite, diorite, hornblendite, and granite porphyry in the southeastern part of the mountains. [96] It is also cut by veins of milky quartz, fragments of which are included in the overlapping basal conglomerate of the Abo sandstone. The pre-Cambrian complex was eroded to a peneplane before the Paleozoic rocks were deposited.

The Abo sandstone, of Permian or Carboniferous age, is in unconformable contact with the pre-Cambrian rocks. It forms most of the high escarpment northeast of the fluorspar area. Its basal member is a gray feldspathic conglomerate, from 15 to 25 feet thick, composed of a matrix of coarse angular sand containing numerous fragments of white quartz as much as 2 inches in diameter, and smaller pieces of feldspar. Most of this material was evidently derived from nearby pre-Cambrian rocks. Above the conglomerate is dark-gray shale about 10 feet thick, and over the shale is light-gray fossiliferous microcrystalline limestone, which Darton [97] reported to be 40 feet thick and to contain fossils identified by G. H. Girty as of Permian age. The remainder of the formation consists of light- to dark-red sandstones and sandy shales. The lower sandstone strata are thick and cross-bedded; the upper beds are medium-bedded and slabby. A thickness of 600 to 700 feet is assigned to this formation by Darton.

Rocks of the Permian system above the Abo sandstone were mapped by Darton as a single unit, the Chupadera formation. The unit consists of a massive pink or buff sandstone overlying interbedded slabby sandstones and limestones and underlying more massive sandstones and limestones. Its thickness ranges from about 200 feet, north of Mount Sedgwick, to approximately 430 feet in Zuni Canyon. [98]

During the Quaternary period extensive lava flows flooded the lowlands south of the mountains. Tongues of lava also invaded the transverse valley between Paxton Spring and Malpais Spring and flowed down Zuni Canyon and a small canyon a quarter of a mile north. Two cinder cones were formed near the fluorspar area (Plate 18). The lava is black, brick-red, light or dark brown, dense or vesicular basalt. Its surface is scoriaceous

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[96] Goddard, E. N., The 21 and 27 fluorspar mines, Zuni Mountains, Valencia County, New Mexico: U. S. Geol. Survey open file report, p. 2, Jan. 1945.

Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, p. 140, 1928.

Idem, p. 141.

and ropy, and is broken into angular blocks formed by the movement of liquid lava beneath a congealed surface. In many places the basalt rises as steep slopes of jumbled lava blocks above the more recent alluvium that has accumulated beside it. In some places the flows cross the trends of nearby fluorspar veins and probably cover extensions of these deposits, but no fluorspar has been found in the basalt. The freshness of the basalt and its position in youthful valleys attest the geologic recency of its formation.

The southeastern part of the Zuni Mountains is a broad anticline that trends northwest and forms the larger part of the pear-shaped structure that constitutes the entire Zuni Mountains uplift. The sedimentary rocks that once covered the area as flat beds were tilted away from the axis of the structure by the uplift and were subsequently eroded from its higher parts.

FLUORSPAR DEPOSITS

There are many fluorspar veins in the granitic complex of the Zuni Mountains; only the most important of the known deposits are shown on Plate 18. These are fissure veins, most of which strike northeast and dip southeast at angles of 70°-90°. Movement occurred along most of the fissures before they were filled with purple or green coarse-grained high-grade fluorspar. Later movement shattered some of these veins and their wall rocks. The breccias thus formed were then enriched by a second generation of fluorine-bearing solutions that formed red micro-crystalline fluorspar, which irregularly replaced rock fragments, filled interstices, and formed nodules around nuclei. A little barite was deposited in crevices opened still later, and calcite, aragonite, and iron oxides were formed after the barite.

The fluorite is subhedral in partly filled cavities, anhedral in solid veins, and microcrystalline in replacement bodies. It is purple, green, red, or white, and exhibits a wide range in shades of these colors. The coarsely crystalline varieties are translucent or transparent, but the microcrystalline variety is translucent only in thin edges. The chief gangue mineral is quartz, which forms tiny, intimately associated crystals deposited contemporaneously with the fluorite, and coarse drusy coatings formed later. Barite, calcite, and aragonite occur in only minor proportions. The coarsely crystalline green or purple fluorspar is sufficiently pure to meet standard specifications for metallurgical fluorspar, with no beneficiation other than hand-sorting. The microcrystalline variety assays about 80 percent CaF_2. The relatively low grade of the run-of-mine ore from some of the mines is due to dilution by waste, gouge, and residual clay.

The presence of fluorspar veins in pre-Cambrian and Permian rocks and their absence in the basalt indicate that the time of 'fluorite deposition was post-Permian and pre-Quaternary. It was probably associated with some stage of Tertiary vulcanism.

TABLE 37. FLUORSPAR MINES AND PROSPECTS IN THE ZUNI MOUNTAINS

Name	Approximate location	Reference [a]
Mirabal mine	E 1/2 sec. 7 and W1/2 sec. 8, T. 11 N., R. 12 W.	27: 116-117
Ice Caves prospect	E 1/2 sec. 24, T. 10 N., R. 12 W.	
Betts mine	NE 1/4 sec. 19, T. 10 N., R. 11 W.	
Bonita mine	W1/2 sec. 28, T. 10 N., R. 11 W.	
Stella Mae prospect	SW 1/4 sec. 28, T. 10 N., R. 11 W.	
Names not known	E 1/2 sec. 29 and W1/2 sec. 30, T. 10 N., R. 11 W.	
Breece lease prospect	W1/2 sec. 31, T. 10 N., R. 11 W.	
Juniper prospects	NW1/4 sec. 32, T. 10 N., R. 11 W.	
Zuni No. 1prospect[b]	SE 1/4 sec. 8, T. 9 N., R. 11 W.	
Spruce Hill No. 1 prospect	S1/2 sec. 10, T. 9 N., R. 11 W.	
Section15 prospect	N1/2 sec. 15, T. 9 N., R. 11 W.	
Bonnekay prospect	E 1/2 sec. 16, T. 9 N., R. 11 W.	
Twenty-one mine	Secs. 21 and 22, T. 9 N., R. 11 W.	
Twenty-seven mine	Sec. 27 and W1/2 sec. 26, T. 9 N., R. 11 W.	
Porter-Mirabal prospect	Near center sec. 28, T. 9 N., R. 11 W.	

[a] Numerals in italics are references to descriptions in other publications. The first number is the index number of the publication in the bibliography at the end of Part 1 of this bulletin ; the second number or series of numbers refers to the page or pages of the publication on which the article appears.

[b] Not described in this report.

MIRABAL MINE

The Mirabal mine is the northernmost fluorspar property in the Zuni Mountains (Plate 18). It is 3 miles northwest of Mount Sedgwick on the east side of Diener Canyon, at an altitude of about 8,000 feet. In November 1944 the best road to it from Grants, 26 miles distant, was by way of Zuni Canyon. The last few miles of this road are impassable when very wet.

The property comprises 15 unpatented claims called Fluorite Nos. 1 to 4, Mirabal Nos. 1 to 8, Hillside Nos. 1 and 2, and Zuni Chief. Johnston [99] describes it as the Columbia-Columbine prospect. Moises Mirabal has owned and intermittently worked the group since 1918. About 1930 Urcic and Chase of Gallup leased and operated it. Early in 1944 the Grants Fluorspar Company

[99] Johnston, W. D., Jr., op. cit., pp. 116-117, 1928.

acquired the property and began work on the northern of two principal vein systems. The extent of mining in the main area of development as of November 1944 is shown on Plate 19.

The veins cut a pre-Cambrian gneissic aplite[100] with schist inclusions. Two principal vein systems 1,350 feet apart, and scattered exposures farther northwest, occupy east-striking faults, shear zones, and subsidiary fractures. Horizontal and vertical striations, and others pitching 15°-35° westward, record recurrent movements within the disturbed zone. The fluorspar veins range within very short spaces from mere stringers to masses as much as 10 feet wide. The ore bodies within these veins are from 100 to 250 feet long. In grade they range from siliceous noncommercial material to almost pure fluorite, and contain the following types of fluorspar : (1) purple slightly siliceous veins that represent the first or at least an early stage of 'fluorite mineralization; (2) brecciated; masses of fragmented purple fluorspar and rock that are encrusted and cemented by red or reddish-brown microcrystalline fluorspar ; and (3) reddish-brown siliceous masses that appear to have been formed by replacement of the wall rock. The accompanying table of assays indicates the tenor of the ore.

The more northerly of the two main vein systems is exposed chiefly on the Fluorite No. 1 claim, which has yielded most of the ore and is the site of operations of the Grants Fluorspar Company. The westernmost exposure of this vein, in a shallow adit close to stream level on the east side of the canyon, shows fluorspar at the intersection of three faults. About 100 feet east and 20 feet above this shallow adit is an adit that in November 1944 was 269 feet long. A vein of fluorspar 2 feet wide at the portal continues on the surface 40 feet up the slope, but underground it branches into stringers within a few feet of the portal. The adit entered an ore body 100 feet from the portal and in May 1944 had penetrated this body for 70 feet. The ore body is siliceous and brecciated, and is from 3 to 71/4 feet wide. Its tenor is indicated by assay No. 1 in Table 38. This ore shoot is interpreted as being in a breccia at the intersection of two faults exposed on the surface above it. East of the ore shoot the adit was reported to be in silicified rock and low-grade ore. The adit was extended in 1945, and the operators report that it was in good ore below . the stopes of the main workings.

Near the top of the hill, about 450 feet east of the portal of this adit and 140 feet above it, a shaft 65 feet deep gave access to a stope that extended 100 feet westward in November 1944. This ore shoot is in a sheeted and brecciated zone, the strike of which varies from that of the rest of the vein by as much as 20°, a

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[100] Determination by E. N. Goddard, U. S. Geological Survey.

TABLE 38. ASSAYS OF ORE FROM THE MIRABAL DEPOSITS

Assay No.	Description of samples	Chief constituents (percent)				
		CaF_2	SiO_2	$BaSO_4$	Al_2O_3	$CaCO_3$
	Fluorite No. 1 claim					
1.	Mill assays of 40 tons from stopes on adit level, 110 to 150 feet from portal of adit	52-58	---	---	---	---
2.	Selected sample of red microcrystalline ore from above locality	50.7	17.6	---	---	---
3.	Channel sample in main shaft at 35-foot level; width of ore 8 feet	68.5	6.7	---	---	---
4.	Grab sample from material rejected during hand-sorting of ore from stopes above 35-foot level in main workings	44.8	25.8	---	---	---
5.	Sample of selected broken ore from main workings	88.1	4.3	3.4	---	2.3
6.	Average of mill assays of 3,435 tons of ore from stopes between 40- and 60-foot levels in main workings	57.4	---	---	---	---
7.	Chip sample from outcrop 190 feet east of adit portal; width of ore 24 inches	63.1	20.0	---	---	---
8.	Chip sample from outcrop 235 feet east of adit portal; width of ore 24 inches	54.7	8.7	---	---	---
9.	Chip sample 350 feet east of shaft in trench; width of ore 48 inches	86.0	5.8	none	---	---
10.	Chip sample 410 feet east of shaft in trench; width of ore 55 inches	77.3	11.4	0.3	---	---
	South vein, Hillside No. 2 claim					
11.	Open cut about 800 feet east of west end of claim; width of ore 36 inches	81.5	9.3	---	---	---
12.	Open cut east of locality No. 10; width of ore 36 inches	79.9	10.0	---	---	---
13.	Face of tunnel 26 feet long at east end of the vein; width of ore 36 inches	68.3	15.0	---	---	---
14.	Composite of 5 samples with assay Nos. 3, 4, 11, 12, and 13 above	72.6	12.9	1.8	4.4	0.7
	Workings on the Mirabal No. 3 claim					
15.	Chip sample from a cut near east end of vein; red microcrystalline ore	86.5	8.2	---	---	---
16.	Grab sample from stock pile at locality of assay No. 13	75.3	17.0	---	---	---

1—Oral communication from James H. Mallery.

2, 7-10, 15, 16—Samples and assays by U. S. Geological Survey.

3, 4, 11-14—Assays by H. F. Mills ; data supplied by M. Mirabal.

5—Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 4, p. 117, 1928.

6—Records of Grants Fluorspar Co., furnished by William Heim.

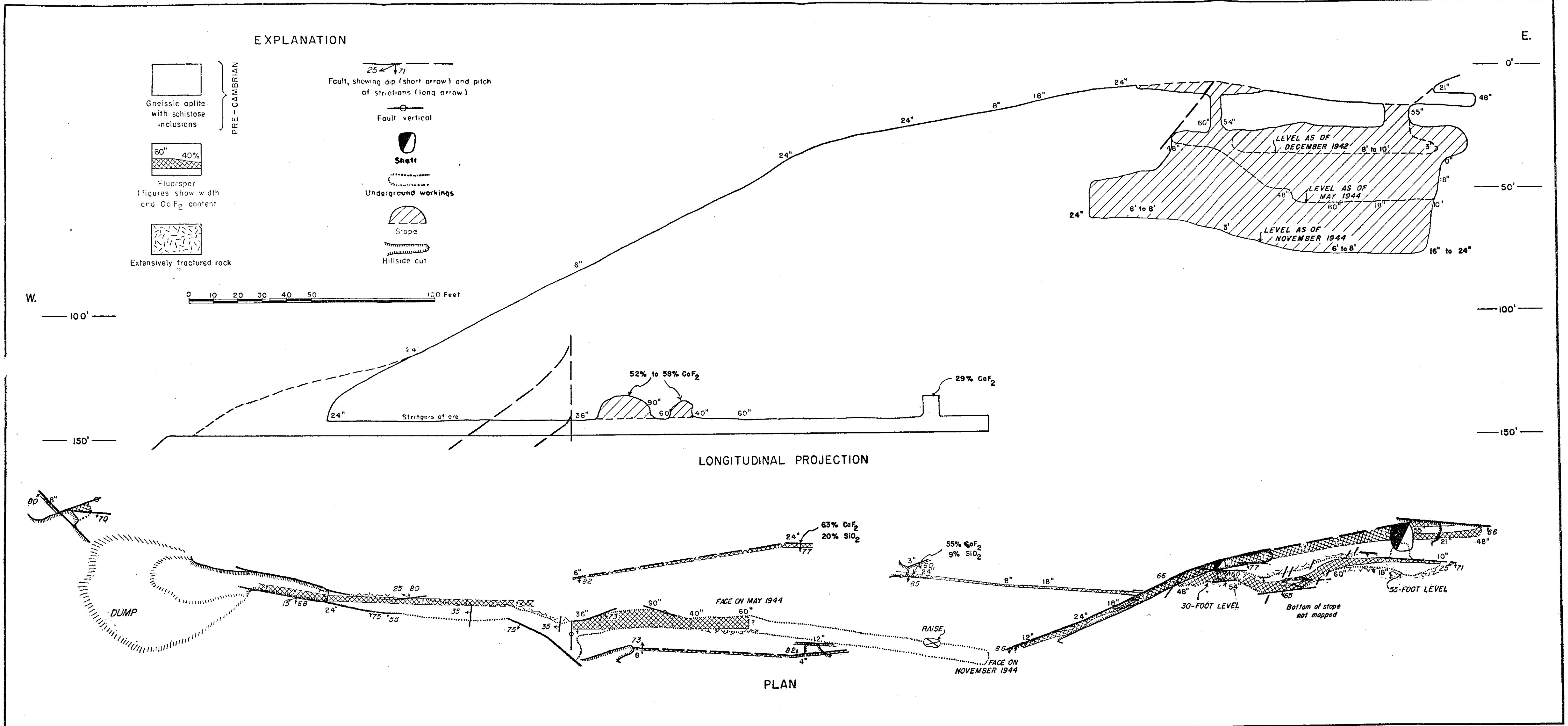
structural condition that is considered favorable for fluorspar deposition. Striations on the walls pitch 25° W. The shoot is about 125 feet long, as much as 10 feet wide, and appears to rake to the west. All of the varieties of fluorspar normally found in the Mirabal deposit occur in these workings, but high-grade coarsely crystalline fluorspar constitutes a large proportion of the ore. In early operations a product containing from 85 to 90 percent CaF_2 was obtained by hand-sorting. [1] The reject, the tenor of which is represented by assay No. 4, Table 38, is suitable for concentration in a modern mill. The tenor of the vein is indicated by assay No. 3, but shipments of ore from April through October 1944, represented by assay No. 6, show a lower average grade.

An open cut 210 feet east of the shaft and 60 feet above it exposes a vein that strikes N. 85° W. and dips 65°-75° S. The hanging wall shows both vertical and horizontal striations. The cut is 250 feet long, and occasional exposures of the vein show widths of ore ranging from 1.5 to 4.8 feet. The tenor of the ore, which is composed mainly of first-generation fluorite with a little barite, is high, as indicated by assays Nos. 9 and 10.

Mirabal Nos. 2, 3, and 4 claims extend successively eastward from Fluorite No. 1 and have been prospected at intervals. On Mirabal No. 2, four exposures scattered over a distance of several hundred feet show siliceous fluorspar 10 to 24 inches thick. On the east end of Mirabal No. 3 a small cut below an old sledge road exposes very siliceous red fluorspar. Above the road an 80-foot trench, trending N. 50°-60° E., shows less siliceous fluorspar, estimated to contain not more than 50 percent CaF_2, in thicknesses ranging from 2 to 5 feet. On the west end of Mirabal No. 4 claim a small pit and an open cut 100 feet farther east and about 50 feet lower expose fluorspar of similar grade and width. The veins strike about N. 65° E., and in the cut dip 73° SW. The two exposures on the west end of the claim are not in line.

The southern of the two main veins is exposed on Hillside No. 2 claim, on both sides of Diener Canyon. It has been prospected at intervals for 1,400 feet, but the west half appears to be too narrow and split up to be of commercial interest. The eastern part is exposed almost continuously for 650 feet by cuts and a short adit, through a vertical range of 150 feet. Here the vein strikes N. 80°-90° E. and dips as much as 10° from the vertical, both north and south. The south wall has striations inclined 35° W. The vein contains coarsely crystalline fluorspar up to a maximum width of about 2 feet ; breccia zones with later fluorspar locally increase the width to 4 feet. The tenor is rather high, as shown by the last three assays in Table 38.

[1] Mills, H. F., private report released by Moises Mirabal.



Data as of November 1944

Geology by H. E. Rothrock

Geologic plan and projection of the mine workings on the west end of Fluorite No. 1 claim, Mirabal mine, Valencia County

Accurate records of the total amount of ore shipped from the Mirabal mine are not available, but fragmentary information suggests that about 5,000 tons had been produced by the end of 1944.

Mining methods at the Mirabal mine are discussed on pages 205-206.

ICE CAVES PROSPECT

The Ice Caves or Acme prospect is $2^1/_2$ airline miles southwest of Malpais Spring and about half a mile east of State Highway 53 (Plate 18). It lies in a shallow valley at the east edge of a tongue of basalt that crosses the granite. The claim was filed by Alton Head and D. L. Cornelius of Grants, New Mexico. The workings are distributed along a vein for a distance of 330 feet and consist of two shallow trenches, 40 and 10 feet long, and a shaft 62 feet deep from which short drifts have been driven at the 40- and 62-foot levels.

The deposit is in a shear zone 4 to 5 feet wide, containing much gouge, striking N. 58° E., and dipping 75°-80° SE. The wall rock is granite. The fluorspar occurs as a vein on both footwall and hanging wall. In the 40-foot trench, the southwesternmost of the workings, the vein is from 6 to 12 inches wide. The 10-foot trench, which is 140 feet to the northeast, was caved at the time of inspection, but large fragments of vein material in the waste indicate that the fluorspar here is about 12 inches wide. The shaft is 150 feet northeast of the 10-foot trench. Its southwest side is in a vertical fault that lies at right angles to the vein and offsets it 5 or 6 feet. Southwest of the cross fault the fluorspar is on the footwall. It is 12 inches wide at the shaft but thins to stringers 5 feet from the shaft on the 40-foot level and 15 feet from the shaft on the 62-foot level. Although the drift on the lower level was extended 35 feet beyond the stringers, no wider bodies were found. Northeast of the cross fault the vein is on the hanging wall and averages 26 inches wide along a drift 15 feet long and on the 40-foot level. Below this level no drifting has been done northeast of the shaft, but the vein in the wall is 12 inches wide 57 feet below the collar of the shaft and decreases to a stringer at the bottom of the workings.

Northeast of the shaft the bedrock is covered by alluvium; southwest of the 40-foot trench the surface consists of alluvium for 90 feet and of basalt beyond. No trace of vein or fault could be found in the basalt, which was evidently erupted after deposition of the fluorspar.

The vein at the surface is very siliceous, but underground it is composed chiefly of green translucent anhedral fluorite. The deposit is too small to support a large mining operation.

BETTS MINE

The Betts mine is about 1$1/_2$ miles southwest of Malpais Spring, in the low hills on the south side of a valley that contains a basalt flow (Plate 18). Mining has been carried on intermittently for several years and has exposed the vein for a distance of 165 feet. A shaft has been sunk to a depth of 82 feet, and most of the ore for a distance of 25 to 35 feet on either side of the shaft has been mined.

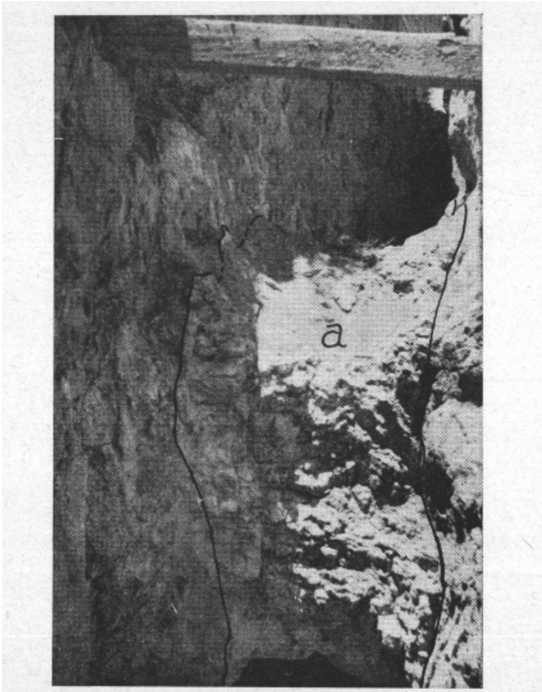
The vein occupies a fissure in the pre-Cambrian granitic complex. The strike of the vein is irregular but is predominantly N. 70° E. The dip is 80° - 85° SSE. The vein contains two ore bodies. One is in the northeast half of the vein and has been excavated for a distance of 80 feet to depths ranging from 10 to 20 feet. In places the cut is about 6 feet wide ; fluorspar in the faces is 6 to 12 inches wide. The other ore body is 45 feet long on the surface and 60 feet long at the 82-foot level ; it is separated from the first body by 40 feet of almost barren material. The stope from the surface to the 82-foot level is 2$^1/_2$ to 3 feet wide; the vein in the faces and pillars is from 6 to 18 inches thick.

The ore occurs in a single unbrecciated vein composed almost entirely of coarsely crystalline banded fluorite. A high-grade product could be obtained by simple crushing and sorting, but the vein is too narrow in the faces to be of commercial value under current market conditions.

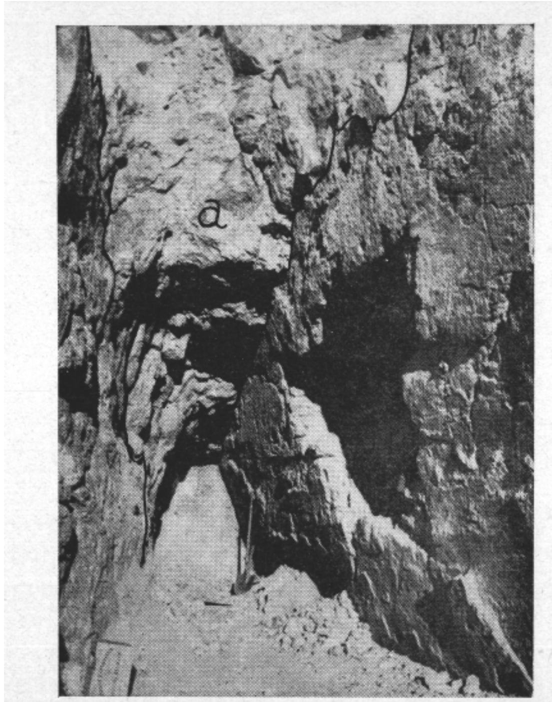
BONITA MINE

The Bonita mine is 2$1/_2$ miles south of Malpais Spring (Plate 18) and 13 miles southwest of Grants by the Zuni Canyon road. It is situated among low hills of pre-Cambrian granitic and metamorphic rocks, only a few hundred feet west of the contact of these rocks with the overlying Abo sandstone. The mine is on Bonita No. 5 claim, which is one of a group of six claims filed by J. L. Cornelius and Alton Head. In 1942 and 1943 it was operated by the Both Mining and Milling Company, and subsequently it was acquired by J. K. Stanland. A shaft about 100 feet deep has been sunk along the vein and at the 75-foot level is connected with an adit that extends eastward 275 feet to the surface and westward 145 feet along the strike of the vein.

A large part of the workings is in or adjacent to a mass of biotite schist. Three fissure veins, striking N. 70°-85° E., occur in this locality, but only the southern one has been developed. Fluorspar crops out irregularly along this vein for a distance of about 800 feet. Its average width throughout this distance is 18 inches, but widths of 3 feet are common in the adit east of the shaft. West of the shaft the fluorspar in the adit ranges from stringers to veins 8 inches thick. The west wall of the shaft for



A. Pillar of fluorspar (a), a remnant of the fissure vein in the White Eagle mine, Grant County.



B. A cut in fault breccia impregnated with fluorite (a) in the Cox fluorspar mine, Sierra County. The hanging wall is well defined by the curved fault plane at the right of the cut.

TWO TYPES OF FLUORSPAR DEPOSIT

25 feet below the adit is barren, but along the east wall a fluorspar vein 6 to 12 inches thick lies on the footwall near the bottom of the shaft.

The middle vein is about 80 feet north of the west end of the south vein. It strikes N. 70° E. and dips 85° SSE. Two pits about 30 feet apart expose a fluorspar vein that is 20 inches wide in the west excavation and 12 inches wide in the other. A third vein, exposed in a shallow trench about 300 feet north of the middle vein, is similar to the other veins.

Ore in the Bonita mine consists of bluish-green or green medium- to coarse-grained vuggy fluorite, with scattered bands of silica, inclusions of brecciated wall rock, and a small proportion of clay. A grab sample from the stock-bin, representative of the ore body east of the shaft, assayed 64.1 percent CaF_2, 14.7 percent SiO_2, and 0.8 percent $BaSO_4$.

An accurate record of the ore that has been shipped from this property is not available, but a compilation of figures from various sources indicates that prior to J. K. Stanland's operation at least 800 to 900 tons,of ore had been shipped. There is no evidence to indicate the depth to which the ore body exposed in the adit extends, but its length probably does not greatly exceed that of the stopes.

STELLA MAE PROSPECT

About a quarter of a mile south of the Bonita mine, on Stella Mae No. 2 claim, a brecciated zone 8 feet wide and striking N. 80° E. is exposed in a small open cut. It contains stringers of fine-grained siliceous fluorspar that constitute about 30 percent of the face. Soil cover prevents tracing the deposit by outcrops.

PROSPECT IN SECTIONS 29 AND 30

A vein in the S1/2 sec. 30, T. 10 N., R. 11 W., trends N. 40° E. and is in approximate alinement with one a short distance to the northeast that extends into the W1/2 sec. 29 (Plate 18). The two veins have similar characteristics and are thought to be closely related structurally and genetically. Both are associated with a porphyry dike that was faulted and impregnated with stringers and veins of coarse-grained fluorite from 2 to 12 inches thick. Striations pitching 70° NE. indicate that movement along the fault was nearly vertical.

BREECE LEASE PROSPECT

In the SW1/4 sec. 31, T. 10 N., R. 11 W., a group of veins striking N. 50° E. is noteworthy because it contains a greater proportion of barite than other fluorspar veins in the Zuni Mountains. The fluorspar in the scattered exposures forms lenticular bodies too narrow to encourage development.

JUNIPER PROSPECTS

The Juniper prospects, part of the property of the Zuni Milling Company, are about 11/4 miles southwest of the Bonita mine (Plate 18) . They comprise three veins that strike northeast and are several hundred feet apart. On the south vein a small open cut exposes a group of banded veins of coarse-grained green fluorspar, that coalesce in an adjoining shaft to form a single vein 2 feet wide. Similar widths of ore have been found in drifts about 40 feet long, west of the shaft at the 55- and 115-foot levels. Drifts east of the shaft, however, exposed only narrow bands of fluorspar. Several hundred tons of ore, which after sorting and washing assayed 90 percent CaF_2, has been sold from these workings. [2] The middle and north veins, on which no development work has been done, were not visited.

SPRUCE HILL NO. 1 PROSPECT

The Spruce Hill No. 1 prospect, 6 miles south of Malpais Spring, is most easily reached by a graded dirt road between the mine and State Highway 174, 5 miles to the south (Plate 18) . According to J. M. Keeney, who filed Spruce Hill No. 1 claim, it lies in section 10, and the vein is very near the south quarter-corner of the section. In the fall of 1944 development consisted of surface excavations as much as 20 feet deep extending for a distance of 100 feet along the vein.

The workings are in granitic rock about 900 feet southwest of the overlapping Abo sandstone. The vein occupies a narrow fault zone that strikes N. 50°-60° E. and dips 75°-85° NW. The fault surfaces are both plane and curved in broad undulations, the axes of which pitch 75° SW. In the northeast end of the workings the vein ranges in width from 6 to 24 inches. In the southwest end, however, ore aggregating 36 inches in thickness occurs along several closely spaced fractures. The ore has been formed by the replacement of fault breccia and wall rock and by the filling of interstices and crevices. It is composed of medium-sized crystals of green fluorite embedded in altered country rock and fault breccia. Ore shipments between November 1 and 27, 1944, had an average CaF_2 content of 76 percent.[3] The wide fractured and brecciated zone that contains the ore body is relatively short on the surface and probably is not appreciably longer underground.

SECTION 15 PROSPECT

The Section 15 prospect is about 400 feet southwest of the Spruce Hill No. 1 workings, across a small ravine, on land in sec. 15, T. 9 N., R. 11 W., under lease to the Zuni Milling Company

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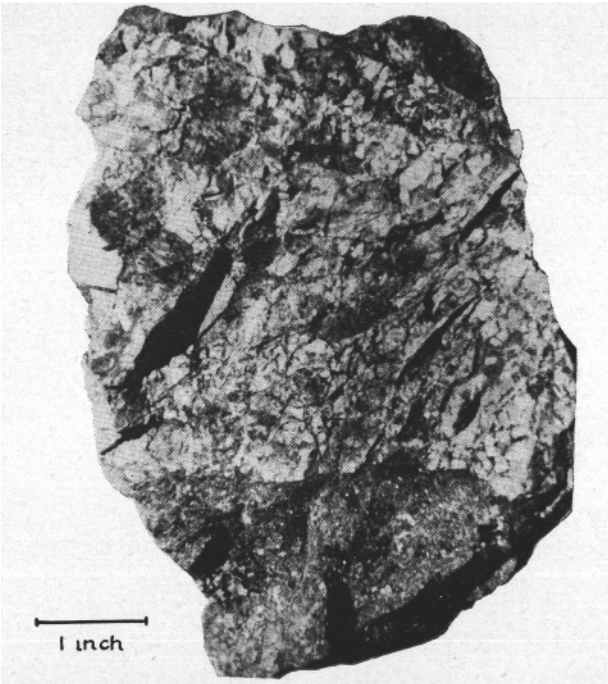
[2] Oral communication from James H. Mallory.
[3] Oral communication from J. M. Keeney.



A.
Granular purple fluorspar from the Red Cloud prospect, Lincoln County. Purple fluorspar (dark gray) has filled the crevices in brecciated quartzitic sandstone (light gray) without replacing it appreciably.

B. Finely crystalline, white flinty fluorspar in the upper adit of the Universal vein, Sierra County. The cavities are lined with drusy quartz and range in diameter from a fraction of an inch to six inches.

TWO TYPES OF FLUORSPAR

(Plate 18). An open cut 30 feet long, an adit 60 feet long, and a raise to the surface at the end of the adit were made by James H. Mallery.

The workings are in a fracture zone that strikes N. 50° E. for 60 feet and then N. 70° E. ; the dip is about 85° SE. Gouge is notably absent, and tight radiating fractures enter the zone from the footwall. Here fluorspar forms only stringers. The raise is in a mineralized zone about 2 feet wide, composed of vein-lets of fluorite as much as 6 inches thick. The raise was so clogged with debris that the height to which mineralization extended could not be determined.

BONNEKAY PROSPECT

The Bonnekay prospect is about a mile by canyon road southwest of the Zuni No. 1 prospect and is on claims filed by J. L. Cornelius, who did much of the early exploration. The property was held for a time by J. K. Stanland and in 1944 was acquired by Roy Boyd, who was operating it at the close of 1944. The workings include an open cut and an adit about 280 feet long near the bottom of the canyon, a short adit about 50 feet higher up the side of the canyon, and trenches over the adjoining ridge. These workings expose the vein for several hundred feet.

The deposit is a fissure vein in a brecciated zone that has an average trend of N. 50° E. but for short intervals deviates from this trend by as much as 20°. The average dip is 55°-65° SE. Fluorspar in these fractures forms irregularly distributed stringers and veins from 1 inch to 36 inches thick. The greater widths are exposed for short distances only. The vein material consists of purple or green fluorite in bands and drusy coatings, with a small proportion of quartz and considerable dilution by fault breccia.

It is reported that two truck loads of ore from the open cut were marketed prior to 1942. Work since then has been chiefly developmental.

TWENTY-ONE AND TWENTY-SEVEN MINES

The Twenty-one and Twenty-seven mines, so named from the sections in which they are situated, lie about 11/4 miles apart in an area of moderately rugged relief at the southeast end of the Zuni Mountains (Plate 18). The main workings of the Twenty-seven mine are approximately 22 miles by State Highway 174 from Grants, and those of the Twenty-one mine are 2 miles farther. The mines were developed by the Navajo Fluorspar Company as a result of exploration by James H. Mallery. These properties and the flotation mill at Los Lunas, built by the Defense Plant Corporation, were acquired by the Shattuck Denn

Corporation in 1944 and operated under the management of the Zuni Milling Company.

Because the writer made only brief visits to these properties, he is indebted to James H. Mallery, superintendent of the mines, and to A. E. Weissenborn of the Federal Geological Survey, for much of the data given below.

The deposits are fissure veins in gneissic granite. They occupy narrow fault zones that contain "horses" of rock and much gouge that is principally on the footwalls. The fissures generally trend N. 50°-65° E., but at irregular intervals they branch eastward for short distances and at these points usually divert the vein from the main fissure to one parallel with it. At these points of bifurcation, according to Weissenborn, [4]

> the footwall gouge usually continues as strong as before but is either completely unmineralized or is accompanied by only a narrow seam of fluorspar. In places stringers of fluorspar enter the wall but rejoin the main vein in a short distance. The veins are cut by a number of cross faults, but the displacement of these never exceeds a few feet and usually is only a few inches.

The principal difference between the Twenty-one and Twenty-seven veins is that the latter was extensively faulted after the fluorspar was formed, and the ore was fractured, pulverized, and mixed with brecciated rock. Later this mass was incompletely mineralized during another period of fluorite deposition. As a result of these processes a wider vein was formed in the Twenty-seven mine than in the other ; but the over-all grade of the Twenty-seven mine is lower because of the rock, gouge, and clay that are mixed with the ore.

The ore consists of coarsely crystalline and microcrystalline fluorite with a minor amount of gangue composed of quartz, calcite, and acicular pyramidal aragonite. The coarsely crystalline fluorite is transparent to translucent and predominantly aquamarine, although purple fluorite is common. Imperfect cubes, many with parallel faces, are found in partly filled cavities. The microcrystalline ore is red, brown, or gray, has a granular texture, and contains finely crystalline quartz, commonly in excess of 10 percent.

In the early days of marketing, several carloads of acid-grade 'fluorspar were prepared by careful hand-sorting, but most of the ore was beneficiated in a jig mill at Grants, where a concentrate containing 80 to 85 percent CaF_2 was made. Prior to November 1943 approximately 65,000 tons of ore had been taken from the mines. [5] The output from November 1943 to December 31, 1944, was 53,686 tons.[6]

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[1] Weissenborn, A. E., Ore reserves at the Navajo fluorspar mines near Grants, Valencia Co., N. Mex.: U. S. Geological Survey Strategic Minerals Investigations Report, p. 6, 1943. (On open file.)

[5] Idem, p. 1.

[6] Data supplied by George A. Warner, general superintendent, Zuni Milling Co.

The Twenty-one vein can be traced on the surface for a distance of about 3,200 feet. Its southwest half has been exploited chiefly by underground workings. At the time of the examination by Weissenborn, these workings consisted of tunnels, called the 100-foot level, driven into a ridge from the adjacent valleys ; a working shaft to the 300-foot level ; drifts 870 feet long on the 200-foot level ; and stopes into the ore. Except for a section of lean ore 170 feet long, beginning 450 feet from the northeast portal, all the workings were in minable ore having an average width of 2.5 feet. There was no appreciable difference between the width of ore on the 100- and 200-foot levels. The average content of the ore mined was 55.0 percent CaF_2, 14.0 percent SiO_2, and 25.0 percent $CaCO_3$.[7]

The Twenty-seven vein can be traced on the surface for at least 4,000 feet. About 2,200 feet of this length has been explored by three underground workings distributed along 3,000 feet of the vein structure. They are called, from southwest to northeast, the 27-3, 27-2, and 27-1 tunnels.

The 27-3 tunnel follows the vein for 1,130 feet ; on the 200-foot level, 100 feet below the tunnel, the vein has been explored for 470 feet. In the southwest end of the workings above the drift on the 200-foot level, the fluorspar is almost continuously of minable grade and averages about 4 feet wide. In the succeeding section of the tunnel, for a distance of 300 feet, the vein is extensively brecciated, and good ore occurs in pockets only. At the northeast end of this section the vein follows a cross fracture for 200 feet, along which the fluorspar is also brecciated and pockety. Thereafter, the workings parallel the main vein and contain ore that is approximately 4.5 feet wide for a distance of 140 feet.

The portal of tunnel 27-2 is 450 feet northeast of the end of tunnel 27-3. The former tunnel is in an ore body 240 feet long, which is stoped to the surface. The width of the stope is from 2.5 to 6 feet. Beyond this ore body the thickness of the vein is 18 inches or less, except for small lenses at the intersections of fractures branching from the main structure.

The portal of the 27-1 tunnel is about 850 feet northeast of the portal of the 27-2 tunnel. Fluorspar in the 27-1 tunnel is narrow and irregular for a distance of 340 feet, beyond which a vein 2 feet thick is exposed in an intersecting cross fault for a distance of 180 feet.

Ore in the Twenty-seven vein includes coarsely crystalline and microcrystalline fluorspar and fault breccia containing various proportions of fluorspar in the form of brecciated veins and interstitial fillings. The average proportions of the chief consti-

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[7] Idem.

tuents of mined ore was 40.0 percent CaF_2, 25.0 percent SiO_2, and 34.0 percent $CaCO_3$.[8]

The faults in which the Twenty-one and Twenty-seven veins were deposited are so persistent in length and have shattered the rock so intensely that they probably extend to much greater depths than have been explored by the workings. As no signficant change has been noted in the character of the ore on the lower levels as compared to that on the upper levels, the fluorspar may be expected to persist at depth in these fractures.

Mining methods at the Twenty-one and Twenty-seven mines are discussed on pages 207-212.

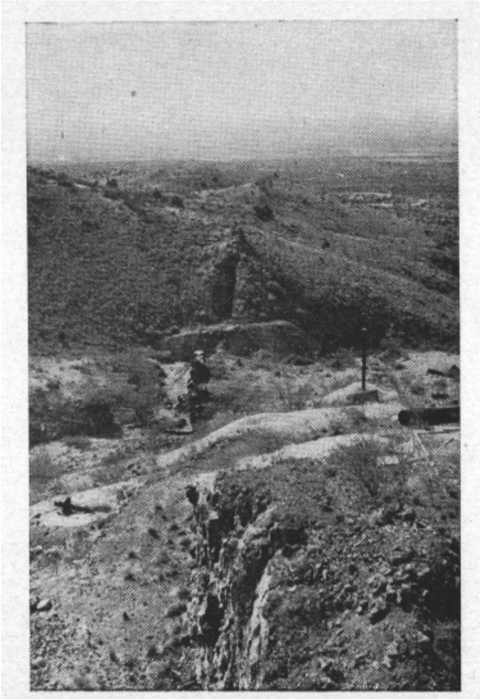
PORTER-MIRABAL PROSPECT

The Porter-Mirabal prospect is a mile west of the Twenty-seven mine and about a quarter of a mile north of State Highway 174 (Plate 18). It is in gneissic granite but is close to one of the lava flows within the mountains. The workings comprise a small open cut on the west side of a draw and an adit 50 feet long in the opposite valley wall. They are in a brecciated zone several feet wide, trending northeast. Horizontal fault movement is indicated by striations. A brecciated vein of coarsely crystalline blue or purple fluorspar traverses the fault breccia. At the portal of the adit the vein is near the southeast side of the breccia and is from 6 to 12 inches wide. At the face it is near the north wall and is 18 inches wide.

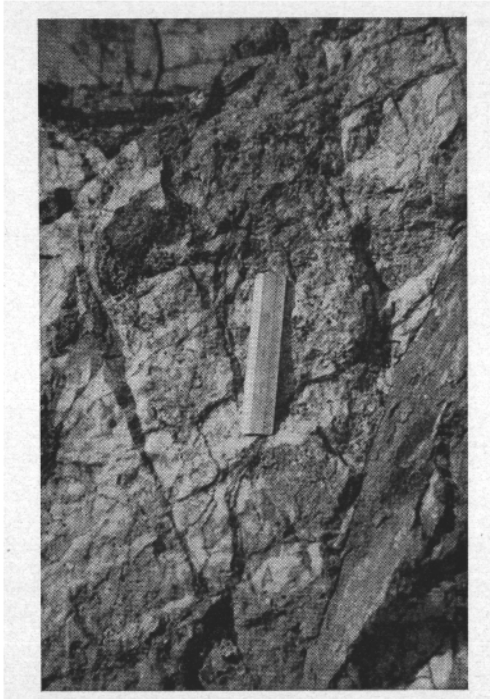
OUTLOOK FOR FLUORSPAR IN THE ZUNI MOUNTAINS

The granitic central part of the Zuni Mountains is favorable territory in which to prospect for fluorspar. One-third of the ore mined in the State during the first eight months of 1944 came from the southeast part of this area. Search should also be made northwest of the known mines and prospects for northeast-trending fissures and fluorspar veins, in those places where the basal members of the Abo sandstone overlap the pre-Cambrian rocks. These structures and veins may not contain minable ore in the Abo sandstone, but they may indicate the position of ore-bearing fractures in the older rocks beneath.

[8] Idem.



A. View southwest from the headframe of shaft No. 2. Excavations and wall-like remnants of siliceous fluorspar mark the position of the vein.



B. Jaspar veins (dark bands) in white fractured fluorspar. The plane of a fault that cuts the vein transversely appears in the right of the photograph.

LYDA K FLUORSPAR VEIN, SIERRA COUNTY

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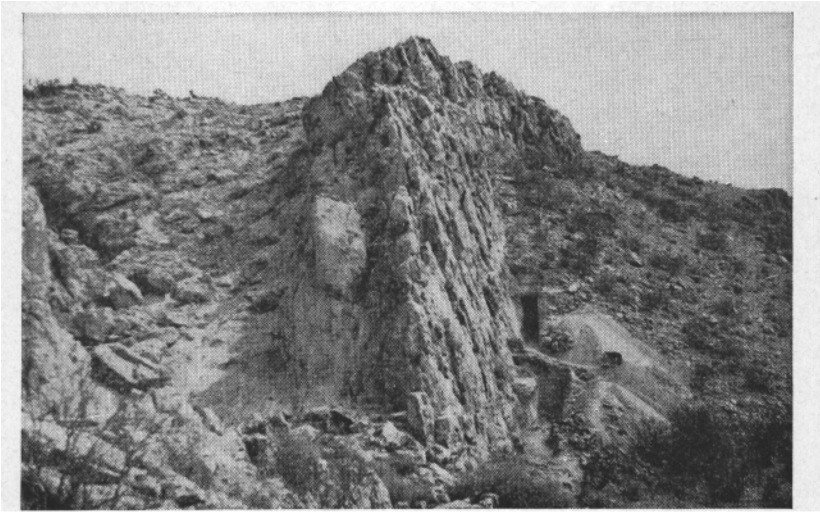
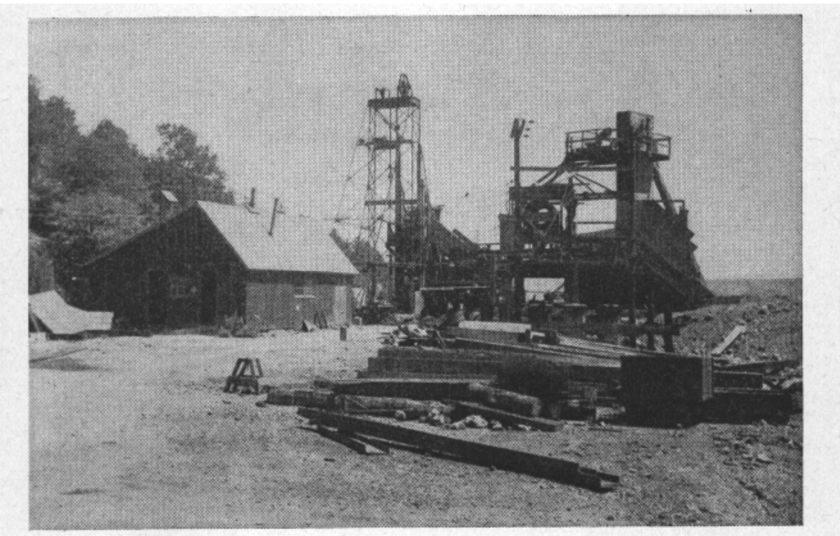
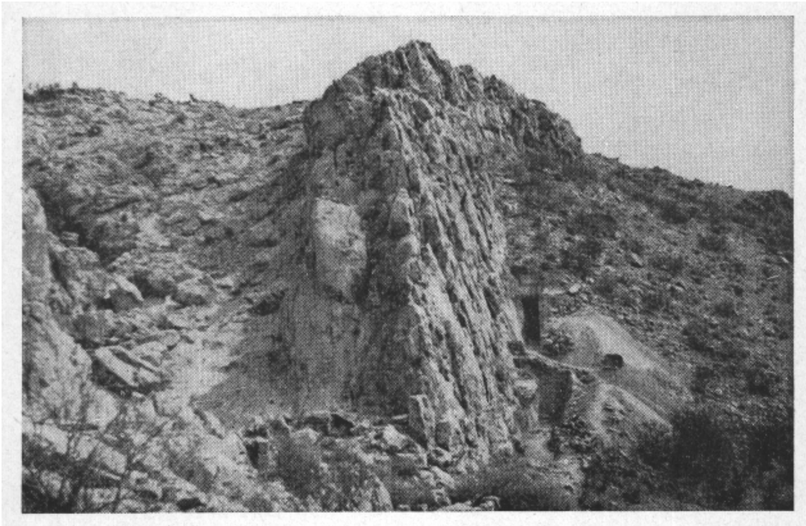


A. Silicified footwall of the Gonzales fluorspar prospect, Socorro County. To the left of the ridge the rock is granite; to the right are down-dragged strata of the Magdalena group. Workings are in the vein and the adjoining fault breccia.



B. Headframe for the Burro Chief mine at the site of the Chemung No. 1 shaft, Grant County. A trommel washing plant is at the right of the headframe.



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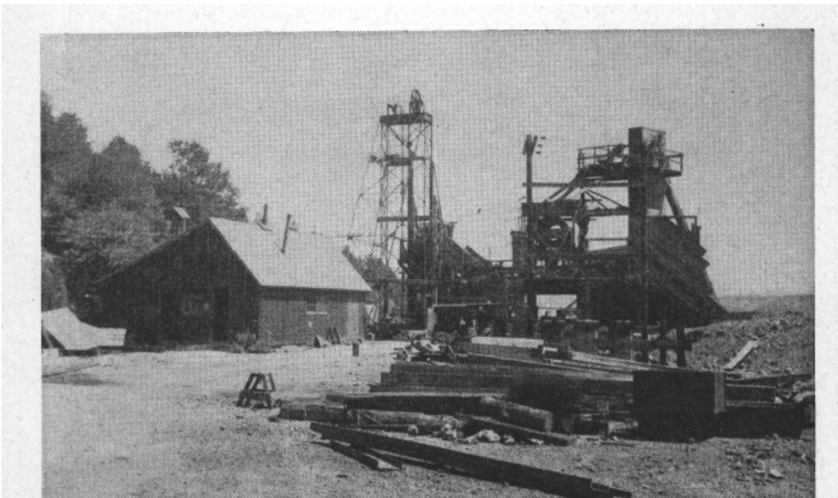

B. Headframe for the Burro Chief mine at the site of the Chemung No. 1 shaft, Grant County. A trommel washing plant is at the right of the headframe.

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PART 2.-MINING AND MILLING OF FLUORSPAR IN NEW MEXICO

CONTENTS

PLATES

FIGURES

PART 2

MINING AND MILLING OF FLUORSPAR IN NEW MEXICO[1]

By

C. H. JOHNSON

Bureau of Mines, U. S. Department of the Interior

INTRODUCTION

Mining and milling methods at New Mexico fluorspar mines in 1943-44 showed wide variation. The few described here were selected partly because they illustrate different methods and partly because the necessary information was readily available. Several other mines and mills in the State, not discussed here, are of equal interest.

The writer acknowledges the assistance of many individuals in gathering the material, in particular the following : George A. Warner, general superintendent, James Mallery, mine superintendent, Ed Hagie, mining engineer, Coyne Hunt, mill superintendent, and Wayne Fowler, metallurgist, of the Zuni Milling Company ; Joseph L. Gillson, Development Department, E. I. du Pont de Nemours & Company ; W. A. Wills, mine superintendent, Lyda K mine, Kinetic Chemicals, Inc.; William Heim, lessee and operator, Mirabal mine ; S. T. Brown, president and manager, and J. W. Wallace, mine superintendent, Brown-Johnson Corporation ; H. L. Gardner, mill superintendent, International Minerals & Chemical Corporation ; Charles F. Johnson, lessee and operator, Huckleberry mine. Members of the staff of the Federal Bureau of Mines likewise contributed information.

HUCKLEBERRY MINE

The Huckleberry mine, near Glenwood, Catron County (Figure 3), is in a relatively flat-lying fluorspar deposit. A room-and-pillar method is employed underground, and small-scale open-pit mining where the ore-body crops out.

The back of the ore-body is defined by a strong gouge-filled fault zone, which pitches and rolls irregularly but has a general dip of about 25° SE. (see pages 44-46 and Plate 3). The floor is undefined structurally, and the thickness of minable ore ranges from 2 to about 12 feet.

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[1] Published by permission of the Director, Bureau of Mines, U. S. Department of the Interior.

Development consists of following the ore, either on the level or up or down considerable pitches. Little underhand mining has been attempted, and except for an exploratory drift and crosscut and short raises driven by the Federal Bureau of Mines, practically no development work has been done in barren ground.

Pillars are left at irregular intervals to support the back, thus tying up a considerable amount of ore. However, experience has shown that close support is necessary and that spans exceeding 8 to 10 feet in width will not stand open indefinitely.

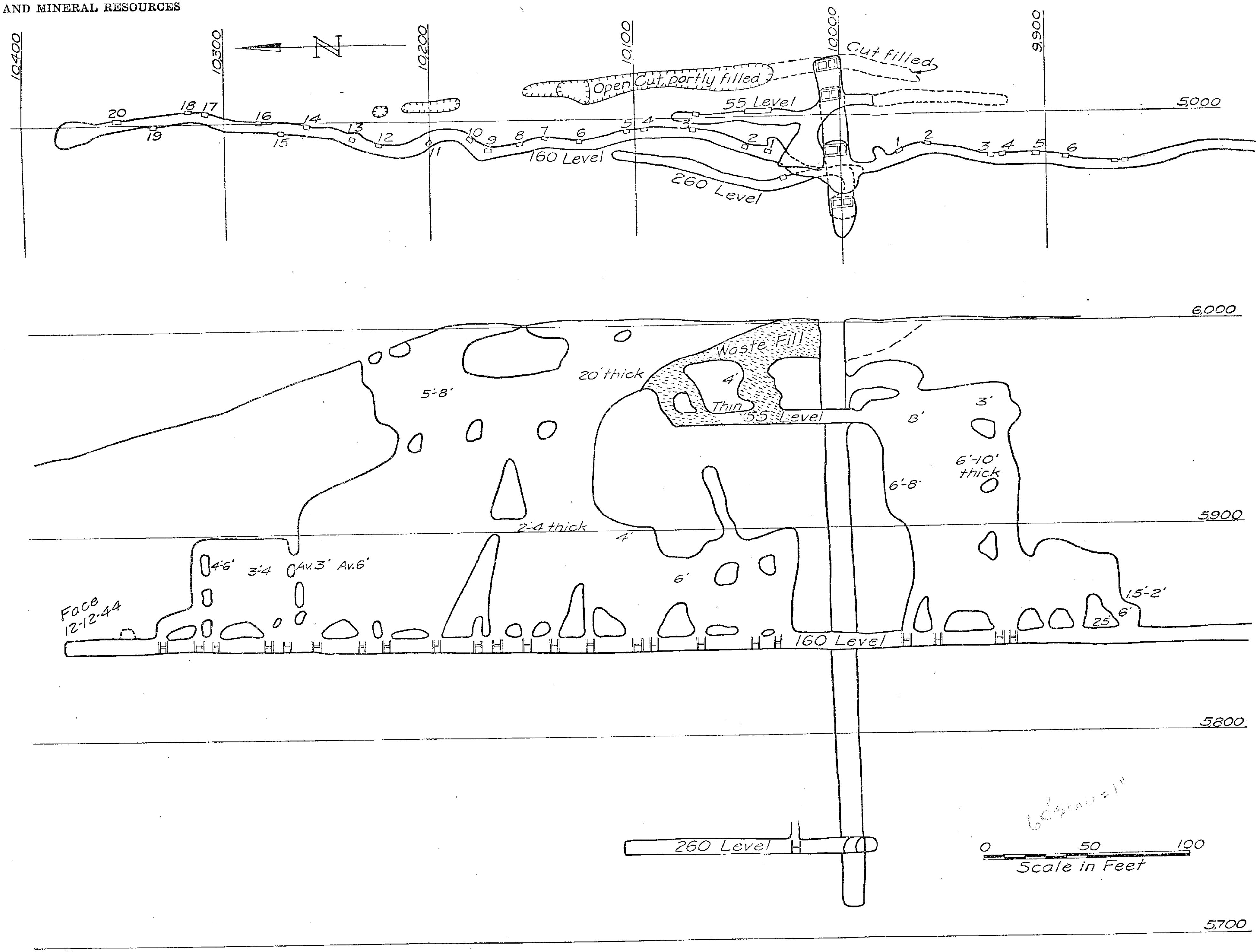
Drilling is done with light hand-held jackhammers. The ore is loaded by hand directly into mine cars, or is moved by wheelbarrow to transfer chutes. The nature of the ore is such that nearly all the fluorite breaks into fine sizes on blasting, while the country-rock breccia, which constitutes most of the gangue, does not break down to any great extent. Consequently it is desirable to discard all coarse material, and a sloping screen with 1-inch openings has been installed for this purpose at the head of the inclined surface tram by which the ore is lowered to the truck bin. All oversize is picked over by hand, and occasional pieces of ore recovered ; about 50 percent of the mine-run is thus rejected, with essentially no loss of fluorspar.

In the summer of 1944 a crew of four men, including the lessee, who acted as foreman, produced 12 to 20 tons of mill ore daily. This was hauled by a contract trucker to the stockpile of the Metals Reserve Company at Gila, a distance of 40 miles, at a rate of $3.15 a ton.

Hoping to find a sufficient tonnage of new ore to justify a larger operation, the Federal Bureau of Mines in 1944 did the underground work previously mentioned and drilled about 75 wagon-drill holes from the surface. The holes range from 10 to 70 feet in depth. Cuttings were caught by a 6-inch cylindrical dust collector connected to the collar of the drill hole. The holes were blown clean every 2 feet, and, if fluorite was present in large amounts, the samples of drill cuttings were analyzed. Sink-float tests, using acetylene tetrabromide diluted with kerosene to about 2.95 specific gravity, were found useful in making rough field determinations of the proportion of fluorite in the cuttings. Test-pits later sunk on several drill holes yielded higher-grade samples than the holes. The result of the exploration work was the location of an appreciable extension of the ore body south of the mine.

GLUM MINE

Prior to 1942 the outcrop of the Clum vein, in the Gila district, Grant County (Figure 5), had been mined in several places near and north of the present shaft. The maximum depth of this mining was about 20 feet. In 1942 M. J. Wallace sank an



Plan and elevation of the Clum mine, Grant County inclined shaft on the vein to develop a level at a vertical depth of 55 feet. During the same year Wallace shipped approximately 1,750 tons of ore by truck to Silver City and Deming. In 1943-44, Brown-Johnson Corporation sank an inclined shaft on the vein to a depth of approximately 300 feet and developed levels at vertical depths of 160 and 260 feet. This company shipped 5,677 tons of fluorspar ore in 1943 to the Metals Reserve Company's mill at Gila, and approximately 14,400 tons in 1944. Production during 1944 was maintained at a fairly constant rate of approximately 1,200 tons per month.[2]

Mining is done chiefly by shrinkage stoping (Plate 25, A) . The vein dips steeply, and the country rock is sufficiently strong so that very little dilution during mining, or subsequent sloughing of walls in empty stopes, is experienced. As shown by the vertical projection of the mine, Plate 24, many spans of 40 to 50 feet are left unsupported.

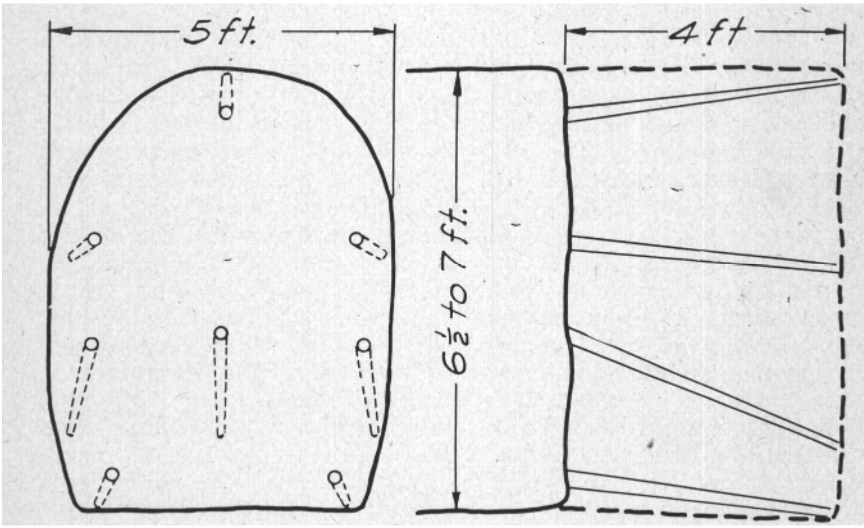


FIGURE 16.—Drift round, Clum mine.

Practically all development work has been in the vein. Figure 16, which illustrates a drift round used on the 260-foot level, indicates that the ground is not difficult to break. Two men can generally muck out, drill, and blast a 4-foot round in one shift ; drilling is done with hand-held jackhammers. Labor contracts for drifting have been let at $5.00 a foot.

Because of the irregularity of the vein and ore-shoots, the stoping method differs somewhat from place to place. The

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[2] The East vein, another Brown-Johnson mine, contributed to this output in the first half of 1944.

usual plan is to install chutes at 15- to 20-foot intervals from end to end of an ore-shoot, leaving solid triangular drift pillars between. Manways were at first maintained in cribbed raises, but later it was found more satisfactory to drive separate man-way raises, protected by solid pillars from the moving ore in the stopes. Access tp the stopes was then gained by occasional break-throughs.

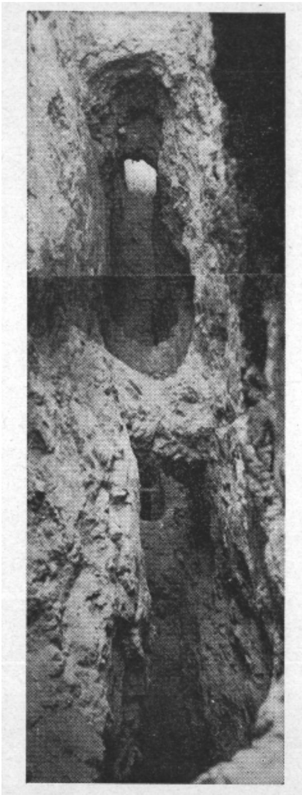
Stoping widths range from 3 to 20 feet ; the average for the mine is probably between 5 and 6 feet. The ore is normally broken by stoper holes drilled from the top of the broken ore in the shrinkage stopes. As the walls in most places are not well defined, careful work is necessary in order to extract the full width of ore without breaking excessive waste. Where practicable, waste or very low-grade areas within the ore-shoots are left as pillars, but a small tonnage of good ore is unavoidably left to support the hanging wall. Twenty-foot pillars are left on both sides of the shaft,

Ore is hand-trammed to the shaft in 12-cubic-foot cars, and dumped through 8-inch grizzlies into pockets directly over the shaft. Hoisting is done with a bucket of 1,500 pounds capacity, sliding on skids in the shaft and dumping automatically onto the sorting grizzly. The latter is made of inverted sloping rails set 2 inches apart. Five to 10 percent of the material normally broken in drifts and stopes is rejected by hand-sorting at the surface. Fine and coarse ore are shipped together. The Brown-Johnson Corporation trucks its ore to the mill at Gila, a distance of about 10 miles, using two 5-ton trucks.

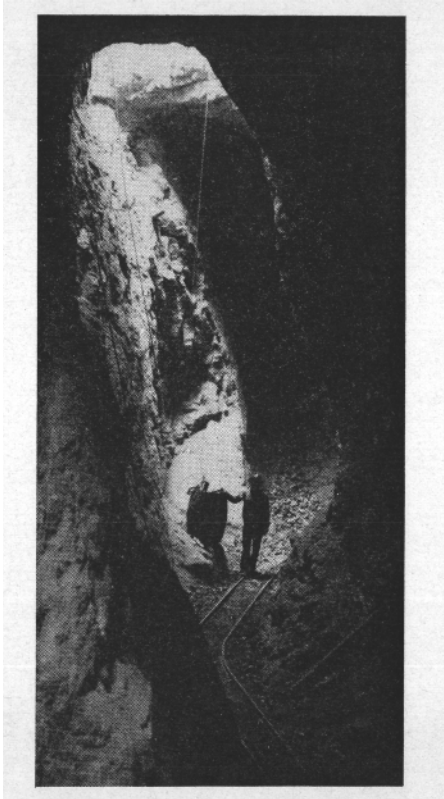
Usually, 25 to 35 men are employed, working on two 8-hour shifts, 6 days a week. The normal day-shift crew consists of a foreman, a shift boss, three or four miners, four trammers, a skip tender, a sorter, a hoistman, a mechanic, and two truck drivers ; the night-shift crew includes a shifter, two miners, three trammers, a hoistman, and a sorter. The average over-all output is approximately $1^1/_2$ tons delivered to the mill per man-shift.

Mine equipment consists chiefly of a portable gasoline-engine compressor ; a single-drum hoist powered by a gasoline engine ; a small electric generator ; and an engine-driven ventilating fan. The bill for gasoline, including that used in the trucks, has averaged about $750 a month, or $0.60 per ton of ore. An unusual feature of this operation is the installation of electric lights in the shaft and along the drifts. Although not common at small mines, this improvement in working conditions is believed to have more than repaid the investment of a few hundred dollars in equipment, installation, and gasoline. A view of the surface plant is shown on Plate 26, B.

Surface trenching by the Federal Bureau of Mines north



A. Empty shrinkage stope at the Clum mine, Grant County, showing irregular walls.



B. Stope in the Mirabal mine, Valencia County.

and south of the Clum shaft failed to disclose other ore-shoots of minable size, although the vein, containing some fluorspar, was traced several hundred feet in both directions. However, an ore-shoot cropping out about 400 feet south of the shaft had been mined to a depth of a few feet before the start of the Brown-Johnson operation, and appeared to have promise of downward continuation. Accordingly, the south drift on the 160-foot level was driven 250 feet beyond the southernmost minable ore-shoot in an effort to find such a downward extension. This exploratory Work, which was not successful in finding new ore, is mentioned because it is typical of experience in many fluorspar mines, and similar work must usually be taken into account in forecasting operating costs.

The geology of the Clum mine is discussed on pages 81-84.

GREENLEAF MINE

The Greenleaf mine, in the Fluorite Ridge district northeast of Deming, Luna County (Plate 15), has been an important New Mexico fluorspar producer. It was first operated by D. F. McCabe, and later, under lease, by E. J. Marston. Production ranged from 10 to 50 tons a day. About a third of the total production was shipped as metallurgical ore, the remainder as ore of milling grade.

A shaft inclined at 70° to 80° has been sunk on the vein to a depth of 397 feet. The most important mining level is the lowest or 350-foot level. This extends almost 300 feet north of the shaft and 145 feet south of it.. Stopes have also been developed from the 213-, 167-, 113-, and 76-foot levels, but work from below has removed the floors of most of the upper-level drifts. Efforts to sink the shaft deeper in the summer of 1943 were blocked by a flow of water that exceeded the capacity of the small pumps and electric generator then available.

Ore is mined from a number of closely spaced parallel or branching veins, so that in many places the stopes overlap. Individual stopes are 25 to 100 feet in length, and from 25 to 160 feet in height. Stoping widths differ greatly from place to place, ranging up to 15 feet but averaging about 4 feet.

Both walls and ore are strong, so that shrinkage stoping is feasible, and this method is employed throughout the mine. No serious dilution or sloughing of walls after drawing occurs. Narrow pillars are left to protect the shaft, but elsewhere only occasional small pillars of ore are found necessary to support the hanging wall. Generally waste or low-grade areas can be made to serve this purpose. No back-filling is done except as a convenient method of disposing of waste from development work or from sorting at the shaft collar. Stope backs are carried either horizontally or moderately inclined, as seems desirable in each stope.

Tramming from stope chutes and drift faces to the shaft is done in 1,200-pound buckets on dollies ; no ore pockets are cut.

Almost all development work is in the veins. Relatively little crosscutting is done, but a "long-hole" drill is used to good advantage to test the walls for parallel ore-shoots. This drill is a heavy drifter, using jointed steel and detachable bits. Visual examination of the cuttings is sufficient to determine the presence or absence of fluorspar in the hole.

The Federal Bureau of Mines in 1943 thoroughly trenched the northward extension of the Greenleaf vein system, in an effort to discover other ore-shoots. As the overburden gradually deepens northward into a broad shallow wash, the northernmost trenches had to be dug as much as 12 feet deep to reach bedrock. Because of the depth of trenches, averaging about 9 feet, and the degree to which the gravelly soil is consolidated, only about 1.6 cubic yards was excavated per manshift. A vein containing fluorite was traced more than 100 feet beyond the northernmost mined ore, but with decreased thickness and grade.

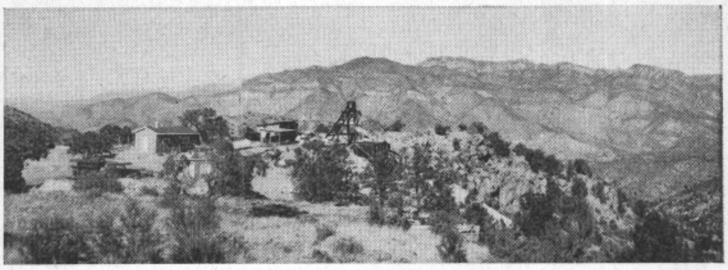
Chief items of surface equipment (Plate 26, A) at the Greenleaf are a 315-cubic-foot skid-mounted Diesel compressor, a gasoline-engine-driven electric generator of about 10 horsepower, and a single-drum hoist driven through a low-gear transmission by a gasoline truck engine. An electric triplex pump is installed at a sump on the 367-foot level near the shaft.

Deeper development of the Greenleaf mine was halted in 1943 because of the difficulty of sinking the shaft below the water level, which is just below the 350-foot level. Although the shaft was sunk about 30 feet lower, the pumps and generator proved inadequate, and in addition ground conditions were found much worse than above the water level. Whereas the shaft to 350 feet had required no supporting timber, it was found that under the water the walls of the vein were loose, and that regular square-set shaft timbering would be necessary.

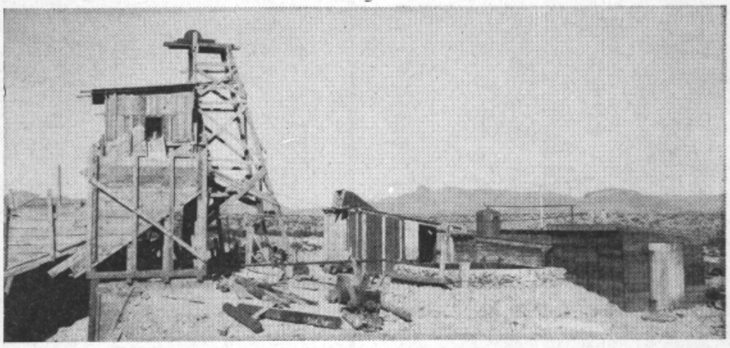
A discussion of the geology of the Greenleaf mine is given on pages 133-136.

LYDA K MINE

In 1942-1944 a development program was carried on at the Lyda K mine in Sierra County (Figure 14), during which several hundred feet of underground work was done with the purpose of establishing substantial ore reserves. Metallurgical research was also conducted, to determine the best method of treating the ore. Actual production consisted of 204 tons of hand-sorted metallurgical-grade ore, shipped in 1943. In July 1944 the owner, Kinetic Chemicals, Inc., closed the mine.



A. Surface plant at the Greenleaf mine, Luna County, showing sorting shed.



B. Surface plant at the Clum mine, Grant County.

The plan and elevation of the Lyda K vein and mine workings are shown in Plate 27. Shaft No. 2, the original exploratory shaft, was sunk vertically to a depth of 87 feet about 1927. At that time a drift was run 125 feet northeast on the 71-foot level, and a raise or stope carried to the surface a short distance southwest of the shaft. This shaft was deepened by Kinetic Chemicals to 240 feet, and a new level was established at 220 feet. At that point the shaft was about 10 feet to the southeast, or footwall, side of the vein. Two crosscuts were driven from the shaft through the vein, and drifts were run northeast and southwest in the hanging wall along the vein. Both the 71- and the 220-foot northeast drifts entered a low-grade siliceous section of the vein, which discouraged further advance. The southwest drift followed a vein 5 to 6 feet wide, carrying about 70 percent fluorite, to its face about 80 feet from the shaft.

The No. 1 or Higrade shaft was sunk in 1942 to a depth of 126 feet, and a level was started at 106 feet. This shaft is vertical, in the hanging wall, and at the 106-foot level is 25 feet from the vein. A drift was run 185 feet northeast from the shaft crosscut, and another about 325 feet southwest ; the latter was connected by two raises with the 71-foot level of the No. 2 shaft. The 106-foot level from the No. 1 shaft, as also the drifts from the No. 2 shaft, were driven in the country rock along one side of the vein. The country rock was drilled and broken more easily than the vein material and was free from the tendency of the vein to "ravel" and cave. A future advantage of this practice would be the ability to mine the vein completely without losing the level.

Early in the history of the property the No. 3 or westernmost shaft was sunk to a shallow depth. It was later deepened to 260 feet, with levels at 60, 120, and 240 feet. The 120-foot level is at a proper elevation to connect with the 220-foot level of the No. 2 shaft. The shaft is on the footwall side of the vein, which here dips about 75° northwest. A 30-foot crosscut on the 120-foot level, and an 80-foot crosscut on the 240-foot level, were required to reach the vein.

Besides this exploratory and development work, which permitted the vein to be examined and sampled at many points and furnished representative lots of ore for metallurgical testing, some diamond drilling was done. In 1937, six holes were drilled from the surface along the southern portion of the vein. They intersected it at depths as much as 260 feet below the surface. Although some information was obtained, and each hole intersected some ore about where expected, core recovery was so poor that little reliance could be placed on the results.

All shafts are timbered (except the No. 2 above the 71-foot level) and almost completely lagged. Each is provided with a skip compartment and a manway, respectively 42.5 by 60 inches and 28.5 by 60 inches, inside dimensions. Sets and posts are of 6- by 6-inch timber, skip guides of 4- by 4-inch, and platforms and lagging of 2- by 12-inch plank. The skips, interchangeable from shaft to shaft, are 36 by 58 inches in section.

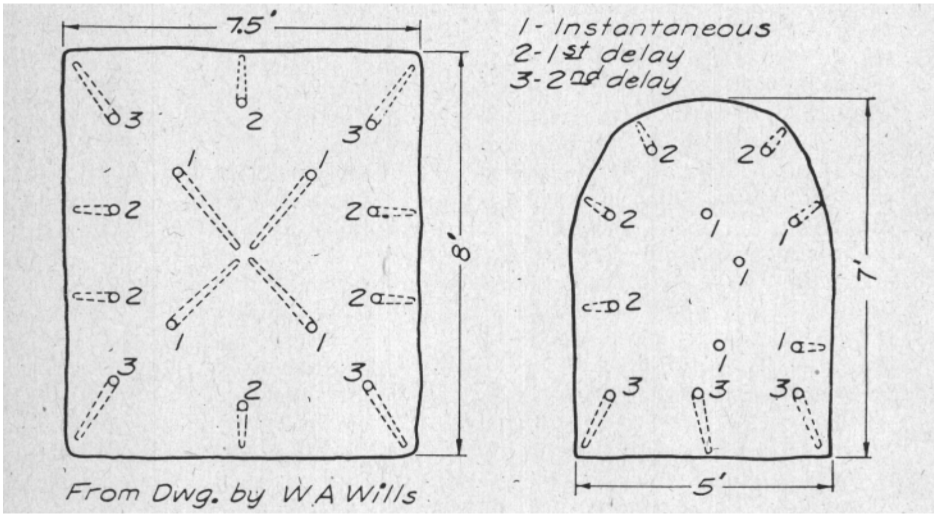


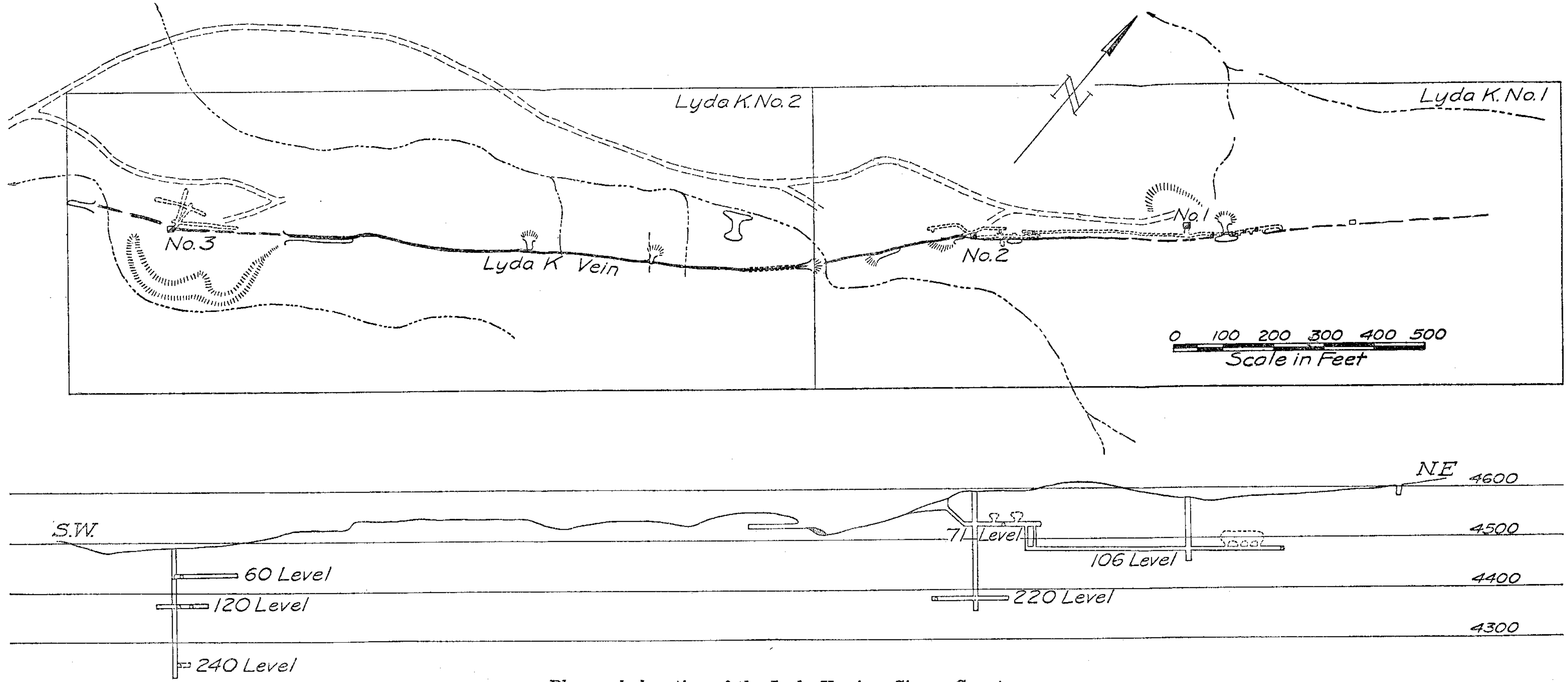
FIGURE 17.—Shaft and drift rounds, Lyda K mine.

A 14-hole round, 3 feet deep, is used in shaft sinking (Figure 17) . Drifts, which are untimbered excepting for a few "heavy" sections, are driven about 5 by 7 feet in the clear. A 12-hole round, 4 feet deep, diagrammed in Figure 17, is a typical drift round, although rounds are varied to meet varying conditions.

Forty-percent gelatin dynamite is used, with about 4 cartridges to the hole ; average powder consumption is 24.6 pounds for a 14-hole round and 21 pounds for a 12-hole round. Practically all blasting is done electrically.

Jackhammers weighing 45 and 55 pounds are used for sinking and drifting, and stopers for raising and in stopes. Tramming is done with 14- and 16-cubic-foot end-dump cars on 18-inch track. A 220-cubic-foot portable gasoline compressor furnishes air for drilling : it is provided with a 3- by 6-foot or 3- by 7-foot receiver. Air for ventilation is obtained from a displacement-type blower (6 cubic feet per revolution) driven by an automobile engine.

Two geared single-drum hoists, driven by automobile engines, have been used. One, powered by a 4-cylinder truck engine, has a 21-inch drum and is employed for sinking, using a



Plan and elevation of the Lyda K mine, Sierra County bucket and a half-inch rope. The other, with a $^{3}/_{4}$-inch rope on a 30-inch drum, driven by an 8-cylinder engine, is used in mining. A crushing and sorting plant was built at the No. 1 shaft in 1943, with the purpose of making some metallurgical fluorspar, which was in great demand at that time. Cars are hoisted to a platform about 9 feet above the shaft collar, and there dumped over a $1^{1}/_{2}$-inch grizzly, the oversize going to a 12- by 18-inch jaw crusher. Crusher product and grizzly undersize go to a $^{21}/2$-by 8 foot trommel with $^{1}/_{2}$-inch and $^{3}/_{4}$-inch openings. Trommel undersize is chuted into cars and stockpiled. The oversize passes onto a 24-inch picking belt 20 feet long, from which ore is picked by hand and thrown into a chute. From this it is drawn at intervals and screened ; the oversize is reduced in a 7- by 10-inch crusher ; and the ore is finally stored in 25-ton bins. The picking belt reject is trammed to a waste dump.

Extensive metallurgical research on Lyda K ore has led to the conclusion that acceptable acid-grade concentrate could be obtained with fair recovery, but only through a rather complex process. According to Gillson,[3] the problem is complicated by the presence of abundant fine quartz inclusions in some of the fluorite, and by decomposed rock or gouge that creates excessive slimes and makes froth control difficult in flotation. The solution appears to be to remove the objectionable gouge, and to separate the coarse fluorite from the more siliceous ore, prior to grinding. Then the high-grade product can be ground lightly, avoiding sliming, while the balance of the ore can be ground sufficiently fine to liberate the abundant very fine quartz.

The geology of the Lyda K mine is discussed on pages 163165. (See also Plate 22) .

MIRABAL MINE

The Mirabal mine, in the Zuni Mountains west of Grants, Valencia County (Plate 18) , was a small producer in the summer and fall of 1944, when the mine road was free of snow. From. April to November W. H. Heim, lessee of the property, shipped 300 to 600 tons of ore a month to the Los Lunas mill of the Zuni Milling Company. Most of this ore was produced by underhand mining on a single ore-shoot. Meanwhile, the same vein was developed by a low-level adit.

Plate 19 shows the status of mining and development on the north vein in November 1944, and a photograph taken some months earlier (Plate 25, B) shows the open stope on the main ore-shoot.

Work on the Mirabal property prior to 1944 consisted in part of irregularly spaced trenches across the north and south

[3] Gillson, Joseph L., personal communication.

veins, which served to locate the outcrops of minable ore-shoots. In addition, several open cuts had been carried to depths of 5 to 10 feet on the more promising shoots, an underground stope 12 feet high had been worked about 85 feet west from the bottom of a 50-foot shaft on the north vein, a 220-foot adit had been driven east on the north vein, and another had been run along the south vein.

Heim's work was done on the north vein only. He installed a portable compressor, built a headframe, equipped the shaft with a small gasoline hoist, and began mining. He also installed a compressor at the lower north vein adit, and began to drive the face of that working toward the main ore-shoot. This was done chiefly to develop a lower mining level, but the drift also explored several hundred feet of the vein. A considerable proportion of the material broken was shipped as mill ore, although no large shoot of high-grade ore was found. At the end of October 1944 the face had almost reached the expected position of the main ore-body.

Driving in this section of the North vein is a slow and costly operation, because the low-grade or barren vein material and silicified wall rock are extremely hard. Drilling is slow and bit consumption excessive.

Mining consists of "benching down" the floor of the stope. The ore is broken by vertical holes, spaced 2 to 3 feet apart, drilled with hand-held jackhammers. It is shoveled into buckets that are trammed to the shaft on dollies. From time to time the shaft is deepened to permit starting a new bench. As the vein is steep and the wall strong, no pillars or timbering are required to support the hanging wall, although support doubtless would be needed if the stope became much longer or deeper.

At the shaft collar, the ore is dumped onto a 2-inch grizzly and the coarse waste sorted out (Plate 28, A). Coarse and fine ore are trucked separately, by contract truckers, to the Zuni Milling Company's crushing and loading plant at Grants. The trucking rate for this 27-mile haul, over a fair to poor dirt road, is 10 cents a ton-mile.

Ten to twenty men were employed at various times ; during October and November, 1944, three or four of these were engaged in opening a new road to connect the mine with the railroad at Bluewater. This road would shorten the haul 10 or 12 miles. In October and November, mining was also carried on in the open cut about 400 feet east of the shaft. This was done by laying track in the cut and benching the ore down to the track level.

A discussion of the geology of the Mirabal mine is given on pages 179-183.

TWENTY-ONE AND TWENTY-SEVEN MINES

Two fluorspar deposits, the Twenty-one and Twenty-seven veins, on the Zuni Milling Company's property in the Zuni Mountains, Valencia County (Plate 18), are among the largest New Mexico producers. James Mallery and Vernon Taylor began an intensive and systematic program of prospecting and exploration in the district about 1938, employing at first a few men and later as many as 20. In December 1940, trenching was started on two promising veins, one in sec. 21 and the other in sec. 27, T. 9 N., R. 11 W.

Although bedrock is well covered in this wooded district (Plate 28, B) , the overburden in most places is not deep. Trenching to a depth of 3 feet is generally sufficient to expose vein outcrops, and the average trench depth on the Twenty-one and Twenty-seven veins is only about 18 inches. The decomposed granite soil is handled readily by pick and shovel. Very little blasting was done, though an effort was made to cut deeply enough into the vein to determine its true width. The Twenty-one vein was tested by trenches spaced at about 25-foot intervals for a total length of 2,700 feet, and the Twenty-seven vein for a comparable distance.

Few samples were taken for analysis from the Twenty-one vein, as this deposit was found to be of uniform high grade, with dense green massive ore and sharply defined walls ; the thickness of the vein was the only important factor to be determined. The trenches on the Twenty-seven vein were sampled before underground work was begun.

Several kinds of land ownership are involved in the district. Mineral rights on most odd-numbered sections have passed from railroad into private ownership ; some of the remaining area is public land, some is State land both with and without mineral rights, some is in the Cibola National Forest, and some is Indian land. The necessity for accurate location of the veins with respect to land boundaries and the determination of ownership was one of the important items of expense in the exploration program.

First mining on both veins was in open cuts. The entire length of the Twenty-one vein outcrop was stripped by a bulldozer, and mining was started near the bottom or on the side of almost every ridge whose slope was sufficient to gain a good height of face readily without sinking. This mining was done under labor contracts. Clean mining and careful sorting produced metallurgical-grade ore; James Mallery states that one 60-ton car of picked, washed lump ore contained 98.5 percent fluorite and only 0.4 percent silica.

Although both veins strike northeast and dip 55° to 85°

southeast, they are about a mile apart and are very different from a mining viewpoint (see pages 187-190) . The Twenty-one vein is richer, more regular, and narrower, and it has better walls.

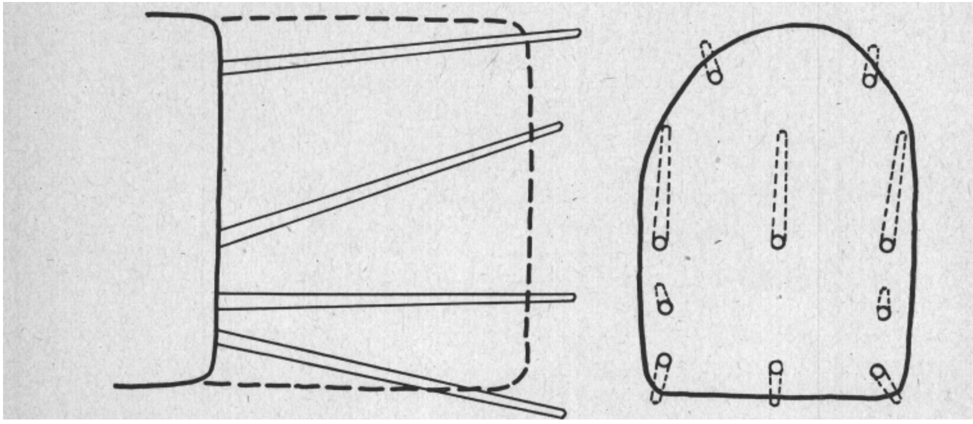


FIGURE 18.—Drift round, Twenty-seven mine.

Its ore is softer, breaks more finely, and tends to pack in raises. The hanging wall of the Twenty-seven, on the other hand, is blocky in many places and generally requires support. Stoping widths in the Twenty-one vein range from 18 inches to 8 feet, and average about 30 inches ; corresponding widths for the Twenty-seven vein are 10 inches to 22 feet, with an average of 3 feet.

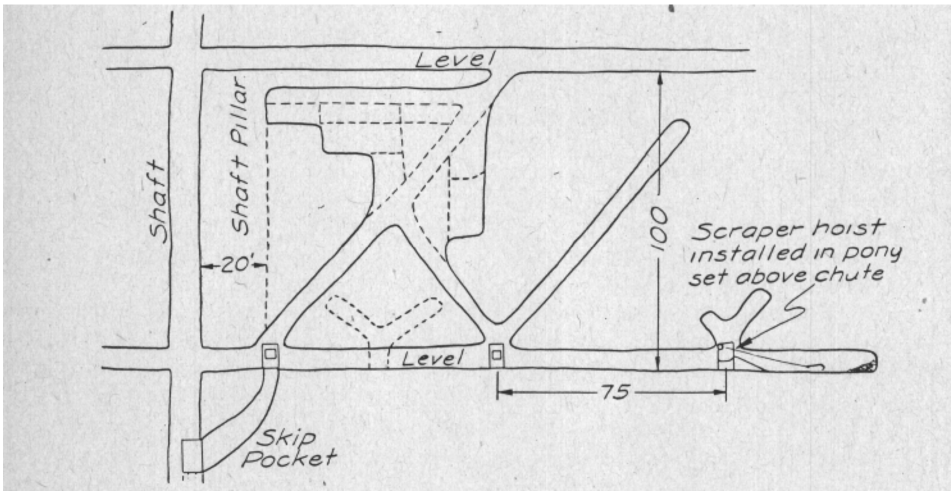


FIGURE 19.—Diagram of former stoping method, Twenty-one mine.

In the summer of 1942 an adit was started on each vein, in preparation for underground mining. Both adits were driven "on the vein", and were made about 5 by 7 feet in section. The adits were timbered only where necessary for stope preparation, as the ground in both veins ordinarily stands safely over drift widths. Drifting was done with medium-weight mounted jackhammers, using $^{7}/_{8}$-inch hexagonal steel with detachable bits. The usual drift round consisted of seven to ten 6-foot holes. A 10-hole round is shown in Figure 18.

Hand shoveling has been eliminated in sub-level drifts and stopes. A small Eimco-Finlay air-powered track-mounted loader is used in some drifts in the Twenty-seven mine. Drifts are driven by 75-foot lengths, this distance being the standard interval between stope raises. A double-drum compressed-air scraper

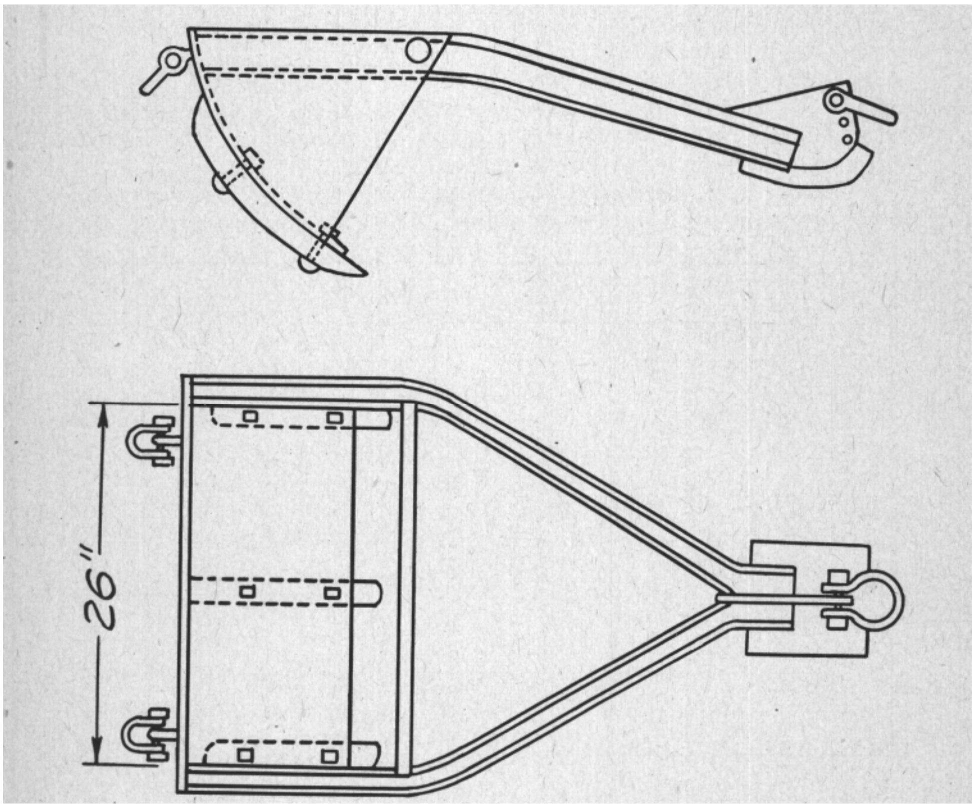


FIGURE 20.—Scraper for drifts and stopes, Twenty-one and Twenty-seven mines.

hoist having a 1,000-pound rope pull was set up in a pony set above the farthest-in chute, and a scraper slide was built to discharge directly into the chute, as shown in Figure 19. The scrapers, which are 28 inches wide and weigh about 200 pounds, are made in the mine blacksmith shop. Teeth are provided for use on coarse, hard ore ; otherwise a straight lip is satisfactory. The design of the scrapers is shown in Figure 20.

For the development of levels at 100- to 150-foot intervals below the adit levels, shafts have been sunk on both veins. These are full-timbered two-compartment inclined shafts, each containing a manway and a skip compartment. Figure 21 shows the timbering of the Twenty-seven shaft. Both shafts were started down on the vein, and the Twenty-seven shaft continued so to the third level. The Twenty-one shaft went a few feet into the foot-wall, as the vein 'flattened slightly ; farther down, the vein came back to the shaft. Twenty-foot shaft pillars have been left on both sides of the shafts.

Different stoping methods have been developed for the two mines. The Twenty-one vein lends itself well to open stoping, whereas the Twenty-seven vein requires timbering or some other support except in a few of its thinner parts.

The system of stoping illustrated in Figure 19 was used for some time in the Twenty-one mine. The raises were driven the

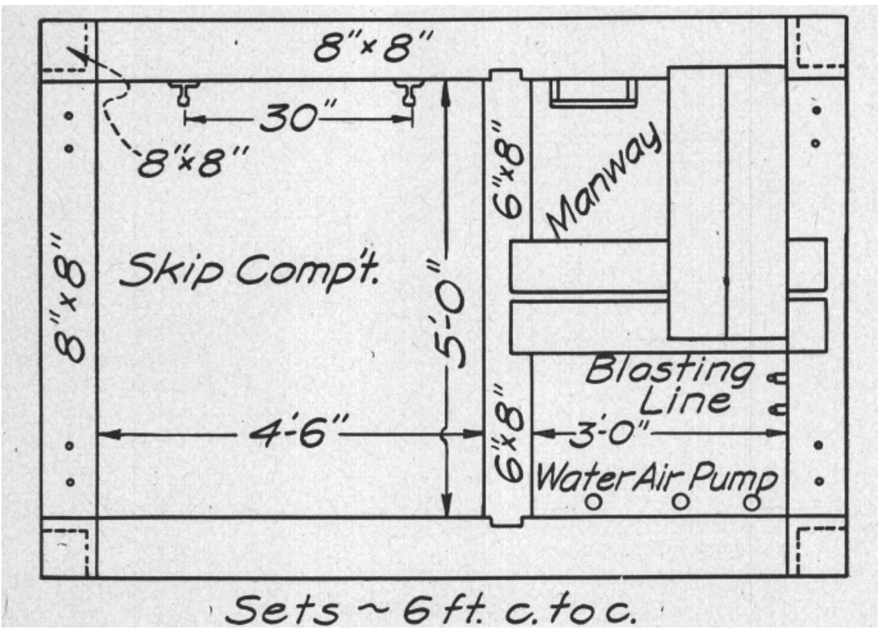
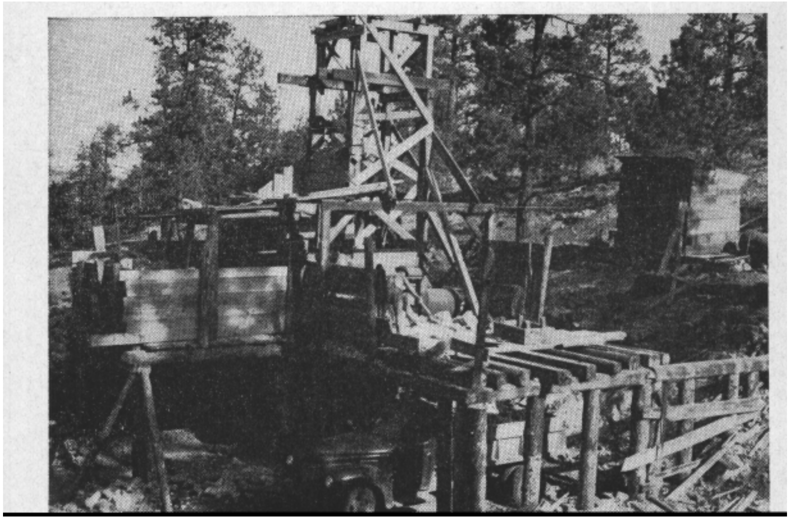
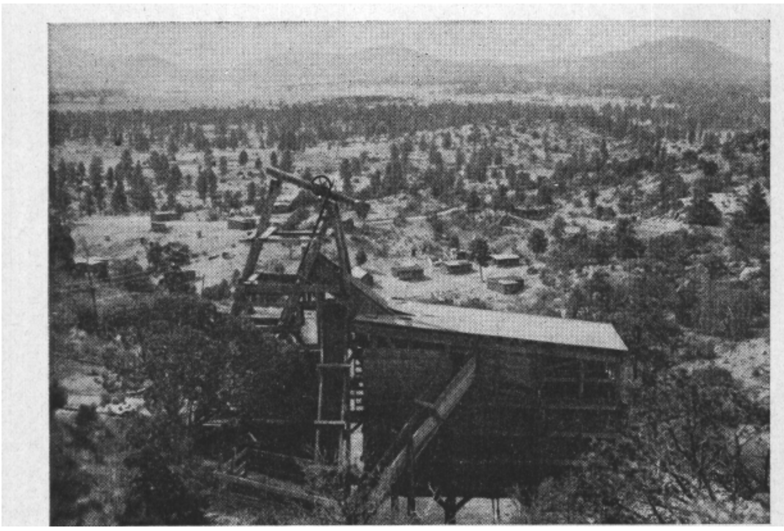


FIGURE 21.—Timbering in shaft, Twenty-seven mine.



A. Headframe and sorting platforms at the Mirabal mine, Valencia County. Truck is loading coarse ore.



B. Headframe and sorting shed at the Twenty-seven mine, Valencia County.

full width of the ore, and just steep enough to cause the broken ore to slide freely to the chutes. After a pair of raises "holed through" to the level above, various methods of stoping were used to remove the inverted trianglar block of ore above them. Underhand mining (benching down) was then carried on from a sublevel driven about 12 feet below the upper level ; or 4- to 6-foot rounds were drilled and blasted from the side of the block, by drilling horizontal holes with hand-held jackhammers ; or stopers were used to mine upward from the bottom of the raise. The block of ore under the raises and between chutes was benched down by underhand stoping. When the slope became too flat for the ore to run to the chutes, a scraper was at times installed ; but the more common procedure was to install a chute in the middle of the block, through which much of the remaining ore was pulled out. Solid pillars were left above the drifts where the vein was narrow. Stulls were used in these stopes chiefly to hold the working platforms and to support occasional loose hanging-wall slabs.

Subsequently, inclined raises were abandoned in favor of vertical raises, the distance between raises was increased to 100 or 150 feet, and scrapers were used in the stopes to pull the ore to the chutes.

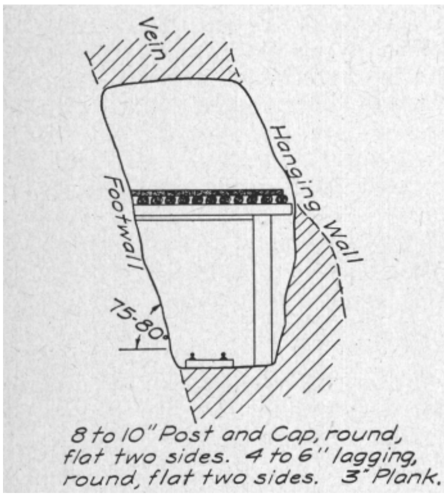


FIGURE 22.—Drift set, Twenty-seven mine.

In the Twenty-seven mine a modified square-set method is used in most of the stopes, with 7-foot floors carried on "half-sets," i. e., sets whose caps are blocked against the walls and supported by one or more posts (Figure 22) , but usually lacking girts. Figure 23 illustrates a stope that has been mined about halfway to the level above. No more than drift width of ore is removed on the level, the stope being silled out and floored to the full width of the vein on the second floor. Chutes are installed at 100-foot centers. Drilling is done from the top floor of the stope, and drag scrapers are used on the floor below to pull the broken ore to the chutes.

Little sorting is done underground. Waste sorted at the surface is returned to the stopes through waste raises to fill worked-out stopes.

Thirty-percent ammonia gelatin dynamite, in 7-inch cartridges, is used throughout the mines. The low-strength explosive and short cartridges were adopted because of the tendency of most miners to break the ore finer than desirable for effective sorting.

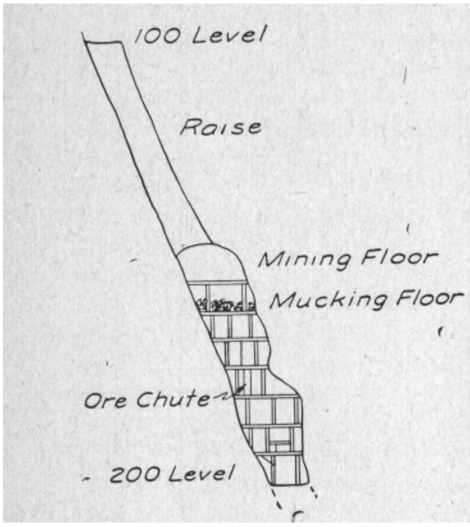


FIGURE 23.—Section through stope, Twenty-seven mine.

Underground tramming is done in 18-cubic-foot roller-bearing end-dump cars, which carry about a ton of ore when heaped full. Each level has two ore pockets, one opening on either side of the shaft, directly under the first stope chute.

The skips are of the 4-wheel self-dumping type. The skip in the Twenty-one mine holds 11/4 tons ; the one in the Twenty-seven mine holds 3/4 ton. They dump onto flat-sloping grizzlies, where the coarse ore is picked out of the oversize and thrown into a coarse-ore bin. The coarse waste is similarly picked out, and is chuted back into the mine (Figure 24) . The grizzlies are made of inverted rails, with spacing of about 2 inches.

Coarse and fine ore are trucked separately, under contract, to the railroad at Grants, a road distance of 20 miles. At Grants the fine ore is dumped directly into railroad cars. The coarse ore is dumped into one of two bins, from which it is fed through a 9- by 36-inch crusher, set to about 3 inches, onto a conveyor belt and into the cars.

LOS LUNAS MILL

The Los Lunas fluorspar mill of the Defense Plants Corporation (Plate 29, A) was built in 1943. Designed by Denver Equipment Company, it was built under contract by the Murch. Jarvis Company, and is operated by the Zuni Milling Company. This company, originally a subsidiary of Peerless Oil and Gas Company, was sold late in 1943 to the Shattuck Denn Mining Company, which at the same time acquired the mining properties of the Navajo fluorspar mines, south of Grants. Various additions and changes in equipment were made after the completion of the mill.

The mill is situated on a straight spur about 200 yards off the line of the Santa Fe Railway, a quarter of a mile south of the town of Los Lunas. It is housed in a steel building about 80 feet square. The railroad spur, built on an earth ramp, enters the building about 20 feet above the main floor level, passes over the ore bins, and is carried about 150 feet beyond the building on a trestle. A steel 100,000-gallon water-storage tank is beside the track at the upper end of the ramp.

Ore is received in 50- or 70-ton hopper-bottom cars, from which it is dumped into a 150-ton parabolic steel bin with a single discharge gate. Two 22-inch inclined conveyors carry the ore to a vibrating screen above the 9- by 18-inch Allis-Chalmers jaw crusher. Screen undersize, minus $^{3}/_{4}$-inch, by-passes the crusher and joins the crusher product in the boot of an elevator. From the top of the elevator the fine ore is chuted into a 250-ton bin. This bin, which adjoins the coarse-ore bin below the track, is about 35 feet long and has two discharge gates, so that some segregation of different ores is possible if desired.

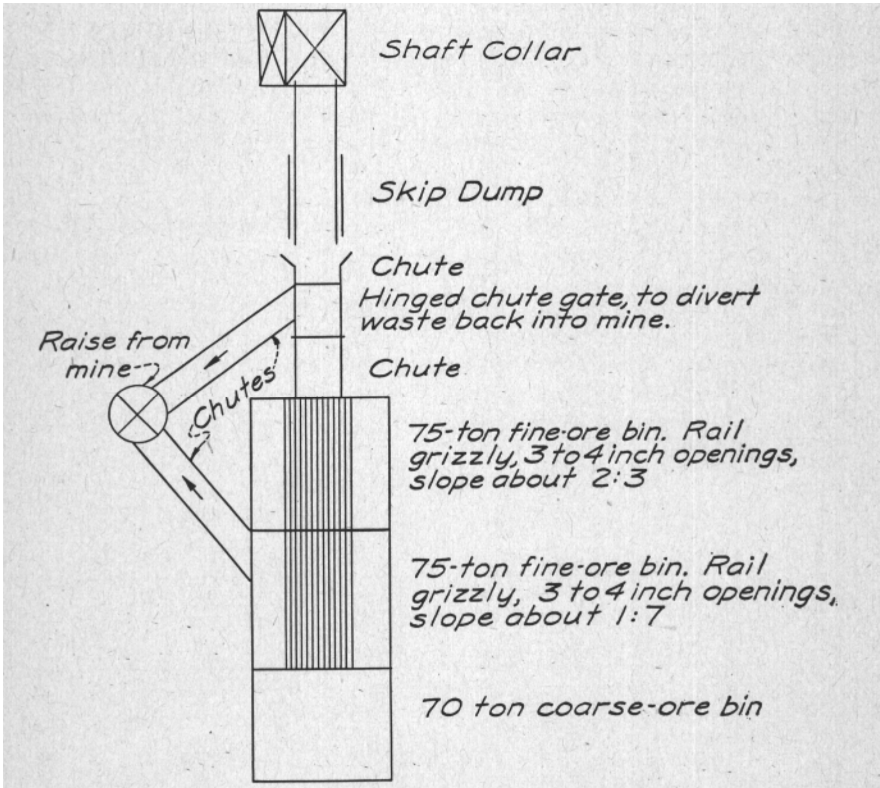


FIGURE 24.—Diagrammatic plan of sorting platform and ore bins, Twenty-seven mine.

From the fine-ore bin, 16-inch conveyor belts move the ore to either of two ball mills. One of these is a Denver 4- by 5-foot mill, the other a Marcy No. 64 grate-discharge mill. Both mills operate in closed circuit with 42-inch Akins classifiers.

Classifier overflow, minus 65-mesh and about 45 percent minus 200-mesh, is pumped to a Denver 5- by 5-foot conditioner, from which it flows by gravity to the rougher cells. The latter are six No. 21 (42-inch) Denver Sub-A machines, as are the six cells making up the first cleaners. The second, third, fourth, and fifth cleaners comprise 16 No. 18 (32-inch) Denver Sub-A cells, in two banks of eight each. Figure 25 shows the flow of final cleaner flotation products in effect in November 1944.

Flotation tailings are pumped to a wooden launder which carries them to the tailings ponds east of the mill. No water was being reclaimed from tailings at the time the mill was visited, although this had been done when water was scarce. The re-use of tailing water affects flotation results adversely.

Concentrates are pumped to a Dorr 20- by 8-foot thickener, thence to a Denver 4- by 5-foot filter. Filter cake drops directly into the hot end of a Denver 4- by 29-foot drier, which is gas-fired and operates under forced draft. The exhaust air, at a temperature of about 150° C., is passed through a cyclone-type dust separator.

A bucket elevator raises the kiln and cyclone dust to the top of the steel concentrate bin. From this bin the concentrate is piped by gravity into boxcars or covered hopper cars for shipment.

A gas-burning steam boiler outside the mill building furnishes steam to heat the pulp in the flotation cells. This is to be converted to a direct water heater for supplying warm water to all make-up points throughout the circuit.

All equipment is driven by individual electric motors. Power

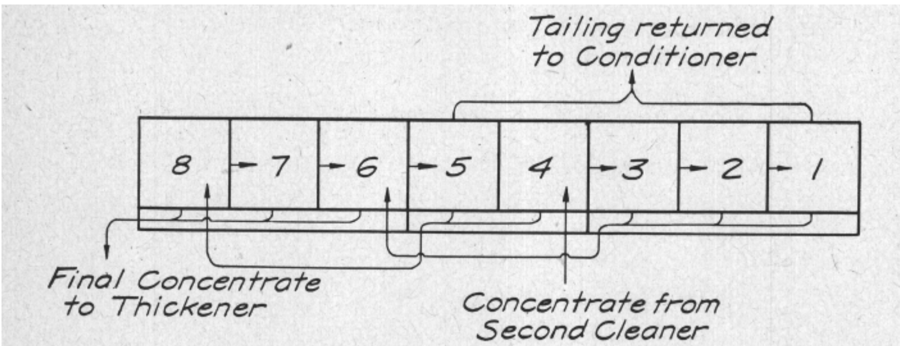
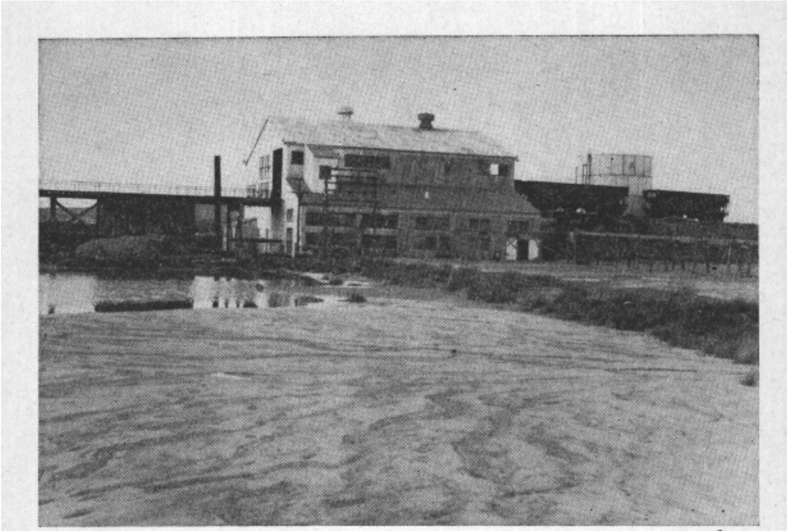


FIGURE 25.—Diagram of final cleaner cells, Los Lunas mill.



A. Los Lunas fluorspar mill of the Zuni Milling Company.

B. Gila fluorspar mill of the Metals Reserve Corporation.

is purchased from the Albuquerque Electric. Company. Some water is purchased from the town of Los Lunas, the balance being obtained from a well on the property. Fresh-water requirements are four times the tonnage of ore put through the mill. The water is not treated, although a zeolite water-softener was part of the original equipment of the mill.

The Los Lunas mill has a capacity of 4 to 6 tons per hour, or roughly 150 tons per day. The smaller ball mill is not necessary in reaching this capacity, and is not in frequent use since installation of the larger mill. Filtration and drying were the "bottlenecks" at the time the plant was visited.

The mill feed is sampled manually at 15-minute intervals; concentrate and tailing are sampled automatically at the same interval.

Ore is received chiefly from two mines in the Grants district; smaller tonnages are received more or less regularly from a third mine. The three ores differ sharply in grade and in milling characteristics, and the mixing obtained in railroad cars and mill bins does little to prevent severe fluctuation in the flotation feed. The fluorite content of the mill feed commonly ranges from 35 to 55 percent. Lime (calcite) in the mill feed ranges from a usual 8 to 10 percent to an occasional high figure of 35 percent. Recovery varies day by day from 60 to 75 percent.

Flotation reagents in use in November 1944 were B-23 alcohol frother, oleic acid collector, sodium silicate disperser, and quebracho lime depressant. Soda ash was used for pH control. The best flotation temperature was about 100° F.

Change room and showers, as well as supply store rooms, are partitioned and ceiled off along one side of the mill building. The analytical and metallurgical laboratories are in a separate small building. Complete facilities are available for small-scale ore testing. All analyses for fluorspar are made by the distillation method.

GILA STOCKPILE AND MILL

In anticipation of a critical shortage of metallurgical-grade fluorspar, the Metals Reserve Company in June 1943 authorized the International Minerals & Chemical Corporation, as its agent, to build and operate a fluorspar mill at Gila (Plate 29, B). At the same time and through the same agency, Metals Reserve established a fluorspar buying office and stockpile at the millsite, where ores amenable to concentration in the proposed plant were purchased. Approximately 50,000 tons of mill ore was delivered to this stockpile in the course of 2 years.

A buying schedule was published, which at the start offered 14 cents a unit for all ore of 50 percent or higher fluorite content, ,with a deduction of 0.3 cent a unit for each percent below 50, down to the minimum acceptable grade of 40 percent. Very soon the price was raised to 17 cents, with a 0.4-cent penalty. This price, which held until September 1944, covered most of the period of mill operation. In September the price was reduced to 15 cents, and remained at that level into 1945. The specifications, terms, and purchasing procedures under the last schedule were as follows.

Metals Reserve Company
Washington 25, D. C.

INFORMATION CONCERNING PURCHASE OF DOMESTIC FLUORSPAR ORES AT GILA, NEW MEXICO

(This Circular supersedes in all respects Circular dated October 19, 1943)

Beginning January 15, 1945, Metals Reserve Company (herein sometimes called "Buyer") has arranged to purchase, from the producer, fluorspar ores suitable in form, content, and quality for treatment by the processes to be used in its plant at Gila, New Mexico. This is a continuation of the Purchase Program established to purchase small tonnages of ore from the different producers by International Minerals & Chemical Corporation, Agent, Metals Reserve Company. The terms and provisions of this Circular will be effective until June 30, 1945.

DEFINITIONS

The term "ton" means a short ton of 2,000 pounds, avoirdupois, dry weight.

The term "unit" means 0.01 (one per cent) of a ton.

The term "lot" means such quantity of fluorspar as shall be delivered during any single day, except that the minimum weight of such a lot shall be 10 tons and such minimum weight may be delivered over a period of more than one single day.

QUALITY

The ore shall contain not less than 40% calcium fluoride (CaF_2) and shall be suitable in form, content and quality for treatment by the process known in the fluorspar trade as the "sink-and-float" method, unless otherwise agreed upon between Buyer and Seller. Buyer shall have the right, at its sole option, to reject any ore which contains less than 40% calcium fluoride (CaF_2) or which Buyer shall, in Buyer's sole judgment, determine to be unsuitable for treatment by the said "sink-and-float" method.

DELIVERY

Delivery of fluorspar shall be made by wagon or truck at Seller's cost unloaded at Buyer's stockpile at its plant at Gila, New Mexico.

WEIGHING, SAMPLING AND ANALYSIS

Buyer shall, without cost to Seller, provide adequate facilities for unloading truck and wagon deliveries and for weighing and sampling the fluorspar so delivered. (Wagons and trucks are to be weighed light and loaded without cost to Seller). A representative sample of each lot of fluorspar delivered hereunder shall be taken by Buyer at Buyer's expense at the time of weighing for determination of moisture content and analysis. Buyer's weights and moisture determination shall be final and the basis of settlement hereunder. Seller may, at its expense, be represented at such weighing and sampling. A representative pulp of the sample of each lot shall be divided into three parts and distributed as follows: one to Buyer, one to Seller upon his request, and one held as an umpire sample. The umpire sample shall be packaged, sealed, dated, initialed and marked for identification by the respective representatives of Buyer and Seller and shall be held by Buyer. Buyer shall have his sample analyzed by an analyst selected by Buyer. The results of Buyer's analysis shall be final and the basis of settlement hereunder, unless within ten days after date of sampling Seller shall deliver to Buyer the results of Seller's analysis (obtained at Seller's expense) showing a variation from Buyer's analysis of more than 0.5% in calcium fluoride content.

If such variation does not exceed 1.5% in calcium fluoride content, the exact mean of Buyer's and Seller's results shall be final and the basis of settlement hereunder. In case the analysis of the Buyer and the analysis of the Seller show a variation greater than 1.5% in calcium fluoride content, the umpire sample shall immediately be sent by Buyer to an umpire selected from the following analysts : Critchett & Ferguson, El Paso, Texas; Hawley & Hawley, Douglas, Arizona; and Ira Wright, Silver City, New Mexico. In case the umpire's analysis falls between the analysis of Buyer and the analysis of Seller, then the umpire's analysis shall govern in settlement hereunder: otherwise the analysis of the party nearer to the umpire's analysis shall govern in settlements hereunder. The cost of the umpire's analysis shall be paid by the party whose analysis is further from the umpire's analysis.

PRICE

For ore containing 50% or more of calcium fluoride (CaF_2) delivered hereunder, Buyer shall pay the base price of 15 cents per unit (one percent) of calcium fluoride (CaF_2) contained therein, and said base price shall be reduced by 0.4 cent per unit (one percent) of contained calcium fluoride (CaF_2) for each 1% of calcium fluoride (CaF_2) under 50% contained in said ore, fractions computed pro rata in all cases.

PAYMENT

Promptly after the receipt of analysis and moisture determination by the Buyer, the settlement sheet for each lot together with a check in payment will be mailed by Buyer to Seller. (Although lots may be delivered in one or more loads, payment therefor will be made only when the aggregate deliveries equal or exceed the 10-ton lots stipulated).

Sampling was done by hand, taking 25 to 35 pounds of ore from each truckload after it was dumped on the mill stockpile. While the mill was in operation, analyses were made in the analytical office at the mill, where the distillation method was used. Before ore was accepted from each mine, its amenability to treatment was determined by sink-float tests.

The Gila mill was one of the first in the country to treat fluorspar ore by the sink-float, or heavy-medium separation, process. The following description of the mill was written about August 1, 1944.

The crushing section of the mill and the powerhouse annex are of concrete and frame construction, but the main concentrating section is of concrete and steel. The mill is situated on the side of a small flat-topped hill, at the bottom of which is a wide level valley.

A double-drum 15-horsepower electric hoist and drag scraper pull ore from the stockpile onto a 9-inch grizzly over a

10-ton coarse-ore bin at the head of the mill. A 3- by 5-foot apron feeder delivers the ore, over a 2-inch grizzly, to a 9- by 16-inch primary jaw crusher, from which an 18-inch conveyor moves the minus 2-inch products to the secondary crusher. The latter is an 18-inch Telsmith "Intercone", driven by a 20-horsepower motor. It is protected to some degree against tramp iron by a stationary magnet of the chute-bottom type, and fines are bypassed through a $^3/_4$-inch grizzly in the feed chute. The cone is set at $^5/_8$-inch. The crushed ore is conveyed by a 16-inch belt to a bin with an effective capacity of about 100 tons.

From the fine-ore bin a belt feeder delivers ore to the wash ing and sizing screen, a Telsmith rotary scrubber and double trommel with high-pressure sprays in the scrubber sections. The inner trommel serves chiefly to reduce wear on the outer screen, which is perforated with 1/2- by $3/_4$-inch slots.

The washed screen oversize is chuted directly to a 10-foot Wemco heavy-medium cone. The heavy medium consists of ferrosilicon and water. For the initial charge, 100-mesh ferrosilicon is used, make-up additions being about 65-mesh. Stirrer arms in the cone are rotated at about 6 revolutions per minute by a 3-horsepower motor. An air lift, which raises the sink product from the bottom of the cone, is furnished with air at a pressure of 40 pounds by a Sullivan electric-driven air-cooled compressor.

The density of the medium is the critical factor affecting the operation of this machine. In August 1944 this density ranged from 2.68 to 2.71 near the top of the cone, and from 2.85 to 2.90 near the bottom. Some months later, to meet changed characteristics of mill feed, the density was raised appreciably. Ferrosilicon consumption was slightly more than 2 pounds per ton of ore milled.

Two 3- by 10-foot Allis-Chalmers low-head vibrating screens in series receive float-and-sink cone products in parallel streams on opposite sides of longitudinal partitions. The screen cloths, protected by $^3/_8$-inch screens, have 0.069-inch by $^3/_8$-inch openings. On the first half of the first screen, where no sprays are used, much of the ferrosilicon adhering to the concentrate and tailing is drained off into a sump, from which it is returned directly to the cone. Over the balance of the screens, water sprays remove the rest of the heavy medium, which is then pumped to the reconditioning section of the mill. Tailing is conveyed to a .dump ; concentrate is raised by bucket elevator to a 165-ton bin, from which it is trucked to the concentrate stockpiles.

Diluted medium passes over magnetizing blocks to a 16- by 6-foot thickener, thence to two Crockett-type Dings magnetic separators, one 12-inch and one 24-inch, in series. The thickener overflow is pumped by a 2-inch Ingersoll-Rand centrifugal pump to the sprays over the vibrating screens. Tailing from the magnetic separators goes to waste.

A 30-inch Wemco "densifier" receives the cleaned ferrosilicon, and regulates both density and quantity of heavy medium fed back ,to the cone. A 6-inch by 9-foot screw conveyor moves the ferrosilicon from the densifier to a demagnetizing coil, whence it is pumped into the cone, thus completing the circuit.

The trommel undersize is dewatered and conveyed to the jigs by an Akins-type classifier, the slime overflow being laundered to the tailing pond.

Two 4-compartment 18- by 32-inch Ellis-type Denver jigs were installed, but normally only one of these is used. The hutch screens have $^1/_8$- by $^5/_8$-inch openings and are bedded with coarse fluorspar. The jigs are operated at about 170 revolutions per minute. Tailing is sent to the dump by launder, while the four hutch products are combined, dewatered in a drag classifier, and chuted into the concentrate bucket elevator.

Water is pumped from two shallow wells on the property into a 65,000-gallon steel tank above the mill. Some water is reclaimed from the tailing pond. The balance, which flows away from the pond, is used for irrigation on a farm below the mill. Water consumption was about 275 gallons per minute; of this only about 225 gallons was new water.

Power is supplied by two 8-cylinder 167-horsepower 85-kilowatt Caterpillar diesel generators. A 195-horsepower Waukesha-Hesselman diesel is installed for standby purposes.

Operating rate of the mill was about 14 tons an hour, for $15^1/_2$ hours daily, 6 days a week, or approximately 5,400 tons a month. Treating 55 to 60 percent ore, the mill had a daily output of 95 to 100 tons of concentrate containing about 86 percent fluorite and 9 percent silica.

Individual performances of cone and jigs varied greatly with different ores, and were not readily determined. The following operating data were believed typical of July and August, 1944, which was perhaps the most successful period of the year. About 70 percent of the trommel feed was plus $^1/_8$-inch and went to the cone. Cone recovery was about 75 percent, in the form of an 85- to 87-percent concentrate; cone tailing was about 25 percent fluorite. About 30 percent of the feed was minus 1/8-inch and was deslimed and jigged; it was appreciably richer than the cone feed. Jig recovery was 55 to 60 percent, in the form of an 85-percent concentrate; jig tailing and slimes together averaged about 45 percent fluorite.

Thirty-one men were employed, including those engaged in receiving and sampling ore, but excluding contractors who trucked concentrate to stockpiles and bulldozed coarse tailing away from the conveyor.

PART 3.-USES AND MARKETING OF FLUORSPAR

PART 3

USES AND MARKETING OF FLUORSPAR

By

A. D. HAHN

Formerly Professor of Mining, New Mexico School of Mines

The bulk of the fluorspar produced in the United States is consumed by the steel industry, 60 to 70 percent of the total amount being of metallurgical grade (Figure 1). The material should run 85 percent calcium fluoride, not more than 5 percent silica, and not more than 0.3 percent sulfur, although, at some western steel plants, spar carrying as little as 80 percent calcium fluoride with 6 to 7 percent silica has been accepted. A sliding scale is used by some manufacturers, based on the fact that one part of silica requires two and one-half parts of fluorspar to flux it. Thus a fluorspar containing $87^1/_2$ percent calcium fluoride and 6 percent silica is equivalent in fluxing power to one containing 85 percent calcium fluoride and 5 percent silica.

In the basic open-hearth manufacture of steel, the hearths are lined with magnesite ($MgCO_3$) or dolomite ($CaMg(CO_3)_2$), and limestone or dolomite also forms part of the fluxing charge. A large part of the sulfur in the molten iron combines to form a calcium sulfate in the slag. Such a basic slag is stiff and viscous ; therefore an average of 8 pounds of fluorspar per ton of steel is used to make the slag more fluid and to allow it to take up the sulfur and phosphorous more readily. The presence of any sulfur in the fluorspar is undesirable, as this sulfur might be reintroduced into the molten steel.

Foundries use 3 percent of the fluorspar produced. The lump form of spar is preferred for this purpose, and some foundries will accept lumps as much as 12 inches in diameter. Electric steel plants use 14 pounds of fluorspar for each ton of steel charged into the furnace. Minor amounts of fluorspar are used as flux in many metallurgical operations.

A large part of the fluorspar produced in New Mexico in 1944 was of metallurgical grade, and the bulk of this production was shipped to Pueblo, Colorado.

The second important use of fluorspar is in the manufacture of hydrofluoric acid, which absorbs 25 to 30 percent of the total fluorspar output (Figure 1). Consumers buying acid-grade concentrate demand a product containing 97.5 percent CaF_2, with a minimum CaF_2 content of 97 percent. A penalty of 3 percent of the purchase price for each unit of CaF_2 below 97.5 percent is assessed against the seller. Correspondingly, a premium of 3 percent of the purchase price is paid for each unit of CaF_2 above 97.5 percent. In those cases where the buyer's and the seller's analyses for fluorspar content do not agree, it is arranged that a third analyst, called an umpire, satisfactory to both parties, shall analyze the shipment; settlement is then made on the umpire's result.

In the aluminum industry, hydrofluoric acid is used in the manufacture of artificial cryolite and in the production of aluminum fluoride. These compounds are components of the electrolytic bath in the aluminum reduction cells. The acid is also used in the manufacture of synthetic catalytic compounds that are said to increase the yield of gasoline as much as 25 percent in the refining of petroleum products ; much of New Mexico's 1944 production was sold as acid-grade concentrate to the oil-refining industry at Houston, Texas.

Hydrofluoric acid is the key fluorine-bearing chemical used in the manufacture of inorganic and organic fluorides. From these and from the silicofluorides are derived many industrial fluorine compounds, including insecticides, preservatives, and dyestuffs. A new demand is rapidly being developed for a refrigerating medium known as "Freon" or "F-12". This synthetic organic compound, dichlorodifluormethane, is reported to be nonexplosive, non-inflammable, and practically non-toxic. This is the gas that has been used in a mosquito bomb by the United States armed forces ; it kills all insects within a few minutes and lasts 20 times as long as an ordinary spray.

In the chemical industry fluorspar is used in the extraction of potassium from feldspar and from portland-cement flue dust, and to facilitate the fusion and contact of the ingredients in the manufacture of calcium carbide and cyanamide. Chromium fluoride, CrF_3, made when chromium oxide salts are acted upon by hydrofluoric acid, is used as a mordant in dyeing wool. There is no injurious action by chromium fluoride on either wool fibre or dyestuff. On account of the insolubility of the alkaline earths, soluble salts of hydrofluoric acid, especially sodium fluoride, have been used as softening agents for boiler water.

In the ceramics industry fluorspar is of value in the manufacture of enamel ware. Fluorspar is fused with other ingredients, including feldspar, borax, soda ash, silicia, cryolite, and sodium nitrate, to produce a material called "frit". This is then coated on the ware to be enameled and is fused in an enameling furnace. There is an increasing demand for enameled commodities in a great variety of uses. Formerly, the chief outlet was in the form of sanitary and cooking ware. Then the use broadened to include vitreous-enamel signs, stoves, and refrigerators, and dairy, canning, and chemical equipment. Expansion of these uses has included parts for buildings. The future possibilities for enamel ware are almost unlimited.

Part of the demand for fluorspar in the ceramics industry is due to its value in the manufacture of opalescent, opaque, and colored glass.

There are numerous minor uses for fluorspar and its derivatives, such as in the frosting of electric light bulbs, in the pickling of metals, in chromium plating, and in the etching of glass. Magnesium fluosilicate in solution is applied to the surface of cement roads and walls to protect them from weathering. Comparatively small quantities are used as a paint pigment, and as a binder for constituents of emery wheels. Some fluorspar is used in coating welding rods and in the manufacture of carbon electrodes.

A small quantity of fluorspar is used for optical purposes, such as correcting the color and spherical-aberration errors in lenses of spectroscopes, microscopes, and small telescopes. Physical tests are required for use in optical purposes. The National Bureau of Standards requires that the spar must be as clear as glass and free from cloudiness, inclusions, and cracks or incipient cleavage marks. Colorless material is most desirable, but material faintly tinged with yellow or green may be of value. Jewelry and ornaments have been made from colored fluorspar.

Consumers of fluorspar in steel plants and iron foundries are listed in Tables 39 and 40.

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS

Name of consumer	Address	Location of plant
ALABAMA:		
Republic Steel Corporation	Cleveland, Ohio	Alabama City
Kilby Steel Company	Anniston	Anniston
Connors Steel Company	Birmingham	Birmingham
Tennessee Coal, Iron and Railroad Company	Birmingham	Ensley, Fairfield
CALIFORNIA:		
Alloy Steel & Metals Company	Los Angeles	Los Angeles
Warman Steel Casting Company	Huntington Park	Los Angeles
American Brake Shoe & Foundry Company (American Manganese Steel Division)	New York, N. Y.	Los Angeles, Oakland
Pacific States Steel Corporation	Niles	Niles
General Metals Corporation	Oakland	Oakland
Judson Steel Corporation	Oakland	Oakland
Columbia Steel Company	San Francisco	Pittsburgh, Torrance
Bethlehem Steel Company	Bethlehem, Pa.	South San Francisco, Vernon (Los Angeles)
National Supply Company	Pittsburgh, Pa.	Torrance
COLORADO:		
American Brake Shoe & Foundry Company (American Manganese Steel Division)	New York, N. Y.	Denver
Colorado Fuel & Iron Corporation	Pueblo	Pueblo
CONNECTICUT:		
Farrel-Birmingham Company	Ansonia	Ansonia
Stanley Works (American Tube & Stamping Plant)	New Britain	Bridgeport
DELAWARE:		
Worth Steel Company	Claymont	Claymont
American Brake Shoe & Foundry Company (American Manganese Steel Division)	New York, N. Y.	New Castle
DISTRICT OF COLUMBIA:		
Naval Gun Factory	Washington	Washington
GEORGIA:		
Atlantic Steel Company	Atlanta	Atlanta
National Traffic Guard Company	Atlanta	Atlanta
Glover Machine Works	Cordele	Cordele
Le Tourneau Company	Atlanta	Toccoa

[a] From a list by the U. S. Bureau of Mines, Metal Economics Division.

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS (CONTINUED)

Name of consumer	Address	Location of plant
ILLINOIS:		
Laclede Steel Company	St. Louis, Mo.	Alton
Crane Company	Chicago	Chicago
Kensington Steel Company	Chicago	Chicago
Pettibone Mulliken Company	Chicago	Chicago
American Locomotive Company (Railway Steel Spring Division)	New York, N. Y.	Chicago Heights
American Brake Shoe & Foundry Company (American Manganese Steel Division)	New York, N. Y.	Chicago Heights
Columbia Tool Steel Company	Chicago Heights	Chicago Heights
Union Malleable Iron Company	Moline	East Moline
American Steel Foundries	Chicago	East St. Louis, Granite City
General Steel Castings Corporation (Commonwealth Division)	Eddystone, Pa.	Granite City
Granite City Steel Company	Granite City	Granite City
National Malleable & Steel Castings Company	Cleveland, Ohio	Melrose Park
Keystone Steel & Wire Company	Peoria	Peoria
Carnegie-Illinois Steel Corporation	Pittsburgh, Pa.	South Chicago
International Harvester Company	Chicago	South Chicago
Republic Steel Corporation	Cleveland, Ohio	South Chicago
Northwestern Steel & Wire Company	Sterling	Sterling
INDIANA:		
American Steel Foundries	Chicago	East Chicago
Joslyn Manufacturing & Supply Company	Fort Wayne	Fort Wayne
Carnegie-Illinois Steel Corporation	Pittsburgh, Pa.	Gary
Inland Steel Company	Indiana Harbor	Indiana Harbor
Youngstown Sheet & Tube Company	Youngstown, Ohio	Indiana Harbor
Continental Steel Corporation	Kokomo	Kokomo
Ingersoll Steel & Disc Company	New Castle	New Castle
IOWA:		
Ordnance Steel Foundry Company	Bettendorf	Bettendorf
KENTUCKY:		
American Rolling Mill Company	Middletown, Ohio	Ashland
Andrews Steel Company	Newport	Newport
MARYLAND:		
Rustless Iron & Steel Corporation	Baltimore	Baltimore
Bethlehem Steel Company	Bethlehem, Pa.	Sparrows Point

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS (CONTINUED)

Name of consumer	Address	Location of plant
MASSACHUSETTS:		
General Electric Company	Schenectady, N.Y.	Everett, Lynn
Chapman Valve Manufacturing Company	Indian Orchard	Indian Orchard (Oak Street)
American Steel & Wire Company	Cleveland, Ohio	Worcester
MICHIGAN:		
Ford Motor Company	Dearborn	Dearborn
Rotary Electric Steel Company	Detroit	Detroit
Great Lakes Steel Corporation	Ecorse	Ecorse
MINNESOTA:		
American Steel & Wire Company	Cleveland, Ohio	Duluth
MISSOURI:		
Sheffield Steel Corporation	Kansas City	Kansas City. St. Louis
Scullin Steel Company	St. Louis	St. Louis
American Brake Shoe & Foundry Company (American Manganese Steel Division)	St. Louis	St. Louis
NEW JERSEY:		
Crucible Steel Company of America	New York, N. Y.	Harrison
Taylor Wharton Iron & Steel Company	High Bridge	High Bridge
John A. Roebling's Sons Company	Trenton	Roebling
NEW YORK:		
Republic Steel Corporation	Cleveland, Ohio	Buffalo
Wickwire Spencer Steel Company	New York	Buffalo
Pratt & Letchworth Company, Inc.	Buffalo	Buffalo (Black Rock)
Wickwire Brothers	Cortland	Cortland
Symington-Gould Corporation	Depew	Depew
Allegheny-Ludlum Steel Corporation	Brackenridge, Pa.	Dunkirk, Watervliet
Bethlehem Steel Company	Bethlehem, Pa.	Lackawanna
Simonds Saw & Steel Company	Lockport	Lockport
General Electric Company	Schenectady	Schenectady
Crucible Steel Company of America	New York	Syracuse
OHIO:		
American Steel Foundries	Chicago	Alliance
Republic Steel Corporation	Cleveland	Canton, Cleveland, Massillon, Warren, Youngstown

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS (CONTINUED

Name of consumer	Address	Location of plant
OHIO (continued):		
Barium Stainless Steel Corporation	Canton	Canton
Timken Roller Bearing Company (Timken Steel & Tube Division)	Canton	Canton
Jones & Laughlin Steel Corporation	Pittsburgh, Pa.	Cleveland
Electric Alloys Company	Elyria	Elyria
National Tube Company	Pittsburgh, Pa.	Lorain
Sharon Steel Corporation	Sharon, Pa.	Lowellville
Empire Sheet & Tin Plate Company	Mansfield	Mansfield
Marion Steam Shovel Company	Marion	Marion
American Rolling Mill Company	Middletown	Middletown
Wheeling Steel Corporation	Wheeling, W. Va.	Portsmouth, Steubenville
Buckeye Steel Castings Company	Columbus	South Columbus
Follansbee Brothers Company	Follansbee, W. Va.	Toronto
Copperweld Steel Company	Warren	Warren
Carnegie-Illinois Steel Corporation	Pittsburgh, Pa.	Youngstown
Youngstown Sheet & Tube Company	Youngstown	Youngstown
OKLAHOMA:		
Sheffield Steel Corporation	Kansas City, Mo.	Sand Springs
PENNSYLVANIA:		
Jones & Laughlin Steel Corporation	Pittsburgh	Aliquippa, Pittsburgh
Vulcan Crucible Steel Company	Aliquippa	Aliquippa
Babcock & Wilcox Tube Company	Beaver Falls	Beaver Falls (Morado Station)
Bethlehem Steel Company	Bethlehem	Bethlehem, Johnstown, Steelton
Allegheny-Ludlum Steel Corporation	Brackenridge	Brackenridge
Carnegie-Illinois Steel Corporation	Pittsburgh	Braddock, Clairton, Duquesne, Farrell, Munhall, Pencoyd, Vandergrift
Braeburn Alloy Steel Corporation	Braeburn	Braeburn
Universal-Cyclops Steel Corporation	Bridgeville	Bridgeville
American Rolling Mill Company	Middletown, Ohio	Butler
Union Electric Steel Corporation	Pittsburgh	Carnegie

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS (CONTINUED)

Name of consumer	Address	Location of plant
PENNSYLVANIA (continued):		
Lukens Steel Company	Coatesville	Coatesville
Colonial Steel Company	Pittsburgh	Colona (Monaca)
American Steel & Wire Company	Cleveland, Ohio	Donora
A. M. Byers Company	Pittsburgh	Economy
General Steel Castings Corporation (Eddystone Works)	Eddystone	Eddystone
Pittsburgh Steel Foundry Corporation	Glassport	Glassport
Central Iron & Steel Company	Harrisburg	Harrisburg
Harrisburg Steel Corporation	Harrisburg	Harrisburg
National Forge & Ordnance Company	Irvine	Irvine
Alan Wood Steel Company	Conshohocken	Ivy Rock
Latrobe Electric Steel Company	Latrobe	Latrobe
Vanadium Alloys Steel Company	Latrobe	Latrobe
Firth-Sterling Steel Company	McKeesport	McKeesport
National Tube Company	Pittsburgh	McKeesport
Pittsburgh Crucible Steel Company	New York, N. Y.	Midland
Pittsburgh Steel Company	Pittsburgh	Monessen
Midvale Company	Philadelphia	Nicetown
Edgewater Steel Company	Pittsburgh	Oakmont
Roxboro Steel Company	Pencoyd	Pencoyd
Henry Disston & Sons, Inc.	Philadelphia	Philadelphia
Philadelphia Navy Yard	Philadelphia	Philadelphia
Phoenix Iron Company	Phoenixville	Phoenixville
Crucible Steel Company of America	New York, N. Y.	Pittsburgh
Carpenter Steel Company	Reading	Reading
National Malleable & Steel Castings Company	Cleveland, Ohio	Sharon
The Duraloy Company	Scottdale	Scottdale
American Steel Foundries	Chicago	Verona
Jessop Steel Company	Washington	Washington
Mesta Machine Company	Pittsburgh	West Homestead
RHODE ISLAND:		
Washburn Wire Company	Phillipsdale	Phillipsdale
TENNESSEE:		
Knoxville Iron Company	Knoxville	Knoxville
TEXAS:		
Texas Steel Company	Fort Worth	Fort Worth
Sheffield Steel Corporation	Kansas City, Mo.	Houston
VIRGINIA:		
Newport News Shipbuilding & Dry Dock Company	Newport News	Newport News
Norfolk Navy Yard	Norfolk	Portsmouth
Norfolk & Western Railway Company	Roanoke	Roanoke

TABLE 39. CONSUMERS OF FLUORSPAR IN STEEL PLANTS
(CONCLUDED)

Name of consumer	Address	Location of plant
WASHINGTON:		
Puget Sound Navy Yard	Bremerton	Bremerton
Pacific Car & Foundry Company	Renton	Renton
Washington Iron Works	Seattle	Seattle
Bethlehem Steel Company	Bethlehem, Pa.	Seattle
Western Steel Casting Company	Seattle	Tacoma
WEST VIRGINIA:		
Wheeling Steel Corporation	Wheeling	Benwood
Weirton Steel Company	Weirton	Weirton
WISCONSIN:		
Grede Foundries, Inc. (Milwaukee Steel Foundry Division)	Milwaukee	Milwaukee
Bucyrus-Erie Company	South Milwaukee	South Milwaukee

TABLE 40. CONSUMERS OF FLUORSPAR IN IRON FOUNDRIES[a]

Name of consumer	Address	Location of plant
Alabama:		
American Cast Iron Pipe Company	Birmingham	Birmingham
California:		
Washington Eljer Company	Los Angeles	Los Angeles
General Metals Corporation	Oakland	Oakland
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Richmond
Connecticut:		
Crane Company	Bridgeport	Bridgeport
Illinois:		
American Car & Foundry Company	New York, N. Y.	Chicago
Crane Company	Chicago	Chicago
United States Radiator Corporation	Edwardsville	Edwardsville
Western Electric Company	New York, N. Y.	Hawthorne Station (Chicago)
The Moore Corporation	Joliet	Joliet
Walworth Company	Kewanee	Kewanee
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Litchfield
Indiana:		
C. & G. Foundry & Pattern Works	Indianapolis	Indianapolis
Perfect Circle Company	New Castle	New Castle
Studebaker Corporation	South Bend	South Bend
Maryland:		
Koppers Company (American Hammered Piston Ring Division)	Baltimore	Baltimore
Massachusetts:		
Crompton & Knowles Loom Company	Worcester	Worcester
Michigan:		
Ford Motor Company	Dearborn	Dearborn
Budd Wheel Company	Detroit	Detroit
East Jordan Iron Works	East Jordan	East Jordan
United States Foundry Corporation	Kalamazoo	Kalamazoo
Ideal Furnace Company	Milan	Milan
Clover Foundry Company	Muskegon	Muskegon
Campbell, Wyant & Cannon Foundry Company	Muskegon	Muskegon

[a] From a list by the U. S. Bureau of Mines, Metal Economics Division.

TABLE 40. CONSUMERS OF FLUORSPAR IN IRON FOUNDRIES (CONCLUDED)

Name of consumer	Address	Location of plant
MICHIGAN (continued):		
Sealed Power Corporation	Muskegon	Muskegon
Wilson Foundry & Machine Company	Pontiac	Pontiac
Sparta Foundry Company	Sparta	Sparta
Eaton-Erb Foundry Company	Vassar	Vassar
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Ypsilanti
Central Specialty Company	Ypsilanti	Ypsilanti
MISSOURI:		
Green Foundry Company	St. Louis	St. Louis
NEW JERSEY:		
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Bayonne
NEW YORK:		
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Buffalo
Kennedy Valve Manufacturing Company	Elmira	Elmira
OHIO:		
Babcock & Wilcox Company	Barberton	Barberton
Hill & Griffith Company	Cincinnati	Cincinnati
Westinghouse Electric & Manufacturing Company (Cleveland Works)	Pittsburgh, Pa.	Cleveland
American Radiator & Standard Sanitary Corporation	Pittsburgh, Pa.	Elyria
Electric Auto-Lite Company	Fostoria	Fostoria
Quality Castings Company	Orrville	Orrville
National Supply Company	Pittsburgh, Pa.	Toledo (Wagon Works)
E. W. Bliss Company (Toledo Machine & Tool Division)	Toledo	Toledo
PENNSYLVANIA:		
Treadwell Engineering Company	Easton	Easton
Westinghouse Electric & Manufacturing Company (Lenhart Works)	Pittsburgh	East Pittsburgh
Standard Stoker Company	Erie	Erie
American Radiator & Standard Sanitary Corporation	Pittsburgh	Pittsburgh
RHODE ISLAND:		
General Fire Extinguisher Company	Cranston	Cranston
TENNESSEE:		
Crane Enamelware Company	Chattanooga	Chattanooga
WISCONSIN:		
Rundle Manufacturing Company	Milwaukee	Milwaukee

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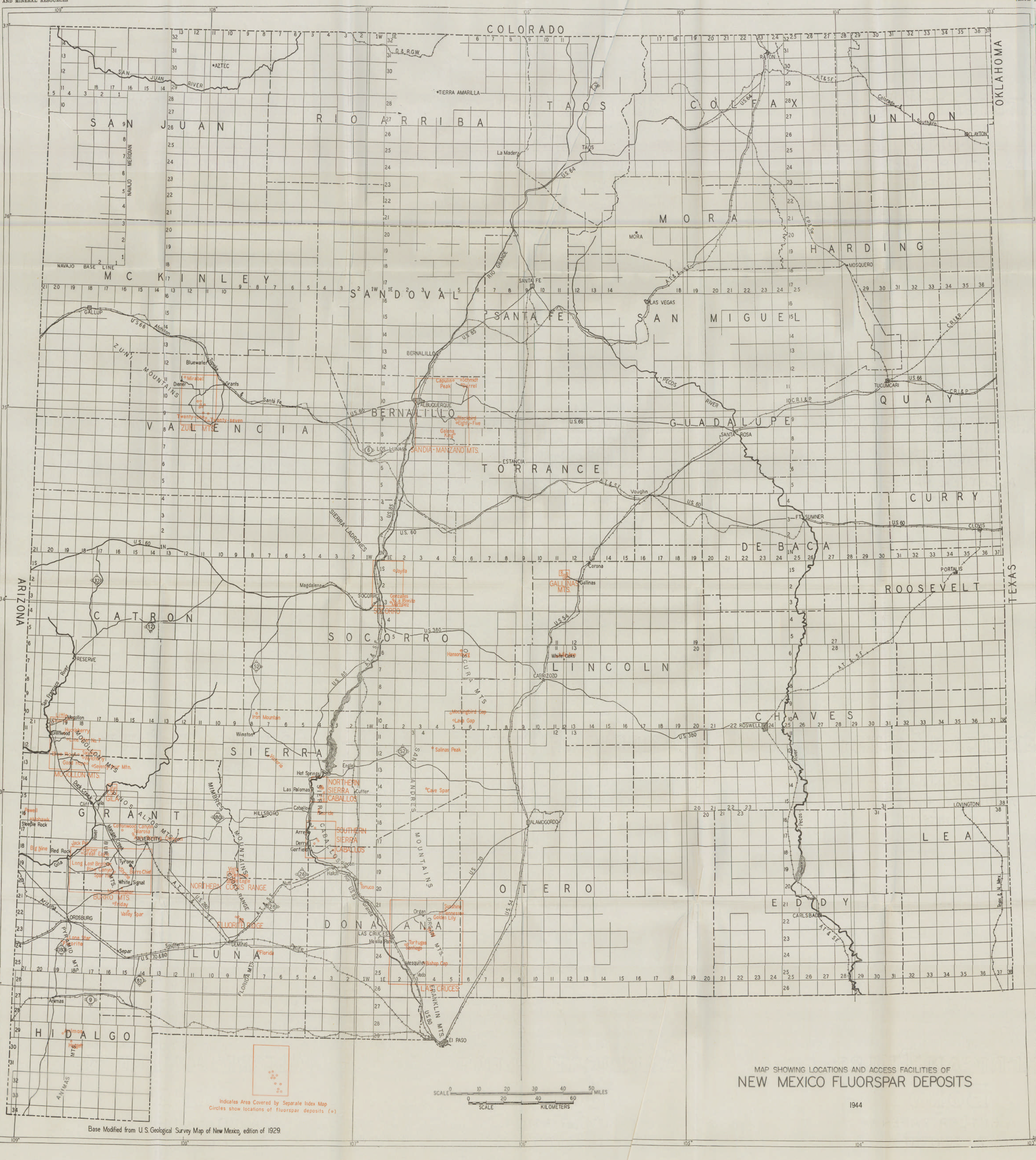
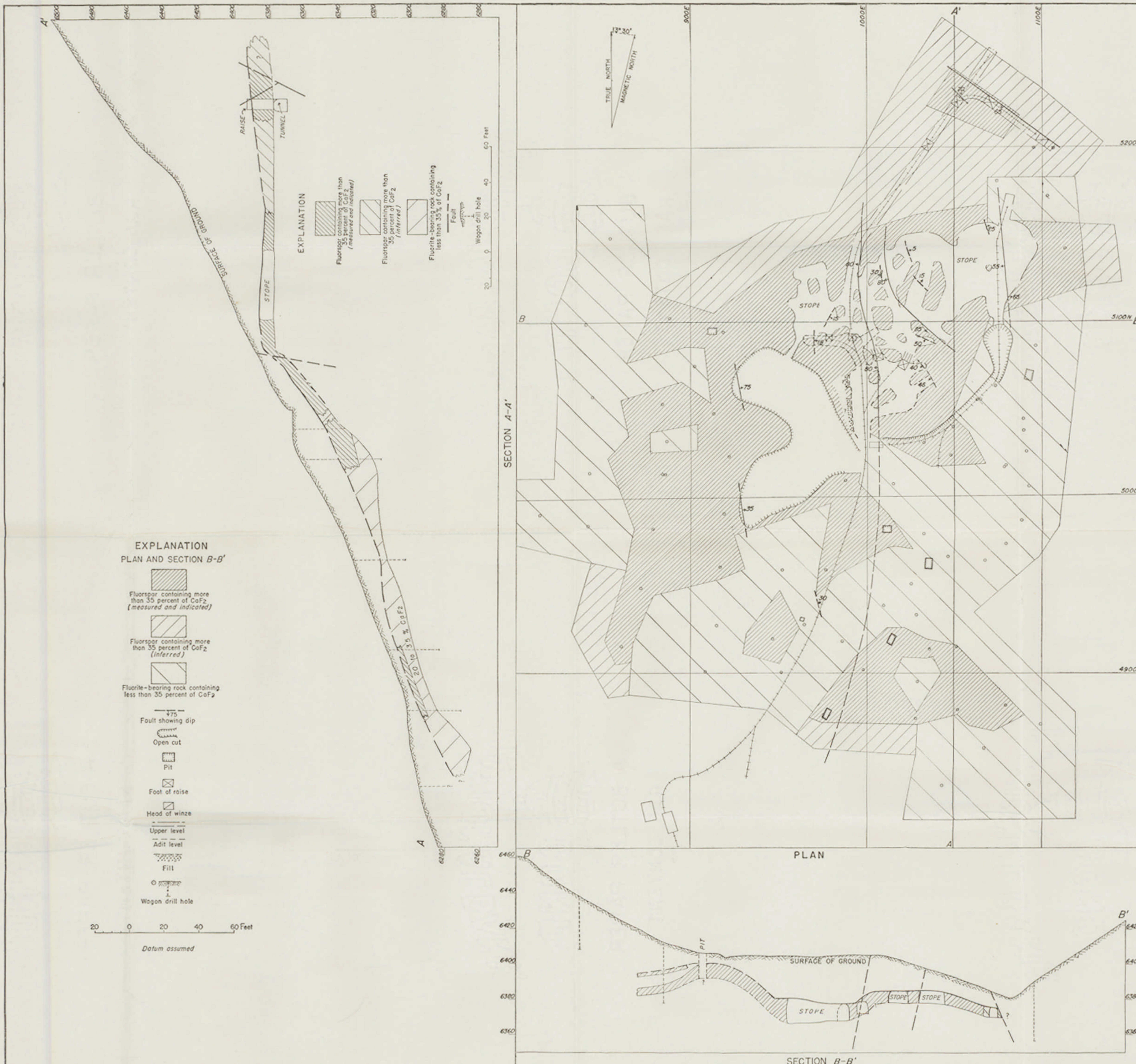
Figures in *italic* indicate main references.



MAP SHOWING LOCATIONS AND ACCESS FACILITIES OF
NEW MEXICO FLUORSPAR DEPOSITS

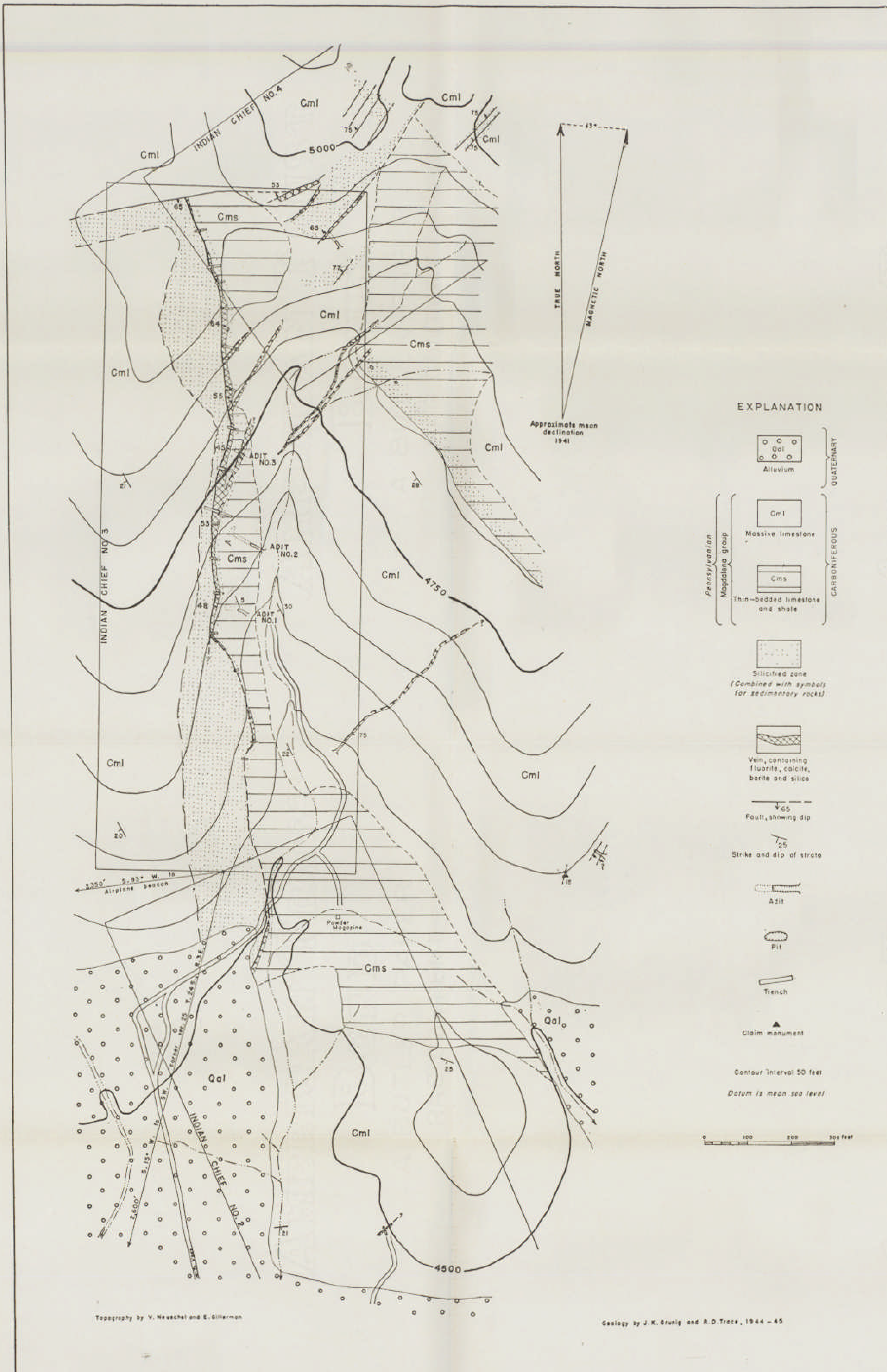
1944



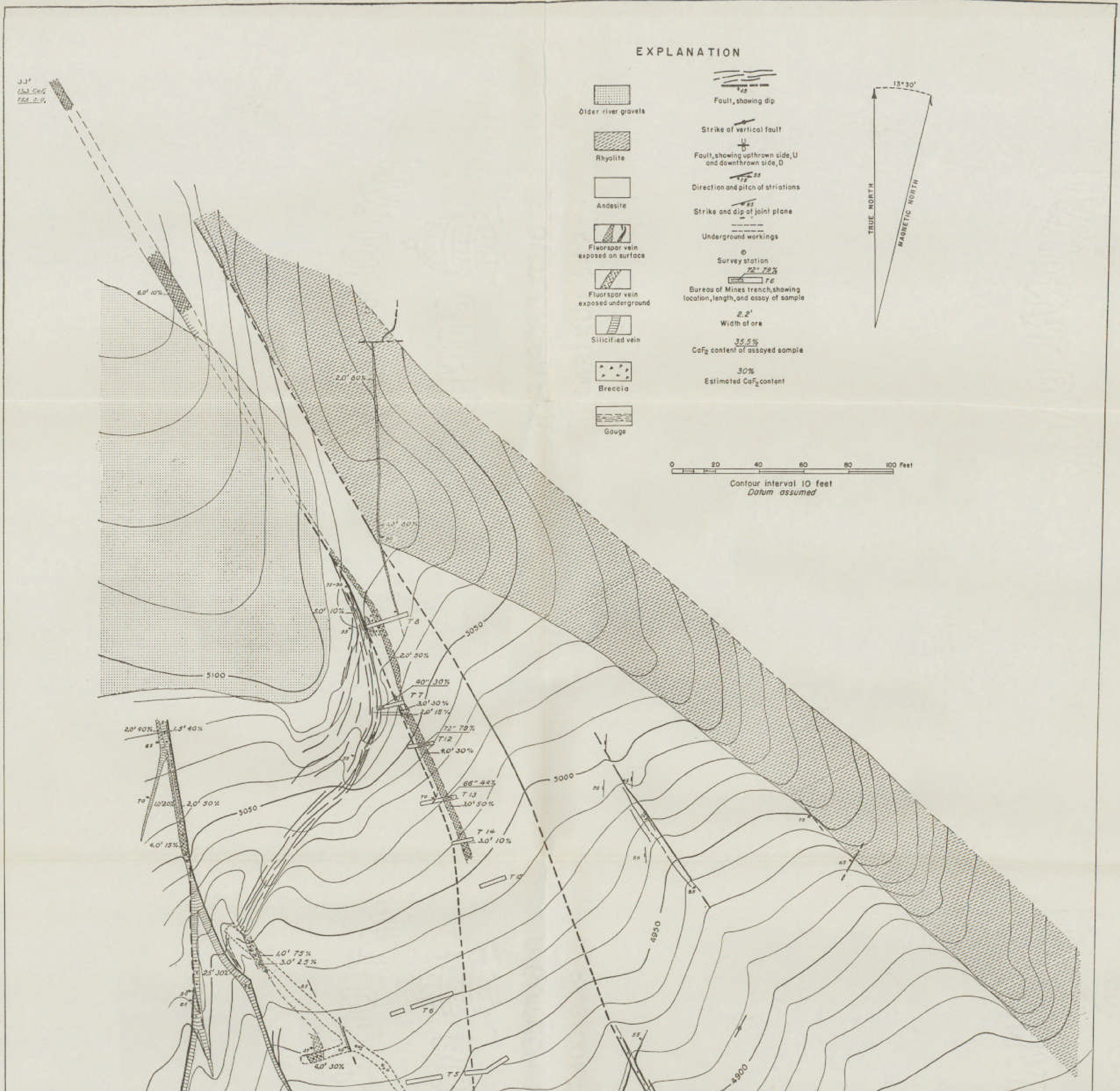
Base map and exploration by U. S. Bureau of Mines

Mine map and sections of the Huckleberry mine, Catron County, showing location of fluorspar bodies

Boundaries of fluorspar bodies determined by R. D. Trace, December 1944



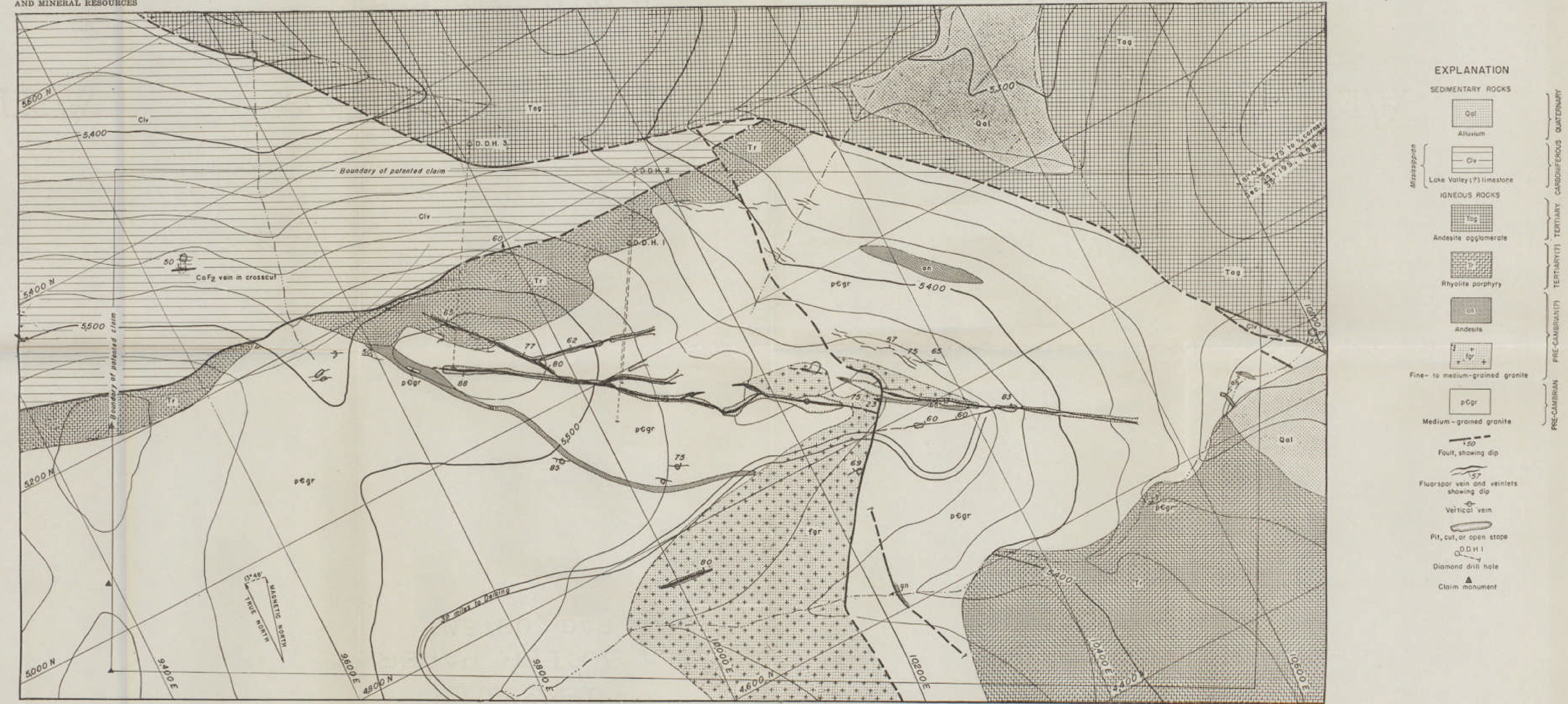
GEOLOGIC AND TOPOGRAPHIC MAP OF BISHOP CAP FLUORSPAR PROSPECT, DONA ANA COUNTY, NEW MEXICO



Base and topography by J. K. Grunig and J. O. Fisher

Geologic map of the Last Chance prospect, Grant County

Geology by H. E. Rothrock, 1944

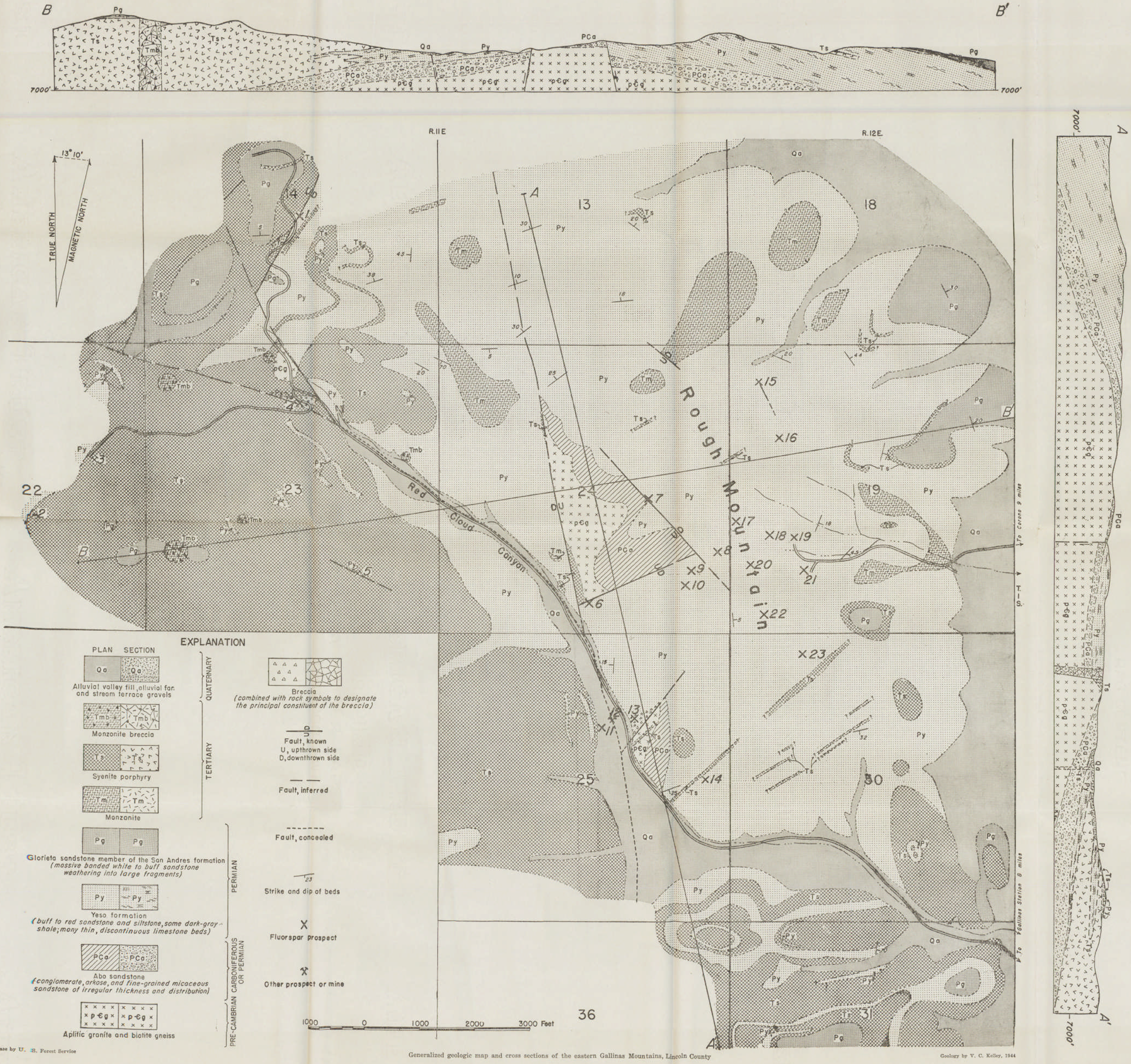


GEOLOGIC MAP OF THE WHITE EAGLE FLUORSPAR MINE, GRANT COUNTY, NEW MEXICO

50 0 50 100 150 FEET

Contour interval 20 feet
Datum is assumed

Geology and topography by Elliot Gillerman and R. D. Trace
July 1945



INDEX TO MINES AND PROSPECTS

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			T. 1 S., R. 11 E.
1.	Sky High	Fluorite	SE¼ 14
2.	Rare Metals	Iron minerals	SE¼ 22
3.	American	Iron minerals	NE¼ 22
4.	All American	Fluorite	N½ 23
5.	Iron Lamp	Iron minerals	SE¼ 23
6.	Helen S	Fluorite	S½ 24
7.	Eagle Nest	Fluorite	SE¼ 24
8.	Bottleneck	Fluorite	SE¼ 24
9.	Hilltop	Fluorite	SE¼ 24
10.	Conqueror No. 4	Fluorite	SE¼ 24
11.	Deadwood	Copper minerals and fluorite	NE¼ 25
12.	Red Cloud	Copper minerals	NE¼ 25
13.	Red Cloud	Fluorite	NE¼ 25
14.	Rio Tinto	Copper minerals and fluorite	E½ 25
			T. 1 S., R. 12 E.
15.	Last Chance	Fluorite	NW¼ 19
16.	Buckhorn	Copper minerals and fluorite	NW¼ 19
17.	Congress	Fluorite	SW¼ 19
18.	Hoosier Girl	Fluorite	SW¼ 19
19.	Old Hickory	Fluorite	SW¼ 19
20.	Hoosier Girl	Fluorite	SW¼ 19
21.	Eureka	Fluorite	SW¼ 19
22.	Summit	Fluorite	SW¼ 19
23.	Name unknown	Fluorite	NW¼ 30

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Sky High	1	SE¼ 14
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Base by U. S. Forest Service

Generalized geologic map and cross sections of the eastern Gallinas Mountains, Lincoln County

Geology by V. C. Kelley, 1944