STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
E. G. Koch, Director

BULLETIN 28

FLUORSPAR DEPOSITS IN MONTANA

By

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MONTANA SCHOOL OF MINES
Butte, Montana
April 1962

TABLE OF CONTENTS

ILLUSTRATIONS

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ABSTRACT

This bulletin outlines the geologic setting of fluorspar deposits and occurrences within Montana. Brief descriptions of the relationship of the fluorspar to the country rock are given. Petrographic studies indicate that this mineral occurs in many different rock types under different modes of occurrence. Photomicrographs are used to illustrate the different textural variations in which this mineral occurs as well as the petrofabrics of the host rock units.

Considerable information was drawn from earlier works by Weed and Pirrson (1896-97), Ross (1950), and Sahinen (1957). Maps are used wherever feasible to illustrate location, topography, and geologic relationships. The bulletin is divided into 2 parts, the first to give general information on mineralogy, statistics, beneficiation methods employed, and uses and specifications. The second part is divided into 3 subdivisions: (1) deposits related to the Idaho batholith, (2) deposits related to the Potassic Province, and (3) deposits related to the Boulder batholith, and one out-lying deposit in the Pryor Mountains.

INTRODUCTION

The demand for fluorspar is growing, and the amount consumed in the United States has almost tripled in the last 30 years. Further expansion in the aluminum and steel industries will result in even greater demand for fluorspar in years to come. In the light of this increasing demand and in line with this Bureau's program of commodity surveys, a study of the fluorspar resources of Montana was undertaken by the Bureau in 1958.

PREVIOUS WORK

Ross (1950) had previously made a survey of the fluorspar prospects of the State, but his work was done prior to the discovery of

I L L U S T R A T I O N S, Cont'd.

the fluorite deposits on Crystal Mountain in Ravalli County and on Fish Creek in Mineral County. Taber (1952) first described the Crystal Mountain deposits, and they were also described by Sahinen (1957).

ACKNOWLEDGMENTS

Field work for this report was done in 1956 and 1957 by W. C. Ackerman assisted by David Dahlem and D. C. Lawson. Ackerman left the Bureau in May 1959, before completing the manuscript for publication. The present report, completely rewritten and updated by U. M. Sahinen, is based on Ackerman's manuscript and the previous work of Ross (1950), Taber (1952), and Sahinen (1957). F. N. Earll critically read the final manuscript.

The assistance of many individuals in the field is acknowledged; among these, Les Sheridan and Phelan Frey of the F & S Mining Co., Butte; Frank Bryant of Landusky; and Walter Lehman of Lewistown deserve particular mention. F. A. Crowley assisted in petrographic analyses, and R. I. Smith gave helpful council on Xrays. Chemical analyses were made by C. J. Bartzen, Bureau analyst.

GENERAL DATA ON FLUORSPAR

PHYSICAL PROPERTIES

Fluorite, or fluorspar as it is known in commerce, is a fairly common mineral. Chemically it is a calcium fluoride (CaF_2), being composed of 51.1% calcium and 48.9% fluorine. The pure mineral ranges in color from deep purple through different shades of blue, green, and yellow to colorless. It crystallizes in the Isometric System as cubes that commonly show penetration twinning. The cleavage is perfect octahedral, and good cubic crystals can be readily cleaved into regular octahedrons. It is harder than calcite, but much softer than quartz, and can be readily scratched with a knife blade. The specific gravity is 3.18, the pure mineral being appreciably heavier than quartz and slightly heavier than calcite. The mineral can be readily distinguished from calcite by its lack of effervescence with dilute hydrochloric (muriatic) acid, and from quartz by its softness. Powdered fluorite with equal amounts of borax and potassium bisulfate will give a momentary brilliant green flame when heated on platinum wire.

USES AND SPECIFICATIONS

The uses of fluorspar are many, but in general can be classified into 3 principal grades: acid, ceramic, and metallurgical.

Acid Grade

Acid grade fluorspar is the highest grade and must contain 97% or more of calcium fluoride. Specifications further call for less than

1% each of silica (SiO_2), alumina (Al_2O_3), calcium carbonate ($CaCO_3$), and iron oxides, and no manganese, chromium, or sulfides. Hydrofluoric acid, made from acid grade ore, is vital to the aluminum industry where it is used in making synthetic cryolite and aluminum fluoride necessary in the reduction of alumina to metallic aluminum. About 47 pounds of cryolite and 58 pounds of aluminum fluoride are necessary to make 1 ton of aluminum; or in terms of fluorspar, theoretically, it requires about 140 pounds of acid grade ore to make 1 ton of aluminum. One ton of fluorspar is required to make $14\frac{1}{4}$ tons of aluminum.

Ceramic Grade

The ceramic industry uses finely ground fluorite to make opalescent, opal, and other glasses. Fluorite is also used in glazes and enamels. For this purpose, fluorspar must contain at least 94% calcium fluoride, less than 4% silica, and less than 0.14% iron oxide.

Metallurgical Grade

One of the most important uses of fluorspar is as a flux in making steel in open hearth and electric furnaces. The fluorspar, used essentially in slag control, is shovelled on or around lumps of lime floating in the slag and aids in dissolving these lumps. It is also used to thin the open hearth bath without changing its basicity or oxidizing properties, and is also added after the steel is tapped to aid in thinning and flush-removal of the remaining slag in the furnace bottom. Consumption of fluorspar may be up to 10 pounds per ton of steel.

Metallurgical grade fluorspar should contain at least 60 effective units (percent) of calcium fluoride. Effective units are determined by subtracting 2.5 units (percent) of calcium fluoride for each unit (percent) of silica present. Maximum allowable silica is 6%, and allowable sulfur is 0.3% (fluorspar containing 6% silica would have to contain at least 75% calcium fluoride to make 60 units of effective calcium fluoride). Other detrimental impurities are barite, sphalerite, and calcite. For metallurgical use, fluorite is generally ground to a minus-1-inch-plus-15-mesh size with an allowable 15% fines.

Other Grades

Fluorite crystals are used in the optical industry in the manufacture of lenses for microscopes. For this purpose, the fluorite crystals must be free from cracks, inclusions, cloudiness, or cleavage traces, and large enough to yield clear pieces at lease $\frac{1}{2}$ inch in diameter.

Fluorspar is also used in the manufacture of organic compounds and insecticides and in the refining of gold, lead, copper, and antimony.

PRODUCTION

The world's production of fluorspar comes from deposits in the United States, Mexico, U.S.S.R., China, Italy, West Germany, Spain, France, United Kingdom, and Canada. In 1958, the United States produced about 319,513 short tons of fluorspar and imported 392,164 short tons. Acid grade fluorspar sold for $50 to $55 per short ton; metallurgical grade ranged from $33 to $41 per short ton.

The largest deposits of fluorspar in the United States are in the Rosiclare district of southern Illinois and adjoining Kentucky. Here the fluorspar occurs in fault zones and as replacements in limestone. This area yielded about 52% of the domestic production in 1957. Fluorspar is also mined in Colorado, California, Nevada, and Montana.

In Montana shipments of fluorspar in 1957 amounted to 64,339 tons or nearly 20% of the United States total. In 1958 mine production increased substantially but shipment dropped to 53,654 tons. Smaller shipments to the steel mills and cessation of 1 mining operation which shipped its output to the GSA Stockpile caused the decline. Cummings-Roberts was the only producer. Of the total production in 1958, 65% was sent to stockpile, 34% was consumed by the steel industry, and the remainder was used at metallurgical and cement plants. (Fulkerson, Kingston, and Kauffman, 1959).

From 1948 to 1958 inclusive, Montana has produced 240,966 tons of fluorspar valued in all at about $7,365,572. Production was mostly from Ravalli and Mineral Counties.

BENEFICIATION

Beneficiation is necessary not only to upgrade fluorspar ores, but also to obtain a product which is uniform in size and chemical composition. Methods of beneficiation may range from hand-sorting to gravity and flotation methods.

Gravity methods utilize washing, tabling, jigging, and heavy media separation. Heavy-media plants are popular in the Rosiclare district in Illinois in conjunction with flotation and jigging. Ferrosilicon is used in the heavy media. Sulfides associated with the fluorspar are removed by jigs.

Flotation is used to beneficiate most of the domestic fluorspar at the present time. Practically all the acid grade fluorspar is produced by this method. Reagents most commonly used are fatty acids, such as oleic acid as a collector, sodium silicate as a depressant for quartz, and tannin as a depressant for calcite. Ores ranging in grade from 35 to 50% calcium fluoride can be upgraded to products ranging from 85 to 98% calcium fluoride by flotation methods.

Fluorspar concentrates are commonly pelletized to prevent excessive dust losses in furnace feeds. Low temperature binders are cement, starches, and flour, which set at 50° to 212° F; medium-temperature binders are by-products of wood pulp and petroleum and set at about 500° F.; high temperature binders are compounds which set at 1,250° to 1,450° F. Sizes of pellets range from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter.

DESCRIPTION OF DEPOSITS

In the following pages not only the commercial deposits are described, but also those deposits or occurrences that may become commercial through further development, as well as occurrences which may never become commercial, yet shed some light on the mode of occurrence and origin of fluorspar in Montana.

An attempt has been made to group the different deposits into geologic provinces. Whether such a grouping is justified is problematical, nevertheless, they appear in groups as follows:

1. Deposits related to the Idaho batholith
2. Deposits related to the Boulder batholith
3. Deposits related to the Potassic Province of central Montana
4. Deposits in the Pryor Mountains

Deposits of the first group have several features in common; and all of the deposits that have been worked commercially occur in this group. All of these deposits are in Belt sediments of Precambrian age around the margins of the Idaho batholith, and are somewhat similar mineralogically.

The second group has 1 feature in common: the fluorite occurs in hydrothermal veins associated with metallic minerals or quartz or both. They are related to the Boulder batholith or its satellites.

The third group of occurrences is peculiar in that the fluorite is commonly associated with gold ores and has been of value to prospectors as an indicator mineral in their search for gold deposits associated with the potassic rocks of central Montana's isolated mountain groups.

The fourth "group" consisting of 1 deposit in the Pryor Mountains does not fit in with any of the other three. Here the fluorite is associated with uranium ores.

The distribution of fluorspar deposits in Montana is shown on map in figure 1.

DEPOSITS RELATED TO THE IDAHO BATHOLITH

CRYSTAL MOUNTAIN

The writer was prevented from examining the deposits in person, therefore, the following description has been taken from the reports of Taber (1952) and Sahinen (1957).

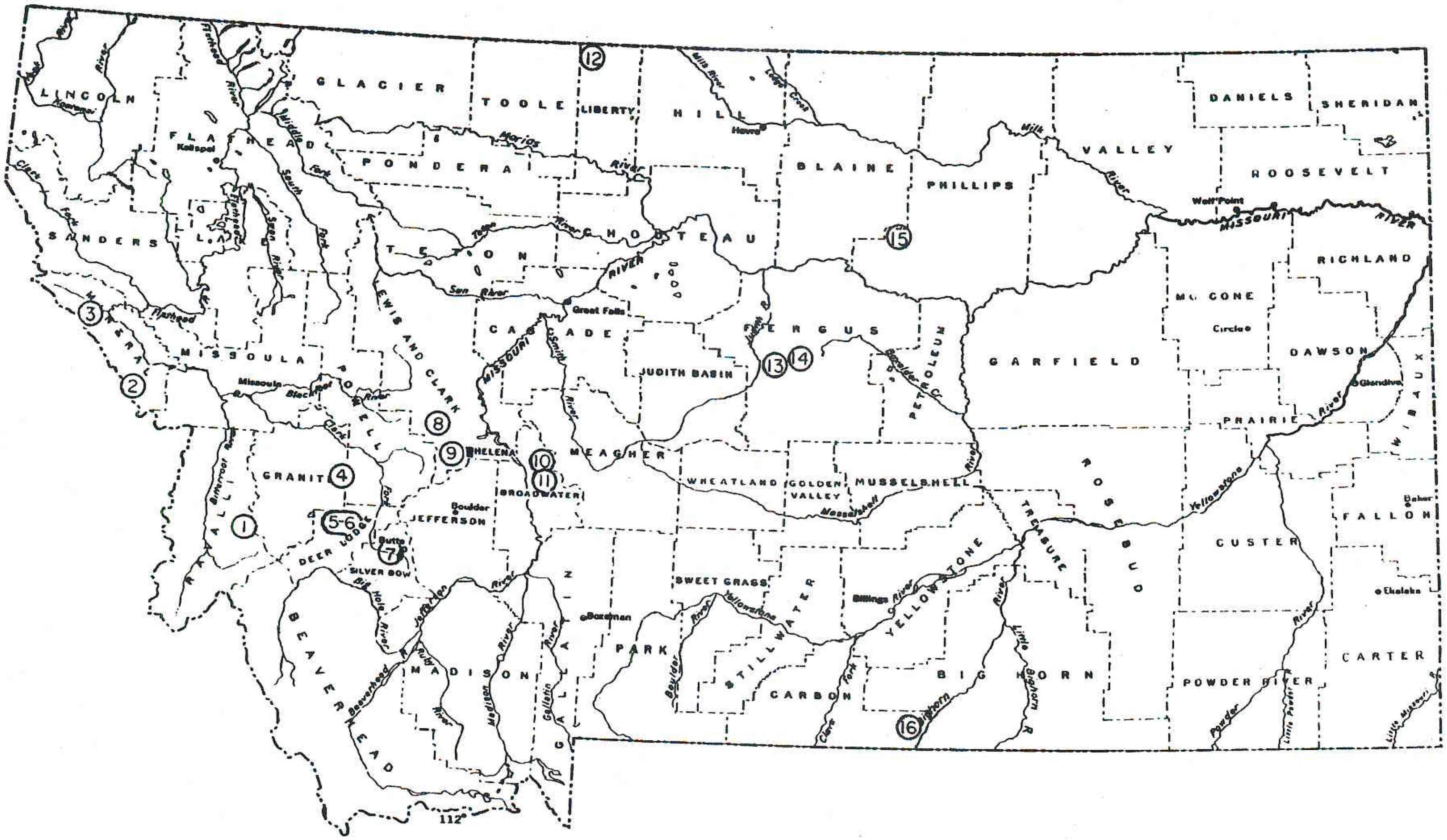

Figure 1. -- Map showing known major fluorspar localities in Montana.

(1) Crystal Mountain mine
(2) Snowbird mine
(3) Spar mine
(4) Albion prospect
(5) Jetty prospect
(6) Weathervane prospect
(7) Silver Bow deposits
(8) Bald Mountain mine
(9) Boeing prospect
(10) Boulder Mountain prospect
(11) Normandy prospect
(12) East Butte deposits
(13) South Moccasin Mountains
(14) American Flag prospect
(15) Antone Butte prospect
(16) Old Glory Uranium mine

The Crystal Mountain fluorite deposits are on the Rye Creek-Sleeping Child divide in secs. 17 and 18, T. 3 N., R. 18 W., in southwestern Ravalli County. The present operating pit is 26 miles by road east of Darby and lies at an elevation of 6,800 feet above sea level. The area is heavily wooded except for the outcrops themselves (see figure 2), which are largely devoid of vegetation.

The deposits were first noted by A. E. Crumley and L. I. Thompson in 1937 while they were building the Forest Service trail along the Rye Creek-Sleeping Child divide. The trail passed directly over the eastern or Retirement outcrops, but no one recognized the mineral. In 1951, Crumley and Thompson saw a collection of minerals in Darby and remembered the fluorite outcrops; they were persuaded to return to the outcrops for samples of what they thought was beryl. (The green fluorite of Crystal Mountain greatly resembles pale-green transparent beryl or aquamarine.) During this year, Crumley and Thompson, with R. D. Flightner, staked the present claims, and, on recommendation of P. H. Toepfer of the Federal Bureau of Mines, sent samples of the material to that Bureau's offices in Albany, Oregon, where they were, of course, identified as high-grade fluorspar. The Bureau of Mines then proceeded to develop the deposits by bulldozer trenching, blasting, and sampling. The results of the Bureau's testing were published as Report of Investigation 4916 (Taber, 1952).

Cummings-Roberts Co. of Compton, California opened the first pit in 1952 and made the first commercial shipment in September of that year. Yearly shipments as published in the U. S. Bureau of Mines Minerals Yearbook are as follows:

1952	-	16,160	short tons
1953	-	5,932	" "
1954	-	15,102	" "
1955	-	25,223	" "
1956	-	59,775	" "
*1957	-	64,339	" "
*1958	-	53,654	" "
Total		240,185	short tons

In 1959 and 1960 the Cummings-Roberts Co. was the only producer of fluorspar in Montana. The fluorspar is shipped to the United States Steel Company plant in Utah, and to other purchasers in Seattle, Portland, San Francisco, Los Angeles, and Chicago. Shipments are made under contract in large volumns to steel companies, foundries, and ceramic plants. Some single car lot sales are also made.

The deposits occur in 2 separate groups of outcrops 3,000 feet apart. The smaller, Retirement, group consists of 2 small elliptical outcrops about 60 feet wide and 150 feet long lying near the section line between sections 17 and 18 at an elevation of 7,300 feet above sea level. These outcrops are on the crests of small knolls and do not appear to be very thick. Their attitude suggests that they are the erosional remnants of a flat-lying vein. A mass of white quartz

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*Includes production from Snowbird mine in Mineral County.

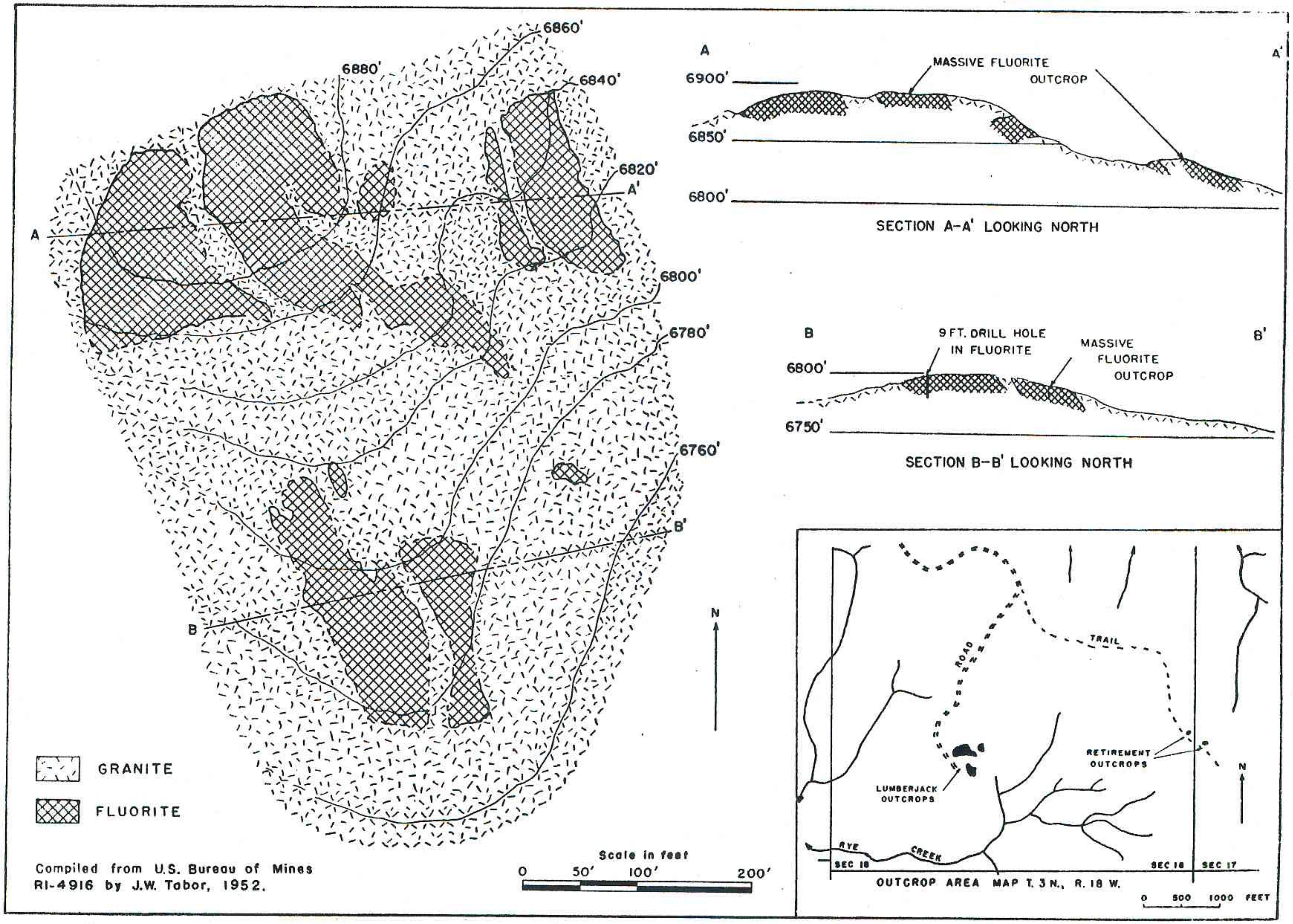

Figure 2 — PLAN AND SECTIONS, CRYSTAL MOUNTAIN FLUORITE DEPOSITS

overlies the western outcrop, and veinlets of glassy quartz occur in the flat-lying footwall, which consists of granite and fine-grained grey gneiss. (See figure 3.)

The larger, Lumberjack, group of outcrops are in the $NE\frac{1}{4}SW\frac{1}{4}$ sec. 18, T. 3 N., R. 18 W., at an elevation of about 6,850 feet. This group includes 3 main bodies, 100 to 200 feet wide and 200 to 400 feet long. They are irregular closely spaced deposits in granite. These deposits are being mined by open pit methods at present. Stripping and mining has disclosed these deposits to be flat-dipping tabular lenticular ore bodies with a southeasterly dip of 10° to 35°. Individual outcrops are separated by granite dikes. Recent development seems to indicate that the deposits continue below the surface down-dip.

The fluorite is exceptionally pure and remarkably uniform in appearance and quality. It ranges in color from pure white through pale green to deep purple. The deep-purple fluorite bleaches white in the sunlight at the outcrop. The material is coarsely crystalline, the individual grains ranging in diameter from about one-tenth of an inch to as much as one inch, but on the whole averaging less than one-half inch. The impurities are chalky white altered feldspar, sericite, quartz, and black biotite mica. Average grade of the material is better than 96% calcium fluoride. Weighted averages of 9 samples taken by the U. S. Bureau of Mines showed 97.2% calcium fluoride, 1.44% silica, and 0.13% iron. Besides the elements of fluorite, calcium and fluorine, spectrographic analysis showed the presence of very small amounts of aluminum, magnesium, iron, silicon, sodium, zirconium, copper, cobalt, barium, nickel, titanium, and columbium.

Weiss, Armstrong, and Rosenbloom (1958, p. 20) state that "some, but not all, of the dark-purple fluorite is abnormally radioactive." They recognize 3 different radioactive occurrences in the Lumberjack outcrops.

1. Biotite concentrations (with halos of dark-purple fluorite around biotite crystals) are slightly radioactive.

2. Fergusonite (metacolumbate and tantalate of yttrium with halos of dark-purple fluorite) in coarsely crystalline light-colored fluorite.

3. Radioactive dark-purple fluorite band about 1-foot thick and 50 feet long assayed 0.13% equivalent uranium and 0.078% chemical uranium; the difference between the equivalent and chemical assays is suspected of being due to the presence of thorium. Very little of the dark-purple fluorite in the Retirement outcrops was found to be radioactive, and then only very slightly so.

A peculiar feature of these outcrops is that no vegetation grows on them; and at the surface, the sun has bleached them pure white; consequently, they can be readily spotted from an airplane (or on aerial photos, on which they resemble patches of snow).

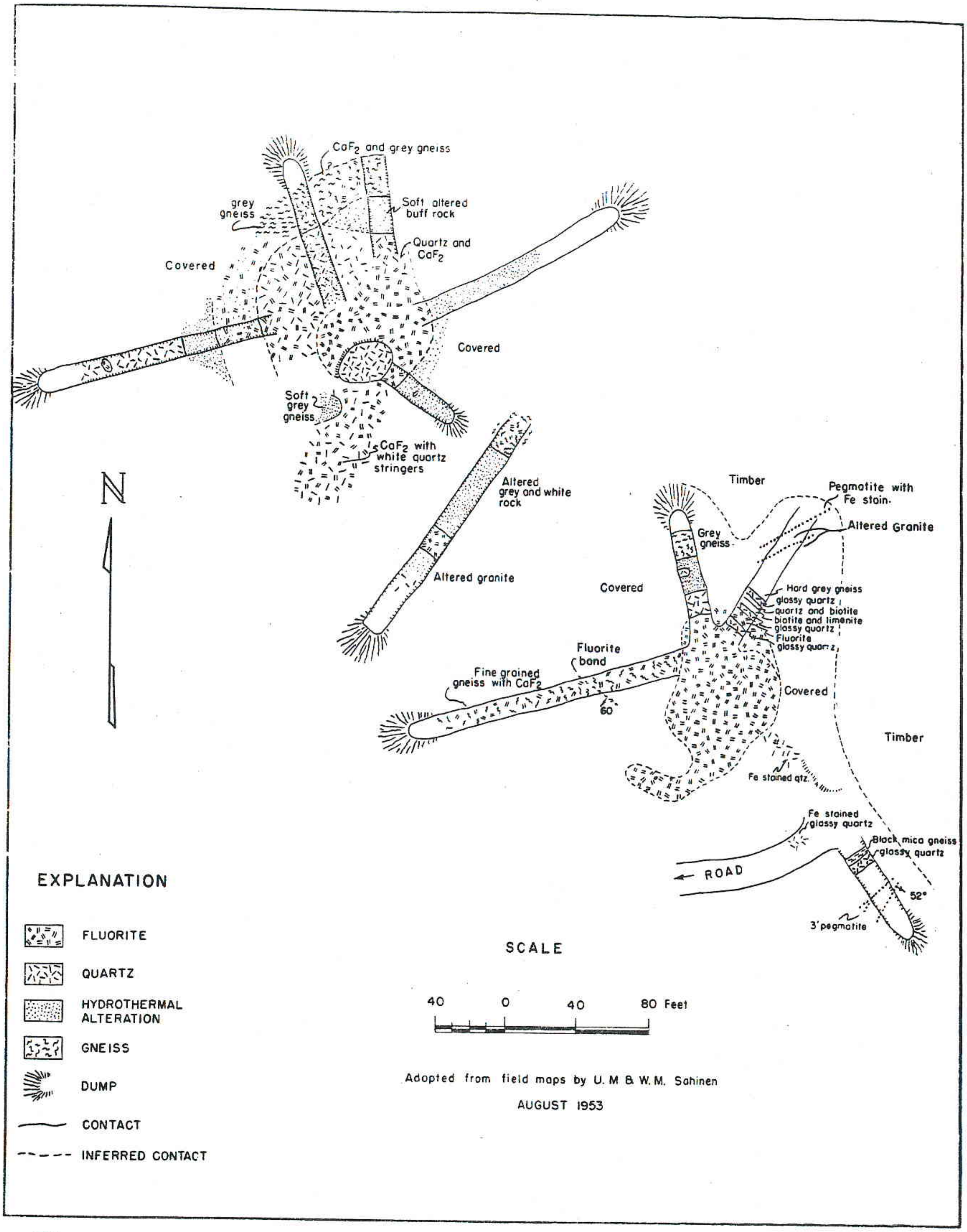

Figure 3.--Geologic map of the Retirement fluorspar outcrops, Crystal Mountain Mine, Ravalli County, Montana.

Late in 1956 a crushing, screening and sorting plant was erected near the pit. The plant has a capacity of 400 tons of coarse metallurgical-grade fluorspar per 8-hour shift. Larger pieces of granite waste rock are picked out on a conveyor belt, and the fines from screening are stockpiled for future milling and production of acid-grade rock.

More recently another plant for treating the ore has been erected at the railroad siding in Darby, but details of this plant are not available.

Beneficiation tests conducted on this ore by the U. S. Bureau of Mines resulted in the following conclusions (Taber, 1952, p. 7):

1. Calculated heads on various tests range from 95.8 to 96.2% CaF_2 (calcium fluoride), and the head assay figure was therefore discounted.

2. By crushing to minus ½-inch and screening at 35-mesh, the oversize may be recovered as a product containing 97.67% CaF_2 accounting for 95.5% of the fluorspar present. Other assays are: SiO_2, 0.82%; Fe_2O_3, 0.21%; $CaCO_3$, 0.20%; S, 0.05%; Pb, less than 0.05%; Zn, less than 0.1%.

3. The minus ½-inch feed may alternatively be screened at 10-mesh and the oversize beneficiated by a sink-float operation; the resulting concentrate contains 98.8% CaF_2 with 79.6% recovery. The undersize, ground to minus 28-mesh, may be passed through a wet cyclone to recover a second concentrate of 97.8% with 7.8% additional recovery. Combined concentrates will have the following average analysis: CaF_2, 98.7%; SiO_2, 0.25%; $CaCO_3$, 0.54%; S, less than 0.30%; Pb, less than 0.05%; Zn, less than 0.1%; Fe_2O_3, 0.10%.

4. Tailings from either of the alternative procedures will make acceptable flotation heads.

5. The major portion of the gangue material is found in the minus 65-mesh fraction.

SNOWBIRD

The Snowbird fluorite mine is in unsurveyed sec. 20(?), T. 12 N., R. 25 W., in southwestern Mineral County. It is on the headwaters of Cedar Log Creek below the crest line of the Bitterroot Range, which forms the boundary between Montana and Idaho. The property can be reached by driving 33 miles up (south) Fish Creek road no. 343, which leaves U. S. Highway 10, 9 miles west of Alberton. The last 14 miles of road was cut by the F & S Mining Co. of Butte in 1956. The deposit was mined out by the F & S Mining Co. in less than 2 years, and the description that follows is of purely historical interest.

The property consists of 19 unpatented claims named Snowbird 1 through 19. Mining began late in 1956 when the F & S Mining Co. opened the pit. Four men were employed. The fluorite was scooped into trucks and hauled to the head of Fish Creek where it was crushed and screened to a minus 1-inch-plus-15-mesh product and shipped to a Government stockpile in Pueblo, Colorado. Approximately 6,500 short tons of metallurgical grade fluorspar were produced in 1956 and 1957 when the deposit was exhausted.

The bedrock of the fluorite area is composed of argillite, argillaceous limestone, slate, and limy quartzite of the Wallace Formation of the Precambrian Belt series. (See figure 4.) The Idaho batholith has intruded these metasediments to the south, and evidence of the intrusion is noted in the contact metamorphic effects on the argillite member of the Wallace Formation which here strikes S. 10°-30° E. and dips 40°-50° NE.

The spotted argillite consists of perfect spherical metacrysts of light-colored dipyre (a scapolite) about 2 mm in diameter in a purplish argillitic ground-mass. In hand specimen, only the dipyre is recognizable, but under the microscope the ground-mass is seen to be composed of fine-grained equigranular quartz, biotite, sericite, zircon, and minor tourmaline. X-ray studies indicate that the zircon contains hafnium, and rare-earth elements were also detected by X-ray fluorescence. Under the microscope the light-colored metacrysts most closely resemble the scapolite mineral dipyre, composed essentially of the marialite molecule ($Na_4Al_3Si_9O_{24}Cl$) with minor amounts of the meionite molecule ($Ca_4Al_6Si_6O_{24}CO_3$). The spheres are almost perfect, occasionally zoned, and of fairly uniform size. Where the spherulites have formed very close to each other, they meet along a straight edge. Such perfect spheres of uniform size throughout suggests that they were formed by pneumatolytic (gaseous) action rather than by hydrothermal alteration or solutions.

The fluorite-bearing body is pod-like with the long axis striking east. It crosscuts the spotted purple argillite and is exposed for 600 feet in length and 150 feet in width at the widest point. (See figure 4.) Near the east end of the deposit there is a 20-foot shear zone, but the pod itself is offset only a few feet. The major portion of the pod is massive white quartz which stands out above the surrounding country rock. It forms the hanging wall portion of the deposit. The quartz contains no inclusions, but protruding from the mass are euhedral hexagonal crystals of quartz ranging in size from minute to as much as 2 feet in diameter and 4 to 6 feet long. The footwall portion of the vein is made up mainly of massive but crystalline pale yellow-brown calcite and subordinate fluorite. The calcite also contains brown siderite in masses $\frac{1}{2}$ to 2 inches in diameter and small grains of iron sulfide.

The fluorite occurs in the calcite in pockets of various size. It is massive and crystalline and ranges in color from white through green to deep purple. The contacts between calcite and fluorite are sharp, but the fluorite contains some included impurities as assays of it ranged from 96.2 to 96.5% calcium fluoride. There was very little difference in the assays of different colored fluorites.

The order of crystallization in the vein is quartz, calcite, and fluorite, but there was a slight overlap in crystallization between

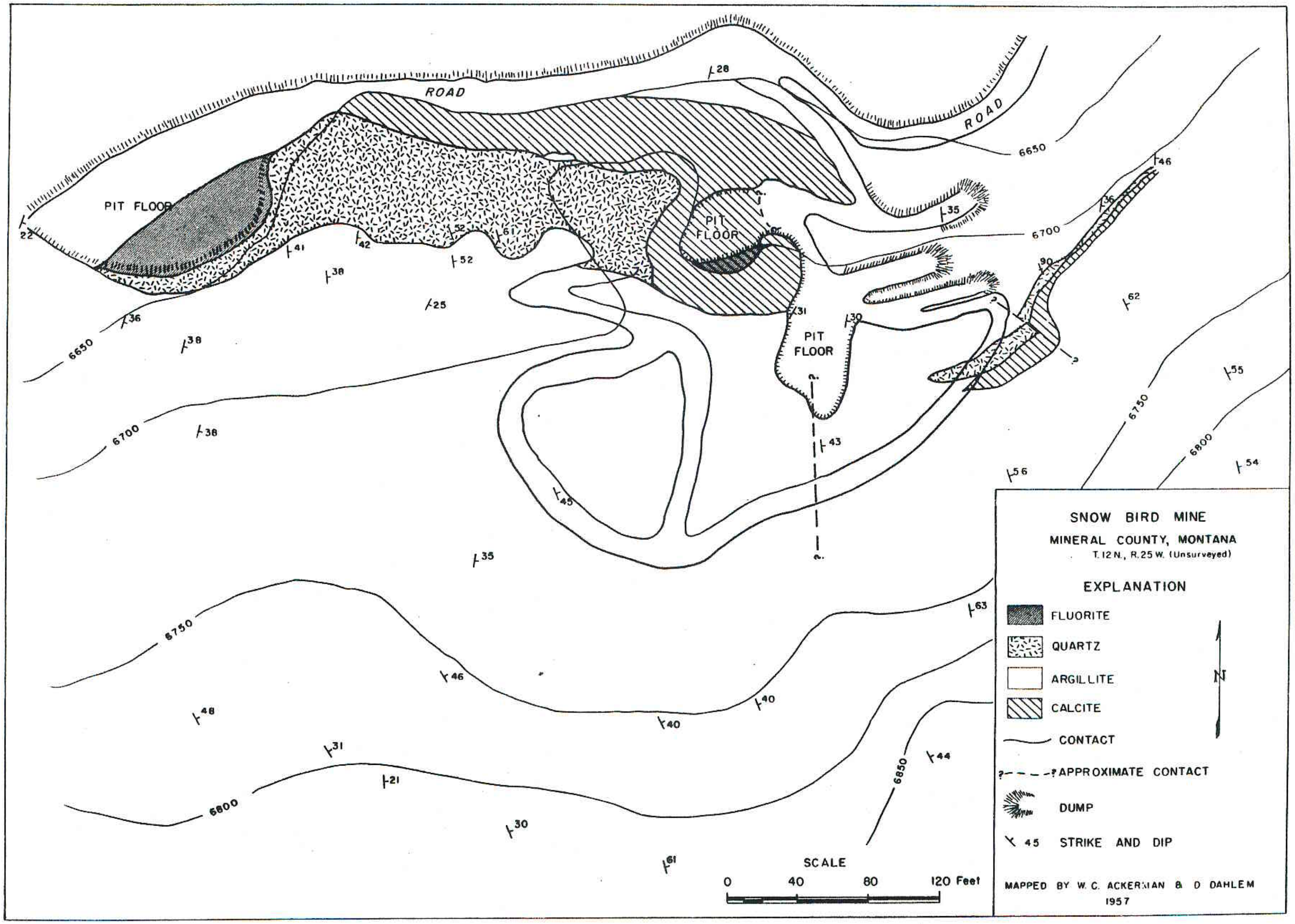

Figure 4.--Geologic map of Snowbird fluorspar deposit, Mineral County, Montana.

the calcite and quartz. The vein is thought to be of hydrothermal origin, but the texture as a whole is decidedly pegmatitic.

SPAR MINE

The Spar fluorite deposit is (was) on the ridge between Dry Creek and Bear Creek in sec. 31, T. 17 N., R. 27 W., in central Mineral County. It is about 12 miles by graded (unpaved) road westward from Superior, the County Seat and nearest shipping point. The deposits were examined by Ross and Reimund in 1944 (Ross, 1950). Much of the information given below is from Ross's report.

The Spar claim was located by Joseph Brooks on June 3, 1943. Brooks and his associates, C. W. Brass and F. E. Scott, all of Wallace, Idaho, purchased the rights of certain prior locators, organized the Spar Mining Co., and started development in 1944. Late in 1944 the property was taken over by the Coeur d'Alene Extension Mines, Inc. of Wallace, Idaho, but Brooks and his associates maintained control. All the fluorspar developed in 1944 was mined out in that year. The Wilson Creek deposits were discovered in 1948, and the low-grade Lime Gulch deposits in 1949. In 1948 the Coeur d'Alene Extension Mines, Inc. leased the Wilson Gulch and Bear Creek (Spar mine) properties to Mr. J. Bettles who produced 318 tons of fluorspar averaging 96.6% calcium fluoride. The properties were subsequently (1949) leased to the Riverside Mining Co. of Wallace, Idaho which shipped 422 tons of fluorspar in 1949 and 41 tons on 1950. This is the last reported production.

The bedrock in the general area of the fluorite deposits consists of quartzite, argillite, calcareous quartzite and argillite, dolomite, and "sideritic" limestone of the Wallace Formation of Precambrian (Beltian) age. (See figure 5.) Ross (1950, p. 207) noted "segregation structures" which are typical of the Wallace Formation of Ross's Piegan Group (Ross, 1950). The beds are strongly folded and in general strike northwest, but in detail the strike and dip vary widely. Fracturing has developed sheeted zones and breccias. In places the metasediments have been cut by prominent, irregular, lenticular masses of white quartz. The fluorite of the original discovery at the Spar mine was associated with such a mass. No igneous rocks occur in the immediate area, but the Idaho batholith lies about 35 miles to the south, and a large diabase sill has been reported about 10 miles away along the Idaho border.

At the Spar mine the fluorite is associated with a large mass of pure white quartz about 150 feet long and 30 feet wide. The mass strikes about N. 80° W. The fluorite occurred in irregular pods and lenses from several inches to several feet in diameter. Calcite and ankerite together with minor amounts of galena, tetrahedrite, and pyrite are associated with the fluorite. A sample cut by Ross (1950, p. 208) in the original discovery pit was reported to contain 98.57% calcium fluoride, 1.18% silica, and 0.14% carbonate. The sample was cut across a 45-inch face showing some limonite stained fractures, and fluorite streaks which occurred in the quartz forming the walls of the pit.

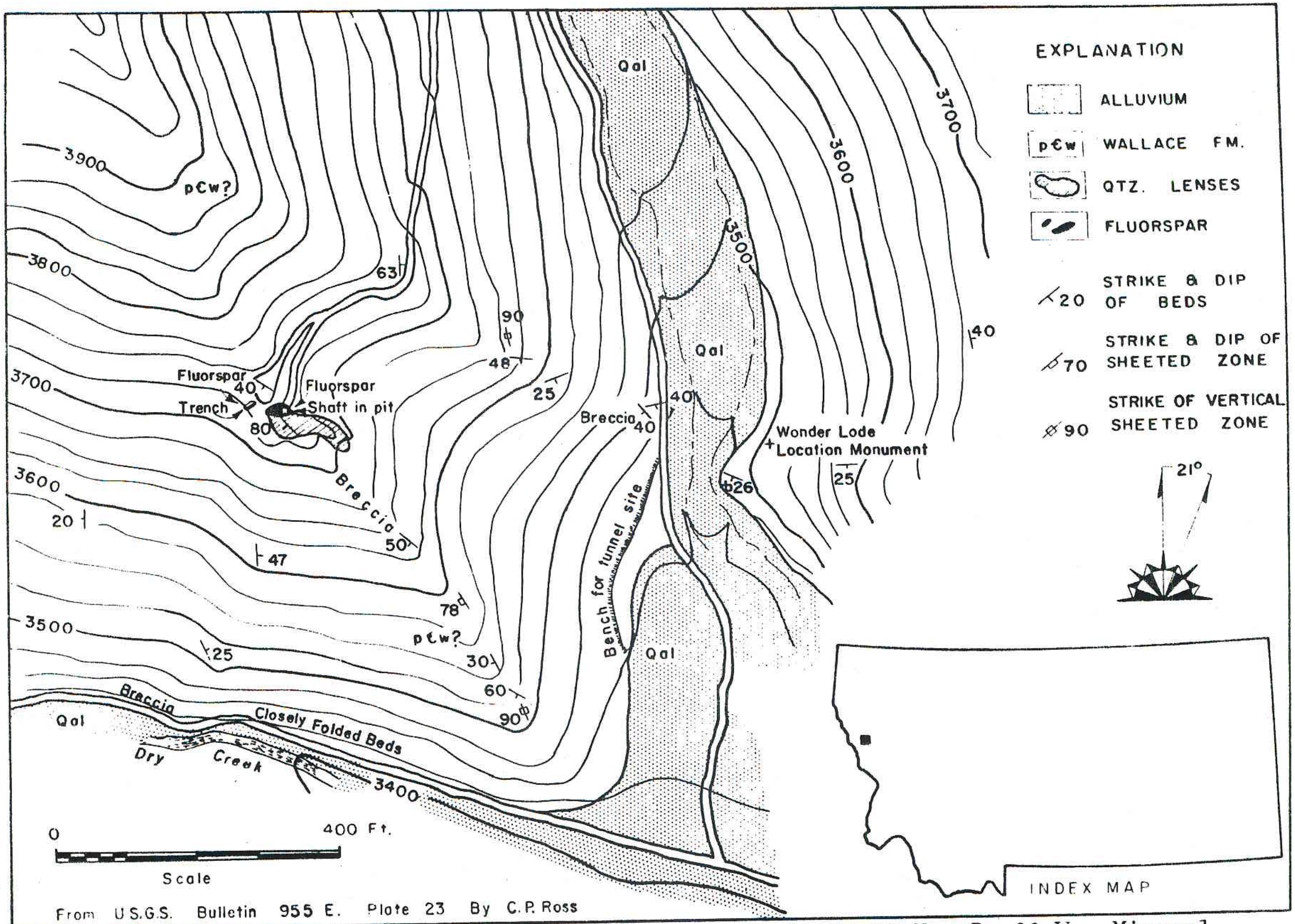

Figure 5.--Geologic map of Spar fluorspar prospect, T. 17 N., R. 29 W., Mineral County, Montana.

Production from this property came from surface workings and 2 adits driven under the outcrop, 1 at a depth of 20 feet and the other at 90 feet, all on the Spar claim. The major adit at the bottom of Bear Gulch (about 250 feet below the outcrops) was driven 600 feet into and under the fluorite outcrops, but did not encounter any fluorite. About 250 feet of this work was done in 1950, the last time that the property was reported as operating.

DEPOSITS RELATED TO THE BOULDER BATHOLITH

The Boulder batholith and associated intrusives have been studied by many workers during the past 50 or 75 years, and literature concerning it is voluminous. The many different mining districts associates with the batholith and its outliers have been pretty thoroughly studied as to mineral assemblages, and fluorite has been noted in several of the districts, although nowhere has it yet been found in commercial deposits. The more promising deposits of fluorite appear to occur near the margins of the batholith. Fluorite occurs sparingly as a gangue mineral in the manganese-zinc veins in the Philipsburg district, in the deeper levels (800 feet). Emmons and Calkins (1913, p. 55) noted fluorite of metamorphic origin in the Silver Hill Formation at the head of Mill Creek, south of Anaconda, and as a primary mineral in granite on Lost Creek, north of Anaconda. In the deposits described below, the fluorite is essentially a mineral of hydrothermal origin associated with metalliferous veins.

ALBION MINE

The Albion mine is in the $SW\frac{1}{4}SW\frac{1}{4}$ sec. 34, T. 8 N., R. 12 W., in eastern Granite County. It is about 10 miles by road southeasterly from Maxville in an area known as the Deer Lodge Basin.

Emmons and Calkins (1913, p. 248) described the mine as follows: "Two tunnels are driven on 2 veins, and altogether more than 1,000 feet of drifts have been run. The ore mined (was) for the most part too low grade to ship, and the (value of) production of the mine has not exceeded a few hundred dollars. The principal vein is in the quartzite and sandy or calcareous shales of the Quadrant Formation, which (strikes north and) dips about 80° W. The vein occupies a shear zone, which conforms approximately with the bedding * * *. It has been followed for about 800 feet and is from 1 to 3 feet wide. About 400 feet from the portal a dike of porphyry striking eastward ends abruptly at the vein. Since it occurs only to the east of the vein, it has presumably been faulted by movement along the zone which the vein occupies. The minerals are quartz, limonite, malachite, chrysocolla, pyromorphite, pyrite, and grey copper (and the ore was valued chiefly for its silver content).

"About 200 feet east of this vein, and connected with it by a crosscut, is another vein which strikes S. 32° E. and dips 77° W.

Its footwall is granite and its hanging wall calcareous shale. It is narrower than the west vein and has not been so extensively explored. The ore, which is not greatly oxidized, consists of quartz, fluorite, zinc blende, galena, and grey copper, and is said to carry about 20 ounces in silver and $2 in gold to the ton."

The mine was visited by the writer during the summer of 1957. The mine itself was inaccessible due to a caved portal, and only a very small amount of fluorite was found on the dumps. Specimens of vein matter examined in thin-section showed that fluorite replaces vein quartz. The "porphyry" mentioned above is a porphyritic biotite granite.

Apparently the fluorite occurrence in this mine is not of commercial significance or more of the material would have been found on the dumps.

JETTY MINE

The Jetty mine is in sec. 27, T. 5 N., R. 12 W., on the north slope of Garrity Hill in Deer Lodge County, 6 miles west of Anaconda. The property, also known as the Balkan lode, lies at the eastern end of the Anaconda Range.

The bedrock is composed of Paleozoic strata (Madison Limestone and Quadrant Quartzite) which strike north-northwest and dip southwesterly. The fluorite occurs in a hydrothermal metalliferous vein parallel to the bedding in the steeply dipping Madison Limestone. The vein is developed by 4 adits, 3 of which lie one above the other on the vein. The fourth and lowest adit is offset to the west. The vein matter is composed of quartz, fluorite, barite and sulfides. Quartz is predominant in the upper adit, fluorite in the middle adits, and barite in the lower adit. Sulfides occur throughout, but may be more plentiful in local areas. The character of the vein is such that hand specimens can be selected that are composed solely of any one of the minerals or a mixture of all of them. The ore is complex enough in places to suggest several periods of mineralization.

The barite is massive, white to grey in color, and has a pearly luster. The texture of the massive barite may be coarsely laminated. Fluorescent X-ray analyses show the presence of strontium, indicating that the mineral is an isomorphous mixture of barite with some celestite. The fluorite is purple and coarsely granular. It may occur massive, as disseminated grains, or as irregular masses. The sulfides are either sparsely disseminated or occur massive in the quartz, barite, or fluorite portions of the vein. Lead-grey boulangerite (lead-antimony sulfide) is the most abundant sulfide. Sphalerite (zinc sulfide) is next in abundance. Silver-bearing tetrahedrite (copper-antimony sulfide) occurs sparingly, and minute disseminated grains of pyrite may be observed in some specimens.

Under the microscope the ore is seen to contain barite in large lath-like grains separated by fine-grained quartz. Fluorite occurs in large coarse grains as well as in fine seams. Sphalerite shows zoning and is partially anisotropic, indicating the presence of wurtzite, the high-temperature zinc sulfide, which is stable above 1,020° C. and which inverts very slowly at lower temperatures. A mineral identified by Crowley* as stibnite occurs abundantly in massive form, in disseminated blebs and grains and in needle-like intergrowths with sphalerite. Occasional grains of pyrite tetrahedrite can be observed.

The order of crystallization suggested by microscopic observation is quartz, barite, fluorite, and sulfides. A second period of mineralization resulted in deposition of more quartz and barite.

Variations in the mineral content of the complex mixtures is well illustrated by the following analyses:**

Sample No.	Barite	Fluorite	Silica	Calcium Carbonate	Silver (ounces)	Lead	Zinc	Total
1	95.4	Nil	2.8	0.7	0.2	1.4	Tr.	100.3
2	73.2	1.8	12.7	0.5	3.0	4.3	2.7	95.2
3	17.0	21.2	56.0	1.6	4.5	6.6	0.2	102.6
4	47.0	Nil	44.6	0.3	2.1	1.2	0.2	93.3
5	51.3	Nil	26.8	0.3	4.2	1.2	7.5	87.1

Although the analyses above represent fairly select samples, they do suggest the possibility that the ore in this mine might yield a profit if properly treated. Four salable products could be made (1) a siliceous lead sulfide concentrate, (2) siliceous zinc sulfide concentrate, (3) a barite concentrate, and (4) a fluorite concentrate.

WEATHERVANE HILL

The Weathervane Hill fluorite prospect is south of the smelter stack at Anaconda on what is known as Weathervane Hill in sec. 13, T. 4 N., R. 11 W., in Deer Lodge County.

The bedrock of Weathervane Hill is composed of upper Paleozoic and upper Mesozoic strata apparently in fault contact. The sedimentary rocks are overlain by Tertiary lavas to the west and south, and outliers of the Boulder batholith are exposed 2 miles to the west and also 2 miles to the southeast.

The fluorite occurs in a fault zone that strikes N. 10° W. and dips 80°-85° NE. Slickensides are evident on the east slope of the hill, which is the hanging wall and down-thrown side of the fault zone that drops metamorphosed Cretaceous strata down against Paleozoic Limestone on the footwall. The footwall limestone contains many black chert inclusions (Madison Limestone ?). The fault zone is highly brecciated. Cubic fluorite crystals in places almost perfectly clear and ranging in size up to 1 inch across occur in fissures and vugs and as "coatings" or white crusts of minute cubes on the dark slickensided surfaces.

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*Frank A. Crowley, personal communication
**Analyses by C. J. Bartzen

Analyses of the different rock units may range from 5 to 85% fluorite. The cherty limestone may carry as much as 15% calcium fluoride with small amounts of lead and silver. More development work is necessary before the extent of the deposits or their probable worth can be determined.

Regarding the property Ross (1950, p. 213-214) states, "The distribution of the fluorspar is so irregular that mining of any large quantity would be a difficult and costly procedure, even if the deposit extends far underground. The present shallow pits and 2 short caved tunnels give no basis for prediction as to the continuity of the fluorite mineralization at depth. The largest single fluorspar body seen was fully 2 feet in maximum width but scarcely more than 20 feet long. Most exposures reveal fluorspar pockets a few inches to a few feet in maximum dimension. No pattern was detected in the distribution of these pockets.

"The following table gives the salient results of sampling and laboratory studies by the Anaconda Copper Mining Co.:

	CaF_2
Sample of crystals	96.0
High-grade outcrop	94.5
Average outcrop	54.0
Representative sample	47.8
Best flotation concentrate	81.9
Best sink-float concentrate	81.1

"The expense of testing this zone of fluorite mineralization adequately is scarcely warranted at present. Small-scale mining and hand sorting of the ore would yield a small amount of high-grade fluorspar. If overhead costs were kept at a minimum the deposit might be worked in this way at small profit during a period of high price for fluorspar."

SILVER BOW DEPOSITS

The Silver Bow fluorite deposits are 6 miles west of Butte along Silver Bow Creek in the $E\frac{1}{2}SE\frac{1}{4}$ sec. 13, T. 3 N., R. 9 W. and the SW corner sec. 18, T. 3 N., R. 8 W. (See figure 6.) U. S. Highway 10 and 4 railroads (Northern Pacific; Union Pacific; Chicago, Milwaukee, St. Paul & Pacific; and the Butte-Anaconda & Pacific) cross the property.

The principal exposures are on the Bull Moose claim (patented) owned by John Clark and the Helehan family and the Merrimac claim (patented) owned by the Silver Bow Copper Co. Some fluorite (with barite) is said to occur on the Wrong Font claim (unpatented) located by John Helehan in 1944. The deposits on the Bull Moose and Merrimac claims were exposed by shallow pits and trench, but these are now mostly buried under the road-fill of the new 4-lane highway built across the property in 1957. A 100-foot drift along a shear zone striking S. 30° E. on the Wrong Font claim did not expose any fluorite.

The bedrock of the area is composed of igneous rocks of and related to the Boulder batholith and include quartz monzonite, aplite,

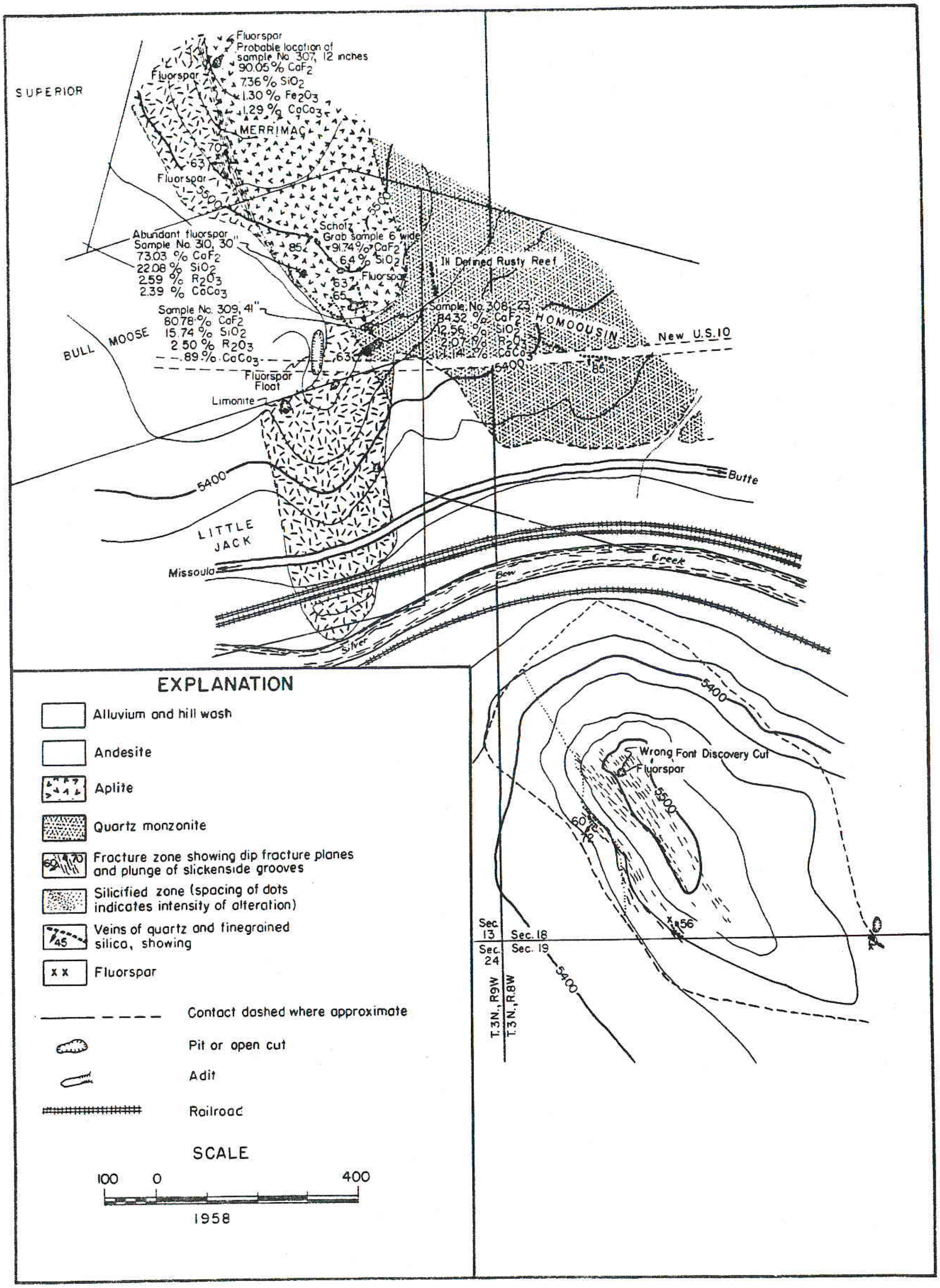

Figure 6.--Geologic map of Silver Bow fluorspar prospect, Silver Bow County, Montana. "Modified from U.S.G.S. Bull. 955-E."

and andesite. The outcrop is isolated from the main mass of the batholith by Tertiary sediments, but the quartz monzonite and aplite are probably continuous, underneath the sediments, with similar rocks in the western part of the Butte district. Extrusive andesite occupies the most westerly part of the area and is in fault contact with the quartz monzonite and aplite intrusives. The fault contact is a shear zone that strikes N. 30° W. and dips 60°-70° SW. It is apparently a normal fault dropping extrusive lava against intrusive granitic rocks, and is probably related to the Whiskey Gulch-Continental fault system of the Butte district, which is post-mineral. At the Silver Bow deposits, however, the shear zone is silicified and contains parallel veins of quartz and fine-grained silica associated with fluorite. This mineralization is undoubtedly much later than that which produced the gold-silver-copper-zinc-lead-manganese deposits of the Butte district. The contact between the reddish andesite and the intrusive rocks is well exposed in the road cut on the new U. S. Highway 10, 6 miles west of Butte.

The quartz monzonite is a coarse-grained porphyritic rock composed essentially of orthoclase and plagioclase feldspars with 15 to 20% quartz. Orthoclase and plagioclase occur in about equal amounts. Accessory minerals are hornblende, biotite, apatite, and zircon.

The aplite is similar to that widely distributed in the western part of the Butte district. It is a medium- to fine-grained rock composed essentially of feldspars with about 35% quartz and 5% dark-colored accessory minerals, principally biotite.

The andesite is a dark-red porphyritic rock composed of plagioclase phenocrysts ½ to 4 mm across in a very fine-grained ground mass stained red by iron oxide. Specimens from the adit on the Wrong Font claim show specular hematite. The rock has been subjected to hydrothermal alteration and, near surface, also to weathering, and as a result exact identification of the original feldspars is difficult, if not impossible.

The following information concerning the fluorite occurrence is taken mostly from Ross (1950, p. 216-218) who examined the deposits when they were better exposed than now. Minerals other than those in the country rocks are chalcedony, quartz, fluorite, and pyrite with its oxidation products. In the more fissured rock, veinlets of chert-like silica are plentiful; some of the silica rock is brecciated, with the fragments coated with fluorite. The fluorite is most conspicuous of the vein minerals but is subordinate in amount to quartz and chalcedony. Most of the fluorite is moderately coarse-crystalline and ranges from colorless to deep purple. Much of the crystalline fluorite fills openings in sheared and brecciated rock, previously silicified. Some white earthy fluorite, probably formed by solution and redeposition by ground water, coats minor fractures and cleavage faces. Pyrite is scarce, and all of it somewhat altered, but may have been more widespread, before oxidation. Most of the observed exposures are not developed for more than a few feet below the present surface.

The fluorite occurs in shoots within a fracture zone along the contact of andesite and intrusive "granite" and aplite. The zone strikes northwest and dips southwest. The main fracture zone mapped by Ross is over 2,000 feet long and locally over 100 feet wide. The rocks of the zone have been impregnated with silica and stained by iron oxides. Locally, rusty quartz veins occur in the silicified zone, and the fluorite bodies are scattered throughout the zone (but are very discontinuous). The distribution is shown on figure 6, which has been modified from Ross's map (1950, p. 28). The principal exposures of fluorite are on the east end of the Bull Moose claim. Here the bands of high-grade fluorite range from an inch or 2 up to about 3½ feet. An exposed width of 8 feet has been reported, but no such width was seen by the writer. The length of exposures might be measured in tens of feet. Material between high-grade bands contains little or no fluorite. The tabulation below shows the grade of the material as sampled by Ross (1950, p. 218).

Analyses of samples from the Silver Bow prospect:

Sample No.	Width inches	Percent CaF_2	SiO_2	R_2O_3	$CaCO_3$
306	float	83.11	14.00	1.70	1.32
307	12	90.05	7.36	1.30	1.29
308	22	84.32	12.56	2.03	1.14
309	41	80.78	15.74	2.50	0.89
310	30	73.03	22.08	2.58	2.39
Scholz	grab	91.74	6.50	-	-
Arithmetical average		83.84	13.02	2.02	1.40

The following summary taken verbatim from Ross's report still holds true today (1959).

"The analyses show that a product of metallurgical grade could be made by selective mining followed by hand sorting, without the necessity of milling. The individual bodies of material comparable to the samples are small, and much waste rock would have to be moved in mining them. No underground workings that penetrate fluorspar existed at the time of visit, and the trenches were shallow and extensively slumped. In order to obtain a satisfactory concept of conditions to be expected in mining these deposits, the trenches would have to be cleared out and extended, and the ground between the richer fluorspar seams would have to be sampled. The precious metal content of the samples listed above is not recorded, but it is possible that enough gold and silver are present to warrant recovery with the fluorite."

Any scheme to develop the deposits further will be complicated by the right-of-way of the recently constructed 4-lane highway, U. S. 10, over the very best of the exposures.

BALD BUTTE

The Bald Butte mine lies within the Marysville mining district, in Lewis and Clark County, 17 miles northwest of Helena. The mine is on

Bald Butte in the $W\frac{1}{2}$ sec. 10, T. 11 N., R. 6 W., $3\frac{1}{2}$ miles southwest of the old mining camp of Marysville. The mine is developed by open cuts and underground workings, but the latter are inaccessible, and therefore the examination of fluorite-bearing material was restricted to the dumps.

The bedrock at Bald Butte is the Helena Limestone of the Belt Series of Precambrian age. The limestone is cut by numerous dikes and sheets of microdiorite which tend to conform to the bedding of the limestone, which here strikes about N. 30°-45° W. and dips 20°-35° NE. The limestone has been altered by contact action into a hornstone. The hornstone is grey and very fine grained and contains stringers and thin layers of fine-grained white quartz. Under the microscope, the dark bands are seen to consist of splintery actinolite and flaky green mica set in an exceedingly fine-grained feldspathic ground mass. A large dike of porphyritic diorite, known locally as "Belmont porphyry," also cuts the limestone along a northwest trend. According to Barrell (1907, p. 12) the microdiorite is a fine-grained dark-colored crystalline rock, porphyritic in places. It consists of lime-soda plagioclase and one or more of the minerals hornblende, biotite, and (locally) pyroxene. The microdiorite is exposed for 300 to 1,000 feet along the strike and is 10 to 50 feet thick. The Belmont porphyry (Barrell, 1907, p. 110) consists of phenocrysts of acidic plagioclase, lesser amounts of biotite, and a few crystals of hornblende, the whole set in a feldspathic micrograniitic ground mass. Where more completely altered, in the Bald Butte zone of mineralization, the feldspars of the Belmont porphyry are transformed to sericite and quartz, and the biotite phenocrysts still show unaltered laminae, but these are interleaved with fine-grained layers of quartz, fluorite, and sericite. Like the adjacent hornstone, the whole rock mass has been minutely shattered and infiltrated with quartz and fluorite.

Barrell (1907, p. 110) described the mine as follows: "The larger veins are clear instances of filled fissures. The open cuts follow the course of the large dike of Belmont porphyry, in which they are excavated. The 'porphyry' with the microdiorite and hornstones which form its walls, especially the hanging wall, are intimately and minutely fractured, the direction of the principal set of fractures running parallel to the course of the dike. The cracks are infiltrated with quartz and fluorite, and the wider seams show many alternations of these 2 minerals, the fluorite on the whole appearing to be of later origin and in 1 case at least to have penetrated the primary quartz along a second set of fractures. They are not sharply distinct, however, as some deposition of quartz has followed fluorite."

Several samples of fluorite, hornstone, and microdiorite were taken from the dump at the Bald Butte mine. The fluorite is massive and pale purple in color. It also occurs disseminated and interlaced with white vein quartz. The fluorite appears to form definite veinlets crossing and interlacing the specimens. The quartz shows similar characteristics. The hydrothermal vein matter contains evenly disseminated pyrite. The microscope reveals that fluorite replaced the original vein quartz, but does not have any specific pattern of replacement and does not occur in euhedral crystals. The quartz, however, has a definitely crystalline mosaic texture.

The fluorite specimens examined carried an average of 30% calcium fluoride and 41% silica with 5% aluminum and iron oxides combined. Whether or not there is much of this type of material underground could not be ascertained because of the inaccessibility of the underground workings. However, judging from Barrell's descriptions of the fluorite occurrences, it is obvious that no fluorite ore occurs at this property that could be marketed without extensive beneficiation.

BOEING

The Boeing prospect was not visited by the writer, and the following data concerning it is condensed from the report by Ross (1950, p. 210-212).

The Boeing prospect is in the Austin mining district in Lewis and Clark County, about 3½ miles west of Austin. The Northern Pacific Railroad and the Montana Power gas line pass close to the property. The property was visited by Ross in 1944.

The deposit is in mineralized Madison Limestone (Mississippian) cut by a biotite-rhyolite dike that has been almost completely altered to montmorillonite (bentonite). The deposit is developed by an open pit, a 60-foot adit, and a 16-foot winze off the floor of the adit. There is a 10-foot crosscut off the bottom of the winze. The main exposure of fluorspar is in the open pit where it strikes N. 20° W. and dips 70°-80° SW. It is from 3 to 6 feet wide over a height of 7 feet and its length is about 30 feet. At its lowest point, about 25 feet below the surface, the maximum dimension is about 2 feet. The shape is similar to that of the metalliferous deposits of the district, which are described as irregular pockets or pipelike bodies in limestone. In 1944, Ross cut a sample across 41 inches near the surface that carried 81.76% calcium fluorite, 10.09% silica, and 2.52% carbonates; and another sample across 2 feet of vein in the crosscut off the winze bottom carried 60.37% calcium fluoride, 12.88% silica, and 7.72% carbonates.

Obviously the deposit, as developed, is of no great consequence; and further, the material could not be marketed without beneficiation.

BOULDER MOUNTAIN

The Boulder Mountain fluorite deposit is in the SE¼SE¼ sec. 9, T. 9 N., R. 3 E., near the Broadwater-Meagher County line. The area can be reached by driving 3 miles east of Townsend along State Highway 6, thence north 10 miles, and thence up Duck Creek and its Middle Fork for 7 miles. The fluorite is on the crest of Boulder Mountain. This deposit is probably the same as that described by Ross (1950, p. 220) as on Duck Creek Mountain, T. 9 N., R. 3 E.

The bedrock of the area is a porphyritic granodiorite that occurs as a stock intruded into the Newland Formation (Piegan Group) of the Belt Series of Precambrian age. The granodiorite contains light-colored feldspar phenocrysts, mostly plagioclase, 1 to 4 mm across, disseminated in a medium-grey phaneritic ground mass. Under the microscope, the phenocrysts are seen to be orthoclase and oligoclase in a fine- to medium-grained ground mass of quartz and feldspar. Biotite is abundant, but subordinate to feldspar. Iron oxides and an amphibole occur in minor quantities. Sericite is prevalent throughout the entire rock.

The granodiorite stock, in turn, is cut by a leucocratic (light-colored) syenite dike. The stock is an outlier of the Boulder batholith and was probably intruded in early Tertiary (Paleocene ?) time. The leucocratic syenite, however, may be more directly related to the intrusives of the Potassic Province of central Montana, and perhaps these deposits and the Normandy described below should really be included with those of the Potassic Province described later.

The syenite consists essentially of microcline and perthite with an occasional phenocryst of replacement albite. Accessory minerals are quartz, hematite, and minor apatite and fluorite.

The fluorite occurs as a series of small veins in what appears to be a shear zone within the light-colored syenite dike. The fluorite veins range in width from less than 1 inch to 2 inches in a zone not over 8 inches wide. The fluorite veinlets are exposed in several pits. The largest pit is 6 feet square and 8 feet deep. The area is cut up by bulldozer work, and other pits in the dike also show fluorite. The fluorite veinlets and the shear zone strike about N. 30° W. and dip about 70° SW and parallel the general trend of the dike. The fluorite is dark purple in color and medium to coarse grained. Large white to smoky quartz crystals are scattered in the fluorite-bearing vein. The 8-inch fluorite-bearing zone was sampled and ranged in grade from 12.8 to 85.0% calcium fluoride and 10.6 to 82.2% silica with traces of gold. The wall rock immediately adjacent to the fluorite assayed 1.2% fluorite with a trace of gold. The exposures can hardly be considered commercial in their present state of development.

NORMANDY FLUORITE PROSPECT

Within the same general area of the Boulder Mountain fluorite prospect, the U. S. Bureau of Mines (Reed, 1951) has reported another occurrence of fluorite known as the Normandy prospect. This prospect is in sec. 24, T. 9 N., R. 3 E., at an elevation of 8,000 feet, in Broadwater County near the Meagher County line. Fluorite is exposed in 2 shallow discovery cuts. Reed's (1951, p. 56) description follows:

"A fracture filling and replacement vein in Belt Limestone has been exposed by 2 prospect cuts about 50 feet apart. This vein strikes northwestward, dips about 80° SW, and ranges in width from 13 inches to 6 feet. At 1 exposure the vein consists of 6 inches of impure fluorite and an equal width of shattered limestone veined with thin stringers of fluorite and quartz. About 5½ feet of limonite and quartz lightly streaked with fluorite are exposed on the vein footwall at the second cut. The hanging wall unit consists of 0.9 foot of impure fluorite. Samples cut from this exposure assayed as follows:"

Width Feet	Calcium Fluoride Percent	Silica Percent	Calcium Carbonate Percent	Iron & Aluminum Oxides Percent
0.9	35.2	51.5	0.6	6.2
5.6	1.8	54.6	0.4	18.3

The deposit is practically undeveloped, and little can be said of its possibilities as a commercial source of fluorspar.

DEPOSITS RELATED TO THE POTASSIC PROVINCE

The fluorite occurrences of the so-called Potassic Province are related in origin to the alkalic intrusives of the area. Fluorite deposition has not been selective petrographically, as fluorite is now found in every known rock type in the area, including the sedimentary rocks. The fluorite does, however, represent the final differentiate [hydrothermal (?) solutions or gaseous (?) emanations] of the magma that produced the alkalic rocks. The area has yet to produce a ton of commercial fluorspar--but the fluorite has been of economic significance in that it has served as an indicator for the prospectors and gold miners of the area in their search for gold deposits.

The fluorite mineralization is found within intrusive syenite as well as in the aureole zones of the intrusives, but large deposits of fluorite far out in the surrounding rock have not been observed here, as we find in the aureole zone of the Idaho batholith (see Crystal Mountain, Snowbird, and Spar deposits). Noteworthy is the occurrence of porphyritic textures near zones of fluorite mineralization. Zoning of feldspars is prevalent and plagioclase feldspars exhibit fine lamellar twinning, rather than the broad twinning attributed to plagioclase that has crystallized from a gradually cooling magmatic melt.

SWEETGRASS HILLS

The Sweetgrass Hills consist of 3 related groups of hills called West, Middle, and East Buttes. Fluorite occurs in all 3 groups, but only that on East Butte has any commercial significance. East Butte is in northwestern Liberty County just below the Canadian line and 20 miles north of Chester, the county seat of Liberty County.

East Butte is composed essentially of a porphyritic syenite intruded into upper Paleozoic and Mesozoic sedimentary rocks, which form a series of upturned peripheral rings around the intrusive. The intrusive has isolated blocks of sedimentary units within its mass, and dikes and sills radiate from the center of uplift. The sedimentary rocks exposed in and around East Butte range in age from Mississippian (Madison Limestone) to Upper Cretaceous (Judith River Formation), but only the Madison Limestone is of interest as far as fluorite is concerned.

The igneous rock of East Butte is an alkalic syenite. The porphyritic syenite in contact with the limestone in the principal fluorite area on Tootsie Creek has prominent euhedral phenocrysts of white to pinkish orthoclase feldspar roughly 1 to 4 mm across. The texture and composition varies somewhat from place to place. In places the ground mass is aphanitic; elsewhere it is composed of feldspar. Some exposures are devoid of dark minerals, and others show up to 15% hornblende, biotite, and pyroxene. The igneous masses are believed to be laccolithic, but Ross (1950, p. 190) summarizes them as follows: "The larger masses have domed the sedimentary rocks above them, and in a few places, sufficient evidence of the presence of a floor exists to warrant the concept that some of the igneous masses are laccolithic. The larger masses without any known evidence of floors can equally well be regarded as stocks."

Although the Madison Limestone shows some recrystallization near igneous contacts, the other intruded sedimentary formations show little, if any, contact metamorphism. According to Ross (1950, p. 184) the Madison Limestone in the fluorite area is white to grey, crystalline, and moderately thick bedded with locally abundant chert concretions /Mission Canyon (?) Formation/. The thickness is about 1,000 feet, but the top has been removed by pre-Jurassic erosion, and the base has been cut out by igneous intrusion.

In the Sweetgrass Hills, according to Ross (1950, p. 192), all fluorspar of commercial interest so far recognized is on East Butte, and the best of these are in the Tootsie Creek area, mainly in sec. 20, T. 36 N., R. 5 E. The principal exposures are shown in figure 7, which was compiled from Ross's maps. The principal fluorite bodies are in or adjacent to the zones of marbleized Madison Limestone, which here borders the syenite of Mount Royal. In contrast to the distribution of fluorite, deposits of iron, gold, and other metals are either in the syenite or in extensively metamorphosed rock, originally limestone. During the writer's visit to the area (1957) The Anaconda Company of Butte was investigating a copper-lead deposit in syenite on the western flank of Mount Royal over the crest of the mountain from the Tootsie Creek fluorite deposits. So far, the metallic deposits have not proven to be of commercial significance.

The fluorite occurs as veins and replacement seams in Madison Limestone. It is best developed on the Malvina claim. Ross (1950, p. 195) states: "The fluorspar lodes of East Butte are replacement deposits with only a subordinate amount of filling of open spaces. The larger bodies exhibit the results of some sheeting and brecciation * * * generally along directions * * * parallel to bedding * * *. The fluorspar masses are diverse in detail. Most * * * closely follow bedding or sheeting. * * * some masses are irregular. A few masses are nearly flat, and others are roughly spherical. Parts of nearly

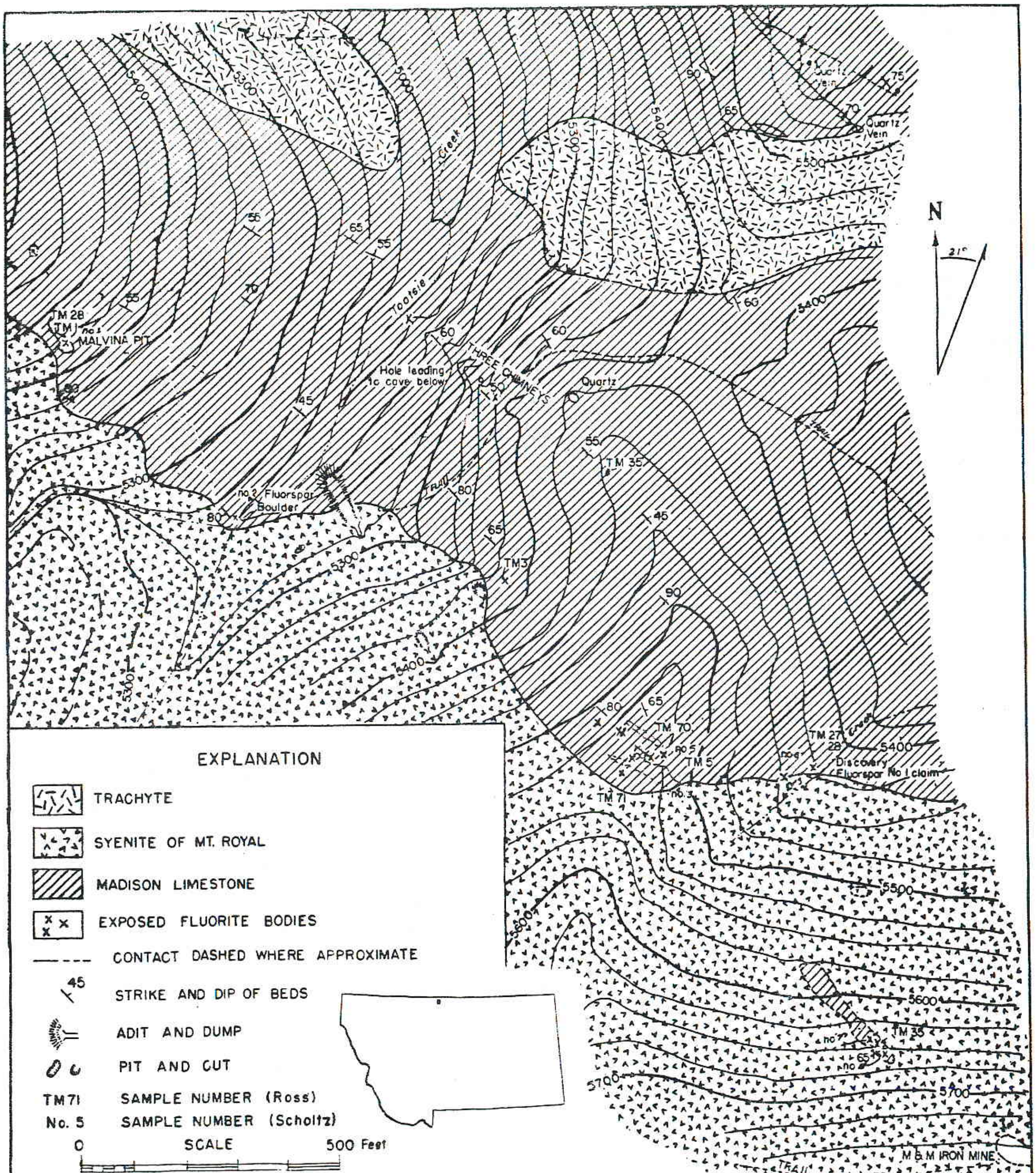

Figure 7.--Geologic map of Tootsie Creek fluorspar deposits, East Butte, Liberty County, Montana. "Modified from U.S.G.S. Bull. 955-E."

all exposures * * * show flecks and small grains of fluorite disseminated through limestone * * *.

"Any estimates as to the size of the fluorspar bodies is liable to a large error as there are few exposures and the known bodies are only poorly exposed in pits and shallow shafts * * * some mineralized zones attain width of fully 10 feet, and some can be followed fairly continuously along the strike for as much as 50 feet. Most individual bodies are much smaller, but they are scattered in the Tootsie Creek area through a zone in limestone which * * * is well over 2,000 feet long and is at most several hundred feet wide. This zone contains the only fluorspar bodies in the Sweetgrass Hills that seem of present commercial interest, with the possible exception of those about a quarter of a mile upstream from it."

The 20 analyses of sampling by Schulz and Ross (Ross, 1950, p. 197) are shown in table 1. Location of the samples as near as can be determined are shown on figure 7. Regarding these samples, Ross (Ross, 1950, p. 196) states: "* * * the calcium fluoride content ranges from 3.06 to 87.01%, with the average content of samples representative of typical better-grade ore somewhat less than 50%. In bodies of minable size, the content probably would be less than 40% of calcium fluoride. Silica, the only important contaminating constituent, ranges from 1.68 to 43.83%. The expected average silica content of ore mined from the exposures sampled is close to 30%. As the more siliceous ribs are most likely to be exposed, it seems possible that exploration at depth combined with selective mining might result in a product with a calcium fluoride content of appreciably more than 50% and a silica content of less than 20%.

"Obviously any fluorspar mined from this district will require concentration to bring it up to a grade suitable for marketing. The U. S. Bureau of Mines * * * tests show that flotation of the material is difficult, largely because constituents are so intimately interlocked as to require fine grinding for separation. In the tests it was necessary to grind * * * (to) 200-mesh * * * to obtain a fluorspar product of ceramic grade containing 95.2% of calcium fluoride and 0.6% of silica, but the recovery was poor. Fluorspar of metallurgical grade was obtained from material ground to * * * 150-mesh. Tests * * * indicated that concentration of the silver may be practical, at least in fluorspar with a precious metal content similar to that of the richer samples."

SOUTH MOCCASIN FLUORITE OCCURRENCES

The South Moccasin Mountains are one of the larger satellitic uplifts of the Judith Mountain group located near the geographical center of Montana. They rise 2,200 feet above the surrounding plain to an elevation of about 5,800 feet above sea level. The geology has been described by Miller (1959). The fluorite occurrences are in secs. 11 and 12, T. 16 N., R. 17 E. and the NW$\frac{1}{4}$ sec. 35, T. 17 N., R. 17 E.

TABLE 1.--Analyses of fluorspar samples from East Butte.*

	Width Feet	CaF_2 %	SiO_2 %	RCO_3 %	$BaSO_4$ %	Gold oz/ton	Silver oz/ton
1. Malvina dump, grab	-	73.94	7.00	-	-	0.02	1.10
2. N edge Malvina pit	1.50	39.87	1.68	54.42	0	Tr	Tr
3. 3' NW of No. 2	2.75	76.42	1.75	20.76	0	Tr	0.30
4. Boulder, Tootsie Cr.	-	87.01	7.20	-	-	1.50	0.20
5. E slope, Tootsie Cr.Valley	1.80	28.87	43.83	26.63	0	Tr	Tr
6. Grab from pit	-	55.39	21.98	20.81	0.12	Tr	0.10
7. Ridge N of Upper Dry Cr.	1.17	39.26	34.43	20.55	0	Tr	1.64
8. 10' S of No. 7	0.83	40.28	35.92	21.20	1.04	0.04	11.66
9. 10' SE of No. 7 (?)	3.33	54.21	17.74	26.12	-	-	-
10. 50' E of No. 7	9.00	47.26	26.80	-	-	0.005	2.10
11. Same place as No. 10	7.50	39.24	36.56	23.79	0	Tr	1.98
12. Fluorite No. 1, 120 lb.	-	58.60	24.40	7.95	-	0.015	8.60
13. Fluorite No. 1, discovery	2.00	62.99	31.57	4.91	0	Tr	0.68
14. Fluorite No. 1, discovery	2.33	3.06	14.42	81.22	0	Tr	Tr
15. Fluorite No. 1, discovery	0.67	17.09	29.72	50.90	0	Tr	Tr
16. Center M & M claim	4.00	52.26	27.20	-	-	0.02	5.20
17. Center M & M claim	3.00	42.25	29.20	-	-	0.01	1.80
18. Near 16 & 17	1.33	44.25	29.20	17.30	0	Tr	1.76
19. Upper Tootsie Cr. off map	0.58	40.56	57.18	0.91	0	Tr	0.28
20. Upper Tootsie Cr. off map	1.00	39.73	56.57	1.54	0	Tr	Tr

* Modified from U. S. Geological Survey Bulletin 955-E, p. 197

The bedrock of the area in sec. 12 consists of upper Paleozoic and Mesozoic sedimentary rocks that have been faulted and uplifted. To the east and north these rocks have been intruded by porphyritic syenite and porphyritic leucorhyolite. Miller (1959, p. 21-30) states that the igneous rocks of the South Moccasin represent 2 stages of igneous intrusion. The earlier injections, which are limited to the northwest part of the mountains, consist of a concordant mass of porphyritic syenite. A later period of uplift is related to the emplacement of a body of porphyritic leucorhyolite. Both magmas were forced to spread laterally upon encountering Madison Limestone (Mississippian), but the leucorhyolite was able to utilize faults related to the earlier period of uplift and intrusion, and thus a part of it passed beyond the massive limestones into younger strata of Jurassic and Cretaceous age. The later body, which disturbed the sedimentary rocks in the northeastern part of the mountains, is thus locally discordant. The geology of the area is shown in figure 8.

Miller (1959, p. 42) noted fluorite as a gangue mineral with the gold-silver ore of the Golden and Dawes lode claim near the center of NW¼ sec. 35, T. 17 N., R. 17 E.; in minor amounts with the dickite clay in the Whitware clay deposit near the center of the SW¼ sec. 12, T. 16 N., R. 17 E.; and in a small localized area of alteration and brecciation adjacent to a large fault along the west side of the NW¼ sec. 12, T. 16 N., R. 17 E. This last deposit was examined by the present writer and is described below. Ackerman also observed fluorite within a zone 3 to 4 feet wide within a porphyry area in the NW¼ sec. 11, T. 16 N., R. 17 E. This zone of mineralized porphyry lies along the crest of a north-south trending ridge.

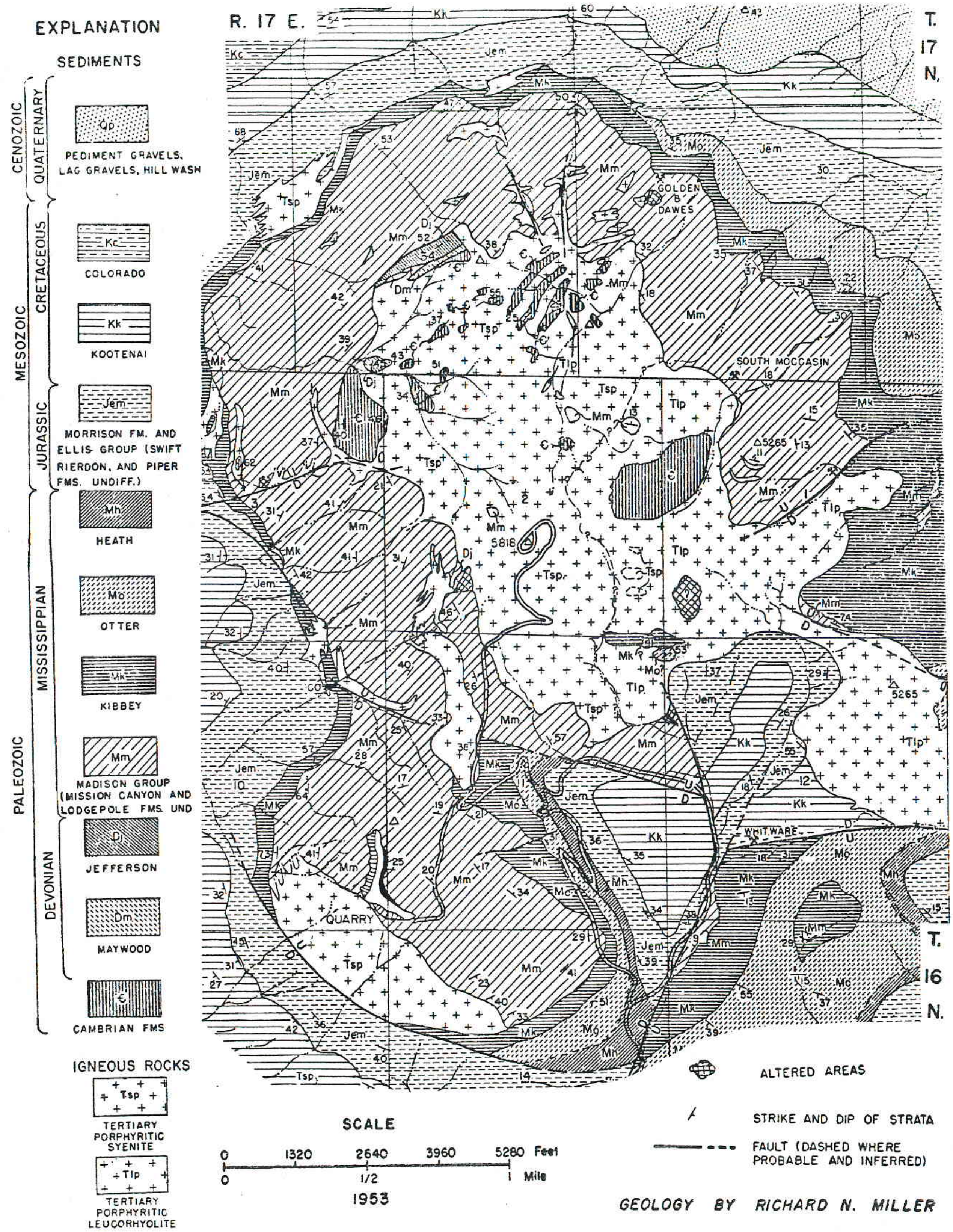

Figure 8—GEOLOGIC MAP OF THE SOUTH MOCCASIN MOUNTAINS, FERGUS COUNTY, MONTANA

In the $NW\frac{1}{4}$ sec. 12, T. 16 N., R. 17 E., the fluorite occurs as narrow stringers and veins in or near a fault zone along which Jurassic rocks have been dropped down against porphyritic leucorhyolite and Madison Limestone. The fluorite mineralization appears more prevalent in the fault zone within the Madison Limestone. The fluorite mineralization probably represented the last stages of igneous activity, and the fault zones apparently served as channelways for the hydrothermal solutions which attacked and replaced the limestone. The limestone is grey to blue grey in color, and locally contains abundant fossil brachiopods. The fluorite-bearing zone, light-purple pink in color, was sampled, and the analyses of the samples ranged between 33.8 to 91.0% calcium fluoride, 0.2 to 54.2% silica, and 1.0 to 3.5% calcium carbonate.

Under the microscope, the fluorite of the fault zones appears white in color, is fine grained, and is seen to replace limestone. Disseminated throughout the fluorite are residual grains of limestone, iron oxides, and minute grains of quartz. Small amounts of actinolite along minute fractures are probably a product of contact action. Both the fluorite and limestone are disseminated with small grains of diopside, a product of contact metamorphism in magnesian limestones that contain silica. The diopside occurs as small colorless to pale-green grains. Another rock section of fine-grained siliceous rock from the fault zone shows euhedral crystals of fluorite along fractures.

Several specimens from the intrusive (leucorhyolite) zone were also examined in thin section under the microscope. White to pale-purple fluorite occurs as disseminated grains and as replacements of previously altered plagioclase along minute fractures. The porphyritic leucorhyolite itself contains large crystals of clear sanidine, up to an inch in length, which make up about 2/3 of the rock. Weathered surfaces also exhibit cloudy to white phenocrysts of plagioclase (andesine) and clear quartz. The phenocrysts lie in a felsitic, chert-like matrix. Accessory minerals are iron oxide, fluorite, and occasionally biotite and zircon. The rhyolite is also cut by veinlets of quartz, which, under the microscope, show a mosaic texture.

These deposits are not of commercial significance as possible sources of fluorspar, at least not under present economic conditions.

AMERICAN FLAG PROSPECT

The American Flag fluorite prospect lies within 100 yards northwest of the summit of Judith Peak at an elevation of 6,400 feet. It is in the $W\frac{1}{2}$ sec. 19, T. 17 N., R. 20 E., in Fergus County, Montana. The prospect is 4 miles north of Maiden, an old mining camp 9 miles east of the railroad at Brooks.

Judith Peak is composed essentially of porphyritic syenite. At the crest where bulldozers have recently (1958) cleared a site for a radar station, the fresh rock is a bright reddish-pink porphyritic syenite with large feldspar phenocrysts. At the summit the rock appears crushed and filled with narrow quartz seams that are said to carry a little gold. Southward there is a gradual increase in the number and size of quartz phenocrysts until they reach an inch or more in length about a quarter of a mile east of the "Chimneys." Here the rock is a porphyritic granite, and it seems uncertain whether it is a differentiated phase of the main body or a later intrusion. About a hundred yards northwest of the summit the syenite is greatly altered and leached and is light in color. Here it is cut by a 10-foot vein of quartz and fluorite on which the American Flag claims are located. The same or a similar vein appears across Armell Gulch on the north side, and it also has been claimed. Near the vein, at the discovery point, the syenite varies in texture, and the size of the phenocrysts increases away from the quartz-fluorite body. The fluorite-bearing vein contains from 22.8 to 34.0% calcium fluoride, 52.8 to 66.9% silica, 2 to 4% lead, 0.1 to 0.5 ounce of silver per ton, and a trace of gold. The fluorite is purple in color, is intimately associated with quartz, and has a dense to fine-grained texture. Galena occurs as disseminated grains, and occasionally a grain of pyrite may be observed. Under the microscope the fluorite does not always show a deep-purple color, and it is seen to replace the fine- to medium-grained vein quartz.

Another occurrence of fluorite in this vicinity lies over the ridge to the west on Lincoln Gulch drainage, 300 feet from the American Flag discovery. Here the fluorite occurs in fine seams and individual grains in a hard, dense-green, fine-grained dike rock (tinguaite). The dike strikes east-west and is about 5 feet wide. The fine seams of quartz and fluorite dissect the rock in all directions, and occasional grains occur scattered in the matrix which appears to be composed of amphibole. The tinguaite averages 17.3% calcium fluoride, 32.4% silica, 0.5% lead, 0.1 ounce per ton in silver and a trace of gold.

The American Flag fluorite deposits are not sufficiently developed to show their true worth. If present in sufficient quantity, the material might be up-graded to a salable product by concentration, with a possible lead-silver by-product.

Weed and Pirsson (1896-7, p. 594) mention fluorite association with gold in different properties in the Judith Mountains. They state that the association is intimate and that generally the amount of gold present increases in proportion as the amount of fluorite increases. Thus, the highest grade ores were found in the Spotted Horse mine, the ores of which also had the largest proportion of fluorite. The ores of the Maginnes carried less fluorite and less gold. The New Years mine was still lower in both fluorite and gold. The low-grade Gilt Edge properties show none of the brilliant purple fluorite noticeable in the ores of the other mines, although colorless fluorite is sparingly present.

ANTONE PEAK FLUORITE OCCURRENCE

The summit of Antone Peak lies in the $NW\frac{1}{4}SE\frac{1}{4}$ sec. 12, T. 25 N., R. 24 E., near the center of the Little Rockies in southern Phillips County. It is one of the most prominent peaks and landmarks of the mountains. The peak can be reached by fair mountain road from Zortman through the property of the Ruby Gulch mine. Zortman is a small mining camp on the eastern edge of the Little Rockies Mountains.

The Little Rocky Mountains consist of a core of intrusive porphyritic syenite surrounded by successive rings of upturned sediments ranging in age from Middle Cambrian (Flathead Formation) to Upper Cretaceous (Judith River Formation). The flat plains beyond the island-like mountain mass are underlain by Bearpaw Shale. Antone Peak itself is almost centrally located in the syenite core.

Although fluorite has never been mined as an ore of fluorspar in the Little Rockies, it has served an economic function as an indicator mineral in the exploration for gold deposits in these mountains, as it has in the Judith Mountains to the south.

At Antone Peak fluorite is sparsely disseminated throughout the porphyritic syenite, and samples were collected from the original discovery pit of the Antone claim. These samples averaged between 2 and 3% calcium fluoride and also contained traces of gold and silver with a lead content of 0.5 to 0.8%. Weed and Pirsson (1896, p. 427) state that the gold ores of the Little Rockies are tellurides in an intimate mixture of quartz and brilliant purple fluorite that is readily recognizable. Association of fluorite and gold has been noted by different observers elsewhere in Montana and in Colorado.

The porphyritic syenite containing the fluorite is stained brown by limonite on weathered surfaces; fresh surfaces are grey. Medium to large, pink to transparent feldspar phenocrysts are profusely scattered throughout a grey ground mass. Throughout the rock are minute vugs, which under the stereoscopic microscope show a lining of fine white needle-like crystals of quartz in which are nested small grains of pyrite and/or tellurides. Under the microscope, the phenocrysts of pink orthoclase (soda-plagioclase) have a cloudy appearance due to alteration. Carlsbad twinning and zoning are apparent. Oligoclase shows fine albite twinning, and small inclusions of oligoclase may occur in the orthoclase phenocrysts. The ground mass is so fine grained that individual minerals are difficult to recognize. Phenocrysts in which zoning is still obvious (sanidine) do not show much alteration. Green hornblende and opaque iron oxides occur as accessory minerals.

The fluorite occurrences on Antone Peak are of no commercial significance as a source of feldspar, at least not under present economic conditions.

D E P O S I T S   I N   T H E   P R Y O R   M O U N T A I N S

OLD GLORY MINE

The Old Glory is an uranium property in the Pryor Mountains of southeastern Carbon County. The mine lies near the crest of Big Pryor Mountain in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 32, T. 8 S., R. 27 W. It is reached by fair county road from Warren, 12 miles to the west. The geology of the Pryor Mountains is described by Blackstone (1936).

Big Pryor Mountain is the southwesternmost of 4 upthrust fault blocks that comprise the Pryor Mountains. At the Old Glory the rock in which the uranium-fluorite deposits are found is the Madison Limestone of Mississippian age. The deposits are found in the upper 200 to 250 feet of the Madison Formation in which brecciation and cavernous conditions are pronounced. The ore bodies appear to be invariably associated with collapsed caverns in which the limestone is brecciated and recemented by silica. In regard to the fluorite, Jarrard (1957, p. 37) states:

"In some places the mineral fluorite has been found in close association with the uranium minerals. This association would suggest hydrothermal origin, probably resulting from (associated with) faulting and folding of the Madison Limestone. Despite the suggestion of hydrothermal origin, the writer (Jarrard) is of the opinion that the deposits occur as a result of deposition from meteoric or surface waters and that the ore controls are of a chemical rather than structural nature. That some of the high-grade material is of recent deposition is shown by the discovery of unchanged bones of small rodent-like mammals occurring embedded as much as a foot or more in the ore material. Other than having at times a coating of soft tyuyamunite, the bones * * * appear to be no more than a very few years of age."

Under the microscope, the fluorite ranges in color from white to deep purple. The sharp euhedral grain boundaries normally associated with hydrothermal deposition are completely absent; instead, the fluorite occurs as small ovules and spheroids, with concentric structure, which are clearly a metasomatic replacement of the oolitic limestone. Occasionally the composition of the centers of the oolites are different from the peripheral material. The metasomatic replacement was effected by fluorine-bearing meteoric waters (ground water) which also carried some uranium and vanadium in solution. The fluorine reacted with the calcium carbonate of the limestone to produce fluorite, and the uranium and vanadium were precipitated as tyuyamunite, calcium-uranium vanadate. The yellow tyuyamunite and purple fluorite make a striking appearance, because where uranium is present the fluorite is deep purple. Where uranium is absent the fluorite is colorless.

Not enough is known of the fluorite occurrences in the Pryor Mountains to make any predictions as to their economic worth.

SUMMARY AND CONCLUSIONS

To date (1962) the only commercial production of fluorspar in Montana has come from deposits in Precambrian rocks bordering the Idaho batholith (Crystal Mountain, Snowbird, and Spar mines). These deposits are typical hydrothermal deposits associated with massive white quartz masses. Much of the fluorspar is coarse grained, and selective mining yields a commercial product. The lower-grade run-of-mine material at the Crystal Mountain deposit can be readily beneficiated to a relatively high-grade product with no great loss of material. Figures on reserves at Crystal Mountain are not available. Known reserves at the Snowbird and Spar mines are exhausted.

Other fluorspar deposits of the State, in-so-far as now known occur in contact replacement zones, fissures, and shear zones, and are not of present economic significance. For the most part, these other deposits are intimately associated with other minerals (quartz and other gangue minerals, metallic sulfides, and wall rock) and the mixture is usually so fine grained as to require very fine grinding for separation of the fluorite prior to beneficiation. Occasionally stringers and veinlets of pure fluorite are observed. All of the deposits in the Boulder batholith area and the Potassic Province would require additional prospecting before their potential could be inferred; and only those in the East Butte sector of the Sweetgrass Hills are considered at present likely to develop into commercial deposits.

Beryllium is sometimes found associated with fluorite, but qualitative tests for beryllium on all fluorite-bearing samples collected in Montana on this survey failed to show the presence of the metal.

B I B L I O G R A P H Y

Barrel, Joseph, 1907, Geology of the Marysville mining district, Montana: U. S. Geol. Survey Prof. Paper 57.

Blackstone, D. L., Jr., 1936, Structure and stratigraphy of the Pyror Mountains, Montana: Ph.D. Thesis, Princeton University, 87 p.

Emmons, S. F., and Calkins, F. C., 1913, Geology and ore deposits of the Philipsburg quadrangle, Montana: U. S. Geol. Survey Prof. Paper 78.

Fulkerson, F. B., Kingston, G. A., and Kauffman, A. J., Jr., 1959, The mineral industry of Montana: Preprint from the U. S. Bur. Mines Minerals Yearbook, 1958.

Gates, R. M., 1953, (Emmons, Ed.), Selected petrographic relationships of plagioclase: Geol. Soc. Amer. Memoir 52.

Hunt, W. J., Ed., 1957, Rockhound still important: Nor. Pac. Ry., Northwest, v. 31, no. 1, p. 89.

Jarrard, L. D., 1957, Some occurrences of uranium and thorium in Montana: Mont. Bur. Mines & Geol. Misc. Cont. 15.

Johannsen, Albert, 1938, A descriptive petrography of the igneous rocks: Univ. of Chicago Press, v. 4.

Kemp, J. F., and Billingsley, Paul, 1921, Sweetgrass Hills, Montana: Geol. Soc. Amer. Bull., v. 32.

Miller, R. N., 1959, Geology of the South Moccasin Mountains, Fergus County, Montana: Mont. Bur. Mines & Geol. Memoir 37.

Reed, G. C., 1951, Mines and mineral deposits (except fuels), Broadwater County, Montana: U. S. Bur. Mines Inf. Circ. 7592.

Ross, C. P., 1950, Fluorspar prospects in Montana: U. S. Geol. Survey Bull. 955-E.

Sahinen, U. M., 1957, Mines and mineral deposits, Missoula and Ravalli Counties, Montana: Mont. Bur. Mines & Geol. Bull. 8.

Taber, J. W., 1952, Crystal Mountain fluorite deposits, Ravalli County, Montana: U. S. Bur. Mines R. I. 4916.

Travis, R. B., 1955, Classification of rocks: Quarterly of the Colorado School of Mines, v. 50, no. 1, p. 12.

Weed, W. H., and Pirsson, L. V., 1896-7, Geology and mineral resources of the Judith Mountains of Montana: U. S. Geol. Survey Ann. Rpt. 18, pt. 3.

Weed, W. H., and Pirsson, L. V., 1896, The Geology of the Little Rocky Mountains: Jour. Geol., v. 4, no. 4.

Weiss, P. L., Armstrong, F. C., and Rosenblum, Samuel, 1958, Reconnaissance for radioactive minerals in Washington, Idaho, and western Montana, 1952-1955: U. S. Geol. Survey Bull. 1074-B, 48 p.