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FLUORSPAR PROSPECTS OF MONTANA

BY

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FLUORSPAR PROSPECTS OF MONTANA

By Clyde P. Ross

ABSTRACT

This report, based mainly on field studies by E. A. Scholz in 1943 and by C. P. Ross in 1944, summarizes available information in regard to the occurrence of fluorspar in Montana. Although the mineral fluorite has long been known to exist in the State it was not until World War II changed market conditions that serious interest was aroused in the State's fluorspar deposits. Up to the close of 1944 there had been little production.

The Sweetgrass Hills in Liberty and Toole Counties contain a number of deposits. Nearly all of commercial interest are in the discontinuous border of Madison limestone around the alkali syenite mass of Mount Royal in East Butte. The deposits close to Tootsie Creek are scattered over a large area and include material of tenor sufficiently encouraging so that some work was done on them by private parties in 1943. The discontinuous character of the deposits and uncertainties as to the future of the fluorspar industry resulted in the termination of this activity before much had been accomplished.

The Spar prospect, Mineral County, is a recent discovery in an area where no other fluorspar deposits are known. It contained a body of exceptionally high-grade fluorspar within a small lens of quartz enclosed in strata of the Belt series of pre-Cambrian age, but this body proved to be so small that it was soon worked out.

The Boeing prospect near Austin, Lewis and Clark County, is one of a number of small, more or less pipelike, silicified deposits in Madison limestone, some of which have been explored for gold. The Boeing prospect is the only one known to contain fluorspar, but prospecting may reveal others in the district. Another prospect in limestone of Paleozoic age near the Anaconda smelter, Deer Lodge County was visited.

The Silver Bow prospect in Silver Bow County has not been thoroughly explored for fluorspar. The deposits are in a long fracture zone at the contact between andesitic rock and the Boulder batholith. This zone has been explored a little for copper. Analyses show the presence of fluorspar of encouraging tenor, but the size and average tenor of the individual fluorspar shoots are as yet undetermined; most of the shoots are thought to be small. Prospecting was resumed here in 1946.

In the Judith Mountains, in the Little Rocky Mountains, and in other ranges scattered over Montana deposits containing fluorite are known but up to the close of 1944 little attempt had been made to find commercial deposits of fluorspar in these districts, and little was known about them.

If a strong demand for fluorspar develops so low-grade fluorspar can be sold in Montana, prospecting will be accelerated and more information about the deposits should be forthcoming.

INTRODUCTION

SCOPE OF THE REPORT

Wartime increase, both in the demand for fluorspar and in its uses, resulted in widespread search for new sources of supply. The U. S Geological Survey's preliminary investigations of fluorspar prospects in Montana, started at the request of the War Production Board, were made in 1943 by Edgar A. Scholz, who visited about 20 deposits and occurrences in the State and recorded data. His general reconnaissance and more thorough work on a few of the most promising deposits constituted an invaluable guide for the detailed studies of the favorable areas by C. P. Ross in the summer of 1944. Much of Scholz's data were presented in confidential reports for the use of governmental agencies[1] and are now incorporated in this report, which summarizes all information available at the end of 1944 on the fluorspar prospects in Montana. The deposits that were known to have been explored were visited by one or both of the geologists mentioned, and the principal deposits were studied in detail. The distribution of the known fluorspar occurrences in Montana is shown in figure 6.

The present report is based on field work as above described, and also on published articles and unpublished records of the U. S. Geological Survey and Bureau of Mines. As most of the published reports on the mineral deposits of Montana were written before the possibility of exploiting fluorspar deposits there was seriously considered, information about fluorspar is incomplete.

Some of the fluorspar deposits of the Sweetgrass Hills in Liberty and Toole Counties were explored in 1943. They were visited by Scholz in 1943 and for five weeks in the summer of 1944 were studied by C. P. Ross accompanied by W. C. Reimund. Most of this time was spent in detailed work at the fluorspar prospects on Tootsie Creek, the principal ones in the area.

The Spar prospect, Mineral County, was visited August 12 to 15, 1944, and again September 11 to 14, 1944, by C. P. Ross and W. C. Reimund. A preliminary study of the Boeing prospect in Lewis and Clark County was made by Scholz in 1943, and the prospect was visited by Ross and Reimund on August 11, 1944. The Silver Bow prospect 6 miles west of Butte was investigated by Scholz in 1943. Four days were devoted to its study by Ross, with the assistance of

[1] Scholz, E. A., Preliminary report on the Tootsie Creek fluorspar occurrence, Sweetgrass Hills, Liberty County, Mont.: U. S. Geol. Survey Confidential Rept., Aug. 7, 1943; Preliminary report on the Silver Bow fluorspar prospect near Butte, Silver Bow County, Mont.: U. S. Geol. Survey Confidential Rept., Aug. 10, 1943; Preliminary report on the Boeing fluorspar prospect near Austin, Lewis and Clark County, Mont.; U. S. Geol. Survey Confidential Rept., Aug. 12, 1943; A reconnaissance of some minor fluorspar prospects in Montana: U. S. Geol. Survey Confidential Rept., Aug. 12, 1943.

Reimund, in September 1944, with a brief revisit in September 1946. Ross also made a brief visit to a prospect near the smelter of the Anaconda Copper Co. at Anaconda.

Fluorite is known to occur in many other localities and information on these localities obtained from published reports, visits by Scholz, and other sources is outlined as a guide for future investigations.

ACKNOWLEDGMENTS

The spirit of cooperation and helpfulness encountered in all areas visited added much to the pleasure and effectiveness of our work. The staffs of the Federal Bureau of Mines at Helena and of the Montana Bureau of Mines and Geology at Butte cooperated throughout; Murl H. Gidel and others connected with the Anaconda Copper Co. were most helpful; the Regional Geologist of the Federal Geological Survey, Spokane, Wash., and his staff facilitated the work in many ways. To them acknowledgment and thanks are given.

The investigations in the Sweetgrass Hills were greatly aided by C. E. Erdmann and J. T. Gist of the Conservation Branch of the Federal Geological Survey. A. B. Martin and his brother, Carl Martin, who did exploratory work at the principal fluorspar property in the area were helpful to Scholz and later to Ross. Officials of Liberty County and ranchers in the vicinity of the Sweetgrass Hills were equally cooperative. Special thanks are due to Mr. and Mrs. Harry Demarest and Mrs. Lydia Roke.

The examination of the Spar property near Superior, Mineral County, was facilitated by James Brooks, who was in charge of exploration work at the time of the two visits made by Ross. Romeyne Ogle aided Scholz, and Thomas J. Helehan aided Ross with local information about the Silver Bow property, Silver Bow County. Scholz likewise was assisted during his visit to the Boeing prospect, Lewis and Clark County, by L. S. Rapes and by Alva J. Haley, Chief geologist for the Great Northern Railway.

DEFINITION, SPECIFICATIONS, AND USES OF FLUORSPAR

Fluorspar is defined as a mineral aggregate containing enough fluorite to meet the qualifications of ore or potential ore. Fluorite, the essential constituent of fluorspar, is a mineral, with specific properties and a definite chemical composition—calcium fluoride (CaF_2).

The minimum content of CaF_2 that must be present if fluorspar is to be mined at a profit depends on several factors, the main ones being: accessibility of transportation and markets; local availability of suitable milling facilities; size of the ore bodies; character of the ore; and type and quantity of impurities. Under especially favorable conditions fluorspar ore containing as little as 35 percent of CaF_2 has been exploited; however, in regions less advantageously situated or in deposits where the fluorspar is mixed with objectionable impurities, ore containing less than 50 or 60 percent of CaF_2 generally cannot be mined and treated profitably now. Silica, sulfides, and barite are the common impurities that are disadvantageous. Ore that contains much finely disseminated sulfides or silica is finely ground and concentrated by flotation to produce a marketable product. No satisfactory method of removing excessive barite has yet been tested by large-scale commercial operation.

In prewar days most of the fluorspar mined in the United States came from western Kentucky and southern Illinois. Since the war began, the manufacture of steel, aluminum, and other products that require fluorspar has greatly increased, imports have been curtailed, and many new uses for fluorine compounds have been developed. In consequence, demand for fluorspar in 1944 was unusually heavy. Although the steel industry continued to be the largest consumer, the requirements for the ceramic industry, aluminum metallurgy, hydrofluoric acid manufacture, high-octane gasoline production, and welding rod coatings were substantial. The chief uses of hydrofluoric acid are in the manufacture of refrigerants, air-conditioning material, and insecticides.

Because new uses have been developed, the proportion of acid-grade fluorspar consumed in the United States has been steadily increasing until in 1945 it amounted to about a third of the total, whereas prior to the war it amounted to only 5 to 16 percent. Tonnages actually consumed of metallurgical-grade and ceramic-grade fluorspar, for which specifications are somewhat lower than for acid-grade fluorspar, were much greater than in peacetime; but in percentage of total consumption metallurgical-grade material fell from an average of about 80 percent to 60 percent, and ceramic-grade material from about 15 percent to 5 percent. The recently aroused interest in fluorspar deposits that might become a source of acid-grade material is a direct result of the shift in relative demand.

DISTRIBUTION OF DEPOSITS

The mountains that occupy most of Montana west of longitude 108° have long been known to contain diverse mineral deposits, some of them outstanding sources of the nation's supplies of copper and other metals. The production of fluorspar has been meager, but the presence of its essential constituent, fluorite, in many of the metal deposits is known. Information about the distribution of fluorite is still incomplete. As prospecting continues, new localities presumably will be found, and some of those in which the mineral now appears to be merely a minor constituent of the gangue in metallic lodes may prove to contain shoots in which the fluorite is sufficiently concentrated to be of commercial interest.

The principal localities in Montana that have been explored for fluorspar include the Sweetgrass Hills in Liberty and Toole Counties, the Spar property near Superior in Mineral County, the Boeing prospect near Austin in Lewis and Clark County, and several claims near the town of Silverbow in Silver Bow County. The geology of these fluorspar areas was mapped in 1944 (see fig. 6).

Other localities in which fluorite is known to be present are the Little Rocky Mountains in Phillips County, the Judith Mountains in Fergus County, Duck Creek Mountain in the Belt Mountains in Broadwater County, the Marysville district in Lewis and Clark County, several places near Philipsburg in Granite and Deer Lodge Counties, and many of the mines at Butte. Each of these occurrences is located approximately in fig. 6. The data are summarized for each deposit, with the exception of the Butte area where the fluorite appears to be solely of mineralogic interest.

TYPES OF DEPOSITS

Most of the fluorite in Montana is either in metalliferous lodes or in deposits similar to such lodes. Many are replacement deposits in limestone, either along the bedding or in shear and breccia zones in which displacement is slight. The Madison limestone is the most common host rock for fluorspar deposits of this type. Some quartz, generally fined grained, invariably accompanies the fluorite in the replacement deposits, and subordinate quantities of sulfides, particularly pyrite, are irregularly distributed. In those deposits originally mined for their metallic content, the sulfides present may reach significant proportions. A little barite and, locally, other minerals have been reported. Fluorite in significant amounts is confined to shoots that constitute only a small part of the limestone that is recrystallized, silicified, and otherwise shows the effects of mineralization. The shoots are irregular in size, shape, and distribution.

The other deposits are chiefly parts of quartz veins in which fluorite is locally so abundant that it is the dominant mineral. The veins differ in mineral composition, structure and host rocks. Some, locally almost completely replaced by fluorite, are lenses of coarsely crystalline white quartz in rocks of the Belt series. Others are shear and breccia zones in rocks that include Belt strata, various Paleozoic sedimentary rocks, volcanic rocks of Tertiary or Cretaceous age, and granitic and other intrusive igneous rocks. In these zones, quartz and other silica minerals have been introduced on a comparatively large scale, and fluorite in significant proportions is confined to shoots whose dimensions generally have not been accurately determined. Where paragenesis has been recorded, most of the fluorite is shown to be of later origin than most of the quartz. In those deposits that

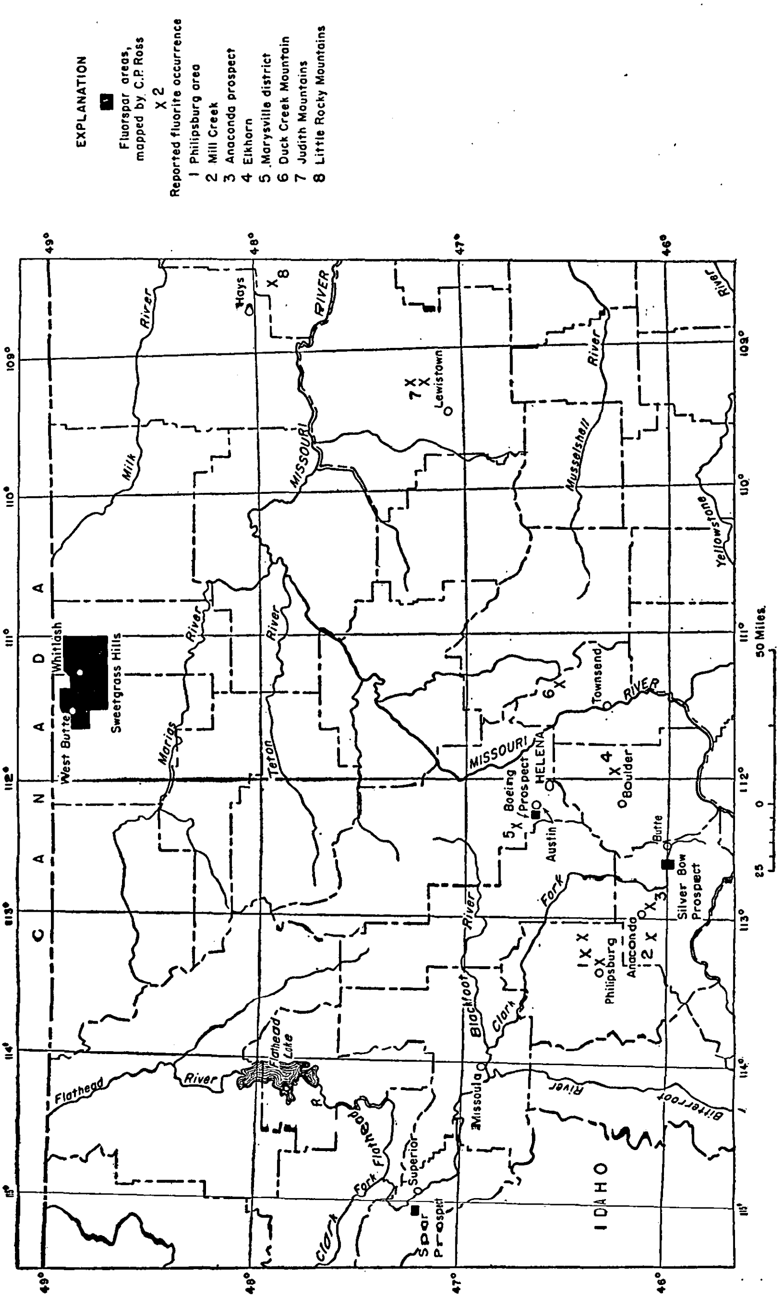

FIGURE 6.—Index map of part of Montana, showing the location of mapped fluorspar-bearing areas, and the approximate location of other known occurrences of fluorite.

have been explored mainly for fluorspar the mineralogy is simple and, with the exception of a little gold and silver, the metallic constituents are few. In some of the bodies mined for metals and containing fluorite in patches, the mineralogy is more complex and the proportions of the different minerals more varied.

THE SWEETGRASS HILLS, LIBERTY AND TOOLE COUNTIES

GEOGRAPHY

The Sweetgrass Hills are in northwestern Liberty County and northeastern Toole County, in north-central Montana, a short distance south of the Canadian border and between 20 and 30 miles north of the Great Northern Railway, mainly in T. 36 and 37 N., R. 1 to 5 E. There are three related groups of hills, termed respectively the West, Middle, and East Buttes. The three groups, one of which is shown in plate 18, rise steeply from the widespread plains and are so steep and compact that from a distance they look like three individual buttes. They are called the Three Buttes on early maps, based chiefly on records of those passing along the main routes of travel, miles away. The names, Sweet Grass Hills, and its French equivalent Montagnes du Foin de Senteur, were early applied to them by hunters and traders.[2] Each butte is so intricately dissected as to constitute a group of hills that viewed from within the group has little resemblance to a butte, as that term is ordinarily used (see pl. 18*B*). Each group, however, includes one or more steep-sided, little-dissected, butte-like masses. Some of the outliers—such as Haystack and Grassy Buttes—are better examples of buttes than are the main groups of hills.

The map, plate 19, shows the general features of the Sweetgrass Hills with as much accuracy as available information permits. It is based mainly on aerial photographs, furnished by the Agricultural Adjustment Administration, combined with data from county maps and other sources. In the absence of adequate control, no attempt has been made to adjust the mosaics formed from the aerial photographs. It is believed, however, that errors and distortions thus introduced into plate 19 are not such as to detract seriously from its usefulness. As township and section corners were found in the field and identified on the photographs in only a few places, the placing of claim boundaries and other features with reference to township boundaries is only approximate.

[2] Dawson, G. M., Report on the geology and resources of the region in the vicinity of the Forty-ninth Parallel from the Lake of the Woods to the Rocky Mountains: British North American Boundary Commission, Montreal, 123 pp., 1875.

The outlines of the groups of hills and the positions of most of the principal peaks are shown by hachures on plate 19. The larger igneous masses shown on this map correspond broadly to the more prominent individual mountains and buttes of the group.

The border of the plains area around the hills is 4,000 to 4,500 feet above sea level. Mount Royal in East Butte has an altitude of 6,918 feet according to measurements made by J. T. Gist of the U. S. Geological Survey, and Mount Brown, 1½ miles to the north, is a little higher. The highest part of West Butte may be even higher above sea level. The towns along the main line of the Great Northern Railway in the plains south of the hills have altitudes of a little more than 3,000 feet. These altitudes and the radial drainage patterns apparent on plate 19 are evidence of the rather steep slope of the plains away from each of the groups of hills that compose the Sweetgrass Hills.

The climate of the hills and vicinity is semiarid, with moderately severe winters. Weather Bureau records show an annual precipitation of about 10 inches at Chester, county seat of Liberty County, on the Great Northern Railway, and of 12 to 15 inches at stations nearer the hills. There is a wide range of precipitation in different years; commonly several feet of snow falls in the hills, providing a reserve of moisture to feed the streams. The larger creeks—such as Tootsie, Sage, and Halfbreed Creeks in East Butte—maintain a small surface flow, at least along their upper reaches during the summer months, unless the snowfall of the previous winter has been exceptionally light. If mineral-dressing mills or similar installations requiring large amounts of water are built in the hills, special provision to conserve the available water, such as the construction of reservoirs, would be needed; much of the water normally runs off in spring floods.

The average temperature at stations for which records exist is about 40° F., and recorded extremes range from more than 100° during short periods in the summer to more than 50° below zero during severe winters. There is a large diurnal temperature range, especially in the hills, where frosts and snow flurries may occur at almost any time during the summer.

Pines and other types of evergreen form dense groves of small trees in the hills, but ridge tops and peaks together with large parts of the valley slopes have only widely scattered, generally stunted trees. The trees may serve as a source of mine timbers, although they are not ideal for this. Lumber for most purposes would have to be shipped in. The open areas are covered with grass, or, in steeper parts, with rock talus. The surrounding plains and also the more open parts of the hills are range lands for cattle and sheep. Dry farming of grain and other crops is practiced, mostly near the railroad.

PREVIOUS WORK

The geology of the Sweetgrass Hills, formerly called the Three Buttes, is depicted in diagrammatic fashion on the map that accompanies Hayden's account of his trip along the Yellowstone and Missouri Rivers in 1859 and 1860.[3] Dawson [4] mapped and described the geology of the hills in 1874 and briefly revisited the area 10 years later,[5] and Weed and Pirsson [6] supplemented his report by petrographic descriptions of specimens furnished by Dawson. These authors referred also to recent (1895) discovery of copper and the precious metals in the hills and to the presence of coal on the flanks of the hills, and noted that these discoveries had caused an influx of prospectors. The mineral deposits were described in somewhat more detail by Ledoux [7] in 1891 as a result of studies he made for the Great Northern Railway, which was then planning construction through that region. He visited Mount Royal (then called Mount Morris), the prominent part of East Butte, and noted the presence of gold, copper, and especially iron deposits, on the slopes of this mountain.

Kemp and Billingsley [8] in 1921 noted and mapped the major geologic features of the area. Their work provided a valuable basis for the more detailed studies of later years. Kemp contributed much petrographic detail, supported by three chemical analyses by H. S. Washington. A number of reports have been published in connection with the investigation of oil and gas in the surrounding plains. Most of them refer only incidentally to the Sweetgrass Hills, but they give much pertinent information about the stratigraphy and structure. Among them may be cited an early report by Stebinger,[9] which summarizes data then available on the whole of north-central Montana; one by Collier [10] which includes structural and other data on Sweetgrass Hills, but deals mainly with areas to the west and south; and another by Pierce and Hunt [11] on the region east of the Sweetgrass

[3] Hayden, F. V., Geological report of the exploration of the Yellowstone and Missouri Rivers under the direction of Capt. W. F. Raynolds: 40th Cong., 2d sess., S. Doc. 77, 1869.

[4] Dawson, G. M., op. cit., pp. 123–129.

[5] Dawson, G. M., Report on the region in the vicinity of the Bow and Belly Rivers, Northwest Territory: Geol. and Nat. Hist. Survey of Canada, Report of Progress 1882–1884, pp. 16c–18c, 45c–48c, 1885.

[6] Weed, W. H., and Pirsson, L. V., On the igneous rocks of the Sweetgrass Hills, Mont.; Am. Jour. Sci., 3d ser., vol. 50, pp. 309–313, 1895.

[7] Ledoux, A. R., Notes on the Sweetgrass Hills of Montana and the Kootenai Mines of British Columbia: New York Acad. Sci. Trans. vol. 10, pp. 57–60, 1891.

[8] Kemp, J. F., and Billingsley, Paul, Sweetgrass Hills, Mont.: Geol. Soc. America Bull., vol. 32, pp. 437–478, 1921.

[9] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–91, 1917.

[10] Collier, A. J., The Kevin-Sunburst oil field and other possibilities of oil and gas in the Sweetgrass Arch, Mont.: U. S. Geol. Survey Bull. 812, pp. 57–189, 1930.

[11] Pierce, W. G., and Hunt, C. B., Geology and mineral resources of north-central Chouteau, western Hill, and eastern Liberty Counties, Mont.: U. S. Geol. Survey Bull. 847, pp. 225–264, 1937.

Hills. A paper by Perry[12] which summarizes data on natural gas throughout Montana includes data on the Sweetgrass Hills and vicinity.

Much geological work has been done in and near the Sweetgrass Hills by C. E. Erdmann of the Conservation Branch of the U. S. Geological Survey. The preliminary maps issued as a result of this work include three that cover part of the Sweetgrass Hills and vicinity.[13]

General data on the glacial deposits that cap so much of the plains surrounding the Sweetgrass Hills are given in papers by Calhoun[14] (1906), and Alden[15] (1932).

In 1943 when the possibility of developing the fluorspar resources of the hills first aroused interest, the area was visited by representatives of the Federal Bureau of Mines and Geological Survey. As a result the Bureau of Mines issued a brief report for the use of government agencies in July 1943. A similar report prepared by Edgar A. Scholz was issued on August 7, 1943, by the Geological Survey, based on a visit by Scholz accompanied by the Martin brothers, on June 19, 1943. Scholz had previously seen the deposits in 1940 in the company of E. S. Perry and J. M. Conrow of the Montana Bureau of Mines and Geology. These reports were of much assistance in the work on which the present paper is based. That by Scholz constitutes an excellent summary of the principal features of the geology of the best known of the fluorspar deposits and includes a summary of the results of metallurgical tests performed by the Bureau of Mines and released by that agency.

SCOPE OF PRESENT INVESTIGATION

In July and early August 1944, the Sweetgrass Hills were studied by C. P. Ross, accompanied by W. C. Reimund. All three buttes that compose the Sweetgrass Hills were visited. As East Butte is the only one in which fluorspar deposits of commercial interest are known, most of the field work was concentrated there. Areal geologic mapping was restricted to the part that appeared to have direct bearing on the occurrence of fluorspar. Detailed studies were made of the

[12] Perry, E. S., Natural gas in Montana: Montana Bur. Mines and Geology, Mem. 3, pp. 57–73, 1937.

[13] Erdmann, C. E., Preliminary structure contour map of the Bears Den-Flat Coulee-Whitlash districts, north-central Mont.: U. S. Geol. Survey, 1930; Structure contour map of the Dunkirk-Chester region, Toole and Liberty counties, Mont.: U. S. Geol. Survey, 1939; Preliminary map of the areal and structural geology of T. 36 N., R. 1 E., Toole County, Mont., showing Kicking Horse Dome and Simmons Creek anticlinal nose: U. S Geol. Survey, 1942.

[14] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

[15] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, 1932.

fluorspar prospects on Tootsie Creek, the principal ones in the area. East Butte was searched for other occurrences of fluorspar and (as indicated in plate 19) several were found. Only incidental attention was given to deposits of minerals other than fluorspar.

The extensive knowledge gained by C. E. Erdmann in many years of field work in and near the Sweetgrass Hills was made available through reports, published and unpublished, and through enlightening personal discussions and correspondence. He and J. T. Gist made a plane-table traverse from the northwestern part of sec. 34, T. 36 N., R. 5 E., to the summit of Mount Royal to furnish control for the writer's geological work in this part of the Sweetgrass Hills.

GENERAL GEOLOGY

The outline of the geology of the Sweetgrass Hills here presented includes only features that have a bearing on problems related to the fluorspar deposits. The boundaries of bodies of the Madison limestone, which contain most of the fluorspar deposits, were traced in the field, using aerial photographs with a scale of roughly 1:20,000. At the same time data were obtained regarding the hybrid metamorphic rocks and the different intrusive masses. The boundaries of the rocks shown on plate 20 are based largely on published maps [16] supplemented by unpublished information from C. E. Erdmann, but modified somewhat on the basis of the aerial photographs. The numerous sills and dikes are shown on plate 19 only along that part of Tootsie Creek where detailed mapping was done around the fluorspar deposits. Kemp and Billingsley have shown that these smaller igneous bodies are plentiful in all three buttes, but their maps, cited above, differ sufficiently in the base used from that of plate 19 so that it is impracticable to transfer details of this kind. The formation names and much of the data on structure given below are largely based on previous work, particularly that of C. E. Erdmann. The age assignments given to the different rocks are those of Erdmann, as no diagnostic fossils were collected during the present investigation.

SEDIMENTARY ROCK UNITS

PALEOZOIC STRATA

The only formation of Paleozoic age exposed anywhere in or close to the Sweetgrass Hills is the Madison limestone, which partly surrounds some of the igneous masses, notably that of Mount Royal in East

[16] Kemp, J. F., and Billingsley, Paul, Sweetgrass Hills, Mont.: Geol. Soc. America Bull., vol. 32, figs. 3, 4, 5, 1921.
Erdmann, C. E., Preliminary structure contour map of the Bears Den-Flat Coulee-Whitlash districts, north-central Montana; U. S. Geol. Survey, 1930; Preliminary map of the areal and structural geology of T. 36 N., R. 1 E., Toole County, Montana, showing Kicking Horse Dome and Simmons Creek anticlinal nose: U. S. Geol. Survey, 1942.

Butte. The limestone forms a single outcrop in sec. 36, T. 37 N., R. 1 E., in West Butte. Drill records of holes in the surrounding plains indicate that Devonian and older Paleozoic beds are present at depth there, but the Quadrant formation (Pennsylvanian), exposed in other parts of Montana, has not been recognized anywhere in the vicinity of the Sweetgrass Hills. It may have been removed by erosion before Mesozoic deposition began.

The Madison limestone in the Sweetgrass Hills consists of white to gray, crystalline limestone, moderately thick bedded, with chert concretions which are locally abundant. Argillaceous beds in the formation are rare. The full thickness is approximately 1,000 feet, but in the exposures in the hills the base of the formation has been invaded by igneous rock, and the top was cut into by erosion in early Mesozoic time. Consequently only a few hundred feet of beds are preserved. The few fossils noted in the course of the field work were so altered by recrystallization as to be without diagnostic value. The general appearance of the formation is indicated by plate 21*A*, which shows nearly the entire thickness of the unit that is present on the east slope of the valley of Tootsie Creek. The conspicuous white outcrops in plate 18*B* are of Madison limestone.

Close to igneous contacts in the vicinity of the upper reaches of Tootsie Creek and in sec. 28, T. 36 N., R. 5 E., and also in the small exposure in West Butte, the limestone has been rendered rather coarsely crystalline. Most outcrops of this recrystallized rock are stained by limonite, derived presumably from disseminated pyrite. Some of the limestone is partly silicified; some contains sparsely disseminated amphibole needles and other silicate minerals. Small bodies of the limestone engulfed in the igneous rock on the northeastern slopes of Mount Royal have been almost completely replaced by iron oxides with some sulfides and other minerals. This contact-metamorphic rock is described in more detail in the section on mineral deposits. Locally, some attention has been paid to the possibility of using the recrystallized, but otherwise only slightly altered, limestone as a source of marble for construction material, but no quarrying has ever been done.

The hybrid metamorphic rock mapped separately as shown on plate 20 was probably derived in part by replacement of Madison limestone, although thoroughly altered parts of younger beds may be included. The metamorphic rock is intricately invaded by tongues of a fine-grained, green igneous rock that appears in places to merge into the metamorphic rock. The metamorphic rock is commonly green and fine-grained and retains vestiges of stratification. In places, notably in the general vicinity of the Brown Eyed Queen mine, the dense green rock has white feldspar crystals irregularly distributed through it. Veinlets of green rock, indentical in character with the metamorphic rock, cut some of the Madison limestone. Along upper Sage Creek near the northern border of the metamorphic rock, the material is exceptionally variegated. Some of it has the appearance of a breccia in part of which the fragments are as smoothly rounded as the pebbles in a conglomerate. Some of these fragments consist of unreplaced limestone.

The appearance of the metamorphic rock under the microscope reflects its hybrid character. It is varied both in texture and in composition. Much of it is a fine-grained aggregate of quartz and chlorite, with some calcite. In many places rock of this character merges with that in which orthoclase and sodic plagioclase are so abundant as to produce a semblance of igneous texture, with or without phenocrysts. In a few places biotite is conspicuous. Some of the rock contains amphibole needles.

The rock, which seems undoubtedly igneous as seen in the field, has in thin section somewhat less clean cut igneous texture than its megascopic appearance suggests. It consists mainly of somewhat altered sodic plagioclase in poorly defined laths. Interstitial quartz is moderately plentiful. Chlorite and other micaceous alteration products are common, and some calcite is present.

MESOZOIC STRATA

The oldest Mesozoic unit recognized in the Sweetgrass Hills is the Ellis formation (Upper Jurassic). It crops out in East Butte in a broken and highly irregular arc that starts in sec. 31, T. 36 N., R. 5 E., swings north through the eastern part of T. 36 N., R. 4 E., around the igneous masses of Mount Royal and Mount Brown, and in the northwestern part of T. 36 N., R. 5 E. commences a southward swing that, with interruptions, carries it east of Mount Brown and across Tootsie Creek to its end in sec. 32, T. 36 N., R. 5 E. This statement is based on Erdmann's field work, which unfortunately is not yet complete enough to permit the formation to be shown on plate 19. Erdmann's published map of T. 36 N., R. 1 E., shows that a little of the Ellis formation is exposed on the west side of West Butte. The stratigraphic sections accompanying his published maps, cited above, indicate that the Ellis formation in this part of Montana ranges in thickness from 130 to 235 feet and consists of gray and black calcareous shale, thin dark limestones, and some gray calcareous sandstone near the base. There is a clear erosional unconformity between the Ellis formation and the underlying Madison limestone, and probably one between the Ellis and younger beds also.

The consolidated sedimentary rocks above the Ellis formation are all of Cretaceous age. They constitute the bedrock nearest the surface for all parts of plate 19 not otherwise indicated on that map, except where the Ellis formation is exposed as indicated in the preceding paragraph. The following correlation table summarizes published data on the five Cretaceous formations in and close to the Sweetgrass Hills.

Cretaceous strata in the vicinity of the Sweetgrass Hills

Age	Formation	Thickness (feet)	Character
Upper Cretaceous	Judith River formation.	0–600	Continental and brackish-water deposits, mostly shale and sandstone with oyster beds, marl, and some coal. The upper part is lighter colored than the lower.
	Claggett shale	0–500	Gray and brown marine shale with some sandstone. Lower part contains brownish-black shale with calcareous concretions, bentonite beds, and black chert pebbles near base.
	Eagle sandstone	0–380	Upper part is light-colored continental shale and sandstone with conglomerate and thin coal beds. Lower part is the Virgelle sandstone member. Transitional into the Colorado shale below.
	Colorado shale	970–1845	Gray marine shale with beds of bentonite, sandstone, and concretionary limestone.
Lower Cretaceous	Kootenai formation	305– 515	Maroon, green and gray sandy shale, with sandstone beds.

QUATERNARY DEPOSITS

The plains surrounding the Sweetgrass Hills are extensively mantled by glacial deposits which in places, such as the area south of Mount Lebanon in East Butte, extend in broad lobes into the hills. These deposits attain a maximum thickness of approximately 200 feet and effectively conceal the bedrock over large areas. They were laid down by a continental glacier advancing from the northeast during the Wisconsin stage.[17] The glacial ice was split and moved around the three buttes composing the Sweetgrass Hills, they were neither covered by the continental glacier nor affected by mountain glaciation within their confines.

The glacial mantle seriously affected the drainage around the hills. In the areas west of East Butte fluctuating lakes and ponds are still

[17] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, p. 28, 1906.
Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, p. 108, 1932.

numerous. Throughout the area the need to supplement the inadequate natural water supplies has led the ranchers to make artificial ponds by means of low dams in topographically favorable locations; many of these ponds are made practicable by the glacial topography. The streams have not been able to establish normal drainage patterns. Instances of stream piracy are numerous, and this process continues to be operative. Marshy areas and ill-defined divides similarly point to disrupted drainage.

Within the mountains most major streamways have inner gorges that record recent rejuvenation. Flood plains and other alluvial deposits later than the glacial materials are not extensive. Along Sage Creek in sec. 17, T. 36 N., R. 5 E., and possibly in other areas underlain by Madison limestone, part of the drainage passes through underground caverns.

IGNEOUS ROCKS

Igneous rocks in the Sweetgrass Hills form rather large masses and numerous sills and dikes. Most of the sills and dikes and some of the smaller masses are not shown on plate 20. The distribution of the igneous rocks is shown in greater detail on the maps of the three buttes published by Kemp and Billingsley.[18] Their report is the most complete presentation of the igneous geology of the Sweetgrass Hills. Except for data gathered in the course of examination of mineral deposits in East Butte, the following summaries are based on their work.

West Butte contains three irregular intrusive masses and several sills, all regarded as quartz diorite porphyry by Kemp and Billingsley. They reported that one sill, in or near sec. 18, T. 37 N., R. 2 E., contains a little fluorite. Middle Butte contains three exposed masses of dioritic rocks and numerous sills and dikes that range in character from trachyte to minette, according to Kemp and Billingsley. The minette sill is reported to contain inclusions of gneiss, granite, quartzite, and schist. These inclusions led Erdmann to infer that the Belt series is absent there and that Paloezoic strata rest directly on old, thoroughly metamorphosed material.

East Butte, in which the fluorspar deposits are situated, includes about a dozen masses of igneous rock (only the larger ones are shown on plate 20) and innumerable narrow sills and dikes. The map made by Kemp and Billingsley shows more than 30 sills and dikes; detailed studies would add many to this number.

The largest exposed igneous mass in East Butte is that forming Mount Royal. This mass is an alkalic syenite of somewhat varied texture and composition. Most of it is medium-grained and indis-

[18] Kemp, J. F., and Billingsley, Paul, op. cit., figs. 3–5.

tinctly porphyritic. The dominant constituent is alkali feldspar, commonly both orthoclase or anorthoclase and albite. In places the feldspar has the appearance of ill-defined perthitic intergrowths. Commonly some interstitial quartz is present. The proportions and character of the ferromagnesian minerals are varied. In some exposures they are almost completely absent; in others, pyroxene, hornblende, and biotite may constitute 15 percent of the rock. The pyroxene observed during the present study is augite, possibly somewhat soda-rich. Kemp and Billingsley[19] noted the presence of aegirite needles in the groundmass, but aegirite was not found in the rock examined by the writer during the present investigation.

The sills along upper Tootsie Creek are finer-grained, but otherwise similar to the syenite of Mount Royal. They commonly form topographic saddles, such as the one shown in the middle distance in plate 21*A*. The sills studied by the writer can be conveniently considered to be of sodic trachyte. The rocks consist of orthoclase and sodic plagioclase, plus smaller quantities of hornblende, biotite, pyroxene, and quartz. Most of them contain chlorite, calcite, and other alteration products. Descriptions in the paper just cited indicate that many of the other igneous rocks in East Butte are similar to these. One plug about 10 feet in diameter was called tinguaite by Kemp and Billingsley, who published a rock analysis made by H. S. Washington. The rock consists mainly of orthoclase containing phenocrysts of aegirite or aegirite-augite, and aegirite needles in the groundmass. No nepheline was detected by Kemp and Billingsley, but they noted that the analysis suggests the presence of some such silicate in the rock, possibly in glass in the groundmass. Several minette dikes were reported by them in the parts of East Butte not studied in detail during the present investigation. A specimen from one of these dikes, also analyzed by H. S. Washington, contains abundant biotite phenocrysts and some augite. The feldspar of the groundmass appears to be mostly orthoclase. Chlorite, calcite, and other alteration products are plentiful.

On the basis of the structural history of the region, intrusion of the igneous rocks is inferred by Erdmann to have taken place in Eocene time. He points out that the igneous masses of the Sweetgrass Hills could not have been in existence at the time—the Sweetgrass Arch—referred to in the discussion of structure which follows was formed because the arch shows no evidence of the buttress effects that would have resulted if the igneous masses has been in place. According to Erdmann the youngest rocks involved in the folding which produced the arch belong to the Willow Creek formation, which

[19] Kemp, J. F., and Billingsley, Paul, op. cit., pp. 455–460

he regards as of Paleocene age, and the erosion of the Sweetgrass Hills had begun before the White River group (Oligocene) was laid down.

STRUCTURE

The Sweetgrass Hills are on the eastern flank of a very broad, somewhat irregular anticline which extends southward from the Canadian border across much of Montana, and has been referred to as the Sweetgrass Arch.[20] On the generalized map showing the structure of the Montana plains by Dobbin and Erdmann,[21] the three buttes that compose the hills appear as three steep domes. More detailed studies [22] reveal that each of these domes is made up of a number of closely associated domes and noses. Several of the domes have exposed cores of igneous rock, and it seems probable that most of the similar domes within the hills also have igneous cores, not yet cut into by erosion. Some of the noses also may be related to igneous masses.

Kemp and Billingsley [23] believed that the igneous masses which underlie domical uplifts in the sedimentary rocks of the Sweetgrass Hills are laccoliths. Observations made during the present investigation are in agreement with the concept that the domical uplifts are related to igneous intrusion. The narrow zones of abruptly upturned beds (see pl. 23*A*) that encircle the igneous bodies of Mount Lebanon, Mount Royal, and other localities seem to admit of no other explanation.

The presence of floors of sedimentary rock beneath the supposed laccoliths is not everywhere satisfactorily demonstrable. Kemp and Billingsley [24] suggested that the two smaller laccolithic bodies in West Butte and one in Middle Butte rest on Colorado shale, but their evidence was not clearly stated. They inferred that the principal intrusive masses in East Butte have floors of Madison limestone, and supposed that the smaller ones, such as that of Haystack Butte, were enclosed in Colorado shale. Although the inferences in regard to all three buttes are logical, direct evidence of the presence of an exposed floor was not cited. During the studies in 1944, some evidence of this kind was obtained for the igneous mass between Sage and Tootsie Creeks, in and near sec. 16, T. 36 N., R. 5 E., but not for any of the others. One of the minor tributaries of Sage Creek has exposed Madison limestone dipping under the western border of this

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[20] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 64–65, 1917.

[21] Dobbin, C. E., and Erdmann, C. E., Structure contour map of the Montana plains: U. S. Geol. Survey, 1932 (revised 1935).

[22] Erdmann, C. E., Preliminary structure contour map of the Bears Den-Flat Coulee-Whitlash districts, north-central Montana: U. S. Geol. Survey, 1930. Preliminary map of the areal and structural geology of T. 36 N., R. 1 E., Toole County, Mont.: U. S. Geol. Survey, 1942.

[23] Kemp, J. F., and Billingsley, Paul, op. cit., fig. 2.

[24] Kemp, J. F., and Billingsley, Paul, op. cit., pp. 446, 450.

mass at a very low angle. Tributaries of Tootsie Creek in sec. 20, T. 36 N., R. 5 E., show a floor of the Ellis formation extending under the same mass, as is indicated by the shape of the contact on plate 19. This map also shows a patch of sedimentary rock in the gorge of Tootsie Creek in sec. 21, where the gorge appears to have cut through the igneous mass into the floor. The upper surface of the sedimentary mass exposed in the sides of the gorge at this place is nearly flat. The igneous mass north of Sage Creek in and near sec. 5, T. 36 N., R. 5 E., has a shape that suggests the presence of a floor, but this mass was not closely examined during the present investigations.

As mapped by Kemp and Billingsley, and by Erdmann,[25] the distribution of sills and especially of dikes in East Butte favors the concept that they were formed during the doming of the sedimentary rocks that they intrude. Many of the details have not been worked out, but it seems clear that in East Butte the dikes fill radial tension cracks in the roofs of the larger igneous masses.

In West Butte much of the roof of the largest intrusion has been eroded away. Kemp and Billingsley mapped comparatively few sills and no dikes here, and indicated that much of the sedimentary rock that might contain them is covered with Pleistocene and later deposits. The faults mapped by Erdmann[26] around the southern part of West Butte do not show a radial pattern. One scissors fault strikes nearly north through the western foothills. Another fault downthrown on the side toward the plains, nearly coincides with the circular border of the main intrusive mass, in the small part of West Butte that appears on Erdmann's published map. He labelled this mass a stock, an interpretation that seems more in keeping with the fault pattern than does Kemp and Billingsley's idea that it is a laccolith with a concealed floor. In an unpublished paper Erdmann states that some time after the initial domical uplifts the partly cooled and stiffened igneous masses were forced upward through the overlying sedimentary rocks. This concept is doubtless based largely on the evidence of circular faults, such as the one in West Butte just referred to. Faults of this type have not as yet been mapped in the other buttes.

In summary, the topographic elevations of the Sweetgrass Hills correspond rather closely to structural uplifts genetically related to igneous intrusions. The larger masses have domed the sedimentary rocks above them, and in a few places sufficient evidence of the presence of floors 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.

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[25] Erdmann, C. E., Preliminary structure contour map of the Bears Den-Flat Coulee-Whitlash districts, north-central Montana: U. S. Geol. Survey, 1930.

[26] Erdmann, C. E., Preliminary map of the areal and structural geology of T. 36 N., R. 1 E., Toole County, Mont.: U. S. Geol. Survey, 1942.

MINERAL DEPOSITS

HISTORICAL NOTES

The topographically conspicuous Sweetgrass Hills have long been of interest to prospectors, but during much of the latter part of the nineteenth century search for minerals was hindered by the fact that the hills were in an Indian reservation. In the late 1880's [27] and early 1890's [28] the presence of gold, silver, copper, lead, iron, and coal in the hills was known. The Great Northern Railway is reported to have purchased the claims in the western part of T. 36 N., R. 5 E., near Tootsie Creek, in 1896. These claims contain the principal fluorspar deposits of the region, but the numerous pits, shafts, and tunnels in them were driven mostly in search of gold and copper.

The gold placers near Gold Butte in Middle Butte probably began to be productive on a small scale in the 1880's, although the first published record that has been found is for 1898.[29] There have been several brief revivals of placer mining during the present century, but it seems probable that the total yield of placers near Gold Butte is less than 2,000 ounces of gold.

In West Butte a little lead ore containing some gold and silver was produced in 1908.[30] The coal mine, on the southeastern border of West Butte, shown in plate 2, has been worked at times to supply local needs since its discovery, which may have been about 1890.

Drilling for gas and oil in the general vicinity of the Sweetgrass Hills began in 1915,[31] and both oil and gas, particularly the latter, have been found. The gas wells in the Bears Den area northeast of East Butte, which are so close to the fluorspar prospects that they might aid in their development, were shut down before the writer's visit in 1944, but there has been renewal of interest in them since.

The fluorspar deposits evidently did not attract the attention of the early miners, as they are not mentioned in any of the published accounts of the mineral resources of the hills. Kemp and Billingsley [32] reported the presence of fluorite in a specimen of igneous rock from West Butte but make no mention of this mineral in their description of East Butte, where the principal deposits are. Both C. E.

[27] Swallow, G. C., and Trewarthen, J. B., Reports of the Inspector of Mines and Deputy Inspector of Mines for the six months ending Nov. 30, 1889, p. 53, Journal Pub. Co., Helena, Mont., 1890; Swallow, G. C., Trewarthen, J. B., and Oliver, Jacob, Reports of the Inspector of Mines and Deputy Inspector of Mines for the year ending Nov. 30, 1890, p. 20, Journal Pub. Co., Helena, Mont., 1891.

[28] Ledoux, A. R., Notes on the Sweetgrass Hills of Montana and the Kootenai Mines of British Columbia: New York Acad. Sci., Trans. (Abstract) vol. 10, pp. 57–60, 1891.

[29] Calderhead, J. H., Montana Bur. Agr., Labor and Industry, 6th Ann. Report, 1898, p. 174, 1898.

[30] Heikes, V. C., Montana—Gold, silver, copper, lead and zinc in the western States: U. S. Geol. Survey Min. Resources for 1908, part 1, p. 448, 1909.

[31] Perry, E. S., Natural gas in Montana: Montana Bur. Mines and Geology Mem. 3, p. 68, 1937.

[32] Kemp, J. F., and Billingsley, Paul, op. cit., p. 450.

Erdmann[34] and E. S. Perry[35] have long known of the presence of fluorite in East Butte, but it was not until Perry showed the deposits to A. B. Martin of Butte and an engineer from the U. S. Bureau of Mines in April 1943, that exploration for this mineral began. Mr. Martin and his brother directed prospecting in the area from the summer of 1943 until the spring of 1944.

FLUORSPAR DEPOSITS

DISTRIBUTION

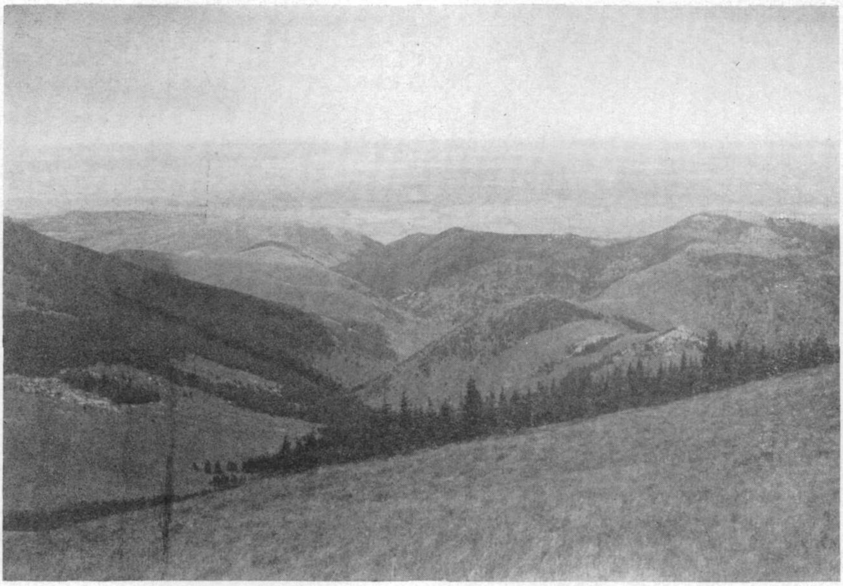
All fluorspar deposits of commercial interest so far recognized in the Sweetgrass Hills are in East Butte. Nearly all are in T. 36 N., R. 5 E., but a few scattered occurrences extend over the boundary into T. 36 N., R. 4 E. The principal group, referred to as the Tootsie Creek deposits, are clustered along Tootsie Creek and its tributaries, as shown in plate 20. This group is mainly in sec. 20, T. 36 N., R. 5 E., but is believed to extend into the eastern part of sec. 19. Section and claim boundaries are not plainly enough marked on the ground to be tied to the survey represented by plate 20; their approximate positions with reference to the deposits can be judged from plate 19. A few deposits of fluorspar are revealed in pits close to an easterly fork of Tootsie Creek about a quarter of a mile upstream from the main group and a short distance east of the border of plate 20. These exposures and those of the main group of claims are probably the only ones in which prospecting for fluorspar has been undertaken. They are close to comparatively extensive underground workings driven in search of gold, copper, and iron, but these workings, now caved, are not so placed as to yield much information regarding fluorspar even if they could be reopened.

There are scattered flecks of fluorite in the cliffs on the eastern side of the valley of Sage Creek in sec. 17, T. 36 N., R. 5 E. These cliffs can be seen near the center of plate 18*B*, which illustrates the character of the topography in this area. Fluorite is present also in several of the prospect pits scattered over the high ground between Sage and Halfbreed Creeks, mostly on the slope of the valley of Halfbreed Creek. Most of these pits are in sec. 19 of the same township as those mentioned above, but some may extend into sec. 24, T. 36 N., R. 4 E. Similarly, fluorite is present in prospect pits and shallow shafts along upper Corral Creek, mostly in sec. 31, T. 36 N., R. 5 E., but probably extending into sec. 36, T. 36 N., R. 4 E.

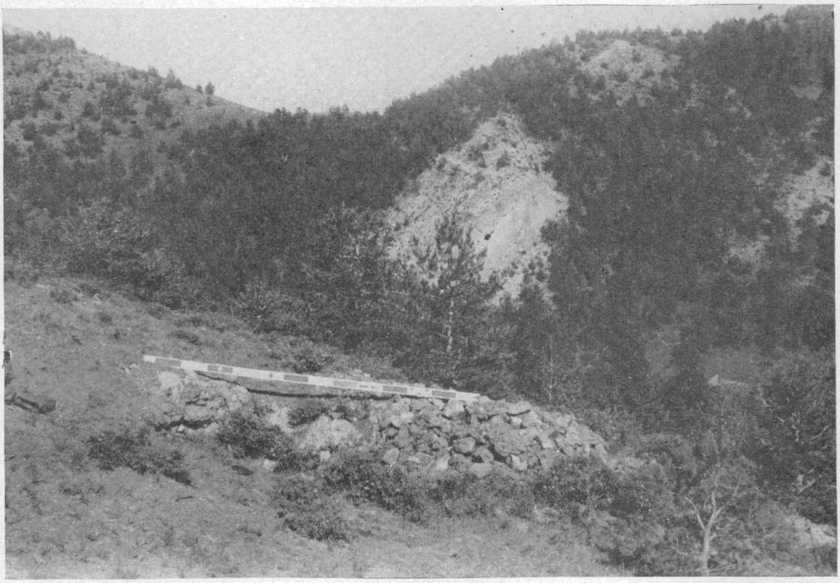
No fluorspar is known in Middle Butte. In West Butte fluorite has been recognized in a specimen of igneous rock from near the middle

[34] Erdmann, C. E., Personal communication.
[35] Perry, E. S., Personal communication.

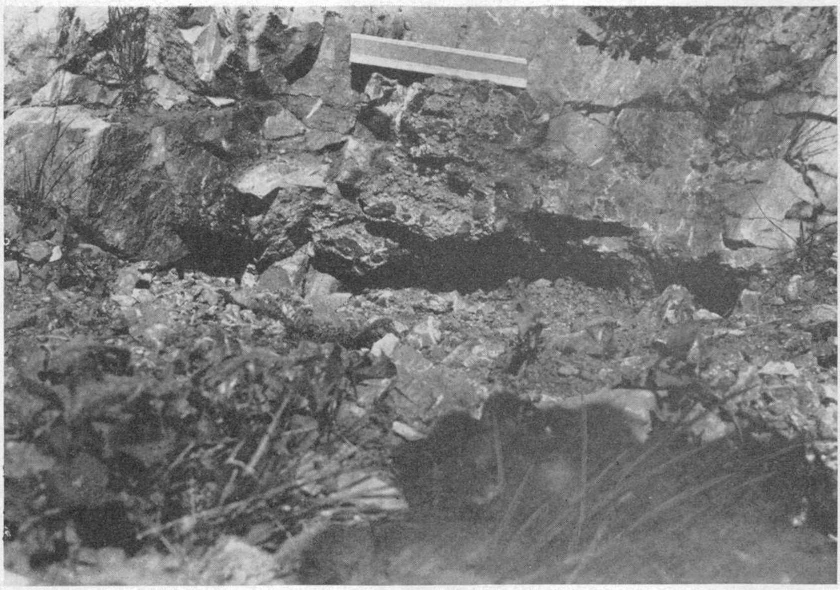
A A GENERAL VIEW OF EAST BUTTE FROM THE SOUTH.



B VIEW DOWN SAGE CREEK FROM THE TOP OF MOUNT ROYAL, ONE OF THE HIGHER SUMMITS OF EAST BUTTE.



A VIEW ACROSS TOOTSIE CREEK WITH THE MALVINA CUT IN THE FOREGROUND AND THE CHIMNEYS IN THE MIDDLE DISTANCE.



B A CLOSE VIEW OF SOME OF THE FLUORSPAR BODIES IN THE MALVINA PIT, SHOWING THE EFFECTS OF BRECCIATION OF THE FLUORSPAR.

of the boundary between T. 37 N., R. 1 E., and T. 37 N., R. 2 E., but apparently only under the microscope.[36]

GENERAL GEOLOGIC RELATIONS

It will be noted on plate 19 that the fluorspar in the localities listed above is in exposures of Madison limestone. A few of those in the main Tootsie Creek group (see pl. 20) and the outcrops on upper Tootsie Creek are in xenoliths in the syenite of Mount Royal. The minor fluorspar occurrences throughout East Butte are in limestone not conspicuously metamorphosed. The principal fluorspar bodies in the vicinity of Tootsie Creek, however, are in or adjacent to the zones of marbleized limestone, which here border the syenite of Mount Royal. Altered limestone similar to that at the Tootsie Creek deposits is conspicuous in and near sec. 28, T. 36 N., R. 5 E., but fluorspar is not known in this locality. No fluorite has been reported in any of the limestone that has been extensively replaced by contact metamorphic minerals, such as that in which the iron deposits occur. The only place where intensely altered limestone is known to contain fluorite is on the eastern fork of Tootsie Creek about a quarter of a mile above the main Tootsie Creek deposits, where small, much brecciated masses of limestone enclosed in syenite have been so thoroughly invaded and replaced by igneous material that their original character is obscured.

The Tootsie Creek deposits are in Madison limestone close to the border of the large syenite mass of Mount Royal. Most of the fluorspar in other localities is in Madison limestone near stringers and small sills of trachyte.

In contrast to the distribution of the fluorspar, the deposits of iron, gold, and other metals that have received most attention in East Butte are either in the syenite or in extensively metamorphosed rock, which, although in large part derived from the Madison limestone, now retains little resemblance to limestone. Most of the scattered prospect holes that have helped to reveal minor occurrences of fluorspar were put down mainly in the search for metallic ores, but metallic ores were not found in sufficient quantities to be of value.

No fluorspar deposits have been found in Middle and West Buttes, probably because there are no exposures of Madison limestone in Middle Butte; only a very small block is exposed in West Butte. The latter is a sliver along a curved fault[37] on the border of a large igneous mass. The locality in the central part of West Butte, from which, as already noted, fluorite of microscopic dimensions has been

[36] Kemp, J. F., and Billingsley, Paul, op. cit., p. 450.
[37] Erdmann, C. E., Preliminary map of the areal and structural geology of T. 36 N., R. 1 E., Toole County, Mont.: U. S. Geol. Survey, 1942.

reported, was not visited during the present investigation. The fluorite-bearing specimen is from a sill, apparently quartz diorite, but as inclusions of various rocks are reported in the intrusive masses of West Butte it is quite possible that the fluorite here is genetically related to a limestone inclusion. The occurrence may be similar to that on upper Tootsie Creek, where a casual observer might overlook the presence of limestone because the limestone body is small, poorly exposed, and metamorphosed.

MINERALOGY

The minerals of the fluorspar deposits are few and simple. They include fluorite, quartz, calcite (mainly as a constituent of the country rock), and some barite, specularite, and pyrite, probably with small amounts of other sulfides. Analyses show a little gold and silver, but if they occur as separate minerals they have not been recognized. Probably much of the precious metal content is in the pyrite or enclosed in the oxidation products of that mineral.

The fluorite is commonly rather dark purple; some is pale, but colorless fluorite seems to be rare. In a few places, notably the Malvina cut (see pl. 21), the fluorite has weathered nearly black. Most of the fluorite was formed as a replacement of the limestone, but where it crystallized in open spaces it is in cubes, rarely more than an eighth of an inch wide. The crystals, which nestle between quartz prisms, are lighter-colored than most of the fluorite in the replacement bodies.

Most of the quartz in the fluorspar deposits occurs as indefinitely-bounded fine-grained replacements of limestone. It is somewhat more plentiful in the rock on the borders of marbleized zones than within these zones. Here and there in the limestone small quartz veins and bands lie approximately parallel to the bedding, and replacement of the limestone by quartz is almost complete. In most linings of open spaces in brecciated limestone, small quartz crystals predominate over other minerals.

The analyses of samples from the Tootsie Creek deposits listed below show that barite is rare in the fluorspar of the area. However, a few geodes contain plentiful barite tablets among the quartz prisms.

Pyrite in tiny grains is probably widely distributed through the marbleized zones, but in the outcrops and shallow excavations it is almost completely oxidized to limonite, which gives the yellow color characteristic of most of the marbleized zones containing the fluorspar deposits. The less well recrystallized limestone, even where it contains a little fluorite, and the marbleized zones that are free of fluorite, do not have the yellow limonite stain; a fact which may be of some aid in prospecting. The pits in outlying localities, such as the upper reaches of Halfbreed and Corral Creeks, were for the most part sunk on rusty streaks in the limestone, some of which retain a little unoxidized pyrite. Undoubtedly these streaks rather than the fluorspar near them determined the locations of the pits. A little specularite is present in limestone in some of these pits and has been noted also in a few of the small intrusive bodies.

The former presence of some copper-bearing sulfide is suggested by faint green stains in a few fluorspar exposures and the presence of 0.03 percent of copper in the only sample of the fluorspar in which a search for copper appears to have been made. No such sulfide has yet been reported in any of the fluorspar deposits, although, as noted below, several are present in the other lodes of the area. The same sample contained 0.05 percent of lead, but no zinc. Galena is rarer than copper sulfides in most lodes in East Butte seen during the present investigation, but presumably is present in minute quantities in some of the fluorspar.

CHARACTER OF THE LODES

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 of the limestone country rock, generally along directions that are approximately parallel to the bedding. None of the sheeted or brecciated zones can be traced far in exposures existing in 1944, and none appears to correspond to major structures. They were formed during minor movements of adjustment in the comparatively steep beds on the flanks of the syenite mass of Mount Royal.

The fluorspar masses are diverse in detail. Most of the fluorspar is in bands and streaks that rather closely follow planes of bedding or sheeting. There are, however, abrupt departures from this parallelism, and some masses are irregular and apparently entirely without pattern, as can be seen in plate 21*B*. A few masses are nearly flat and others are roughly spherical. Parts of nearly all exposures of fluorspar show flecks and small grains of fluorite disseminated through limestone. Rarely, the fluorspar has been brecciated, as shown in plate 21*B*.

Any estimate 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. The distribution and size of the principal known bodies can be judged from plates 21 and 22 and from the detailed description of the Tootsie Creek area, which follows. From them it will be seen that some mineralized zones attain widths 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 the limestone which with its outlying xenoliths, 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 21 analyses that have been made of samples from these 2 groups of fluorspar deposits and from one of the outlying occurrences are tabulated below. The locations from which the samples came are indicated on plates 20 and 22, except sample TM 52, which was gathered from pits on the east slope of the upper valley of Halfbreed Creek. The locations of the first eight samples in the table, taken prior to the present investigation and copied from E. A. Scholz's [38] unpublished report, are known only approximately. The calcium fluoride content ranges from 3.06 to 87.01 percent, with the average content of samples representative of typical better-grade ore somewhat less than 50 percent. In bodies of minable size, the content probably would be less than 40 percent of CaF_2. Silica, the only important contaminating constituent, ranges from 1.68 to 43.83 percent. The expected average silica content of ore mined from the exposures sampled is close to 30 percent. 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 percent and a silica content of less than 20 percent.

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 at its experiment station at Salt Lake City, Utah, conducted tests on a sample (Scholz No. 6 in the table below) obtained near the location monument on Fluorite No. 1 claim. The tests show that flotation of the material is difficult, largely because the constituents are so intimately interlocked as to require fine grinding for separation. In the tests it was necessary to grind the samples to a size which would pass a 200-mesh screen to obtain a fluorspar product of ceramic grade, containing 95.2 percent of calcium fluoride and 0.6 percent of silica, but the recovery was poor. Fluorspar of metallurgical grade was obtained from material ground to pass a 150-mesh screen. Tests aimed at concentration of the silver in the fluorspar indicate that concentration of the silver may be practical, at least in fluorspar with a precious-metal content similar to that of the richer samples shown in the table.

[38] Scholz, E. A., Preliminary report on the Tootsie Creek fluorspar occurrence, Sweetgrass Hills, Liberty County, Mont.: U. S. Geol. Survey, August 7, 1943.

Analyses of fluorspar samples from East Butte

Samples Scholz 1–8 analyzed by Union Assay Office, Inc., Salt Lake City, Utah; samples TM 1–71 analyzed by Norman Davidson and S. H. Cress, U. S. Geological Survey]

	Percent				Ounces per ton	
	Calcium fluoride	Silica	Carbonate	Barium sulfate	Gold	Silver
Scholz No. 1, Grab sample from dump of Malvina pit	73.94	7.0			0.02	1.1
Scholz No. 2, Boulder, west side of Tootsie Creek	87.01	7.20			1.50	.2
Scholz No. 3, 40-inch channel sample, area of plate 22 [1]	54.21	17.74	26.12			
Scholz No. 4, 24-inch channel sample, area of plate 22	54.48	22.6			.005	1.0
Scholz No. 5, 9-foot channel sample, area of plate 22	47.26	26.8			.005	2.1
Scholz No. 6, 120-pound sample from locality near Fluorite No. 1 location monument [2]	58.6	24.4	7.95		.015	8.6
Scholz No. 7, 4-foot channel sample, center of M and M claim	52.26	27.2			.02	5.2
Scholz No. 8, 3-foot channel sample, center of M and M claim	42.25	29.2			.01	1.8
TM 1, 1.5-foot channel sample, north edge of Malvina pit [3]	39.87	1.68	54.42	0	Tr.	Tr.
TM 3, 1.8-foot channel sample, cut on east slope of the valley of Tootsie Creek	28.87	43.83	26.63	0	Tr.	Tr.
TM 5, 7.5-foot channel sample, area of plate 20	39.24	36.56	23.79	0	Tr.	1.98
TM 27, 2.0-foot channel sample, near Fluorite No. 1 location monument	62.99	31.57	4.91	0	Tr.	.68
TM 28, 2.75-foot channel sample, 3 feet northwest of TM 1	76.42	1.75	20.76	0	Tr.	.30
TM 33, 1.33-foot channel sample, from large xenolith on M and M claim	44.25	29.20	17.30	0	Tr.	1.76
TM 35, Grab sample from pit north of area of plate 20	55.39	21.98	20.81	0.12	Tr.	.10
TM 38, 2.33-foot channel sample near Fluorite No. 1 location monument	3.06	14.42	81.22	0	Tr.	Tr.
TM 39, 0.67-foot channel sample near Fluorite No. 1 location monument	17.09	29.72	50.90	0	Tr.	Tr.
TM 44, 0.58-foot channel sample, upper Tootsie Creek	40.56	57.18	.91	0	Tr.	.28
TM 45, 1.0-foot channel sample, upper Tootsie Creek	39.73	56.57	1.54	0	Tr.	Tr.
TM 50, Grab sample, upper Halfbreed Creek	16.49	25.81	40.75	0	Tr.	Tr.
TM 70, 1.17-foot channel sample, area of plate 20	39.26	34.43	20.55	0	Tr.	1.64
TM 71, 0.83-foot channel sample, area of plate 20 [4]	40.28	35.92	21.20	1.04	0.04	11.66

[1] Analysis also showed R_2O_3, 1.05 percent; manganese oxide, 0.01 percent.
[2] Analysis also showed copper, 0.03 percent; lead, 0.05 percent; zinc, none; sulfur, 0.05 percent; iron, 0.50 percent; alumina, 0.15 percent; loss on ignition, 12.9 percent; tellurium, none.
[3] Analysis also showed: Manganese oxide, 0.07 percent.
[4] Analysis showed no copper or lead.

DETAILS OF THE TOOTSIE CREEK DEPOSITS

Observations made at the fluorspar exposures in the area near Tootsie Creek shown in plate 20 are summarized below. The descriptions start with the southeastern part of the area and proceed diagonally across it toward the northwest. The M and M iron mine, shown in plate 20, is not described here as it is not known to contain fluorspar.

Several outcrops of marbleized limestone are hidden among the trees in an area on the hillside north and northwest of the old M and M iron mine, and 300 to 500 feet from that mine. They appear to be isolated xenoliths, or possibly the tips of roof pendants, enclosed in syenite. Each contains fluorspar. The one that is about 250 feet long and that forms somewhat prominent bluffs contains the most fluorspar. Samples Scholz 7 and 8 and TM 33 taken during the present investigation are from this body and were probably cut close to one another in the southern part of the outcrop. The well-exposed part of the limestone block is about 50 feet long and contains fluorspar in a sheeted zone that ranges up to 6 feet in width. The analyses show that the best parts of this zone contain about 45 percent of calcium fluoride and a little less than 30 percent of silica.

The next fluorspar exposures of significance are in an outcrop just north of Dry Creek at the location monument of Fluorite No. 1 claim, which was located by the Martins in 1943. The outcrop is over 10 feet long, 2 to 3 feet high, and elongate roughly at right angles to the strike of the fluorspar and the containing beds. Bands of moderately silicified material with streaks of fluorite alternate with less silicified limestone containing disseminated fluorite. The following sequence was noted in this outcrop. The limestone at the southern end of the exposure is essentially lacking in fluorspar. Just north of it is a little more than a foot of crystalline limestone with fluorite disseminated in fine grains throughout, making up roughly 5 percent of the band. Next to this is a 2-foot, irregularly rounded mass of silicified limestone, rather uniformly impregnated with fluorite. Sample TM 27 shows that this mass contains 62.99 percent of calcium fluoride and 31.57 percent of silica. Beyond this rich band is 2.3 feet of crystalline limestone, which, as Sample TM 38 indicates, contains 3.06 percent of calcium fluoride and 14.42 percent of silica disseminated through it. Next in the sequence is a band about 0.35 of a foot wide, in which fluorite and quartz crystals are irregularly distributed. This band is a little richer than the one represented by Sample TM 38. Parts of it may contain 10 percent of calcium fluoride. Beyond it is about 1.4 feet of essentially barren limestone. The next zone, 0.67 foot wide, has bands of fluorspar up to a quarter of an inch wide rather closely spaced. Sample TM 39 yielded 17.09 percent of calcium fluoride and 29.72 percent of silica. This banded zone is adjoined by 1.37 feet of limestone with tiny grains of fluorite very sparsely disseminated. Beyond this is an irregular mass 3 inches in diameter rather thoroughly impregnated with fluorite, adjoining a 6-inch zone of finely disseminated material at the north end of the exposure.

Sample No. 6, reported by Scholz, is made up of material from the outcrop just described and loose pieces of fluorspar picked up nearby. This sample, which weighed 120 pounds, was used by the Federal Bureau of Mines for metallurgical tests. It evidently consisted of the more thoroughly mineralized material as it yielded 58.6 percent of calcium fluoride, 24.4 percent of silica, and only 7.95 percent of calcium carbonate. The description just given indicates that in a zone 10 to 11 feet wide across the beds and the deposit there is a band only about 2 feet wide within which fluorspar of a grade comparable to the analysis just cited could be obtained. Exposures on either side of the outcrop described are so poor that it is impossible to determine how far the different bands extend along the strike. Loose blocks of fluorspar are fairly plentiful on the hillside above the outcrop; part of them have come down from near the ridge crest. With due allowance for float from above, it seems probable that there are separate fluorspar bodies from the Fluorite No. 1 location monument to the ridge top in the limestone, close to the syenite boundary.

The next outcrops upslope from the location monument of Fluorite No. 1 claim are on the southeast side of the ridge crest in the area shown in plate 22. Throughout most of this area the cover of hillwash and soil is thin, and several of the fluorspar bands have been partly exposed by prospectors. Plate 22 shows that the fluorspar in the area mapped is confined to the irregular zone of recrystallized limestone on the north side of a tongue of syenite projecting from the main mass. The most extensive of the fluorspar deposits are along the ill-defined boundary between altered and fresh limestone. If the bedrock were scraped clean, the fluorspar bands would be somewhat more continuous than is shown on plate 22, but it is believed that the general pattern of irregular and discontinuous fluorspar bodies not over a foot wide would remain. Most of the bodies mapped are definitely banded and occupy parts of the limestone sheared parallel to the bedding. The quartz also present in these shear zones adds to the resistance to weathering. There are probably zones of comparatively unsilicified limestone concealed under detritus that contain disseminated fluorite, but most of them are likely to be of too low grade to add much to the ore reserves.

The fluorspar body near the northeast corner of the mapped area shown on plate 22 is the largest exposed within that area and is an almost structureless impregnation of the limestone. The limestone mapped on plate 22 as unmetamorphosed is so only in comparison with the more thoroughly modified material south of it. Spots of yellow, rather coarsely crystalline limestone are included, and in several places limestone otherwise scarcely altered is faintly sheared and contains added quartz.

The tenor of the better fluorspar ore in the area of plate 22 is shown by samples Scholz Nos. 3, 4, and 5 and samples TM 5, TM 70, and TM 71, cut in 1944. This area is close to the east end of the patented Malvina claim (see pl. 19), and sample Scholz No. 5 probably came from essentially the same place as sample TM 5. The precise sources of his samples 3 and 4 are not known and so are not plotted on plate 22, but they probably came from near the spots where samples TM 70 and TM 71 were cut. All three of Scholz's samples yielded somewhat more calcium fluoride and less silica than those obtained during the present investigation. Together the six samples indicate that the area shown in plate 22 contains fluorspar bodies whose tenor ranges from a little less than 40 to over 50 percent of calcium fluoride and from a little more than 20 to over 35 percent of silica. Sample TM 71 yielded the only barite so far reported in analyses from the Tootsie Creek deposits, although barite is known to be present in other exposures here.

The slope of Tootsie Creek valley northwest of the area of plate 22 is covered by a dense grove of small trees beneath which exposures of bedrock are poor. Fluorspar bodies similar to those mapped in plate 22, however, extend 100 feet beyond the northwestern border of that map, and it would not be surprising to find that they extend down the slope to the pit where sample TM 3 was obtained, a distance of about 400 feet. Sample TM 3 comes from a vertical cut 1.3 feet long on the south side of an irregular mass which shows no visible bedding or shear planes. It yielded 28.87 percent of calcium fluoride and 43.83 percent of silica, which is a lower tenor than its appearance suggests. The pit is probably one of those opened during the early prospecting for gold, but the sample contains only traces of the precious metals.

The promontory near the center of the area shown on plate 20, called the Chimneys because of chimneylike solution cavities in it, has disseminated fluorite in several spots but no visible fluorspar bodies of commercial size or grade. The early prospectors explored some rusty quartz here by a pit or shallow shaft, now caved. A grab sample (TM 35) was obtained from a small recent pit about 150 feet uphill from this pit. This sample yielded 55.39 percent of calcium fluoride and only 21.98 percent of silica, but the quantity is probably small. Barite crystals are conspicuous in geodes in this sample, but barium sulfate was not reported in the analysis.

A little fluorspar in rusty limestone is exposed on the north side of Tootsie Creek close to the fork of that stream. Nearby is a loose boulder of comparatively rich fluorspar ore. Probably this boulder is the one from which Scholz obtained his sample No. 2 (see table, p. 197), although it has probably been broken up somewhat, as he estimated that it represented a mineralized zone 3 feet wide. Sample Scholz No. 2 is the richest in calcium fluoride on record from the region. It yielded 87.01 percent of calcium fluoride and only 7.2 percent of silica.

On the north side of Tootsie Creek in the altered limestone near the syenite contact fluorspar is present at intervals through a vertical range of over 650 feet and a horizontal distance of over 650 feet. Overburden is probably not thick enough to conceal large fluorspar bodies, so the scarcity of exposures of fluorspar recorded on plate 20 is not encouraging. The best exposure is in the pit or shallow caved shaft termed the Malvina pit; it is close to the west end-line of the Malvina claim. A general view of this pit is shown in the foreground of plate 21*A*. The pile of fluorspar at the right of the pit in this view constitutes the largest amount of this material so far mined in the Sweetgrass Hills. As exposed in the pit, the fluorspar forms conspicuously irregular bodies in recrystallized limestone which is more thoroughly brecciated than in most of the other exposures in the area. Sample TM 1 was taken from a horizontal channel 20 inches long in a nearby flat-lying irregular breccia zone. The analysis (table, p. 197) shows 39.87 percent of calcium fluoride and 1.68 percent of silica. Sample TM 28 came from a channel 2.75 feet long, cut approximately parallel to the beding in the side of the same pit but a yard northwest of sample TM 1, and in less brecciated rock. The analysis shows 76.42 percent of calcium fluoride and 1.75 percent of silica—the highest tenor yet recorded from the Tootsie Creek area with the exception of the loose boulder that Scholz sampled near the creek bank.

PROSPECTS ON UPPER TOOTSIE CREEK

The only fluorspar exposures on upper Tootsie Creek that seem to warrant description are those about a quarter of a mile southwest of and above the forks of Tootsie Creek; they are shown on plate 21. Here, on a small bench on the west side of the stream, a vertical pit has exposed a breccia of igneous rock, most of which resembles the green porphyritic rock in the hybrid metamorphic material prominent on the margins of the syenite body in the vicinity of the Brown Eyed Queen mine. This rock contains disseminated pyrite and calcite. The syenite nearby contains bodies of coarse, dark-green hornblende. An irregular cut in the stream bank on the east slope of the creek valley has exposed another zone of breccia which includes a vein of fluorspar that strikes N. 50° E. and dips 72° NW. The breccia consists of rusty syenite with included blocks of coarsely recrystallized limestone. The fluorspar vein has a width of 7 inches on the north side of the cut where sample TM 44 was obtained, and a width of a foot on the other side where sample TM 45 was taken. The two samples yielded 40.56 and 39.73 percent of calcium fluoride and 57.18 and 56.57 percent of silica, respectively, and have an average carbonate content of only about 1 percent, although calcite is fairly plentiful in the vein. Geodes lined with small quartz crystals are common, and limonite derived from the oxidation of pyrite is abundant. The vein is exposed for several feet and probably extends under the overburden along the creek bank.

DEPOSITS OF METALLIC MINERALS

The lodes in East Butte that contain metallic minerals are grouped around the borders of the syenite of Mount Royal, mostly in the patented claims shown on plate 19. Lodes in Middle and West Buttes are not sufficiently well known to warrant description here.

MAGNETITE DEPOSITS

The principal iron deposits are on the M and M and Mountain Chief claims; although iron minerals occur also on the Malvina claim. The claims were patented in 1896, and they have been worked intermittently since then. Probably no iron ore was ever shipped, but there may have been a little gold obtained from the Malvina claim, where the principal fluorspar shoots are. All the underground workings are short, but were not safely accessible in 1944.

Most of the iron deposits are in or close to xenoliths or roof pendants of Madison limestone; some are in fracture zones in the syenite. Magnetite and specularite form aggregates in the deposits in limestone. Ledoux [39] reports an assay of 60 percent of iron with a little phosphorus for material from a 54-foot shaft with a cut extending from it for 40 feet, all in ore. The gangue minerals in limestone include calcite, diopside, wollastonite, pale-green mica, and quartz. Pyrite and chalcopyrite are present in all of the iron deposits but are most abundant in the fracture zones in syenite, where quartz is the principal gangue mineral; calcite, biotite, and chlorite are also present.

SULFIDE DEPOSITS

The Brown Eyed Queen mine, with its six patented claims, is a mile southwest of Mount Royal (see pl. 19). A small amount of rich copper ore is reported to have been shipped from here late in the nineteenth century and in the thirties of the present century. The

[39] Ledoux, A. R., Notes on the Sweetgrass Hills of Montana and the Kootenai mines of British Columbia: New York Acad. Sci., Trans. vol. 10, No. 1, p. 60, 1891.

workings consist of a shaft, presumably less than 50 feet deep, with cuts leading from it to the south, east, and west. The most distinct of the visible vein walls strike N. 75° E. and stand nearly vertical. Small ore piles nearby contain bornite irregularly distributed through a gangue of fine-grained quartz with some calcite.

The Gagnon prospect on Ribbon Gulch has a tunnel about 15 feet deep on the east side of the stream, and several cuts nearby. According to local report a little ore has been shipped. There are several fracture zones of diverse trends; some of them contain stringers of galena and small amounts of other minerals.

There are scattered prospect holes in other places along Ribbon Gulch and also near Halfbreed Creek. Of them only the prospects containing fluorite have been mentioned. Some of those in the hybrid metamorphic rock were sunk on stringers of coarse, glistening, smoky quartz with little sulfide. Pits in somewhat metamorphosed limestone near Ribbon Gulch do not disclose a lode of any kind.

PLACER DEPOSITS

Prospecting for placer gold was widespread in East Butte near the turn of the century. The total gold production was small, and there has been little activity for a long time. Apparently the principal placer mining was done in No. 1 placer claims on Tootsie Creek, but some was done on Halfbreed, Sage, and other creeks and, according to Ledoux,[40] on the south slopes of East Butte also. The distribution of the workings suggests that the placer gold of East Butte may have been derived in part from the fluorspar lodes.

SUMMARY

The summaries of available information about the mineral resources of the Sweetgrass Hills suggest that the minerals will be of interest in times of especially keen demand, or, particularly in regard to the gold and copper deposits, in times of especially slack demand for labor elsewhere. Under the economic conditions existing in 1943 and 1944, the fluorspar deposits were the only deposits that might be of commercial interest in the near future. Fluorspar is now known to be distributed rather widely in East Butte, and intensive prospecting for it would doubtless disclose occurrences not yet discovered. Search for fluorspar in the other buttes has been less thorough than in East Butte, but it is doubtful that any deposits of commercial value crop out on them.

Most of the fluorspar occurrences in East Butte appear to be small, and the group that has been referred to above as the Tootsie Creek deposits is the only one that, on the basis of present knowledge, offers

[40] Ledoux, A. R., op. cit., p. 59.

encouragement for further exploration. The mineralized zone in which the Tootsie Creek deposits lie is impressively large, and exposures of fluorspar within it are widespread and numerous. From this locality only 4 of the 22 samples for which records are available contain much less than 40 percent of calcium fluoride, but the high content of silica in many of the samples is very deleterious. Probably all the material represented by the other 18 samples and similar material from exposures not sampled are susceptible of concentration in a flotation mill into a product of metallurgical grade, although only 9 of the samples have a tenor in excess of 50 percent of calcium fluoride. The fine grinding necessary to accomplish this, however, would result in a fluorspar product not now favored by steel producers. As fluorspar mining is at present not in operation in the vicinity, difficulty should be anticipated in establishing a new industry unless the market price of fluorspar advances substantially. All equipment and skilled labor would have to be brought in from a considerable distance, necessitating improvement of the present road from the Great Northern Railway at Chester, and construction of nearly 3 miles of new road from the place where the county road crosses Tootsie Creek to the mining property.

Difficulties such as those mentioned above can be overcome if market prices are adequate and the deposits prove capable of sustained production for a sufficient period for amortization. From this viewpoint the individual fluorspar shoots now known are not so large as could be desired. Some fluorspar zones are 8 to 10 feet wide, but they include low-grade bands. Few of the exposures contain fluorspar with a tenor in excess of 40 percent of CaF_2 over uninterrupted widths of more than a foot, and known lengths along the strike are likewise small. In considering these facts it must be remembered that exploration has not been very extensive. Anyone interested in further development of the Tootsie Creek deposits would do well to make bulldozer cuts over the part of the area shown in plate 22 and along the slope from there to the vicinity of the location monument on Fluorite No. 1 claim (see pl. 20). If encouraging results were obtained, similar exploration within the mineralized zone to the west would be warranted.

SPAR PROSPECT, MINERAL COUNTY

The Spar prospect is near the southwest corner of T. 17 N., R. 27 W., in the Lolo National Forest, and about 12 miles by graded unpaved road from Superior, the county seat (see fig. 7). This prospect was visited August 12 to 15, 1944, and again September 11 to 14, 1944, by C. P. Ross and W. C. Reimund. Information obtained during a plane-table survey of the prospect and a rapid reconnaissance of the surrounding area is summarized below. Plate 23 shows all development work done up to September 14, 1944.

The approximate shape and location of the Spar property, based on data furnished by Joseph J. Brooks, the manager, are shown on the map of part of Mineral County, Mont. (see fig. 7). As the claims have not yet been surveyed, no claim map is available.

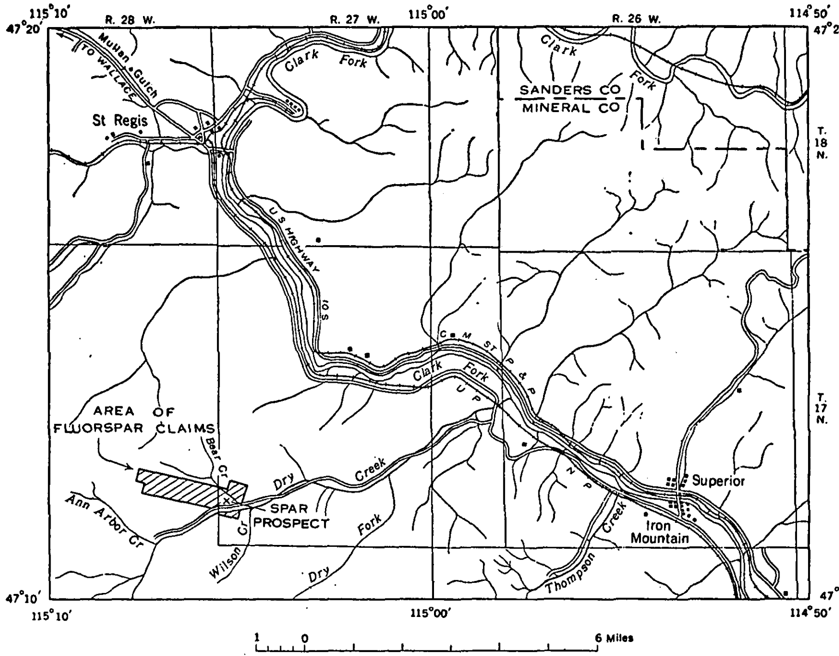


FIGURE 7.—Map of part of northeastern Mineral County, Montana, showing approximate location of the Spar fluorspar prospect.

HISTORY

Prospecting has been carried on in Mineral County for many years, and a number of lode and placer mines have been opened.[41] Some of these mines are only a few miles south of the area here considered, and others are beyond Clark Fork, the principal river in the county. Comparatively little prospecting has been done in the vicinity of the Spar property, reportedly because panning for gold along Dry Creek did not yield encouraging results.

Fluorspar prospecting in the area began with the staking of the Spar claim on June 3, 1943, by Joseph Brooks. A location notice close to that of Brooks indicates that on June 2, 1943, the ground was located as the Fat Chance claim by F. R. Lanum, Si Cornett, and

[41] Directory of Montana mining properties: compiled by Works Projects Administration Mineral Resources Survey, Carl J. Trauerman, Supervisor, Cecil R. Waldrodon, Asst. Supervisor, in cooperation with the Mining Assoc. of Montana: Montana Bureau of Mines and Geology Memoir no. 20, pp. 80–81, 1940.

Thomas Day, but Mr. Brooks states that he and his associates have purchased those rights. When the writer visited the property in August 1944, Joseph Brooks, associated with C. W. Brass and F. E. Scott, all three of Wallace, Idaho, had formed the Spar Mining Co. and started work. A pit was being sunk near the northwestern end of an outcrop of vein quartz on the point of the spur between Bear and Dry Creeks. A trench about 10 feet long was near the pit. A bench had been cut at the foot of the spur to serve as a portal site for a proposed crosscut tunnel, and a road to connect this place with the pit had been started.

Between August 15 and September 11 the property was taken over by the Coeur d'Alene Extension Mines, Inc., of Wallace, Idaho. The acquisition of the Spar prospect by this company is reported to have been for purposes of financing the fluorspar enterprise; control is said to remain essentially in the hands of Messrs. Brooks, Brass, and Scott.

The six claims that had been located prior to August 1944 were increased to twenty soon after the Coeur d'Alene Extension Mines took over, and it is understood that several additional claims at the eastern end of the group have been staked since. The original Spar claim, at the southeastern corner of the group of twenty claims, is the only one on which fluorspar has been found. A little fluorspar, however, is reported to have been found a short distance north of the company's property. So little work had been done at the latter place up to September 1944 that it was not certain whether the quartz mass from which the fluorspar is reported to have come is in place or is a transported boulder.

In mid-September the road up to the pit on the Spar claim had been finished, the border of the pit had been leveled off by a bulldozer, and the first set of timbers for a proposed shaft was in position in the pit. At that time work was being concentrated on the erection of a building to house the compressor, in order that the tunnel could be driven far enough that snow would not prevent mining during the winter. When Wayne Lowell, of the University of Montana, visited the mine later in 1944, the principal known pod of fluorspar had been mined out. The tunnel had been driven and had encountered a brecciated quartz zone containing small pods and stringers of siderite but not fluorite. Very little work has been done at the prospect since then.

GENERAL GEOLOGY

The rocks in the general vicinity of the Spar prospect consist of a very thick sequence of dominantly light-colored quartzite and argillaceous beds. Many are calcareous, and some are fairly pure dolomite and ferruginous limestone. Some of the rocks, especially those containing carbonate minerals, weather brown or red. Many of them show variations in color on fresh fractures which correspond to raised, rusty masses on weathered surfaces. Most of the masses resemble "segregation structures" in similar rocks in Glacier National Park.[42]

An unpublished geologic map of western Montana [43] shows the area as underlain by the Newland formation of the Belt series. Comparison of the characteristics of the rocks with descriptions of the Belt units in other regions, combined with oral discussion of Belt stratigraphy with E. S. Perry and L. L. Sloss of the Montana Bureau of Mines and Geology, led to a tentative acceptance of this correlation, although the rocks here described have a larger proportion of quartzitic material than their supposed equivalents in other regions. The Newland formation as used on the map cited corresponds, at least in part, to the Wallace formation of the Belt series in the Coeur d'Alene region of Idaho.[44] On the basis of data gathered and conclusions reached by Russell Gibson and his associates on areas northwest of the area here described,[45] it seems best tentatively to classify the rocks at and near the Spar prospect as belonging to the Wallace formation and hence to be of pre-Cambrian age.

The beds of the Wallace (?) formation along the valley of Dry Creek have undergone moderately intense and somewhat irregular folding. In a few places the beds are contorted and closely folded. Near the Spar prospect most of the rocks strike northwest (see pl. 23), but there is much variation in both strike and dip. This irregularity in attitude may have resulted partly from disturbances that have so fractured the rocks as locally to produce steep sheeted zones and areas of intense brecciation, as indicated on plate 23. Plate 24*A* shows one of these brecciated areas, and plate 25 shows the somewhat ill-defined sheeting in the vein quartz of the Spar prospect.

In many places the Wallace (?) formation is cut by conspicuous, irregularly lenticular bodies of milky-white vein quartz, at least one of which contains fluorite (see pl. 24*B*). In addition the breccia zones mentioned above are cut by ill-defined veinlets of quartz, most of them containing siderite. These veinlets in places constitute the

[42] Fenton, C. L., and Fenton, M. A., Belt series of the north: stratigraphy, sedimentation, paleontology: Geol. Soc. America Bull., vol. 48, pp. 1925–1929, 1937.

[43] Lambert, G. S., Preliminary geologic map of western Montana: Montana Bur. Mines and Geology, compiled 1924.

[44] Clapp, C. H., and Deiss, C. F., Correlation of Montana Algonkian formations: Geol. Soc America Bull., vol. 42, p. 693, 1931. Clapp, C. H., Geology of a portion of the Rocky Mountains of northwestern Montana: Montana Bur. Mines and Geology Mem. no. 4, pp. 17–22, 1932.

[45] Gibson, Russell, Jenks, W. F., and Campbell, Ian, Stratigraphy of the Belt series in Libby and Trout Creek Quadrangles, northwestern Montana and northern Idaho; Geol. Soc. America Bull., vol. 52, pp. 363–380, 1941. Gibson, Russell, Geology and ore deposits of the Libby quadrangle, Montana: U. S. Geol. Survey Bull. in preparation, 1946.

principal cement in the breccias. A little siderite is visible here and there in the larger quartz lenses. Very small quantities of sulfides, probably mainly pyrite and galena, occur in the vein quartz.

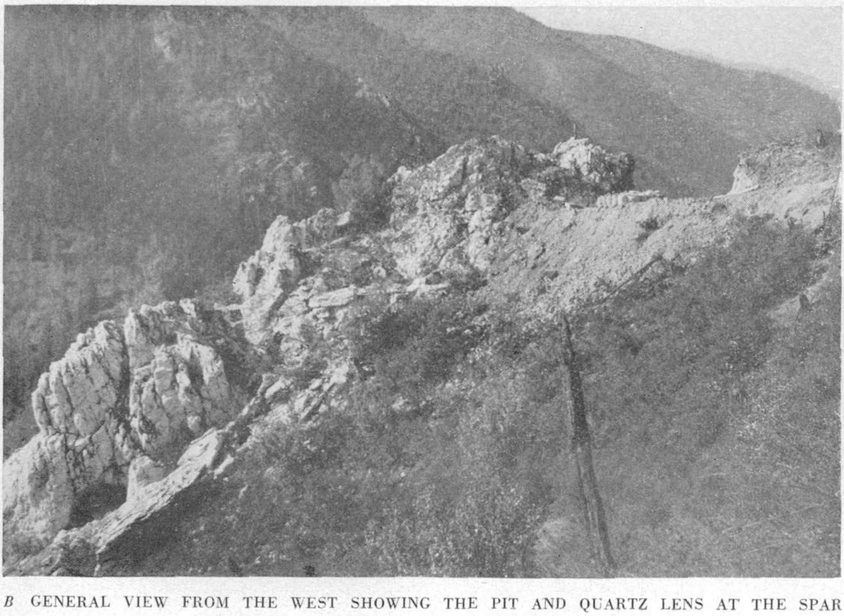
In the area between Ann Arbor and Bear Creeks, few individual quartz lenses greatly exceed 100 feet in length, but in some places several such masses crop out at intervals along a nearly straight line. The trends of the lenses are widely varied and have no obvious relation to the trends of the quartzite beds which they cut. Most of the larger lenses trend from N. 70° E. to S. 70° E. Like the sedimentary rocks, the quartz lenses are much jointed, and are cut locally by closely spaced steep fractures which generally trend northwest. With the exception of the unconsolidated alluvial deposits along streamways, no other rocks are exposed in this area.

FLUORSPAR PROSPECT

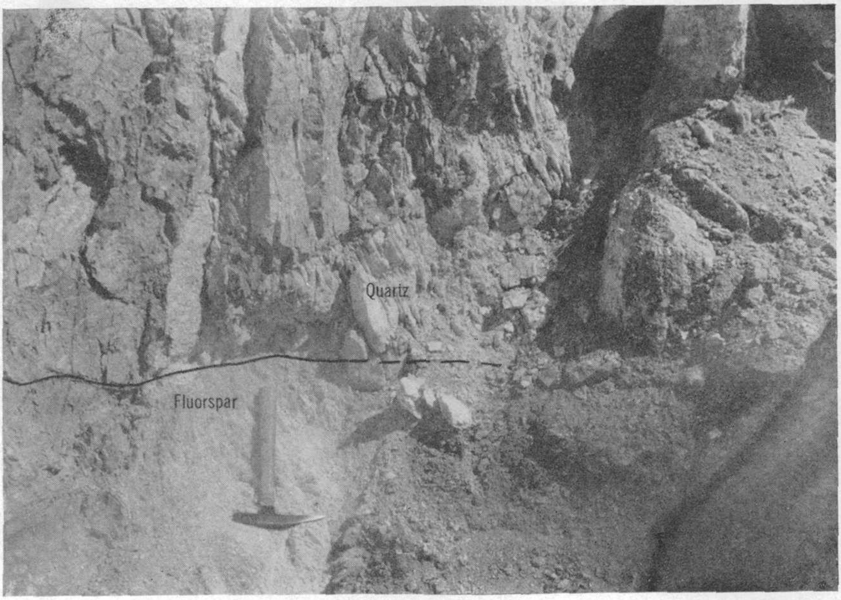
The only fluorspar body of economic interest so far discovered is that in the large pit on the point of the spur between Bear and Dry Creeks. Both this body and the smaller mass in a trench 20 feet northwest of the pit are mainly in milky-white vein quartz, but in the lower part of the pit the fluorspar has spread into the quartzite that borders the quartz mass. When the writer saw it in August 1944, the irregular pit was 6 to 7 feet in diameter at the top and roughly 4 feet deep. The floor was in coarsely crystalline, nearly colorless fluorite. A sample cut across this body for a distance of 45 inches was analyzed by Norman Davidson of the U. S. Geological Survey, who reports that it contains 98.57 percent of calcium fluoride, 1.18 percent of silica, and 0.14 percent of carbonate. This analysis is said to be similar to those obtained by the Bureau of Mines and by others who have sampled this prospect. The face sampled was crossed by a few steep fractures stained with limonite, but otherwise was fluorite. The vein quartz forming the walls of the pit contained fluorite streaks. Neither these streaks nor the larger mass in the lower part of the pit were clearly defined, but their dominant trend is about N. 30° W., although the main body of vein quartz at this place strikes more nearly N. 80° W. Mr. Brooks found a little galena near the bottom of the hole.

When the writer revisited it in September 1944, the pit had been deepened enough to accommodate the first set of timber for a shaft. The pit averaged nearly 12 feet in diameter at the rim, which was probably only a little above the place that had been the bottom of the pit in August. The shaft set was about 6 feet in each of its three dimensions, and its top was about level with the rim of the pit. The timber rested entirely on fluorspar, which extended a foot or more on all sides outside the borders of the set. The fluorspar body has been found to widen downward and to extend into the quartzite on its

A BRECCIATED AREA IN BEDS OF THE WALLACE (?) FORMATION BELOW THE PIT ON THE SPAR FLUORSPAR PROSPECT.

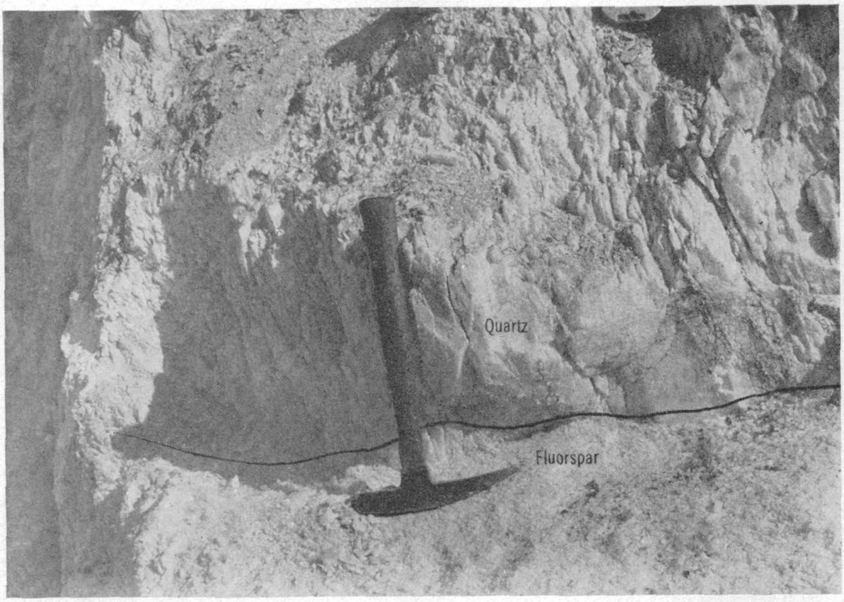


B GENERAL VIEW FROM THE WEST SHOWING THE PIT AND QUARTZ LENS AT THE SPAR FLUORSPAR PROSPECT.



A THE NORTHEAST WALL OF THE PIT, AUG. 12, 1944.

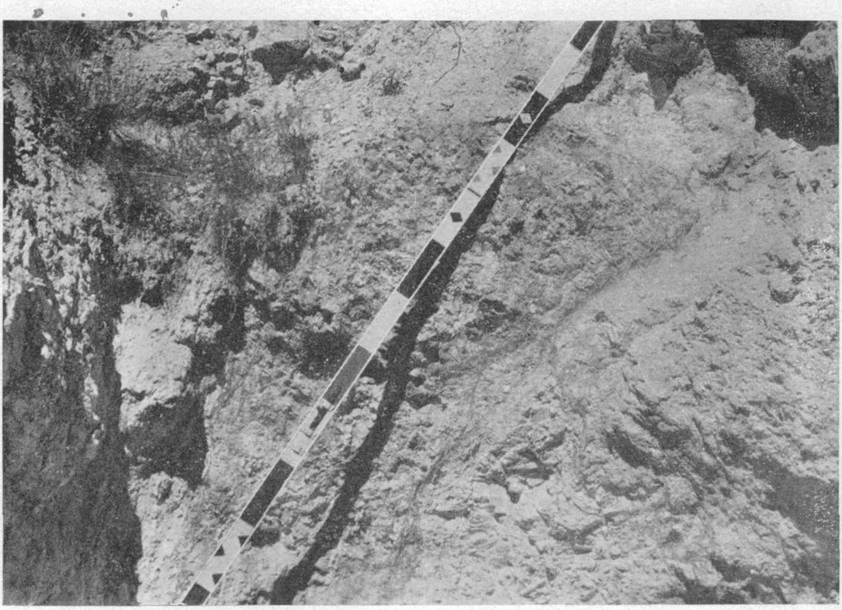
The light-colored material against which the hammer rests is fluorspar which terminates upward against quartz.



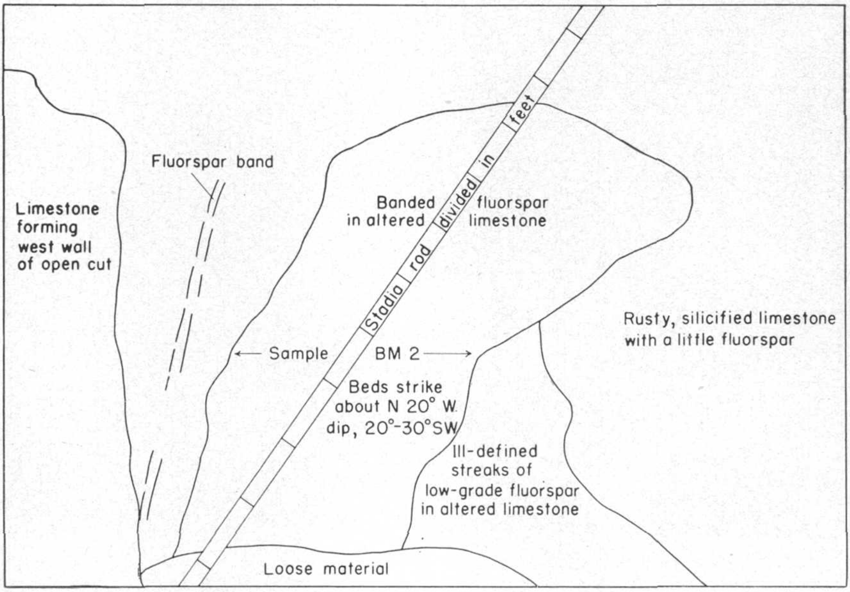
B A DETAIL OF THE PIT WALL, SEPT. 11, 1944.

The hammer head rests on the upper contact of the fluorspar; the handle is against quartz.

VIEWS OF THE SPAR FLUORSPAR PROSPECT.



A VIEW OF THE PRINCIPAL FLUORSPAR EXPOSURE IN THE BOEING OPEN PIT.



B EXPLANATORY SKETCH OF *A*.

A

B

CLOSE VIEWS OF THE MINERALIZED BRECCIA AT THE PROSPECT NEAR THE ANACONDA SMELTER.

Dark areas are mostly fluorspar.

northern side. At the shaft site the top of the fluorspar mass dips about 30° N. The irregularly shaped fluorspar body in the east wall of the pit lies south of the southeast corner of a shaft that was sunk after the writer's first visit (fig. 8). About 40 sacks of ore, estimated

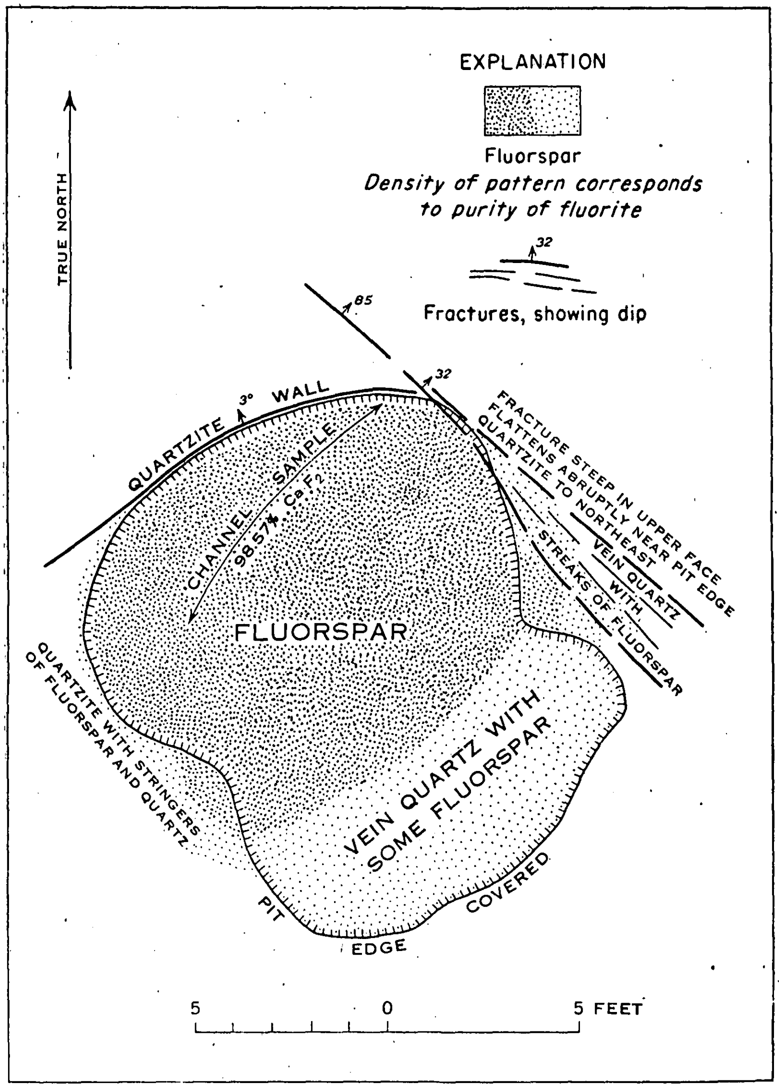


Figure 8.—Sketch of the fluorspar body in the pit at the Spar prospect.

by Mr. Brooks to contain a total of 5 tons of selected fluospar, was obtained in the excavation for the shaft timbers and was stacked for shipment. The trench about 20 feet west of the pit is 10 feet long. In it is exposed a 3-inch seam of purple fluorspar which strikes N. 10°

W. and dips 30° NE. Some of the fluorspar in the pit was faintly purple.

Although the evidence is meager, probably the fluorspar was formed later than the vein quartz and replaced it. It was guided, to some extent at least, by sheeted zones, illustrated in plate 25, that trend N. 20° to 40° W., and cut both the vein quartz and the enclosing sedimentary rocks. The fluorspar bodies thus may be transverse to the quartz lens and may extend into its walls.

The Spar prospect constitutes a new locality for fluorspar in Montana. The high quality of the product commands attention, but the only promising fluorspar body found so far was soon mined out. If further exploration is contemplated, it might be well to test the ground by diamond drilling, possibly from the bench prepared for a tunnel site (see pl. 23). The first holes should explore the area directly beneath the pit; others should explore the area under the small quartz veins on the nose about 300 feet northeast of the pit, and a third series should test the ground under the ridge nose. This last series of holes, especially if extended somewhat west of the ridge nose, should yield information as to the possible presence of fluorspar along the sheeted zones in the sedimentary rocks. The rocks to be penetrated are moderately hard but are so jointed and sheeted that difficulty might be experienced in obtaining continuous drill core. The tunnel planned in 1944 would have to be nearly 550 feet long in order to reach a point directly under the pit. If sufficient fluorspar is present the tunnel would be conveniently situated for use in mining the ground above it, but extensive crosscuts and raises would be required to yield complete information. The suggestions here given do not take into account any exploration that may have been carried out since September, 1944.

BOEING PROSPECT, LEWIS AND CLARK COUNTY

LOCATION

The Boeing prospect (see fig. 6) is about 3.5 miles west of Austin, Lewis and Clark County, along a gravelled road which leaves U. S. Highway No. 10 a short distance west of Helena and rejoins that highway several miles beyond the prospect. The Northern Pacific Railway and a high-pressure natural gas line belonging to the Montana Power Co. are close to the property. The prospect was visited in the summer of 1943 by Scholz and on August 11, 1944, by Ross and Reimund. Little mining appears to have been done in the interval between the two visits.

GENERAL GEOLOGY

The Boeing prospect is in the Austin mining district, which is best known for placer deposits but includes a number of lode deposits.[46] It is in limestone and a felsitic dike that cuts the limestone (see fig. 9). According to Pardee and Schrader's geologic map, the limestone belongs to the Madison limestone (Mississippian); its con-

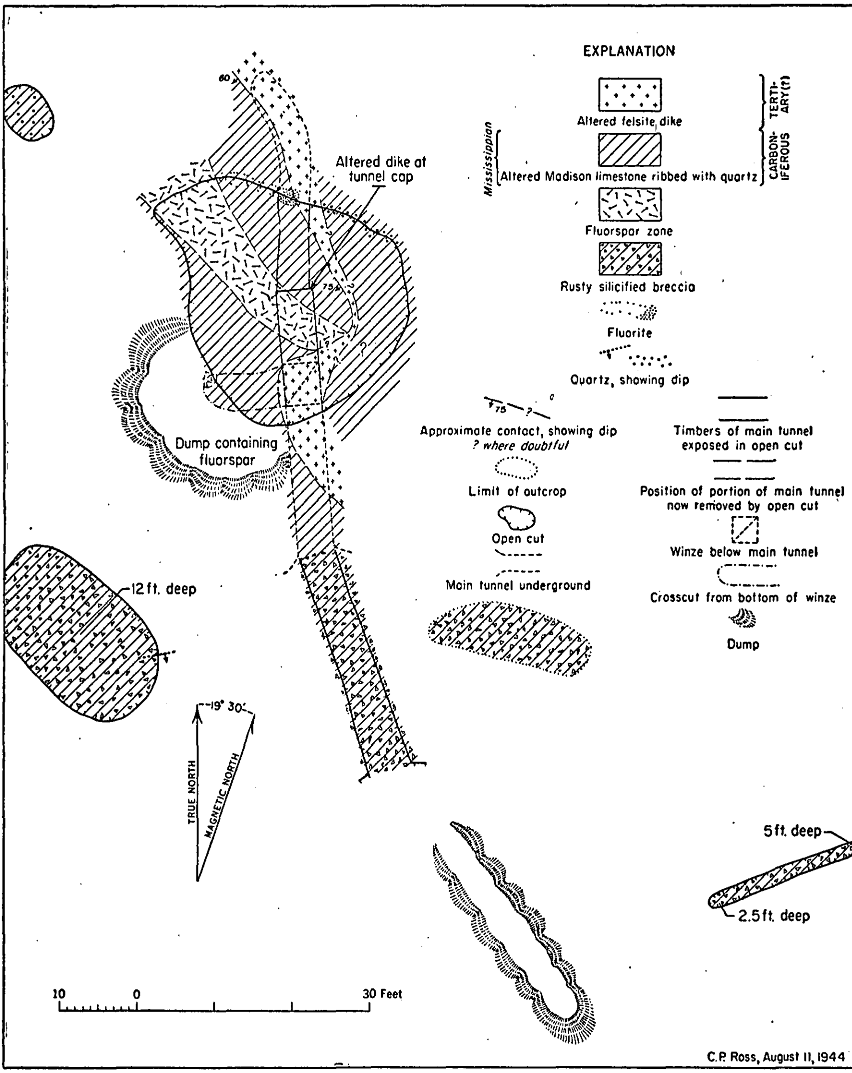


FIGURE 9.—Map of the Boeing fluorspar prospect, Lewis and Clark County, Montana.

tact with a quartz monzonite stock is only a short distance south of the prospect. Both the limestone and the felsite are highly mineralized. The dike rock is so thoroughly changed to clay that much of the original texture is nearly obliterated. According to a determination made by Victor T. Allen of the Geological Survey for Edgar A. Scholz,

[46] Pardee, J. T., and Schrader, F. C., Metalliferous deposits of the Greater Helena mining region, Mont.: U. S. Geol. Survey Bull. 842, pp. 59–62, pl. 2, 1933.

the dike is biotite rhyolite altered to montmorillonite. Apparently the dike is narrow and very irregular. Its footwall is not sufficiently exposed in the present workings to be traced accurately.

FLUORSPAR PROSPECT

At the time of the writer's visit in 1944 the workings on the Boeing fluorspar deposit included a tunnel over 60 feet long, broken near its northern end by an open pit (see fig. 9). A winze 16 feet deep has been sunk in the floor of the tunnel. A crosscut extends about 10 feet west from the bottom of the winze. Pits and trenches in the vicinity of these workings appear to contain almost no fluorspar. Scholz noted a little fluorspar in the altered dike rock 60 feet southeast of the tunnel dump. In the main workings fluorite is disseminated in irregular masses in those parts of the limestone in which silicification has not been intense. The principal exposure is in the northwest corner of the open pit where banded fluorspar that strikes N. 20° W., and dips 70° to 80° SW., is exposed in the steep face, pictured in plate 26, over an area about 3 feet wide in its lower part, nearly 6 feet wide near the top, and a little more than 7 feet in maximum height. The lower part of this face is covered by slide material which may conceal some fluorspar. One narrow band with conspicuous fluorite is visible west of the main area, and some fluorite is disseminated in the limestone between that area and the dike to the east. A small quantity of fluorite has formed within the dike rock also. Fluorite is fairly plentiful in the southeastern wall of the open cut just northeast of the winze. Probably a zone containing fluorite in abundance extends from this place diagonally across the open pit to the face previously described (as indicated by dashed lines in figure 9). Fluorspar is exposed also in the northwest corner of the crosscut from the bottom of the winze.

If, as seems probable, the fluorspar exposures in the pit and near the bottom of the winze are connected, there is an irregular body of fluorspar 2 to nearly 6 feet wide. Such a body is exposed for nearly 30 feet in length near the surface of the ground and decreases in size below. At the lowest place, which is about 25 feet below the surface, the maximum dimension is about 2 feet. This body may extend somewhat beyond the 1944 workings both in depth and in width. The part of the fluorspar body that originally extended across the open pit has been mined and was on the dump at the time of visit. The shape of the deposit is evidently similar to that of metalliferous deposits found elsewhere in the Austin district. They are described[47] as irregular pockets or pipelike bodies in limestone, which contain iron oxides and small amounts of lead and copper sulfides, with their oxidation prod-

[47] Pardee, J. T., and Schrader, F. C., op. cit., pp. 59–62, 1933.

ucts. The lodes have been mined mainly for their gold and silver content. None except the one here described has been reported to contain fluorspar.

Scholz in 1943 took a sample across a width of 3 feet in the northwestern face of the pit, which yielded 55.04 percent of calcium fluoride and 14.0 percent of silica. In the following year Ross cut a sample across a width of 41 inches in the same face as that sampled by Scholz, which yielded 81.76 percent of calcium fluoride, 10.09 percent of silica and 2.52 percent of carbonates, and another across a width of 24 inches in the crosscut from the winze which yielded 60.37 percent of calcium fluoride, 12.88 percent of silica, and 7.72 percent of carbonates. The analyses of the samples cut by Ross were made by Norman Davidson of the Geological Survey.

FLUORSPAR PROSPECT NEAR ANACONDA, DEER LODGE COUNTY

A deposit of fluorspar on the "weather vane" hill back of the smelter of the Anaconda Copper Mining Co., Anaconda, Mont., has been known to officials of the company for a long time. It was visited on September 21, 1944, by the writer, guided by an Anaconda engineer.

The deposit is a highly irregular shattered and mineralized zone several hundred feet long in limestone of Paleozoic age. It is bleached nearly white in the shattered zone but is almost black in fresh exposures. The fractures and irregular openings in the shattered limestone are lined with chert and fluorite. Much of the fluorite is in well-formed crystals lining vugs, and high-grade specimens are readily obtainable. Plate 27 shows the character of the more richly mineralized outcrops. 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 two 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 (percent)
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 a small profit during a period of high price for fluorspar.

SILVER BOW PROSPECT, SILVER BOW COUNTY

The Silver Bow fluorspar prospect is 6 miles west of Butte in the valley of Silver Bow Creek (see fig. 6), a small, sluggish, silt-laden stream, and is along the boundary between T. 3 N., R. 9 W., and T. 3 N., R. 8 W. The principal exploration for fluorspar up to 1944 was in sec. 13, T. 3 N., R. 9 W., in a group of five patented claims called the Eva, Superior, Delia, Bull Moose, and Little Jack. Plate 28 shows the approximate locations of parts of three of the claims named and also two adjacent claims patented by the Silver Bow Copper Co., whose property includes a large area northeast of the Silver Bow prospect. The hill just south of the stream also contains fluorspar; the Wrong Font claim was located there on June 1, 1944, by Thomas J. Helehan of Butte, who also represents the family group that holds a half interest in the five patented claims north of the stream. The other half interest is reported to be held by a group headed by John Clark of Hollywood, Calif.

The prospect is half a mile east of the Silver Bow railroad station. U. S. Highway No. 10S and three sets of railroad tracks traverse the property. Two sets of tracks are used by the Chicago, Milwaukee, St. Paul and Pacific Railroad and the Butte, Anaconda and Pacific Railway. The other set of tracks is used by the Union Pacific Railroad and the Northern Pacific Railway. Thus, the Silver Bow prospect is exceptionally well situated with respect to transportation by highway and railroad. It is not close to any plant for the benefication of fluorspar, but some of the large mineral dressing plants in the region could be modified to treat fluorspar ore.

The prospect was visited by Scholz in 1943. Ross and Reimund devoted four days in September 1944 to the preparation of the plane-table map on which plate 28 is based. The claim lines on this map are based on a General Land Office plot of their patent survey. Only one claim corner was found at the prospect and was identified by T. J. Helehan, one of the owners, who was kind enough to visit the area with C. P. Ross and point out various features of interest. Among these features were the locations of samples taken by G. M. Bennett of the United States Bureau of Mines. The analyses of these samples were made available for publication in this report with the permission of Mr. Helehan.

A geologic map of the fluorspar property and its vicinity, prepared in January 1944 by C. V. Campbell in connection with his studies at the Montana School of Mines, was of assistance in furnishing a geologic setting.

GENERAL GEOLOGY

The bedrock in the vicinity of the Silver Bow prospect is of igneous origin (see pl. 28). It consists of quartz monzonite, aplite, and andesite, and is extensively covered by hillwash and alluvium. The hillwash has been mapped only where thick enough to hide the character of the bedrock beneath.

The quartz monzonite is believed to be part of an isolated exposure of the Butte quartz monzonite, which appears to underlie the region and is covered extensively by Tertiary lake beds and lava.[48] At the Silver Bow prospect it is a moderately coarse-grained rock of granitic texture and consists essentially of 10 to 15 percent of quartz, about 10 percent of biotite, and about 75 percent of feldspar in which oligoclase-andesine is so much more plentiful than the potash feldspar that the rock approaches granodiorite in composition. The composition corresponds closely to that given by Weed for the Butte quartz monzonite, except that no hornblende has been noted near the Silver Bow prospect.

The aplite is similar to a rock widely distributed in the Butte district, commonly called aplite but also referred to as alaskite and aplite granite.[49] The contact with the quartz monzonite is poorly exposed near the fluospar prospect but may be gradational. The aplite is distinctly finer grained and somewhat lighter colored than the quartz monzonite. It contains roughly more than 60 percent of feldspar, and about 35 percent of quartz, with scattered shreds of bleached biotite and a few epidote grains. Much of the feldspar is sericitized beyond recognition. The less altered grains consist in part of microcline. The quartz monzonite and aplite are components of the Boulder batholith which, according to geologists familiar with the region,[50] is of late Cretaceous or early Tertiary age.

The andesite is a dark reddish-brown fine-grained rock which looks like lava. The rock examined during the present investigation is so full of coloring matter, largely iron oxides, and so fine-grained that it

[48] Weed, W. H., Geology and ore deposits of the Butte District, Mont.: U. S. Geol. Survey Prof. Paper 74, pp. 31–36, pl. 1, 1912; Andrews, D. A., Lambert, G. S. and Stose, G. W., Geologic map of Montana: U. S. Geol. Survey in cooperation with Montana Bur. Mines and Geology: Oil and Gas Investigations, Preliminary Map 25, sheet 2, 1945.

[49] Weed, W. H., op. cit., pp. 36–40.

Perry, E. S., The Butte mining district, Mont.: Internat. Geol. Cong., 16th Sess., 1933, Guidebook 23, Excursion C–2, p. 5, 1932.

[50] Billingsley, Paul, The Boulder batholith of Montana: Am. Inst. Min. Met. Eng. Trans., vol. 51, p. 46, 1945.

Perry, E. S., op. cit., pl. 1.

is undeterminable. Scholz [51] states that on the basis of thin-section study E. S. Perry regards it as an andesite. Scholz says that the red volcanic rock is probably early Cretaceous in age. Billingsley,[52] on the contrary, maps this rock as a member of the Tertiary volcanic rocks, and the writer believes Billingsley to be correct in his identification. The andesite is in fault contact with the quartz monzonite and aplite (see pl. 28).

FLUORSPAR DEPOSITS

MINERALOGY

The mineralogy of the fluorspar deposits on the Silver Bow property is simple. Apart from the minerals of the igneous country rocks, the only ones that have been recognized are chalcedony, quartz, fluorite, and pyrite and its oxidation products. The introduced silica minerals are all fine grained and formed mainly by replacement. In the more thoroughly fissured parts of the rock veinlets of chert-like material are fairly plentiful. Some of them are brecciated, and the fragments are coated with fluorite. Part of the silica in both replacement deposits and veins is quartz, but probably most of it is chalcedony. Fluorite is the most conspicuous of the introduced minerals, although in total volume it appears to be subordinate to silica. Most of the fluorite is moderately coarsely crystalline and ranges from colorless to deep purple. Some of the crystalline fluorite occurs as a succession of somewhat wavy bands, but most has no well-defined structure. Rarely, openings are lined with small fluorite cubes. Much of the crystalline fluorite fills openings in sheared and brecciated material, which was probably everywhere previously silicified. A small amount of nearly white earthy fluorite, in part botryoidal, coats minor fractures and cleavage faces. This variety, which seems quantitatively insignificant, may result from solution and redeposition by ground waters.

Pyrite is present only as tiny, rather widely scattered crystals, all somewhat altered. The abundance of iron stains on the rock suggests that prior to oxidation pyrite was widely, though sparsely, disseminated. It was probably most abundant in the main shear zone, but extended into silicified but little-fractured material and even into the comparatively unaltered rock beyond the silicified areas.

MODE OF OCCURRENCE

The fluorspar deposits of the Silver Bow prospect constitute shoots within a fracture zone along the contact between the andesite and rocks of the Boulder batholith. The zone, with irregularities and interruptions, strikes northwest and dips southwest, and probably on

[51] Scholz, E. A., op. cit.
[52] Billingsley, Paul, op. cit., pl. 1.

the whole is nearly vertical. The fracture zone is reported by J. T. Helehan to extend a considerable distance north of the Superior claim, but with diminishing amounts of fluorspar in the outcrops. Within the area studied, the rocks of the fracture zone have been broken by numerous subparallel fractures, locally so closely spaced as to constitute sheeted zones. In places, the rock within the fracture zone has been broken into masses of breccia. A few fractures that branch from the main zone have been mapped. Both Scholz and Campbell, in the unpublished maps referred to above, show cross faults trending north of east which are also mineralized with fluorspar. These mineralized cross faults were not found during the study made in 1944. It seems that the principal mineralized zones trend northwest approximately parallel to the border of the intrusive body, but are individually so discontinuous as to indicate that they are interrupted by cross fractures. If there are cross fractures of significant size in the area mapped (pl. 28), they may be in the area of poor exposures just north of the pit from which sample 310 was taken (see table, p. 218). This pit is one of the localities where a cross fault is plotted on the maps of Scholz and Campbell. Campbell plots several comparatively long faults, in part occupied by quartz veins at intervals for a distance of about 500 feet north of the area shown in plate 28.

The part of the main fracture zone mapped is over 2,000 feet long and locally well over 100 feet wide. The rocks of the zone have been impregnated with silica and stained with iron oxides at the surface so in places their original character is obliterated. In the southern part of sec. 18 and the northern part of sec. 19, T. 3 N., R. 8 W., the silicified zone spreads to a width of over 200 feet, although fractures are less pronounced than in the narrower parts of the zone farther north. Locally, there are narrow rusty quartz veins in the fractured zone, in silicified rock of the main zone, and in the monzonite and aplitic rocks beyond the limits of the main zones.

The fluorspar bodies are scattered through the main silicified zone. Their distribution is indicated on plate 28, but the size of the individual shoots cannot be determined with accuracy without additional excavation. The principal fluorspar exposures at the time of visit were in the eastern part of the Bull Moose claim. They were distributed through a part of the main fracture zone nearly 250 feet long and from 50 to 90 feet wide. The bands of rich fluorspar range in width from a few inches to about 3.5 feet. Scholz noted one place where fluorspar was essentially continuous for a width of 8 feet. The lengths of individual bands were not revealed by exposures existing at the time of visit. They are certainly longer than as plotted on plate 28, which shows only fluorspar actually observed. From the exposures seen, the lengths can be inferred to be of the order of tens,

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rather than hundreds of feet. Much of the material between the bands contains little or no fluorite. Taking into consideration the fluorspar exposures north of the Bull Moose claim, the zone which should be explored by anyone interested in developing a fluorspar mine here is at least 650 feet long. The detrital material along Silver Bow Creek conceals a larger segment of the mineralized fracture zone. The presence of fluorspar in at least two spots on the almost unexplored Wrong Font claim, south of the stream, together with reports of fluorspar outcrops north of the mapped area, encourages the hope that the length of the fluorspar lode may prove to be much in excess of the figures given. In the summer of 1946 a crosscut adit was started by Mr. Helehan on the Wrong Font claim, which should give information on the extent of the fluorspar there.

The table below indicates the tenor of the richer fluorspar bands. The locations of the samples—except sample No. 306, which is a sample of fluorspar float—are plotted approximately on plate 11 from information furnished by Mr. Helehan. The numbered samples were collected by G. N. Bennett of the U. S. Bureau of Mines. The one labeled Scholz was collected by E. A. Scholz, U. S. Geological Survey. The constituents grouped in the table as R_2O_3 include mainly ferric oxide and alumina.

Analyses of samples from the Silver Bow prospect

Sample number	Width of sample cut	Percent			
		CaF_2	SiO_2	R_2O_3	$CaCO_3$
306	Float	83. 11	14. 00	1. 70	1. 32
307	12 inches	90. 05	7. 36	1. 30	1. 29
308	22 inches	84. 32	12. 56	2. 03	1. 14
309	41 inches	80. 78	15. 74	2. 50	0. 89
310	30 inches	73. 03	22. 08	2. 58	2. 39
Scholz	Grab sample	91. 74	6. 5		
Arithmetical average		83. 84	13. 02	2. 02	1. 40

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 fluorspar.

MINOR OCCURRENCES

Fluorite is present in the gangue of many metalliferous lodes throughout Montana. Also, there are many places, in addition to those described in this paper, in which fluorite is the principal valuable constituent of the lode. In most localities the fluorite content of known deposits is too low, or the shoot containing it is too small, to be of commercial value now. Some of the occurrences of this kind have been visited by members of the Geological Survey during the wartime search for fluorspar, and data on others are contained in previously published reports. In very few places other than those already described has there been any attempt to mine fluorspar. The prospecting work done in the fluorspar localities has been chiefly in search for metals. In the future prospecting of any ore district where fluorite occurs, the possible presence of workable deposits of fluorspar should be borne in mind.

The Little Rocky Mountains, Phillips County, contain a number of mineral deposits. All the mines are small, and their principal product has been gold. Several of the lodes, mainly small veins in syenitic intrusive bodies in T. 25 N., R. 25 E., contain fluorite.[53] This mineral although abundant locally is of sporadic distribution and is rarely in bodies more than 2 or 3 feet in maximum dimension. Fluorite has also been noted in replacement deposits in limestone. In deposits of both types, most of the fluorite is fine grained, and much of it is intimately mixed with quartz. In the summer of 1943, E. A. Scholz visited the Little Rocky Mountains. His unpublished report mentions eight properties in which fluorite has been noted, but agrees with the impression gained from published accounts that known deposits are either so small or of such low grade that at present they are of little interest as potential sources of fluorspar.

The Judith Mountains, northeast of Lewistown, Fergus County, contain numerous veins and replacement deposits in and near T. 17 N., R. 19 E., which are valued mainly for their gold content. These deposits are mostly in the granitic and syenitic intrusive rocks and adjacent Madison limestone. Many of the lodes contain purple and pink fluorite, most of it in rather small deposits and intimately mixed

[53] Emmons, W. H., Gold deposits of the Little Rocky Mountains, Mont.: U. S. Geol. Survey Bull. 340, pp. 96–116, 1908.

Corry, A. V., Some gold deposits of Broadwater, Beaverhurst, Phillips, and Fergus Counties, Mont.: Montana Bur. Mines and Geology Mem. 10, pp. 11–16, 1933.

Dyson, J. L., Ruby Gulch gold mining district, Little Rocky Mountains, Mont.: Econ. Geology, vol. 34, pp. 201–213, 1939.

with siliceous material.[54] Scholz's unpublished report mentions six deposits containing fluorspar. In one of them the fluorspar is probably 7 feet wide, but a sample yielded only 35 percent of calcium fluoride and 61 percent of silica.

Scholz records a fluorspar prospect on Duck Creek Mountain in the Belt Mountains, 23 miles northeast of Townsend, Broadwater County, in T. 9 N., R. 3 E. Some of the fluorite is coarsely crystalline. The quantities exposed at the time of his visit in 1943 were small. Fluorspar is also reported near Elkhorn in Jefferson County, west of Townsend, probably in T. 6 N., R. 3 W. Published reports [55] give only passing mention of the presence of fluorspar in both of these localities.

The Marysville district in Lewis and Clark County contains lodes which have been worked since 1876 for their gold, silver, lead, and copper content. In recent years comparatively little mining has been done. A few of the mines, notably the Bell Boy and Bald Butte (T. 11 N., R. 6 W.), have fluorite as an abundant constituent of the cement of breccias in hornstone. So far as can be judged from published reports,[56] the fluorspar bodies are not large and contain much material other than fluorite. If the deposits are mined for their metal content, the possibility of the recovery of fluorspar as a byproduct should be considered.

According to the published reports just cited the Marysville district contains a quartz diorite stock, related to the Boulder batholith, which has intruded and metamorphosed calcareous and argillaceous rocks belonging to the Belt series. There are numerous and diverse small intrusions, mostly dikes, and some remnants of Tertiary lava and sedimentary deposits. The lodes fill fractures in contact-metamorphosed Belt rocks. The lodes range up to 20 feet in width and to half a mile in length, but most ore shoots are only a few hundred feet long. Fluorite is absent from most of them, but where present it is a constituent of the cement of breccia zones formed later than the main part of the lode, and is of small extent. The breccia zones may be 3 or 4 feet wide and a few hundred feet long.

Near Philipsburg, Granite County, a few of the lodes contain fluorite. These lodes includes deposits on the Albion, Banker and Mys-

[54] Corry, A. V., op. cit., pp. 36–41.

[55] Pardee, J. T., and Schrader, F. C., Metalliferous deposits of the Greater Helena mining region, Mont.: U. S. Geol. Survey Bull. 842, pp. 139–171, 192–309, 1933.

Corry, A. V., op. cit., pp. 16–23.

[56] Weed, W. H., Gold mines of the Marysville district, Mont.: U. S. Geol. Survey Bull. 213, pp. 88–89, 1903.

Barrell, Joseph, Geology of the Marysville mining district, Montana—a study of igneous intrusion and contact metamorphism: U. S. Geol. Survey Prof. Paper 57, pp. 105–111, 1907.

Knopf, Adolph, Ore deposits of the Helena Mining region: U. S. Geol. Survey Bull. 527, pp. 61–76, 1913.

Pardee, J. T., and Schrader, F. C., op. cit., pp. 63–76.

tery claims, and in the Hope mine, in T. 8 N., R. 12 and 13 W., and T 7 N., R. 13 W. The following notes are abstracted from the description of the Philipsburg quadrangle by Emmons and Calkins [57] supplemented by notes made by E. A. Scholz about the Banker and Mystery claims in 1943.

The Albion mine in Deer Lodge Basin at the time of Emmons' examination was one of the minor properties in the region. A vein 200 feet east of the one on which the principal exploration was undertaken consists of quartz, fluorite, sphalerite, galena, and tetrahedrite between a footwall of granitic rock and a hanging wall of calcareous shale.

The Banker claim along Boulder Creek close to Princeton contains two small veins in limestone in which fluorite was not noted by Emmons. Scholz, however, saw a stringer of high-grade fluorspar as much as 6 inches wide on this claim and also noted a narrow vein containing some fluorspar on the nearby Mystery claim.

The Hope mine, east of Philipsburg, is one of the larger and older mines of the region. It contains a number of ore bodies formed by replacement in Jefferson limestone. Emmons noted that fluorite was found on the lower levels of this mine, associated with quartz and pyrite.

In addition to the occurrences in lodes noted above, fluorite is reported to be abundant in a metamorphosed shale belonging to the Silver Hill formation (Cambrian) and in a decomposed granitic rock along Mill Creek, in Deer Lodge County, in the southeastern part of the Philipsburg quadrangle in T. 4 N., R. 12 W. Fluorite is regarded by Emmons and Calkins as a primary constituent of an alkaline granite found on Lost Creek in Granite County.

CONCLUSIONS

The known fluorspar deposit in Montana are so diverse that few general rules for prospecting can be given. Most deposits are apparently of replacement origin, but are localized along somewhat poorly defined zones of shearing. Commonly the fluorite in the deposits of the State has the distinctive purple color and octahedral cleavage that make it easily recognizable. Prospectors should remember, however, that the mineral may be colorless, or tinted with green or other colors. It may also be so fine grained or so mixed with other constituents that the cleavage is not readily seen.

The summaries of available data given in this report on areas in Montana where fluorspar is known show that the occurrences are fairly numerous and widely distributed. Few deposits are known to be of high grade, and most appear to be small and irregular in shape. Ex-

[57] Emmons, W. H., and Calkins, F. C., Geology and ore deposits of the Philipsburg quadrangle, Mont.: U. S. Geol. Survey Prof. Paper 78, pp. 128–129, 155, 213–218, 248–250, 1913.

ploration up to the summer of 1944 was meager and insufficient to permit close calculation of reserves. Deposits such as those of the Sweetgrass Hills and of the Silver Bow area when adequately explored might prove to be more extensive than it is now safe to assume. The Spar prospect near Superior contains extremely high-grade fluorspar, but it apparently occurs only in very small shoots. Thus, until further exploration is done, the fluorspar deposits of Montana on the whole must be regarded as potential resources for future exploration and development rather than as deposits of demonstrated importance. On the other hand the possibility of discovery of deposits that can be mined profitably in periods of normal demand is sufficiently good to justify further exploration of the best of the known deposits. As far as can now be judged, the demand for fluorspar in times of peace will be greater than it was before the second World War, and unless new discoveries of considerable magnitude are made in the present producing districts, these districts will not long be able to meet this demand fully. The possibilities that new industrial enterprises may be located in the northwestern part of the United States and that plants already existing there may be enlarged make it likely that there will be increased demands for fluorspar in this part of the United States. Few fluorspar deposits of large size are known to exist in the northwest.

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