General Features of Colorado Fluorspar Deposits[1]

By

DOAK C. COX, Geologist

United States Geological Survey[2]

COLORADO SCIENTIFIC SOCIETY PROCEEDINGS

VOLUME 14

No. 6

DENVER, COLORADO

1945

1. Prepared in cooperation with the State of Colorado, Colorado Metal Mining Fund, Colorado Mining Association, and Geological Survey Board of Colorado. An address delivered at joint meeting of the Western Division of the American Mining Congress and the Colorado Mining Association January 27, 1944.
2. Published with permission of the Director, Geological Survey, United States Department of the Interior.

GENERAL FEATURES OF COLORADO FLUORSPAR DEPOSITS

by

DOAK C. COX, Geologist

CONTENTS

ILLUSTRATIONS

Credit for much of the work represented by this paper belongs to Joseph Otto Fisher, whose able and valued assistance in 1943 and 1944 was ended upon his entering military service, and whose death in action was reported in April, 1945. His help and especially his companionship will always be remembered.

INTRODUCTION

History and previous work

The Geological Survey has been interested in fluorspar deposits in Colorado since 1905, when figures of output for the State were first recorded in the Geological Survey's Mineral Resources volume.[3] Prior to that, however, several geologists of the Survey had described areas in Colorado that contained fluorspar. As early as the 1870's, fluorspar was mined in small amounts near Evergreen and carted to Central City, where it was used in smelting the ores of precious metals. In 1873 or 1874, the first shipment of fluorspar from the Jamestown district was reported. Output was small and probably sporadic until 1903 when the demand for fluorspar of metallurgical grade for use at Pueblo began. The estimated output from 1874 to 1905 amounts to only 3,500 tons.

When E. F. Burchard,[4] Geologist of the Geological Survey, made a reconnaissance of the fluorspar producing districts of Colorado in 1908, six mines were being operated in the Jamestown district—the Blue Jay, Yellow Girl, Emmett, Early Bird, Tip Top, and Lookout. Some of these mines are still in operation. Their output between 1902 and 1908 was about 8,700 tons. During that period fluorspar was still being mined in the Evergreen district, where the output was about 100 tons a year. The Antelope Creek deposit, southeast of Rosita in Custer County, had been discovered and 800 tons had been shipped from it between 1906 and 1908. Those were the real beginnings of fluorspar mining in Colorado. The chief stimulation from then until a few months before World War I, and again through the depression, was the need for fluorspar to satisfy the plant requirements of the Colorado Fuel and Iron Co. in Pueblo.

During World War I the Colorado Geological Survey cooperated with the Federal Government in investigating workable deposits of many critical minerals, including fluorspar. The results of the State Survey's work were published in 1920 in Colorado Geological Survey Bulletin 18, by Harry Aurand. Aurand listed almost 40 districts in which fluorspar occurs, including eight districts from which it had been mined. Newly developed areas included a district near Eldorado Springs, where a small amount of fluorspar was mined in 1917; the St.

[3]Hovey, E. O., Fluorspar: Mineral Resources U. S., 1905, p. 1102, 1906.
[4]Burchard, E. F., Fluorspar in Colorado: Min. Sci. Press, vol. 99, pp. 258-261, 1909.

Peters Dome district, near Colorado Springs, where fluorspar was mined in 1910 and 1911 and again in 1917 and 1918; the Red Mountain district, near Ouray, where the Barstow mine had been operated in 1917 and 1918; the Jefferson district, in Park County, where fluorspar had been mined in 1913 and 1914; and the Wagon Wheel Gap district, where an important deposit was discovered in 1911, from which shipments were begun in 1913.

Three years after the war there was a slump in fluorspar mining; in 1929 and in the 1930's there was a second and worse slump. During the early 1920's, between these times of low output, the Northgate district, in Jackson County, and the Cotopaxi district, in Fremont County, had become productive; and in the early 1930's mining had begun in the Browns Canyon, Poncha, and South Platte districts. In 1926 and 1927 E. F. Burchard again examined Colorado's fluorspar deposits as well as those in some other western states for the Federal Geological Survey. His description of the districts, issued in 1933, are the most recent that have been published.[5]

Output

More than 300,000 tons of fluorspar had been shipped from mines in Colorado to the end of 1943. Up to 1910 the State furnished a little less than 2 percent of the United States output, or about 1½ percent of the country's needs, 21 percent having been furnished by imports. In the next decade Colorado's output was eight times as large as it had been from 1870 to 1910 and increased to 4 per cent of the nation's output. It amounted to 6 per cent of the national output in the 1920's, and to 5 percent from 1930 through 1941.

During the war years 1917 and 1918, Colorado's share of the total output of fluorspar in the United States was 11 percent, indicating a greater response to the increased prices than was made in the rest of the country. A corresponding increase has occurred during World War II. In 1942 Colorado's contribution to the total output was 9 percent and in 1943, 12 percent.

Fluorspar during World War II

In 1942 the War Production Board, because of the rapidly growing shortage of fluorspar resulting from increasing needs in the manufacture of many war necessities, requested the Geological Survey to undertake an expanded program of study

[5]Burchard, E. F., Fluorspar deposits in western United States: Am. Inst. Min. Met. Eng. Tech. Pub. 500, pp. 7-14, 1933; also published in Am. Inst. Min. Met. Eng. Trans., vol. 109, pp. 374-381, 1934.

of the fluorspar deposits of the United States. As part of this program, several Survey geologists have examined or reexamined fluorspar properties in Colorado. The principal investigations have been by E. N. Goddard, who had previously (1930-33) made a detailed geologic study of the Jamestown district; by T. G. Andrews, who examined several important areas during the fall of 1942; and by J. O. Fisher and the writer, who have made detailed studies of the Browns Canyon and Northgate districts as well as examinations of many other areas throughout the State.

The immediate objectives of these studies have been (1) to estimate resources of fluorspar in the State and make geologic data available to the different War Agencies for planning purposes; (2) to outline, through detailed study and mapping of the geology, areas favorable for prospecting and exploration by owners or by the Federal Bureau of Mines and other governmental agencies; and (3) to supply the various mine operators with geologic information likely to aid current operations.

This paper presents some of the results of the war program. It is planned to prepare and issue detailed reports with large-scale maps on all the important fluorspar areas. The report on the Jamestown district, by E. N. Goddard, will be available soon; in fact, preliminary maps of this district have already been placed in open files. This report will be followed by reports on other areas as soon as it is possible to complete the field and office work on them. The investigations are being carried on through cooperative arrangements between the Federal Geological Survey, the Colorado State Geological Survey Board, and the Colorado Metal Mining Fund.

LOCATIONS AND MODES OF OCCURENCE

On the accompanying map of Colorado (fig. 1) are shown nearly all the districts from which fluorspar has been reported. Forty-seven have been plotted. Fluorspar has been reported from perhaps 10 more places, but the reports have not been verified by the writer. In only 14 of the districts plotted has fluorspar been mined and marketed. In 8 more districts it occurs in small veins which have not been economically exploitable. In the remaining 25 districts the fluorspar occurs as a gangue mineral, principally with sulfide ores, or as a few crystals only. Most of Colorado's output of fluorspar has come from 4 main districts: Jamestown, Northgate, Salida, and Wagon Wheel Gap.

This article deals principally with the economic deposits. Some non-economic occurrences, representing types that are productive in other regions, will, however, be referred to briefly.

Range of conditions of formation

Fluorspar is remarkable among hydrothermal minerals for the great range in conditions under which it may be deposited. It is known at one extreme as a primary mineral in igneous rock, and at the other, as a constituent in hot-spring deposits.

It is described as a primary constituent of the pre-Cambrian Pikes Peak and Cripple Creek granites near the Cripple Creek district. It occurs also in a pegmatite, probably of pre-Cambrian age, in the South Platte district, Jefferson County. All other fluorspar occurrences in Colorado are believed to be of Tertiary age, but some may be in part of late Cretaceous age. Fluorite occurs as a primary or secondary mineral in several Tertiary igneous rocks—for example, the bostonites at Clear Creek, Georgetown, and Jamestown; and the monzonite of the Empire district. It occurs as a pegmatite mineral in a quartz monzonite stock in the Jamestown district.

Fluorite is an abundant gangue mineral in a few contact-metamorphic deposits, and in hypothermal cassiterite, wolframite, and molybdenite veins. At Climax, Colo., some fluorspar occurs with quartz in the molybdenum veins, and is also present in later veinlets composed mainly of topaz, quartz, sericite, and sulfides.

Most fluorspar occurrences, however, are epithermal or perhaps partly mesothermal; that is, they were formed relatively low in the range of temperatures in which ore minerals are deposited. The deposits at all the localities shown in figure 1, with the few exceptions already noted, were formed at

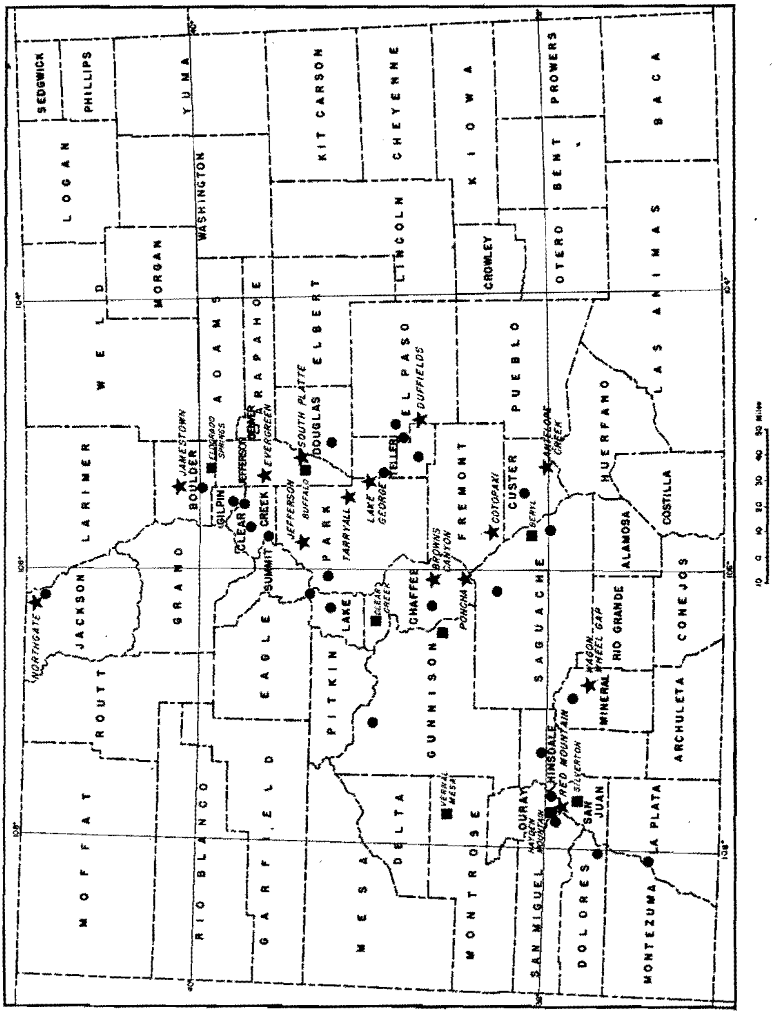

FIGURE 1.—Index map of Colorado showing distribution of fluorspar deposits. ★ Productive fluorspar districts; ■ districts with small fluorspar veins; ● districts with fluorspar as gangue.

relatively low temperatures. Some of them appear, by reason of geological setting and structural and mineralogical character, to have been deposited at somewhat greater depths and pressures than others, for example, those deposits in which fluorspar occurs as gangue and the related deposits at Jamestown appear to have been formed at higher temperatures than the deposits at Browns Canyon, Northgate, and Wagon Wheel Gap, which belong to a distinctive class not closely related to metalliferous deposits.

Deposits not closely related to metalliferous deposits

Deposits of this class are known in the three districts just named as well as in the Poncha and some smaller districts. The writer has given close study to those at Browns Canyon, Northgate, and Poncha; published descriptions of the Wagon Wheel Gap deposits prove them also to belong to this class, which formed typically at relatively low temperatures.

In this type of deposit the principal veins follow vertical or steeply inclined well-defined faults, fault-breccia zones, or shear zones. Such zones are ordinarily 3 to 6 feet wide but may be more than 40 feet wide. In some places the 40-foot zones are mineralized throughout their full width. In several districts there are two or more nearly parallel veins, and in some localities these are united by cross veins. Many of the veins are traceable for a thousand feet or more, and segments that are several hundred feet long contain enough fluorspar to make ore shoots. Where the veins occupy fault-breccia zones, both walls are commonly very highly polished and slickensided (see fig. 2). The breccia itself is in many places cut by several slickensided slips, which join and separate from one another in anastomosing fashion. Figure 2 shows the slickensided walls of a fluorspar vein in the Colorado mine, Browns Canyon district. In the shear zones, which differ from the breccia zones only in being brecciated to a smaller degree, the footwall is generally more clearly defined than the hanging wall. There may be a well-marked slickensided fault containing gouge, on the footwall, and a system of subparallel minor slips spaced farther and farther apart in the hanging wall, which is not sharply defined. The nearly vertical veins may change the direction of their dips within short distances, and either wall may be well or poorly defined.

Characteristic varieties of fluorspar.—The fluorspar in veins not associated with metalliferous deposits, instead of being coarsely crystalline and cleavable, is columnar or fine grained to microgranular. The columnar fluorspar forms veins ranging from a fraction of an inch to more than a foot thick, as well as reniform and botryoidal masses commonly containing cores of country rock. It is colorless, white, purple, or green, and is frequently banded and fibrous, forming the so-called "ribbon spar."

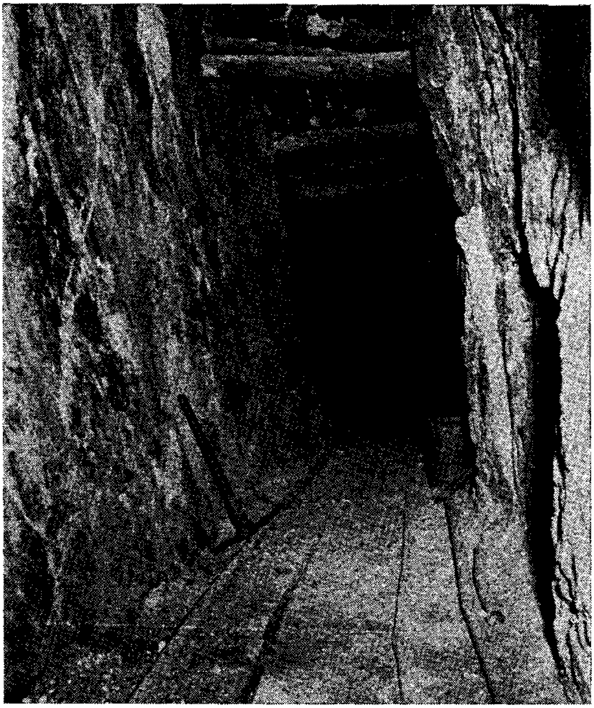

FIGURE 2.—Slickensided walls of fluorspar vein zone in Colorado mine, Browns Canyon district, Chaffee County.

Moderately fine granular fluorspar occurs in small veins and irregular masses. It is white or green. In some localities the grains are only loosely bound together, the aggregate being known as "sugar spar." The fine-grained and microgranular fluorspar occurs in veins ranging from a fraction of an inch to 2 or more feet in thickness. It is generally white or banded with one or more colors—pale red, green, or purple—forming the variety called "bacon spar." In many places fine-grained fluorspar partly replaces fault breccias (see fig. 3).

Associated minerals.—The silica generally associated with the fluorspar in this type of deposit is chert or chalcedony rather than conspicuously crystalline quartz. Silica is commonly intergrown with the fine-grained fluorspar, and there are all gradations between soft pure fluorspar and hard chalcedony. As the chalcedony may be banded like the fluorspar, the hard-

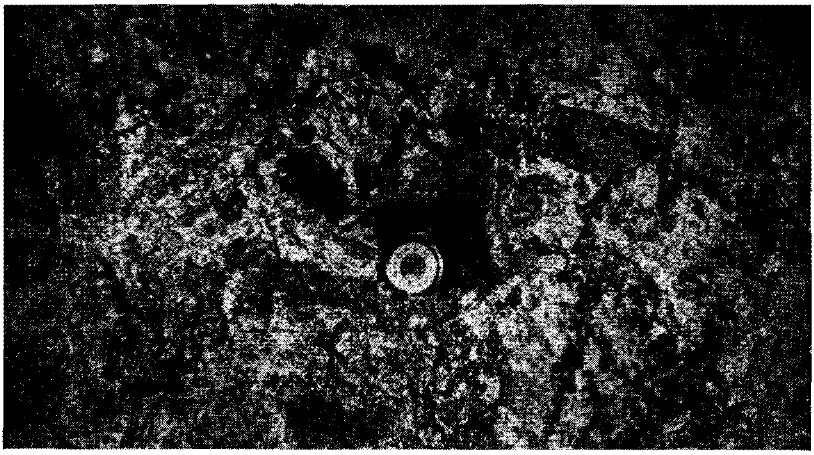

FIGURE 3.—Fluorspar in fault breccia, Camp Creek mine, Northgate district, Jackson County. Dark patches are granite fragments; light ground mass is fine-grained fluorspar.

ness of the aggregate is the principal field clue to its composition. In some places silica replaces gouge and breccia, leaving dark-red or grey cherty masses.

Sulfides, mostly pyrite, are present in most of the deposits, but only in small amounts and generally in very fine grains. They occur either in veinlets or disseminated in altered wall rock. Calcite is rare. Barite is also rare in most of the deposits, but a few deposits contain excessive amounts of it. A white claylike mineral, probably kaolinite, is associated with the fluorspar in some deposits.

Alteration of the wall rock was generally not very intense, and its effects are limited to a width of a few feet on either side of the vein. Where the wall is of granite, it may be stained brownish and locally greenish or bluish, owing to chloritization and the formation of some fine grains of sulfide minerals.

Productive structures and ore shoots.—Recurrent movement took place along many of the faults during and after mineralization. Brecciated parts of the veins are common. In some places the brecciated fluorspar is cemented by later fluorspar, which usually differs in appearance; in other places fissures are filled with brecciated fluorspar and country rock showing no signs of cementation.

Parts of the veins ranging from a few tens of feet to a thousand feet in length have been mined. The larger shoots are not of uniformly good grade and width but contain more or less well-defined high-grade shoots separated by narrower and lower-grade parts.

FIGURE 4.—Watercourse in fluorspar vein, Bopp prospect, Browns Canyon district, Chaffee County. View looking up into opening.

Vugs and watercourses are common in the veins, but are apparently of post-mineral origin as they are not drusy. Some of the larger watercourses are as much as 4 feet by 8 feet in horizontal cross section and extend through vertical distances of 30 feet or more. One is shown in figure 4. Many of these large openings are partly filled with wad, and veins of manganese oxides mark older openings that have been filled.

The number and kinds of openings available for ore deposition depend on the type of wall rock. In soft schists the fissures contain a large amount of gouge and fine breccia, which were apparently not particularly susceptible to mineralization. Where they are in granite or rhyolite, the faults contain coarser breccia, which was more permeable and afforded more opportunity for the deposition of fluorspar in its interstices.

Relation of hot springs to origin.—Several fluorspar deposits of this type are apparently associated with hot springs. The best known example is the deposit at Wagon Wheel Gap. The Mineral Hot Springs nearby were described by Emmons and Larsen[6] in 1913. The fissure vein from which the main output has come is on the same strike as two hot springs, and there is a third hot spring not far from the others. The temperatures of the springs range from 135° to 150° F. The spring water was not analyzed for fluorine, but analyses of the travertine deposited from one of the springs showed 0.22 percent of fluorine, as well as some barium and zinc. This quantity of fluorine would be equivalent to 0.45 percent of fluorite. It was said that the springs contained masses of barite and fluorite before they were cleaned out. Spring deposits up the valley slopes indicate that the springs migrated down slope as the valley was cut deeper.

At Ojo Caliente, N. Mex., fluorspar veins are associated with the thermal springs.[7] An analysis of the salts in the spring waters[8] shows 0.19 percent of fluorine.

The Poncha Springs deposit southwest of Salida is only two or three thousand feet from the Poncha Hot Springs, which have temperatures ranging from 80° to 170° F. It appears, however, that no tests for fluorine have been included in any analyses of the waters or tufas of these springs. Warm water issues from several springs in the Browns Canyon district, and water in some of the mines in that area is warm; however, no analyses of the waters are available, and no spring deposits are being formed in Browns Canyon.

The temperature of the waters in the springs discussed and the presence of fluorine in their waters and in the deposits of these springs strongly suggest that the veins and springs are genetically connected. Inasmuch as the springs are still

[6]Emmons, W. H., and Larsen, E. S., The hot springs and mineral deposits of Wagon Wheel Gap, Colo.: Econ. Geology, vol. 8, pp. 235-246, 1913.

[7]Lindgren, Waldemar, The hot springs at Ojo Caliente and their deposits: Econ. Geology, vol. 5, pp. 22-27, 1910.

[8]Lindgren, Waldemar, Mineral deposits, 4th ed., p. 54, 1933 (gives 0.19 percent F in salts from Ojo Caliente, quoted from Clark, F. W., Data of geochemistry: U. S. Geol. Survey Bull. 770, pp. 192-194, 198, 1924); the hot springs at Ojo Caliente and their deposits: Econ. Geology, vol. 5, p. 26, 1910 (quotes an analysis by Hillebrand in U. S. Geol. Survey Bull. 113, p. 114, 1893, showing 5.2 parts per million of F, equivalent to 10.7 parts per million of CaF_2, or 0.01 percent of total solids; calcareous tufa from a deposit near the spring and in line with the fluorspar vein contained 0.44 percent of F, or 0.9 percent of fluorite).

flowing, the vein deposits are inferred to be relatively young and probably were formed near the surface. No special attention, however, has been given to the amount of erosion that has taken place since most of the veins were formed, presumably in late Tertiary time.

The physiographic setting of Browns Canyon gives further and more direct evidence about the age and relations of the deposits in that district. Some of the veins there are in faults that cut a rhyolite flow, which is believed to have been originally only a few hundred feet thick. Except for gravels, which at one time filled the Arkansas Valley to a level slightly above the highest veins, this rhyolite is the latest rock known in the district. At no time since the fluorspar was deposited could more than a few hundred feet of rock have covered the highest veins, and further physiographic study may possibly reveal that the highest fluorspar deposits were formed less than a hundred feet beneath the surface.

Vertical extent of shoots.—As yet few of the deposits have been mined to any great depth. Maximum vertical distances through which individual veins are exposed are 200 feet in the Northgate district, 400 feet in the Browns Canyon district, and 600 or 700 feet in the Wagon Wheel Gap district. Of 11 ore shoots that are exposed vertically for 50 feet or more and on which information is adequate, 4 become poorer at depths of 50 to 100 feet, 4 show no consistent change with depth, and 3 seem to improve in depth. Some veins that improved or remained the same through the first 50 to 100 feet ultimately became poorer. Three ore shoots have apparently been bottomed or nearly so. Each of these shoots was considerably longer than it was deep. Evidence available at present, however, is insufficient to justify a definite statement that deposits of this type are invariably longer than they are deep.

With even less certainty can any statement be made regarding the probable occurrence of more ore shoots in depth. At Northgate, fluorspar veins are exposed through a vertical range of 900 feet—the maximum for districts in Colorado. Inasmuch as the maximum exposed vertical extent for a single vein is 600 to 700 feet, it may be that in any particular district some veins will pinch out at depths where other veins are just opening up. Not enough exploration downward has been done to show whether a so-called bottomed shoot may be separated from a deeper shoot by a barren interval.

Grade of ore.—The quality of the ore in various deposits and even in different parts of the same deposits varies greatly.

Fluorspar of metallurgical grade can be produced from a few of the richer veins by only a little hand sorting; in other veins the ore is so siliceous that a product of metallurgical grade could not be made by either a jigging or a sink-float process. In most places where concentration is by flotation, silica is so finely

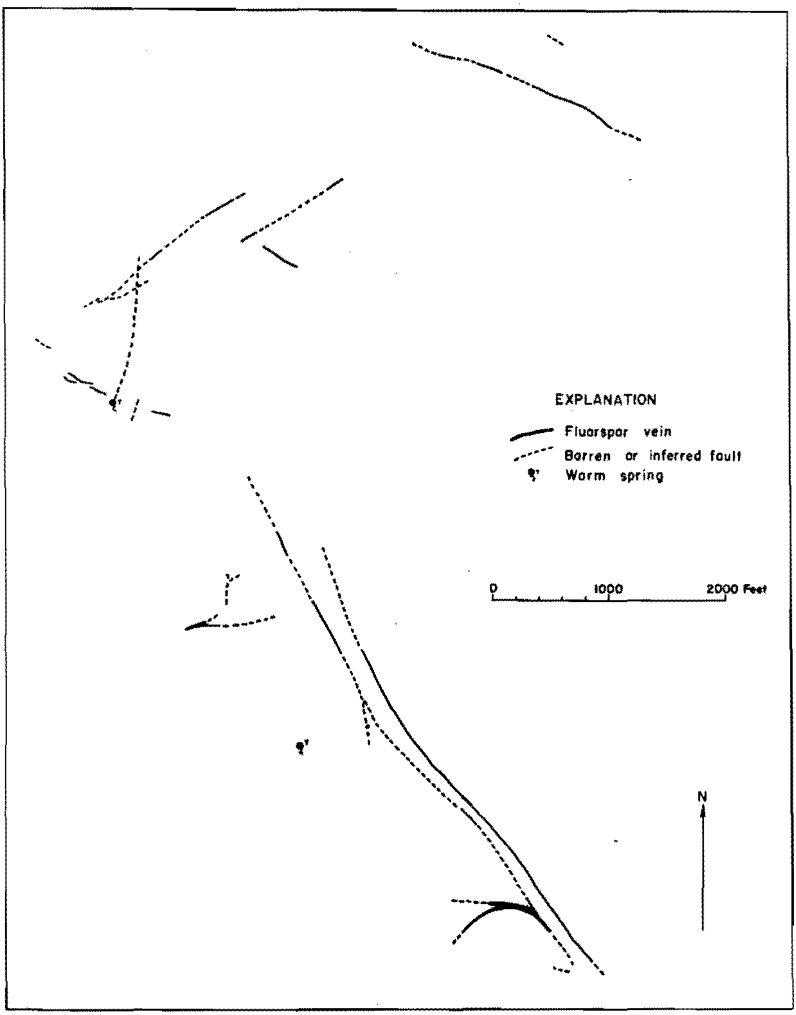

FIGURE 5.—Sketch map of vein system in the Browns Canyon district, Chaffee County.

inter-grown with the fluorspar that production of acid-grade material from most of the crude ore is difficult; most of the flotation plants produce ceramic-grade fluorspar.

Notes on individual districts.—The general characteristics of the deposits not closely related to metalliferous deposits have been treated in such detail that only a few remarks need be made on some of the districts.

Figure 5 shows the pattern of ore shoots and barren faults in the Browns Canyon district. This district has more veins than most others of its type. The country rocks are a complex of granite, gneiss, and schist and a porphyritic rhyolite flow. The longest vein, in the southern part of the district, has been mined for a horizontal distance of 1,600 feet. The widest vein, which at one point is more than 35 feet across, occurs at a place where faults between the rhyolite and the granite-gneiss complex intersect.

In the Poncha district the deposits are veins that occupy a shear zone in granite gneiss which contains lenses of soft schist. In some places the shear zone is as much as 40 feet wide. This district also has an unusual deposit consisting of many small veinlets without an identifiable pattern scattered over an area of about 100 acres in rocks that are badly disintegrated but probably of the same kind as those in the shear zone.

In the Northgate district the country rocks are granite, gneiss, and schist with small areas of feldspathic sandstone (arkose) that is probably of Tertiary age. Two groups of veins are known in the district. One consists of two or more northward-trending veins, which have been traced for 1,600 feet and at one point intersect at a low angle to form a deposit 25 feet wide. The other group, 1½ miles northeast of the first, consists of a vein system that apparently extends more than a mile. The largest vein has a maximum width of 40 feet and has been mined by open-pit methods (fig. 6). This vein system is as yet poorly exposed and incompletely shown. One analysis of soil over the deposit suggests that it may be possible to trace these veins by systematic soil sampling. No surface residual concentrations of fluorspar comparable with the "gravel deposits" of the Illinois-Kentucky field are known in the West, but it seems quite possible that enough fragments of fluorspar may have been shed from unexposed veins to locate them by chemical analysis or perhaps by heavy liquid separation of the overburden.

The Wagon Wheel Gap deposit, according to Burchard,[9] is in a vein zone that cuts the rhyolitic tuff and breccia country rock and contains one to several smaller more or less parallel veins of fluorspar. The vein zone can be traced for more than half a mile. The maximum width of the fluorspar is about 35 feet. In addition to barite, which is an unusual constituent in deposits of this type, the Wagon Wheel Gap deposit apparently contains more sulfides than most such deposits.

Need for exploration.—Exploration is far from complete and should be encouraged in most of these districts. Several good

FIGURE 6.—Open pit on the Fluorine vein, Northgate district, Jackson County. View from south end of cut.

deposits are known only from surface exposures. Exploration of the horizontal extensions of many known deposits is in-

[9]Burchard, E. F., Fluorspar deposits in western United States: Am. Inst. Min. Met. Eng. Tech. Pub. 500, pp. 8-10, 1933.

complete. Several known faults have not been adequately tested for additional near-surface deposits, and there has been little search for new faults. The Geological Survey's program of detailed mapping in these districts has already indicated some places where further exploration is desirable, and others will doubtless be suggested as the work continues.[10]

[10]Since this address was presented, several places suggested by the Geological Survey as worthy of further exploration have been tested with good results. At Northgate, for example, the Western Fluorspar Corporation stripped the postulated northward extension of the large deposit that was being mined in 1943 by open pit methods and revealed that the mineralized area extended 300 feet farther and had an average width of 25 feet. This extension also was mined by open pit methods in 1944. The Federal Bureau of Mines, in cooperation with the Geological Survey, began exploration of suggested deposits in the State during 1944, starting in the Northgate district.

Deposits closely associated with metalliferous deposits

Jamestown deposits

The remaining member of the four leading productive fluorspar districts in Colorado is near Jamestown, Boulder County. This area and its ore deposits have been studied in detail by E. N. Goddard.[11] Fluorspar in this district is associated with metalliferous deposits, some of which have been worked for their precious-metal content. With one or two exceptions, however, none of the principal fluorspar deposits in the Jamestown district are actually part of metallic ore bodies. Most of them are in different and distinctive structural surroundings.

Location and general geology.—The district is in an area of pre-Cambrian schist and gneiss that has been intruded by two stocks of Laramide age[12] (early Tertiary?)—one an earlier granodiorite stock at Jamestown, and the other a later small porphyry stock, whose composition ranges from sodic quartz monzonite to sodic granite, that borders the granodiorite stock at the north. Structural details in the later stock suggest that it was intruded upward at a moderate angle underneath the granodiorite stock. The forces produced by this intrusion resulted in the rupture of the country rock first in a zone of faults and brecciated areas trending generally N. 70° W. along the south and southwest side of the stock, then, farther south, in a zone trending N. 40° W. Along faults of both systems, movement was downward on the south sides of the fractures, that is, the upthrown side is toward the stock.

Occurrence of fluorspar deposits.—The principal fluorspar deposits are concentrated on the west side of the stock where the two zones of faulting and brecciation intersect, but there are other fluorspar-bearing veins 3,000 to 4,000 feet south of the stock. The fluorspar was deposited in both the breccia zones and in the fault fissures.

The fluorspar breccia zones are roughly lenticular bodies of broken country rock cemented by fluorite. They range from 10 to 70 feet in width and from 50 to 400 feet in length. Some are parts of considerably larger barren silicified breccia zones. In some of the breccia deposits, the fluorspar is of two ages: the earlier fluorspar, generally coarse-grained and associated with massive sulfides, that was brecciated and mixed with

[11]Goddard, E. N., The influence of Tertiary intrusive structural features on mineral deposits at Jamestown, Colo.: Econ. Geology, vol. 30, pp. 370-386, 1935; Fluorspar deposits of the Jamestown district, Boulder County, Colo.: U. S. Geol. Survey unpublished ms. (nine preliminary maps and brief text released for public inspection in open files of the Geological Survey, Oct. 16, 1944).

[12]Lovering, T. S., and Goddard, E. N., Laramide igneous sequence and differentiation in the Front Range, Colo.: Geol. Soc. America Bull., vol. 49, pp. 49-50, 1938.

crushed granite; and the later fine-grained fluorspar that cements the earlier breccia. Certain features of some of the zones suggest that the brecciation was in large part due to collapse brought about by the solution of some of the fluorspar. In some places brecciated fluorspar or pieces of sulfide ore are found in tongues extending out into barren breccia; in other places the breccia exhibits local bedding that is horizontal or nearly so. That the brecciation was controlled in part by jointing is shown by the patterns of both the borders of the zones and the high-grade parts within the brecciated areas. These high-grade parts are in part veins of the late cementing fluorspar and in part concentrations of the early brecciated fluorspar.

In some localities the fluorspar breccia zones grade into deposits of the vein type, and the typical veins show brecciation. The vein deposits range from 150 to 1,000 feet in length and are as much as 20 feet wide. They contain coarsely crystalline fluorspar that has been brecciated, though not as extensively as in the breccia deposits, and cemented with later fine-grained to microgranular fluorspar, quartz, carbonates, clay minerals, and small amounts of sulfides. The veins west of the stock are mostly short, relatively wide veins some of which grade into breccia deposits. To the south, however, a system of longer, narrower veins, containing ore that is less brecciated, extends for a distance of about 3,000 feet.

Typically the late fluorspar is purple, commonly very dark, though wine, grey, and other colors are present. The early fluorspar in the veins is white or pale purple. The texture ranges from very fine grained to coarsely crystalline.

Figure 7 shows plans of some typical breccia zones and veins copied with some simplification from Goddard's maps. In general the breccia zones and most of the veins are lenticular. The veins show irregularities caused by mineralization along breaks crossing the main fissures. The simple vein illustrated at the lower left (fig. 7) is part of one of the long, narrow veins in the system south of the stock.

Grade and impurities of the ore.—The Jamestown deposits vary widely in grade. Neither veins nor breccia deposits contain much ore that is suitable for shipping direct, even as metallurgical fluorspar. The average ore in the veins is of higher grade than that in the breccia deposits. Some ore from high-grade pockets and some hand-sorted material has been shipped direct, but all ore mined recently has been milled. One of the two mills operating in 1943 on ore from the district is strictly a flotation plant producing acid-grade fluorspar. The other is a combination jig-table and flotation mill, which makes both metallurgical and acid-grade products.

The silica content of most of the deposits is high, and the quartz is so intimately mixed with the fine-grained fluorspar as to require fine grinding for separation. The value of lead, copper, gold, and silver in the sulfides is sufficient to make the saving of sulfide concentrates from most of the ores profitable.

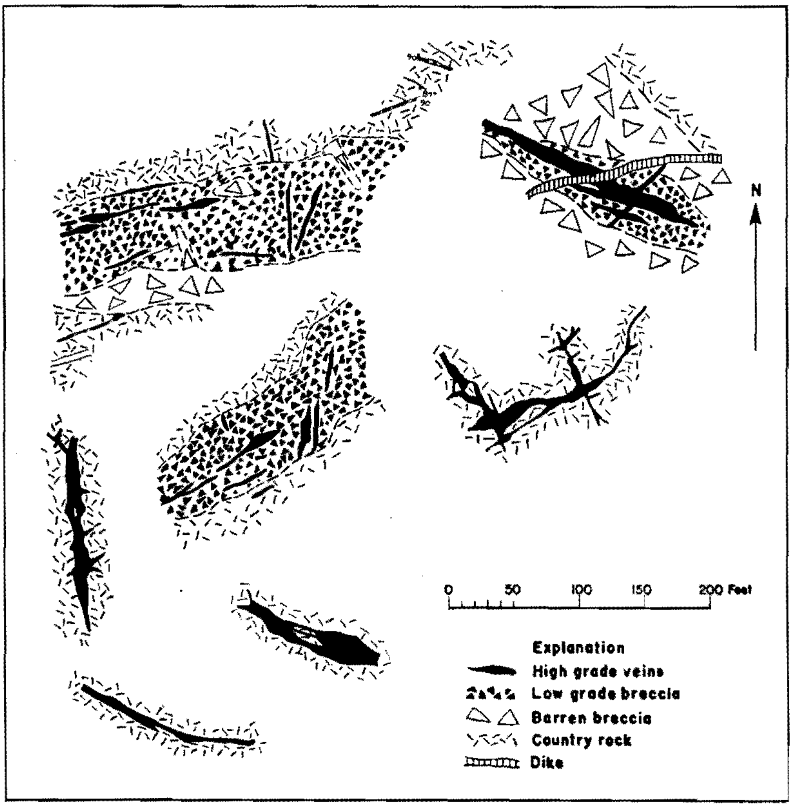

FIGURE 7.—Typical veins and breccia zones, Jamestown district, Boulder County. After E. N. Goddard.

Extent of the ore bodies.—In few mines is it likely that any of the breccia deposits extend along the strike far enough to connect with one another. Even the veins west of the stock appear to be discontinuous horizontally. The nearby barren breccia zones, however, are much more extensive; and some of them show likelihood of containing fluorspar deposits at greater depth. Though the commercial deposits are relatively short, they may be fairly extensive vertically. The deposits so far exposed range in altitude through about 400 feet. In spite of this shallowness of exposure, it is obvious that at least several and perhaps most of the ore bodies are pipelike in shape; several have already been explored to depths greater than their lengths. According to Goddard, it "seems reasonable to expect that most of the fluorspar bodies will persist to a depth of at least 300 feet and many may persist to 500 feet or more".[13] The best method for increasing knowledge of the reserves in the district appears, therefore, to be (1) exploration beneath the present workings, rather than exploration along the strike in a search for horizontal extensions of the productive areas; and (2) exploration of some of the nearby barren breccia deposits beneath the surface.

Other deposits related to metalliferous deposits

Several other commercial or near-commercial fluorspar deposits in Colorado are related to metalliferous deposits. Some are in important metalliferous districts. Most of these deposits cut metalliferous veins or occur near them. Few of the deposits in which the fluorspar occurs as gangue material have any commercial promise. The fluorspar in nearly all of them is moderately or coarsely crystalline, rather than finely granular or columnar in structure as in deposits of the Browns Canyon type. Quartz is associated with the fluorspar in all these deposits; chalcedony occurs in only a few deposits and in small quantity. Barite and calcite have been seen in some deposits. Some of the veins have slickensided walls, but this feature is not as common nor as extensive as in those deposits that are not associated with metalliferous deposits, most of which were probably formed at lower temperatures. There are clay slips on the walls in some places, and locally they cut through the deposits.

Several fluorspar veins associated with metalliferous deposits are known in the San Juan Mountains. One, in the Barstow mine, Red Mountain district, contributed about 1,500 tons of fluorspar during and shortly after World War I. The fluorspar vein[14] in the Barstow mine dips steeply, is 3 to 5 feet wide and cuts across the main gold-bearing Barstow vein, which was displaced laterally 5 feet by the fault along which the fluorspar vein occurs, though the latter showed no slickensiding.

[13]Goddard, E. N., personal communication.

[14]Aurand, H. A., Fluorspar deposits of Colorado: Colorado Geol. Survey Bull. 18, p. 68, 1920.

According to C. R. Wilfley,[15] the fluorspar was coarsely crystalline, readily cleavable, and generally light green. It occurred as masses surrounded by brown clay. Quartz was associated with the fluorspar but apparently was not intimately intermixed, for, though the fluorspar was shipped without any treatment except washing, the product always contained more than 85 percent of CaF_2 and 5 percent or less of SiO_2. The vein was exposed about 1,000 feet below the surface on two levels 140 feet apart. The vein was not found on the surface, and nothing is known of its extension downward. Laterally it pinched out in both directions within a few tens of feet. Other similar veins have been reported at the Aspen and Dakota mines near Silverton and at a property on Hayden Mountain near Ouray.

The fluorspar deposits in the Evergreen and Buffalo districts in Jefferson County are also associated with sulfides. One of the Evergreen deposits furnished the first output in the State; the other was worked during World War I. According to Aurand,[16] the veins are in steeply dipping fissures with slickensided walls and range from 1 to 5 feet in width. One of the veins could be traced for a quarter of a mile and the other for several miles, although workings along each actually exposed them for distances of considerably less than 100 feet. The fluorspar, which was purple and green, was associated with quartz and sulfides of lead, zinc, and copper.

In the Jefferson district, near Kenosha Pass, are some sizable deposits which were worked in 1913-14 but neglected thereafter until the autumn of 1943. The fluorspar is light green to deep purple and is generally associated with large quantities of quartz. Aurand[17] described one vein as being 3 to 15 feet wide but containing only 15 to 18 inches of commercial fluorspar. A deposit which is now receiving attention and which may be part of the same vein, is reported to be about 30 feet wide in one place. In addition to the quartz a considerable amount of barite is associated with the fluorspar.

Two deposits of this type have been worked in the St. Peters Dome district, known also as the Cheyenne Mountain district, El Paso County. They may be parts of the same vein, which, if continuous, must be almost a mile long. The vein occupies a steeply dipping fissure in granite and in some places is composed mainly of fluorspar whereas other parts contain large and even dominant amounts of quartz and barite. The walls are noticeably slickensided in a few places. The fluorspar

---

[15]Personal communication.
[16]Aurand, H. A., op. cit., p. 59.
[17]Idem, p. 72.

is coarsely crystalline and white, purple, or green. Vein widths range from 3 to 12 feet, and some of the greatest widths contain the highest-grade fluorspar. The ore will have to be milled because, even in the best parts of the deposits, the fluorspar is intimately veined with quartz. Parts of the deposits contain abundant sulfides.

Other related deposits, including some having records of output, are the Antelope Creek deposit in Custer County, the Cotopaxi deposit in Fremont County, deposits near Lake George and Tarryall in Park County, and other deposits in Chaffee, Gunnison, Montrose, and Saguache Counties.

Although fluorspar is a conspicuous gangue mineral in many metalliferous deposits, no attempt seems to have been made to obtain fluorspar concentrates from them. Such concentration would probably be difficult, for other common gangue minerals beside the fluorspar include quartz, barite, calcite, rhodochrosite, and rhodonite, all fairly close to fluorspar in specific gravity. Even though such concentration may not now be economically practicable, some of the metalliferous deposits with relatively large quantities of fluorspar gangue should be considered, at least, as possible future sources of fluorspar.

CONCLUSION

In 1933, when the total output in Colorado was about 180,000 tons, Burchard[18] estimated probable reserves in the State at 400,000 tons. Now, though another 100,000 tons has been mined, recent exploration indicates that the probable reserves are at least twice that figure. It is as true now as when Burchard wrote it in 1909 that "geologic conditions appear favorable for the occurrence of much more fluorspar than has yet been discovered, and that further prospecting for the mineral is therefore to be encouraged."

[18] Burchard, E. F., op. cit., p. 24, 1933.