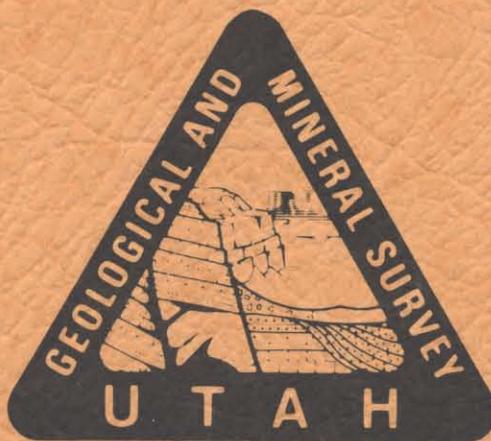


GEOLOGY OF THE
FLUORITE OCCURRENCES, SPOR MOUNTAIN,
JUAB COUNTY, UTAH

by Kenneth C. Bullock



UTAH GEOLOGICAL AND MINERAL SURVEY
a division of the
UTAH DEPARTMENT OF NATURAL RESOURCES

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UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108

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GEOLOGY OF THE FLUORITE OCCURRENCES, SPOR MOUNTAIN,

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by K. C. Bullock¹

ABSTRACT

Uraniferous fluorspar deposits of Tertiary age are found mainly in Upper Ordovician and Middle Silurian dolomites. These fluorspar deposits, regarded as epithermal in origin, occur predominantly as breccia pipes in dolomite adjacent to faults and intrusive rhyolite breccia bodies. Minor occurrences are veins in dolomite, disseminations in volcanic rocks, and mineralized intrusive rhyolite breccia plugs and Paleozoic landslide breccias. More than 99 percent of the ore has been produced from breccia pipes in dolomite. The shipped fluorspar ore consists of 60 to 95 percent fluorite, which is intermixed with variable amounts of montmorillonite, chalcedony, quartz, calcite, and dolomite. The ore may be white, bluish, purple, green, tan or reddish brown. There are five types of ore in the fluorspar deposits: (1) pulverulent, (2) boxwork, (3) crystalline, (4) aphanitic, and (5) sponge fluorite. The first two types constitute the bulk of the ore. Pulverulent ores are typical of near surface weathered portions of breccia pipes, whereas boxwork type ores are more common to unweathered or deeper ores in the breccia pipes. The boxworks are composed of a network of fluorite veinlets around dolomite fragments within the breccia pipes. Hydrothermal fluids subsequently dissolved the dolomite fragments and left open vuggy spaces. At the same time or shortly afterwards many voids have been partly or completely filled with younger generation minerals. The form and location of the fluorspar ore bodies have been determined by stratigraphic, lithologic, structural, and chemical controls.

INTRODUCTION

Location and Accessibility

Spor Mountain is one of three topographic units which comprise the Thomas Range in west-central Juab County, Utah. It lies immediately northwest of Topaz Mountain, within Townships 12 and 13 South, Range 12 West, Salt Lake Base and Meridian. The area is accessible from U. S. Highway 6, 8 km southwest of Lynndal and 18 km northeast of Delta. An asphalt haulage road used by Brush-Wellman, Inc., extends 70 km to the northwest from U. S. Highway 6 to the southern end of Spor Mountain. Improved dirt roads extend along the eastern

side and southern end of Spor Mountain, and several unimproved roads provide access to the area. Spor Mountain is 78 km from Lynndal and 88 km from Delta on paved roads.

Physical Features

Spor Mountain is a small topographic landform of the Basin and Range Province, about 160 km west of its eastern boundary. Spor Mountain forms the southwestern part of the Thomas Range, and is separated from the main range by The Dell, a valley 1 to 3 km wide. Spor Mountain trends north then northwest, and is somewhat arcuate in shape. It is 9 km long and as much as 4 km wide. Its highest peak has an elevation of 2007 m, and the mountain has a local relief of about 500 m.

Along the eastern side of Spor Mountain, especially the central and northern parts, the topography is steep and rugged with V-shaped valleys; whereas the western slopes are more gentle. Along the southern and western sides, low hills protrude through sand and gravel cover of Lake Bonneville beds. Lake terraces of sand and gravel, as much as 15 m high, are found at the mouths of valleys, and wave-cut benches are prominent in the southern part of the mountain.

Previous Work

Spor Mountain attracted little geologic attention until 1941 when a fluorspar deposit was staked by George Spor and sons on the southeast side of the mountain. Some geologic mapping of a few fluorite deposits was done in the 1940's by W. R. Thurston for the U. S. Geological Survey; W. P. Fuller for North Lily Mining Company, J. J. Beeson for U. S. Steel Corporation, Geneva, Works; and James Quigley for Chief Consolidated Mining Company. The fluorite district was first briefly described in literature by Fitch, Quigley, and Barker (1940, p. 62-66). Bauer (1952, 47 p.) made a geologic study of the Lost Sheep mine. The Union Pacific Railroad Company made investigations by Cochran (1952, 78 p.) and by Chojnacki (1964, p. 131-164). Descriptions of known fluorite deposits were made by Thurston, Staatz, and Cox (1954, p. 24-35). A preliminary geologic study of the Thomas Range was reported by Staatz and Osterwald (1956, p. 131-136), and a detailed study was made by Staatz and Carr

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(1964, 188 p.) A detailed study of the geology of the Thomas Range fluorite district was made by Staatz and Osterwald (1959, 97 p.); and Bullock (1976, p. 24-56) gives a detailed account of all known fluorite deposits in the district.

Uranium was discovered in The Dell on the east side of Spor Mountain in 1953 and is present also in the Spor Mountain fluorite deposits. Published reports relative to uranium mineralization include: Bloecher (1952, 23 p.); Staatz and Osterwald (1959, p. 52-59); Bowyer (1963, p. 15-22); Cohenour (1963, p. 4-7); Staatz and Carr (1964, p. 130-157); Leedom and Mitchell (1978, 22 p.); Lindsey, Naeser, and Shawe (1975, p. 597-604); Lindsey (1978, p. 29-30; 1979, p. 65-79); and Ludwig and others (1980, p. 221-232). Beryllium deposits in tuffs at Spor Mountain were discovered in 1959, and studies related to these occurrences include: Staatz and Griffiths (1961, p. 941-950); Montoya, Havens, and Bridges (1962, 15 p.); Cohenour (1963, p. 4-7); Griffiths and Rader (1963, p. B16-B17); Staatz (1963, 36 p.); Williams (1963, p. 36-59); Shawe (1968, p. 1149-1161); Park (1968, 105 p.); Lindsey, Ganow, and Mountjoy (1973, 29 p.); and Lindsey (1977, p. 219-232). Volcanism which is critical to fluorite, beryllium, and uranium mineralization in the Thomas Range is reported by the following authors: Staatz and Osterwald (1959, p. 34-42); Staatz (1963, p. 11-23); Staatz and Carr (1964, p. 73-119); Shawe (1972, p. B67-B77); Lindsey, Naeser, and Shawe (1975, p. 597-604); and Lindsey (1978, p. 25-27; 1979a, p. 1-64; 1979b).

Present Work and Acknowledgments

The present work is a study of the geology of the fluorite occurrences in Spor Mountain, and their relationships to the uranium and beryllium deposits and to the volcanic history of the area. Data and concepts have gradually accumulated and have modified over a period of nearly forty years. Clarification of the Paleozoic stratigraphy is given, classification of the volcanic sequences has changed, the structural setting is reviewed, fluorite occurrences are updated, and the forms of the fluorite ore bodies and the types of ore are described in some detail. The fluorite deposits appear to approach exhaustion; whereas beryllium mining flourishes, uranium may once again be important, and other mineral production may be on the horizon in the Thomas Range and adjacent areas.

The author desires to express appreciation to the many geologists who have devoted considerable time to field observations and laboratory studies to our present

knowledge of the geology of the Thomas Range and adjacent areas. I would express appreciation to the Department of Geology, Brigham Young University, for the professional development leave to complete field studies and for the preparation of this manuscript.

PALEOZOIC SEDIMENTARY ROCKS

General Statement

Paleozoic rocks at Spor Mountain range in age from Lower Ordovician to Upper Devonian. The strata include 10 formations that have a total thickness of about 1,465 m. These rocks are comprised mostly of dolomite, with some quartzite, shale, and limestone, and minor chert. The Paleozoic strata strike north and northeast, and dip at moderate angles to the northwest. They are considerably faulted with duplication of strata several times. Folding is unimportant at Spor Mountain.

Ordovician System

Garden City Formation

The Garden City Formation is of Lower Ordovician age, and was first described by Richardson (1913, p. 408-409) in northern Utah. It crops out in the hills 2 km south of the southern end of Spor Mountain, and in a small outcrop on the east side of Spor Mountain just west of the southern end of Eagle Rock Ridge. Staatz and Osterwald (1959, p. 9-13) described and measured 223 m of exposed Garden City Formation in the hills south of Spor Mountain, and further stratigraphic details are given by Staatz and Carr (1964, p. 31-36) in the Thomas and Dugway Ranges. South of Spor Mountain, the Garden City Formation is gray to greenish-gray limestone. The bedding is very irregular and thin, commonly less than 3 cm thick. Thin laminae of fissile green shale separate many beds of limestone. Some beds contain irregular chert nodules, and others are characterized by edgewise conglomerates.

Swan Peak Formation

The Swan Peak Formation was named by Richardson (1913, p. 409) from its occurrence on Swan Peak in northern Utah. At Spor Mountain the Swan Peak Formation consists of a lower shale member and an upper quartzite member. The formation is described by Staatz and Osterwald (1959, p. 13-17) at Spor Mountain, and by Staatz and Carr (1964, p. 36-38) in the Thomas and Dugway Ranges. The shale member conformably overlies the Garden City Formation. It crops

out most abundantly at the extreme southern end and along the eastern side of Spor Mountain. It consists of brownish-green to green, somewhat fissile shale. It is commonly stained reddish-brown on fractures and along bedding planes. The shale member measures 77 to 118 m in thickness. The quartzite member of the Swan Peak Formation is resistant to weathering and forms prominent reddish-brown cliffs along the eastern side of Spor Mountain, and in the hills at the extreme southern end of the district. The quartzite is uniform, generally white or may be pinkish where unweathered, and reddish-brown to black where weathered. Individual beds range from 0.3 to 3 m in thickness. Most of the quartzite is fine-grained and consists of clear interlocking quartz grains. Cross-bedding is common throughout the quartzite member. A section measured near the Floride mine on the southeast side of Spor Mountain gave a thickness of 180 m. The maximum thickness of the two members of the Swan Peak Formation is 299 m in this district.

Fish Haven Dolomite

The Fish Haven Dolomite is of Upper Ordovician age, and was named by Richardson (1913, p. 409-410) from its exposures in southern Idaho. At Spor Mountain the Fish Haven Dolomite has been described by Staatz and Osterwald (1959, p. 17-21), and in the Thomas and Dugway Ranges by Staatz and Carr (1964, p. 39-41). The Fish Haven Dolomite is found in a series of faulted blocks along the eastern side of Spor Mountain. It conformably overlies the quartzite member of the Swan Peak Formation. The Fish Haven Dolomite is comprised of two members. The lower member forms about two-thirds of the formation, and is thin to medium-bedded and is light-gray to black dolomite, limy dolomite, and limestone. This member typically forms slopes. The upper member is a resistant black-mottled dolomite, which forms a prominent band along the mountain side. The rock is dark-gray to black, medium-grained dolomite, which weathers to slightly lighter hues. The most distinctive feature is the dark mottling. Locally it contains poorly preserved cup corals and crinoid stems. The combined thickness of the two members of the Fish Haven Dolomite range from 85 to 92 m at Spor Mountain.

Floride Dolomite

The Floride Dolomite was originally named by Staatz and Osterwald (1950, p. 21-22) from exposures at the Floride mine on the southeast side of Spor Mountain,

Thomas Range, Utah. It is further described by Staatz and Carr (1964, p. 41-42) in their study of the Thomas and Dugway Ranges. The formation lies between the Ordovician Fish Haven Dolomite and rocks of known Silurian age. Staatz and Osterwald assigned an Ordovician and/or Silurian age to the Floride Dolomite. Budge (1972, p. 50-54) identified Upper Ordovician corals in the Floride Dolomite, hence it is assigned to this system in this report. The Floride Dolomite forms a slope and is poorly exposed between the massive dark ledges at the top of the Fish Haven Dolomite and the base of the overlying Bell Hill Dolomite. The Floride Dolomite consists of thin-bedded, fine-grained, gray, smooth-weathering dolomite and limy dolomite. The upper part of the formation is cherty and limy. The thickness of the Floride Dolomite ranges from 30 to 41 m at Spor Mountain.

Silurian System

Bell Hill Dolomite

The Bell Hill Dolomite was named by Staatz and Osterwald (1959, p. 23-25) from the Bell Hill mine on the southern end of Spor Mountain, Thomas Range, Utah. It is further described by Staatz and Carr (1964, p. 42-44) in their study of the Thomas and Dugway Ranges. The Bell Hill Dolomite is the lowermost of four Middle Silurian formations that make up most of Spor Mountain. The Bell Hill Dolomite is found in fault blocks throughout the southern and central parts of Spor Mountain. The formation is a dark-gray, coarse-grained dolomite, except for the upper part which is a light-gray, partly limy dolomite. The Bell Hill Dolomite is a resistant formation and forms steep hills with prominent outcrops, except for the upper part that is a slope former. The rock is massive and is characterized by detrital sand grains of dolomite, local cross-bedding, banding, and a few distinctive layers. The Bell Hill Dolomite ranges in thickness from 120 to 131 m in Spor Mountain.

Harrisite Dolomite

The Harrisite Dolomite was named by Staatz and Osterwald (1959, p. 25-26) for exposures that cap the hill east of the Harrisite mine in Spor Mountain, Thomas Range, Utah. Additional stratigraphic information on this formation is given by Staatz and Carr (1964, p. 44-45) from their studies of the Thomas and Dugway Ranges. The Harrisite Dolomite is found in numerous northeast trending fault blocks throughout Spor Mountain.

tain. The Harrisite Dolomite is a massive dark-gray to black, sandy textured, locally banded dolomite. It contains as much as twenty percent of black chert, chiefly as nodules and discontinuous layers along the bedding. The Harrisite Dolomite is characterized by numerous faint wormlike markings of white dolomite. The white markings are dolomite replacements of the remains of the chain coral *Halysites*. The Harrisite Dolomite shows considerable variation in thickness, ranging from 36 to 53 m in Spor Mountain.

Lost Sheep Dolomite

The Lost Sheep Dolomite was named by Staatz and Osterwald (1959, p. 26-28) for its occurrence at the Lost Sheep mine in the northern part of Spor Mountain, Thomas Range, Utah. Staatz and Carr (1964, p. 45-47) give further details to the Lost Sheep Dolomite in their report on the Thomas and Dugway Ranges. The Lost Sheep Dolomite is widely distributed on the west slopes of Spor Mountain and on the small neighboring Eagle Rock Ridge. The Lost Sheep Dolomite is comprised of two members. The lower and middle parts of the formation are called the gray member, consisting of light-gray, sandy-textured dolomite with some mottled dolomite and one thin bed of black cherty dolomite. The upper third of the formation is called the cherty member, and is comprised of gray dolomite with abundant pink and gray chert bands parallel to the bedding and up to 15 cm thick. The Lost Sheep Dolomite ranges in total thickness from 66 to 77 m in Spor Mountain.

Thursday Dolomite

The Thursday Dolomite was named by Staatz and Osterwald (1959, p. 28-29) for outcrops at the Thursday mine at the northern end of Spor Mountain, Thomas Range, Utah. Staatz and Carr (1964, p. 47) give further descriptions of this formation in their report on the Thomas and Dugway Ranges. The Thursday Dolomite is best exposed in the northern half of Spor Mountain, where it caps a series of long northeast-trending ridges and to the east on Eagle Rock Ridge. Smaller outcrops are found in faulted blocks in the southern half of the mountain. The Thursday Dolomite is a rather uniform light-gray, medium-grained, friable rock, which is generally a slope former. In the northern part of Spor Mountain

a medium-grained, gray dolomite approximately 5 m thick contains bands of pink chert up to 10 cm thick, and occurs about 41 m above the base of the formation. Although the Thursday Dolomite is quite common on Spor Mountain, it is difficult to measure due to numerous faults. A composite of two measured sections gives the Thursday Dolomite a thickness of 100 m.

Devonian System

Sevy Dolomite

The Sevy Dolomite was named by Nolan (1935, p. 18-19) from exposures in Sevy Canyon in the Deep Creek Range in western Utah. The formation is described in Spor Mountain by Staatz and Osterwald (1959, p. 29-31); and by Staatz and Carr (1964, p. 49-51) in their report on the Thomas and Dugway Ranges. Most of the formation crops out on the west and northwest flanks of Spor Mountain; and on isolated hills and ridges that project above the Lake Bonneville beds on the western side of the mountain. The Sevy Dolomite is a fine-grained, uniform, medium-gray dolomite. Weathered surfaces are grooved and rough with small curving and criss-crossing solution channels. The formation is thin to medium-bedded, dense, and has a somewhat lithographic texture. There is no completely exposed section of the Sevy Dolomite in Spor Mountain, but the best indicated thickness that is partly covered by alluvium is 342 m.

Engelmann Formation

The Engelmann Formation was named by Staatz and Carr (1964, p. 51-53) from its exposures in Engelmann Canyon in the Dugway Range, western Utah. The rocks were previously described in Spor Mountain by Staatz and Osterwald (1959, p. 31-32) as the Simonson-Guilmette Formation, undivided. The Engelmann Formation is exposed in several hills as isolated outcrops, which lie to the west of the northern part of Spor Mountain. The Engelmann Formation is a massive, sandy-textured, light-gray to black dolomite with some interbedded limestone. Only the basal section of the formation is exposed at Spor Mountain, and here the dolomite is commonly calcareous. A partial section of the lower Engelmann Formation at Spor Mountain is 107 m thick.

TERTIARY VOLCANIC ROCKS

Oligocene (?) Epoch

General Statement

Tertiary volcanic rocks of the Thomas Range were first mapped and divided into a younger and an older volcanic group by Staatz and Carr (1964, p. 73-117). Shaw (1972, p. B67-B77) reclassified the volcanic rocks of the Thomas Range into three assemblages; and geochronologic studies by Lindsey and others (1975, p. 597-604) confirmed much of the three-fold classification of the region. Later work by Lindsey (1978, p. 25-31) indicates that the history of volcanism and tectonism in the Thomas Range was inadequate to relate it to the beryllium, uranium, and fluorine mineralization, and to provide reliable guides especially for uranium exploration. A more refined stratigraphic framework for the Thomas and Dugway Mountains was developed by Lindsey (1979a, 101 p.) from field mapping, geochronology, petrography, and trace element studies; and a geologic map by Lindsey (1979b) was recently released covering his investigations. The Tertiary volcanism at Spor Mountain, which is a part of the Thomas Range, is a somewhat condensed version of Lindsey's mapping, simply because all units are not represented in the fluorspar district.

Eocene Epoch

Drum Mountain Rhyodacite

The oldest formation of volcanic rocks exposed in the Spor Mountain fluorspar district is the Drum Mountain Rhyodacite, which was named for exposures in the Drum Mountains (Lindsey, 1979a, p. 15). The rhyodacite crops out discontinuously around Spor Mountain, and unconformably overlies sedimentary rocks of Paleozoic age. The formation is about 150 m thick in the southern part of The Dell on the east side of Spor Mountain.

The rhyodacite consists of dark, rusty-brown weathering, volcanic flows and flow breccias. It contains abundant euhedral phenocrysts of plagioclase and hypersthene up to 4 mm in diameter, set in a matrix of plagioclase microlites and glass. A single fission track date of 41.8 ± 2.3 m.y. on zircon (Lindsey, 1979a, p. 6) indicates a late Eocene age.

Landslide Breccia

Large masses of breccia outcrop along the eastern base of Spor Mountain, just west of the Eagle Rock Ridge. The Breccia zone extends north-south about 3 km and up to 0.4 km east-west, and has long been considered to be an intrusive breccia (Staatz and Carr, 1964, p. 85). New evidence presented by Lindsey (1979a, p. 26-28) indicates that the breccia formed from landslides and related debris flows from along a steep mountain escarpment. The escarpment is interpreted as the western rim of the Thomas caldera, whose outline is delineated by a ring fracture zone of the Joy fault in the northern Drum Mountains and The Dell fault system on the east side of Spor Mountain. All northerly trending faults mapped in this area are downthrown on the east side, suggesting that they form a complex, step-like boundary on the western side of the caldera.

The breccia on the east side of Spor Mountain formed by sliding and flowage off a northerly trending break-away zone. Landslides moved east over a valley floor covered by the Drum Mountain Rhyodacite (Lindsey, 1979a, p. 28). The breccia consists of a mixture of dolomite, limestone, and quartzite in a finer dolomite matrix. The breccia for the most part is massive and unsorted, indicating a turbulent landslide transport. Locally, the breccia is faintly bedded, and probably represents water-saturated debris flows deposited during heavy rain storms. The maximum thickness of the landslide breccia is estimated to be 80 m.

Oligocene Epoch

Dell Tuff

The Dell Tuff was named by Lindsey (1979a, p. 29) for a slightly welded gray to pink rhyolitic ash-flow, which crops out extensively at The Dell on the east side of Spor Mountain. The Dell Tuff unconformably overlies the Drum Mountain Rhyodacite and the landslide breccia at Spor Mountain. The tuff is about 180 m thick at the north end of The Dell. This formation was called a quartz-sanidine crystal tuff by Staatz and Carr (1964, p. 80-81). The rock contains over 50 percent crystals, consisting of euhedral crystals of quartz and sanidine, and lesser amounts of plagioclase and biotite. The groundmass contains white pumice and shards of glass that are slightly welded. The rock is poorly undurated and exposures weather to loose bipyramidal quartz crystals and a soft, ashy soil. An average age of $32.0 \pm$

0.6 m.y. (Lindsey, 1979a, p. 11) for the Dell Tuff was determined by ten fission track dates on zircon, sphene, and apatite, and indicates an Oligocene age.

Miocene Epoch

Spor Mountain Formation

The Spor Mountain Formation is named by Lindsey (1979a, p. 33, 1979b) from exposures at the type section on the southwest side of Spor Mountain. The formation is composed of two members, the beryllium tuff and the overlying porphyritic rhyolite. In most places both occur together and are restricted to the vicinity of the district. Angular unconformities separate the Spor Mountain Formation from older and younger rocks. The beryllium tuff member overlies lower Paleozoic strata, the Drum Mountain Rhyolite, and the Dell Tuff.

The beryllium tuff member is comprised of stratified, tan, vitric tuff and tuffaceous breccia. It contains abundant clasts of carbonate rocks, and some clasts of quartzite and volcanic rocks. The tuff includes thin beds of ash-flow tuffs and bentonite. At The Dell it also contains epiclastic tuffaceous sandstone and conglomerate in the lower part. The thickness ranges from about 20 m to 60 m. Much of the tuff has been hydrothermally altered to clay, fluorite, and potassium feldspar. The beryllium tuff member contains all the important deposits of beryllium and uranium discovered to date in the district, and that which hosts beryllium ore averages about 8 percent fluorite.

The overlying gray to red porphyritic rhyolite member of the Spor Mountain Formation conformably overlies the beryllium tuff member. The porphyritic rhyolite crops out as lava flows, domes, and small plugs on the west and south of Spor Mountain and in The Dell. The porphyritic rhyolite contains abundant phenocrysts of euhedral sanidine, dark quartz, plagioclase, and biotite, and abundant microscopic topaz in the matrix. The rhyolite has a maximum thickness of about 500 m in the district. An age of 21.3 ± 0.2 m.y. is estimated from one fission track date and one K-Ar date (Lindsey, 1979b) for the porphyritic rhyolite member of Spor Mountain formation, indicating an early Miocene age.

Topaz Mountain Rhyolite

The Topaz Mountain Rhyolite was named by Erickson (1963), and redefined by Lindsey (1979a, p. 38) for a large complex of rhyolite flows, domes, and

interbedded units of stratified tuff on Topaz Mountain in the Thomas Range. The entire complex unconformably overlies all older Tertiary volcanic rocks, which have been largely faulted and tilted in the range. The formation contains distinctive sequences of lithologies of three relative ages. The sequence of each subgroup consist of thin stratified tuff, breccia, black vitrophyre, and thick, layered, gray to red, alkali rhyolite flows. These were described as the younger volcanic group in the Thomas Range by Staatz and Carr (1964, p. 86-102). The three subgroups represent a complex of flows and domes that lack broad lateral continuity, and have been derived from numerous volcanic vents within the range.

The thick alkali rhyolite flows contain phenocrysts of quartz, sanidine, biotite, and plagioclase. The minerals topaz, beryl, garnet, hematite, bixbyite, and pseudobrookite occur in lithophysae in the flows. Tan, stratified tuff occurs at several places beneath rhyolite flows that extend for several kilometers; whereas only breccia or vitrophyre occur at the base of some domes and short flows. The stratified tuff units are rarely more than 30 m thick. The maximum thickness of the Topaz Mountain Rhyolite is about 700 m (Lindsey, 1979b). Four fission track and two K-Ar dates of the various alkali rhyolite flows range from 6.1 to 6.8 ± 0.3 m.y.

The Topaz Mountain Rhyolite comprises the bulk of the main Thomas Range, which lies immediately to the east of Spor Mountain. Small plugs of alkali rhyolite were intruded along faults that cut rocks of Paleozoic age on Spor Mountain. The plugs may belong to either the Topaz Mountain Rhyolite or the porphyritic rhyolite member of the Spor Mountain Formation, or both.

QUATERNARY ROCKS

Lake Bonneville Beds

Spor Mountain is bounded on the north, west, and south by Pliocene Lake Bonneville sediments that are poorly consolidated. The maximum elevation of these deposits is about 1585 m, the highest level of Lake Bonneville. Clay and marl beds occupy the lower parts of the adjacent basins, and range from massive to finely-laminated beds. Sand and gravel deposits are widely distributed mostly as shoreline features, such as beaches, spits, and bars. The largest bar lies on the northwestern end of Spor Mountain. It is arcuate in form, 15 m high, and 1 km long. Tufa and tufa-cemented conglomerate are restricted to the shoreline at the outer edges of the Bonneville terrace. Tufa-cemented

conglomerate is conspicuous on outcrops of Paleozoic rocks on the south end of Spor Mountain. Wave-cut terraces of the Bonneville level are well exposed on a hill on the south end of Spor Mountain.

Alluvium

The valleys and flats in and around Spor Mountain are covered by alluvium of Quaternary age. Below the 1585 m elevation the alluvium overlies the Lake Bonneville sediments, and it is difficult to distinguish between them. Alluvial fans comprised of boulders, gravel, and sand are present. Alluvial cover surrounds numerous low hills and extends up some valleys for considerable distances on the western side of the mountain. Talus and slope wash are found at the base of some cliffs, especially on the steeper eastern slopes.

STRUCTURE

General Statement

The structural history of Spor Mountain area is complex, and intimately related to the regional setting of the Thomas, Dugway, Drum, Little Drum, and other nearby ranges. This region is characterized by a long period of uplift with individual ranges that trend to the northwest. The uplift is comprised of exposed Paleozoic strata that are tilted to the west and northwest, and are highly faulted. The area is part of a Tertiary caldera complex, that has been modified by Basin-and-Range faulting. Four general episodes in the structural history of the region have been recognized: (1) an early period of compression that formed thrust faults, (2) a period in which numerous transverse and strike faults were formed, (3) a period of Tertiary caldera subsidence faults, and (4) a period of Basin-and-Range faulting. Each episode may be characterized by continuous or renewed movement along faults, repetitive caldera subsidence, and overlapping of these episodes.

Thrust Faults

The oldest faults on Spor Mountain are thrusts which are the result of at least one period of compression during the Sevier Orogeny. These faults are confined to rocks of Silurian age at the surface, and are exposed in three areas (Staatz and Osterwald, 1959, p. 43) in the mountain. Thrusts occur at the southern end of Spor Mountain about 213 m southeast of the Harrisite mine. A second thrust area cuts Silurian strata along the west side of Eagle Rock Ridge on the east side of Spor Mountain. A third thrust area has a trace of

1980 m, and lies near the northwest end of Spor Mountain. These thrust faults dip westward and have a dip-slip movement of less than 300 m. The thrusts are prevolcanic in age, and are cut by faults of all other systems.

Transverse and Strike Faults

Hundreds of strike and steep transverse faults cut the Paleozoic rocks in Spor Mountain. For convenience these faults are grouped together, yet some of them may be related to a previous compressional episode, and many to the younger episodes. The transverse and strike faults in Spor Mountain have been assigned to three sets (Staatz and Osterwald, 1959, p. 43-45) from older to younger: (1) northeast-trending normal and reverse strike faults, (2) northwest-trending transverse faults, and (3) east-trending transverse faults.

Northeast-trending normal and reverse faults cut across the trend of Spor Mountain, and repeat the sequence of sedimentary strata as many as 11 times in 6 km. These faults form the dominant structural feature of the mountain. Most of the faults dip between 35° and 65° SE, and the dip-slip movement ranges from a few centimeters to as much as 335 m. Most of the large ridges of Spor Mountain are separated by these faults, and many of the canyons follow major northeast fault traces.

The northwest-trending transverse faults intersect and commonly offset the northeast set of faults. All the Paleozoic strata in Spor Mountain are cut by faults of this series. They are observed throughout the length of the mountain, but are most numerous in the northeastern part. The northwest faults have high angle to vertical dips, and the displacement ranges from a few meters to as much as 200 m or more.

A few east-trending transverse faults cut across Spor Mountain. They intersect and offset all previous described sets. Most of the east-trending faults dip steeply to the south, and displacement ranges from 90 to 150 m.

Caldera Subsidence Faults

Spor Mountain forms the northwestern rim of the Thomas caldera (Shawe, 1972, p. B67-B77), which is a major structural feature of the area. The western boundary of the caldera is delineated by the ring fracture zone of the Joy Fault in the Drum Mountains and the Dell Fault system on the east side of Spor Mountain (Lindsey, 1970a, p. 43-47). The highlands of

Spor Mountain and the northwestern and central Drum Mountains comprise the western rim of the Thomas caldera complex. The northerly trending faults mapped in The Dell by Lindsey are downthrown on the east side, indicating that they form part of a step-like western boundary of the Thomas caldera complex. The caldera subsidence faults have been modified by Basin-and-Range faulting.

Basin and Range Faults

Faults of early Basin-and-Range age are common in Spor Mountain, and have modified the caldera structure. Modification was accomplished by rejuvenation of earlier faults and by the development of new north-trending faults (Lindsey, 1979, p. 48-49). The faulted structure within the caldera was determined by mapping numerous lineaments on aerial photographs in the alluvium and the Topaz Mountain Rhyolite. Many of these lineaments pass into well-exposed faults in rocks older than the rhyolite. The north-trending Dell Fault system was formed during caldera subsidence, but was rejuvenated by Basin-and-Range movements as shown by large offsets of the Spor Mountain Formation. In addition, the rim of the Thomas caldera contains numerous faults of Basin-and-Range age. Many of the major faults on Spor Mountain extend beyond the Paleozoic rocks, and cut the Lower Miocene Spor Mountain Formation and volcanic rocks of Oligocene and Eocene ages. Faulting of Basin-and-Range age is evident at the beryllium mines on the southwestern side of Spor Mountain. Northeasterly and easterly trending high-angle normal faults displace the Spor Mountain Formation as much as 200 m or more. This section has thrown the beryllium tuff and porphyritic rhyolite members into blocks that are tilted 15° to 30° NW. Similar basin-and-range faulting on the eastern side of Spor Mountain extends into The Dell, where they cut volcanic rocks as young as the Spor Mountain Formation.

FLUORITE DEPOSITS

General Statement

Uraniferous fluorite deposits are found on Spor Mountain, where they occur as breccia pipes, veins, and disseminated deposits. Over 99 percent of the ore has come from breccia pipes that are associated with Ordovician and Silurian dolomites as the host rocks. The breccia pipes typically occur along shattered zones formed first by faulting, and then a pipe-like form resulting from explosive activity prior to mineralization. The shipped ore contains 60 to 95 percent fluorite,

which is intermixed with variable amounts of montmorillonite clay, quartz, chalcedony, calcite, and dolomite host rock. The ore may be white, bluish, purple, green, buff, yellow, or reddish-brown. It ranges from pulverulent masses to crystalline textures, and from angular to rounded boxwork structures. Production of the fluorite ore is currently low, and the district is approaching exhaustion. The most complete studies of the geology of the district, mineral deposits, and individual mines are given by Staatz and Osterwald (1959, 97 p.), Staatz and Carr (1964, p. 130-148), and Bullock (1976, p. 29-57).

History and Production

Commercial production of fluorspar in Utah began in 1918 and has continued erratically to the present. Early production in the state during the years 1918-1924 came from Tooele County, yielding only 904 tons of ore. Later production from 1935-1943 came from Beaver County, resulting in 4,025 tons of fluorspar. The Spor Mountain deposits in Juab County began production in 1944 and have continued to the present. Spor Mountain has been the only important source of fluorspar in Utah, yielding about 350,000 tons of ore to 1980 (see figure 1). Details of the individual mines at Spor Mountain and other deposits in the state have been previously described by Bullock (1976, 89 p.).

Fluorspar was first discovered in Spor Mountain in 1936 by the Spor brothers of Delta. Later, in 1941 George Spor and his two sons, Chad, and Ray, staked the Floride claim, then the Floride Nos. 1 and 5 claims in 1944, and the Floride Nos. 13 and 18 in 1953; all of which were productive. Shipments of ore began in 1944 on the Floride pipe, which yielded about 12,000 tons of ore through a period of years. Production of fluorspar for the other Spor properties include: Floride No. 1 mine 2,000 tons, No. 5 mine 6,500 tons, No. 13 mine 2,000 tons, and No. 18 mine 1,000 tons. Spor operations have produced about 23,000 tons (Chad Spor, personal communication, 1980) of fluorspar to the year 1980.

The next discovery was on the Dell claims, which were located in May 1947 by Earl Willden, T. A. Claridge, and Lafe Morley of Delta. They sold this property to Ward Leasing Company of Salt Lake City, which mined one large and two small pipes. Production at the Dell mine is estimated to be about 12,000 tons. The Dell No. 5 claim contained at least three pipes, known as the Red pit deposits, and produced about 14,000 tons of ore. The Dell properties have been idle since 1955.

A number of mining claims were located in Spor Mountain the year of 1948. The first of these was the Fluorine Queen and the Fluorine Queen Nos. 1-4 claims, that were staked in March by F. B. (Scott) Chesley and W. E. Black of Delta. Production began in 1948 on the Fluorine Queen pipe or East pit, which produced 24,087 tons by the end of 1956. Additional production came intermittently over several years and by 1980 this pipe had produced about 67,000 tons of fluorspar. The Fluorine Queen No. 1 pipe or Middle pit yielded about 15,000 tons from 1949 to 1956. Additional ore was removed by underground workings by U. S. Energy Corporation during the 1970's. The Middle pit has produced about 33,000 tons of ore to 1980. The Fluorine Queen No. 4 mine is known as the West pit. This pipe yielded about 3,000 tons of fluorspar in the early 1950's from a porphyritic rhyolite plug, and an additional 800 tons in recent years. The Fluorine Queen No. 2 mine or Fissure pit produced about 3,000 tons of crystalline ore in the early 1950's, and a small tonnage in the mid-1970's. The Fluorine Queen properties have produced about 107,000 tons (F. B. Chesley, personal communication, 1980) of ore from 1948 to 1980.

The Lost Sheep claims Nos. 1-4 were staked on May 10, 1948, by Albert and Earl Willden of Delta in the northern part of Spor Mountain. The Lost Sheep pipe or Purple pit began production in 1948 and has produced ore almost continuously to the present. The Lost Sheep mine is the largest fluorspar deposit in Utah. Mining has continued to a depth of 122 m, yielding 160,000 tons (Albert Willden, personal communication, 1980) of ore to the year 1980. The nearby Badger Hole pipe on the same claim as the Purple pit yielded an additional 600 tons of ore; and the Green Crystal property produced about 800 tons of fluorspar.

The Blowout claim was located on a pipe adjacent to the Lost Sheep claim on May 19, 1948, by Tass and Rex Claridge. Through the years 1950-1958 about 10,200 tons of ore were mined. An additional 1,460 tons were mined during the 1970's. The total production of the Blowout claim is at least 11,660 tons of ore.

The Bell Hill claims Nos. 1-7 were staked in 1949 by C. D. Searle, D. W. Searle, T. E. Searle, and H. J. Rutherford of Delta. Six ore bodies occurred on this property, but about 95 percent of the ore came from one large pipe, where the ore was mined from the surface to a depth of 60 meters. Exploratory work extended to a depth of 85 meters. The property was leased and sold several times, but is presently owned by Richard Moody of Delta and Salt Lake City. Production

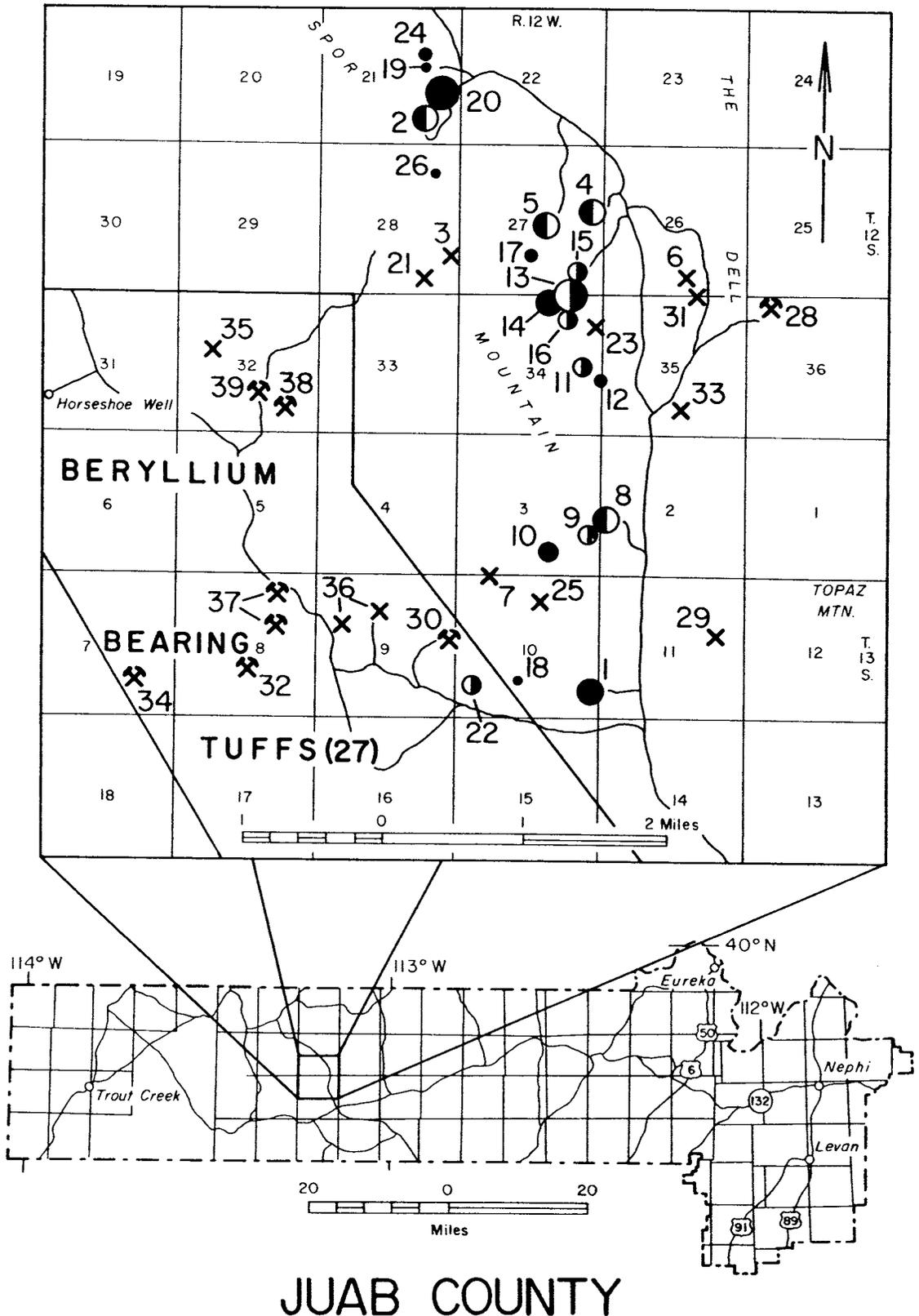
from 1950 to 1956 was 23,644 tons, and intermittent production between 1957 and 1974 yielded an additional 8,886 tons; or a total tonnage from the Bell Hill property of at least 32,530 tons of fluorspar ore.

During the year of 1948 and 1949 several small ore pipes and veins were discovered on Spor Mountain. The following mines yielded some production of fluorspar: Harrisite 55 tons, Hilltop 316 tons, Luckie Louie 1,432 tons, Oversight 598 tons, Thursday 55 tons. Minor additional production has recently come from the Oversight mine. The total production from these mines is at least 2,556 tons to the year 1980.

From 1944 to 1948 all fluorspar ore was shipped to Geneva Works, U. S. Steel Corporation, Geneva, Utah. Since 1949 the ore has been sold to Continental Ore Buying Company, CF&I Steel Corporation, Kaiser Steel Corporation, U. S. Steel Corporation, Sheffield Steel Company, Bayley Fluorspar Company, and others. Fluorspar production from Spor Mountain from 1944 to 1980 is approximately 350,000 tons, although the documented shipped ore by the U. S. Bureau of Mines is considerably less.

Mineralogy and Grade of Ore

The fluorspar ore at Spor Mountain consists of 60 to 95 percent fluorite, which ranges from soft pulverulent masses to dense aphanitic or hard boxwork types. Very little fluorite is crystalline as is found in most commercial deposits. In fact, the ore shows little resemblance to the fluorite from most parts of the world, and is very deceptive to most observers. In appearance, the fluorite resembles that of either a soft friable clay or a dense fine-grained siliceous rock. The color may be white, blue, purple, green, buff, yellow, reddish-brown or any admixtures. The purple color is generally indicative of the presence of uranium in the ore, which varies from 0.003 to 0.33 percent uranium (Staatz and Carr, 1964, p. 134-135). Although the deposits show abnormal radioactivity, visible uranium minerals are rare. Carnotite has been identified from the Eagle Rock and Bell Hill properties, and a fine-grained powdery uranium mineral was found at the Harrisite, Floride, and Fluorine Queen No. 4 mines. The uranium content increases from north to south in the district. Bell Hill mine on the extreme southern end of Spor Mountain has the highest uranium content. Fluorite samples from the Bell Hill, Fluorine Queen, and Luckie Louie mines contain traces of beryllium ranging from 0.004 to 0.002 percent (Staatz, 1963, p. M25), whereas the other fluorspar deposits contain no detectable beryllium.



Base map from United States Department of the Interior
Geological Survey "State of Utah" 1959 1:500,000

Figure 1. Index map, Spor Mountain mineral occurrences.

MINERAL LOCATIONS

FLOURSPAR MINES AND PROSPECTS

1. Bell Hill Mine
2. Blowout Mine
3. Blue Queen Prospect
4. Dell Mine
5. Dell No. 5 Claim
6. Eagle Rock Prospect
7. Evening Star Prospect
8. Floride Mine
9. Floride No. 1 Mine
10. Floride No. 5 Mine
11. Floride No. 13 Mine
12. Floride No. 18 Mine
13. Fluorine Queen Mine
14. Fluorine Queen No. 1 Mine
15. Fluorine Queen No. 2 Mine
16. Fluorine Queen No. 4 Mine
17. Green Crystal Mine
18. Harrisite Mine
19. Hilltop Mine
20. Lost Sheep Mine
21. Lost Soul Prospect
22. Lucky Louie Mine
23. Non Ella Prospect
24. Oversight Mine
25. Prospector Prospect
26. Thursday Mine
27. Beryllium Bearing Tuffs

URANIUM MINES AND PROSPECTS

28. Yellow Chief Mine
29. Buena No. 1 Prospect

BERYLLIUM MINES AND PROSPECTS

30. Blue Chalk Mine
31. Claybank Prospect
32. Fluro Mine
33. Hogsback Prospect
34. Monitor Mine
35. North End Prospect
36. Rainbow Mine
37. Roadside Mine
38. Sigma Emma Mine
39. Tarus Mine

FLOURSPAR PRODUCTION

- 0 - 500 TONS
- 500 - 1,000
- ◐ 1,000 - 5,000
- 5,000 - 10,000
- ◐ 10,000 - 25,000
- 25,000 - 50,000
- ◐ 50,000 - 100,000
- 100,000 - 200,000

✕ Mine

✕ Prospect

Gangue minerals associated with the fluor spar deposits at Spor Mountain include montmorillonite, chalcedony, quartz, dolomite, and calcite. The most common gangue mineral is montmorillonite. It occurs as a white waxy clay mineral. On drying it becomes powdery and has the appearance similar to white fluorite. Montmorillonite usually increases in abundance with depth of the ore deposit. It is intimately intermixed with fluorite, and is abundant in voids and boxwork structures; or it may occur as round balls or massive exposures in or adjacent to fluor spar ore. Recent surface workings at the Lost Sheep Purple pit have exposed montmorillonite masses several meters wide.

Chalcedony is considerably less abundant than montmorillonite, and is present in a number of deposits. It occurs as a dark-gray dense aphanitic mineral, and resembles, or may actually include, some chert found in the dolomite bedrock. Quartz occurs as small clear crystals, which line some voids and boxworks. The coatings of quartz are deposited on either fluorite or chalcedony. White wedge-shaped dolomite crystals accompany quartz in some deposits. Calcite is the least abundant gangue mineral, but occasionally is found in boxwork structures.

The tenor of the Spor Mountain fluor spar ore varies widely from mine to mine, and within any individual deposit. Most of the shipped ore contained from 60 to 95 percent fluorite. The fluorite content of many deposits was high, especially in the upper part of the ore occurrence. Due to the fine grain size of the ore and the lack of distinctive character of fluorite and montmorillonite, it becomes difficult to estimate the tenor of the ore by visual inspection. The overall tenor of a deposit decreases with depth, although the increase in gangue minerals may occur on one side or just in part of the ore body. The increase in silica with depth comes mainly from an increase in montmorillonite, since chalcedony and quartz are but minor constituents of the ore. There are exceptions, however, where quartz and chalcedony make substantial contributions to an increase in silica with depth of mining.

One of the major harassments to the mine operators has been the commercial grading of fluor spar ore, which is purchased on the basis of effective fluorite content. The effective fluorite, CaF_2 , is determined from an analysis of the ore by subtracting 2 1/2 percent of fluorite for each 1 percent of silica in the ore. For example, an ore containing 85 percent of fluorite and 4 percent silica would be rated at 75 percent effective. The principal silica contaminant is montmorillonite. Success-

ful or partially successful removal of this gangue from the lower grade ores has been achieved by crushing and jigging operations, and in some cases by washing of the ore.

Forms of the Ore Bodies

Fluor spar ore has been mined commercially at Spor Mountain from 38 known deposits; and other properties have warranted some exploration and development work, resulting in little or no ore production. These deposits fall into five types: (1) breccia pipes, (2) fissure veins, (3) disseminations, (4) intrusive rhyolite breccia plugs, and (5) landslide breccia. No bedded replacement deposits have been discovered in this district.

Breccia Pipes

Breccia pipes are by far the most important deposits in Spor Mountain. Thirty-five out of 38 productive bodies are breccia pipes which lie within the Ordovician Fish Haven and Floride Dolomites, and the Silurian Bell Hill, Harrisite, Lost Sheep, and Thursday Dolomites (see table 1). One ore body is associated with an intrusive rhyolite breccia pipe, and two fissure veins were productive. About 98 percent of the shipped fluor spar ore has come from breccia pipes in dolomite, and 1 percent each from the fissure veins and the intrusive rhyolite breccia plugs.

In plan view the pipes vary in shape from circular, oval, elongate, arcuate, H-shaped, and irregular in form; and range in size from less than 1 m to 58 by 34 m at the East pit, Fluorine Queen mine (see figure 2). The deepest and most productive breccia pipe is the Purple pit, Lost Sheep mine, which was mined to a depth of 122 m (see figure 3). In cross-section, several pipes are vertical, but many show an eastward plunge at angles of 50° to 90°. The pipes show their greatest widening of flaring toward the present ground surface, as shown especially well in the Bell Hill, Fluorine Queen (East pit), and Lost Sheep (Purple pit) pipes. With depth, the fluor spar pipes show a consistent tendency to narrow, and many ore bodies split forming smaller pipes or narrow elongated ore bodies, such as at the Lost Sheep (Purple pit), Bell Hill, and Oversight pipes. Although much of this decrease is gradual with depth, some pinch rapidly as found at the Fluorine Queen (East pit) and the Luckie Louie pipes. The Harrisite and Floride pipes are terminated against faults. The Dell pipe narrows slightly with depth, but is terminated against the Swan Peak Quartzite Member with small stringers of fluorite extending into the quartzite.

Table 1. Productive geologic occurrences of fluorspar at Spor Mountain.

Mine	Breccia Pipes in Dolomite	Intrusive Rhyolite Breccia Pipes	Veins
**Bell Hill	5	0	0
*Blowout	3	0	0
*Dell	3	0	0
*Dell No. 5	5	0	0
*Floride	1	0	0
Floride No. 1	1	0	0
*Floride No. 5	1	0	0
Floride No. 13	1	0	0
Floride No. 18	2	0	0
**Fluorine Queen (East pit)	1	0	0
**Fluorine Queen No. 1 (Middle pit)	1	0	0
Fluorine Queen No. 2 (Fissure pit)	0	0	1
Fluorine Queen No. 4 (West pit)	0	1	0
Green Crystal	1	0	0
Harrisite	2	0	0
Hilltop	2	0	0
**Lost Sheep	2	1	0
Luckie Louie	1	0	0
Oversight	2	0	0
Thursday	1	0	1
T O T A L S	35	2	2

**Major Producers

*Important Producers

Small Producers



Figure 2. East pit breccia pipe, Fluorine Queen mine.

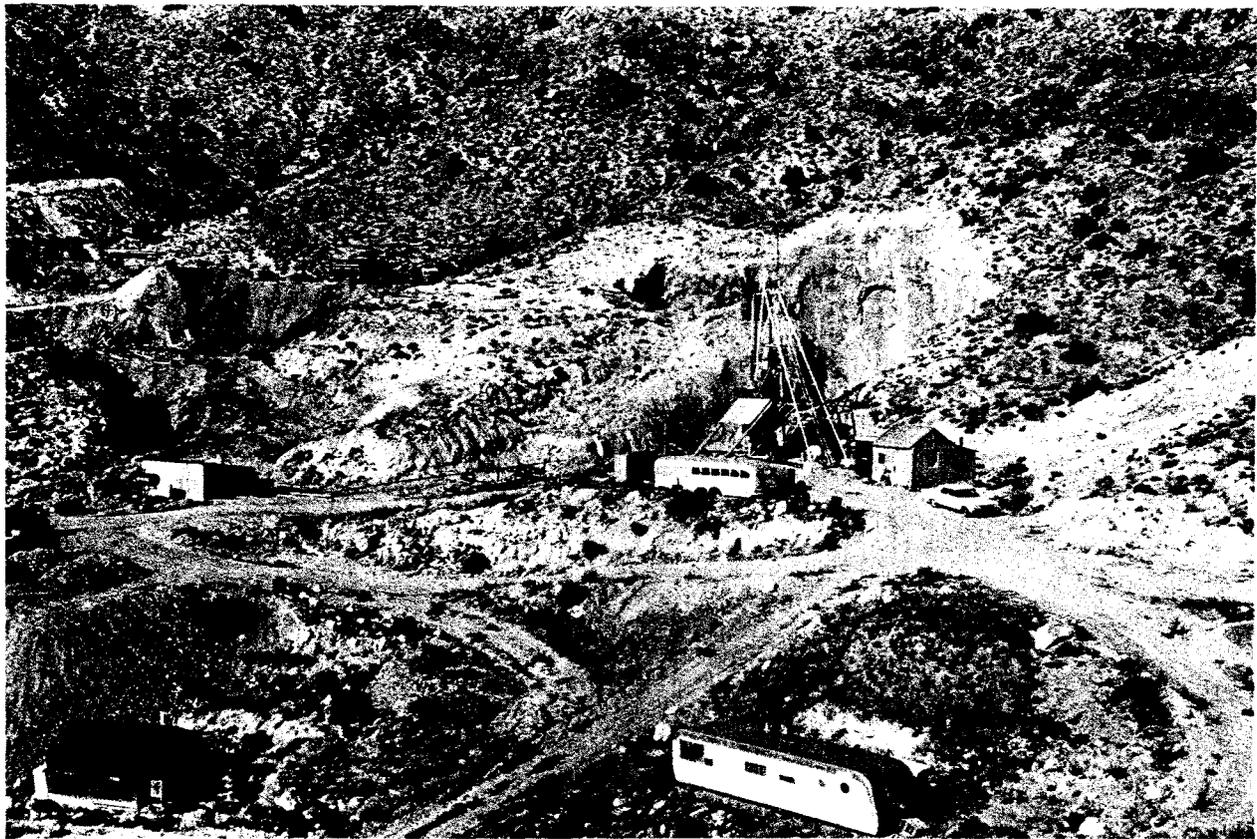


Figure 3. Purple pit breccia pipe, Lost Sheep mine.

Most of the margins of the breccia pipes are surprisingly smooth and sharp, and the fluorite ore is in direct contact with unaltered dolomite or only separated by a thin layer of montmorillonite clay. Irregular pipe-like ore bodies, however, normally have ragged margins and veinlets of fluorite extend outward into the bounding dolomite rock. Mineralization in the smaller pipes tends to be complete. The larger pipes, such as the Bell Hill, Fluorine Queen (East pit), and the Lost Sheep (Purple pit) pipes, had some ores with considerable intermixtures of dolomite, and some areas within the pipes contained highly brecciated dolomite with little or no fluorite ore. The adit level of the Fluorine Queen (East pit) pipe had a large irregular horse of dolomite not exposed at the surface. Table 2 summarizes some of the physical features of the larger breccia pipes.

Fissure Veins

Fluorite fissure veins at Spor Mountain are fairly common, but nearly all are small and nonproductive. The veins vary in width from less than 1 cm to nearly 5 m at the Fluorine Queen No. 2 (Fissure pit) mine. In

length they range from a few centimeters to 73 m at the Thursday mine. Several prospects were located on small fluorite veins, such as the Blue Queen, Eagle Rock, Evening Star, Lost Soul, and Prospector properties, and on the Red Hill claim at the Dell mine. The Eagle Rock vein is 12 m long and from 2 mm to 1.2 m wide, and consists of dark purple, hard boxwork fluorite. The Evening Star prospect has several small veins up to 20 cm wide with massive aphanitic type ore. The Red Hill vein at the Dell Mine is 12 m long and averages 45 cm wide. Most of the productive breccia pipes have small individual veins or networks of veins in the adjacent dolomite rock. The fissure veins are more abundantly associated with elongate or irregularly-shaped breccia pipes, such as at the Blowout and Bell Hill mines. The base of several breccia pipes become elongate and vein-like; and at the Dell mine the pipe bottomed against massive quartzite with fluorite veins up to 15 cm wide extending downward into the quartzite.

Only two fissure veins are known to have shipped commercial fluorite ore, namely, the Thursday and Fluorine Queen No. 2 (Fissure pit) mines. Two fluorite

Table 2. Features of Larger Breccia Pipes in Dolomite.

Mine	Surface Plan View	Maximum Surface Dimensions	Depth of Ore	Cross-section or Termination with Depth
Bell Hill	H-shaped	40 by 15 m	61 m	2 lenticular bodies, narrows.
Blowout	Elongate, irregular	34 by 9 m	66 m	Lenticular, narrows
Dell	Circular	13 by 12 m	67 m	Pipe, terminates against quartzite.
Floride	Oval	30 by 12 m	24 m	Pipe, terminates against fault.
Fluorine Queen (East pit)	Oval	58 by 34 m	24 m	Pipe, 2 lenticular bodies at 24 m, narrows rapidly.
Fluorine Queen No. 1 (Middle pit)	Elongate, irregular	32 by 12 m	52 m	Lenticular body, still in ore.
Lost Sheep (Purple pit)	Arcuate	49 by 18 m	122 m	Toothlike pipe, 3 small pipes at 76 m, 1 at 122 m.

bodies are exposed at the Thursday mine workings, a small breccia pipe and a fissure vein. The vein occurs in the Silurian Thursday Dolomite along the footwall of a fault that strikes N 43°-60° W, and dips from 70°-82° NE. The fault is exposed throughout the mine adit and in the large open pits at the surface. The fissure vein has a maximum width of 4.2 m in the surface workings and 1.8 m in the main adit level, 20 m below the surface. This vein is exposed on the surface for 73 m and in the adit for 53 m. All fluorspar ore came from the surface workings mainly on this fissure vein. The fluorspar ore is white to pale purple. The ore is fine-grained and sugary in texture, and locally contains small pockets of coarsely crystalline fluorite. Narrow veins of white crystalline calcite are abundant at the contact of the dolomite rock and the fluorspar ore. Because the ore from the Thursday mine was highly siliceous, it was mixed with higher grade ore from the Lost Sheep mine to bring this product up to metallurgical grade. The Thursday mine produced about 100 tons of ore, and has an ore potential of a few hundred tons of highly siliceous ore that will require beneficiation.

The Fluorine Queen No. 2 (Fissure pit) mine has been the only important commercial fissure vein deposit in Spor Mountain to date. The ore occurs along a fault in the Silurian Bell Hill Dolomite that strikes N 48° E and dips 73° SE. On the surface the fissure vein measured 18 m long and was 2.4 to nearly 5 m wide. The ore was mined from the surface to a depth of 12 m. An adit was driven 21 m below the surface outcrop, where a stope and raise extended to the surface. Approximately 3,000 tons of ore were shipped from the Fissure pit deposit in the early 1950's. In 1972 the U. S. Energy Corporation mined additional ore. Fluorspar from the Fissure pit deposit differed from most of the ore in Spor Mountain in two ways: the occurrence is a fissure vein deposit; and the fluorite is coarsely crystalline and banded (see figure 14). The ore was colorless to pale green, and averaged 90 percent fluorite and 5 to 6 percent silica. The ore was slightly radioactive. The Fissure pit deposits produced about 3,500 tons of ore (F. B. Chesley, oral communication, 1980), but the deposit is now depleted.

Disseminations

Fluorite occurs as disseminations in volcanic rocks along the east, south, and west sides of Spor Mountain. The extent of these deposits has not been fully evaluated. The distribution of fluorspar in volcanic rocks is irregular, but may constitute up to 15 percent of the rock. Mineralization occurs in rhyolite, rhyodacite, and volcanic tuff. The richest and most extensive occur-

rences are in the more porous volcanic tuffs associated with the beryllium deposits of Spor Mountain (Staatz, 1963, p. M2). Fine-grained fluorite replaces clay layers around large lithic fragments in the tuff, is deposited around smaller vitric fragments, and replaces dolomite clasts within the tuff. Fluorite is generally purple, although in places it is white and cannot be distinguished from other white minerals in hand specimens.

Beryllium is present as the mineral bertrandite and is found in stratified tuffs of the Miocene Spor Mountain Formation, with varying amounts of accompanying fluorite. Fluorite and bertrandite are found in altered tuff of the mineralized areas, and both minerals show high concentrations in the altered dolomite pebbles and clasts. Argillic and feldspathic alteration characterize the mineralized tuffs (Lindsey, Ganow, and Mountjoy, 1973, 20 p), the latter representing the most advanced stage. The argillic tuff contains as much as 80 percent montmorillonite clay, less than 20 percent potash feldspar, and 1 to 5 percent fluorite. Enclosed dolomite pebbles and clasts range from white calcite to complete replacement by opal, chalcedony, quartz, purple fluorite, montmorillonite, and manganese oxides. Feldspathic tuff consists of over 20 percent feldspar, up to 30 percent cristobalite, as much as 40 percent montmorillonite clay, and 1 to 8 percent fluorite. Dolomite pebbles and clasts are replaced by quartz, opal, chalcedony, and purple fluorite, or by montmorillonite, fluorite and manganese oxides. Uranium occurs in opaline silica that is intergrown with fluorite. The maximum beryllium content of these pebbles and clasts might be between 3 and 4 percent, associated with a fluorite content as high as 50 percent.

Beryllium ore production to date at Spor Mountain has been restricted to operations by Brush Wellman, Inc. Mining operations indicate that the beryllium normally ranges between 3 and 15 percent fluorite with an average of 8 percent (Leland Davis, oral communication, 1980). The ore averages between 0.7 and 1.1 percent BeO; and ranges from 0.002 to 0.015 percent U₃O₈. Trace amounts of thorium and a number of other chemical elements are present. Only beryllium and uranium are recovered during the milling processes. Although Brush Wellman, Inc., has not attempted to recover fluorite in their processing plant near Lynndyl, the tailings pile from this operation constitutes a large potential source of low-grade fluorspar ore.

Intrusive Rhyolite Breccia Plugs

In the central and northern part of Spor Mountain intrusive rhyolite breccia plugs lie along linear faulted

structures or cut the Paleozoic strata indiscriminately. Many of these lie nearby or are in contact with fluorspar pipes and veins. The intrusive breccia plugs have been derived from an intrusive body that must underlie the district, from which escaping gases and rhyolite masses have been expelled. During this violent eruption dolomite clasts were incorporated with the gases and rhyolitic rock. The resulting intrusive plugs range from wholly porphyritic rhyolite rock to masses containing large quantities of dolomite rubble. The numerous plugs may belong to either the porphyritic rhyolite member of the Spor Mountain Formation or the Topaz Mountain Rhyolite, or both.

The Fluorine Queen No. 4 mine was developed in an intrusive rhyolite breccia plug and produced a few thousand tons of low grade ore. Recently, several hundred tons of fluorspar ore were produced from a wholly rhyolite plug adjacent to the Purple pit at the Lost Sheep mine. Other intrusive rhyolite breccia plugs contain veinlets and replacements of fluorite, but apparently the occurrences are too low grade for commercial use.

Landslide Breccia

The landslide breccia zone on the east side of Spor Mountain was formed by sliding and flowage of lower Paleozoic sedimentary rocks following the subsidence of the Thomas caldera. The breccia probably began moving as a coherent mass of fractured and brecciated strata, which disintegrated into landslides and debris flows during heavy rainfall. The steep caldera escarpment and abundant moisture were probably responsible for the development of the landslide breccia. The breccia moved eastward over a valley floor covered by the Drum Mountain Rhyodacite.

Landslide breccia on the Dell property is veined and partially replaced by fluorite. Near the portal of a 35 m adit on the Red Hill claim is a 12 m long fluorite vein that cuts landslide breccia. It averaged 45 cm wide. One outcrop of landslide breccia assayed 40 percent fluorite. The breccia has not been drilled, but it has been trenched by a series of bulldozer cuts. The occurrence of fluorspar within landslide breccia is a new concept for the district, and the economic potential is yet to be determined by exploration and development work on the east side of Spor Mountain.

Types of Ores

Spor Mountain fluorspar deposits are comprised of five differing textural and structural types of ores.

Unlike the coarse textured crystalline fluorite of most districts, the bulk of the ores consists of soft pulverulent masses, boxworks, or dense aphanitic types. In addition, there has been limited production of coarse-textured crystalline and sponge fluorite ores. Any individual deposit may be primarily one of these types, but normally the ores are mixtures of two or more of these varying textures and structures.

Pulverulent Ores

Much of the production of fluorspar ore from Spor Mountain has consisted of soft pulverulent masses with a fine-grained texture (see figure 4). It is friable and claylike, and ranges in color from white, tan, reddish-brown, bluish, to purple, or any admixtures. Large quantities of pulverulent ore was mined from the Bell Hill, Blowout, Floride, Fluorine Queen (East pit), upper half of the Fluorine Queen No. 1 (Middle pit), Dell, Dell No. 5, and Lost Sheep mines. Smaller quantities of this type of ore came from the Dell Nos. 1, 2, and 3, Floride Nos. 1, 5, 13, and 18, Fluorine Queen No. 4 (West pit), Harrisite, Thursday, and Luckie Louie mines. Pulverulent ore from the Bell Hill, Blowout, and Dell No. 5 mines, and others to a lesser extent, had weak yet well developed boxwork structures, which upon mining formed soft and powdery ore. The framework of this type of boxwork ore appears to have been originally calcite or dolomite that was later partially to completely replaced by fluorite. The dominant gangue mineral is montmorillonite, followed by lesser amounts of calcite, dolomite, quartz, and chalcedony. Calcite gangue was especially high at the Bell Hill and Harrisite properties.

Most of the pulverulent type ore appears to be genetically related to replacement of highly brecciated dolomite and fines, and to weak boxwork septa, especially those with original calcite or dolomite septa. All fluorspar ore bodies lie within the zone of oxidation, and weathering may have contributed to the predominance of pulverulent ore. Quantities of this type of ore decrease in abundance at depth at most mines, but especially at the Blowout, Fluorine Queen No. 1 (Middle pit), and Lost Sheep deposits.

Boxwork Ores

The most impressive ores from Spor Mountain are those with cellular boxwork structures. The cellular patterns are distinctly angular, and the cell walls range from easily friable to solid rigid structures (see figures 5 and 6). The boxwork ores constitute the second most abundant commercial type of ores in the district, and



Figure 4. Purple, soft, pulverulent fluorite, with calcite boxwork, Bell Hill mine.



Figure 5. Purple, angular, thin-walled fluorite boxworks. Middle pit, Fluorine Queen mine.



Figure 6. Large, angular, thick-walled boxworks in reddish-brown fluorite, Green Crystal mine.

have been found in varying amounts in most mines. The boxworks are composed of a network of fluorite veinlets (stockworks), occasionally calcite or dolomite veinlets, that surround dolomite fragments within the cryptovolcanic breccia pipes in the dolomite strata. Hydrothermal fluids subsequently dissolved the dolomite clasts and left open vuggy spaces. At the same time or shortly afterwards many voids have been partly or completely filled with younger generation minerals. The boxworks may remain open voids, but they usually have been partially to completely filled with fluorite, montmorillonite, chalcedony, quartz, calcite, or dolomite, or some combination of these minerals. The ores range from white, gray, tan, yellowish, green, brown, reddish-brown, bluish, or pale to dark purple hues.

The boxwork structures vary from easily friable frameworks to hard dense varieties. The Bell Hill, Blowout, and Dell No. 5, and other mines to a lesser extent, had abundant fine-grained friable boxworks, which upon mining easily crumbled into pulverulent type ores. The septa of the friable boxworks are thin-walled fluorite or may consist of calcite or sometimes dolomite, whose frameworks have been partly or completely replaced by younger fluorite. The Oversight and Hilltop mines contained nearly all dense boxwork type ores. The Fluoride No. 5 and Green Crystal mines were mostly hard dense boxwork type ore, with some soft

pulverulent and solid aphanitic types present. The Lost Sheep and Fluorite Queen No. 1 (Middle pit) mines graded from largely pulverulent type ore in the upper part of the breccia pipes, into abundant hard, dense boxwork ore with depth.

The shapes of the boxworks in this type of ore are typically angular (see figures 5 and 6), and related to the original shape of the dolomite clast, around which the fluorite veinlets have formed. Some boxworks are linear, whose forms have been controlled by selective replacements along bedding within a dolomite clast. Occasionally, a thin curvilinear boxwork can be found resulting from replacement of an algal stromatolite structure (see figure 7).

The size of the openings in the boxworks depends upon the original size of the dolomite clasts, as determined by the degree of shattering from cryptovolcanic explosions that fashioned the breccia pipes in the dolomite strata. Boxworks range in size from 1 mm to 12 cm (see figures 5 and 6). Larger boxworks may be present, but were not observed in the ore by the writer.

The wall thickness of the boxworks is related to the width of the original fracture, to any replacement of dolomite along the fracture, and to later infillings of younger generations of fluorite. Thin-walled boxworks

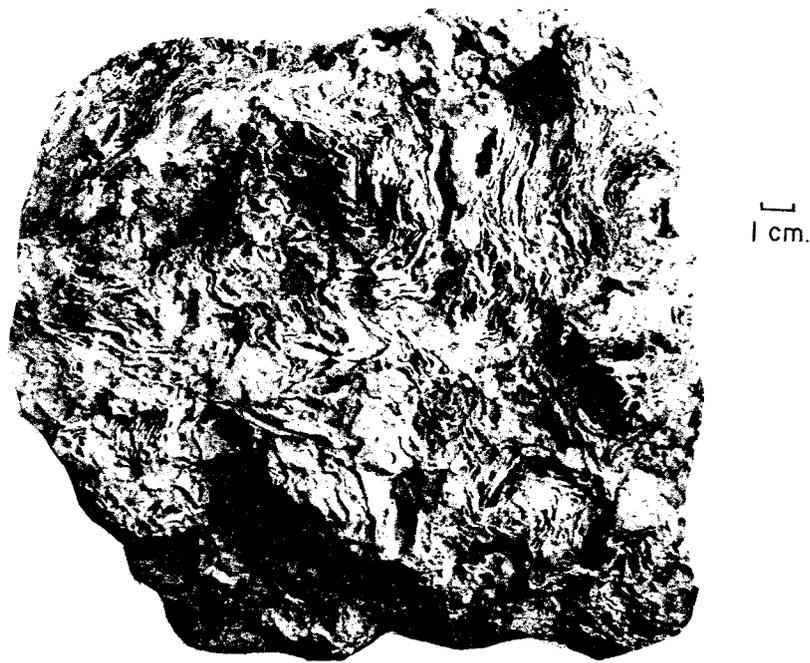


Figure 7. Thin curvilinear fluorite boxworks, replacement of algal stromatolite structures. Purple pit, Lost Sheep mine.

measure less than 1 mm (see figure 5), and thick-walled boxworks are up to 2 cm or wider (see figure 6).

Some boxworks remain essentially void, whereas others have partial to complete infillings of fluorite (see figure 8), or variable amounts of gangue minerals. At least three generations of fluorite have been observed in the boxwork ore. Some of the most common paragenetic sequences are as follows:

(Group A)

Septa	Infillings
White to pale green	light brown
White to pale green	light brown . . . light purple
White to pale green	reddish brown. purple
White to pale green	light purple . . . dark purple

(Group B)

Septa	Infillings
Light brown	pale green
Light brown	purple pale green
Dark brown	pale brown. pale green
Pale purple.	light green colorless
Dark purplish brown	pale brown. purple

Group A appears to be more typical of the southern and central fluorspar deposits at Spor Mountain, whereas Group B is more characteristic of the northern mines.

Gangue minerals found within the voids of the boxwork type are montmorillonite, chalcedony, quartz, calcite, and dolomite. The gangue minerals have formed late in the history of mineralization. Montmorillonite is by far the most common gangue mineral and occurs as partial to complete fillings within the boxworks (see figure 9). It occurs as a soft white powdery material, which is largely responsible for the high silica content of some ores. Chalcedony gangue is common to the Bell Hill, Fluorine Queen, Lost Sheep, and Luckie Louie mines, and a number of small prospects. Quartz occurs as small clear to white crystals which coat the boxworks (see figure 10), and is found in the lower parts of the Bell Hill, Blowout, Hilltop, Oversight, and Lost sheep mines. Calcite forms the boxwork septa of some Bell Hill ore (see figure 4); and has been found within fluorite boxworks at the Bell Hill, Blowout, and Fluorine Queen mines (see figure 11). The quantities of gangue minerals increase in abundance with depth in the mine, especially the montmorillonite, quartz, and chalcedony contents.

Aphanitic Ores

Hard, compact, and fine-textured fluorite masses

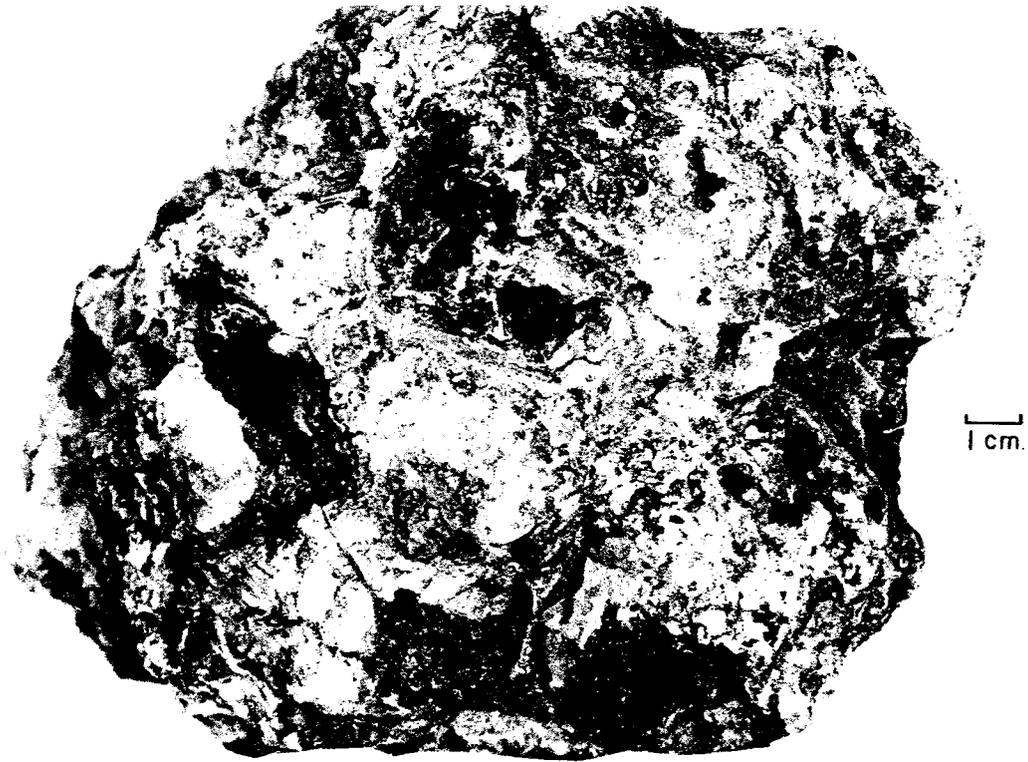


Figure 8. Purple fluorite boxworks, filled with green massive and crystalline fluorite. Purple pit, Lost Sheep mine.



Figure 9. Purple fluorite boxworks, with partial fillings of white montmorillonite clay. Middle pit, Fluorine Queen mine.

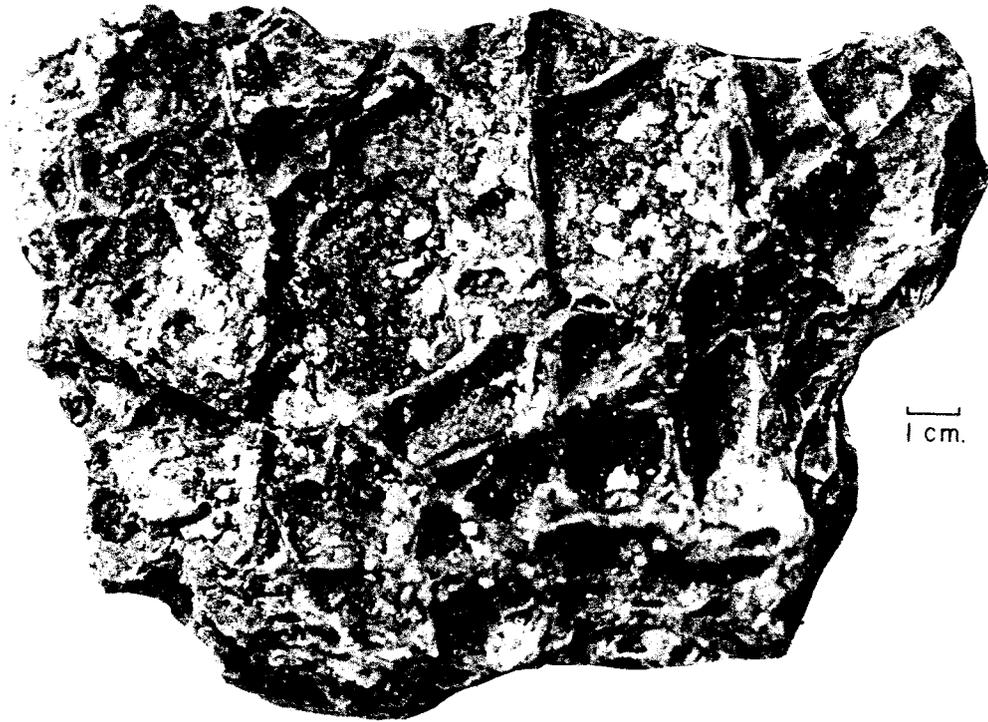


Figure 10. Pale purple fluorite boxworks, with colorless to white quartz druses. Purple pit, Lost Sheep mine.

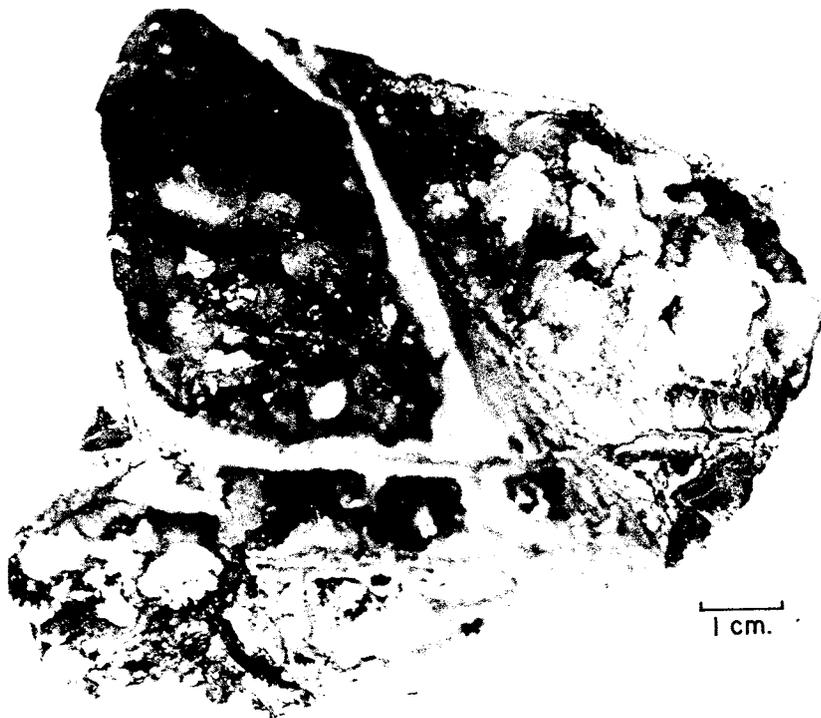


Figure 11. Pale purple fluorite boxworks, with partial fillings of colorless to white calcite. Middle pit, Fluorine Queen mine.



Figure 12. Aphanitic fluorite, with characteristic rhythmic banding. Dell No. 5 mine.

have been found in many of the Spor Mountain fluorspar deposits. It may occur as lumps in the pulverulent or friable boxwork types ores, or it may be concentrated in large solid masses within the breccia pipe. At the Dell No. 5 mine aphanitic type ore occurred as lumps in the more friable boxwork ore, and on the western side of the pipe it made up large areas of high grade dense ore averaging 92.8 percent fluorite. At the Green Crystal mine in places aphanitic ore was found as solid masses that assayed 92.5 percent fluorite. The Evening Star prospect consisted of massive aphanitic ore in veins up to 20 cm wide.

Aphanitic type ore is fine-grained and massive with characteristic rhythmic type banding (see figure 12), indicating deposition in open spaces and cavities. These openings likely were fashioned in part by explosive action that developed the breccia pipes by faulting, and in part by solution of dolomite during hydrothermal processes. Fluorite mineralization subsequently partially to completely filled the available openings with aphanitic ores. The deposits range from white, tan, brown, reddish-brown, and pale to dark purple hues. Aphanitic ores constitute the third most abundant type of ore, but the tonnage is small compared to the pulverulent and boxwork type ores.

Sponge Ores

Some fluorspar ores have structural patterns that

are rounded, hollow, tubular, and columnar in form (see figure 13), with open structures that anastomose aimlessly through the ore. These forms are called sponge ore by the writer, and best developed at the Lost Sheep and Dell No. 5 mines. The openings are interconnected for the most part, and suggest free circulation of hydrothermal fluids. The ores have a dense fine-grained textures and rhythmic type banding as found in the massive aphanitic type ores, but the rounded, hollow, tubular, and columnar structures are distinctive for the sponge type ore. Some samples show relic angular boxwork structures less than 1 mm wide (see figure 13), but for the most part these septa have been replaced or they were not present at the time of fluorite deposition. Rhythmic banding of fine-grained fluorite along open channelways is characteristic. Deposits of sponge ore varies from smooth rounded forms to hollow, elongated, or grotesque shapes. The color of the individual bands alternate from white to brown, variable tones of brown, white to purple, or pale to dark purple. The ores are high grade, averaging over 90 percent fluorite with small quantities of montmorillonite or silica gangue.

The sponge and aphanitic types of fluorspar ores are apparently inherent to the deeper or the more open parts of the breccia pipes. These ores are associated with areas of free circulation of fluids. The massive aphanitic type ores have been deposited in larger open channelways and cavities, whereas the sponge type ores have a somewhat more restrictive circulation through dolomite

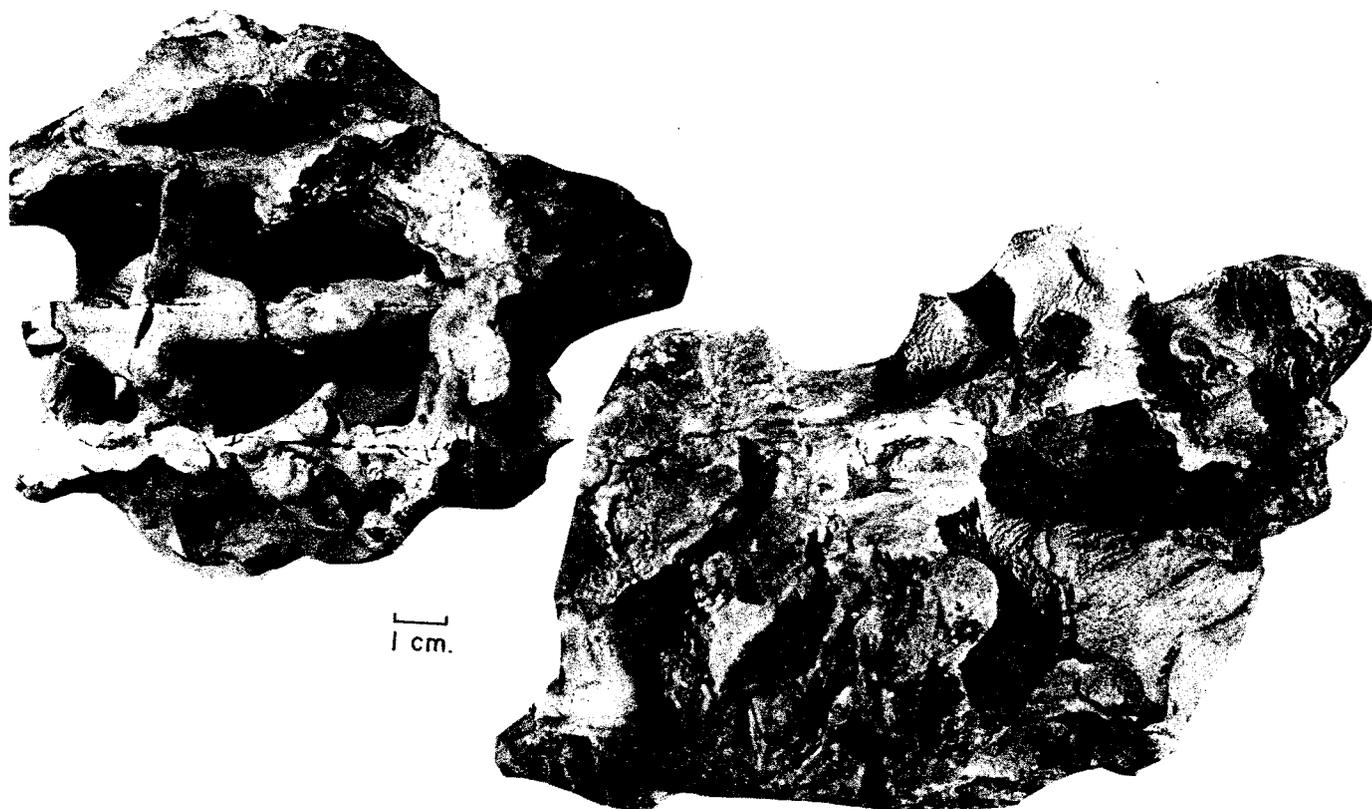


Figure 13. Sponge fluorite, with rounded, hollow, tubular, and columnar forms. Purple pit, Lost Sheep mine.

breccia. The breccia in some cases developed thin boxwork structures, but for the most part it was dissolved by hydrothermal fluids. Subsequently, the open spaces were filled with fine-grained banded fluorite along avenues of circulating fluids. The total tonnage of sponge type ore is not known, but it was a minor importance in the district.

Crystalline Ores

Coarse-textured fluorite, in which large distinct crystals or cleavage masses are recognizable, is rare at Spor Mountain. On the other hand, tiny scattered crystals along veinlets, or fine-granular drusy crusts of fluorite in boxwork ore can be found in many deposits. The large producing mines such as the Bell Hill, Blow-out, Dell No. 5, Floride, Fluorine Queen (East pit), Fluorine Queen No. 1 (Middle pit), and Lost Sheep mines, and others, contained fine druses of fluorite lining much of the boxwork ore. Purple cubic crystals less than 1 mm in size are typical. Occasionally, some boxworks are filled with colorless, white, or pale green fluorite crystals measuring 1 to 5 mm in diameter.

Colorless or pale purple cubes of fluorite, measuring 1 to 2 mm, were found at the Hilltop and Dell No. 5 mines. Small pieces of green fluorite crystals and cleavage masses are found on the dump at the Blue Queen prospect. The Green Crystal mine was named from the thin green crusts and tiny green crystals that line some of the boxworks in this ore. Small crystals appear to occur sporadically through veinlets at many mines. The fissure vein at the Thursday mine locally contained small pockets of coarsely crystalline fluorite.

The only commercial deposit of hard crystalline fluorite ore with coarse-granular textures, came from the Fissure pit of the Fluorine Queen No. 2 mine in the central part of Spor Mountain (see figure 14). The ore was typical of most commercial fluorite deposits, consisting of coarsely crystalline cleavage masses and banded crystalline ores. The ore was colorless to pale green and dense. About 3,000 tons of ore were mined in the early 1950's, and an additional few hundred tons were mined in 1972. The Fissure pit deposit is located along a fault in the Silurian Bell Hill Dolomite. The fault strikes N 38° E and dips 73° SE. On the surface the

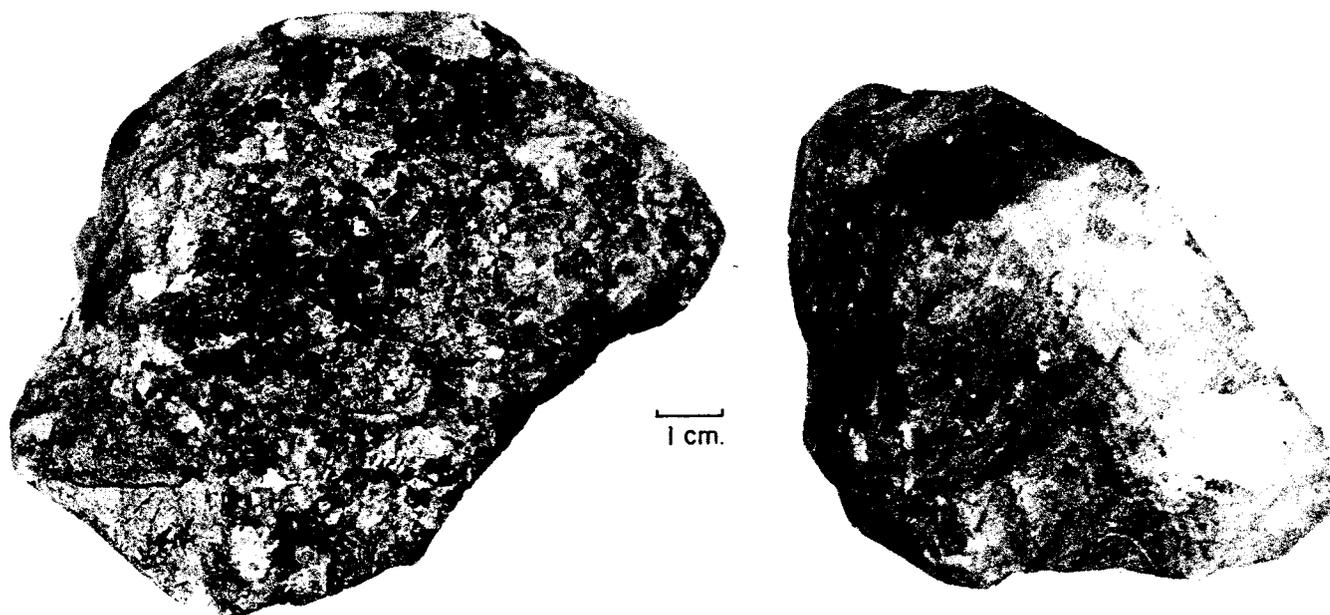


Figure 14. Coarsely crystalline and banded fluorite, colorless to pale green. Fissure pit, Fluorine Queen No. 2 mine.

deposit measured about 18 m long and 2.4 to 4.6 m wide, and was mined to a depth of 21 m. The ore averaged about 90 percent fluorite and 5 to 6 percent silica. The ore was only slightly radioactive. Fluorspar from the Fissure pit deposit differed from most of the ore at Spor Mountain in two ways: the occurrence is a fissure deposit, and the fluorite is dense coarse-textured and banded.

Associated Features

Although scarce some relict structures have been observed in the fluorspar ore from Spor Mountain. Relict bedding and thin beds or lenses of chert (see figure 15) have been found in a few deposits, especially in the workings of the Blowout and Lost Sheep mines. Silurian fossils completely replaced by fluorite have been found in at least three mines. Bauer (1952) found a *Favosites* sp. in the ore at the Lost Sheep mine. Staatz and Carr (1964) discovered a *Favosites* sp. in the east pipe of the Fluorine Queen property, and a horn coral in the large pipe at the Bell Hill Mine. The author found several replaced algal stromatolites (see figure 7), and bryozoa in the ore at the Lost Sheep mine.

Factors Controlling Form and Location of Ore Bodies

The mineralizing fluids that formed the fluorspar

deposits at Spor Mountain were probably derived from a magmatic source below the district. The fluids had to pass through hundreds of feet of country rock, and many changes may have occurred in the hydrothermal fluids as they moved to sites of deposition. The major factors controlling the form and location of fluorspar ore bodies are: (1) stratigraphic (2) lithologic, (3) structural, and (4) chemical.

Stratigraphic Controls

The main stratigraphic controls of the ore bodies at Spor Mountain include the fluorspar breccia pipes and veins in the Ordovician Fish Haven and Floride Dolomites, and the Silurian Bell Hill, Harrisite, Lost Sheep, and Thursday Dolomites. The breccia pipes may be confined to one sedimentary rock unit, but they commonly cross more than one unit. The pipes cut the sedimentary rock layers at angles from 40° to 80°. At depth the pipes narrow or split forming smaller pipes or narrow elongate bodies. They terminate against quartzite, or pinch out, or may be cut off by faults. Nearly all the commercial ore from Spor Mountain has come from breccia pipes within the above named dolomitic strata. Thirty-five breccia pipes have been productive, yielding from less than 100 tons to over 160,000 tons of ore per pipe. Only two fissure veins in dolomite have been productive. The Fissure pit of the Fluorine Queen No. 2 mine lies in the Silurian Bell Hill Dolomite, and

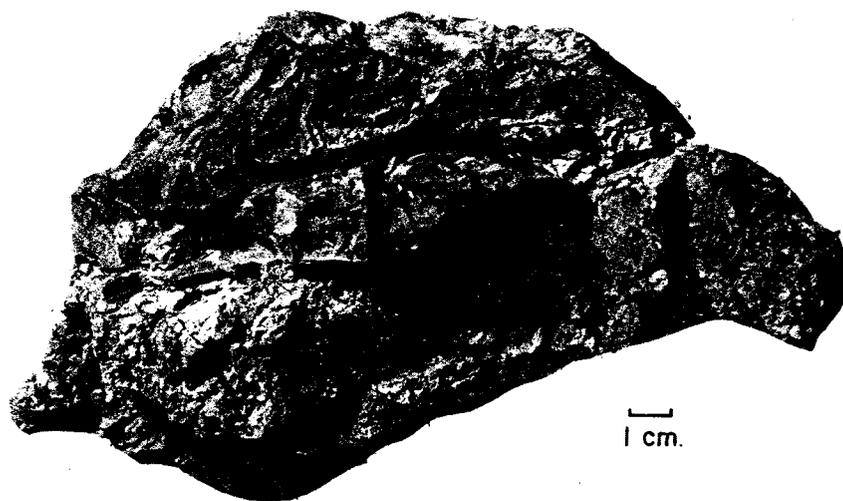


Figure 15. Unreplaced chert lens in light-brown fluorite. Lost Sheep mine.

yielded about 3,000 tons of ore. The Thursday mine lies in the Silurian Thursday Dolomite, and produced less than 100 tons from a fissure vein and a few tons from a small breccia pipe.

Small veins of fluorite also occur in the upper few meters in quartzite of the Ordovician Swan Peak Formation, and the lower 30 m of the Devonian Sevy Dolomite. The largest breccia pipe at the Dell mine, on the east side of Spor Mountain, bottomed against the massive quartzite member of the Swan Peak Formation. Small fluorite veins, up to 15 cm wide, extend for 2 to 3 m into the quartzite. At the Purple Spar prospect on the extreme northern end of Spor Mountain, purple veinlets of low-grade fluorite cut the lower beds of the Devonian Sevy Dolomite.

Nearly all commercial production of fluorite ore from Spor Mountain has been confined to the Upper Ordovician dolomites (Fish Haven and Floride) and the Silurian dolomites (Bell Hill, Harrisite, Lost Sheep, and Thursday). No commercial fluorite has been discovered within or below the quartzite of the Ordovician Swan Peak Formation, nor above the Silurian Thursday Dolomite.

Lithologic Controls

Fluorite has two main lithologic associations at Spor Mountain, i.e., fluorite is found within igneous rock bodies. These occurrences are (1) with intrusive rhyolite breccia plugs largely in the central and northern

portion of the district, and (2) with the beryllium tuff member of the Spor Mountain Formation on the flats surrounding the mountain. Numerous intrusive rhyolite breccia plugs occur along northeast-trending strike faults; and they are found also near, at the contact or within fluorite breccia pipes in dolomite strata in the district. The intrusive rhyolite breccia plugs form bodies of widely varying outcrops, many which are only a few meters across. One of the larger bodies occurs on the east side of the Lost Sheep property, and measures 375 m long and 125 m wide. The intrusive plugs cut Paleozoic sedimentary rocks, which are generally shattered at the contact. They usually form smooth weathered slopes with brickred soil, that is strewn with large breccia blocks. Rock materials of the plugs varies greatly in size and composition from place to place. The rock consists of small to large blocks of volcanic and sedimentary rocks in a matrix of secondary dolomite and volcanic materials. The sedimentary rocks are mostly dolomite and the igneous rocks are almost wholly porphyritic rhyolite. Intrusive breccia at the Lost Sheep and Blowout mines is almost exclusively porphyritic rhyolite.

The Fluorine Queen No. 4 mine is the only commercial fluorite deposit mined from an intrusive rhyolite breccia plug. The deposit lies at an elevation of 1830 m in the central part of Spor Mountain, and cuts the Silurian Bell Hill Dolomite. The intrusive plug is L-shaped, extending to the northwest about 40 m long and 9 m wide with a projection to the east-northeast about 24 m long and 4.5 m wide. The porphyritic rhyolite breccia plug is gray and fine-grained and con-

tains scattered phenocrysts of smoky quartz. The rock is iron stained and montmorillonite clay coats some of the fractures. In the center of the northwest-trending plug was a somewhat circular mass about 12 m in diameter of red dolomitized breccia, which contained low-grade fluorspar. About 3,000 tons of ore was mined in the early 1950's, that averaged 60 percent fluorite and up to 12 percent silica. This ore was blended with higher grade materials from nearby breccia pipes in dolomite. The deposit remained idle until 1972 when U. S. Energy Corporation mined about 800 tons of additional ore from the open pit. The fluorspar was white to lavender, and the matrix contained abundant carbonate material. The ore was slightly radioactive, ranging from 0.01 to 0.02 percent uranium. Other intrusive rhyolite breccia plugs contain some fluorite, but their economic potential has not been determined.

Large beryllium-bearing deposits occur in stratified volcanic tuffs on the flats surrounding Spor Mountain (Staatz, 1963, 36 p.). Fluorite, which is closely associated with the beryllium mineralization, represents a large tonnage of low-grade fluorspar (Bullock, 1976, p. 55-56). The principal deposits lie in an area about 3 km wide and 6 km long on the western and southern sides of Spor Mountain. Additional deposits are found at The Dell on the east side of the mountain. The beryllium-fluorite bearing deposits are associated with the beryllium tuff member of the Lower Miocene Spor Mountain Formation (Lindsey, 1979a, p. 33-36; 1976b). The beryllium tuff member ranges from 20 to 60 m in thickness. It is comprised of stratified vitric tuff and tuffaceous breccia, with abundant clasts of carbonate rocks and a few clasts of volcanic rocks and quartzite. The tuff includes bentonite and thin beds of ash flows. Much of the tuff has been hydrothermally altered to clay, potassium feldspar, and fluorite.

Beryllium ore production to date at Spor Mountain has been restricted to operations by Brush Wellman, Inc., which operates large open pits. The Roadside mine, which was first in operation, initially measured 15 to 40 m deep and 1,160 m long. The Blue Chalk mine is 30 m deep and 425 m long. In 1974 the Fluro pit was developed, measuring 45 m maximum depth and 520 m long. Each of these mines may be enlarged for additional ore. Other active beryllium mines include the Monitor, Rainbow, Sigma Emma, and Tarus mines. Mining operations indicate that the beryllium-bearing tuff deposits normally range between 3 percent and 15 percent fluorite for an average of 8 percent. An analysis of a large ore sample from a stockpile averaged 12.67 percent fluorite, 64.0 percent silica, and 1.91 percent calcite.

Brush Wellman, Inc., has not attempted to recover fluorite at their processing plant northeast of Delta. The tailings pile from this operation averages 8 percent fluorite, and constitutes a large potential source of low-grade fluorspar ore.

Structural Control

The fluorspar deposits at Spor Mountain are strongly controlled by the following structural features: (1) faulting, (2) cryptovolcanic breccia pipes, and (3) intrusive breccia plugs. Several bodies are found along or adjacent to linear zones in the highly faulted Spor Mountain area. Most of the faults associated with the fluorspar bodies are northeast strike faults or easterly trending transverse faults. One small deposit and two prospects lie along northwest trending transverse faults. Two commercial fissure vein deposits, the Fluorine Queen No. 2 and the Thursday mines, are localized along faults in dolomite. Small veins along faults are found at the Blue Queen, Eagle Rock, Lost Soul, Nonella, and Purple Spar prospects. A myriad of veinlets are found with the various deposits in the district. Commercial breccia pipe deposits closely associated with faults include the Bell Hill, Dell No. 5, Floride, Floride No. 18, and Harrisite mines. Many other breccia pipes lie near faults, but they are not exposed in the mine workings. The numerous transverse and strike faults that cut Spor Mountain, and the caldera subsidence faults on the east side of the mountain, likely have had significant structural control on the movement and localization of mineralizing fluids in the district.

The principal structural control for the fluorspar deposits at Spor Mountain are cryptovolcanic breccia pipes in the Upper Ordovician and Silurian dolomites. These breccia pipes are circular, oval, elongate, or irregular in outline, and vary from less than 1 m to as much as 58 by 34 m in diameter. Most are smooth walled, and decrease in size with depth by forming smaller pipes or narrow elongate bodies. They terminate against quartzite, pinch out, or may be cut off by a fault. These breccia pipes have been fashioned by cryptovolcanic action in which gases of magmatic origin have been violently expelled through Paleozoic dolomites. These overlying sedimentary rocks were shattered at points of maximum pressure, forming funnel-like breccia pipes. The open brecciated rock in the pipes was the major site for fluorspar deposition by mineralizing fluids. Thirty-five of these structural forms in dolomite have been commercially mined in the district, and others are likely to be found in the future. From 1 to 5 breccia pipes have been found at each of the following mines:

Bell Hill, Blowout, Dell, Dell No. 5, Floride, Floride Nos. 1, 5, 13, and 18, Fluorine Queen, Fluorine Queen No. 1, Green Crystal, Harrisite, Hill Top, Lost Sheep, Lucky Louie, Oversight, and Thursday mines (see table 1).

The intrusive rhyolite breccia plugs are considered both as lithologic and as structural controls in regard to the fluorite occurrences at Spor Mountain. Their lithologic relationships have been previously discussed, as well as some of their important structural features. Structurally, they are intrusive plugs that were forcefully emplaced into Paleozoic rocks at Spor Mountain. They are partially mineralized, and perhaps played an important role in directing the mineralizing solutions into the productive breccia pipes in dolomite rocks. Intrusive rhyolite breccia plugs are in contact with fluorspar ore at the Bell Hill, Blowout, Dell No. 5, Fluorine Queen No. 4, Hilltop, Lost Sheep and Thursday mines; and other mines have nearby outcroppings of plugs.

Chemical Controls

The fluorspar ore bodies at Spor Mountain were formed from hydrothermal fluids by replacement of country rock and by fracture and cavity fillings. The principal controls involved were: (1) direct deposition of fluorite in fracture and cavity openings, (2) the replacement of dolomite and country rock by fluorite, and (3) the solution of dolomite within boxworks, followed by partial to complete cavity fillings.

The first step in the process of mineralization within Spor Mountain was the fracturing of Paleozoic strata by faulting. Later during the period of Tertiary volcanism the explosive action of gases violently shattered dolomite rock, and was responsible for the development of intrusive rhyolite breccia plugs and cryptovolcanic breccia pipes. Faulting assisted in the localization and distribution of many of these explosive features. Within the mountain area hydrothermal mineralization was controlled and concentrated predominantly along the cryptovolcanic breccia pipes. Deposition of fluorite likely began as fissure and cavity fillings along various types of openings; but of special interest is the development of a network of fluorite veinlets forming around a large percentage of dolomite breccia within the pipes. The original deposition of fluorite around dolomite breccia fragments formed the framework (septa) for the abundant boxwork type ore. Hydrothermal fluids subsequently dissolved the dolomite breccia fragments and left open vuggy spaces. At the same time or shortly afterwards many voids were partly or

completely filled with younger generation fluorite. Gangue minerals within the boxworks may include montmorillonite, quartz, dolomite, calcite, and chalcidony.

Massive and dense crystalline ore of commercial value has been found only along two veins as fissure fillings and replacements of dolomite. Dense and aphanitic type ore has resulted from direct deposition of fluorite in open spaces, and replacement of dolomite in some cases. Abundant pulverulent type ore appears to have been formed by direct replacement of breccia fines, which retained this friable texture in the fluorspar ore. Also pulverulent ore is associated with calcite boxworks. Later surges of fluorine-bearing fluids deposited ore in the boxwork, rendering a friable fluorspar ore. This relationship is best observed in the Bell Hill ores.

Fluorite disseminations and replacements occur in the stratified beryllium tuff member of the Spor Mountain Formation in the flats surrounding Spor Mountain. Fluorite occurs as replacements of dolomite clasts in the tuff, disseminations in hydrothermally altered tuff, and as mineral coatings on tiny mineral grains in the tuff. The beryllium ore averages 8 percent fluorite, but no attempt has been made to recover it. The beryllium-fluorite deposits have been formed from hydrothermal fluids that moved along faults in and near Spor Mountain, then spread laterally through porous stratified tuff.

Alteration

Hydrothermal alteration of dolomite, rhyolite breccia, and volcanic tuff is widely recognized at Spor Mountain. The most common gangue mineral and alteration product in association with the fluorspar deposits is calcium-magnesium montmorillonite clay, a product of argillic alteration. The montmorillonite occurs as a white waxy clay mineral in varying amounts in the ore. Within the breccia pipes in the Paleozoic dolomite montmorillonite is found intermixed with fluorspar ore, within fluorite boxworks, interlayered with fluorite and as rounded balls or elongated veinlike masses within the ore. Argillic alteration is more abundant in the deeper portions of the breccia pipes. The clay has been somewhat successfully removed from commercial ore by jiggling and by washing. To a lesser degree, silicification is found also in the lower parts of the larger breccia pipes. The silica is present in the form of chalcidony and quartz. Chalcidony is a dark-gray dense aphanitic mineral resembling chert. Quartz is present as small clear to white crystals that occur as druses within the voids of the boxwork type of ore.

At the Lost Sheep mine a rhyolite breccia plug lies immediately adjacent to the Purple pit fluorspar deposit. A recent open cut in the plug has exposed a montmorillonite replacement that measures several meters wide. Strong argillic alteration is associated with several rhyolite plugs, as found at the Prospector prospect, and the Bell Hill, Blowout, Dell No. 5, Fluorine Queen No. 4, and Thursday mines.

Disseminated fluorite accompanies the beryllium deposits around Spor Mountain. The beryllium ore occurs in the beryllium tuff member of the Miocene Spor Mountain Formation. Hydrothermal alteration associated with these deposits has been investigated by Lindsey, Ganow, and Mountjoy (1973, 20 p.). Vitric and zeolitic tuffs are present outside the mineralized area, whereas argillic and feldspathic tuffs are present in the mineralized area. The first stage or early alteration is characterized by argillization of vitric tuff, forming montmorillonite clay. Much of the argillic alteration is incomplete, but may comprise as much as 80 percent of the tuff. An advanced alteration is marked by the conversion of the argillic tuff to feldspathic tuff, with the appearance of potassium feldspar. This late stage of alteration is also characterized by fluorite-silica replacement of the carbonate clasts or nodules within the volcanic tuff. The silica is represented by chalcedony and opal. Individual nodules may contain as much as 90 percent calcite, 80 percent chalcedony, 70 percent opal, or 50 percent fluorite. The beryllium content in the nodules may range as high as 3.2 percent.

ORE GENESIS AND SUMMARY

Fluorite, beryllium, and uranium mineralization at Spor Mountain was associated with Miocene volcanism of the Thomas Range. This stage of volcanism was contemporaneous with early Basin-and-Range faulting and was characterized by eruptions of volcanic ash and pumice and quiet eruptions of alkali rhyolite as flows and domes (Lindsey, 1979a, p. 1). The first phase of Miocene volcanism erupted and deposited the beryllium tuff and porphyritic rhyolite members of the Spor Mountain Formation. After a long period of block faulting, thin stratified tuff and thick alkali rhyolite flows of the Topaz Mountain Rhyolite were erupted. Both the Spor Mountain Formation and the Topaz Mountain Rhyolite are fluorine rich as evident from abundant topaz in each formation. Mineralization appears to have begun during or shortly after eruption of Spor Mountain Formation rhyolite, and evidently continued episodically or more or less continuously until after eruption of Topaz Mountain Rhyolite (Ludwig,

K.R., and others, 1980). Volcanism was accompanied by lithophile metal mineralization, which deposited commercial quantities of fluorite, beryllium, and uranium.

The Spor Mountain area apparently is underlain by a large pluton of alkali rhyolite composition, that has been responsible for the volcanic eruptions and the source materials for the Spor Mountain Formation and the Topaz Mountain Rhyolite. Guided in large part by the abundant faults on the mountain, cryptovolcanic eruptions fashioned the fluorspar breccia pipes in Paleozoic dolomite, and provided avenues for intrusions of closely associated porphyritic rhyolite plugs. Mineralizing fluids rising from the cooling pluton, subsequently deposited epithermal fluorite, beryllium, and uranium throughout the district.

Hydrothermal fluids deposited uraniumiferous fluorspar in breccia pipes and along some faults in Ordovician and Silurian dolomites on Spor Mountain. The uranium content of the fluorspar deposits increase toward the south end of the mountain, and some central and southern deposits contain detectible amounts of beryllium. Other hydrothermal fluids guided mainly by east and northeast trending faults were responsible for the beryllium mineralization in the district. The mineralizing fluids deposited the beryllium mineral bertrandite, fluorite, and uraniumiferous opal in the beryllium tuff member of the Spor Mountain Formation, that lies in the valleys surrounding the mountain. No primary uranium minerals have been found. The deposits at the Yellow Chief mine in the Dell consist of secondary uranium minerals in the beryllium tuff member of the Spor Mountain Formation. The uranium ore likely was derived by ground water leaching of nearby primary hydrothermal deposits or uranium-rich volcanic rocks. The three chemical elements fluorine, beryllium, and uranium are genetically interrelated in time and space, and represent lithophile metal mineralization associated with Miocene volcanism of the district.

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