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Fluorspar Deposits Near Meyers Cove, Lemhi County, Idaho

By
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Moscow, Idaho
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Fluorspar Deposits Near Meyers Cove, Lemhi County, Idaho

by
ALFRED L. ANDERSON

ABSTRACT

This report describes the recently productive fluorspar deposits in the Salmon River Mountains near Meyers Cove in western Lemhi County, Idaho, which from June 1951 to April 1953 yielded 10,978 tons of acid grade, 998 tons of ceramic grade, and 100 tons of metallurgical grade spar. These deposits occur as fillings and replacements along zones of complex fissuring and fracturing in tuffaceous rocks of the Casto (Permian?) and Challis (Tertiary) volcanics and in bodies of intrusive rhyolite porphyry and granophyre (Miocene). The volcanic rocks have been folded into a broad anticlinal arch, with the arch broken by faults, but complex zones of fissures and fractures, which occur well out on the flanks of the arch, appear to have been induced by horizontal shear in the deep basement rocks, independent of the folding.

The fissure and fracture fillings are composed largely of coarse, generally banded or crustified fluo-
rite with variable but generally small amounts of bar-
rite, cryptocrystalline fluoroite, and chalcedony. The fluo-
rite is somewhat spotty in its distribution along the
fissure and fracture zones but tends to form len-
ticular shoots up to 16 feet thick and several hun-
dreds of feet long. The individual shoots have a vertical range of several hundred feet, unless short-
ed by erosion, but other shoots are known to con-
tinue the mineralization at depth. Although the de-
posits belong to the shallow epithermal group, the
fluorspar is known to have a vertical topographic range of not less than 2,000 feet. Recent operations have expended much of the proven reserve, and addi-
tional development is need to make more of the fluor-
spar available for mining. The outlook for the devel-
opment of a large reserve of fluorspar is bright.

INTRODUCTION

PURPOSE AND SCOPE

Study of the fluorspar in the vicinity of Meyers Cove in western Lemhi County was undertaken by the Idaho Bureau of Mines and Geology in response to urgent requests for geologic data that might as-
sist in the immediate and long-time development of the deposits. The need of further study in the area had long been appreciated by the Idaho Bureau of Mines and Geology, for the preliminary report1 made after a brief reconnaissance examination in 1942, at the time the fluorspar discoveries were being made, was known to be inadequate for present-day needs. Although the early report was based wholly on out-
crop studies, the surface showings were such that the conclusions regarding the economic potentialities of the newly discovered deposits were quite optimistic. Since then the Idaho Bureau of Mines and Geology has watched with a deep sense of satisfaction the transition of these raw prospects into full-fledged productive mines. With the accumulated data of 10 years of exploration and development to draw upon, the time was indeed ripe for a comprehensive rein-
vestigation of the fluorspar deposits.

The investigation has been concerned primarily with the geologic aspects of the fluorspar mineraliza-
tion and has touched on other features of the geology only in so far as these features might bear on the fluorspar problem. As the character of the rock ap-
ppeared to have little to do with the localization of the fluorspar deposits, detailed stratigraphic and pse-
ographic studies were not attempted. Instead much of the time was spent on structural observations a-
long the main zones of mineralization, with particu-
lar attention to the structural characteristics of the deposits and the structural conditions regarded as fundamental in controlling the distribution and oc-
currence of the fluorspar.

FIELDWORK

Two seasons in the field were necessary to ac-
complish the work desired. The first season got un-
derway shortly after the middle of June 1952, and
continued with little interruption until late August. During this interval the writer was assisted by James V. McDonald and Warren E. Ove, students in the School of Mines at the University of Idaho, who spent much of their time with the plane table, estab-
lishing control points for topographic and geologic map-
ing along the main zones of mineralization. The control was entirely by stadia and extended over eight, 18 x 24 inch plane table sheets, with a scale of 100 feet to the inch and a contour interval of 10 feet. Some mapping was also done underground.

In the second season in the field the work was re-
sumed about mid-June and continued into early Au-
gust. This time the writer was assisted by Mr. Clay-
ton Reynolds, also a student at the University of Idaho. The season was spent in preparing a ge-
ologic map of the area based on aerial photographs, which had been enlarged to 3 inches to the mile, and
in bringing up to date the maps of the underground workings, which had been added to considerably dur-
ing the intervening months.

ACKNOWLEDGEMENTS

The study of the district was greatly facilitated through the hearty cooperation and many favors rendered by the management of Fluorspar Mines, Inc., then operating the property, and by the present owner. The writer is particularly indebted to the officials of Fluorspar Mines, Inc. for housing and other privileges and wishes to express his deep gratitude and appreciation to Messrs. J. R. Simplot, President, Keith Madill, Manager, Don Ferguson, Engineer, and Al Lewis, Superintendent, for their many courtesies and helpful assistance. He also wishes to convey his gratitude to Mr. Arthur E. Chambers, owner of the property, for his helpful cooperation.

Grateful acknowledgements are also extended to the field assistants, Messrs. McDonald, Ove, and Reynolds, without whose aid the accomplished fieldwork would not have been possible.

PREVIOUS GEOLOGIC WORK

The district has received some attention in the past, especially since the discovery of the fluor spar deposits in 1942, but the only published data on the fluor spar deposits are those by the writer, prepared after the reconnaissance examination in 1942. Earlier, C. P. Ross had given a paragraph to the antimony deposit at Meyers Cove in his report on the ore deposits in Tertiary lava in the Salmon River Mountains and later had redescibed the deposit at somewhat greater length in a report dealing with the geology and ore deposits of the Casto quadrangle, published in 1934. In his later report Ross included a geologic map that covers a considerable part of the area containing the fluor spar deposits, but, although he shows and describes the different rock formations and the geologic structure in some detail, he makes no mention of the fluor spar mineralization.

Not long after the writer’s reconnaissance in 1942, the area attracted the attention of the U.S. Bureau of Mines and the U. S. Geological Survey. After some preliminary investigation, the Bureau of Mines started an exploration project that continued from 1943 through 1944. During this interval many deposits were explored by bulldozer trenching, after which they were sampled and the results of the sampling together with maps of the exploratory work made available in an open-file report. The U.S. Geological Survey also initiated a Strategic Minerals Investigation with topographic and geologic mapping in charge of D. C. Cox. This geologic work continued through 1944, but the report based on this investigation has not yet been published. Several private reports have been made on the fluor spar deposits by geologists in the employ of different companies during the late forties, but these reports are not for public use.

GEOGRAPHY

LOCATION AND ACCESSIBILITY

Meyers Cove is in east-central Idaho in the western part of Lemhi County about 38 miles by air or 68 miles by road southwest of Salmon, the county seat, or 28 miles by air or 53 miles by road north-northwest of Challis, the county seat of Custer County (Fig. 1). It is in Sec. 6, T.17N., R.17E., Boise meridian along the east boundary of the Casto quadrangle at about 114° 30' west longitude and 44° 50' north latitude. Meyers Cove is on Camas Creek, a tributary of the Middle Fork of the Salmon River, at the junction of the West Fork and Silver Creek.

The fluor spar deposits are mostly 1 to 3 miles below Meyers Cove in unsurveyed Ts. 18 N., Rs. 16-17E., Fig. 2). Camas Creek flows through the area of fluor spar mineralization in a northwesterly direction, and, as the stream serves as a forest boundary, the fluor spar deposits southwest of the creek are in the Challis National Forest and those on the northeast side in the Salmon National Forest.

The area is remote from town and railroad, but is no longer difficult to reach. The most practical approach is from Challis over paved U.S. Highway 93 to the mouth of Morgan Creek, 9 miles below town, and thence up to the head of Morgan Creek and over the 7,578-foot summit into the upper Panther Creek drainage along a recently completed mine road built to truck cobalt and copper concentrates from the Blackbird district. Thirty miles from the turn-off on U.S. Highway 93, a branch extends over a low divide and follows Silver Creek to Meyers Cove, a distance of 12 miles. The improved road to the Blackbird district was opened to traffic during the late months of 1961 and the branch into Meyers Cove during the late summer of 1962. These roads are maintained throughout the year, with mail trucked to Kohlt daily except Sunday, and to Meyers Cove on Mondays and Fridays.

The nearest railroad is at Mackay, a terminus of a branch line of the Union Pacific, which connects with the main line at Blackfoot, Idaho, 25 miles north of Pocatello. As Mackay is 82 miles from Challis, the fluor spar has to be trucked about 105 miles before shipment can be made by rail.

SURFACE FEATURES

Meyers Cove, a basin-like opening of several hundred acres of arable land, is tucked far back in the Salmon River Mountains, an extensive mountainous mass of the dissected plateau or upland type, carved and drained locally by Camas Creek and its tributaries West Fork, Silver Creek, and Duck Creek. Except for the small basin at Meyers Cove, the region is entirely mountainous with rugged slopes rising steeply and in places precipitously from Camas Creek to ridge crests more than 2,000 feet above (Pl. 1). A bench mark at Meyers Cove records an altitude of 5,185 feet above sea level and another about 3 miles down Camas Creek, an altitude of 5,040 feet. The ridges rise locally to 7,500 feet, very steeply to 7,000 feet, and then more gradually to 8,000 feet and above in
Figure 2. Geologic map of the Meyers Cove area (based on Aerial photographs).
Figure 1. Index map showing location and approach to Meyers Cove.
CLIMATE AND VEGETATION

Although some distance within the Salmon River Mountains, the district has a climate that is not particularly severe. Rainfall records are not available, but the presence of sagebrush on the southward-facing slopes and timber on those that face to the north suggest subhumid conditions with perhaps 20 inches of precipitation annually along the valley bottoms but with considerably more on higher peaks and ridges. The first six months of the year are normally the wettest and the three summer months, the driest. Some stormy but much fine weather continues through the autumn. From late June to early September the precipitation, if anything, comes as heavy showers of short duration, occasionally as more gentle rains lasting 12 to 24 hours. During much of the remainder of the year, storms may last for several days at a time. The snow depth in the main valley floors, but may accumulate to several feet at higher levels. The snow does not interfere seriously with travel in and out of Meyers Cove.

The winters are rather long and from November to March the average daily temperature probably rarely exceeds 25° F., but may for short periods of time drop below zero. The relatively short summer season is delightful, with warm pleasant days and fairly cool, invigorating nights. Frost may occur at any time but is rare from mid-June to late August. The daily range in temperature is considerable in both summer and winter with shifts of 40° in a single day not uncommon.

The vegetation reflects the subhumid climate with kind and density of growth dependent largely on altitude and degree of exposure to the sun. On lower, southward-facing slopes, the vegetational cover is chiefly sagebrush and grass (Pl.3,A), but with increasing altitude and especially in sheltered areas the trees take over so that as a whole the north slopes and higher ridges are rather heavily forested (Pl.2). The main growth consists of fir and spruce and these provide a supply of timber ample for all mining purposes.

GEOLOGY

GENERAL FEATURES

Except for some intrusive granite and small bodies of porphyry and diabase and a minor covering of terrace gravel and alluvium, the area around Meyers Cove is underlain throughout by volcanic rock (Fig. 2). This volcanic rock belongs to two great groups of eruptives, the Casto and the Challis. The two differ considerably in age and degree or extent of alteration and deformation, but, because of local intense hydrothermal alteration along the main zones of fluor spar mineralization, they are difficult to tell apart. The Casto volcanics are thought to be of Permain (?) age, whereas the Challis volcanics are known to be of Tertiary (Oligocene) age. The two groups of volcanics, which are in unconformable contact
A. ANTLER RIDGE
Relatively low ridge between the forks of Duck Creek with broad summit erosion surface gently tilted against the escarpment of higher mountains in the background. The low ridge is the result of recent normal faulting.

B. FLUORSPAR RIDGE
Ridge contains most of the important fluor spar deposits in the district. Duck Creek canyon on the left; Fluorspar Gulch on the right. Most of the deposits are near the crest of the ridge.
The volcanics form abundant rough outcrops, in part of cliff-like character, especially in the canyons occupied by Camas and Rock Creeks. Some of the more conspicuous ledges and cliffs mark the zones where the rock has been silicified by mineralizing fluids and thus made more resistant to erosion than the surrounding rocks. The general roughness of the outcrops is one of the principal features used to differentiate between the Casto and Chalils volcanics, for the latter locally erode to smooth slopes.

Composition. - Although the alteration tends to mask the identity of the volcanics, the flows and tuffs appear to have an intermediate to acid composition and may be divided into andesitic and rhyolitic rocks, with some dacites included with the andesites and some quartz latites with the rhyolites. All rocks seem somewhat siliceous with some quartz even in the andesites, either as accessory grains or as a part of the devitrified glass in the groundmass. Variable amounts of more or less completely devitrified glass appear to characterize most of the rocks of the Casto volcanics.

The andesitic as well as the closely related dacitic rocks, flows and tuffs, are generally rather dark colored and range from moderately dark gray to greenish gray depending on the extent of alteration. Some of the flows show a weak motting from included fragments of purplish, greenish, and dull reddish rock, whereas much of the tuffaceous and agglomeratic rock has a rather pronounced greenish motting. All rocks may also contain fragments of dull white or gray feldspar crystals, those in the flows broken during flowage of the lava. The andesites and dacites are more or less conspicuously porphyritic and may contain up to 30 percent broken and unbroken plagioclase phenocrysts, mostly less than 1 mm. long, and less than half as much biotite, hornblende, or augite, generally completely altered to chlorite or to chlorite and epidote. The phenocrysts in the dacites also include small corroded and embayed grains of quartz. These several phenocrysts along with fragmental rock inclusions, which are themselves porphyritic, are generally embedded in dull, anaphitic ground-masses, some of which are flow banded.

The thin sections reveal that the plagioclase phenocrysts are composed of andesine, largely obscured by alteration products, chiefly sericite and epidote, and that the groundmasses are usually feldspathic andesitic texture, with some devitrified glass, most abundant in the dacites. Some of the dacites also contain widely scattered microspheulites, which indicates that some orthoclase is also present. The quartz in the groundmass may occur as small accessory grains in the andesite and as more abundant grains in the dacite. Both rocks have accessory apatite, zircon, and magnetite. The tuffaceous and agglomeratic rocks are composed largely of the same materials as the flows and thus contain the same minerals as the flows. The clastic rocks, however, may contain a somewhat higher proportion of devitrified glass. Perhaps the most striking feature of the flow and pyroclastic rocks is their alteration, with both chlorite and epidote present in relative abundance.

The rhyolitic and quartz latitic rocks are light colored with the rhyolites mostly drab gray to green-

VOLCANIC ROCKS
Casto Volcanics (Permian?)

Distribution. - The Casto volcanics underlie about half the mapped area (Fig. 2) and are a part of the large mass that stretches diagonally northeastward across the middle of the Casto quadrangle from the vicinity of Casto past Meyers Cove. The southeast boundary crosses the West Fork of Camas Creek about 2 miles above and Camas Creek itself about a mile below Meyers Cove. On the east side of Camas Creek, their contact extends a short distance up Fluorspar Gulch and then turns northwest to swing around the end and north side of Fluorspar Ridge into the upper drainage of Duck Creek (Fig. 2). The position of the contact in Fluorspar Gulch and around the northeast side of Fluorspar Ridge is particularly noteworthy, for it indicates that the Casto volcanics extend under the ridge beneath a cover of Chalils volcanics.

As exposed along Camas Creek, the body of Casto volcanics is about 3 miles wide. Its northwest boundary is its contact with an extensive mass of Tertiary granite and this contact falls just within the northwest corner of the map-area (Fig. 2). Except for small bodies of Tertiary intrusive rock and a narrow strip of alluvium along Camas Creek, all the bedrock between the southeast boundary and the granite is composed of the Casto volcanics.

General Character. - Throughout the area the Casto volcanics appear to be composed entirely of flow and pyroclastic materials with nothing that can be recognized as derived from non-igneous sources. As the flows commonly contain numerous broken feldspar phenocrysts and fragmental lava inclusions, their rock usually has a clastic appearance and is not always easy to distinguish from the pyroclastics. The latter consist for the most part of rather coarse tuffaceous or the agglomeratic materials up to an inch in diameter. The problem of distinguishing between flows and fragmentals is made even more difficult by the presence of welded tuffs which resemble flows and their breccias. Added to this is the widespread alteration, which affects all members alike and thus further obscures the relation. Until the volcanics are studied and mapped in detail, the proportions of the various kinds of rocks cannot be known, but from incomplete study, the pyroclastic rocks appear to make up a considerable part of the local succession.

Because of their alteration, the volcanics have a rather general dull, mottled appearance, with outcrops that are decidedly soubrous. There are, however, local areas of more intense alteration along the mineralized zones where the rock has been bleached and thus possesses a much lighter color. Because of weathering some of this more highly altered rock has been painted in vivid shades of brown and red, resulting from the oxidation of small but variable amounts of pyrite, added to the rock during its alteration.

ish gray and with the quartz lattices mottled in shades of gray, green and red, largely because of variously colored fragmental inclusions. The rhyolitic rock is usually fine grained, almost chertlike and decidedly stony in appearance, even when displaying a rather prominent fluidal banding. The flows have few visible phenocrysts. On the other hand, the quartz lattices tend to resemble flow breccias and are conspicuously porphyritic. The few phenocrysts observed in the rhyolites consist of small grains of sodic plagioclase, orthoclase, and corroded and embayed quartz contained in groundmasses which appear to be composed largely of devitrified glass. The quartz latite usually has a liberal sprinkling of plagioclase phenocrysts with but a scattering of orthoclase and quartz grains. These are set in groundmasses composed largely of devitrified glass or of devitrified glass and microgranular quartz and orthoclase. Some flows also show microsperulitic quartz and orthoclase. Both the rhyolites and quartz lattices contain grains of chlorite pseudomorphous after biotite and also accessory grains of magnetite, siren, and apatite. Secondary products are abundant, and in addition to chlorite, include sericite, and, in the quartz lattices, also epidote. In and around the more highly altered zones, the feldspars have been almost completely converted to secondary products. Much secondary quartz has infiltrated into some of the rhyolitic rocks. The tuffaceous equivalents of these rocks are generally fine grained and are difficult to distinguish from the flows, even with the microscope.

**Challis Volcanics (Oligocene)**

**Distribution.** The Challis volcanics cover much of the country southeast of the mass of Casto volcanics and underlie about as much of the district as do the Casto volcanics (Fig. 2). These younger rocks are a part of a broad blanket that extends almost continuously to and beyond the town of Challis from which the volcanics receive their name. At one time these volcanics covered much of south-central Idaho, but subsequent erosion has stripped off parts of the cover, revealing here and there the basement of older rocks, which, at Meyers Cove, consists of the older group of Casto volcanics.

**General Character.** At Meyers Cove the Challis volcanics are dominantly tuffaceous but there are some flow and some beds of well-stratified fine-grained sediment. Although not so shown on the map (Fig. 2), the volcanics are divisible into two fairly well distinct units, the lower of which consists dominantly of tuffaceous rocks of andesitic and dacitic composition with some intercalated sedimentary rock and the upper of which is composed of rhyolitic flows and tuffs. The boundary between the two extends northeastward from Meyers Cove along the drainage divide of Silver Creek and roughly parallel to and about a mile southeast of the contact of the Casto volcanics. As the lower unit is the host for the Fluorspar deposits in Fluorspar Gulch and on Fluorspar Ridge, it is the one of greatest interest. It has little rock of flow origin but consists largely of rather coarse tuffaceous or fine agglomeric materials with some intercalated flowlike beds of welded tuff. In Fluorspar Gulch and on Fluorspar Ridge these rocks are highly altered and are difficult to distinguish from the also altered rocks of the Casto volcanics.

**Composition.** The tuffaceous rocks in the lower unit resemble in part those which compose the immediate underlying Casto volcanics and are made up largely of small fragments of andesite and dacite up to an inch in diameter in a fine matrix consisting largely of glass in various stages of devitrification and alteration to clay minerals. Where not too highly altered, the tuffs have a greenish motting, which is lost in the more highly altered rock along the main zones of mineralization. Where more highly altered the rock has a bleached appearance and is dull white or gray.

The welded tuffs in the lower unit are difficult to distinguish from the flows. The upper beds of the more highly altered zones, the rock is rather dark and is composed of breccia-like fragments of porphyritic andesite and dacite welded together by brownish glass, which in places has fluidal whirls. Rock of this kind is fairly widespread in the vicinity of the Big Lead and Powderhouse veins and on the slope above the M and M. Where considerably altered the welded tuff is indistinguishable from the other altered tuffs.

The sedimentary beds intercalated in the lower unit shows prominent stratification. The beds are thinly laminated, much like shale, and form units up to 20 feet or more thick. The beds are white to light gray and may represent fine-grained water-laid tuff. Such beds are exposed along the crest of Fluorspar Ridge between the Big Lead and the Bear trap and at a number of places along the road from the bottom to the top of Fluorspar Gulch.

The rhyolitic flows and tuffs of the upper unit are light colored, and, as they are mostly outside the mineralized area, they have not lost the freshness of appearance that normally characterizes the rocks of the Challis volcanics. The flows are generally light gray, but may be pinkish or lavender. The rocks are more or less conspicuously porphyritic with numerous quartz and some feldspar phenocrysts in what otherwise would be dense, aphanitic or glassy, flow-banded groundmasses. Some of the flows have an abundance of spherulites up to an inch or more in diameter. The tuffs associated with the flows are fine to moderately coarse and like the flows are composed largely of rhyolitic materials.

**SEDIMENTARY ROCKS (QUATERNARY)**

The only rocks mapped as sedimentary are the stream-made deposits along the main valley bottoms. These deposits comprise terrace gravels and the present floodplain and channel sands and gravels, the former of Pleistocene and the latter of Recent age.

**Terrace Gravels (Pleistocene)**

The terrace gravels are most widespread in the basin-like area of Meyers Cove and form the low benches that rise above the present floodplain of Camas Creek and the West Fork (Fig. 2). Remnants of such terraces appear elsewhere along Camas Creek and its larger tributaries, but, except along a part of Rams Creek, are too small to map.
These terrace deposits are composed mostly of coarse gravels with admixed boulders and sand, derived chiefly from the harder and more resistant rocks of the Casto and Challis volcanics. These terraces occur at several levels and appear to be the remains of alluvium that accumulated in the main stream valleys during the Pleistocene when the streams received more debris from glaciers in the headward regions than they were able to carry away. Since then the present streams have entrenched in the older valley fill, and, except in the broader, basin-like areas, have washed away much of the earlier accumulation.

**Alluvium (Recent)**

The present stream alluvium is largely restricted to the valley flats along Camas Creek and its main tributaries, the West Fork and Silver Creek (including lower Bams Creek) (Fig. 2). The strip of alluvium along Camas Creek extends some miles above Meyers Cove and about 4 miles below where it ends as the stream enters the deep narrow canyon on its way to the Middle Fork of the Salmon River (Pl. 1). The alluvium may be traced up the West Fork about 2 1/4 miles and up Silver Creek for more than 5 miles. The strip is narrow, with a maximum width of a quarter of a mile a short distance below Meyers Cove and less than several hundred yards elsewhere. Along the smaller streams the strip is too narrow to map.

This young stream alluvium is composed largely of coarse sand and gravel with admixed boulders. The gravelly material usually predominates, but in some protected stretches, the alluvium is mostly sand. These sands and gravels are composed of the same kinds of rocks as the terrace gravels. They are, in fact, largely reworked terrace deposits.

**INTRUSIVE IGNEOUS ROCKS (MIocene)**

The intrusive igneous rocks are represented by diabase and closely related rhyolite porphyry, granophyre, and pink granite. All of these form bodies large enough to be mapped (Fig. 2), most of them as dikes and small stocks, the pink granite as a much larger mass.

As these rocks intrude the Challis as well as the older Casto volcanics, they belong to the group of Tertiary intrusives recognized as of lower Miocene age.

**Pink Granite**

The pink granite is exposed at the northwest corner of the map-area (Fig. 2), and is a part of a large batholithic or perhaps laccolithic mass that forms a broad band, about 7 miles wide, that extends northward from the west-central to the northeastern part of the Casto quadrangle. The body there branches, the short eastern branch terminating near Yellow-jacket and the western branch continuing northward several miles beyond the quadrangle.

The rock that forms the larger part of the mass is pale pink and of variable but generally rather coarse grain. It shows some variation in composition in different places but is typically a granite composed largely of perthitic microcline and variable but lesser amounts of quartz, oligoclase-andesine, biotite and hornblende, with such minor accessories as zircon, apatite, and magnetite. In general the microcline comprises more than half of the rock and the quartz more than half of the remainder, with rarely more than 5 percent of combined biotite and hornblende. Much of the rock has a typically granular texture, combined in places with the granophyric or micropegmatitic.

**Granophyre**

The granophyre forms two small, somewhat ovoid bodies on the high ridge between Dick and Camas Creeks and several small dikes on Antler Ridge (Fig. 2).

The bodies are somewhat altered and hence their rock is light gray, without the pinkish cast so characteristic of much of the rock in other parts of the region. The rock is inconspicuously porphyritic and at first glance appears essentially aphanitic. Its porphyritic character is more apparent in thin section, which reveals a few small scattered phenocrysts of soda plagioclase and still fewer ones of orthoclase and quartz and of chloritized hornblende and biotite. These phenocrysts are contained in granophytic groundmasses composed almost wholly of microperthitic quartz and orthoclase or of both microgranular and microperthitic quartz and orthoclase. The rocks contain variable amounts of secondary chlorite, sericite, epidote, and calcite, and those along zones of fluorspar mineralization show also extensive argillic alteration.

**Rhyolite porphyry**

The bodies of rhyolite porphyry appear to be more numerous than those of granophyre, with no less than ten of them large enough to be shown on the geologic map of the district (Fig. 2). They are larger and more numerous in the canyon wall on the southwest side of Camas Creek than elsewhere with only three mapped on the northeast side of the creek, two of them on Fluorspar Ridge. Although in part somewhat ovoid, these bodies are more dikelike as compared with the granophyric bodies and tend to be elongated in northeastward, less commonly in easterly and northwesterly directions. The bodies are ledge-forming and produce some of the most prominent cliffs and ledge outliers in the district (Pl. 5,A).

Unlike the granophyres, the rhyolite porphyries are conspicuously porphyritic and contain an abundance of quartz phenocrysts 1 to 2 mm. long and less numerous but somewhat larger orthoclase crystals and an occasional grain of soda plagioclase in what otherwise would be a light-gray, fine-grained, essentially aphanitic rock. The rocks also show traces of former biotite or hornblende crystals. Viewed in thin section, the numerous quartz phenocrysts appear as corroded, partly resorbed, and embayed crystals. The quartz and other phenocrysts are contained in microgranular groundmasses of quartz and orthoclase, the latter commonly as rather poorly defined granules. The rock usually shows some indication of alteration in the presence of variable but usually minor amounts of sericite and chlorite. In the mineralized
zones, however, the rock may show extreme alteration, generally represented by intense silicification. Only the outlines of the phenocrysts are preserved in the highly silicified dikes as on Fluorspar Ridge.

Although mapped as granophyre by Ross, these bodies are classed as rhyolite porphyry because of the absence of micro-pegmatitic or granophytic textures, which distinguish the granophyres, and because of the marked resemblance of the rock to the porphyritic rhyolites or quartz porphyries.

Diabase
Small bodies of diabase barely large enough to spot on the geologic map of the area (Fig. 2) are exposed along the crest of Fluorspar Ridge just above the Big Lead, along the road a short distance below camp, and on the ridge behind the large body of rhyolite porphyry southwest of Camas Creek. These bodies seem to be more pod than dikelike. Two of them are in contact with bodies of rhyolite porphyry, but whether they intrude the porphyries was not learned.

The diabasic rocks are not much altered, and, except for minor surficial effects of weathering, are remarkably fresh in appearance and resemble dark-gray, nearly black, fine-grained basalts. The body of Fluorspar Bl dike is a coarse-grained porphyritic and contains numerous, scarcely discernable black grainy olivine laths a little larger than the grains of the groundmass. These phenocrysts occur in what otherwise would be a granular rock of diabasic texture composed of leucite augite and magnetite, with the leucite as laths and the others as interstitial grains. Elsewhere the diabase appears to lack olivine and is a fine-grained granular rock composed of leucite and abundant grains of augite and magnetite, with the augite largely altered to calcite and occurring interstitially between the leucite laths and the magnetite cubes. These rocks contain tiny needles of apatite.

STRUCTURE

General Features
The volcanic rocks at Meyers Cove have been deformed by folding and faulting, but, because of the absence of distinctive marker beds and flows and because of the limited and generally obscure bedding and flow banding, especially in the older rocks, the structural features and their relationships are difficult and in part impossible to work out. Consequently, except along the main zones of mineralization, only the broader structural features are considered.

Folds
The older Casto volcanics show evidence of more intense deformation than the Challis volcanics and contain folds that are not expressed in the younger group of rocks. On the other hand there is a fold of major magnitude which involves both groups of volcanics. Thus two groups of folds may be recognized, one older than and the other younger than the Challis volcanics. For simplicity of discussion these are designated and described as older and younger folds.

Older Folds. - Little was learned about the older folds, except that the folding was not very intense. Flow banding indicates steep dips locally, but there is no suggestion of crumpling or overturning. Although individual folds were not distinguished, the tendency appears to be for broad folds. The trend of the folded flows and tuffs is generally N. 50°-75° E., which is about the same as for the belt of volcanics as a whole. Dips locally are as steep as 80° SE. Whatever the nature of the folding, the folds apparently have had little, if any influence on the localization of the fluor spar deposits.

Younger folds. - The fold which also involves the Challis volcanics is the dominant structural feature of the region. This fold has arched or domed the Casto and Challis volcanics and its influence extends far beyond the boundaries of the Casto quadrangle. The rocks at Meyers Cove are on the southeast flank continuing beyond Challis. The axis of the arch strikes about N. 40° E. and crosses Camas Creek about 7 miles below the district. Erosion of the top of the arch has removed the cover of Challis volcanics and has exposed the core of Miocene pink granite and intruded Casto volcanics.

The changes in the attitude of the flows and tuffs in the Casto volcanics as a result of the arching have not been worked out, but the once essentially flat flows and tuffaceous beds of the bordering Challis volcanics now dip southeast at angles of 60°-70° along the north slope and bottom of Fluorspar Gulch, decreasing to 30°-40° on the ridge above Silver Creek, leveling off to 5°-10° with increasing distance from the district (Fig. 2). The abnormally high dips in Fluorspar Gulch may have been accentuated by faulting, but definite evidence is lacking.

This arching of the volcanics has apparently had little direct influence on the localization of the fluor spar deposits which are well out on the flank of the arch and not in any fractures which might be attributed to local collapse of this broad anticlinal structure.

Faults
Both groups of volcanics are extensively and complexly faulted, but, except where the faults have been marked by intrusive bodies or by veins and zones of rock alteration, they are difficult to prove, largely because of the lack of dependable horizon markers in the Casto volcanics and the paucity of good rock exposures in the Challis. Where bedrock is exposed, it generally shows extensive fracturing, commonly with a master set of fractures which divide the rocks in such a way as to simulate bedding or stratification. These fractures are probably related to those which directed intrusion and mineralization. But aside from the fault systems reflected in dike and vein patterns, there are some faults (apparently normal), some of which are relatively old and some of which are so young that offsets are still reflected in the topography. Some of the faults in the Casto volcanics are probably older than those in the Challis, but they cannot be safely differentiated from those in the Challis. For convenience of description, the faults are assigned to four groups, one of which includes the older faults, the second, those which directed igneous intrusion,
the third, those which controlled the mineralization, and the fourth, the young normal faults.

Older faults.—The older faults comprise some of the more prominent faults in the district and may be recognized from offsets in the volcanics, local discords of strike and dip of the flows and tuffs, and from the alignment of some of the gulches. No distinction is made between those in the Casto volcanics and those in the Challis. Some of those in the Casto may be thrust faults but most appear to be normal. Those in the Challis volcanics appear to be the normal variety.

Most of the faults conform to two general sets, one of northeasterly and the other of northwesterly trend. The larger and better developed faults strike about N.25°-30°E. and the smaller ones, so well-defined faults about N.35°-40°E. and the smaller ones, so well-defined faults about N.25°-30°W. The faults of northeast trend have the largest average throw and are the more easily recognized. Some of these were mapped in the field, but, because they comprise so few of the many faults present, they were omitted from the published maps.

These faults appear to be without influence on the mineralization, and many of them, because of their normal character, may have in part been associated with local collapse of the broad arch.

Faults controlling dike intrusion.—The faults which directed dike intrusion are not everywhere clearly defined, largely because of the ovoid shape of some of the intruded masses. However, some of the masses mapped as ovoid simply mark the broad outline of several dikelike bodies, individually too small and too closely spaced to be mapped singly. Most of the dikes show control by northeast fractures, but one of the mapped bodies trends northwest and another nearly due east (Fig. 2). Some of the intrusives may have been guided by faults belonging to the older group of normal faults, but, because of the likeness of the dike pattern to the vein pattern, most of them, like the mineralized faults, may have been formed in response to horizontal shear in the basement rocks. These faults are somewhat older than those which directed the mineralization.

Faults controlling mineralization.—Because of the mineral filling and bordering zones of altered rock, the mineralized faults and fracture zones are among the most conspicuous in the district and among the most easily recognized and mapped. Their structural relations are revealed by the vein patterns, which are not much different from those of the dikes. These faults are grouped so as to form three fairly well-defined zones or belts of mineralization, each trending in a northeasterly direction and each made up of individual faults of northeast, exceptionally northwestern trend. The faults within each of the zones conform to several well-defined sets of which the more prominent strike N.20°-30°E., N.50°-60°E., N.70°E., and N.20°W. These sets are somewhat oblique to the trend of the individual zones of mineralization, each of which may contain two or three or all sets, with one or two more prominently developed than the others. In these zones some faults conform first to one set and then to another, with the change from one set to the other marked by more or less abrupt changes in strike and to lesser extent in dip. Some of the faults dip steeply, even reverse dip, but most of them have moderate to rather low dips, ranging mostly from 25° to 40°. Some of the most productive veins have dips as low as 25°. Faults with northeast strike almost invariably dip northwest whereas those with northwest strike dip southwest.

The structural characteristics of the faults, most of which have produced complex fissure and fracture zones, are discussed later in connection with the structural relations and habits of the fluor spar deposits.

These faults apparently reflect no great movement, the lack of markers preventing any precise measurements, but the direction of movement, indicated by grooves on slicken-sided surfaces and by the relation of openings along the fault to changes in strike and dip, is very evident. These features indicate essentially horizontal movement, with the angle ranging from 0° to 25° from horizontal along different faults. The movement appears to be directed obliquely upward on the hanging wall side, from the southwest on northeast fractures and from the northwest on northwest fractures (footwall side). Grooves on other slicken-sided surfaces of different attitude apparently reflect local adjustments along the complexly fractured fault zones.

The fracture system that controls the mineralization appears to be independent of and perhaps only remotely related to other faulting and may best be explained as a reflection of deep, essentially horizontal shear in the basement rock which has induced much tear and other adjustments in the volcanic rocks near the surface. The earliest rupturing in response to the deepseated shear apparently provided for the escape and channeling of intrusive magma and the later rupturing for the upward movement of the mineralizing fluids.

Young normal faults.—Some of the faults which cause minor offsets of the mineralized fractures may be regarded as young faults (Fig. 10), but the designation here applies particularly to faults of larger magnitude which have come into existence so recently that their presence is indicated by well-defined fault scarp. One such fault occurs in the upper drainage of Banks Creek with its presence marked by the high, sharply incised escarpment that rises 1,000 feet or more above an area of relatively low mountainous country, forming locally the summit of Antler Ridge, and lower ridges along side (Pl.2, A). This fault has displaced an old erosion surface, and the surface of the downdropped block is now tilted against the escarpment at a moderately low angle. The tilting of the summit surface is not only apparent to the eye (Pl. 2) but is also reflected in an asymmetrical drainage pattern which shows that the tributaries flowing northwest down the tilted slope are much longer than those which flow southeast against the slope (Fig. 2). This fault may be traced in a north-easterly direction for several miles. It is poorly expressed along lower Duck Creek and apparently does not extend across Camas Creek. Its course, however, is sharply defined above the main forks of
Duck Creek and may be readily traced across the divide at the head of Duck Creek into the Rams Creek drainage.

This fault probably belongs to the group of Late Tertiary and Quaternary age which are conspicuous features in many parts of central and southern Idaho. Such faults are elsewhere classed as block faults.

**FLUORSPAR DEPOSITS**

**HISTORY**

The fluorspar-bearing ledges were probably noted by the early-day prospector and by many others since but ignored because of the absence of metallic mineralization. That this is so may be inferred from the fact that a location was made many years ago on the one deposit that did contain metals—the stibnite-barite deposit at the southwest end of the main zone of fluorspar mineralization. Apparently the nature of the fluorspar mineralization was not recognized and locations made until 1941 and news of the discovery was not generally known until 1942. Credit for the early locations goes to Reese Miles and Roy Johnson of Salmon, Idaho.

Shortly after word of the discovery reached the Idaho Bureau of Mines and Geology, the writer accompanied by Messrs. Miles and Johnson spent two days, July 28 and 29, 1942, in the area in a reconnaissance examination of the fluorspar-bearing ledges. The results of the examination were made available to the public in a pamphlet published by the Idaho Bureau of Mines and Geology in March 1943.

Not long after the locations were made, the claims were acquired by Arthur E. Chambers and an active program of exploration and development was instigated. During 1943 an access road was constructed from Meyers Cove to the deposits on Fluorspar Ridge by the U.S. Bureau of Public Roads, and while this work was in progress a building and sampling project was begun by the U.S. Bureau of Mines and a Strategic Minerals Investigation by the U.S. Geological Survey. Both projects continued into 1944. In 1945 metallurgical tests on the fluorspar were made by the Salt Lake Branch, Metallurgical Division, U.S. Bureau of Mines and by J. H. Heginbotham, metallurgist of the General Engineering Company, Salt Lake, Utah.

During 1944, the Chamac Mines, as the property was then known, completed an 100-ton flotation concentrator which was given a six-day test run in September under the direction of Mr. Heginbotham, who had devised the flow sheet. Because of unfavorable economic conditions, the mill was not operated after the test run and work at the property was temporarily discontinued.

Except for some miscellaneous work by Chamac Mines in 1945 and 1946 in further exposing some of the fluorspar bodies, there was little activity until the autumn of 1946 when preparations were made by the Aluminum Company of America to drill the deposits near the top of Fluorspar Ridge. The actual work was carried on in 1947 with eight holes totaling 2,228 feet drilled on the Big Lead and an equal number of holes totalling 4,240 feet on the Beartrap and South veins. Before completing the exploration program, the Aluminum Company of America withdrew from the district.

On November 28, 1949, the property, then consisting of 75 unpatented claims and 2 mill sites, approximating 1,500 acres, was acquired by the J. K. Simplot Company under lease and bond from Chamac Mines. The new company operated the property as the Fluorspar Mines, Inc., under the general managership of Mr. Keith Madill.

Fluorspar Mines performed some surface stripping in 1950, but actual mining did not get underway until the mill was brought into operation in June 1951. Mining was then carried on at an expanding rate and continued until fire destroyed the mill on April 16, 1953, when all operations ceased. In late summer the property reverted to the original owner.

**PRODUCTION**

In less than two years of active operation, the production totalled 37,432 tons of fluorspar-bearing material delivered at the mill. From this tonnage was recovered 10,978.66 tons of acid grade, 998 tons of ceramic grade, and 100 tons of metallurgical grade fluorspar. The source of the production and the quantity from each source is tabulated below.

<table>
<thead>
<tr>
<th>Source</th>
<th>Quantity</th>
</tr>
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<tbody>
<tr>
<td>Big Lead</td>
<td>29,304</td>
</tr>
<tr>
<td>North Pit</td>
<td>3,567</td>
</tr>
<tr>
<td>Anderson</td>
<td>1,686</td>
</tr>
<tr>
<td>Beartrap</td>
<td>1,304</td>
</tr>
<tr>
<td>M. and M</td>
<td>1,167</td>
</tr>
<tr>
<td>Chamac</td>
<td>404</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37,432</strong></td>
</tr>
</tbody>
</table>

**CHARACTER OF THE DEPOSITS**

The deposits are referred to as veins, but most of them are actually composite and would be more appropriately classed if they were called lodes. They are chiefly fillings of openings along zones of complicated fracturing and fissuring, with some, and locally much, replacement of the bordering rock and included rock fragments. The fillings show the banding and crustification so typical of the epithermal type of mineralization, where deposition has taken place at relatively shallow depths in abundant open spaces.

These deposits contain variable but generally small amounts of barite and chaledonic quartz but are notably free of sulfides. The deposits are composed dominantly of fluorite with included fragments of the wall rock as the principal contaminant. Although some deposits contain veins and masses of quite pure fluorite beneficiation is a necessary step in the utilization of the fluor spar.

**GEOGRAPHIC AND GEOLOGIC DISTRIBUTION**

The deposits are grouped along three rather closely spaced zones of mineralization, each of which trends
A. SOUTH SLOPE OF FLUORSPAR RIDGE

Shows location of and access roads to most of the deposits on Fluorspar Ridge, M (M and M), A (Anderson), P (Powderhouse), B (Big Lead), BT (Beartrap), and S (South vein).

B. ANTICLINAL LEDGE

Fluorspar-bearing ledge with such abrupt change in course that it doubles back on itself and creates a steeply plunging overturned anticline. View along the axis.
in a northeasterly direction. The zone with the most abundant mineralization and to date the most productive deposits is the most southerly one. This zone extends from the end of the spur between Camas Creek and the West Fork across Camas Creek just above the mouth of Fluorspar Gulch, and thence up the north side of Fluorspar Gulch and along and across Fluorspar Ridge on to the upper Duck Creek slope (Fig. 3). This zone of mineralization is about 2 miles long and about 1/2 mile wide and contains its greatest concentration of fluor spar deposits on the upper slope of the spur that rises half a mile west of the spur over the crest of Fluorspar Ridge (Pl. 3 A). A little fluorite occurs in the anthony-barite deposit at the southwest end of the zone, but the important fluor spar mineralization is northeast of Camas Creek.

The second or middle zone of mineralization starts on the steep slope southwest of Camas Creek at or just above the camp and then extends along the south- east side of Duck Creek to the lower end of Antler Ridge, a distance of some 9,000 feet (Fig. 3). The zone is a relatively narrow one with the main centers of mineralization on the steep slope southwest of Camas Creek on the west side of Duck Creek and 200 feet above the spur. The deposits along this zone have received very little attention.

The third or most northerly zone of mineralization crosses Camas Creek about 3/4 of a mile below the mouth of Duck Creek. Half a dozen deposits are known on the southwest side of the creek, spaced over a fairly broad area from creek level to points more than 1,000 feet above, but only two are known northeast of the creek, both apparently along the same zone of fracturing. One better than half way up the slope, the other on the crest nearly 2,000 feet above the creek. This zone is more than a mile long and southwest of Camas Creek up to 1,000 feet wide. Except for the lowest deposit on the southwest side of the creek, all have been prospected but not developed. The one near the creek has a small production.

The deposits are not restricted to any one formation but occur in both the Chalilis and Casto volcanics and in the Miocene porphyries. Those along the southerly zone of mineralization are all in the Chalilis volcanics, particularly in the coarse tuffaceous rocks in the lower part of the series. Those in the Duck Creek zone are in the rhyolitic flows and tuffs of the Casto volcanics and those southwest of Camas Creek also in the Miocene rhyolitic porphyry. Those in the third, most northerly zone are in the Casto volcanics and the rhyolite porphyry (Fig. 2). The kind of rock and its age apparently have little bearing on the distribution of the fluor spar deposits.

**STRUCTURAL RELATIONS**

The deposits and the zones that contain them mark zones of structural weakness, which as pointed out earlier, are believed induced by deep-seated shear in the basement rocks. These zones of structural weakness trend in northeasterly directions, one not quite parallel to the other. The one along Fluorspar Ridge directed about N.30°E., the one along Duck Creek about N.40°E., and the one below camp about N.55°E. These directions do not accord precisely with the strike of the individual faults or mineralized fractures, most of which extend somewhat obliquely across the zone. As stated earlier, most of the fracturing and fissuring that control the mineralization are directed in the northeast quadrant, with only a few faults or fissures in the northwest. The directions with most influence on localizing bodies of fluor spar are N.30°., N.50°E., N.60°., and N.20°W., exceptionally N.70°E., N.40°E., and N.20°E. Except along the Duck Creek zone, the northeast fractures and their contained fluor spar bodies dip northwest, those of Fluorspar Ridge mostly 55°-40°NW., with a range of 25° to 50°, those south of Fluorspar Gulch 55°-60° NW., and the northeast camp 30°-50°NW., 70°-20° NW. Along Duck Creek the dip is 50°SE. to 80°SE. The fluor spar bodies on the northwest fractures dip 30° SW. to 50°SW. The most important fluor spar bodies are those along fissure-fracture zones of N.30°E., N. 30°E., and N. 20°W. trend.

The individual faults and fracture zones are structurally complex and for that reason the fluor spar deposits controlled by the fractures are also structurally complicated. Although generally dominated by fissuring of some given direction, the deposits may also reflect the influence of minor fractures which branch from or extend into the bordering walls, these fractures conforming in strike with the various sets of fractures mentioned in the preceding paragraph.

Thus a given fracture zone may be a composite of the various sets of fractures, each subordinate to the one that actually controls the elongation of the fracture zone. These subordinate fractures generally extend to the borders of the fracture zone, but any one of them may curve on approaching the border and continue parallel to the main fracture or fissure. In many places the minor sets of fractures strengthen and become the controlling set and cause a change in the trend of the fracture zone. This shift in controlling fractures has induced some marked directional changes in many of the veins (Fig. 4). It has for example caused the Beartrap vein on Fluorspar Ridge to change its course from N.25°-30°E. to N.50°E. and of the nearby South vein from N.20°E. to N.60°E. and then back to N.50°E. The Big Lead on the other hand shows even greater curvature, changing its course from N.20°W. to nearly due West. The North vein also shows a phenomenal change from N.20°W. to due North and then gradually to N.20°-40°E. and finally a little south of East. In so doing the vein literally wraps itself around the crest of a steeply sloping ridge. An even more spectacular change is shown by the ledge on the south slope of Fluorspar Ridge between the Anderson and the M and M. This ledge appears on the slope as a southwesterly plunging, overturned anticline (Pl. 3 B). Along other zones the shifting controls are not so conspicuously shown. One of the veins on Antler Ridge changes its course from N.60° E. to N.30°E. and reverses its dip from steeply southeast to steeply northwest. The one at the northeast end of the mineral zone that crosses Camas Creek below the camp curves as an arc from N.60°-70°E. to N.30°E. Other veins, on the other hand, change
course very little, if at all. In general the various sets of fractures play a vital role in the distribution of the fluor spar and in the structural characteristics of the deposits.

The three zones of mineralization are not especially dominated by any one set of fractures, for the various sets are present in each of the zones, or certain sets may be more conspicuously developed in one zone than in another. In the zone that extends across Fluorspar Ridge, the most significant sets are the N.20°W., N.30°E., and N.50°E., for these control the trends of the largest and most important veins, with some veins influenced by combinations of several sets. South of Fluorspar Gulch the prominent set strikes N.70°E., but some of the veins are contained in the N.30°E. and one of the even more northerly sets. Along Duck Creek the deposits are controlled by the N.60°E. and N.30°E. fractures. In the zone below camp the N.55°-60°E. and N.30°E. fractures dominate.

The cause of so many sets of fractures along the zones of structural weakness and mineralization, with so many of these sets also represented within or making up the individual fault or fracture zone is not fully understood. Analyses of local stress conditions for individual fracture zones and for the entire zone of mineralization suggest that the cause is tied in closely with essentially horizontally applied shearing forces carried up from the deep movement in the basement rocks and that those fractures not directly related to the shear components may be related to shortening or elongation accompanying the shearing. The northwest fractures probably represent the complimentary set of shear fractures. This complicated fracturing provides the setting for and framework of the fluor spar deposits.

MINERALOGY

The mineralogy of the fluor spar deposits is comparatively simple, with barite, chalcedony, and a still unidentified chertlike substance as the only minerals other than fluorite. Stibnite is present at the southwest end of the most southerly zone of mineralization, accompanied by barite, chalcedony, and a little fluorite, but it does not appear in any of the fluor spar deposits. Pyrite is scantily present in the altered wall rock of some of the deposits, but has not been observed with the fluor spar. As mining passes below the zone of weathering, it is possible that inconsequential amounts of pyrite may show up in some of the deposits.

Minerals

Barite.—The barite is known to occur only along the zone of mineralization that extends across Fluorspar Ridge. Its distribution is somewhat sporadic, and, whereas it may be relatively abundant in some deposits, it may be largely lacking in others. This sporadic distribution is also characteristic of the individual deposits, which may lack barite in some parts and contain a relative abundance in other parts. Much of the fluor spar that has been mined has contained 2 to 3 percent barite, but some shoots of fluor spar have contained as much as 10 percent barite and some deposits even more.

The barite occurs as fairly coarse grains and crystals, which exceptionally may measure up to an inch long. These may occur as scattered individuals enclosed in the fluor spar as crystals and crystal aggregates resting on and covered by fluorite. Much of the barite is distinctly glassy in appearance and unless closely scrutinized may be easily mistaken for the fluorite. It is, however, distinguished by its high specific gravity, its good basal cleavage, and distinct orthorhombic crystallization.

Chalcedony.—The chalcedonic variety of quartz occurs in most deposits and is abundant in some. It, too, is sporadic in its distribution and may be conspicuous in some deposits and inconspicuous in others. It may show this uneven distribution even within the same deposit. The chalcedony resists weathering and erosion and is largely responsible for the ledge-forming tendencies of the fluor spar deposits.

The chalcedony is present in both massive and banded forms. The massive is the more abundant form and may occur as irregular bodies from a few inches to several feet thick. It has a chertlike appearance and its color may range from white to gray, exceptionally black. The banded chalcedony occurs as much smaller, usually discontinuous, often broken layers or bands. Although not as abundant as the massive variety, because of its prominent banding, it is much more noticeable. The banding is agate-like, with bands generally less than a tenth of an inch thick. These bands are alternately white and gray or less commonly gray and black. Some of the banded chalcedony is also interlayered with equally thin bands of white cryptocrystalline fluorite or with some thicker layers of more coarsely crystalline fluorite. The banded chalcedony and the cryptocrystalline fluorite are so similar in appearance that they can be told apart only by hardness or other tests.

The chalcedony has varied structural habits. Some of it is in short, discontinuous seams or bands along the walls of the fluorite-filled openings. Some of it surrounds fragments of brecciated and partly silicified country rock, and is in turn surrounded by fluorite. In places the chalcedony shows brecciation with the breccia fragments as inclusions within the fluorite. Minor amounts of fluorite also occur as thin seams or selvages between layers of fluorite and here and there on the fluorite.

Fluorite.—The fluorite is somewhat sporadic in its distribution along the zones of mineralization, but it is the chief constituent of the veins and lodes and occurs in small but variable amounts in most of the ledges or zones of otherwise more or less intensely altered rock. The fluorite is generally associated with zones of silicified rock but not all zones of silicified rock contain significant amounts of fluorite. Because of its chemical stability, the fluorite persists in the outcrop and like the chalcedony tends to impede erosion and produce ledges.

The fluorite is rather varied in its habits. Although most of it is coarsely crystalline, some is finely crystalline and some is cryptocrystalline, like the chalcedony.
cedony. Its color is also varied, but, except on Fluor spar Ridge, is prevailing white with but occasional pale greenish cast on freshly broken surfaces. On Fluorspar Ridge the dominant color is pale to deep purple, but there is also green, white, and locally rose-colored fluorite, all within the same deposit, with the different colors even appearing in the same crystal. The cryptocrystalline fluorite, however, is always white, and the finely crystalline, either white or colored. The green may show transition into the purple, less commonly it occurs in seams which cut the purple.

The fluorite shows considerable variation in textural characteristics. Some of the more coarsely crystalline is massive, especially that which appears to replace the altered rock along Duck Creek and below camp and less extensively elsewhere. Otherwise the fluorite shows coarse banding and crustification with bands commonly displaying radial structures, especially if the fluorite forms concentric shells about nuclei of small breccia fragments of the country rock or fragmented chaledony. Usually the surface of the coarsely crystalline crusts is coated with minute crystals of fluorite, but exceptions occur and the fluorite may form coarse crystal druses.

The cryptocrystalline fluorite has all the textural and structural characters of the banded and non-banded chaledony. It may occur separately but more generally it is intimately interbeded with the chaledony and only the knife blade will reveal which is fluorite and which is chaledony. The cryptocrystalline fluorite generally occurs along the walls of the fracture openings on or interlayered with the chaledony and thus is usually buried beneath layers of more coarsely crystalline fluorite. Locally there is minor interbedding of the cryptocrystalline and the crystalline fluorite. The cryptocrystalline fluorite has a rather erratic distribution. Bands are discontinuous and massed with somewhat irregularly. It is much abundant in the deposits near the crest of Fluorspar Ridge, but occurs sparingly elsewhere in the district.

Paragenesis

Although of simple mineralogy, the deposits have a complicated though not difficult paragenetic development, rather easy to work out because of brecciation phenomena and successive banding and crustification. The chaledony reveals its early formation by its preference for the border zones of the deposits and its basal position with respect to the other minerals. Some of it was brecciated before any fluorite was deposited, but the intimate banding with some of the cryptocrystalline fluorite indicates local overlapping of the silica and fluorite deposition, with the fluorite starting later and continuing after deposition of the chaledony had ceased. In some places a structural break is indicated between the deposition of the cryptocrystalline fluorite and the crystalline fluorite, with the crystalline fluorite cementing small breccias of the cryptocrystalline fluorite. In other places there is interbedding between some of the crystalline and cryptocrystalline fluorite, suggesting an overlap in the deposition of the two varieties of fluorite. But more generally the crystalline fluorite rests directly on the surface of the cryptocrystalline or encloses breccias of the cryptocrystalline variety. The basal layer of cryptocrystalline fluorite is generally less than an inch thick and on its surface rest the scattered crystals and crystal aggregates of barite, both beneath a cover of a much thicker layer of the coarsely crystalline, commonly radially developed fluorite, which may terminate outward in crystal faces. This latter fluorite generally comprises the main filling. The fluorite may in turn be coated by tiny crystals of fluorite or in places by thin films of chaledony.

In summary, the mineral sequence from earliest to latest mineral is chaledony, chaledony and cryptocrystalline fluorite, cryptocrystalline fluorite, cryptocrystalline fluorite, cryptocrystalline and crystalline fluorite, coarsely crystalline fluorite, and finally crystalline fluorite and chaledony. The sequence for the fluorite deposits is not nearly so complicated as that recorded in the antimony-barite deposit where the deposition of early-chal. interbeds. Most of the fluorite was followed by fluorite, then by stibnite and barite, in places again by fluorite, and then by abundant coarse-grained barite, which enclosed and replaced the stibnite and earlier minerals. The deposition of the youngest rocks was from thin fissures usually by hole fractures, which formed irregular masses and also thin seams and stringers in fractures that cut across all minerals, including the late chaledony in the irregular masses.18

STRUCTURE OF THE DEPOSITS

As the deposits are chiefly the product of open-space filling, they reflect the structural characteristics of the fissure and fracture zones that contain them. Filled fissures result in simple veins of lenticular habit, but as the fissures are usually bordered by or are contained in zones of shattered, commonly brecciated rock, the veins form but a part of the filling and the structural characteristics of the deposit as a whole are far from simple. Most of the fissure veins are from a few inches to a foot or more thick, and, unless they are supported by bordering seams or stringers or cemented breccias, they are too small to be of present economic interest. Most of them which occur along the complex fracture-fissure zones might be more appropriately classed as seams. There are a few simple fissure veins larger than most, including one on Antler Ridge which measures up to 4 feet thick, but a vein of this size usually holds fragments and thin slabs of the country rock. Even the smaller veins contain variable amounts of wall-rock inclusions.

The structurally complex deposits contain in addition to the fissure veins or seams many other seams, stringers, and irregular masses in the bordering fractured and generally brecciated rock. The structural complexities are well exemplified by the North vein, which occurs along a zone of fissured and somewhat brecciated and otherwise fractured rock. There are several seams parallel to the main shearing separated by slivers or thin slabs of altered rock. These seams are continuous for 30 to 40 feet and then pinch as the walls close in, only to reappear as the walls again spread apart. In places much unfilled space remains,

surrounded by drusy crusts or druses of fluorite. There are also irregular bunches of fluorite, irregular incrustations in open breccias, and stringer-seams in the bordering rock. The assemblage of seams, stringers, and bunches of fluor spar compose lens-like bodies up to 5 feet thick. The structure of some of the other deposits is even more complicated. Some of the larger deposits, like the Beartrap and Big Lead, contain several seams a few inches to a foot or more thick, aligned parallel to the shearing or fissuring and separated by generally thin slabs of altered rock, with the seams displaying local bulging and thinning, even complete pinching, reappearing again farther on or having their place taken by new seams. The main veins or seams are on the foot or hanging walls. In addition to these seams, which usually contain scattered breccia zones, there are also open breccia zones between 2 and 3 feet thick, parallel or nearly parallel to the fissure seams, which are partly, in some places, almost filled with encrusting fluorite. There are also stringers along fractures, as well as irregular bunches of fluor spar, where replacement has accompanied the filling. Some seams of fluorite usually several inches thick may extend diagonally along the mineralized zone, cutting other seams and stringers of fluor spar. Post-mineral movement parallel to the shearing and occurring along the main boundaries of the bodies has formed slickensided surfaces which serve as commercial walls, although some stringers and seams may occur on the other side.

Complex fracturing along the zone of mineralization below camp has brought about a blocky type of deposit quite unlike the others. These bodies are elongated in the direction of the controlling fracture or fissure, but the fluor spar is held outward along cross fractures with much replacement of the rock between the cross fractures. As a result the bodies have sharply irregular walls with angular block-like protuberances projecting outward for short but variable distances. Because of more extensive replacement than usual, these bodies are not as sharply bounded as those of Fluorspar Ridge.

Some mention has been made previously of the structural characteristics of the fluorite itself. As a filling, the fluor spar usually shows banding or crustification and drusy surfaces. Around breccia fragments, the fluorite may show a concentric structure and may form more or less pronounced ovoid bodies with radial structure and outer drusy surfaces. In some deposits the fissurees and breccia zones are almost completely filled with the banded and concentric fluorite. In some of the small seams the fluorite forms a single band, firmly attached to the under wall. All bands display a more or less conspicuous radial structure. Where openings are completely filled, the fluor spar appears massive, yet retains outlines of the banding and radial structure. Fluorspar that replaces the country rock is massive.

**DISTRIBUTION AND LOCALIZATION OF THE FLUORSPAR**

The fissure and fracture zones may be traced for some hundreds of feet and in some cases for several thousands of feet, but the zones are not persistently mineralized and the fluor spar in them may be localized in shoots only a few hundred feet long. Even within the shoots the fluor spar may have a decided spotty or bumpy distribution, with the fluor spar abundant for short distances and then disappearing almost completely, only to reappear as abundantly as before. Fortunately, along the more important deposits, the bunches of fluor spar are separated by such narrow zones of barren or lightly mineralized rock that stoping can continue essentially uninterrupted and the grade of fluor spar maintained at a fairly high level.

As the deposits are chiefly open-space fillings, the localization of the fluor spar has been determined almost entirely by the occurrence and distribution of openings along the fault or fracture zones. In general, the bodies of fluor spar are localized along the more open parts of the fissure and fracture zones. Such openings must depend on favorable structural conditions for their existence, conditions which have induced separation of the fissure and fracture walls.

Openings along fault or fracture zones usually have been induced by movement along curved or wappled fracture surfaces, and the openings in the Meyers Cove area appear to be no exception. As indicated by grooved slickensides, the movement along the main fractures has been almost horizontal or from the southwest (locally southeast) at rather low angles. Thus any deviation of the strike or dip of the fissure or fracture zone in line with the direction of movement would lead to separation of the fracture walls and formation of open spaces.

If the courses of the various fissure and fracture zones are scrutinized closely, it will be observed that the fluor spar bodies occur where the fissure or fracture zones undergo marked changes in trend. Thus along the complex Beartrap fracture zone the fluor spar shoot makes an appearance as the strike changes from N.30°E. to N.50°E. and continues along the N.50°E. stretch. Before changing course to N.50°E., the fracture zone shows only scattered small discontinuous bodies, bunches, and stringers of fluor spar. The South vein shows a similar behavior with the exposed fluor spar shoot also along the fracture zone where the trend has changed from N.20°-30°E. to N.50°-60°E. At the Big Lead the fluor spar body is along a N.20°W. fissure and pinches as the fissure curves into a more westerly direction. The fracture zone with the North vein, which has even greater curvature than the Big Lead, appears more continuously mineralized, but contains the most fluor spar where the strike changes from northeast to northwest. The changes in strike thus seem fundamental in producing openings for the fluor spar and for determining the length of the fluor spar bodies.

With the changes in strike, there are also changes in dip and these dip changes too are important in creating openings for the fluor spar. In general, the shoots of fluor spar seem to favor the more steeply dipping parts of the fissure-fracture zones and tend to pinch as the dip flattens. At the Big Lead the change in strike to a more westerly direction is accompanied by a flattening of dip and a decrease in the quantity of fluor spar. At the M and M the dip began to flatten and the fluor spar body to pinch
within 40 feet of the surface. Changes of dip along some of the fissure-fracture zones may be a prime factor for the termination of individual fluorspar shoots at depth.

In addition to the openings produced by movement along curved fractures, there are also fracture openings resulting from the tensional components of the shearing forces and these have had a part in localizing some of the seams and stringers that extend obliquely along or across the mineralized fracture zone. Separation of complimentary shear fractures within the zone by movement has also added to the amount of open space. Along the zone of mineralization below the replacement along minor cross fractures has been an important factor in forming bodies of fluorspar.

The local swell and bulges of the fluorspar bodies apparently result from local variations of strike and dip of the hanging and footwall and from branching of the fissures. In general, the fluorspar bodies swell as the footwall steepens and draws away from the hanging wall or as the hanging wall flattens and draws away from the footwall. At the Anderson the thickness of the fluorspar body increases from 3 or 4 feet at the outcrop to 13 feet or more not far below as the footwall reverses dip and pulls away from the hanging wall, which doesn't deviate from its course. At the Big Lead fractures of steeper dip extend into the footwall, the fluorspar with them, and they then become the new footwall of the fluorspar body. On the other hand, fractures of flatter dip may enter the hanging wall and produce outward bulges, and, on steepening, become the new hanging wall. Branch fractures which extend diagonally outward into the walls may increase the available space for fluorspar and thus cause a local increase in the size of the fluorspar body. Minor changes in strike of the hanging wall or footwall may tend to draw the walls together or to separate them and thus induce local thinning or swelling of the fluorspar body. Such changes produce "rolls" and a local thickening of the structure with almost complete exclusion of fluorite. The thickening may then give way to opening with reappearance of the fluorite. Such local squeezing of the walls of the fracture zone apparently account for the local impoverished areas.

Bodies of fluorspar may be expected along the fissure-fracture zones wherever the controlling structural features permit adequate openings for the fluorspar. These structurally favorable areas accord with marked changes in strike and dip and such changes may occur almost anywhere along the fissure-fracture zone. Such changes at depth need not be reflected on the surface. Present exploration has shown that some of the shoots exposed on the surface have a limited vertical range and that other shoots not indicated on the surface may occur at greater depth along other parts of the fracture zone. Drilling at the Beartrap and South veins failed to uncover much, if any fluorspar beneath the exposed bodies but did reveal other bodies along strike projections some distance below the surface. Areas structurally favorable for fluorspar deposition may thus appear at any, as yet unpredictable parts of the fracture zone. If depth be-

comes too great, however, the openings may not be as large and numerous as those nearer the surface, but increased replacement of the rock could well compensate for the decrease in the amount of open space.

SIZE OF THE DEPOSITS

The fluorspar deposits are small to moderately large and range from bodies a few inches thick and a few tens of feet long to bodies more than a dozen feet thick and several hundreds of feet long. Those that have been developed average 4 to 5 feet thick, with much thicker bulges locally, and 100 to 300 feet long. The largest body of fluorspar uncovered so far is the Big Lead with a present stop length of 300 feet and a maximum stop thickness of 16 feet. The minimum stoping thickness at the Big Lead has been 3 to 4 feet. The body has been mined for several hundred feet on the dip, but the lower work is incomplete and the full downward extent of the body is not known. The body seems to be smaller at depth than above where as much as 18 feet of mineable fluorspar appears in the outcrop.

Other bodies are appreciably smaller than the Big Lead, but they are still of good mining width. The Bear trap, probably the largest of these other deposits, averages about 4 feet thick, with local bulges that extend out twice as far, and appears to have a mineable length on the surface of at least 330 feet. The downward extent of the body is not known, for holes drilled to explore the body at depth probably straddled the body. Other bodies comparable in thickness to the one exposed on the surface were cut by the drill elsewhere along the Beartrap structure. The nearby South vein averages about 5 feet thick for its exposed length of 140 feet, with some parts 6 to 8 feet thick. Bodies equally as large or even larger have been revealed by the drill elsewhere along the structure. The North vein averages between 3 and 4 feet thick. The Anderson vein is 3 to 4 feet thick on the surface, but on the adit level has increased to 13 feet. It has been stoped for about 100 feet along the strike. The nearby Anderson Flat vein is 4 to 5 feet, locally 8 feet thick where stoped, but its length is 80 feet. Some other bodies nearby form pods up to 12 feet thick and 20 feet long. Other veins are more like the Beartrap and South veins. The M and N measured up to 8 feet thick, but could be stoped for only 140 feet along the strike and scarcely more than 40 feet on the dip. The unmined Powderhouse vein is from 3 to 5 feet thick for about 150 feet, swelling to 12 feet at the lower end and pinching to a foot or two at the other.

Bodies in other parts of the district are much like those mentioned above. One of the veins on Antler Ridge appears to be 4 to 5 feet thick for about 200 feet, and the Chamaec below camp has a stoping thickness of 6 to 7 feet for about 120 feet. Some other bodies are nearly as large.

The downward range of the fluorspar bodies is still largely unknown, but it is probable that the shoots are as long on the dip as they are on the strike, and, thus, if uneroded, should have downward extensions of 100 feet or less up to 300 or 400 feet.
TENOR OF THE DEPOSITS

The deposits are for the most part fairly rich, but the fluor spar must be milled to obtain a product of acid grade. Some of the veins and parts of some of the lodes are composed almost entirely of fluor spar and on assay show up to 85 percent or more of CaF₂, but it would not pay to mine selectively and hence the average tenor of mineable material is appreciably less.

During the recent operations attempt was made to keep the mill heads above 50 percent CaF₂. With some attention to the composition of the material mined, this grade could be and was more than maintained, although the ease and cost of mining of some of the stopes did permit utilization of material with as little as 40 percent CaF₂, especially when blended with higher grade material from other sources. The deposits are known to contain appreciable reserves of better than 50 percent CaF₂ and tremendously larger reserves of fluor spar that will average 25 to 30 percent CaF₂. No attempt was made to compute actual or potential tonnages of either grade of fluor spar.

WALL-ROCK ALTERATION

The fluor spar mineralization has been attended by widespread rock alteration. Effort was made to map the individual zones of alteration as potential targets in the search for fluor spar, but the project had to be abandoned because the alteration has proved to be too extensive and overlapped and merged with the alteration of the other zones, thus forming one broad general zone, which took in all the deposits of the zone of mineralization. However, the fluor spar mineralization is invariably accompanied by more or less restricted silicification, and the local silified zones, reflected in the topography as low ledges, because of the superior resistance of even the weakly silicified rock to erosion, did provide useful targets suitable for mapping. Consequently, all the more readily discernible ledges of silicified rock on Fluor spar Ridge were mapped (Fig. 4), and these included all the known veins as well as lightly mineralized ledges which might conceivably be the surface reflections of deeper occurring bodies of fluor spar.

The rocks along the zones of fluor spar mineralization are extensively bleached and are white to light gray, except where stained by minor patches of reddish and brownish iron oxides. This bleaching has destroyed the original dark colors of the flows and tuffaceous rocks, except in fringe areas, and has given the rocks a dull, more or less earthy appearance, with the fragmental and porphyritic character of the original rock preserved in the alteration products.

The bleaching appears to be largely the result of very widespread argillic alteration, with limited sericitic alteration largely restricted to the immediate vicinity of some of the fluor spar deposits. The silicification in and along the zones of mineralization contribute somewhat to the light color of the altered rocks, but in places the silicified rock is fairly dark. The staining by iron oxides has resulted from the oxidation of sparsely disseminated grains of pyrite, but the actual pyritic alteration was observed only along the No. 2 adit on the Beartrap. There the pyrite occurs as small grains sparsely but widely disseminated through the bleached rock. Elsewhere the bleached rock is within the zone of weathering and the pyrite, if originally present, has been lost by oxidation.

This general alteration is not limited to any particular kind of rock or rock of any particular age. It affects the flows and tuffs within the Challis and Casto volcanics alike, but may not be as widespread in the Casto rocks as in the Challis, probably because of inherent differences in the porosity and permeability of the two groups. The alteration also extends to some of the Miocene porphyries. Some of the latter are more or less extensively silicified and consequently stand out in bold relief. In places along the Duck Creek and lower Camas Creek zones of mineralization, the silicification in or out of the porphyries has been intense and has formed bodies of nearly pure quartz. On Duck Creek some of the extensively silicified rock has apparently been mistaken and mapped as quartzitic rock of the pre-Cambrian Hoo doo quartzite. West of Camas Creek some of the silicified zones form high-standing cliffs and ledges. Fluorspar bodies may occur near but generally not within the highly silicified rock. Although fluor spar mineralization is invariably associated with silicification, not all silicification is accompanied by fluor spar deposition.

GENESIS OF THE DEPOSITS

In accordance with the generally accepted view, the fluorite and other minerals of these fluor spar deposits are probably of magmatic origin with their source in some magma chamber deep within the earth but not beyond reach of the deep-seated shearing, expressed near the surface by the local zones of structural levels. This shearing apparently reached magmatic levels during the later stages of magmatic differentiation and permitted escape of some of the later magmatic products, such as the granophyre and rhyolite porphyry, and eventually the materials of which the fluor spar deposits are composed.

How the materials of the deposits were concentrated within the magma and in what form they made their escape are matters of interesting speculation, but it is probable that they escaped as compressed gaseous fluids and perhaps remained in that condition until well toward the surface. In view of the widespread argillic alteration, the fluids must have been acidic, and, from the minerals now composing the deposits, must have contained an abundance of fluorine and calcium and considerably lesser amounts of barium, sulfur, and perhaps some iron. Under appropriate physiochemical conditions, these elements combined to form fluorite, barite, chalcedony, and pyrite, but, as the pyrite formed out in the wall rock, it could have obtained its iron from the ferromagnesian minerals of the volcanic rocks.

The formation of the deposits reflects a long, more or less continuous passage of fluids of slightly changing composition along the fissure-fracture zones. The earlier fluids permeated the extensively shattered rock
along the fracture zones and induced widespread argillic alteration. This argillic alteration apparently acted as an advanced level of mineralization and was then followed by the introduction of silica and perhaps meager pyrite, and, although the pyritization probably extended far out into the argillized rock, the silica fumed up along and filled more immediate walls of the fluor spar deposits. The silicon content of the fluids, however, was quite variable and may in part represent the silicon abstracted from the rocks at greater depth. Along most lodes there was only minor silicification, but in some places the fluids were exceptionally enriched in silicon and caused very intense and relatively widespread silicification.

The fluor spar mineralization closely followed the silicification, but only after variable amounts of silica as chalcedony had been deposited in the fissures and other openings. Some of the chalcedony was deposited in massive form, but much was put down in banded, agate-like layers. The fluorite began its deposition before that of the chalcedony was complete and the early fluorite, which in places occurs in cryptocrystalline form, is banded with some of the later chalcedony. Some structural interference, with brecciation, occurred during closing stages of the chalcedony-cryptocrystalline furbite deposition, but then fluorite deposition was resumed, with the fluorite now deposited in more coarsely crystalline form. The fluorite deposition thereafter was not continuous but seemed to follow in waves. After the first wave and sometime thereafter general minor amounts of barite were deposited on the first layer of coarsely crystalline fluorite. Then another wave brought in even larger amounts of fluorite which covered the barite crystals and the underlying fluorite. A final wave brought in only meager amounts of finely crystalline fluorite and in some places a little chalcedony, deposited as thin films on the faces of the late fluorite crystals. Some structural movements continued after mineralization and caused slickensided surfaces on the fluorite, generally next to the walls.

The site of fluor spar deposition could not have been very far below the surface. The abundance of openings in the extensively fractured, fissured, and brecciated rock is indicative of breakage under relatively light load and hence under near-surface conditions. The relatively shallow depth of formation is also confirmed by the widespread banding and crustification of much of the fluor spar and by the presence of chalcedony and cryptocrystalline fluorite, structures and minerals regarded as of epithermal or shallow origin.

Just what the temperatures were when deposition took place is not definitely known, but they were probably not very high. The presence of chalcedony and perhaps the cryptocrystalline variety of fluorite suggest that the fluids were chilled in contact with relatively cold near-surface rocks whose temperatures had not been raised much by the preceding stages of argillic and silicic alteration, unless a considerable period of time intervened between alteration and fluorite deposition. Probably the original temperatures were not very high by the time the fluids reached the levels of deposition. The more coarsely crystalline fluorite and barite suggest more leisurely deposition from probably relatively cool fluids.

Inasmuch as the mineralization followed intrusion of the Miocene group, the deposits can be no older than lower Miocene and therefore were likely formed during the mid-Tertiary epoch of mineralization.

**VERTICAL RANGE OF THE FLUORITE**

Despite the fact that the fluor spar was deposited comparatively near the surface, it has a considerable vertical range, indicated by its occurrence at creek level and on ridge crests more than 2,000 feet above. There is little or no apparent change in the character of the fluorite from top to bottom, except perhaps for some evidence of more replacement and less filling at depth as compared with the top, and certainly nothing to indicate an approaching thermal bottom of the mineralization. The depositional range could well approach and even exceed 2,500 feet.

The inferred vertical range should not, however, be taken as a measure of the downward persistence of the individual shoots of fluor spar, for, so far as yet known, the shoots are all structurally controlled and limited in depth by recurrent unfavorable structural conditions. No shoot has yet been traced from top to bottom. Erosion has removed considerable of the top. It is unlikely that any shoot has a vertical range much in excess of 400 feet and that few would even approach this range. Termination of a shoot at depth does not mean that the bottom of mineralization has been reached, for drilling on the Beartrap and South vein structures has demonstrated conclusively that other shoots do exist at depth, though not necessarily on the projected dip of the exposed shoots on the surface. On the contrary the deeper bodies have been found to the side of the exposed bodies on the surface under the less promising surface exposures with only light silicification and meager scattering of fluorite to serve as possible leakage from the bodies below. Drilling has demonstrated that bodies of fluor spar occur at least 800 feet down dip on the Beartrap structure. With structural conditions permitting, bodies of fluor spar may well appear over the full range of fluorite deposition. Unfortunately, there is no way at present of forecasting the location of the structurally favorable areas, but suffice to say that the downward persistence of the fluor spar appears to depend entirely on structural conditions; namely, on those conditions which permit the formation of structurally favorable openings.

With increasing depth the shoots of fluor spar may not be as large and rich as those at higher levels, unless the decrease in the size and abundance of openings with increasing depth is compensated for by an increase in replacement over filling. The fact that more replacement is evident in some of the deposits on lower Duck and Camas Creeks than in the deposits on Fluorspar Ridge may bear on this problem. However, the deposits along the creeks are in the same-

what stronger, more rigid Casto volcanics which are not so likely to produce large openings as the weaker, less heavily loaded Challis volcanics on the ridges. More precise information on the occurrence with depth can come only with continued exploration and development.

DEPOSITS ON FLUORSPAR RIDGE

The deposits on Fluorspar Ridge are along the most southerly zone of mineralization and are contained in the highly altered, coarsely tuffaceous andesitic and dacitic rocks of the Challis volcanics. They are grouped near or along the crest of Fluorspar Ridge (Fig. 4), with some of the deposits on the upper north slope and some on the south slope, descending well down into Fluorspar Gulch (Pl. 3.A). Those on the north slope include the Big Lead, just under the crest at an altitude of 6,800 to 7,100 feet, and the North vein, a little more than a thousand feet east-northeast of the Big Lead at an altitude of 6,630 to 6,720 feet. Those along the west slope include the Beartrap, which crosses the highest point on the ridge at an altitude of about 7,100 to 7,250 feet, and the Powderhouse, which lies just over the crest overlooking the steep upper slope of Fluorspar Gulch at an altitude of 6,700 to 6,900 feet. The South vein is on the south slope a short distance southeast of the Beartrap at an altitude of 7,000 to 7,060 feet. Other veins are lower on the south slope, the M and M at an altitude of about 6,450 feet, and the Anderson, little more than a thousand feet to the southeast, at an altitude of 6,550 to 6,650 feet.

All but two of these veins, the South vein and the Powderhouse vein, have been developed and all are near or along roads (Fig. 4).

BIG LEAD

History and Development

As the Big Lead, the largest and most productive deposit in the district, is on the wooded north slope of Fluorspar Ridge, it was not found until the late summer of 1942, several months after most of the other deposits on the ridge had been discovered. It was soon explored by hand trenching, later by the bulldozer, and then opened by a short adit to provide fluorspar for the mill under construction in 1943. More bulldozing of the outcrop was carried on by the U.S. Bureau of Mines in 1944, and late in the summer a small amount of fluorspar was mined and used in mill tests.

After the Chamac mines suspended operations late in 1944, the Big Lead was generally inactive, except for some additional stripping in 1946, until 1947, when the Aluminum Company of America drilled eight holes on 200-foot centers some distance below the outcrop, totalling some 2,226 feet of work.

After the Aluminum Company of America stopped its exploration program, the Big Lead received no attention until the summer of 1951, when Fluorspar Mines carried on some more stripping to prepare for open cut mining along a part of the outcrop. At the same time work was started on the No. 1 adit. Mining from the open cut began in June and continued until the approach of winter, when all work was transferred underground. Stopping from the No. 1 level began in October and continued through the winter and spring, providing all the fluorspar supplied the mill during those months. The No. 2 adit was started in May 1952, and by late summer had made connection with the No. 1 level by raise. Until mining ceased in April 1953, much of the stopping was carried through from the No. 2 level to the surface, with fluorspar above the No. 1 level dropped to the No. 2 for removal to the bin.

The underground development complete with stopes is shown in Figure 5. This figure excludes the work of the diamond drill but does show the mine development up to the time work was suspended in 1953. The stopes shown in the figure provided 29,594 tons of fluorspar for the mill, including a small tonnage from the open cut.

Structural Relations

The Big Lead, one of the few deposits not directed by the northeast shearing, trends in a general northwesterly direction on a course that takes the form of a broad arc (Fig. 6). It starts off in a N.20°W. direction and then swings more and more to the west until it is finally on a course that is nearly due West. The outside of the arc is relatively smooth but the inside is marred by conspicuous offsets which project into the hanging wall at small angles that take them in a more southerly direction than the main body. The Big Lead dips to the Southwest at about 40°, but the dip is not constant and in places is as steep as 52° and in other places as low as 28°, the decrease according with the change in strike to a more westerly direction.

The Big Lead occupies a broad fissure-fracture zone of more than usual complexity. The larger and more prominent fractures are those which determine the course of the lead and those which include hanging and footwall fractures and many fractures between. Those along the walls control the roughly tabular character of the deposit. These wall fractures are usually not exactly parallel, especially along the dip and the walls therefore show a tendency to spread apart or come closer together as one or the other flattens or steepens. With a local steepening of the footwall fracture or a flattening of the hanging wall fracture without corresponding changes in the opposite walls, there is local swelling or bulging of the fluorspar body. The wall fractures as well as some of those between show evidence of movement during and perhaps even greater movement after mineralization. Much of the post-mineral movement appears to have taken place along the hanging wall fracture which is everywhere slickensided and grooved, with the grooves invariably dipping about 26°NW. There has apparently been less movement along the footwall fracture which is not so conspicuously slickened and not everywhere so sharply defined. The fractures were originally open fractures of broad,
more or less fissure-like character and now hold much of the fluor spar of the deposit.

Zones of brecciation and lesser fractures occur between the walls, with some fractures also outside the walls. Some of the fractures are parallel to the wall fractures, but most of them dip more steeply, in places with angles up to 65°. These fractures usually terminate on the footwall but some locally extend into and continue in the footwall, curving so as to parallel the original footwall fracture, producing a local downward bulge or thickening of the fluor spar body. Some steeply dipping fractures may also come out of the hanging wall and join the hanging wall fracture. Other fractures may swing out into the walls and then draw back or may terminate outward in the wall.

The grooving on the slickensided fractures is such as to indicate that the movement on the fissure-fracture zone was diagonally upward from the west or northwest and that the footwall has moved obliquely upward relative to the hanging wall. The forces responsible for the movement thus acted from a northwesterly direction and the fracturing that has accommodated the Big Lead is apparently complimentary to the northeast fracturing, which elsewhere has afforded the main control on the mineralization.

Occurrence and Distribution of the Fluor spar

The Big Lead arc may be traced for about 350 feet, but the main body of fluor spar is confined to the more southerly part of the arc and is limited to a length of about 300 feet (Fig. 6). Toward the west-northwest the body decreases in size and the shoot comes to an end, although small recurring shoots up to 4 feet thick and 80 feet long appear farther on (Fig. 6). The Big Lead deserves its name, for it has the largest and most conspicuous outcrop in the district and measures up to fully 18 feet thick in the outcrop and 16 feet in the stopes below. Its thickness, however, is variable and the average is nearer 6 to 8 feet, with stopes terminated where the thickness is no more than 3 or 4 feet.

The occurrence and distribution of the fluor spar is dependent almost entirely on favorable structural openings at the time of fluor spar deposition, with replacement playing a subordinate though in places an important role. The fluor spar is not uniformly distributed through the deposit but is inclined to be somewhat spotty. Its distribution appears to be controlled largely by the distribution and the attitude of the controlling fractures. The fractures which exert the main control are those which define the foot and hanging walls, and their spacing determines the general thickness of the fluor spar body, with minor pinches and swells reflecting the local steepening or flattening on one or the other of the walls. The large swells or bulges are mostly influenced by the more steeply dipping fractures that enter the footwall and then swerve to become the main footwall fracture or by the fractures that extend into the hanging wall and take over as a new hanging wall fracture. The fluor spar along the fractures that extend obliquely into the hanging wall also add to the thickness of the deposit.

The influence of the attitude of the hanging and footwall fractures on the distribution of the fluor spar is quite evident in the stope areas underground. Just below the outcrop the more westerly stope disclose that the footwall dips about 33° and the hanging wall about 26° with the walls 6 to 8 feet apart but that with depth the footwall appears to flatten and draw closer to the hanging wall with the result that the thickness of the fluor spar body decreases to 3 or 4 feet just below the No. 1 level and then pinches out almost altogether not far above the No. 2 level. In the more centrally located stopes the walls race steeper and the footwall, which dips 34°-37°, drops away from the hanging wall, which continues on with a dip of about 32°. The walls continue to separate with depth with corresponding increase in thickness of the fluor spar body and locally, where a footwall fracture steepens to 50° with the hanging wall only to 37°, the body attains a thickness of 16 feet. In the more southerly stopes the 32° dip above the No. 1 level increases to 32° below the level and the fluor spar body becomes larger (Fig. 5).

Some further swelling and pinching have been induced by minor undulations along the strike. Some of these cause the body to take a "roll" accompanied by local pinching, with the body resuming much as before on the other side of the "roll."

Characteristics of the Fluor spar

The fluor spar exhibits considerable variation in its textural and structural characteristics. Some of it has formed by replacement of the altered tuffaceous rock and is massive, but the greater part has been deposited in openings and shows the usual banding of long fractures and irregularly defined concentric structures about rock fragments in breccia zones. The most striking feature, however, is the interbanding of cryptocrystalline flourite with the crystalline fluorite and chaledony in agate-like layers. The cryptocrystalline fluorite is apparently more abundant in the Big Lead than in any other deposit.

Most of the fluorite is coarsely crystalline, purplish, and is generally without crystal faces. The fluorite is accompanied by variable but generally very small amounts of barite.

Outlook

The Big Lead had not been worked out when the mine closed and considerable fluor spar remains above the No. 2 level. Much fluor spar also remains unmined in and just under the outcrop and along the outer edge of the most southerly stope and may be expected to decrease even more with depth and westward along the strike. The best prospects for more fluor spar are in the more southeasterly part of the mine where the dip is steep and appears to increase in steepness with increasing depth. The fluor spar that remains along the side of the stope measures from 6 to 8 feet thick. The structural relations suggest that the fluor spar body may be plunging steeply southeast and that it may extend out beyond
Figure 6. Surface map of the Big Lead vein (adapted from map of U. S. Bureau of Mines).
A. NORTH PIT
Steep floor of open pit with undercut on vein in background. Abrupt change in strike and dip causes the vein to pass into the ridge and beyond the reach of surface mining. Vein has steeply plunging anticlinal structure and wraps around the sides and crest of a low broad, steeply sloping ridge.

B. BEARTRAP
Stripped ground and open cut along the outcrop of the Beartrap vein. Portal of the No. 1 adit visible below the open cut. Vein crosses highest point on Flourspar Ridge.
the face of the No. 2 adit. Development should be extended along and below the No. 2 level. That the fluor spar body lies ahead is indicated by the disclosure of 5 feet of 45 percent CaF₂, about 140 feet south of the present stopes. This fluor spar is revealed by the diamond drill in a hole put down by the Aluminum Company of America from a point about 212 feet horizontally south of the southeast shift of the No. 1 level at an altitude of 7,008 feet. The fluor spar was cut at an altitude of 6,908 feet. Other holes put down apparently straddled or were to the side of the fluor spar body. Properly conducted development should result in substantial increase in fluor spar reserves.

More development is needed to define the limits of the fluor spar body. With increasing depth the body is likely to decrease in size and to contain considerable less fluor spar below than above the No. 2 level. As the localization of the fluor spar has been structurally controlled, the body will probably terminate at depth in unfavourable structural conditions. At present, there is no way of knowing just where this will occur or where another favourable structure will appear.

NORTH VEIN
History and Development

The North vein was not among those explored and sampled by the U.S. Bureau of Mines and apparently received little, if any attention until after the midforties. Some surface stripping was then carried on by the Chamaque Mines, possibly in 1946, but nothing more was done until the Fluorspar Mines, Inc. resumed stripping operations in 1950 and prepared the ground for surface mining. As the body of fluor spar parallels the slope over a considerable area, under slight overburden, the open pit mining was practical and permitted easy and rapid withdrawal of the bore fluorspar to the loading ramp below the pit (Pl. 4,A). The mining of the fluor spar got underway in June 1951 and continued into the autumn, supplying much of the fluor spar that went to the mill. The surface mining continued until a change in strike and dip of the appearance of the fluor spar body caused it to pass abruptly into the ridge and beyond the reach of the surface equipment (Pl. 4, A). The surface operations were suspended in November and nothing more was done, except for the removal of the fluor spar under and around the loading ramp during the summer of 1952.

The extent of the surface work and the relation of the deposit to the slope are shown in the plan and sections of Figure 7. During its brief period of operation, the pit produced 5,561 tons of feed for the mill.

Structural Relations

The North vein shows some extraordinary structural relationships. As it approaches the surface its strike changes rather abruptly from N.20° W. to north and northeast and then to about due east and finally to a little south of east (Fig. 7). This change in course causes the vein to wrap around a low, steeply descending ridge and makes it appear like a steeply plunging anticline, overturned to the west. At its most easterly exposure the vein appears to dip 34° NE. It shows little change in dip westward until it reaches the west side of the pit and makes the sharp bend into the ridge. Then its dip changes from 34°-38° NW. to 40°-45° SW.

The vein is along a fissure-fracture rather than along a zone of complex fracturing and thus its structural relationships seem less complicated than in most of the other deposits. The hanging and footwall fractures are fairly prominent and the vein is well defined. The walls show minor undulations and these undulations bear of the local swelling and pinching of the vein.

As the vein steepens and passes into the ridge, it is no longer accessible to open pit operations, although mining did continue down dip as far as the overhang would permit (Pl. 4,A).

Occurrence and Distribution of the Fluorspar

Parts of the vein have been lost by erosion (Fig. 7), but otherwise the vein may be traced along the surface slope for more than 300 feet. At the site of the stripping operations the vein was 3 to 4 feet thick, in places a little more, and was apparently thicker where the vein made its rather abrupt change of course than elsewhere. From 2 to 4 feet of fluor spar still remain at the upper edge and along the southwest side of the pit.

As revealed in the face of the undercut, the vein appears to have a lenticular habit and the fluor spar filling is thickest where the walls of the fissure are most widely separated. The distribution of the fluor spar, as in most other deposits, depends largely on the distribution of favorable structural openings. Much of the fluor spar is a filling of open spaces and occurs as seams a few inches thick parallel to the walls and separated from one another by splitters or bands of altered country rock. Some of the fluorite also cements or partly cements breccias.

Characteristics of the Fluorspar

Filling is generally incomplete and the vein displays conspicuous banding and crustification, with much nodular and concentric growth around fragments of brecciated country rock. The nodules show rather striking radial development. The fluor spar is coarsely crystalline, mostly purplish with some white and greenish coloration, and shows little, if any, cryptocrystalline development. The fluorite is accompanied by some barite, generally as sporadically distributed crystals deeply encrusted by the fluorite.

Outlook

Some fluor spar amenable to surface mining remains, particularly around the nose of the ridge, but the future operations must depend on the fluor spar not accessible on the surface and the extent of this fluor spar can be demonstrated only by underground exploration. The North vein is reported to have been penetrated by drill hole No. 8 (Fig. 8), put down to explore the Beartrap and South veins, which, if so,
Figure 7. Plan and sections of the North vein (vein material in black; mined fluor spar stippled).
means that the vein has recovered from its local steepening and change of strike and has resumed its more general southwesterly course. The drill is reported to have penetrated 13 feet of 30 percent CaF₂. The downward continuance of the body of fluorspar on the west side of the pit and undercut should be checked.

DEPOSITS NEAR THE NORTH VEIN

Deposits of fluorspar are exposed at a number of places south and east of the North pit, but most of them are small and apparently of little consequence, unless they should mark the leakage from more important deposits below. The locations of most of these deposits are shown in Figure 4, but only the larger ones are singled out for description.

The most impressive deposit is one which crops out at several points on the slope above the North pit. The deposit is actually south-southeast of the pit and several hundred feet above, the highest exposure at an altitude of about 6,920 feet and the lowest on the road at 6,820 feet (Fig. 4). These exposures trace out a vein of northeasterly trend which may be followed in the general direction of its strike for about 100 feet. In the small cut on the highest outcrop the vein strikes N.40°E. and dips 45°-48°NW. The dip carries the vein down the steep slope to the road about 200 feet below. The small cut on the high exposure has uncovered about 10 feet of altered, more or less extensively fractured rock with seams and bunches of fluorite. One of the seams swells into a pod or thick lense of essentially massive fluorite not less than 4 feet thick. Down the slope the vein thins and in a cut about 40 feet below the uppermost exposure contains 1 to 5 feet of fluorspar. Along the road the mineralized zone is about 10 feet across and contains a 6-inch seam of fluorite and some scattered stringers and sporadically distributed bunches of fluorite. Much of the fluorite forms thin drusy coatings on fractures. This fluorite is coarsely crystalline, shows the usual crustiform development, and more than usual surface hardness. The color of the fluorite varies from white and rose to green and purple. In places the fluorite has been slickensided by post-mineral movement, directed along the strike of the vein. The slickensided surfaces dip about 40°NW. in the highest exposures and up to 54°NW. along the road, but the striations and grooves consistently dip about 22°SW.

In the same road bank exposure is another vein, perhaps a branch, of quite different trend and dip. This vein strikes N.65°E. and dips about 60°NW. It is 6 to 10 inches thick in the bank but thickens to three feet in a cut about 70 feet from the road. The vein is filled with coarsely crystalline white, rose, green, and purple fluorite.

Another deposit known as the Little Big Lead lies about 500 feet northeast of the North pit along the upper side of the road that descends to North pit. This deposit, a vein, strikes N.20°W. and appears to dip into the slope at a very low angle, perhaps as low as 5°E. Along a part of its course it forms a fairly conspicuous ledge and may be traced along the surface for about 200 feet and then along the bank of the road for another 30 feet. Some trenching has been done along the lower edge of the ledge. In places the ledge material is as much as 8 feet thick, but it contains only minor amounts of fluorspar. There are, however, bunches and small bodies of fluorspar up to 4 feet thick scattered along the ledge together with much chaledony above and below the fluorspar. Some small stringers and bunches also appear in the road bank.

The rock throughout the immediate area is very extensively altered and small showings of fluorspar may appear wherever the rock shows some evidence of local silicification. One such zone has been mapped about 500 feet east of the North pit. It forms a low ledge about 8 feet across which may be traced in a northeasterly direction for about 60 feet. In it are minor seams, stringers, and bunches of fluorite. Another zone about 60 feet wide, approximately 300 feet north-northeast of the one just mentioned, strikes N.40°E., dips 60°NW., and contains some minor seams and bunches of fluorite through the lower 8 feet of the footwall zone. Some fluorspar mineralization is also present along the abandoned road built for the diamond drill work about 400 feet east of the North pit. The mineralized zone appears to be about 6 feet across and, like the others, contains scattered stringers and bunches of fluorite, with some of the bunches measuring up to 6 inches across.

BEARTRAP

History and Development

As the Beartrap is along an open ridge (Pl. 4,B) and has a fairly conspicuous outcrop, it was one of the first to be discovered, but, except for a few early exploratory cuts and pits and some sampling by the U.S. Bureau of Mines in 1944, it received little or no attention until drilled by the Aluminum Company of America in 1947. The drilling consisted of 8 holes in two rows of four each, one row directly above the other, with the holes on 400-foot centers (Fig. 8). Nothing more was then done until the Spring of 1952 when the outcrop area was stripped by the bulldozer and an open cut started along the outcrop. Work on the cut continued much of the summer and supplied considerable fluorspar to the mill, but the dip of the vein soon carried the fluor spar body beyond reach of the open cut and late in the summer a drift was started in the face of the open cut. This drift tapped the vein after a short distance and considerable fluorspar was stoped through to the surface (Fig. 9). During September work was started on the No. 2 adit (Fig. 10) which was driven northwesterly into the ridge from the upper slope of Fluorspar Gulch at an altitude of 6,380 feet or about 200 feet vertically below and some 300 feet west of the open cut on the outcrop. Work continued on the adit until April 1953, and, when discontinued, the adit was 600 feet long and had 865 feet of drifts (Fig. 10). When it was no longer possible to mine from the open cut and the stopes beyond, the No. 1 adit was started. Work on this adit began in March 1953, and had only progressed 50 feet when fire at the mill ended all work on the property.
All the development on the Beartrap is shown in Figures 8, 9, and 10. Figure 10 also contains geology. From the cut and stope shown in Figure 9, came 1,304 tons of feed for the mill.

**Structural Relations**

The Beartrap is along a prominent fissure-fracture zone which shows a rather conspicuous change in trend from N. 30°E. to N. 50°E., with only light fluorspar mineralization indicated in the more northerly direction and more abundant mineralization in the more easterly direction (Fig. 4). The dip of the zone is 35°-40°NW. The fissure-fracture zone is quite structurally complex and shows the usual fissure fractures parallel to the walls, with the outer fractures forming the walls and with a multitude of other fractures between the walls, some of which parallel the main fractures, but most of which extend transversely or obliquely across the zone. Some of the fractures also extend obliquely outward into the hanging wall and may continue outward for many tens of feet without rejoining the main fissure-fracture zone. The smaller fractures, whether parallel or oblique to the more prominent fractures, dip at angles either higher or lower than those which control the trend and attitude of the fissure-fracture zone. These controlling fractures strike N. 50°E. along the main body of fluorspar. The other fractures belong to the other sets recognized in the district, with the N. 30°E. set locally the most prominent of the subordinate sets. At both ends of the main zone of fluorspar deposition, the N. 30°E. fractures gain in strength and become the dominant set of fractures, taking over control of the fissure-fracture zone as a whole. The other sets trend mostly N. 20°E. to N. 20°W., and N. 60°E. to N. 70°E. Many of these fractures swerve to conform with one set and then another.

The hanging and footwall fractures owe much of their conspicuousness to post-mineral movement which had produced slickensided surfaces, deeply grooved, with the grooves dipping 32° SW. These grooves indicate local upward movement from the southwest with the hanging wall tending to override the footwall.

**Occurrence and Distribution of the Fluorspar**

Although the Beartrap structural zone may be traced along the surface for more than a thousand feet, the mineralization shown on the surface extends along the zone for only about 600 feet, with a probable stope-length of about 330 feet (Figs. 8 and 9). This body of commercial fluorspar is confined to the segment of the fissure-fracture zone of N. 50°E. trend and terminates at either end as the N. 30°E. fractures assume control of the structural trend. The fluorspar mineralization does not die out entirely with the change in trend, but the fluorspar content becomes less and spotty for present economic extraction. Apparently the movement along the complex fissure-fracture zone brought the walls rather tightly together in the N. 30°E. direction and lifted them apart in the N. 50°E. direction, thus providing abundant open space needed for sizable bodies of fluorspar. Along the favorable zones the body is 2 to 6 feet thick, with local 8-foot bulges. The average is about 4 feet. The depth to which the body of fluorspar extends is not exactly known. Drill hole No. 1, which tapped the structure some 500 feet down the projected dip reveals 11 feet of 18 percent CaF₂, but the hole may have merely grazed the edge of the fluorspar shoot, which should extend to 6,000 feet. The southeast of the hole (Fig. 8). The drift on the No. 2 adit (Fig. 10) fell short about 200 feet from reaching the open cut on the southwest end of the fluorspar body. The drift explores the structure dominated by the N. 30°E. fracturing and reveals scattered bunches of fluorspar along the structurally unfavorable zone, which is on the downward projection of the lightly mineralized zone exposed in several small trowel-spots of the open cut. In view of the presence of fluorspar on the No. 2 level, the main body exposed in the open cut might well be expected to continue to the same level, a distance of 800 feet measured on the dip. As the body appears to have been straddled terraces 1 and 2, and 1 and 2 holes (Fig. 8), which are 400 feet apart, the fluorspar may possibly extend considerably below the level of the No. 2 adit.

The body exposed on the surface is not the only one on the Beartrap structure. Other drill holes have disclosed the presence of concealed bodies at depths of 400 to 800 feet below barren surface outcrops. Drill hole No. 3 passed through 6 feet of 59 percent CaF₂ at a depth of 450 feet on the dip of the structure, and drill hole No. 5, 400 feet lower on the dip, penetrated 2 feet of 56 percent CaF₂ at 400 feet, and drill hole No. 4, 400 feet down the dip, 5 feet of 59 percent CaF₂ and drill hole No. 8, down dip another 400 feet, 3 feet of 40 percent CaF₂. The holes are too widely spaced for accurate information on the extent of the fluorspar mineralization, but they do indicate the presence of other fluorspar bodies, possibly similar to the one exposed on the surface.

Within the bodies the fluorspar has a rather erratic and trowel-spotty distribution which provides for more or less continuous stoping. The fluorspar is confined between or occurs along fairly well-defined walls with the thickness dependent largely on the spacing of the hanging and footwall fractures. These fractures tend to close 1 and 2 holes (Fig. 8), which are 400 feet apart, and spread apart depending on local variation in dip and strike. If the hanging wall tends to flatten or the footwall to steepen, then the body widens. This behavior is well displayed in the stope beyond the open cut where the hanging wall dips rather consistently at an angle of 35° whereas the footwall locally steepens to 40°, accompanied by a notable increase in the thickness of the fluorspar body. Steepening of the hanging wall then returns the body to its former size.

Although the spacing of the wall fractures tend to mark the boundaries of the fluorspar body, it does not have absolute control of the distribution of the fluorspar between, which may show marked dependence on the minor fractures. Fairly prominent seams of fluorspar a few inches thick generally extend along the walls, but these seams are usually discontinuous and much fluorspar occurs as seams and stringers along the minor fractures of discordant strike and dip. Consequently, the fluorspar is somewhat epis-
Figure 9. Plan and sections of the Beartrap open cut and No. 1 adit (stope shown by stippling), with cross section of vein showing structural relations of the fluor spar.
Figure 10. Geologic map of the Beartrap No. 2 adit level (in part from company maps).
radic in its distribution and has a tendency to be bumpy or form irregular masses. Some seams and stringers are also directed into the walls and locally may add to the thickness of the body. Some idea of the occurrence and distribution of the fluorite may be obtained from the sketch made of the vein in the open cut just under the outcrop (Fig. 9). The bumpy and otherwise irregular distribution of the fluorite is also well displayed along the drifts in the No. 2 adit (Fig. 10).

Characteristics of the Fluorspar

Some of the fluorite has been deposited by replacement, but most of it is a filling of open spaces along fractures and open breccias and shows the usual banding and concentric structures. The fluorite is coarsely crystalline with little, if any of the cryptocrystalline variety, and is mostly purplish with some white, green, and rose. It is accompanied by some barite and in places by considerable chalcedony, the latter chiefly as a replacement of the altered country rock. Pyrite, as sparsely disseminated grains in the altered rock along the No. 2 adit, was not observed with the fluorite.

Outlook

The Beartrap is regarded as one of the most promising fluorite structures in the district. As yet, it has contributed little of its potential reserve of fluorite. The open cut and stopes have removed but a small part of the outcrop. When the No. 1 adit is extended the full length of the fluorite body, it should give 80 feet of backs at the edge of the present stopes (Fig. 9) and 130 feet of backs at a point 100 feet beyond. This is still considerably short of the northeast end of the shoot. About 200 feet of drifting would be necessary on the No. 2 adit level to undercut the fluorite body exposed in the open cut. Should the fluorite body continue to this depth, the backs would be increased to 550 feet measured on the dip.

The size of the other bodies of fluorite revealed by the diamond drill cannot be assessed from the limited work on them, for the holes are too widely spaced for accurate information on the continuity of the fluorite mineralization. There are no grounds for believing that the concealed bodies should be more extensive than the one on the surface. It is probable that the drill holes, spaced 400 feet apart, have penetrated separate shoots. The drilling disclosures certainly invites exploration by crosscuts, drifts, and raises, directed particularly to the known fluorite occurrences.

SOUTH VEIN

History and Development

As the South vein is ledge forming along part of its course, it is among the early discoveries. Whatever work may have been done along the vein soon after its discovery has since been entirely obliterated by more recent bulldozing. The body of fluorite exposed on the surface has been crossed by the road that extends past the Beartrap eastward to the saddle and by the service road that doubles back below the Beartrap (Fig. 4). Extensive trenching has been carried on above the road to the saddle and farther to the northeast at and beyond the end of the fluorite body. Some work has also been done along the road below on the other end of the shoot. The holes drilled on the Beartrap in 1947 were also prolonged to cut the South vein structure (Fig. 5). The only work since has been a single vertical hole drilled by Fluorspar Mines in the spring of 1953, to probe the downward continuation of the fluorite exposed on the surface.

Except for the trenching and diamond drilling, the South vein is entirely undeveloped. The only production has been several truck loads of fluorite broken along the road by the bulldozer.

Structural Relations

The South vein is much like the Beartrap in its structural relations. It tends to parallel the Beartrap and like the latter changes its course from N.20°-30°E. to N.50°E., with little or no fluorite showing along the surface. The veins until it strikes structure strikes to N.50°E. Its dip as measured along the exposed fluorite shoot is 35°-38°NW.

The vein is along a fissure-fracture zone, apparently similar in every way to the one occupied by the Beartrap. The structural complexities are not well revealed in the outcrop of the fluorite shoot, but are probably little different from those which characterize the neighboring deposit.

Occurrence and Distribution of the Fluorspar

The South vein fissure-fracture zone may be traced for more than a thousand feet, largely by the alignment of roccurring low ledges of more or less extensively silicified and locally erosion-resistant rock. Only one body of fluorite is exposed on the surface but other bodies are known at greater depth by drilling. The one on the surface has a fairly conspicuous outcrop, one that rises several feet above the general surface. It is exposed between the two roads and has a length of about 140 feet (Fig. 4). Where exposed in the upper road the body is 6 to 8 feet thick but decreases to 4 or 5 feet for much of the distance. The shoot continues until it is limited by a structure strike to a foot or two just above the lower road (Fig. 8). The pinching of the fluorite, however, has no appreciable effect on the size of the ledge, which remains broad because of broad bands of chalcedonic silica on both sides of the fluorite, with as much as 5 feet of massive chalcedony on the under side of the fluorite. The body has little depth for the drill hole put down vertically into the hanging wall 125 feet from the outcrop encountered no fluorite. This body may well be the remaining segment of a formerly more extensive shoot lost by erosion of Fluorspar Gulch.

Below the lower road, the ledge is low, generally inconspicuous, in places missing entirely. The course of the vein structure may be traced with little difficulty, however, by the recurrent low ledges, which in places contain minor showings of fluorite. Some
of these sparingly mineralized outcrops may represent the leakage from concealed bodies below revealed by the diamond drill or possibly the roots of shoots lost by erosion.

One of the concealed bodies of fluor spar is penetrated by drill hole No. 2, which passed through 8 feet of 71 percent CaF₂ at a point nearly 1,000 feet below the outcrop, measured on the dip (Fig. 8). Drill hole No. 1, 400 feet southwest of No. 2 and about 290 feet to the north of the body exposed on the surface, passed through 11 feet of 43 percent CaF₂, some 800 feet below the barren outcrop. Drill hole No. 3, 400 feet southwest of No. 1, passed through 4 feet of 61 percent CaF₂. Because of the wide spacing of the holes, it cannot be safely concluded that the same shoot has been penetrated in every case. It is more likely that the holes have penetrated several different bodies, each similar in size and characteristics to the one exposed on the surface. Only adequate exploration will reveal the full extent of the fluor spar mineralization and the size and number of fluor spar bodies.

The fluor spar in the outcrop is coarsely crystalline, shows some banding and crustification, and varies in color from white to purple. Much of it is a filling of open spaces, but some has formed by replacement. Its occurrence and distribution is largely dependent on favorable structural openings.

Outlook

The disclosures made by the diamond drill make the South vein structure one of the most promising in the district and suggest that it contains a wealth of richer fluor spar than the Beartrap. Any development of the South vein structure should be carried on in conjunction with the Beartrap and from crosscuts, drifts, and raises from the north side of the ridge.

M AND M

History and Development

The M and M received little, if any attention until the late summer of 1951, when search was made for deposits on the southward-facing slope of Fluorspar Gulch which might be suitable for winter-time operation. A surface showing of some promise was then further bared by stripping and trenching and the site prepared for underground operations. A road was built to the site and in January 1982, an adit was begun about 70 feet vertically below the outcrop (Fig. 11). This adit passed through the vein structure without exposing any fluor spar and continued some distance on the other side. Drifts were then driven in both directions on the weak zone of fracturing on the projected dip of the vein without encountering any fluor spar of consequence. Raisers were then started from each of the drifts to the fluor spar body on the surface. Only the more westerly raise had reached the surface when work was suspended for the summer. Work was resumed during the winter of 1952-53. The fluor spar reached by the two raises was stopped to the surface. With no more fluor spar in sight the M and M was abandoned.

The workings complete with stopes are shown in Figure 11. During its brief period of mining activity the M and M provided the mill with 1,167 tons of high-grade feed.

Structural Relations

The M and M is along a fissure-fracture zone of northeasterly trend, which for the most part strikes about N 55°-60°E., with local departures up to 20°. The dip as revealed underground is 35°-40°NW. The fracture zone is much like the others and is dominated by those fractures which parallel or closely parallel the zone itself. There are also other fractures of more diverse trend and dip, all of which have had some control on the fluor spar deposition. The most prominent fractures are those which form the walls, their prominence accentuated by post-mineral movement which has produced deeply grooved slickensided surfaces, with the grooves aligned in the direction of dip. The body has been broken by other fractures, some of them also with slickensided surfaces, with grooves dipping 42°SE. The wall fractures are the most important ones, for their attitude and spacing determine the thickness and extent of the fluor spar.

Occurrence and Distribution of the Fluorspar

The M and M fissure-fracture zone may be traced for some hundreds of feet, but the main body of fluor spar had a length of only 140 feet (Fig. 11). For some 50 feet the body measured up to 8 feet thick, but despite its impressive surface showing, the body bottomed within 40 feet of the surface, with less than 2 feet of fluor spar showing at the bottom of the stope and no more than an inch on the adit level. The distribution of the fluor spar may be inferred from the outline of the stope (Fig. 11). The body pinched as the structure flattened, the grooves in this case indicating that the hanging wall had moved down relatively to the footwall. The fluor spar body showed some pinching and swelling, reflecting minor undulations of the walls. The fluor spar had a rather bunched distribution, with the main bunched according with local steepening of the footwall. Minor fractures also influenced the distribution of the fluor spar.

The fluor spar was mainly a filling of structural openings and consisted almost entirely of the purplish, coarsely crystalline variety, accompanied in the eastern part of the mine by considerable amounts of barite, some in coarse crystals coated by thin crusts of finely crystalline fluorite.

Outlook

The fluor spar body apparently represented all that remained of a formerly more extensive shoot lost by erosion of Fluorspar Gulch. As the termination of the fluor spar accords with a local flattening of the dip and thus with a downward change to more unfavorable structural conditions, there appears to be no reason why other bodies of fluor spar should not occur along deeper parts of the fissure-fracture zone should the structure again steepen and thus become structurally favorable for fluor spar deposition. At present there is no way of anticipating where these favorable places should be.
Figure 11. Plan and cross section of the M and M workings, showing vein and stopes.
The cropings of the Anderson veins received no attention until the middle of August 1961, when several hand-dug trenches in the bottom of the steep shallow gulch disclosed several feet of fluorspar beneath a thin overburden. Steps were then taken to develop these deposits as well as the one at the M and M. The Anderson adit along the main body of fluorspar was started in January 1952, and continued to be extended into late Spring when shortage of labor forced a temporary suspension of operations. Another adit was also begun late in the Spring on the nearby Anderson flat vein but had made little progress when work was discontinued for the summer. During the late autumn work was resumed on both adits and continued until the loss of the mill the following spring. During this time 1,686 tons of mill feed were stope from the two bodies of fluorspar. The total work with stopes in plan and section are shown in Figure 12.

Structural Relations

The two bodies occupy fissure-fracture zones of parallel trend but unlike dip and consequently the two structures should come together not far below the main Anderson adit. The two zones strike N.30°E., but the main one dips steeply northwest to vertical and the other, the Anderson "flatt" vein, dips 25°-30° NW. Projected down the dip the flat vein should join the other about 30 feet below the main adit level, where not cut off by a southeasterly dipping fault exposed near the face of the main adit (Fig. 12).

The main body is bounded by conspicuous hanging and footwall fractures accentuated by post-mineral movement with the development of prominent slickensided surfaces. These fractures are several feet apart at the surface and dip about 65°NW., but with depth the footwall fracture steepens and reverses its dip so that near the floor of the adit it dips 75°SE. The hanging wall fracture continues on course and in the adit the walls are 13 feet apart. Slickensides on the footwall show vertical grooves, but those on the hanging wall dip 11°SW. Other fractures of lesser magnitude also occur in and along the body. The more prominent of these are shown in Figure 12. Near the face of the adit the body has been cut off by a fault which strikes N.60°E. and dips 40°SE., and which passes under the adit with increasing depth toward the portal. The fault is marked by a broad zone of broken, gongy ground and appears to be of some magnitude. The direction and amount of movement along the fault was not learned, and consequently, the position of the cutoff segment of the body is unknown.

The flat vein is bounded by fairly prominent walls with boundaries also accentuated by post-mineral slippage. Slickensides appear on both walls, each with vertical grooves and striations. In places horizontal grooves appear on minor slickensided surfaces of fractures not parallel to the walls. The hanging and footwall fractures are essentially parallel but locally show minor strike and dip variations which tend to separate and bring the walls more closely together.

The fracturing that controls the steeply dipping vein appears to have been produced by nearly horizontal shearing forces directed as shearing couples from the southwest and northeast, whereas the fracturing that controls the flat vein appears to be the result of the compressive components of the shearing forces and the product of local thrust action.

Occurrence and Distribution of the Fluorspar

The steeply dipping vein may be traced for about 300 feet up the slope above the portal of the main adit and may continue several hundred feet to the southwest under the excavation made for the portal and the road and then under the overburden on the bank above the road. The fissure-fracture zone may be traced into the gulch several hundred yards to the southwest with reoccurring small bodies of fluorspar to mark its course, but the shoot exposed in the adit is at least 100 feet long and may be longer were its extent known beneath the cut and fill in front of the portal. The main body is 3 to 4 feet thick on the surface, but as the footwall steepens and reverses its dip, the body of fluorspar thickens and along the adit measures up to 13 feet across. As the hanging and footwalls approach each other far back in the stope, the body narrows and becomes too small to mine. The strike and dip of the vein as a whole is controlled by the hanging wall fracture, but the local downward bulge is induced by steepening of the footwall fracture. Stopping so far has been carried to a maximum height of 40 feet above the floor of the adit (Fig. 12).

The flat vein is about 12 inches thick near the portal but traced along the surface thickens and for some 80 feet ranges from 4 to 5 feet thick, with local bulges up to 12 feet thick. The dimensions of the fluorspar body are only partly known. The stope has a maximum width of 40 feet, has been carried for 50 feet on the dip, and reveals 2 to 4 feet of fluorspar along the far wall and at least 4 feet of fluorspar along the bottom (Fig. 12). As usual the thickness of the body depends on the spacing of the hanging and footwall fractures, and an increase in thickness is generally associated with a flattening of the hanging wall fracture.

Near and in more or less direct continuation of the Anderson veins are a number of low ledges of weakly silicified rock, most of them with fluorspar. In several of the more intensely altered areas are thick lenses or chimneys of fluorspar, most of them twice as long as wide. These lie 100 to 300 feet southwest of the Anderson portal (Fig. 4). Several near the portal are as much as 8 feet thick, and one, when fully uncovered, contained 12 feet of essentially massive fluorspar. A hole driven horizontally under the outcrop from road level failed to show any fluorspar, indicating that the body bottoms within a few feet of the surface. Another body 6 feet thick and possibly 40 feet long exposed just short of the gulch bottom nearly 400 feet southwest of the Anderson also had no fluorspar when drilled by a hole inclined upward at an angle of 10° not far under the outcrop.

The fluorspar in all these deposits occurs chiefly
as a filling of open spaces and is coarsely crystalline, purple, green, and white. Some of the fluor spar is banded in thick layers and some unfilled openings are lined with rather coarse crystalline aggregates. The fluorite is accompanied by variable but generally small amounts of barite.

Outlook

Considerable fluorite still remains unmined in the Anderson. The quantity in the flat vein is limited by its intersection with the steeply dipping vein and the fault exposed in the rear of the main adit. On the steeply dipping vein the fluor spar may be expected to continue downward, undiminished in size at least to the fault. Because of the steepness of the structure, the fluor spar might well continue to depth considerably below the fault intersection. It is not known where to search for the faulted segment.

Erosion of Fluorspar Gulch has apparently left little more than the roots and stumps of the presently exposed fluor spar bodies. More fluor spar has apparently been left at the Anderson than in the bodies just to the west. These roots or stumps should not mark the bottom of fluor spar mineralization, but, as elsewhere, merely the local interruption of structural conditions favorable for fluor spar deposition. As along the Beartrap and South vein structures, other bodies of fluor spar may be anticipated somewhere at depth along the general zone of fracturing.

POWDERHOUSE

Because of its well-exposed outcrop overlooking the steep upper slope of Fluorspar Gulch, the Powderhouse was one of the earliest discoveries on Fluorspar Ridge. Except for some surface stripping by the bulldozer, the Powderhouse has been little prospected and is wholly undeveloped.

The Powderhouse is along a fissure-fracture zone of considerable length that extends along the ridge in a northeasterly direction, with actual strike about N.50°E. and dip 30°NW. It seems to be largely independent of some prominent zones of N.30° fractures, which approach from below and direct extensive alteration. This alteration has given rise to broad conspicuous ledges, ledges which seemingly project from the Powderhouse and extend far down into the gulch (Fig. 4).

The fluor spar along the fissure-fracture zone may be traced without interruption for about 500 feet below the road (Fig. 4) and less continuously for some hundreds of feet above the road. The lower course is accentuated by clfflike ledges which stand as much as 10 feet above the slope below. At the road crossing the filling is less than a foot thick, but beginning about 100 feet below, the thickness increases to 2 feet and a little farther on to 4 or 5 feet, particularly in the vicinity of the broad ledges controlled by the N.30°E. fracturing. The filling terminates in a body about 12 feet thick, made up largely of scattered teared layers and stringers of fluorite. The nible part of the body is perhaps 150 feet long and 3 to 5 feet thick.

The fluor spar is largely a filling of open fractures, particularly fissure-fractures along the walls, but there is also some replacement of the bordering rock. Both the coarsely crystalline and cryptocrystalline fluorite are represented, with the coarsely crystalline accompanied by minor amounts of barite, always as an undercrust. Much of the fluorite is purplish, especially that deposited in open spaces, but the fluorite deposited by replacement of the altered volcanics is generally white.

The Powderhouse is worthy of more extensive exploration, especially underground. It appears to be one of the more important occurrences on Fluorspar Ridge, but how much of the fluor spar has been lost to erosion can be learned only by probing at greater depth.

OTHER DEPOSITS ON FLUORSPAR RIDGE

Many other ledges or mineralized fracture zones crop out on the south slope of Fluorspar Ridge, some of them on extensions of the zones of mineralization already mentioned and some of them along entirely different zones. Most of them contain small amounts of sporadically distributed fluor spar. This fluor spar could represent leakage from larger deposits at lower levels or vestiges of deposits lost by erosion.

Many small veins a few inches thick and a few feet long appear on the crest of Fluorspar Ridge near the Big Lead and others appear on the slope to the south and west. Several veins of larger size occur on the east side of the steep gulch south of the Powderhouse (Fig. 4). Several of the lightly mineralized zones form conspicuous ledges above and below the road between the top of the ridge and the M and M and the Anderson.

Several deposits on the slope below the Beartrap are singled out for more detailed description. One of these is along the road at the very east edge of the mapped area at an altitude of 6,620 feet (Fig. 4). This deposit, exposed in the road bank, is notable because of the relative abundance of barite. The body may be traced up the slope for only a short distance, but appears to be directed by a small but complex fracture zone about 6 feet wide which strikes N.30°E. and dips 55°NW. Grooves on slickensided surfaces dip 65°SW. The fractures within the zone contain seams of barite 1 to 2 inches thick. On some of the fractures the barite forms drusy crusts. The rock bordering the deposit is extensively bleached and along the deposit itself somewhat silicified.

Another weak zone of mineralization occurs across the gulch southwest of the barite exposure at an altitude of 6,540 feet (Fig. 4). The surrounding rock is extensively bleached and in the fluor spar zone weakly silicified and stained by reddish and brownish iron oxides. The bleaching appears to be controlled by N.30°E. fracturing but the small body of fluor spar, which may be traced for about 12 feet, strikes N.40°E. and dips steeply northwest into the ridge. The mineralized zone is 4 to 5 feet thick and contains several seams of fluorite 6 to 12 inches thick.

Another deposit near the mouth of the steep gulch which descends from the Powderhouse has been deeply trenched by the bulldozer (Fig. 3), but, although appreciable amounts of fluor spar appear in the outcrop northeast of the cut, the bulldozer revealed nothing but highly altered rock.
Figure 12. Plan and section of the workings at the Anderson.
Figure 13. Sketch showing distribution and relations of veins south of Fluorspar Gulch.
DEPOSITS SOUTH OF FLUORSPAR GULCH

The deposits south of Fluorspar Gulch are mostly in the main valley of Camas Creek about a mile above camp, along and on the fringes of the general zone of mineralization that extends across Fluorspar Ridge. Several are aligned along one fairly prominent fissure fracture zone and several others are known in more isolated occurrences. These are along the road that goes up to Fluorspar Ridge, not far from the junction with the road that goes to camp (Fig. 3).

The main mineralization is on the nose of the ridge just south of Fluorspar Gulch, facing Camas Creek (Fig. 3). This mineralization is along a zone of complex fracturing that begins near creek level and extends up the ridge about a thousand feet to an altitude of about 600 feet above the road to camp. The zone is well exposed along the banks of both the camp and mine roads and not so well exposed in three groups of trenches on the slope above (Fig. 19). This zone of fracturing and mineralization trends about N.72°E. and dips steeply northwest, with bodies of fluorite occurring here and there as small shoots along the zone but mostly in fractures which extend obliquely across or out from the zone in more northerly directions. The zone as a whole is comparatively narrow and contains appreciable amounts of fluorite in only a few places; namely where cut by the road to the deposits on Fluorspar Ridge and to lesser extent in the trenches some distance above.

In the bank of the road to camp the zone shows only minor fracturing, rather intense alteration, and no fluorite. Some fluorite does show up in a small cropping along a short distance from the road, but this is the largest exposure is along the road to Fluorspar Ridge, where the road cuts directly across the mineralized fracture zone. The body is 12 feet across, strikes N.70°E., and dips 60°NW., but the structural relations are complicated by the presence of transverse veins which strike N.30°E. and dip 60°NW. These veins do not extend outside the borders of the mineralized zone and are probably the cause of the local bulge in the deposit. The fluorite is mostly a filling of fractures a few inches wide and the body as a whole does not contain as much fluorite as one might think. The length of the body is not disclosed, for there is no surface exposure above the road bank. Slickensides on some of the post-mineral fractures have vertical grooves; on others the grooves dip steeply southwest.

The bulldozed trenches on the slope above the road reveal little fluorite (Fig. 13). In the lowest trench the face is obscured by slide debris, but blocks of fluorite 1 to 2 feet thick had been moved by the bulldozer. Similar blocks also appear in the upper trenches, where again the face of the cuts are concealed by slide debris from above. Some veins, however, are revealed in the middle and upper trenches, but these veins are along oblique fractures. In the lower of the two trenches comprising the middle group an 8-inch vein strikes N.15°E. and dips 60°NW. It has been exposed for only a few feet. The vein in the other trench is 1 to 2 feet thick, strikes N.30°E., and dips steeply northwest. Both veins contain coarsely crystalline greenish fluorite; elsewhere the fluorite is white. Another oblique vein also appears in the upper trench, but the best exposure is another vein in the cut above the trench along the main zone of mineralization. The vein in this cut strikes N.72°E., dips steeply northwest, and has been uncovered for a distance of 8 feet. The vein is about 12 inches thick in the cut. Above the cut the vein loses its identity in a prominent ledge which continues on a short distance up the slope.

Some float appears on the south side of Fluorspar Gulch more or less in line with the oblique veins exposed in the trenches. These may possibly be along a narrow zone of fracturing along or near the nose of the ridge.

Two other veins are known or are indicated by small croppings of fluorite in altered rock near the junction of the mine and camp roads. One appears high in the bank above the mine road in the midst of much altered rock; the other in or near resistant ledges of altered rock just south of the road junction.

The fluorite mineralization south of Fluorspar Gulch appears to be generally weak and spotty, with few bodies of fluorite of appreciable size. The largest and best exposure is the one cut by the road to the deposits on Fluorspar Ridge.

DEPOSITS WEST OF CAMAS CREEK

The deposits west of Camas Creek include those belonging to the zone of mineralization which crosses the creek less than a mile below camp and also those occurring as an extension of the Duck Creek zone. These deposits are all within the Casto volcanics or in bodies of Miocene rhyolite porphyry and granophyre, which intrude the volcanics. The deposits along the zone of mineralization below camp have been prospected along a series of switchback trenches (Pl. 5.A) bulldozed by the U.S. Bureau of Mines in 1944. The only development has been on the Chamac (Red Spar claim) which lies at the base of the slope only a little above creek level (Fig. 14).

CHAMAC

History and Development

Because of conspicuous ledge outcrops, the fluorite bodies at the Chamac were among the early discoveries and among the first in the district to be developed. When the mineralized zone was trenches by the U. S. Bureau of Mines in 1944, much of the local mineralized area not exposed in clifflike outcrops was stripped of its cover. Soon after, Chamac Mines drove the Chamac adit in the main body of fluorite near the base of the slope, storing the fluorite mined in the bin until needed for the mill test. On completion of the mill tests in the early autumn of 1944, work in the adit stopped and was not resumed until the winter of 1952-53, when Fluorspar Mines, Inc., stumped 404 tons of fluorite-bearing material from above the adit level.

The complete development in plan and sections, with geology on one plan, is shown in Figure 15.
The fluorspar has also played an important role in directing the mineralization and particularly in influencing the thickness of the fluorspar bodies developed along the major zones of fissuring. These minor fractures are transverse fractures with most of them striking north-northeast and a few northwest (Fig. 15). Most of those in the northeast quadrant strike N.5°-15°E., exceptionally N.25°E. and dip 70°-80°NW., less commonly 70°-80°SE., and those in the northwest quadrant strike about N.10°W. or N.60°W. and dip 70°NE.

Occurrence and Distribution of the Fluorspar

The fluorspar occurs in more or less tabular or veinlike bodies along the general zone of fissuring and fracturing, with four of them large enough to be mapped (Fig. 15.) Although essentially tabular, the bodies are in part sharply irregular and show numerous angular bulges and restrictions, reflecting the influence of the minor fractures in directing the fluorspar outward into the walls. Replacement of the rock along and between these transverse fractures has given rise to the blocky character of the deposits, so well displayed along the adit level before any of the fluorspar was stope (Fig. 15).

Description of the Fluorspar Bodies

The body in the Chamac adit may be traced for about 140 feet on the surface and for 120 feet underground. It is in part along the contact between the volcanics and the rhyolite porphyry and in part wholly within the porphyry. Its trend changes from N.50°E. well back in the adit to N.60°E. near the portal (Fig. 15). Its dip varies only a few degrees, being 72°NW. at the portal and about 68°NW. back in the stope. As shown on the geologic map of the adit level (Fig. 15), the body has a prominent blocky development along cross fractures, but with its bulges and pinches averages 6 to 7 feet thick. Some of the fluorspar was stope from the portal to a point about 90 feet in, but this work done mostly back in 1944 did not extend for more than 10 or 15 feet above the floor of the adit. The stoping in 1952-53 began about 90 feet from the portal and continued on for 58 feet reaching a maximum height of 50 feet above the level (Fig. 15). The fluorspar in this stope was of excellent grade and averaged well over 50 percent CaF₂. The fluorspar out to the portal is also high grade (50 to 77 percent CaF₂ over widths of 3 to 6 feet), but the backs are limited because of nearness to the surface.

A smaller body about 30 feet long and up to 5 feet thick is exposed on the surface about 12 feet north of the vein in the adit. This body lies in the porphyry with the surface exposure at about the level of the first cut above the portal of the adit at an altitude of about 5,140 feet (Fig. 15). This body has a more easterly trend than the one in the adit, striking about N.70°E., and may join the other in the first short crosscut on the adit level. According to the U.S. Bureau of Mines records, a 2.2-foot sample across the lower end of the body contained 56.63...
Figure 15. Geologic maps and section of the Chamae mine.
Characteristics of the Fluorspar

The fluorspar occurs both as a filling of open fractures and breccias and as a replacement of the highly altered porphyry and volcanics. In places it shows some ill-defined banding, in part in concentric growths about fragments of the country rock, but most of it is massive and without the crustification and drusiness so characteristic of the fluorspar on Fluorspar Ridge. Much of the fluorspar is coarsely granular. Some of it retains poorly preserved inclusions of the silicified country rock, largely destroyed by replacement. The fluorspar is colorless or white, but some of it has a pale greenish cast on freshly broken fractures. It is accompanied by considerable amounts of chalcedony and is in part a replacement of the chalcedony. Because of its white color, the fluorspar is not so easy to recognize, especially underground, and the material mined is of higher grade than anticipated.

Outlook

The body in the adit is probably the largest single source of fluorspar at the Chama. The fluorspar may not continue much beyond the present far face of the stope, but much of it from the portal to the stope is probably of stopping grade and more probably remains to be stoped than has already been stoped (Fig. 15). The depth to which the fluorspar may extend has not been determined, but the fluorspar may be expected to persist some distance below creek level. Any work below the adit level will have to be carried on from winze or shaft. A drift at creek level would provide an additional 30 feet of backs. According to report a large mass of fluorspar was uncovered in the creek channel while excavating for the bridge. This fluorspar was reported in bedrock and has since been covered by stream deposits. The presence of this fluorspar suggests that the vein may have a much greater length than now revealed on the surface.

The two small bodies near the Chama adit should provide stope lengths of 20 to 30 feet. The larger body at the top of the ledge should be explored by the drill, and, should drill disclosures warrant, by an adit drift. The Chama adit should not be extended beneath the outcrop of this body until work at higher levels has demonstrated the position and downward extension of the fluorspar.

OTHER DEPOSITS

A number of bodies of fluorspar occur along the slope above the Chama and a few also on the steep slope above camp, but only those near the Chama have been prospected, mainly by the bulldozer trenching carried on by the U.S. Bureau of Mines (Fig. 15). Despite the names of the claims as “Red Spar” and “Purple Spar”; the fluorspar in all the deposits is white.

The first of these bodies revealed by the bulldozer (Red Spar No. 2) is due west of the Chama along the northwestern edge of the map (Fig. 15) at an altitude of about 5,580 feet. The general zone of alteration trends north rather than northeast and may be traced for about 200 feet. Except for a distance of about 100 feet, the zone appears to be completely lacking in fluorspar. Two small veins in the
projects high above the slope. Some of the fractures show nearly flat grooves of slickensided surfaces or grooves that dip west at very low angles. The porphyry is also cut by a series of northwesterly trending faults of minor magnitude.

DEPOSITS NORTH OF DUCK CREEK

The deposits north of Duck Creek are along the zone of mineralization that crosses Camas Creek less than a mile below camp and are simply on an extension of the mineralized zone that contains the Chamac and other deposits on the southwest side of the creek. These deposits are on the Camas and not the Duck Creek slope, with one, however, on the ridge between the two. The deposits have been explored by a series of switchback trenches (Pl. 5, B) bulldozed by the U.S. Bureau of Mines during 1944. This trenching is also shown in Figure 15.

The trenching has uncovered two rather widely scattered bodies of fluor spar along an extensive, in part discontinuous zone of alteration and mineralization. One of the disclosures is a little over half way up the slope at an altitude of about 6,050 feet, the other on the ridge crest at an altitude of 6,870 feet. This zone of alteration and mineralization may be traced for about 2,500 feet horizontally, including a 500-foot length where all rock exposures are concealed by deep overburden.

The general zone of alteration and mineralization trends N.60°-65°E. and dips 55°-60°NW. This zone cuts the rhyolitic flows and tuffs of the Casto volcanics and a body of granophyre, exposed just below the crest (Fig. 15). Bleaching as a result of argillic alteration is widespread and locally intense. Silicification has also been intense in places and has produced a number of ledge-forming outcrops, one in the saddle across the ridge and several on the slope below. The alteration and mineralization have been directed along a zone of complicated fracturing with the fractures prominently displayed in the areas of fluor spar mineralization.

In the lower exposure scattered lenses of fluor spar 20 to 50 feet long crop out for about 260 feet, with the best showing in two bodies, one about 35 feet and the other about 20 feet long. The larger of the two measures up to 4 feet thick and according to sampling records contains material with 60 percent CaF₂ across widths of 2 to 3 feet. Two parallel lenses in the cut 100 feet below contain up to 20 percent CaF₂. Where exposed in the side of the trench the main body appears to strike N.45°E. and dip 60°NW., thus somewhat obliquely across the general zone of mineralization. Some fluor spar also occurs along N.10°E. fractures. Most of the fluor spar is white, but some is bright green.

The second and smaller of the two bodies lies a short distance above the first. This 20-foot long body strikes N.60°E. and dips 60°-70°NW., parallel to the general zone of mineralization. It contains some mineralized cross fractures that strike N.5°W. and dip 75°SW. The mineralized zone locally is up to 15 feet across, but most of the fluor spar is concentrated in a lenticular body 2 to 3 feet thick. This body contains up to 60 percent CaF₂. The fluor spar, and variscite in respective fracture surfaces but in part fills the fractures completely.

Bodies of lower grade material with 20 percent or more but less than 50 percent CaF₂ are also shown on the map (Fig. 15). These several shoots of high and low-grade fluor spar compose a vein about 150 feet long.

The fluor spar body at the top of the slope is on the lower side of a shallow saddle and forms a part of a prominent ledge 10 to 50 feet wide and 10 to 15 feet high. The vein and ledge are curved, with the strike changing from N.60°-70°E. on the western side of the saddle to N.30°E. on the eastern side. The dip appears to be about 50°NW. The fluor spar body is about 100 feet long, if a smaller 30-foot extension at its southwest end is also included (Fig. 15). Its thickness measures up to 6 feet, with blocklike protuberances tending in places to make it appear much thicker.

The rock locally has been completely fractured, with the fracture system preserved in the ledge matter. These fractures fit into the general N.30°E., N.10°W., and N.20°W. sets, each dipping 47°NW., 70°SE., and 70°SE., respectively. There are also the N.60°-70°E. fractures. Each of these sets has had some control on the mineralization, not only in changing the trend of the body from N.60°E. to N.30°E., but also in inducing a block development of the body, with the fluor spar forming outward bulges along and between the cross fractures. Samples taken by the U.S. Bureau of Mines along the main 70-foot segment of the body show, with few exceptions, 60 to 70 percent CaF₂ across widths of 3½ to 5 feet.

The fluor spar is white or colorless in part cryptocrystalline, and is largely a replacement of the fractured, silicified rock. A little of the fluor spar shows banding and other evidence of deposition in open spaces, but most of it is massive and has made way for itself by replacement. Some chalcedony has also been introduced with the fluor spar.

DEPOSITS ALONG DUCK CREEK

Two groups of deposits are known along Duck Creek, one near the mouth of the creek on the lower slope of Fluorspar Ridge and the other at the lower end of Antler Ridge, about a mile above camp, (Fig. 2 and 3). The first or lower group is on the Morning Sun claim, but the name of the one on Antler Ridge was not learned.

MORNING SUN

The Morning Sun veins are on the south side of Duck Creek about 900 feet east and 300 feet above the former mill at an altitude of 5,400 feet (Fig. 16). The veins lie between the trenches bulldozed by the U.S. Bureau of Mines and appear in low cliffs and ledges. These veins are further exposed in several

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shallow cuts, and one of them also in a 10-foot adit.

The group consists of six short veins grouped along a zone of extensively fractured and altered rock belonging to the Casto volcanics. The veins are near but do not extend into the body of Miocene rhyolite porphyry on the slope just above the former mill (Fig. 16). Neither do the veins reach a very high, precipitous ledge of reddish and brownish iron-stained silicified volcanic rock just east of the trenches. This ledge which extends down the slope in a northwesterly direction apparently carries little, if any, fluor spar and appears to be controlled by short north-easterly trending fractures arranged en echelon. The zone of alteration and mineralization along which the veins occur trends in a northeasterly direction approximately parallel to Duck Creek.

The largest vein is exposed in the front and top of a low cliff, in several cuts on either side of the cliff, and in the face of a 10-foot adit driven in the base of the cliff. The vein strikes about N.60°E., dips 50°SE. and may be readily traced for about 90 feet with much of the fluor spar in a segment about 30 feet long on the side and top of the cliff. On the cliff it appears to be made up of two parallel bodies of fluor spar, each 4 to 5 feet thick and spaced about 8 feet apart. The body in the short adit is 4 feet thick and is composed of white, coarsely crystalline, in part slightly banded fluorite which occurs chiefly as a replacement of a coarse breccia.

Three other veins are exposed about 250 feet northeast of the one just described in line with and possibly as split branches, although they cannot be traced back to the first because of heavy overburden. They are, however, along the same broad zone of fracturing. These veins are also exposed across low cliffs and ledges, but cannot be traced for more than 20 or 30 feet. They strike northeast but perhaps in a more northerly direction than the main vein to the west. They dip 60°-70°SE. The veins are narrow, generally less than 12 inches, but one swells locally to 3 feet.

Two other bodies are exposed less than 100 feet east of the three and at a somewhat higher level. The nearest is exposed in a steep but short ledge and shows 3 feet of fluor spar. Its trend and dip could not be determined. The second also is ledge-forming and may be traced N.65°E. along its strike for about 20 feet. Its dip is 67°SE. This body contains about 8 feet of fluor spar-bearing material.

ANTLER

The veins on Antler Ridge are at the very west end of the ridge just above the forks of the creek and appear on the south slope from near creek level to near ridge crest. Except for some barely discernable location cuts, the veins have not been explored, a procedure hardly necessary in view of the excellent surface exposures.

There are but two veins exposed on the surface, but the presence of others is indicated by float. These veins are in an area of intense and widespread hydrothermal alteration. The rocks have been so thoroughly bleached and in some places so intensely silicified that they tend to stand out in bold relief and resemble quartzitic rock. The country rock locally is composed of rhyolitic flows and tuffs of the Casto volcanics and several small bodies of Miocene granophyre.

Veins that are exposed trend in a northeasterly direction, but, unlike so many veins of the district, dip steeply and even show reversal of dip. The largest vein lies several hundred feet above the south fork of the creek and for some distance stands out in high relief. Both walls have been eroded away from the upper end of the vein and for about 100 feet the bare vein projects upward like a wall, rising as much as 20 feet above the surface. Downslope the ledge lowers and in places disappears. Along the lower slope the vein strikes N.60°E., and dips 80°SE., but up the slope where it projects boldly above the surface the strike changes to N.30°E. and the dip to 80°NW. Altogether the vein appears to be about 250 feet long and to contain about 200 feet of fluor spar-bearing material. The part that projects above the surface is 4 to 5 feet thick and is composed largely of white fluorite. The remainder of the vein may not be quite as thick and may contain more abundant inclusions of the altered country rock. The second vein lies below and a short distance east of the first and appears as though it may be arranged en echelon. The vein is exposed just above the creek and may be traced up the slope for about 100 feet, partly as a low ledge. This vein, like the lower end of the first, strikes N.60°E. and dips 80°SE. It contains up to 3 feet of fluorite.

Float elsewhere on the slope include chunks of fluor spar up to a foot thick.
Figure 16. Topographic and geologic map of camp area showing distribution of the fluorspar deposits (Casto volcanic and alluvium undifferentiated).
Figure 4. Topographic-geologic map of the Faintour Ridge area showing distribution of veins and more prominent alteration zones.
Figure 5. Plan and sections of the underground workings at the Big Lead.
Figure 8. Plan and cross sections of the Beartrap and South veins (based in part on diamond drill records and company maps).