COLORADO SCIENTIFIC SOCIETY PROCEEDINGS

VOLUME 15

No. 1

DENVER, COLORADO

1946

COLORADO SCIENTIFIC SOCIETY

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FLUORSPAR DEPOSITS OF THE JAMESTOWN DISTRICT, BOULDER COUNTY, COLORADO[1]

By

E. N. Goddard[2]

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[1]Published by permission of the Director of the Geological Survey, United States Department of the Interior, in cooperation with the State of Colorado through the Colorado State Geological Survey Board and the Colorado Metal Mining Fund. Printing paid for by the Colorado Metal Mining Fund.

[2]Geologist, U. S. Geological Survey.

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FLUORSPAR DEPOSITS OF THE JAMESTOWN DISTRICT, BOULDER COUNTY, COLORADO

by E. N. GODDARD

ABSTRACT

The Jamestown district, in the central part of Boulder County, Colorado, was chiefly a gold-producing area for many years but during 1942 and 1943 the mining of fluorspar was strongly revived and became the principal activity in the district. During the period 1903-44, 65,838 tons of metallurgical-grade fluorspar and 33,826 tons of acid-grade fluorspar were shipped from the district.

The Jamestown district is in the foothills of the Front Range at the extreme northeast end of the Colorado mineral belt. The fluorspar deposits are localized in an area of pre-Cambrian Silver Plume granite which contains inclusions of schist. These rocks have been intruded by stocks of Tertiary granodiorite and sodic granite-quartz monzonite porphyry, and related dikes.

The fluorspar deposits occupy veins and breccia zones in altered granite and granodiorite on the west and south sides of the sodic granite-quartz monzonite porphyry stock. The breccia zones are from 10 to 70 feet wide and from 50 to 400 feet long. Most of the exploited veins range from a few feet to 20 feet in width and from 150 to 1,000 feet in length. Some deposits are enclosed in large nearly barren breccia zones. In nearly all the deposits, early coarse-grained fluorite is strongly brecciated and cemented by fine-grained fluorite mixed with clay minerals, quartz, pyrite, and some carbonates. Fragments of sulfide minerals, chiefly galena and pyrite, are found in some deposits, and minute grains of pitchblende are sparingly present. The fluorite ranges in color from nearly white through purple to a deep violet that is almost black.

The mineralization seems to have been related to the sodic granite-quartz monzonite porphyry stock, and it is believed that the vein fissures and breccia zones were produced by forces resulting from the intrusion of the stock. Some fluorite was dissolved by later solutions, and available evidence suggests that the brecciation

of the deposits resulted from collapse and gradual settling of the porous bodies thereby developed.

Most of the fluorspar veins contain from 60 to 85 percent of CaF_2, and the breccia zones commonly contain from 5 to 60 percent. Crude ore shipped in the past has contained about 73 to 85 percent of CaF_2 and from 5 to more than 12 percent of silica. In 1943, crude ore containing from 45 to 73 percent of CaF_2 and 12 to 32 percent of silica was being mined and milled to produce both acid- and metallurgical-grade fluorspar.

The fluorspar deposits have been mined to depths ranging from 50 to 480 feet below the surface, and many give promise of extending several hundred feet below the present workings. The resources are therefore estimated to be fairly large, and deeper exploration of most of the productive deposits seems justified. Some of the large nearly barren breccia zones, which contain only small amounts of fluorspar at the surface, are also considered favorable locations for future exploration.

Introduction

The Jamestown district is in the central part of Boulder County, Colo., 33 miles northwest of Denver. (See fig. 1.) Its chief mineral product has been gold telluride ore, but deposits of fluorspar in the central part of the district have been mined for many years. Jamestown, the only settlement in the district, has a popu-

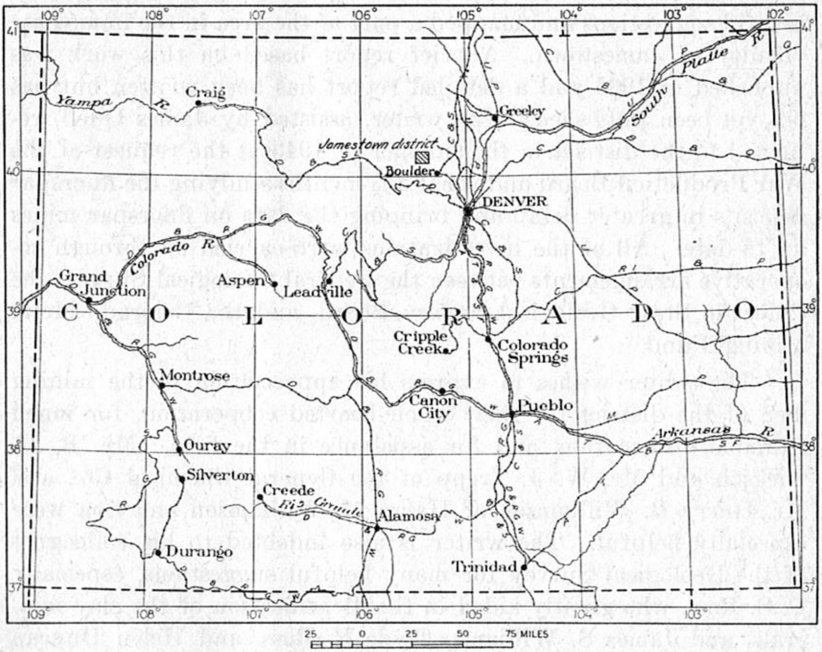


Figure 1. Index map of Colorado showing the location of the Jamestown district.

lation of about 100, and is connected with Boulder, on the Colorado and Southern Railroad, by 17 miles of good gravel road. The fluorspar mines and prospects are grouped rather closely around Jamestown and nearly all are either on or within 500 feet of a good road. The district is in the foothills of the Front Range, 4 to 8 miles west of the plains. Altitudes range from 6,400 to 8,900 feet above sea level. All the fluorspar deposits are on the lower slopes of the valleys of James and Little James Creeks. Their outcrops range in altitude from 7,100 to 7,600 feet above sea level.

Field Work and Acknowledgements

This report is based on two separate periods of field work. During the summers 1930, 1932, and 1933 and the spring of 1934, the writer, assisted at various times by C. D. Hier, J. M. Maxwell, and L. B. Graff, mapped about 35 square miles of the Jamestown district and studied both the gold and the fluorspar deposits. This work was under the supervision of T. S. Lovering, who gave many helpful suggestions and mapped a part of the area in the immediate vicinity of Jamestown. A brief report based on this work was published in 1935 and a detailed report has been written but has not yet been published.[1] The writer, assisted by James Odell, returned to the district in the summer of 1943 at the request of the War Production Board and spent 2½ months studying the fluorspar deposits in greater detail and bringing the data on fluorspar mines up to date. All of the investigations were carried on through cooperative arrangements between the Federal Geological Survey, the Colorado State Geological Survey Board, and the Colorado Metal Mining Fund.

The writer wishes to express his appreciation to the mining men of the district for their whole-hearted cooperation, for much valuable information, and for assistance in the field. Mr. R. H. Dickson and Mr. W. J. Trepp of the General Chemical Co., and Mr. Harry B. Williamson of Harry M. Williamson and Son were especially helpful. The writer is also indebted to his colleagues of the Geological Survey for many helpful suggestions, especially C. S. Ross, who greatly aided in the identification of the clay minerals, and James S. Williams, Clyde P. Ross, and Helen Duncan who critically read the manuscript.

History and Production

Gold was produced in the Jamestown district as early as 1865, but fluorspar was not mined in appreciable quantities until 1903. According to Aurand[2] a small tonnage of fluorspar was shipped

[1]Goddard, E. N., The influence of Tertiary intrusive structural features on mineral deposits at Jamestown, Colo.; Econ. Geology, vol. 30, no. 4, pp. 370-386, 1935; Geology and ore deposits of the Jamestown district, Colo., (Manuscript report in files of U. S. Geol. Survey.)

[2]Aurand, Harry A., Fluorspar deposits of Colorado: Colorado Geol. Survey Bull. 18, p. 13, 1920.

from the Poorman claim to the Boyd smelter at Boulder "as early as 1873 or 1874," and other shipments were made within a few years. In 1903 about 400 tons of fluorspar were shipped from the Blue Jay mine. During the following years from a few hundred to a few thousand tons were shipped annually from the district. In June, 1916, a small mill was built at Jamestown to treat the galena-fluorspar ores from the Alice and Argo mines, but the fluorspar concentrates were not shipped until the following spring. A high point in production was reached in 1918 when 22,810 tons of fluorspar were shipped, but output declined sharply in the following years and from 1930 to 1940 there was very little activity at the mines. In 1940 the General Chemical Co. acquired the Alice, Burlington, Chancellor, Yellow Girl, and other mines, and in 1942 they began producing acid-grade fluorspar in their flotation plant near Boulder. Also in 1940, Harry M. Williamson and Son leased the Argo, Emmett, Brown Spar, Blue Jay, and other properties from the Boulder Fluorspar and Radium Co. and began remodeling the Wano mill at Jamestown. They produced both metallurgical- and acid-grade fluorspar during the next 3 years. In 1943 both companies were actively mining and milling, and a small mill at Jamestown was intermittently operated by Clark H. Clark. The fluorspar output for 1943 reached a peak of over 36,000 tons of crude ore, which ranged in grade from about 45 to 75 percent of CaF_2.

The total output of fluorspar in the district up to and including 1944 has amounted to 65,838 short tons of metallurgical-grade fluorspar averaging between 80 and 85 percent of CaF_2, and 33,826 short tons of acid-grade fluorspar containing about 98 percent of CaF_2[3].

Geology

The Jamestown district is in the foothills of the Front Range at the extreme northeast end of the Colorado mineral belt. In this region highly metamorphosed schists of sedimentary origin, belonging to the pre-Cambrian Idaho Springs formation, and minor amounts of the Swandyke hornblende gneiss of igneous origin have

[3]Data furnished by H. W. Davis, Bureau of Mines, United States Department of the Interior.

been invaded by the Boulder Creek and Silver Plume granites of middle pre-Cambrian age. This complex has in turn been intruded by a sequence of Laramide (early Tertiary?) igneous rocks ranging from diabase to alaskite in composition.

The Jamestown district as a whole is localized where irregular bodies of schist lie between a small batholith of Boulder Creek granite on the south and a large compound batholith of the younger Silver Plume granite on the north. The southern part of the district is occupied by biotite schist containing several tongues of Boulder Creek granite. The foliation of the schist has a general strike of N. 60° E. and a steep southeast dip, but in the southwestern part, it trends nearly north and dips steeply west. The central and northern parts of the district are largely occupied by Silver Plume granite which encloses numerous small bodies of biotite schist and of the associated Swandyke hornblende gneiss. The western part of the district is occupied by an elongate stock of Boulder Creek granite. Two Laramide (early Tertiary?) intrusive stocks, one of granodiorite and the other of sodic granite-quartz monzonite porphyry occupys the central part of the district, and related dikes are scattered through the nearby pre-Cambrian rocks.

Throughout the region, the pre-Cambrian rocks are cut by a series of strong northwest-trending faults called breccia reefs,[4] which are of late Cretaceaus age and are believed to have served as trunk channels for the deep circulation of ore-forming fluids. Most of these faults dip steeply, but some dip at low angles. In many places, the breccia reefs are characterized by silicified fault material colored dark red to purple by finely divided hematite. One of the strongest of these faults, the Maxwell reef, cuts diagonally across the west-central part of the Jamestown district and lies about three-fourths of a mile west of the fluorspar area. This reef strikes N. 30°-40° W. and dips from 75° SW. to 85° NE. The displacement of granite dikes along it indicates that the southwest wall moved down to the southwest about 600 feet. In the central part of the district, the Maxwell reef has been cut by the granodiorite stock of Laramide age. Other faults of this type are the

[4]Lovering, T. S. and Goddard, E. N., Geologic map of the Front Range mineral belt, Colorado [Explanatory text]: Colorado Sci. Soc. Proc., vol. 14, no. 1, pp. 37-42 and 46-47, 1938.

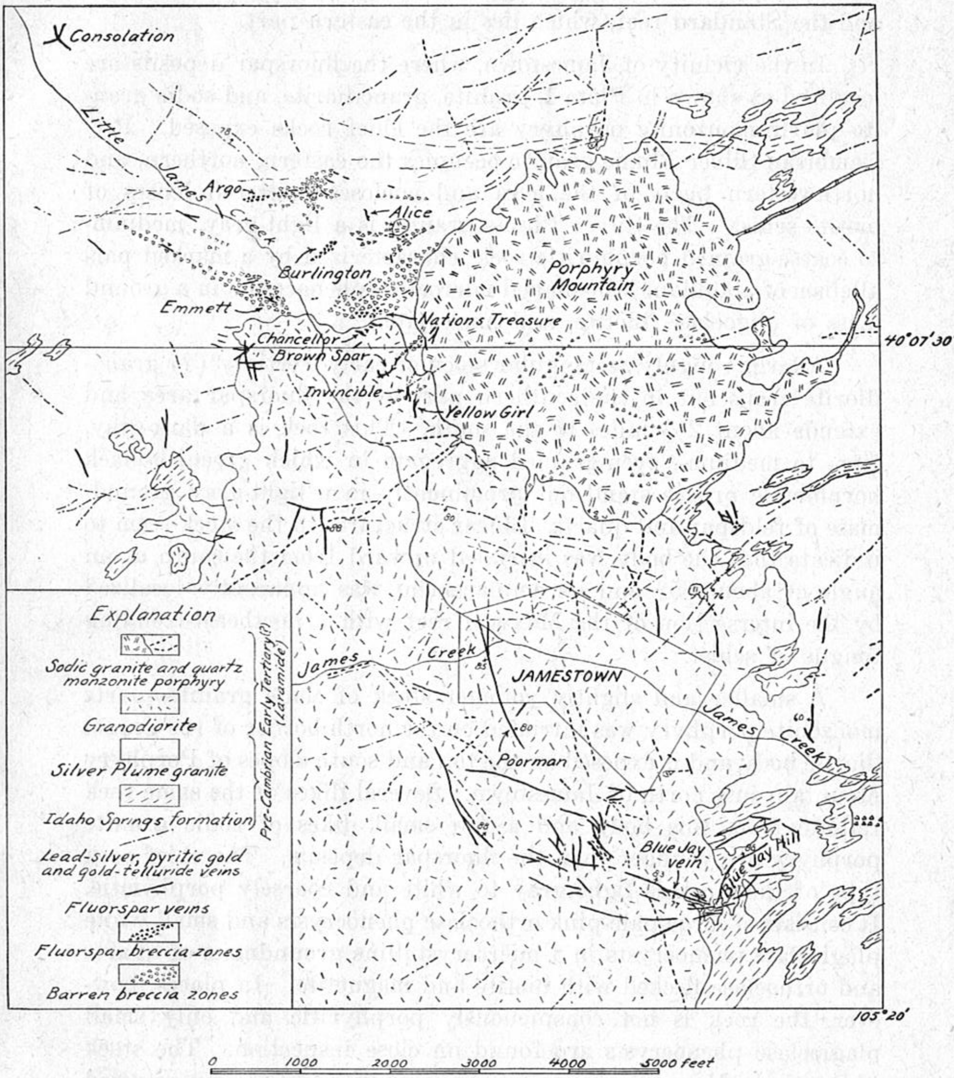


Plate 1. Geologic map of the central part of the Jamestown district, Boulder County, Colo., showing the distribution of the principal fluorspar deposits.

Hoosier reef, which cuts through the western part of the district, and the Standard reef, which lies in the eastern part.

In the vicinity of Jamestown, where the fluorspar deposits are localized as shown in Plate 1, granite, granodiorite, and sodic granite-quartz monzonite porphyry are the chief rocks exposed. Pre-Cambrian Silver Plume granite occupies the eastern, northern, and northwestern parts of the area and encloses scattered lenses of biotite schist. The Silver Plume granite is a light-gray, medium- to coarse-grained porphyritic rock, characterized by a marked parallelism of abundant lath-shaped microcline phenocrysts in a ground mass of oligoclase, biotite, and muscovite.

A large roughly rectangular stock of early Tertiary (?) granodiorite crops out in the southern part of the fluorspar area and extends about 2½ miles to the south. This rock is a dark-gray, fine- to medium-, even-grained aggregate in which greenish-black hornblende prisms stand out prominently in a light-gray groundmass of feldspar and quartz. Linear structures in the stock seem to indicate that the body was intruded upward from the south at an angle of about 65° and its emplacement was apparently localized by the intersection of the Maxwell reef with a northeast-trending tongue of schist.

A smaller and slightly younger stock of sodic granite-quartz monzonite porphyry was intruded on the north border of the granodiorite body and is exposed on the top and south slopes of Porphyry Mountain just north of Jamestown. Several dikes of the same rock radiate from this body and a few small dikes of sodic granite porphyry are younger than the fluorspar deposits. The chief rock type of the stock is light gray to white and coarsely porphyritic. It consists of large pale-pink orthoclase phenocrysts and small white plagioclase phenocrysts in a microcrystalline groundmass of quartz and orthoclase flecked with biotite and magnetite. In places, however, the rock is not conspicuously porphyritic and only small plagioclase phenocrysts are found on close inspection. The stock of Porphyry Mountain appears to be composite and to have resulted from two or more magmatic surges which took place during cooling. Small amounts of fluorite are associated with the latest stage. Linear structures in the stock seem to indicate that it is a somewhat funnel-shaped mass pitching about 55° SW. It is believed that, during emplacement, the magma moved up at this angle in a northeastward direction along the under side of the granodiorite mass. It seems probable that hydrothermal solutions associated with this intrusion deposited the fluorite and partly altered the surrounding granite and granodiorite to sericite, clay minerals, chlorite, and carbonates.

Fluorspar Deposits[5]

Distribution and Size

The fluorspar deposits occur in altered granite and granodiorite, and are confined to a northwestward-trending belt, about 2 miles long on the south and west sides of the Porphyry Mountain stock. (See pl. 1.) The belt is about a mile wide at the southeastern end, just east of Jamestown, but narrows gradually to the northwest. The shape of this fluorspar area was determined by two major zones of fracturing. One of these, represented largely by breccia zones, trends N. 70° W., and is chiefly near the western border of the porphyry stock, but a segment lies close to the southeastern border. The other zone of fracturing, composed chiefly of veins, trends about N. 40° W. and is about a fourth to half mile south of the stock. These two major zones meet on the west side of the stock, where the brecciation and fracturing were the strongest. The brecciation and fracturing are believed to have resulted from forces produced by the intrusion of the porphyry stock. This theory has been discussed in detail in a previous paper.[6]

Most of the exploitable breccia zones and veins of fluorspar are in a small area on the west side of the stock, but veins are abundant in the vicinity of Blue Jay Hill, 3,000 to 4,000 feet south of the stock, and there are a few small beccia zones and veins near its southeast border. Both veins and breccia zones show a variety

[5]In this report, the term fluorspar is used for a mineral aggregate containing enough fluorite to be of commercial interest. Fluorite, the essential constituent of fluorspar, is a mineral having specific properties and a definite chemcial composition—calcium fluoride (CaF_2). In its most limited definition, the word ore is restricted to minerals that are mined for their metallic content, but for want of a more appropriate concise term, it is conveniently applied to several nonmetallic minerals. In this report, fluorspar that is thought to be commercially minable today is called ore.

[6]Goddard, E. N., The influence of Tertiary intrusive structural features on mineral deposits at Jamestown, Colo.: Econ. Geology, vol. 30, no. 4, pp. 370-386, 1935.

of trends, northwest, northeast, and north being the most common. Nearly all dip steeply, but the walls are generally very irregular in detail.

The fluorspar breccia zones are large lenticular bodies of brecciated granite and fluorite cemented by a fine-grained mixture of fluorite and clay minerals. (See pl. 2.) These zones range from 10 to 70 feet in width and from 50 to 350 feet in length. A few of the productive breccia zones and veins grade into larger barren breccia zones that consist of slightly silicified granite breccia containing finely disseminated pyrite and in some places small amounts of fluorite. Within the fluorspar breccia zones there are commonly several high-grade veins of fluorspar ore ranging from 1 to several feet in width, that merge into the breccia.

The fluorspar veins range from a few inches to 20 feet in width and from 150 to 1,000 feet in length. They also are filled with brecciated fluorite but contain only a few granite or granodiorite fragments. Some of the best deposits in the district, such as those at the Chancellor, the Yellow Girl, and the Emmett mines, are in short, relatively wide veins that have some of the features of breccia zones. The most persistent vein in the district is the Blue Jay, which is about 1,000 feet long (see pl. 3) and forms a part of a discontinuous system about 3,000 feet long.

Character

Breccia zones.—The breccia zones, of which Burlington and Argo (see pls. 8 and 6) are the main examples, show great variability in character and composition. The richer parts contain widely scattered granite fragments and consist chiefly of small fluorite fragments, mostly less than 1 inch in diameter, in a fine-grained matrix of fluorite, clay minerals, quartz, and sericite. In the lower-grade parts of the zones, granite fragments are abundant (see pl. 4), and the fine-grained fluorite makes up a smaller proportion of the matrix. This lean material grades outward into barren granite breccia.

Veins.—The veins are composed principally of angular fluorite fragments, both coarse- and fine-grained in a fine-grained mixture of fluorite, clay minerals, carbonate, and silica. (See pl. 5.) Most of

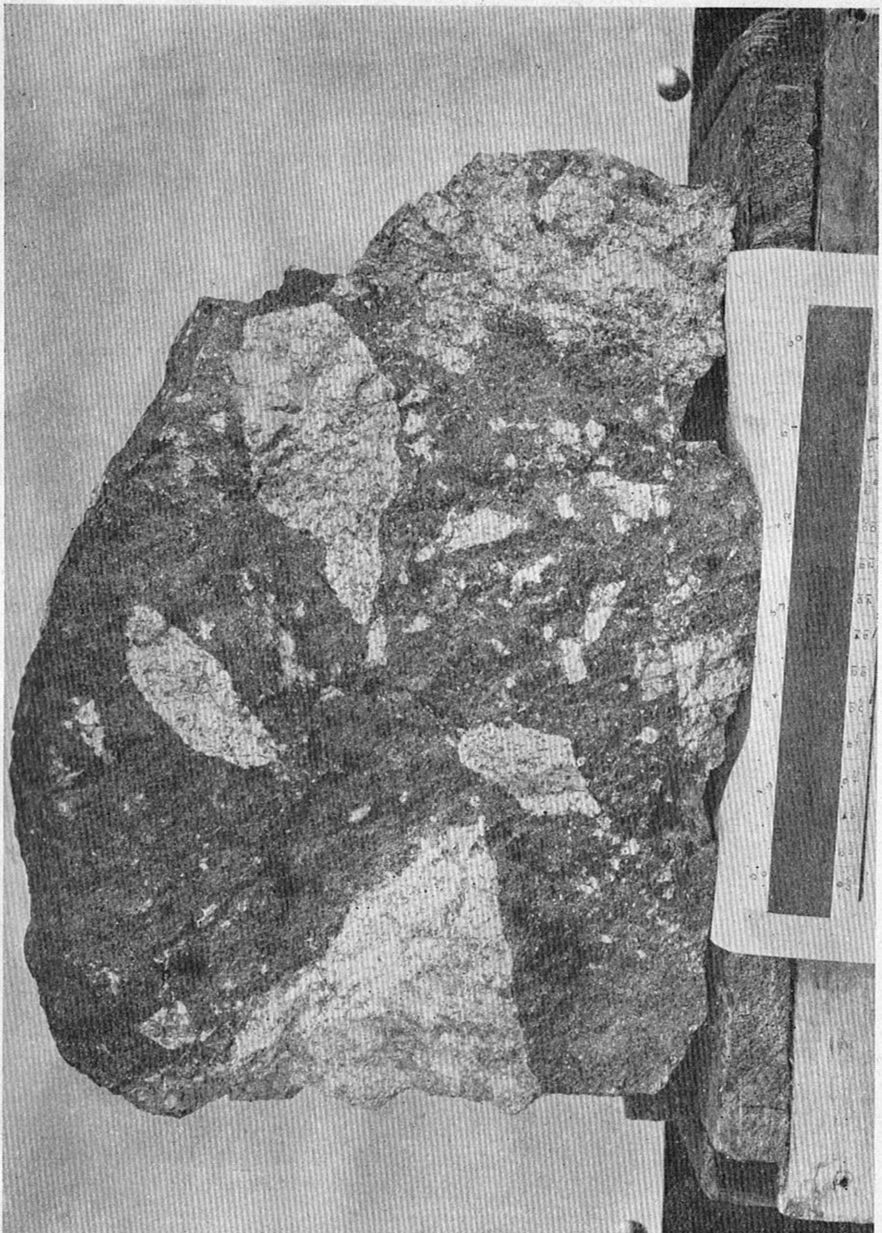


Plate 4. Fluorspar ore from Argo breccia zone, showing granite fragments (light gray) surrounded by fine-grained sugary fluorite (dark gray.) Some clay minerals and quartz are mixed with the fluorite. (Scale in inches.)

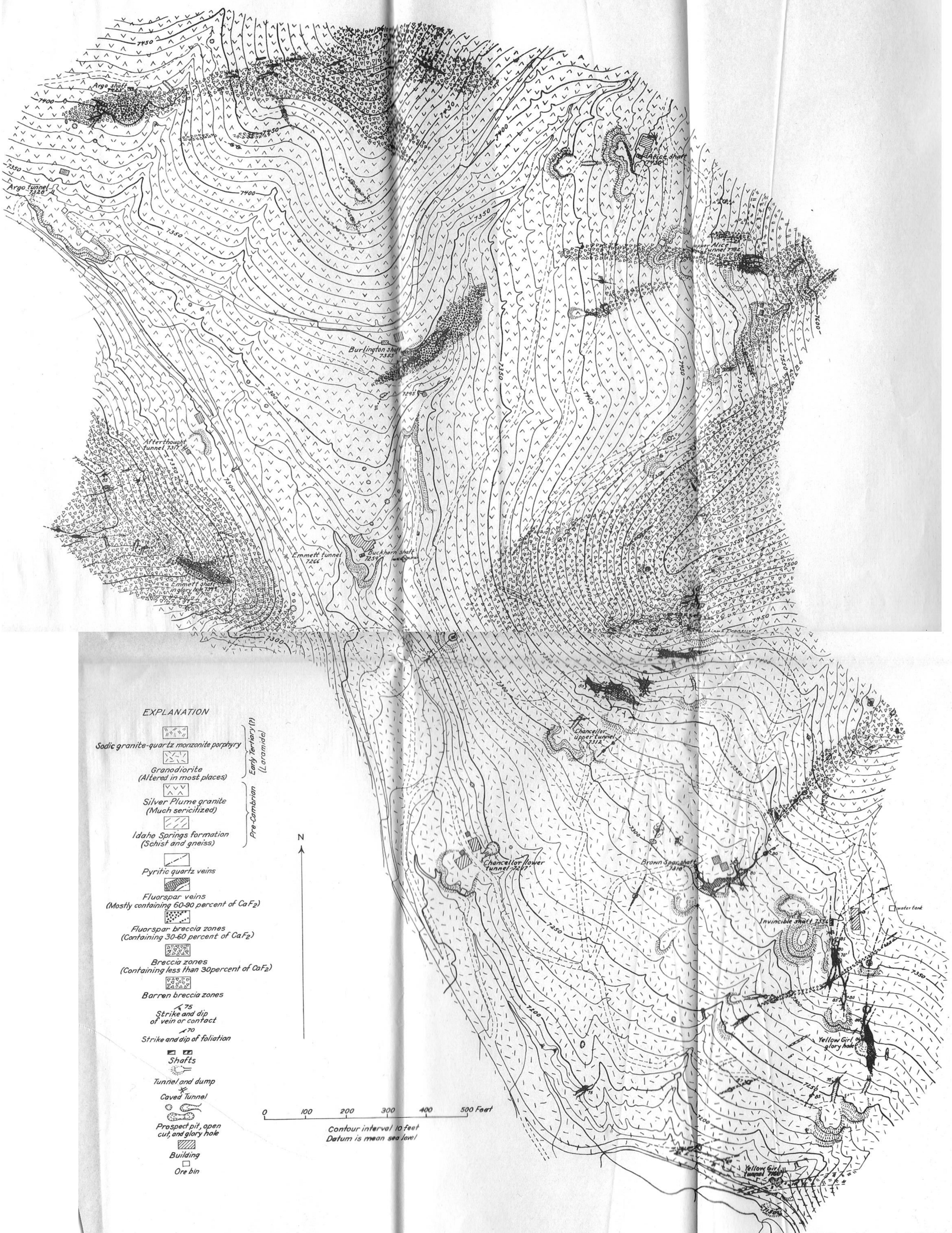


PLATE 2. GEOLOGIC MAP OF THE PRINCIPAL FLUORSPAR-PRODUCING AREA NEAR JAMESTOWN, BOULDER COUNTY, COLORADO

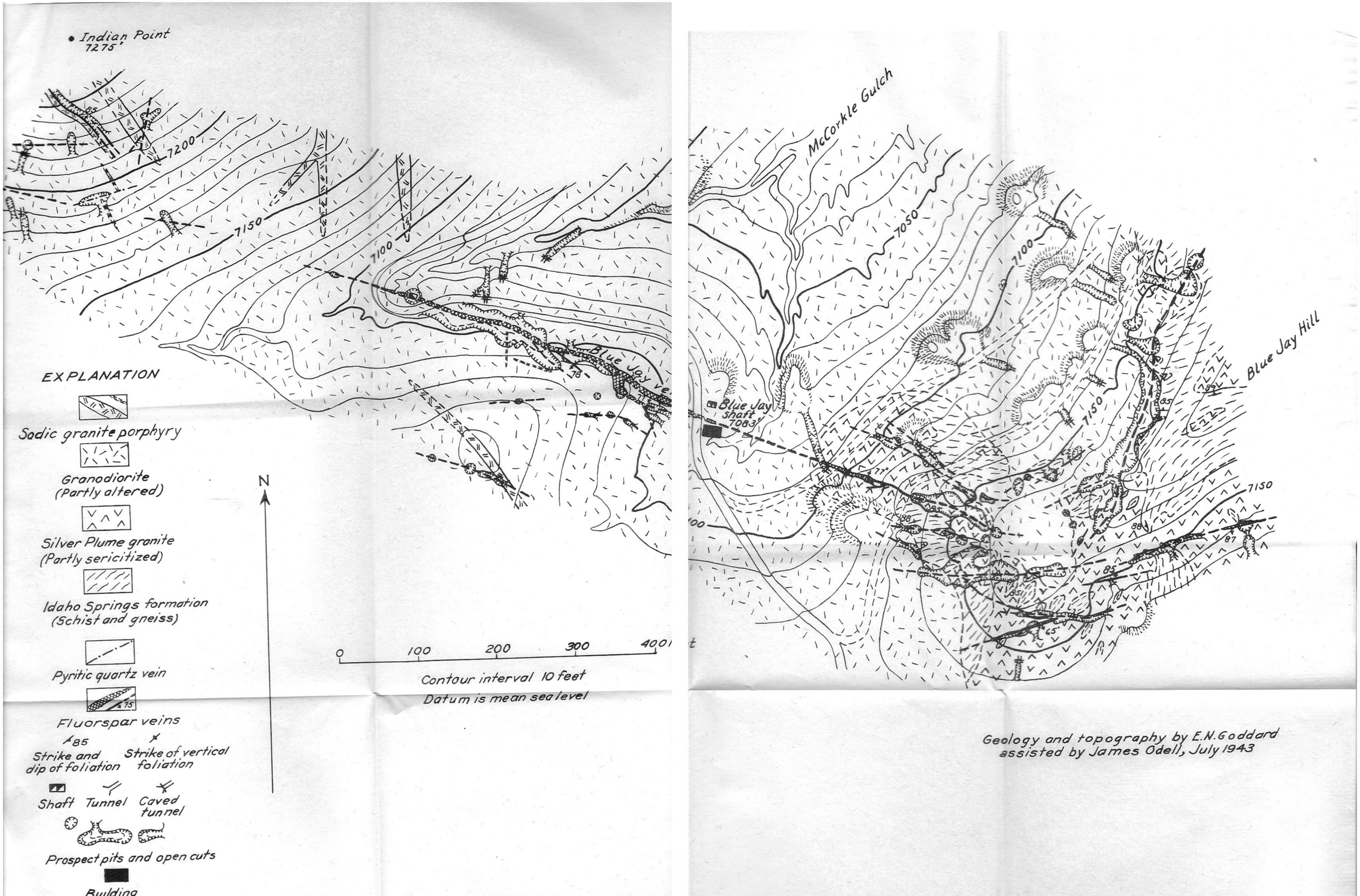
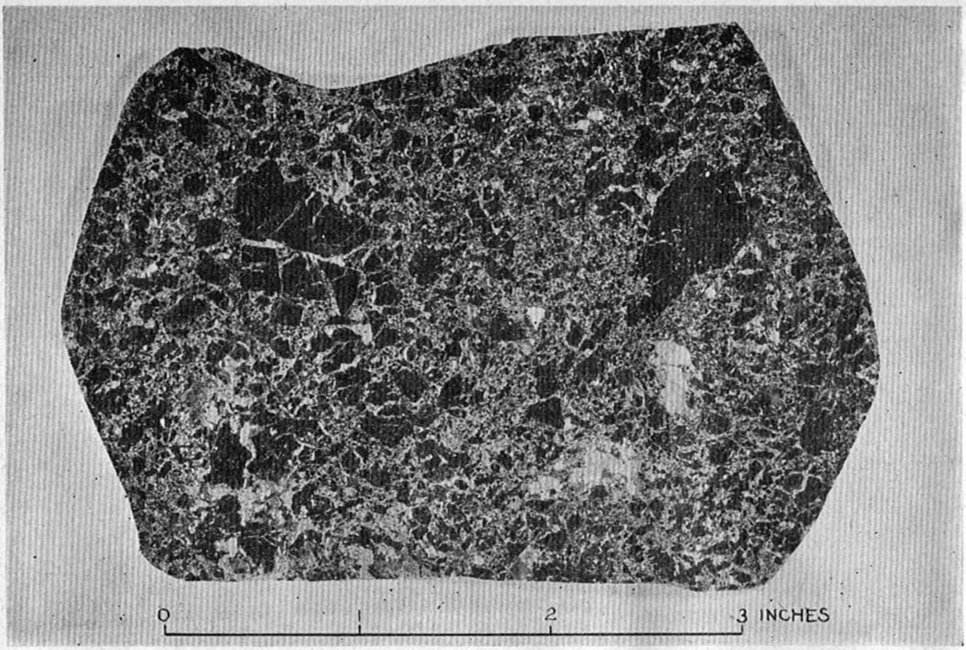


PLATE 3. GEOLOGIC MAP O THE BLUE JAY MINE AND VICINITY

A



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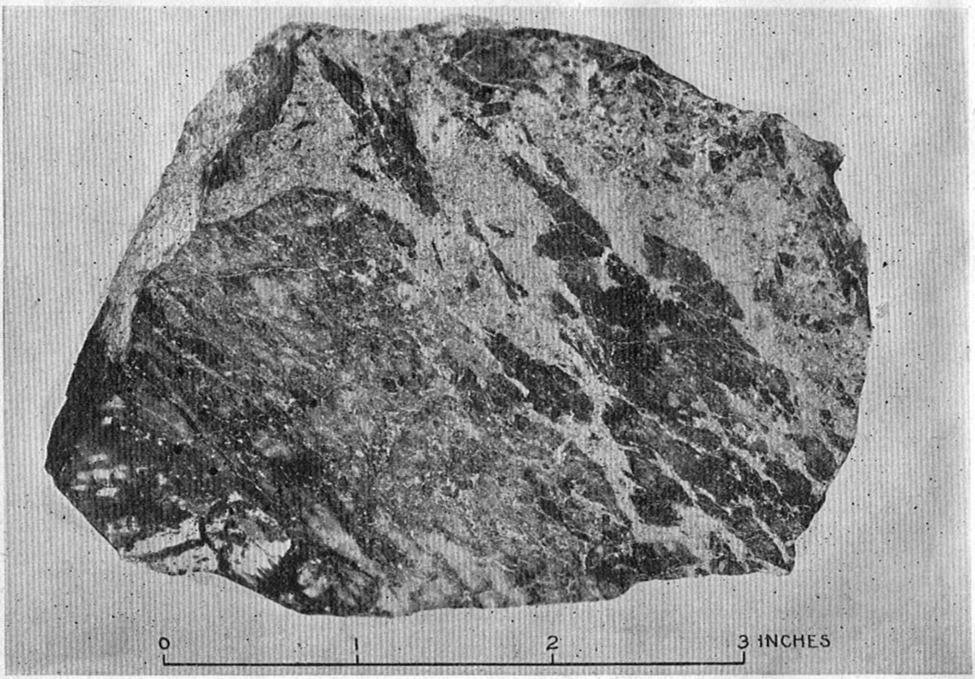

Plate 5. Fluorspar ore from veins. A. Specimen from Blue Jay vein showing breccia fragments of deep-violet fluorite (black) in a matrix of fine grained fluorite, clay minerals, carbonate and quartz. B. Specimen from Yellow Girl vein showing brecciated purple fluorite (light to dark gray, glassy) in a fine-grained matrix of fluorite, clay minerals, quartz and carbonate.

the fluorite fragments are less than 1 inch in diameter, but some, chiefly in the Emmett vein are as much as 2 feet. In places the fragments are closely packed to form rather high grade ore, as in the Emmett and the Blue Jay veins, but in many places they are widely scattered and parts of some veins are made up almost entirely of fine-grained fluorite mixed with clay minerals and other impurities. Pyrite is finely disseminated throughout the matrix and other sulfides are locally present in small quantities. Some veins, notably the Emmett, are enclosed in barren to low-grade breccia zones and some are locally bordered by low-grade breccia deposits.

MINERALOGY

Fluorite.—Most of the fluorite in the district is deep violet in color, but various shades of purple and wine color are common, and some is white to greenish white. The color bleaches rapidly upon exposure to sunlight, and even the deep-violet material on the dumps bleaches to pale purple within a few months and is colorless within a year. Thus the fluorspar outcrops are very inconspicuous and small amounts of fluorite in outcrops of the breccia zones are not easily detectable. The Jamestown fluorite is strongly thermoluminescent. When heated in the dark it takes on a phosphorescent glow at about 94° C., and at higher temperatures, this glow becomes a brilliant green. With continued heating the property of thermoluminescence is entirely destroyed along with the original color.

Most of the fine-grained fluorite is fragmental material resulting from the brecciation of coarse-grained fluorite and from the granulation of fine-grained, sugary fluorite, but in places this material is cemented by a late generation of fine-grained fluorite of purple to violet color. Viewed under the microscope, the early fluorite is nearly clear and contains only a few lines of bubble inclusions, whereas the later material is clouded with innumerable liquid and gas bubble inclusions and contains many small cavities. In some places in the Emmett mine, narrow rims of late fluorite have been deposited in optical continuity with fragments of early coarsely crystalline nearly white fluorite. In many places, the fine-grained fluorite has a sugary appearance, and it is impossible to tell in hand specimens whether both generations of fluorite are present.

Gangue minerals and sulfides.—A variety of gangue minerals are finely intermixed with the fine-grained fluorite and are very irregularly distributed. The most abundant are the clay minerals, including hydrous mica and a member of the montmorillionite-beidellite group, probably nontronite. In addition, quartz, sericite, and finely disseminated pyrite are everywhere present; chalcedony and carbonates, ranging in composition from calcite through ankerite to rhodochrosite are locally abundant. In the Emmett mine an intergrowth of hematite and ankerite cements fluorspar breccia in a few places. In several small veins from which there has been little production, deep-violet fluorite is intergrown with arfvedsonite, the soda amphibole. A few small fluorspar veins east and southeast of Jamestown are bordered by narrow bands of biotite, and in parts of the Poorman vein small flakes of biotite are mixed with calcite in the matrix of the brecciated fluorite. In one part of the Yellow Girl vein, a few small garnet crystals are found in the fine-grained matrix cementing the brecciated fluorite. Adularia is associated with fluorite in small veins east of Jamestown and in miarolitic cavities in the sodic granite-quartz monzonite stock of Porphyry Mountain. In a small vein southeast of Jamestown, and in a specimen from the Emmett mine, coarse-grained fluorite is intergrown with quartz and orthoclase as though part of a pegmatitic phase. In some of the mines, thin seams of gearksutite, a fluorine-bearing clay, cut the fluorspar ore and are believed to be supergene. The arfvedsonite, biotite, adularia and orthoclase appear to be approximately contemporaneous with an early generation of fluorite which preceeded the major period of deposition. The clay minerals, sericite, most of the quartz, and probably some of the carbonates were apparently formed by alteration of granite and granodiorite dust that was mixed with the fine-grained fluorite during brecciation. Chalcedony, some quartz, some carbonate, and hematite were deposited after the brecciation took place, but whether they are earlier or later than the latest fluorite could not be determined.

Small amounts of sulfide minerals are associated with nearly all the large fluorspar deposits; in the Alice mine a pipe-like body of lead-silver ore bordered an irregular flourspar vein and was mined to a depth of 400 feet. Pyrite is finely disseminated throughout the matrix of most of the breccia zones and veins, and most of this pyrite appears to be fragmental. Fragments of galena, pyrite, and mixed sulfides are locally abundant in the Argo and Burlington breccia zones, and pyrite fragments are also found in the Brown Spar mine. The mixed sulfides comprise galena, sphalerite, chalcopyrite, pyrite, tennanite, and enargite. The sulfides were apparently deposited either before or about the same time as the main period of fluorite deposition and they are definitely earlier than the late, fine-grained fluorite. Small amounts of galena, sphalerite and pyrite were also deposited after the brecciation. They form thin veinlets in the coarse-grained fluorite and occupy cavities in fluorspar breccia.

Minute grains of pitchblende are scattered through several of the larger fluorspar deposits and seem to bear a relation to the deep-violet color. These grains were identified in radiographs of several ore specimens by comparison with radiographs of known pitchblende. Geiger Counter analyses made by H. C. Spicer of the U. S. Geological Survey gave the following results:

	Uranium equivalent (Percent)
1. Deep-violet, fine-grained fluorspar breccia from Argo mine, winze level	.0515
2. Deep-violet fluorspar breccia from Blue Jay mine	.0426
3. Violet fine-grained fluorspar breccia from Chancellor lower tunnel	.0391
4. Pale-purple coarsely crystalline fluorite from Emmett mine, 3rd level	.00033
5. White coarsely crystalline fluorite, Emmett mine, 3rd level	.00029

The Geiger Counter, of course, determines only the intensity of the radioactivity as compared with radium and uranium and does not identify the elements present.

Grade

The fluorspar deposits in the Jamestown district show a great range in grade. The veins commonly contain from 60 to 85 percent of CaF_2 and the breccia zones from 5 to 60 percent. Crude ore shipped from the district has ranged in grade from 73 to 85 percent of CaF_2, but most of this came from high-grade pockets or was hand sorted for shipment. In past years ore treated in a small mill at Jamestown contained from 60 to 75 percent of CaF_2. In 1943 crude ore containing from 45 to 73 percent of CaF_2 was being mined and milled.

The silica content in most of the fluorspar deposits is high. It has ranged from 5 to 12 percent in crude ore shipped direct to consumer and from 12 to 32 percent in ore sent to the mill. In some of the lower-grade parts of the breccia zones, the silica content is probably much higher.

Nearly all the fluorspar ore in the Jamestown district must be milled to meet present specifications before it can be marketed. For many years a small mill, equipped with jigs and tables has milled fluorspar at Jamestown, but this method proved inefficient because a large proportion of the fine-grained fluorspar was lost in the tailings. In 1943 two flotation mills were treating Jamestown ore, and because of the fine texture of much of the ore and the intimate mixture of silica this method of treatment seems to be the most efficient. A high- grade fine-grained product suitable for the acid industry is made. In many of the veins, however, considerable coarse-grained fluorspar is mixed with the fine, and it seems probable that a process combining the use of jigs and flotation could produce both metallurgical- and acid-grade fluorspar. If the demand for metallurgical-grade fluorspar were great enough and the price relatively higher, the fine-grained concentrate from the tables could perhaps be pelletized or sintered to provide a uniform product suitable for the steel industry.

In many of the fluorspar deposits the content of galena, chalcopyrite, and associated gold and silver is sufficient to make the saving of a sulfide concentrate profitable. At the Lehman mill in 1933 a galena-pyrite concentrate containing 0.28 ounces of gold and 3.6 ounces of silver to the ton, and 30 percent of lead was recovered