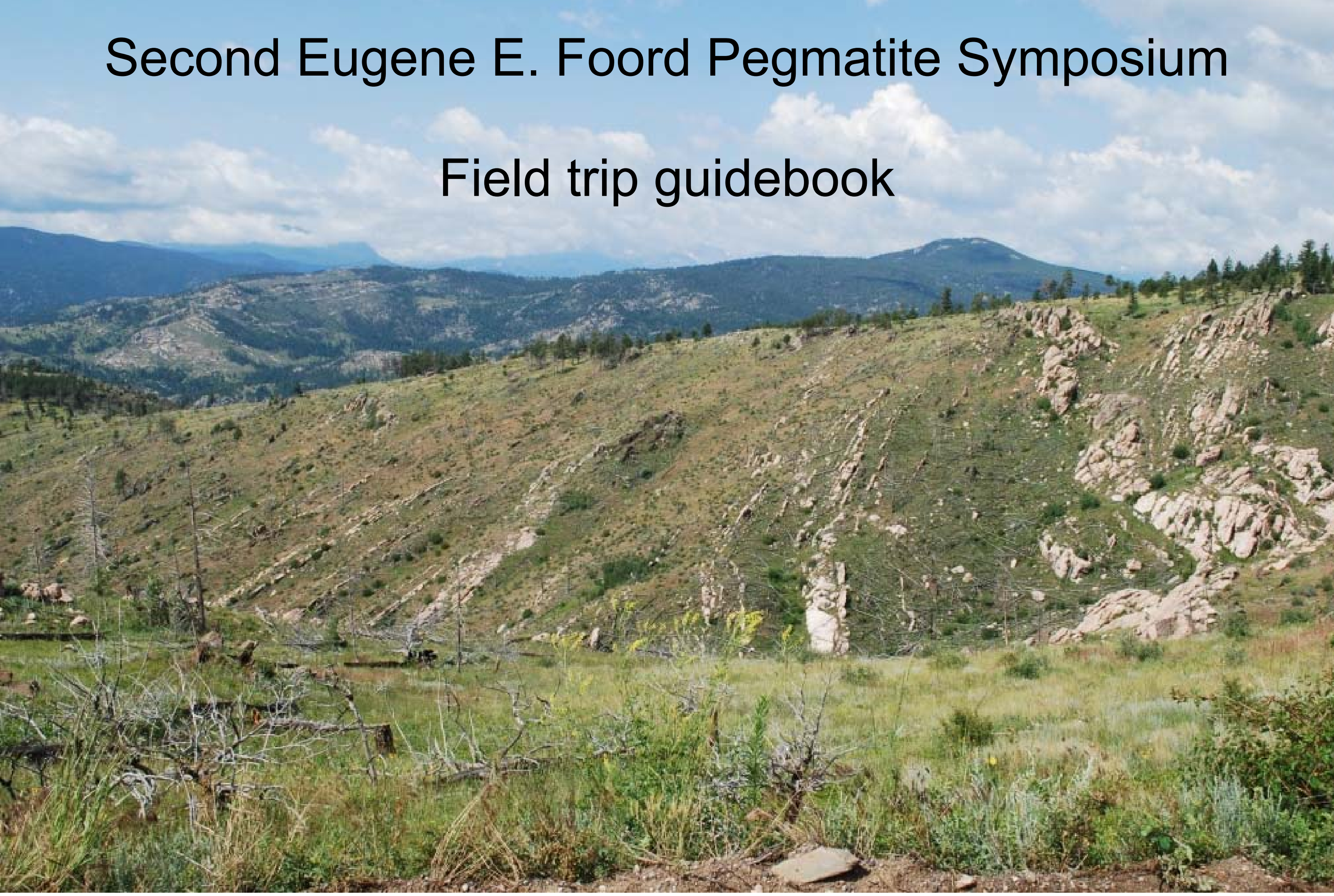
Second Eugene E. Foord Pegmatite Symposium

Field trip guidebook



View of pegmatites in Proterozoic schists south of the Hyatt pegmatite, Larimer County

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Golden, Colorado

July 15 - 19, 2016

Field Trip Guidebook for the Second Eugene E. Foord Pegmatite Symposium

Compiled by Mark Ivan Jacobson
July 2016

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Field Trip schedule

Specific meeting times and places for trips are determined by field trip leaders. Please contact them for confirmation of times and places

MONDAY TRIPS	LEADER	RENDEZVOUS
Eight Mile Park pegmatite field, Mica Lode, Meyers and School Section pegmatites	Steve Wolfe and Jennifer Gerring	8 AM leave Golden. 10:30 AM meet at the Colorado Quarries office on south side of highway 50 and S. 15th Street in Canon City.
Big Bertha pegmatite, South Platte District, Jefferson County	*Jeff Self and Donna Ware*	*8 AM leave Golden. 9:00 AM meet at the Pine Junction Park & Ride on highway 285 between Bailey and Conifer. Forest service will allow us to use the road.*
St. Peters Dome alkali pegmatites, El Paso County	Philip Persson	8 AM leave Golden. 10:00 AM meet at location near Colorado Springs.
Northern Crystal Mountain pegmatite field, Wisom Ranch, Bull Elk Beryl Crystal and Big Boulder pegmatites.	*Mark Jacobson*	8 AM leave Golden 10:00 AM meet at Masonville Mercantile Store.
Amazonite pegmatites, Smoky Hawk claim, Crystal Peak, Teller County	Amber Brenzikofer	8 AM if leaving from Golden. Meet at intersection of highway 24 and Trail Creek road in the Lake George Forest Service work center on NE corner.
TUESDAY TRIPS	**LEADER**	**RENDEZVOUS**
Platt Pegmatite, Carbon County, Wyoming	Steve Zahony	8 AM if leaving Golden, Meet up at the junction of routes 125 and 127, which is 13.2 miles north of Walden.
Brown Derby pegmatites, Quartz Creek pegmatite field, Gunnison County	Mike Perkins	**5:30** AM if leaving from Golden. 10:30 AM meet at junction of State Highway 50 and graded dirt road County 44 on north side. The 4WD road starts later at NFS road 802
Devils Hole pegmatite field, Devils Hole and Chief pegmatites, Fremont County	Steve Wolfe and Jennifer Gerring	8 AM leave Golden. 10:30 AM meet at the rock shop on the south side of route 50, just east of the entrance to the Royal Gorge. Trip ends midway between Salida and Canon city.
St. Peters Dome alkali pegmatites, El Paso County	Philip Persson	8 AM leave Golden. 10:00 AM meet at a location near Colorado Springs.
Southern Crystal Mountain pegmatite field, Hyatt and Storm Mountain pegmatites, Larimer County	Mark Jacobson	8 AM leave Golden. 10 AM, meet at Highway 34 (Big Thompson road) and W. County road 22H at the Dam Store (north side) just before entering the canyon.

Field Trip guide to the amazonite-bearing pegmatites, Crystal Peak, Teller and Park Counties

The following description of the Lake George intrusive center is reprinted from: Field Trip Guidebook from the Eugene E. Foord Memorial Symposium on NYF-Type Pegmatites, Denver, Colorado, September 11-14, 1999, p. 28-34. Publications authored by USGS employees are public domain.

Amazonite-bearing pegmatites of the Lake George Intrusive Center

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Among the numerous pegmatites of the Colorado Rocky Mountain Front Range, those of the Lake George-Florissant area are mineralogically geochemically and structurally of great interest and geologic significance. The host Pikes Peak batholith (PPB) is elongate in plan, approximately 50 x 100 km (5000 km^2), composite and generally subalkalic. The batholith was shallowly emplaced (epizonal) and sharply transects its walls and may have breached its roof as well (Barker et al. 1975). Biotite granite and biotite-hornblende granite is predominant; quartz syenite, fayalite granite and riebeckite granite is present in minor amounts. The slightly younger, elliptical, Lake George intrusive stock, approximately 8 x 6 5 km in diameter, is exposed at the western margin of the PPB, northeast of Lake George (Figure l). Petrologic and field studies of the entire PPB as well as individual plutons and intrusive centers include Barker et al. (1975, 1976), Foord et al. (1995), Hutchinson (1976), Simmons and Heinrich (1980), Simmons et al. (1987), Unruh et al. (1995), Wobus (1976), and Wobus and Anderson (1978). Data for minerals found within the pegmatites in the Lake George intrusive center are given in Foord and Martin (1979).

Lake George Intrusive Center

The Lake George intrusive center is one of seven temporally as well as spatially related centers that have been mapped within or adjacent to the PPB (Figure 1). Six of the centers including the one at Lake George are thought to be along two northwest trending fractures which run parallel to one of the dominant fault trends of the southern Front Range. These fractures are thought to represent old rifts along which anorogenic, alkali plutons were emplaced and presumably served as conduits that allowed syenitic magma from the lower crust to reach epizonal levels rapidly with little time for reaction with crustal rocks (Wobus & Anderson 1978). Barker et al. (1975) proposed that primary, mantle-derived, alkali olivine basaltic magma reacted with and partially melted potassium-depleted rocks of the lower to intermediate crust to produce relatively sodic magmas. These magmas were then shallowly emplaced into the upper crust without further reaction or contamination and subsequently crystallized to form rocks of syenitic composition or may have further differentiated to form fayalite granite and/or riebeckite granite. If the ascending Na-rich magma had reacted extensively with the older Precambrian wall and roof rocks, a more potassic magma would have been produced.

* deceased January 8, 1998.

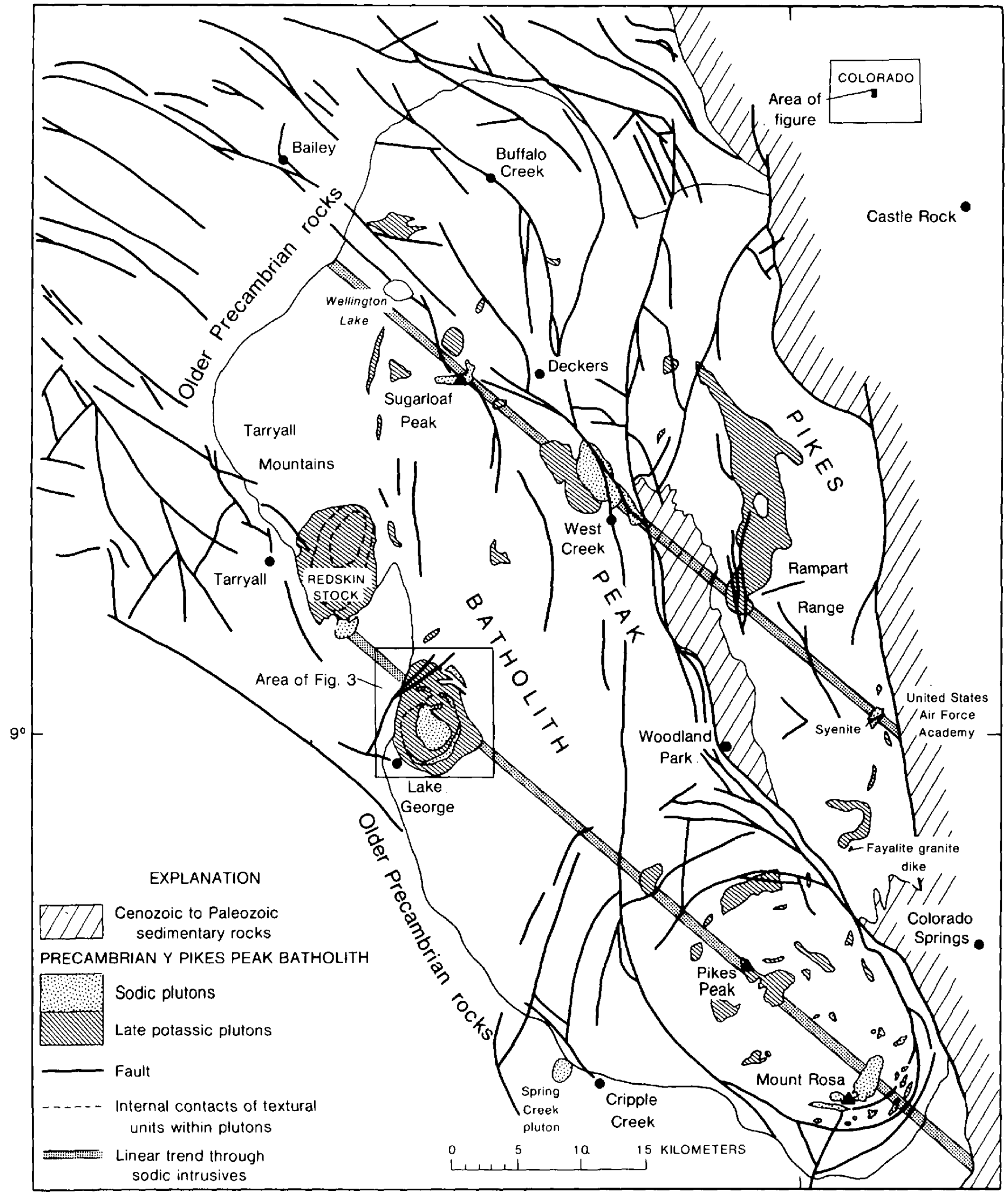

Figure 1. Geologic map of the Pikes Peak batholith showing locations of sodic and late potassic plutons as well as the two northwest trending linear fracture systems through the intrusive center. The Lake George Intrusive Center is shown in more detail in Figure 2. Map modified from Wobus and Anderson (1978).

The Lake George Intrusive Center (Figure 2) contains partial ring dikes of quartz syenite to fayalite granite that are distributed around a central stock of quartz syenite to syenomonzonite. The ring dikes and syenite stock intrude a small, zoned pluton, containing late textural variants of the Pikes Peak granite. The earlier pluton shows zonation from marginal medium-grained granite to central fine-grained granite (Wobus 1976). The presence of large elongate blocks of alkali gabbro as inclusions in the syenite of the central stock and in the fine-grained granite outside the stock is unique.

The host Pikes Peak Granite (Ypc on the map of Wobus and Anderson [1978]) is a pink to reddish-tan, medium to coarse-grained, equigranular to serate, biotite or hornblende-biotite granite and quartz monzonite. It is composed of perthitic alkali feldspar, quartz, oligociase and biotite with or without hornblende. The outermost zone of the intrusive center (Ypm) is comprised of medium grained biotite granite, pink to buff in color, and locally porphyritic with feldspar phenocrysts. It is composed of microcline perthite, quartz, oligoclase and biotite. The next unit closest to the core syenite is a fine grained pink granite (Ypf), which is generally equigranular, with salt and pepper texture caused by biotite distributed among quartz and feldspar grains. It is characterized by a non-perthitic microcline and oligoclase. The central syenite (Ysm) to syenomonzonite, is greenish-tan in color, equigranular, ranging from fine-grained to coarse-grained, and is composed dominantly of perthitic alkali feldspar and separate albite-oligoclase, with ferrohastingsite and minor quartz, altered fayalite, hedenbergite and opaque oxides. The youngest unit, which forms a partial ring dike (Ysg) is composed of quartz syenite to fayalite granite that is pink in color, equigranular, medium-grained, and comprised of interlocking perthitic alkali feldspar laths and quartz, with minor ferrohastingsite, biotite, opaque oxides and altered fayalite. Included blocks of alkali gabbro (Ygb) are composed of andesine-labradorite, augite, iron oxides and conspicuous secondary biotite.

Pegmatites

Pegmatites are concentrated within the potassic rock units (Ypc, Ypm, and Ypf) of the Pikes Peak Granite (Figure 2) and are of the simple type based on their mineralogy, structure and zonation. The pegmatites, pegmatitic segregations, and associated aplitic material are derived from the host granite and range in size from small, lensoid or tabular miarolitic bodies less than 1 m in maximum dimension to dikes up to 50 m in length and several meters in thickness. Larger bodies may pinch and swell markedly over a very short distance Sharp contacts are relatively common between the dikes and the host rocks as well as for the smaller miarolitic lenses and bodies. The basal portion of many, of the dikes and .larger lensoid segregations are generally aplitic and may show poorly defined mineral stratification. However, no "line rock" such as that developed in the complex pegmatite-aplite dikes of San Diego Co., California, has been observed. The basal portions usually contain more albite than the upper portions of the pegmatite dikes, which are generally coarse-grained, have well-developed graphic texture, and are rich in microcline and quartz. The principal mafic mineral is biotite.

The "pocket zone" is centrally located at or slightly above the median line of a dike or lensoid body. Graphic pegmatite is very well developed immediately above and below the pockets. The mineralogy of the pocket zone is very similar to the graphic pegmatite portions of the dikes (microcline, quartz, albite and biotite) except for, the presence of minor amounts of unusual or rare mineral species, with or without the development of amazonite. In some places, the graphic pegmatite beneath pocket cavities is strongly solution-etched. The quartz rods and blebs are effectively removed from the host microcline which results in a rock with a sponge-like appearance. This is believed to be a result of late-stage dissolution by corrosive fluids.

The pockets themselves may be completely filled in by crystalline phases or they may still have some open space remaining. Only a few open and uncollapsed pockets are found near the present ground surface. Most pockets have either partly or wholly collapsed at some time in the past from the effects of near-surface weathering and frost action. Pockets that have not been fractured open or breached by near-surface effects have most closely preserved the original

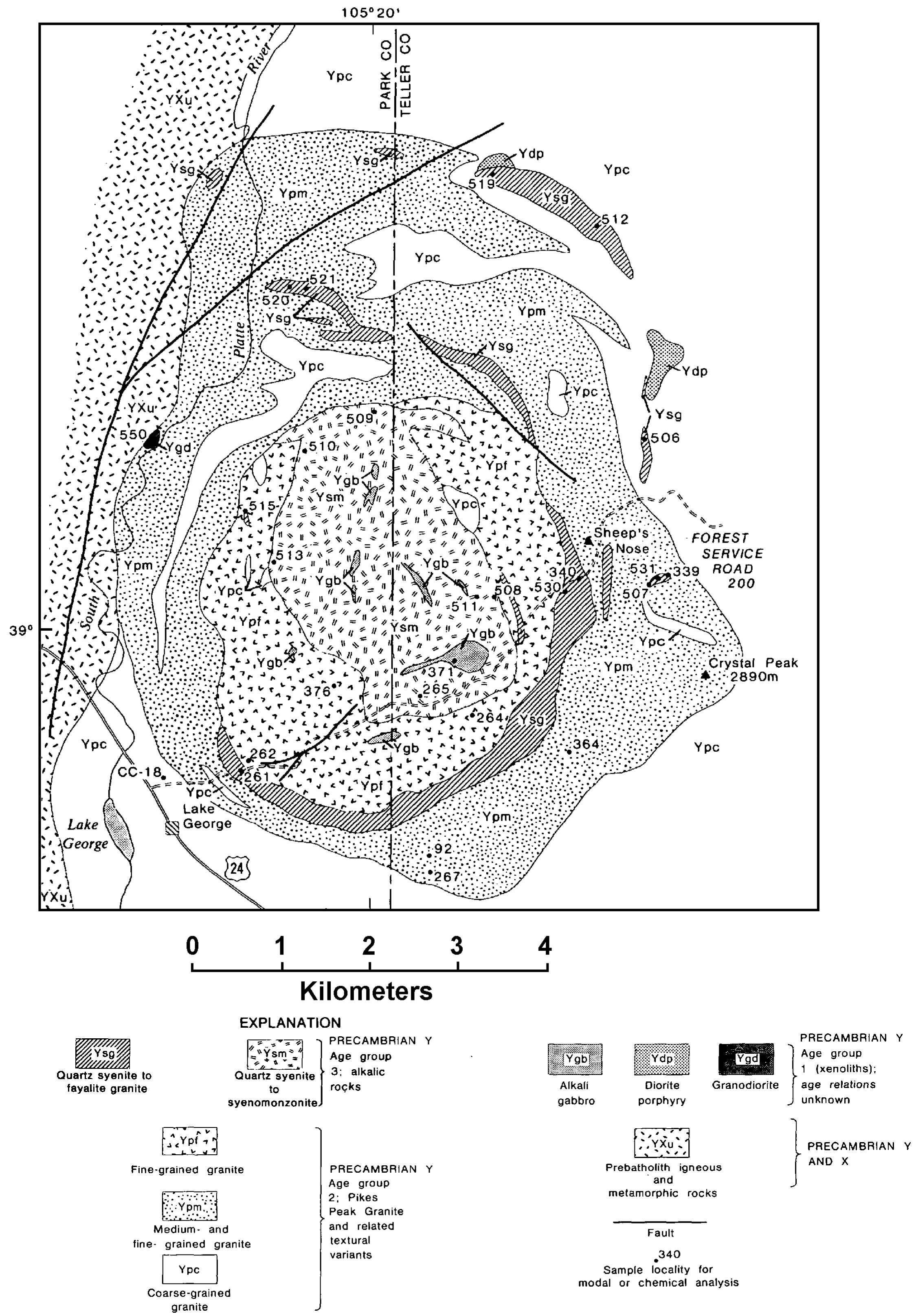

Figure 2. Geologic map of the intrusive center at Lake George. Modified from Wobus and Anderson (1978).

configuration and structure. However, some fracturing and disruption occurred at the time of pocket formation or shortly thereafter as is evidenced by rehealed fractures and the presence of overgrowths on various mineral phases. A few pockets seem to have been "flooded" with late fluorite which frequently permeates and replaces other mineral phases. Evidence of late-stage chemical etching (corrosion) is commonly observed in the pockets. The vast majority of pockets excavated are filled to some extent with dark red-brown, brown or black Fe-Mn hydrous oxides, micas and clay minerals (montmorillonite-nontronite), which contain fragments of previously formed pocket minerals. Of all the several tens of thousands of pockets that have been excavated since 1865, perhaps 20 to 30 % contained amazonite of various hues. The remaining 70 to 80 % contained ordinary microcline in addition to quartz and albite. The particularly striking "white cap" specimens of amazonite are found in less than 1 % of all amazonite-containing pockets. Most pockets are circular to elliptical in plan but they may be irregular in outline as well. In cross-section, pockets are commonly mushroom-shaped, with the floors generally being flat. Dimensions vary from less than 1 x 1 x 0.4 m to more than 3 x 4 x 1.5 inches. Details of the pegmatite mineralogy, particularly of the pocket phases and contained feldspars, as well as other data are given in Foord and Martin (1979). In excess of 30 primary and 12 secondary minerals have been identified from the pegmatite dikes (Table 1).

Table 1. Minerals identified from amazonite-bearing pegmatites in the Pikes Peak batholith.

PRIMARY

Albite	Orthoclase
Apatite	Phenakite
Barite	Pyrite
Barylite	Pyrochlore-microlite
Beryl	Quartz (smoky, amethyst, citrine, colorless)
Biotite-phlogopite	Rhodochrosite
Calcite	Sanidine
Cassiterite	Siderite
Columbite-tantalite	Stibiocolumbite-stibiotantalite
Epidote	Tapiolite
Fluorite	Thorite
Galena	Topaz
Hematite	Tourma1ine (schorl-elbaite)
Ilmenite	Xenotime
Monazite	Zircon
Microcline (amazonite and whitish)	Zinnwaldite
Muscovite	

SECONDARY

Bertrandite	Epidote	Montmorillonite
Bastnaesite	Goethite	Psilomelane
Cerussite	Hematite	Pyrolusite
Chlorite	Hollandite	Todorokite

Almost all microcline crystals studied (either amazonite or regular microcline) are maximum (i.e. structurally well-ordered) microcline The coexisting albite is structurally low albite. The fact that both albite and microcline contain a perfectly long-range-ordered distribution of Si and Al among the tetrahedral sites available in the structures indicates that these feldspars have reached equilibrium in the pocket environment. This is to be expected in such water-rich environments. In contrast, overgrowths contain a more varied and complicated assemblage of feldspars that reflects events during a pocket's evolution maximum microcline, intermediate microcline, mixtures of the two, or mixtures of intermediate microcline and orthoclase. In all overgrowths, blebs of albite, invariably of the well-ordered variety, are rare or absent. The overgrowths on pocket feldspars represent a drastic and rapid change in physiochemical conditions within the pegmatite pockets, which is reflected not only by the structural state of the feldspar, but by the chemistry as well. These features are interpreted to indicate re-opening of pocket systems.

Fractional crystallization of the Pikes Peak magma, as suggested by Simmons and Heinrich (1980), Foord & Martin (1979) and Simmons et al. (1987) resulted in water-enriched liquid segregates of residual fluids richer in quartz and albite than the granite melt, and these fractionates became the parent fluid from which the pegmatites crystallized. Amazonite feldspar is relatively common in pegmatites of the Pikes Peak bathohth because of several factors. The batholith is of the anorogenic type, is probably rift-related, and is related by crystal fractionation processes to a gabbroic parent magma. The derivative magmas produced are highly depleted in Ca, Mg and S owing to early crystallization and removal of olivine, pyroxene, calcic plagioclase and sulfide minerals from the gabbroic magma. They also follow a distinctive pattern of iron enrichment, and elements such as Fe^{+3}, Pb, Mn, Cu and Rb attain relatively high levels of concentration in the granitic compositions that represent the end stages of a protracted history of differentiation. These enrichment trends are further enhanced at the pocket stage of development in the pegmatites, where the crystal grown medium became dominantly aqueous. It is from these last "dregs" of the evolving anorogenic igneous complex that spectacular development of amazonite occurred.

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Field Trip guide to the Eight Mile Park pegmatite field, Fremont County

The following information about the Eight Mile Park pegmatite field is copied from Hanley, Heinrich and Page (1950) and Heinrich (1947, 1948) with updating as needed, based on current knowledge and later research by others as cited.

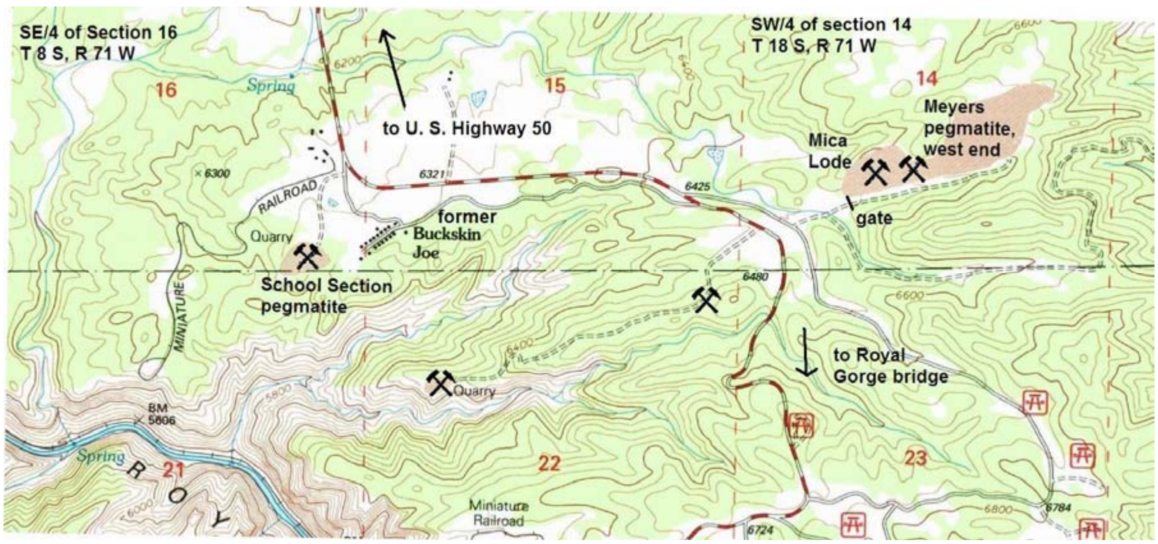

Figure 1. Location index map of the Mica Lode, Meyers and School Section pegmatites just north of the Royal Gorge city park, Fremont County, CO.

Eight Mile Park pegmatite field

Location and general features

Eight Mile Park is 5 miles by air line northwest of Canon City and 8 miles by road. It embraces an area of about 10 square miles in T. 18 S., R. 71 W., sixth principal meridian, Fremont County, and is bounded on the north by U. S. Highway 50, on the east by the eastward-dipping hogback of Cambro-Ordovician sediments, on the south by the Royal Gorge of the Arkansas River, and on the west by westward-dipping Paleozoic sediments.

The northern part of the park is nearly level. Toward the south it changes to a gently rolling country and then into a series of deep valleys and ridges. These valleys and ridges have greater relief near the Royal Gorge. The position of the pegmatites has had an important influence on the topography of the southern part of the district. The trend of the ridges ranges from N. 70° E. to east in conformity with the general trend of the larger pegmatites.

Geology

The district is underlain by Proterozoic igneous and metamorphic rocks that have been intruded by numerous pegmatites and a few mafic dikes. The Proterozoic rocks are overlain unconformably by a sedimentary sequence that begins with the Lower Ordovician Manitou Limestone. The pegmatites do not intrude the sediments and are considered Proterozoic (1700 Mya) in age, although none of them have been age dated by various methods.

The igneous and metamorphic rocks are coarse porphyritic granite, fine-grained granite, aplitic granite, gneissic granite, quartz-mica gneisses, and quartz-mica schists. Gradations between these rocks and lithologic variations probably caused by granitic intrusions are common. The predominant granite north of and within the pegmatite field has been named the Crampton Mountain-Twin mountain batholith and has been dated at 1701 Mya.

This granite is a reddish rock containing huge phenocrysts of red microcline in a coarse-grained matrix of biotite, quartz, and microcline. Large, partly altered schist bodies exposed in it may represent either included blocks or roof pendants. The most abundant wall rock near the pegmatites is a granite gneiss containing biotite, quartz, and red microcline.

The pegmatites are present just interior and exterior to the granite, near its contact with the metamorphic rocks. The pegmatites have profoundly altered the large gneiss inclusions but have affected the wall rocks only by emphasizing or crumpling the metamorphic structures locally. Both the schistosity and gneissic structure strike N. 80° E. and dip steeply to the northwest or the southeast. The youngest instrusives are mafic, aphanitic dikes.

Pegmatites

Pegmatites are abundant in the southern part of Eight Mile Park. Because of their superior resistance to erosion, the pegmatites are well exposed; the outcrops of the wall rocks are relatively few and poor. The pegmatites range in size from lenses several feet long to roughly tabular bodies that are as much as three-quarters of a mile long and 500 feet wide. The larger pegmatites are irregular, pinching and swelling along their length. The wider parts usually are exposed as prominent knobs called "blow-outs" by the miners. The contacts with the wall rock are usually steep or vertical, but at one place in the School Section mine a horizontal contact was observed. The general strike of these pegmatites is N. 75° E.

The chief minerals are feldspar, quartz, and muscovite with accessory biotite, garnet, tourmaline (schorl), and beryl. Bismuth carbonate minerals, columbite-tantalite, and triplite commonly occur in some of these pegmatites. Rarer minerals in the pegmatites to be visited, the Mica Lode, Meyers and School Section pegmatites are gahnite, zircon, elbaite, montebrasite, apatite, wardite, lacroixite, various uranium minerals, and lepidolite.

Graphic and granitic intergrowths of quartz and microcline constitute the largest part of the pegmatites, and a combination of sub-parallel muscovite flakes with quartz is abundant. The rare minerals are mostly associated with the minerals found in the western end of the Meyers Lode pegmatite, which circa 1910 was known as the Royal Gorge no. 2 pegmatite by Sterrett (1909). These include lepidolite, montebrasite, elbaite (green, pink, watermelon), and zircon.

Mica Lode pegmatite

Location

The Mica Lode pegmatite is in the NE 1/4 of the SW 1/4 of section 14, T. 18 S., R. 71 W., sixth principal meridian, where it once formed a pronounced conical knob that was a distinct landmark in the south-central part of Eight Mile Park. Quarrying operations has reduced this landmark to a mere shadow of what it once was. The mine workings can be reached from U. S. Highway 50 by a dirt mine road less than 1/2 mile long.

History

The pegmatite, called the Mica Hill pegmatite (Mica Hill mica mine), has been known by local citizens of Canon City since before 1906. James D. Endicott, the miner and mineral dealer of Canon City, was familiar with this pegmatite but only found minerals of value just to the east of it (Sterrett 1909). J. E. Meyers of Canon City located a claim on the pegmatite in 1928, who sold a half interest to B. O. Halstead in 1929. The deposit was purchased in 1930 and retained until 1939 by the M & S, Inc., of Denver, Colo. In 1944 it was owned by the Colorado Feldspar Co. of Canon City but leased to Robert A. Shipley of that city. In 2016, this pegmatite is owned by Colorado Quarries of Canon City. According to J. E. Meyers the production prior to 1942 was 168,000 tons of feldspar, 25,000 tons of scrap mica, and about 30 tons of beryl. Since 1942 the Metals Reserve Company depot at Salida, Colo., has purchased at least 26.8 tons of beryl from this deposit, and 9,699 tons of scrap mica and 1,091 tons of feldspar have been produced. A mill on the property treated scrap mica-bearing rock but this mill was removed by 1945.

The economic geology and mineralogy of the deposit have been briefly described by Sterrett (1923) and the paragenesis of the pegmatite has been discussed by Landes (1935, 1939). During World War II (Hanley, Heinrich and Page 1950), the pegmatite was mapped by E. Wm. Heinrich in the winter of 1942. A more detailed investigation of the eastern 750 feet of the pegmatite was made during 3 days in September and 6 days in October 1944 by J. B. Hanley assisted at different times by A. F. Trites, Jr., and J. W. Adams. During this investigation the pegmatite was mapped by plane table and telescopic alidade.

Mine workings

The workings consist of four open-cuts near the east end of the pegmatite. The main open-cut, which is on the south side of the pegmatite knob, is roughly triangular in shape with the apex toward the south. It was 215 feet long and 205 feet wide, with a depth of at least 131 feet at the north face in 1944. The deepest part of the pit was flooded to an altitude of 6,045 feet in 1944. This large and deep quarry has been considerably deepened since 1944. Mining has been intermittently active until at least 1990. Another large open-cut, designated the "west" cut, is west of and connects with the main open-cut at an altitude of 6,160 feet. This cut is 60 feet long and 55 feet wide, with a maximum depth of 18 feet. Two smaller cuts are on the east and north slopes of the pegmatite knob. The one labeled "east" cut in the pegmatite map is roughly L- shaped; it is 50 feet long and 18 feet wide and has an average depth of 4 feet. The other is the original discovery hole and is called the "north" cut. It is 59 feet long, 12 feet wide, and about 10 feet deep.

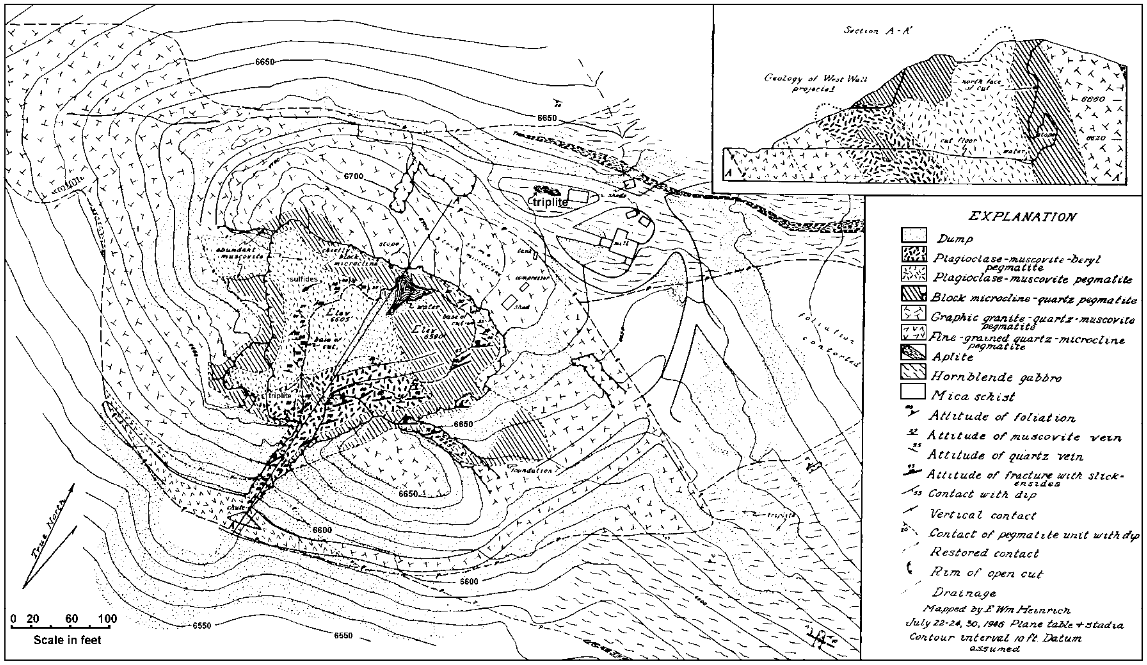

Figure 2. Geologic map of the Mica Lode pegmatite. Modified after Heinrich (1948).

Pegmatite geology

Pegmatite country rock — The wall rock of the Mica Lode pegmatite is probably quartz-mica schist, although granite gneiss occurs near the extreme eastern end. The exposures are very sparse and poor in the vicinity of the pegmatite. In one outcrop on the northwest side of this pegmatite the schistosity strikes N. 68° E. and dips vertically. A body of mixed quartz-mica schist and pegmatite, 50 feet in length and as much as 7 feet in width, is exposed within the pegmatite body from 50 to 100 feet north of the west open-cut. This mixed rock contains schist patches of random orientation that have been reworked by the pegmatite and have lost many of the characteristic features of the original wall rock.

Pegmatite — The Mica Lode pegmatite is an east-trending body that intrudes schists and granite gneisses. It is tadpole-shaped and at least 2,000 feet long. The eastern 650 feet is as much as 400 feet wide, whereas the western end is less than 100 feet wide. The wider part of the pegmatite is well zoned, but the intermediate zone and core are lacking in the narrower parts. The pegmatite contact with the wall rock, where exposed at two places along the north side of the dike, is sharply defined. The contact is not exposed on the south side, and only the approximate position can be mapped. The contacts of the mixed schist and pegmatite body are extremely vague, as would be expected if this body is an inclusion that has been partly assimilated.

The contact dips 60° NE in the north open-cut and 85° SE. near the place where the dike narrows, but the attitude of the contact cannot be determined elsewhere. The zonal structure of the pegmatite is better known and suggests that the upper part of the pegmatite body may dip 20° to 25° N. but may rapidly steepen in depth, in which case the walls also may be expected to steepen in dip with depth. The surface distribution of the different types of pegmatite and the meager structural evidence suggest that the pegmatite body may be lenticular in section as well as in plan.

A distinct brecciated zone, striking N 52° E and dipping 59° NW is exposed for a length of 110 feet and a width of 8 feet in the southeast face of the main opencut at the inner end of the old haulage cut at an altitude of 6,100 feet. This brecciated zone has passed through both the wall zone and core of the pegmatite without any displacement of the zonal contact.

The eastern end of the pegmatite is well zoned. The three zones, which have been mapped, are a wall zone of quartz-microcline-muscovite-biotite pegmatite, an intermediate zone of muscovite-quartz-albite pegmatite containing beryl, and a core of microcline-quartz pegmatite. In addition, a unit of microcline-quartz-muscovite pegmatite cuts across the core into the wall zones and merges with the intermediate zone. No border zone was observed at the two places where the pegmatite contact with the wall rock is exposed. Later mining, circa 1988, exposed a red albitic zone that was particularly rich in white beryl. This unit may have been totally removed but fragments from it might be found in the dump.

The quartz-microcline-muscovite-biotite pegmatite of the wall zones is composed mainly of white to gray quartz, pink microcline, greenish-gray muscovite, and biotite with accessory black tourmaline, garnet, and apatite. A distinguishing characteristic of this zone is the occurrence of blades of muscovite and biotite that are only 2 or 3 inches wide at their outer ends but are more than 1 foot wide at their inner ends. Some of these blades are more than 10 feet long, and all of them have grown at right angles to the pegmatite contact. The average grain size of this pegmatite is probably between 6 inches and 1 foot. This zone is 40 to 50 feet thick along the footwall and at least 18 feet thick along the hanging-wall contact. Where the dike narrows to less than 100 feet it is composed entirely of wall-zone material. The structure of this zone is probably controlled by the external structure of the pegmatite, and the contact of the wall zone with the core or intermediate zone is probably parallel to the walls of the pegmatite.

The muscovite-quartz-albite pegmatite of the intermediate zone is exposed only between the wall zone and the core in the south haulage cut and in the main open-cut. This zone appears to be a pod localized near the footwall at the thickest part of the pegmatite body. It is exposed for 90 feet along the strike, but the lateral extensions are hidden beneath dump material. The zone is 25 feet thick in the walls of the haulage cut. It is parallel in trend to the pegmatite body and dips 22° to 25° N. The exposures suggest that the zone pinches out in depth, but it may widen below the floor of the open-cut.

The zone contains grayish-green muscovite, white quartz, and pale-pink to light-lavender albite with accessory beryl, columbite-tantalite, triplite (Heinrich 1951), and some bismuth carbonate minerals. Muscovite occurs chiefly as clusters of radiating blades but also as aggregates of small flakes and books. It is wedged, fishtailed, reeved, ruled, and has pronounced "A" structure. Because of these defects it can be used only as scrap mica. The albite occurs in large masses associated with the muscovite and is generally subplaty in habit.

The accessory minerals have been of interest to collectors since the pegmatite's discovery. Beryl occurs in pale blue-green to yellow-green subhedral crystals that are often tapered. Many of the crystals are so fractured that they seem to be composed of separate fine grains. The crystals may be as much as 1 foot in diameter and 6 feet long, but the average size is about 2 inches by 1 foot. Triplite occurs in clove-brown masses and rough crystals as much as 1 foot in size (Heinrich 1951). In 1955, radioactive columbite was discovered in the quarry as subhedral to remarkable euhedral crystals in both albite and muscovite (Heinrich 1962). Individual crystals exceeded 2 pounds in weight with more than 1,200 pounds of broken masses reported at that time. Heinrich (1962, 1364) attributed the radioactivity in part to the presence of parsonite, a hydrated secondary uranium mineral, filling cracks and coating crystal faces of columbite as well as uraninite inclusions. In 1982, several large manganocolumbite crystals were still exposed in the quarry. Microprobe analysis by one of Petr Černý's graduate students (Černý 1985 personal communication, microprobe results) in 1985 proved that at least some of the radioactivity is due to urano-plumbo-pyrochlore inclusions in the manganocolumbite.

The microcline-quartz pegmatite of the core forms a large lens 415 feet long and 225 feet wide on the surface. Its apparent thickness is about 150 feet, but its true thickness may be much greater. It is composed of light-buff to pale-pink microcline and grayish-white quartz with accessory muscovite. The individual masses of microcline and quartz are as much as 35 feet long and 10 feet wide. Quartz generally occurs as isolated masses in a microcline matrix. In the face of the main open-cut these quartz masses are exposed as rough rods and teardrop-shaped bodies that are oriented at right angles to the upper contact of the core with the wall zone.

Muscovite occurs in the core as two types of radiating masses formed by wedge-shaped books, some of which are 3 feet in length. The mica books in one type appear to have grown outward from fracture planes, which are usually coated with small muscovite flakes parallel to the fracture plane. In the other type the books are clustered into spherical masses, commonly 10 feet in diameter, that are scattered through the core.

The microcline-quartz-muscovite pegmatite occurs in an irregularly shaped mass near the center of the pegmatite body. The longer axis of the mass appears to be parallel to the strike of the pegmatite. This unit merges with the muscovite-quartz-albite pegmatite in depth, and although most of this unit occurs within the core, it also cuts across the contact between the core and the upper wall zone in the west cut. It contains the minerals of the zones that it transects, but also contains additional muscovite, albite, and garnet. The muscovite occurs typically as aggregates of flakes about 1 inch in size that are intergrown with light-lavender albite around a central mass of quartz and brownish-red garnet. The typical bodies have a tabular form and are as much as 20 to 30 feet in length and height but only 2 to 3 feet in width. They are usually oriented with the length parallel to the long axis of the main pegmatite body and the intermediate dimension vertical. Where this unit is contained within the core, about 40 to 50 percent of the rock consists of core minerals, and the mica masses make up the rest.

The muscovite and associated minerals in the mica masses may have been formed by replacement along concealed fractures or may have resulted from the assimilation of schist xenoliths, a possibility that is suggested by the large quantity of garnet in the central part of the masses. Comparison of the mica and plagioclase within the masses with the same minerals in the core and the intermediate zone might indicate the origin of the unit.

Mineral deposits

The Mica Lode pegmatite up to 1945 has produced over 169,000 tons of potash feldspar, 34,700 tons of scrap mica, 57 tons of beryl, and 615 pounds of columbite-tantalite. The beryl and the columbite-tantalite are in the intermediate zone; the feldspar is in the core and the microcline-quartz-muscovite unit; and the scrap muscovite is recovered from all the units except the wall zone.

Feldspar — The microcline in the core and in the microcline-quartz-muscovite unit is relatively free from impurities. The core prior to mining had a length of 415 feet, a width of 225 feet, and an apparent thickness of 150 feet. A part of it about 150 feet long, 120 feet wide, and from 55 to 85 feet deep was mined out prior to 1945.

The feldspar content of the core was visually estimated at 50 to 60 percent. An estimated 5 to 10 percent of recoverable muscovite also is present. In addition to the feldspar in the core, the microcline-quartz-muscovite unit contains 17 to 20 percent of recoverable microcline.

Scrap muscovite — Muscovite is recovered from the microcline-quartz-muscovite pegmatite unit, the microcline-quartz pegmatite of the core, and the muscovite-quartz-albite pegmatite of the intermediate zone. The mineral has two distinct habits: wedge-shaped books that are fishtailed, reeved, and ruled and have pronounced "A" structure; and small flakes, about 1 inch in size, mixed with albite and other minerals.

The size and shape of the microcline-quartz-muscovite unit is not known beyond the present exposures. However, the block exposed in the west wall of the main open-cut, in the wall between the main open-cut and the west open-cut, and in the north wall of the west open-cut probably extends beyond the present exposures. It is very irregular in shape and size, with a maximum length of 185 feet, a maximum width of 140 feet, and a maximum depth of 115 feet. The unit is visually estimated to contain 35 to 40 percent muscovite; 35 to 40 percent feldspar, at least 50 percent of which is albite; and 20 to 30 percent quartz and garnet. Scrap muscovite makes up 5 to 10 percent of the three blocks of the core and 15 to 20 percent of the intermediate zone.

Beryl — A composite chip sample representing most of the beryl crystals exposed in the main open-cut, analyzed by the Chemical Laboratory of the Geological Survey, had a BeO content of 12.68 percent. Two shipments of beryl sold to the Metals Reserve Company at Salida contained 12.01 percent and 12.44 percent BeO. Many of the beryl crystals are too small to be recovered by hand cobbing, but the beryl usually breaks free from the surrounding minerals, and the recovery can be kept high enough by careful handling to be profitable under 1944 prices.

Columbite — Most of the columbite-tantalite in the deposit occurs in subhedral crystals usually less than 2 inches in size. A later discovery circa 1958 (Heinrich 1962) yielded up to a foot long, euhedral crystals. Beryl and columbite-tantalite occur only in the intermediate zone and appear to be distributed uniformly through it. The intermediate zone is 25 feet thick and is exposed in the main open-cut for at least 90 feet along the strike. It has an average depth of 60 feet down the dip. The ends of the zone at the surface are covered by dumps. About 53 percent of the exposed part of the zone was mined out by 1945. On the basis of visual estimates and past-production figures the zone probably contains 1 to 2 percent beryl. It is estimated to contain also 15 to 20 percent muscovite. The content of columbite-tantalite is not known.

Meyers pegmatite

Location

The Meyers pegmatite in section 14, T 18 S, R 71 W, sixth principal meridian, is east of the Mica Lode pegmatite. The open pit workings in 1945 were 1,500 feet east of the Mica Lode open-cut and 1.5 miles south of U. S. Highway 50. Although the ends of the two pegmatites are within 200 feet of each other, they are not connected on the surface and probably are not connected in depth.

History

During 1906 and 1907, Charles Alexander Begthol, a jeweler in Canon City had teamed up with James D. Endicott to locate and develop local gemstones. This effort led to Endicott discovering opaque green, blue and pink elbaite with lepidolite in a pegmatite, which they claimed as the Royal Gorge no. 2. Sterrett (1909, 844) reported on this find as "on an oval hill about 200 yards east of the Mica Hill mica mine." Unfortunately, all the elbaite was opaque and frequently altered to chalky forms and no pockets were ever found.

After visiting the locality, Douglas Sterrett noted some other minerals of possible scientific interest which he communicated to Waldemar T. Schaller, another U.S. Geological Survey mineralogist-geologist. Schaller contacted James Endicott to provide him with additional samples of the white phosphate mineral. Schaller described the material as a new mineral and successively named it natramblygonite and then as fremontite. Heinrich and Corey (1955) objected to the name and recommended renaming it natromontebrasite since the hydroxyl greatly exceeded fluorine. Unfortunately, Fransolet et al. (2007) discredited natromontebrasite and showed that it was montebrasite with alteration coatings of wardite and lacroixite.

By 1929, J. E. Meyers had claimed the pegmatite and started excavating the central area, just east of where Endicott had prospected the pegmatite. Later it has been operated intermittently by the Colorado Feldspar Co. According to J. E. Meyers the past production has been several thousand tons of feldspar, 200 tons of mica, and about a ton of beryl.

The pegmatite was investigated by E. Wm. Heinrich in the winter of 1942 and was mapped by a combination of plane table and alidade and compass and pace methods. After the main feldspar mining area was abandoned prior to 1980, only collectors occasionally visited the lithium-rich areas to the west.

Mine workings

Two large open-cuts and numerous small exploratory trenches constitute the workings. The eastern and larger open-cut is 120 feet long, 100 feet wide, and 40 feet deep at the face. The central western cut is 120 feet in length, ranges from 10 to 70 feet in width, and is 50 feet deep. The extreme western part of the pegmatite where albitic (cleavelandite) core-margin units outcrop, has only several small prospect pits.

Geology

Both of the two large pegmatites that crop out on the property are lenticular, with tapering ends and several offshoots. The northern pegmatite ranges from 100 to 200 feet in width and has been mapped along the trend for a distance of 1,000 feet. The total length of this pegmatite is nearly half a mile. All the outcrops are composed of a granitic intergrowth of minerals, and the pegmatite probably has little value as a source of hand-separable feldspar, scrap mica, or other pegmatite products.

The Meyers mine is in the southern pegmatite, which is more irregular and ranges from 200 to nearly 500 feet in width. It has been mapped along the trend for a distance of 1,500 feet, and it probably continues for an additional 1,200 feet. The pegmatite has a general strike of N 70° E and appears to be vertical. The contacts are usually conformable to the metamorphic structures of the wall rock but locally cut across the schistosity.

Several large, highly altered schist inclusions have been seen in the pegmatite.

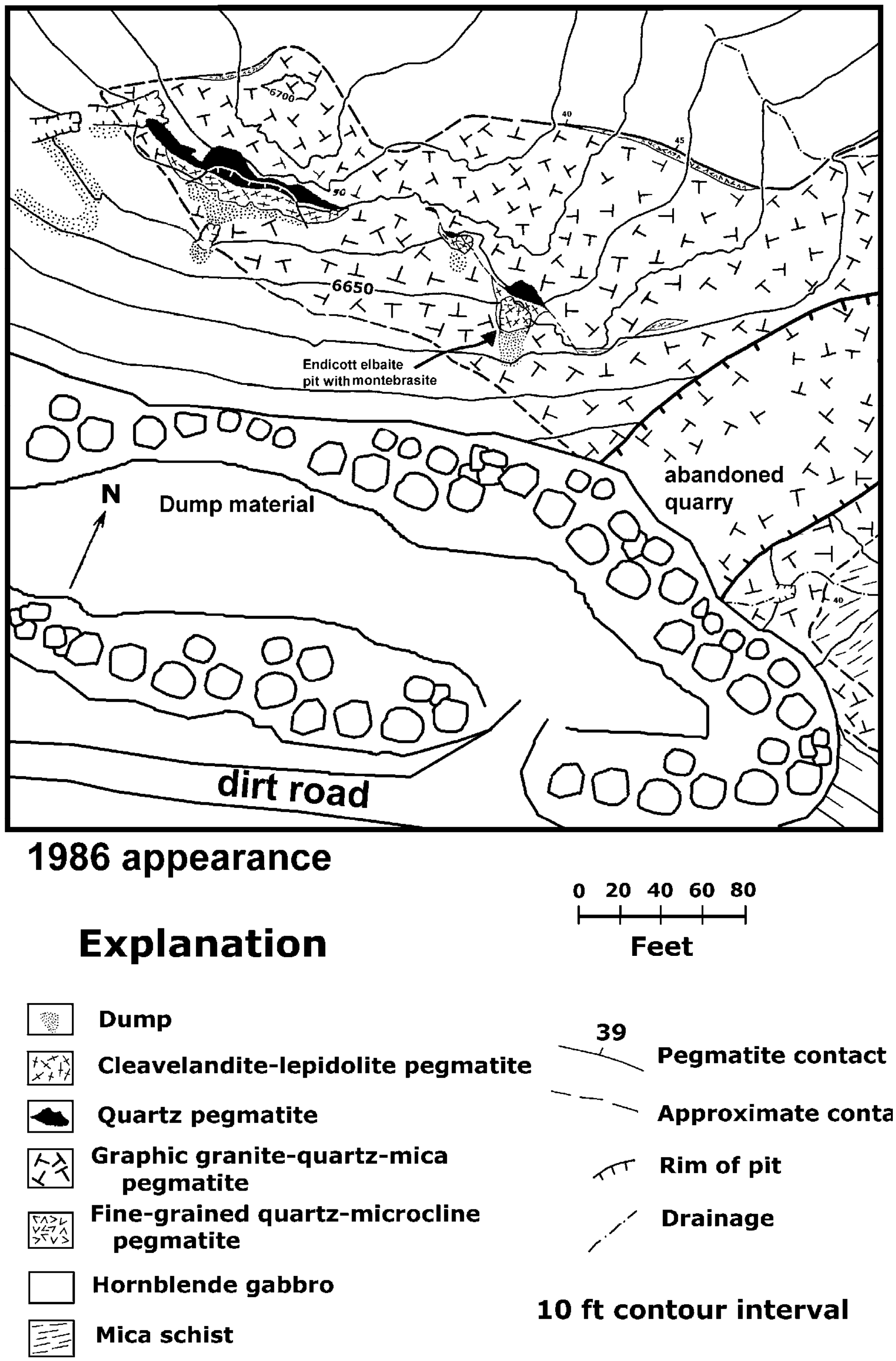

Figure 2. The western end of the Meyers pegmatite showing the quartz core segments with cleavelandite core margin units. Modified from Heinrich (1948).

The pegmatite exposed in the Meyers mine is poorly zoned. The pegmatite consists mainly of quartz-muscovite where the muscovite is intergrown in subparallel arrangement in the quartz and quartz-microcline, sometimes with a graphic texture. Masses of these two pegmatite units are interspersed with transecting bodies of massive quartz, blocks of microcline, and large blades of intergrown biotite and muscovite. A few crystals of beryl were exposed during mining. Most of this pegmatite was mined prior to 1980 and the former quarry has been mostly filled in.

The western end of the pegmatite contains two types of pegmatite: the microcline-muscovite pegmatite described above and cleavelandite-lepidolite pegmatite that occurs as patches within the microcline-muscovite pegmatite. Seven patches, the largest of which is exposed for 50 feet in length and 30 feet in width, were mapped. This material was still exposed in 2013 and also can be found as blocks on the hand-quarried dump below the outcrop.

The microcline-muscovite pegmatite contains quartz, microcline, muscovite, biotite, black tourmaline, garnet, and beryl. The beryl is pale green to dull blue, earthy to chalky, and crumbles upon exposure to weathering.

The minerals of the cleavelandite-lepidolite pegmatite are buff to light-red cleavelandite, lepidolite, quartz, muscovite, beryl, zircon, columbite, apatite, montebrasite, wardite, lacroixite, and several varieties of tourmaline. The cleavelandite occurs in radiating masses in which the plates are as much as 6 inches long. Lepidolite occurs in two forms: fine- to medium-grained, lilac to deep-purple lepidolite and platy, pale-lilac lepidolite. Much of the silvery-green muscovite has an outer rim of pale lepidolite. Beryl in the past has been found as large lemon-yellow euhedral crystals and in smaller subhedral crystals surrounded by fine grained lepidolite. It differs from beryl in the microcline-muscovite pegmatite by having a porcelanous texture, a much brighter yellow color, distinct secondary parting, and no tendency to disintegrate upon exposure.

Manganocolumbite was reported in 1905 to occur on a hill west of Canon City associated with red, green, and black tourmaline in masses that were reputed to have weighed as much as 600 pounds. This material probably came from the Meyers pegmatite. The analysis by Headden (1905) showed the material to be manganocolumbite with a density of 5.6808. The whitish masses of montebrasite found in the lepidolite or adjacent quartz contains wardite, lacroixite and apatite on fractures and external surfaces (Fransolet, Fontan, and de Parseval 2007).

School Section pegmatite

Location

The School Section mine is in lots 1 and 2 in the SE 1/4 of section 16, T 18 S, R 71 W, sixth principal meridian, Fremont County. This pegmatite is 1 mile south of U. S. Highway 50. The Royal Gorge highway passes within a quarter mile of the main cut. The mineral rights on which the pegmatite crops out belongs to the State of Colorado but the surface rights which were originally part of the Buckskin Joe pioneer tourist park were sold in 2010 to Fremont Acquisitions LLC. This subsidiary company, based out of Gunnison county, have graciously allowed permission to visit the pegmatite for this field trip. Parking will be next to the closed entrance gate on the west side.

History

The property was first leased by the State to Robert A. Shipley, who began mining in 1929 and continued until 1931. For the next 4 years it was leased to the M & S, Inc., of Denver. The mine was inactive from 1936 until 1939, when it was leased and operated by the Colorado Feldspar Co. The total production to 1942 was several thousand tons of feldspar, 150 tons of scrap mica, and probably less than a ton of beryl. The property was examined by E. Wm. Heinrich in the winter of 1942 and was mapped by pace and compass. The map was extensively revised by Heinrich and used for his Ph.D. work at Harvard and published later in the *American Mineralogist*. Since 1948, there does not appear to have been any later mining.

By 1948, there were seven open-cuts and three prospect pits, the largest 600 feet in length and as much as 200 feet wide, in the pegmatite.

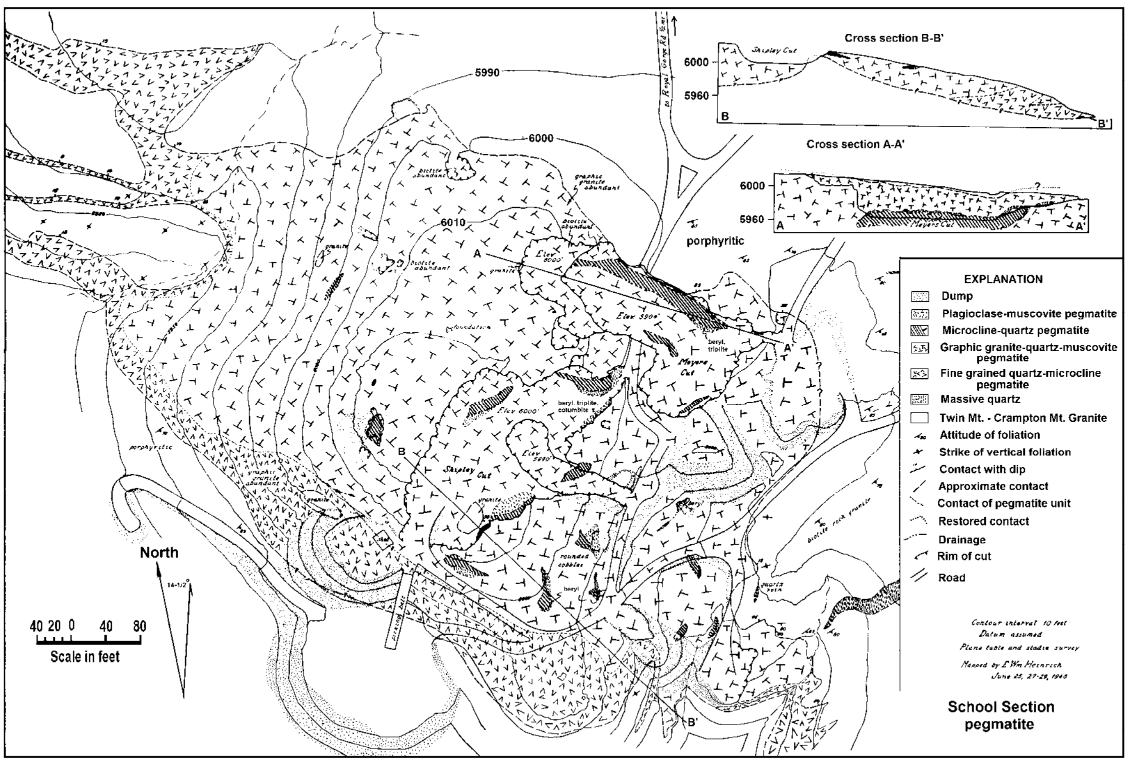

Figure 4. Geologic map of the School Section pegmatite. Modified from Heinrich (1948).

Pegmatite geology

The School Section pegmatite, as interpreted by Hanley, Heinrich and Page (1950) is an irregular, pipe-like intrusive but Heinrich (1948) who spent more time remapping the pegmatite interpreted the pegmatite to a sheet-like body. The pegmatite cross cuts the metamorphic foliation in most places and trends N 73º W. It is exposed for about a half a mile with a maximum width of 500 feet. The pegmatite seems to be about 75 feet thick at its thickest. Exposures to the south, southeast and northwest indicate a mostly flat-lying pegmatite.

The pegmatite is zoned with a discontinuous wall zone of fine-grained quartz-microcline-muscovite with occasional phenocrysts of graphic granite textured microcline, an intermediate zone of graphic granite-quartz-muscovite and isolated core zones of microcline-quartz. Similarly isolated units of plagioclase-muscovite are present around the core margin of the quartz-microcline cores, usually on the underside (footwall) of the core segments.

Most of the pegmatite is composed of the wall and intermediate zones. The wall zone is mostly fine-grained quartz, microcline and muscovite, with only occasional graphic textured microcline crystals. The intermediate zone is mostly graphic granite with the addition of biotite which locally is exceedingly abundant. Blades of intergrown muscovite and biotite as much as 6 feet long have been found in this zone.

The core of quartz and microcline contain the only significant economic mineral – microcline feldspar in blocky crystals. The Meyers and Shipley quarries were made for the feldspar.

The plagioclase-muscovite unit was interpreted by Heinrich (1948, 569) as a replacement unit. These albitic units found adjacent to cores, often with a cleavelandite texture, contain the rarer minerals of a pegmatite. They may very well be of primary origin and not a replacement. As the last crystallizing masses with the core, proof of replacement origin is difficult. In the School Section pegmatite, this albitic unit contains garnet, beryl, schorl, apatite, albite with a cleavelandite texture, triplite, columbite, chalcocite, bismutite and beyerite (Heinrich 1948, Hanley, Heinrich and Page 1950).

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Field Trip guide to the Texas Creek pegmatite field, Fremont County

Devils Hole pegmatite

The text about the Devils Hole pegmatite has been copied from Hanley, Heinrich and Page (1950) with minor additions and changes as needed to update to current conditions.

Location

The Devils Hole pegmatite in the SE 1/4 of the NW 1/4 of section 20, T. 18 S., R. 73 W., sixth principal meridian or 448,912 m E, 4,258,084 m N at 7990 feet elevation, UTM 13, NAD27 (GPS measured). The pegmatite can be reached by a dirt 4WD road from Texas Creek, along the Arkansas River and U. S. Highway 50. The pegmatite is 19 miles by air line west-northwest from Canon City and 22 miles east-southeast from Salida. It is reached from these cities by U. S. Highway 50 to Texas Creek and then by a steep 4WD road to the locked gate turnoff to the quarry.

The region in which this pegmatite occurs has an altitude of about 8,000 feet and is very rugged. Most of the hillsides slope 35° to 40°, but 55° slopes are not uncommon. The stream valleys are mostly narrow gorges in which the watercourse occupies most of the floor, but a few small flat areas have been formed at the places where tributaries join main streams. The main drainage is by East and Bull Creeks, both of which have a small permanent flow sufficient for mining operations. The vegetation is chiefly cactus and yucca, with very little timber other than pinons and cedar except in the bottoms of a few gulches. The average precipitation is less than 10 inches a year, and because of the favorable weather conditions the mine can be operated throughout the entire year.

History

The Devils Hole pegmatite was first discovered and claimed as the Wild Rose by James D. Endicott of Canon city circa 1906. Sterrett (1923, 56) described the pegmatite and noted the rose quartz that would be suitable for gems and the mica could be commercially mined but no mica mining had taken place. Endicott mined it for aquamarine beryl and possibly rose quartz which he sold to Charles Alexander Begthol of Canon City and others. A brief description of the mineralogy, particularly with respect to origin, has been published by Landes (1935).

Since June 22, 1922, the pegmatite has been owned by Earl E. Zingheim of Canon City. He applied for and received his patent these claims on April 21, 1943. Operation during 1940-1948 was intermittent, and in the fall of 1941 the mine was closed down because of increased costs of operation. In September 1943 the mine was reopened and worked for beryl and columbite until May 1944 under a financial arrangement with the Metals Reserve Company, a Federal government subsidized company. E. Wm. Heinrich first visited this mine on October 2, 1942, and between October 25 and 31, 1942, a preliminary map was made by E. Wm. Heinrich assisted by J. B. Hanley. A more detailed map was made during intermittent work in 1943 and 1944 by J. B. Hanley assisted at various times by B. Miller III, J. H. Chivers, and A. F. Trites, Jr. The patented mine was later purchased by the Tezak family. Currently, the pegmatite is owned by Mike Tezak and is intermittently mined for rose quartz.

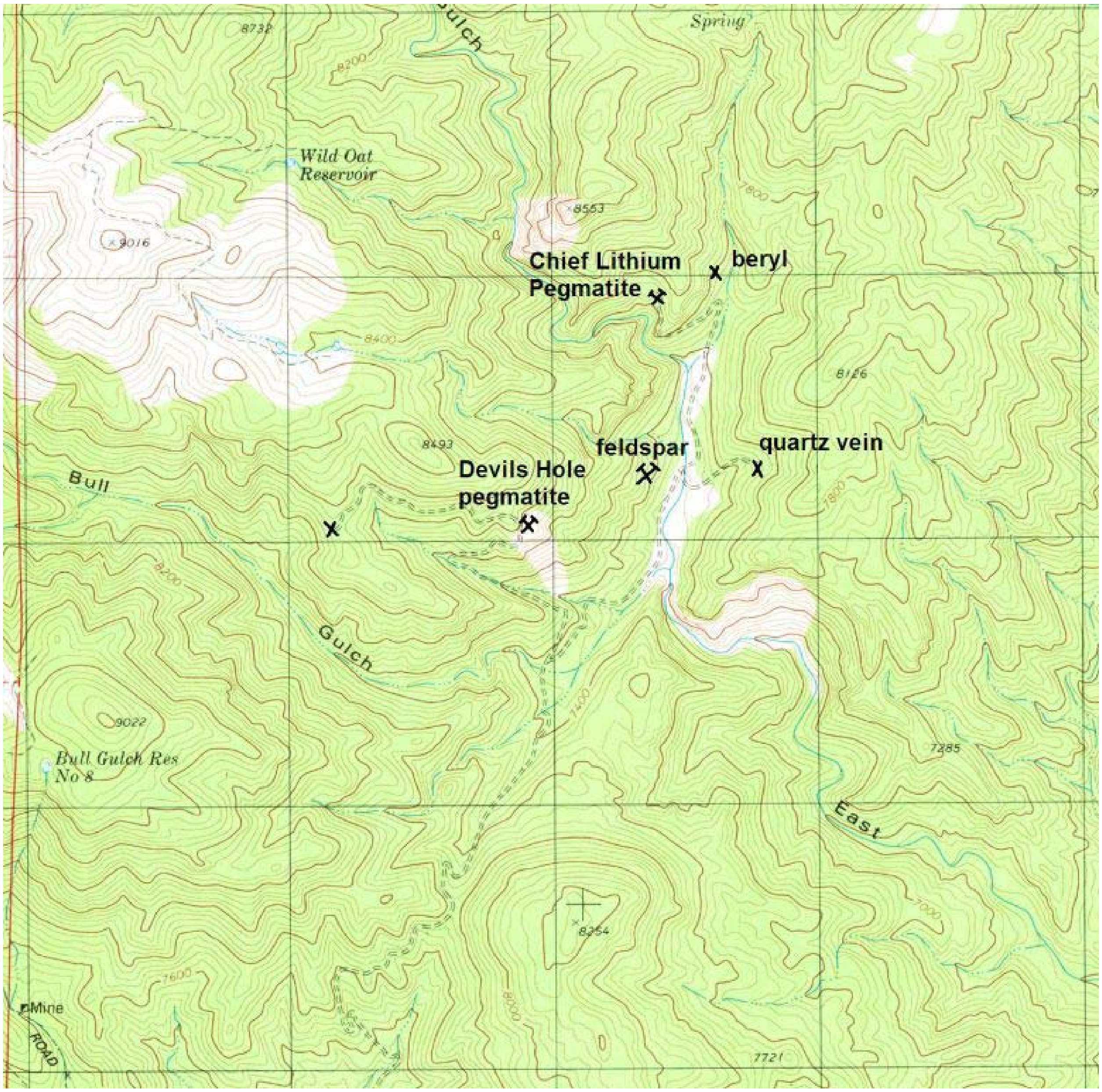

Figure 1. Topographic map of the 4WD dirt route to the Devils Hole and Chief lithium pegmatites. Section squares are 1 mile along an edge. Contours units in feet.

Available production records are incomplete, but according to Earl E. Zingheim, 300 tons of beryl, 16,000 tons of feldspar, and 1,600 tons of scrap mica were produced prior to October 1942. Since that date about 75 tons of scrap mica and less than 10 tons of beryl have been produced, and about 1,000 tons of feldspar has been mined and stock-piled on the property. About 200 tons of rose quartz for ornamental use and about 200 pounds of columbite-tantalite have been recovered.

Mine workings

The Devils Hole pegmatite has been mined by two open-cuts and underground workings from each cut. In 1944, the surface excavation at the southern end of the main pegmatite body, was an open-cut 110 feet long and 35 to 110 feet wide, having a maximum depth of 75 feet. All the underground workings have either been filled or quarried away during the later years. The last operations were exclusively blasting and bulldozing for decorative rose quartz and other materials. In 1944, the northern open-cut, which starts 12 feet north of the main open-cut, was 203 feet long, 8 to 50 feet wide, and from 1 foot to 15 feet deep.

Geology

The Devils Hole beryl pegmatite crops out in an area underlain by Proterozoic schists, gneisses, and igneous rocks. In the Arkansas River Canyon a few miles to the south of the mine extremely large bodies of Proterozoic granite are exposed. Granite may occur near the pegmatite, but no outcrops other than those of small dikes were found in the reconnaissance of the immediate vicinity. Two or three miles west, north, and east of the Devils Hole pegmatite, Tertiary volcanic flows cap the Proterozoic rocks. Several smaller pegmatite bodies occur near the beryl pegmatite, and one of these, about 90 feet to the east and 70 feet lower than the beryl pegmatite, parallels the footwall contact of the main dike for much of its length. Most of these smaller pegmatites are equivalent to coarse-grained granites. They have uniform textures and contain no concentrations of minerals that can be mined profitably.

Metamorphic rocks

Diagnostic minerals, such as sillimanite and diopside, in the schists and gneisses in the vicinity of the Devils Hole pegmatite indicate that the metamorphic rocks are high in grade. Numerous small pegmatite and granite intrusives have been injected into these metamorphic rocks, and some material undoubtedly has been added to the original minerals of the metamorphic rocks.

The metamorphic series includes poorly exposed, interbedded quartz-sillimanite-mica schists, quartz-biotite-feldspar gneisses, amphibolites, diopside gneisses, impure marbles, and banded quartz-mica schists into which small biotite-rich pegmatites and thin quartz veins have been intruded. The foliation of the metamorphic rocks is usually parallel to the bedding, although a slight divergence, not over 10°, is not uncommon. The rocks are flexed into major open folds on the flanks of which minor folds occur. Many minute crenulations are exposed in the diopside gneiss beds.

General features.

The Devils Hole pegmatite crops out as a northward-trending body with two main branches, one of which is irregularly arcuate in shape. The pegmatite is well exposed because of its superior resistance to erosion, but the contacts with the wall rocks are largely obscured by talus. The contacts between pegmatite units are well exposed except in a few places near the hanging wall.

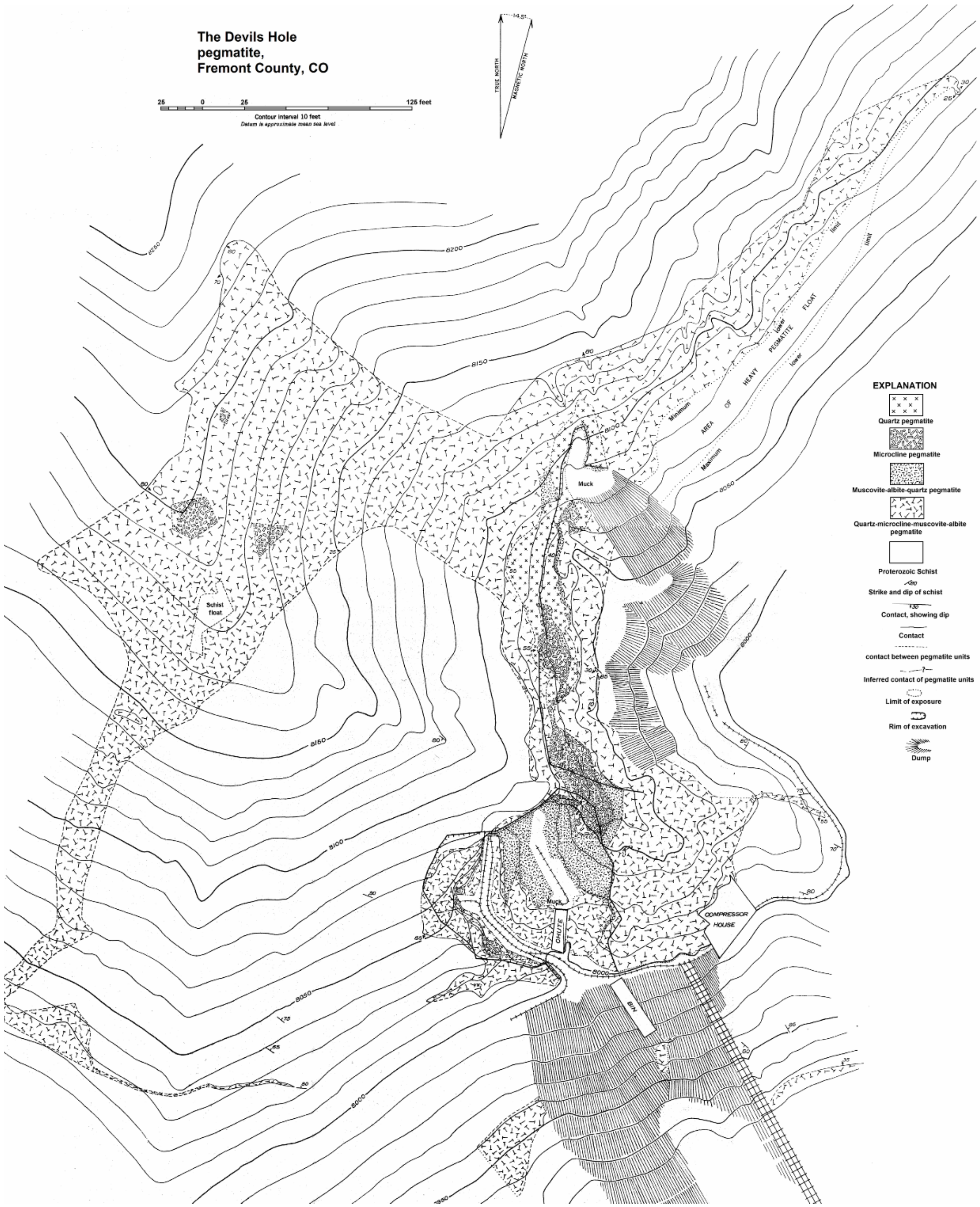

Figure 2. Geologic map of the Devils Hole pegmatite in 1943 before the underground workings were quarried away. Modified after Hanley, Heinrich and Page (1950).

The pegmatite is exposed over an area of 83,000 square feet. The eastern part, which covers 36,000 square feet, contains three zones, but the rest of the pegmatite, including the larger branches, generally contains only the wall zone. The eastern part, in which the workings have been made, is referred to in this report as the main body. The main body trends due north for 350 feet and ranges from 35 to 200 feet in width. The bulbous southern end of this main body, from which two minor branches extend, ranges from 100 to 200 feet in width for a distance of 150 feet. The western branch extends to the northwest, then curves to the south and southeast and, with the main body, forms a nearly complete but irregular circle. The eastern branch trends northeast; it is 300 feet long and 80 feet wide at the junction but tapers to 10 feet in width.

The contacts between the pegmatite and wall rock are gradational. The contact is more definite along the footwall than along the hanging wall, where the gradation from schist to pegmatite may occur over a distance of 5 feet. In general the pegmatite cuts across the bedding and foliation of the wall rock, although the contacts are parallel to the bedding in the north drift and raises.

The walls of the upper part of the main body dip to the west at an average angle of 30° throughout the southern part of the pegmatite, but a steepening of the dip in the underground exposures indicates that the pegmatite may terminate at no great depth. The main body as a whole probably pinches out down the dip less than 150 feet below the floor of the main open-cut. About 40 feet north of the main open-cut the main body narrows, and to the north the east side dips 30° to 40° W. and the west side dips 55° to 60° E. The exposure in the cliff wall at the north end of the main body strongly suggests that the keel of the pegmatite plunges to the south. Cross rolls on the major structure have formed a series of structural troughs and ridges approximately at right angles to the strike of the major structure.

The form of the branches of the pegmatite cannot be accurately determined. The northeast branch probably dips to the northwest as a simple lens, and the arcuate west branch is probably shallow and forms only a veneer on the underlying metamorphic rocks.

In general the pegmatite in the southern part of the main body has a maximum thickness estimated at about 90 feet. The irregular surface shape of the pegmatite body is due to the relation of the topographic surface to the major structure and cross rolls.

Zonal structure — The main body contains a wall zone of quartz-microcline-muscovite-albite pegmatite, an intermediate zone of muscovite-albite-quartz pegmatite, and a core made up of a microcline pegmatite unit and a quartz pegmatite unit. No typical border zone occurs in this pegmatite body. The contacts with the wall rock are gradational, and the wall zone does not show any regular change in texture throughout its thickness from the contact with the metamorphic rocks to the intermediate zone.

The intermediate zone is discontinuous both along strike and along dip and ranges from a few inches to 8 feet in thickness. It is divided in this report into a footwall part and a hanging-wall part because of variations in the content of commercially valuable minerals. Small pods of muscovite-albite-quartz pegmatite are exposed at the shaft and in the northern open-cut above the north room. The pods are probably parts of the intermediate zone, but they are not connected with the main part of the zone and differ slightly from it in lithology.

The microcline pegmatite unit forms the core at the surface in the southern end of the main pegmatite body, but continued mining has shown that this unit is underlain by quartz pegmatite. In the northern end of the main body both units are exposed at the surface. The microcline pegmatite unit in most places in the northern end of the main body is surrounded by quartz pegmatite and appears to form the true core. Although both the quartz pegmatite and the microcline pegmatite seem to reflect the structure in the northern part of the main body, no evidence of structural control of either unit has been found in the southern part, where the pegmatite is best zoned and best exposed in depth.

The zoning in the northern end of the main body is not so distinct as in the southern end. The intermediate zone is less continuous, and the core units usually contain a larger percentage of the minerals of the intermediate zone. For example, beryl is restricted to the muscovite-albite-quartz pegmatite south of the major pinch structure, but to the north beryl has been observed in the quartz pegmatite and in the microcline pegmatite. Further, a few beryl crystals have been found in the wall zone as much as 5 feet away from the contact with the muscovite-albite-quartz pegmatite. The mineral distribution, particularly the distribution of beryl, within the zones in the walls shows that the overlapping of zones is pronounced.

Three small patches of microcline pegmatite are exposed near and on the top of the ridge on which the widest part of the western branch crops out. In these patches the microcline pegmatite contains minerals that occur in the quartz pegmatite and the muscovite-albite-quartz pegmatite in the main body, and the intermediate zone and the core are telescoped. The largest of these patches contains a small concentration of quartz pegmatite.

The structural relationship between zones in depth is best exposed in the north face of the main open-cut and in the west drift. The structural relationship between the zones along the strike of the main body is best shown on the surface, as the north drift is only in the footwall part of the wall zone.

The major structure of the coarse-grained zones is a trough formed by the intermediate and core zones. This structure strikes due north and dips 30° to 45° W throughout the southern part of the main body; the keel plunges to the south from the narrow part 40 feet north of the main open-cut. To the north the trough structure continues to strike due north but is nearly vertical in dip. Seventeen feet north of the end of the northern open-cut it pinches out. According to Earl E. Zingheim, the southern end of this trough did not crop out and was discovered in mining. Minor cross rolls occur in the walls of the trough at two places north of the narrow part and at one place south of it.

The hanging-wall part of the intermediate zone, as exposed in the north face of the main open-cut, dips about 10° W. This decrease in steepness suggests that the crest of the structure was not much higher than the present erosion surface.

The quartz-microcline-muscovite-albite pegmatite of the wall zone is 10 to 30 feet thick in the main body and forms both the eastern branch and the western branch with the exception of the microcline pegmatite patches. The chief component minerals are quartz, reddish microcline, muscovite, and pale-pink albite. The accessory minerals are biotite, black tourmaline, garnet, and magnetite. Biotite, garnet, and magnetite occur most abundantly near the contact with the wall rock and probably represent material added to the pegmatite by assimilation. The texture is granitic, and although the grain size is extremely variable the average size is about 2 inches. Small concentrations of massive quartz, the largest of which is 8 feet long and 1 foot wide, occur in this pegmatite, and blocky masses of microcline 2 feet or more in size have been observed. Bands of fine-grained pegmatite in which the grains are less than a quarter of an inch in size are exposed in the wall zone just north of the main open-cut.

The intermediate zone of muscovite-albite-quartz pegmatite is thickest adjacent to microcline pegmatite, and where it borders the quartz pegmatite it may be represented by only a few inches of albite containing a very small quantity of muscovite. In the north face of the main open-cut the footwall part of this zone, adjacent to microcline pegmatite, has an average thickness of 5 feet, but at the floor level along the west face of the open-cut the zone borders quartz pegmatite and has an average thickness of only 2 feet.

Grayish-green muscovite occurs in radially arranged masses, as much as 5 feet in diameter, composed of wedge-shaped books. It is the dominant mineral of this zone. Pale-pink or white quartz in roughly lenticular masses 2 feet or more in length occurs in the muscovite. Between the muscovite masses and the wall zone pale-pink albite is concentrated, and small crystals of columbite occur in the albite adjacent to the wall zone. Microscopic study shows that the albite has pronounced albite twinning, extinction angles with the cleavage at a maximum of 24°, the intermediate index of refraction of 1.530 ±0.003, and is biaxial "+" with a large 2V. These data indicate that the composition of this albite is near Ab95. Beryl, the most abundant accessory mineral, occurs throughout the zone, although the larger crystals tend to occur in the muscovite and the smaller crystals are concentrated in the albite. The hanging-wall part of this zone contains less beryl and columbite than the footwall part, and the distribution of these two minerals is more erratic in the hanging-wall part. An unusual feature of the zone is the occurrence of muscovite along fractures that probably formed in the late stages of crystallization of the pegmatite. Some of the fractures are planar, others curved; all are characterized by the arrangement of large muscovite books perpendicular to the fractures and on both sides of them. The fractures are commonly coated to a thickness of one-sixteenth of an inch or more with small muscovite plates lying parallel to the fracture surfaces. These mica-coated surfaces do not occur in any of the other zones of the pegmatite.

The core contains two units, microcline pegmatite and quartz pegmatite. The microcline pegmatite unit is nearly pure microcline. The few accessory minerals commonly occur in vugs near the contact of the microcline pegmatite with the muscovite-albite-quartz pegmatite. Quartz, in well-shaped crystals less than 2 inches in length, and a bright-yellow, fine-grained muscovite are the most abundant accessories. A few small blebs of apatite and beryl have been found in the vugs. Small quartz stringers and masses occur throughout the microcline pegmatite.

Three large distinct bodies of microcline pegmatite occur in the main body. The southern and largest of these is bordered by muscovite-albite-quartz pegmatite, and the central and northern bodies are bordered by quartz pegmatite and muscovite-albite-quartz pegmatite.

The quartz pegmatite unit of the core consists almost entirely of pale- to deep-rose quartz, although some parts of it are white. Small quantities of accessory minerals occur in it, chiefly near the northern end of the main body. Minor quantities of an altered bismuth mineral have been found in the quartz pegmatite, and free gold is associated with quartz pegmatite in the west drift. The largest surface exposure of quartz pegmatite is 182 feet in length and as much as 30 feet in width.

Chief Lithium pegmatite

The following description with geologic map has been modified from Heinrich and Vian (1965) with the additions of later field observations. Permission for use of this copyrighted material and figure was granted by the Mineralogical Society of America.

Location

The Chief pegmatite is in the NE 1/4 of the NW 1/4 of unsurveyed section 20, T 18 S, R. 73 W, or 449,363 m E, 4,258,918 m N, at 7585 feet elevation, UTM 13, NAD27 (GPS measured). This location is approximately 3/4 of a mile north of the well-known Devils Hole (Zingheim) pegmatite (Hanley el al. 1950). The deposit lies approximately five miles north of Texas Creek, which is on the south side of the Arkansas River, about 26 miles west of Canon City. Texas Creek is three hours travel time from Denver.

From Texas Creek a steep dirt road extends northeastwardly for about six miles across a divide and into the Devils Hole, a conspicuous topographic basin. The deposit lies on the northern side of Antelope Gulch, about a mile west of the junction between Antelope and East Gulches. After more than 30 years, the 4WD dirt road to the pegmatite has degraded and the 500 feet of the road has been closed by the BLM and must be walked.

The pegmatite, which was on several of a group of five claims, was located by P. A. Weatherson and Sidney G. McClue on June 11, 1957. The early history of the deposit is unknown. From the eastern quarry, the pegmatite appears to have been mined for feldspar during the early or middle 1950's. During that time some feldspar was sold to the feldspar mill of the International Minerals and Chemicals Corporation in Canon City, Colorado. However, lithium minerals were rumored to have been found in this area as early as 1956. The Chief pegmatite was explored for lithium and beryllium in the late 1950's by William McClelland.

The deposit was first examined by Heinrich in 1959 and mapped by him in 1960. It was restudied by Vian in 1962 as part of his Ph.D. research on the geology of the area (Vian 1965) under Heinrich as his supervising professor. The pegmatite is currently (2016) under claim by Bill Tezak of Canon City, whose permission has allowed access for this one-time only symposium field trip.

General geology

In the vicinity of the pegmatite the country rocks are gneisses and schists of what was formerly named the Idaho Springs formation composed of hornblende gneiss, calc-silicate gneiss, cordierite gneiss, quartzite and sillimanite gneiss that has been partially altered to muscovite. The gneiss and schist foliation strikes generally north to northeast and dips south-eastward (Vian 1965). Numerous granitic pegmatites, some of considerable size, crop out on the valley sides of Devils Hole drainage basin. Most of the large pegmatites are very irregular in shape, with a general northeasterly trend. They appear to be related to a body of Proterozoic granite that lies several miles to the southwest of Devils Hole (Vian 1965). The north wall of Devils Hole is capped by a series of Tertiary volcanic rocks which extend from the widespread South Park volcanic field down to the north rim of the Arkansas River Valley.

Pegmatite geology

The Chief pegmatite has been explored by means of two open pits. The eastern excavation, from which the feldspar was mined, is approximately 100 feet long with a generally east-west trend, about 25 feet across, and a maximum of 35 feet tall headwall. The western excavation, in which the lithium pegmatite is exposed, is about 25 feet across and has a maximum depth of about 12 feet. There are, in addition, several small prospect pits and trenches scattered across the pegmatite.

The entire pegmatite is much larger than the part that has been mapped. The mapped section is the thick, western end of a generally northeasterly trending dike. Beyond the mapped area to the northeast the pegmatite continues for at least another 400 feet across the ridge to the east, where several other pits have been dug.

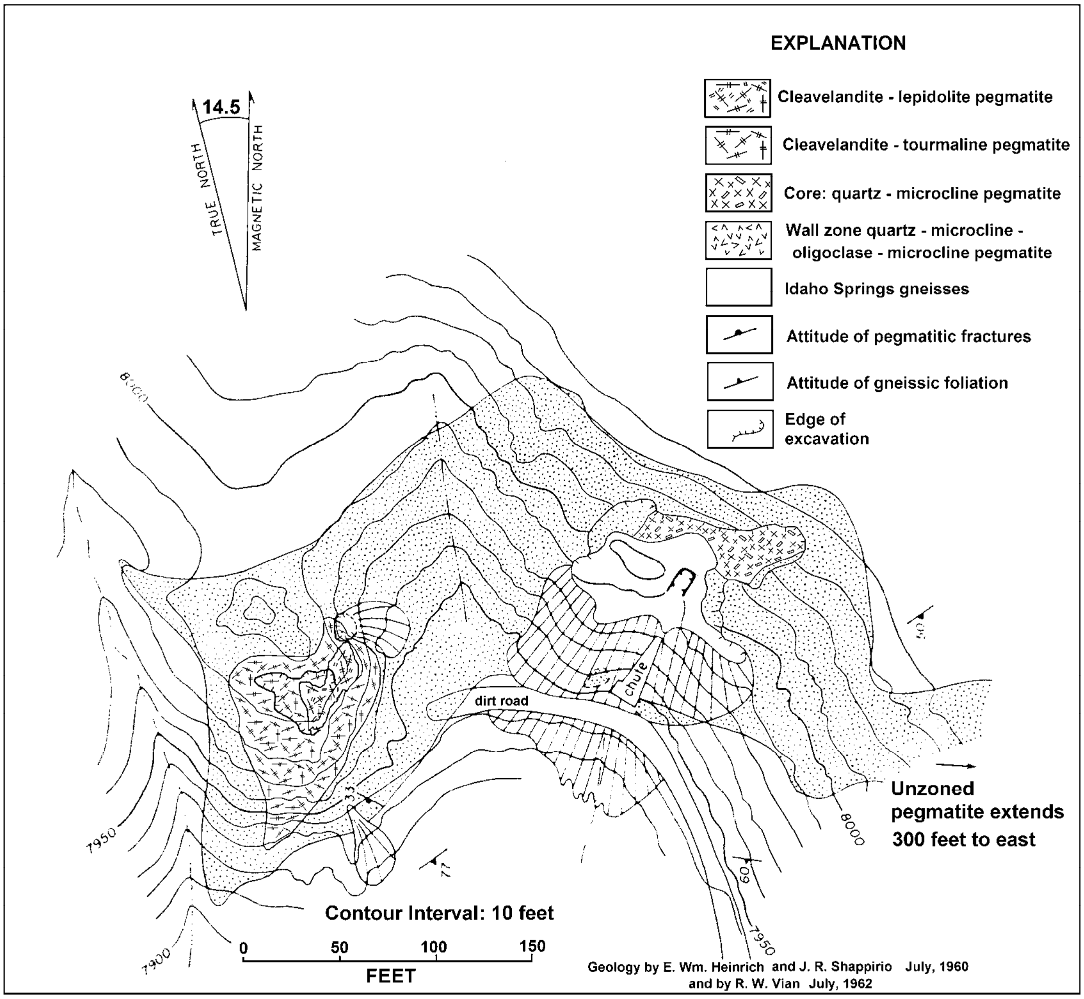

Figure 2. Geologic map of the western end of the Chief Lithium pegmatite. Modified and completely redrafted from Heinrich and Vian (1965).

The mapped part of the pegmatite, which is the thickest section of the dike on its western end and the only part that is distinctly zoned, has a shape that suggests that it is gently dipping to the north. The eastern half of the mapped pegmatite shown in Figure 2, continues northeastward across the adjacent ridge, and dips moderately to the northwest, The eastern part of the dike does not contain lithium minerals but does contain some beryl.

The pegmatite is internally zoned with a wall zone, a core zone and three possible replacement units. The replacement units are found only in the western end of the pegmatite, and are exposed chiefly in and near the western open cut. The cleavelandite-rich units grade into each other and show diffuse and gradational contacts with the wall zone rock. In the marginal parts of the cleavelandite-tourmaline unit, corroded microcline remnants are common. It is unusual, however, that the cleavelandite unit is not found along the core margin as is typical in Colorado, Wyoming, and New Mexico (Heinrich 1948, Jahns 1946).

Within the western end of the pegmatite there is developed a conspicuous planar structure consisting of a series of parallel fractures that also strike northerly and dip westward. Such fractures are absent elsewhere in the dike. The cleavelandite units are believed to have been formed as replacement units of the wall zone pegmatite, localized by the parallel fractures.

Pegmatite units

Wall zone pegmatite: The fine- to medium-grained wall zone pegmatite contains quartz, microcline, plagioclase, muscovite and minor amounts of biotite, garnet and tourmaline Most of the wall zone consists of anhedral granular microcline, quartz, and subordinate sodic plagioclase. Books of muscovite several inches across are clustered in some places. Some of these include needles of schorl. Locally the rock is peppered with rounded spessartite grains, as much as 1/2 inch in diameter, set in a conspicuous dark halo. This halo consists of a rim of granular blue tourmaline and a fine-grained flaky aggregate of dark brown mica. Optical and chemical tests confirm that this mica is zinnwaldite (γ = 1.564—1.570±0.002). No lepidolite appears in the wall zone other than as a very narrow outer rim overgrown on some of the larger muscovite books.

Cleavelandite-tourmaline pegmatite: The larger of the two cleavelandite-rich units contains chiefly cleavelandite, quartz, microcline, muscovite, and schorl-elbaite (black, blue, and green colors). Green tourmaline, which is very abundant locally, appears as rims and outer shells on schorl crystals, slender prisms, 6 inches or less in length, prismatic clusters in cleavelandite, slender prisms embedded in fine grained purple mica, and veinlets of very fine anhedral grains. The microcline, muscovite and quartz in this unit is interpreted to be relicts from the wall zone pegmatite.

Cleavelandite-lepidolite pegmatite: Within the cleavelandite-tourmaline unit, near its northeastern corner, is a small, irregular, tabular mass which, at this spot, appears to underlie the main body of cleavelandite-tourmaline pegmatite, although to the south, cleavelandite-tourmaline rock appears beneath it. Thus originally it was probably enclosed in cleavelandite-tourmaline pegmatite.

This body measures 55 by 20 ft in plan view. It is as much as 15 feet thick at its northern end but is very poorly exposed along the south side of the western cut. It appears to dip about 60° to the west, and its long axis may plunge at a somewhat more shallow angle to the southwest.

Within it are exposed two distinctly different types of pegmatite. The upper part of the exposure, which forms a very pronounced erosional knob, consists almost entirely of cleavelandite and flakes of purple mica that range in diameter from 1/4 to 1 inch, the mica being rather uniformly distributed through the cleavelandite. This mica upon analysis only contains 2.4% Li_2O thus indicating that it is a Li-bearing muscovite. Beneath this rock, the unit consists chiefly of cleavelandite with scattered larger books of lepidolite, a few of which are as much as 10 inches across, although most measure 2 to 6 inches. This mica contained on analysis 5.3% Li_2O, confirming that it is a lepidolite. No additional work has been done to determine the specific IMA approved name for this lithium mica.

Other minerals present as accessories in the cleavelandite-lepidolite unit were yellowish, white, or pale blue beryl, up to 3 inches long; subhedral white to buff topaz up to 6 inches long, sometimes rimmed by a film of fine-grained rose muscovite; apatite, pale blue to gray, anhedral masses several inches or less across; columbite, as thin plates as large as 1/4 x 1/2 inch; purple fluorite in small vugs within the cleavelandite, and a bismuth carbonate (bismutite?) as patches a fraction of an inch long.

B**lack tourmaline and muscovite unit:** Irregular small units of black tourmaline and muscovite. Some of the tourmaline crystals are several inches across and some of the books of muscovite are as much as 1-1/2 feet across. This unit, which is exposed only in the eastern cut, near the core, is too small and too irregular to be shown on the scale of the map.

Quartz-feldspar core. The core of euhedral, coarse grained microcline feldspar in a white quartz matrix is only exposed in the eastern cut. The core was quarried for feldspar.

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Field Trip guide to the Crystal Mountain pegmatite field, Larimer County

This description of selected pegmatites in the Crystal Mountain pegmatite field includes the guide to both the northern and southern field trips. Information for the Wisdom Ranch, Big Boulder and Hyatt pegmatites was extracted from Hanley, Heinrich and Page (1950) and Thurston (1955). Information for the Crystal Snow, Bull Elk Beryl Crystal no. 1 and Storm Mountain pegmatites was extracted from Jacobson (1982, 1986a, 1986b).

Pegmatite field location

The Crystal Mountain pegmatite field is geographically centered around Crystal Mountain in section 26, T7N, R71-72W, about 13 miles west of Fort Collins and Loveland within the Front Range of Colorado. Most of the field's pegmatites are found north of the Big Thompson Canyon and south of Buckhorn Creek. This area can be located on the Crystal Mountain, Buckhorn Mountain, Drake, and Glen Haven 7-1/2 minute USGS topographic quadrangle maps.

The northern part of the field can be reached from Fort Collins via the Rist Canyon road to the Stove Prairie road or from Loveland - Fort Collins to Masonville and hence onto the Buckhorn Canyon road. The Moody Hill and Crystal Mountain roads aceess most of the northern pegmatites. The southern part of the field can be reached from Loveland via the Big Thompson Canyon road, past Drake and then northward towards the Hyatt and Storm Mountain pegmatites and associated pegmatites.

Access and Collecting Conditions

Most of the Crystal Mountain pegmatite field is within the Roosevelt National Forest. Accordingly, the majority of the pegmatites are on public land with no collecting restrictions for personal use but an abundance of other administratively imposed Federal and State requirements if you decide to mine or sell collected material. But at any one time, some of the pegmatites will be under claim, and collecting may be prohibited. In addition, five well-known pegmatite prospects are on private or Colorado state property: the Crystal Silica mine, Tantalum prospect, Sherwood Place prospect, Wisdom Ranch prospect and the Big Boulder pegmatite. The majority of the roads in this area are dirt and are on public land. A few roads are passable only by four-wheel-drive vehicles. The private roads in the area are marked and usually have locked entrance gates.

Pegmatite field mining history

On December 2, 1882; the *Fort Collins Courier* reported that they were “creditably informed that there is considerable excitement, and not without cause, up on the Buckhorn, over the discovery of a rich silver vein which has recently been opened at Crystal mountain…” This reputed discovery of silver and later bismuth ore in white quartz and carbonate attracted a lot of newspaper reports during December 1882 and the beginning of 1883. The reputed district was renamed Bismuth City but all news disappeared, including the mining activity, by September 1883. It is during this prospecting work that the Crystal Silica pegmatite was prospected, probably for silver and discovered bismuth instead. Since there was no economic resource there, all activity disappeared including any traces of the reputed boom town.

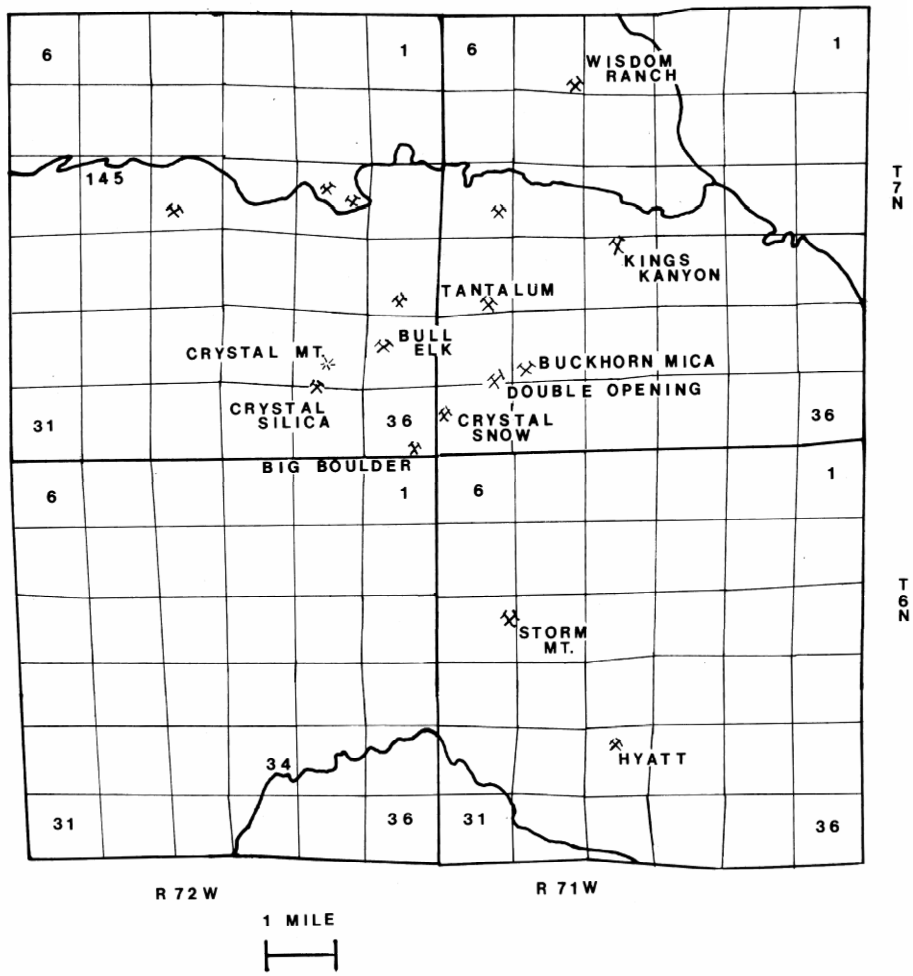

Figure 1. Index map of the Crystal Mountain pegmatite field, Larimer County, Colorado

A mica discovery by a man named Cranston was announced by the *Fort Collins Courier* on December 25, 1884. Further prospecting for mica in the area continued but it was not until August 1910, that the first mica was shipped from the Buckhorn mica mine by the Kitchen brothers, of Masonville (*Fort Collins Courier*, August 25, 1910). By December 1910, the mine was shut down due to unpaid debts (*Fort Collins Weekly Courier*, December 29, 1910). In 1913, Douglas B. Sterrett (Sterrett 1913, 1923) examined the inactive Buckhorn Mica mine.

In 1934, after the presence of beryl in the pegmatites was discovered. A small prospecting boom occurred at this time but died out before the year was over. In 1941 the United Beryllium Ores and Metals Corp. of Denver reputedly bought out the mineral rights on most of the homestead land in the field and secured control of practically all the pegmatites. Some mining was carried on by this company in 1941, but the field was inactive in 1942-44 except for U. S. geological survey work.

During World War II, L. R. Page and J. B. Hanley of the U. S. Geological Survey examined and mapped many of the pegmatites in the field between September 22 and October 7, 1942. They described many of the larger pegmatites but in addition inspected but did not document the Lookout Beryl, Radial Beryl, Plains View, White Rock, Crystal

Snow, Ibex, and Sheep Creek pegmatites, as well as several other pegmatites without names, that were known to contain beryl. From August 1947 to December 1950, a team of U. S. Geological Survey geologists investigated, mapped and sampled many of the pegmatite sin the northern and southern parts of the field. These people included W. R. Thurston, E. N. Hinrichs, W. R. Griffitts, C. S. Robinson, H. D. Wright, W. I. Finch, and A. L. Lang. The United States Bureau of Mines also investigated the area and in 1950-1954 did exploratory mining at the Hyatt pegmatite (Gilkey 1960) to evaluate its potential for beryl mining.

The short term beryl-mining boom created in 1952-1962 by U. S. government price subsidies on beryl led to renewed mining in the field by private individuals as well as a few smaller companies. The Storm Mountain road and mine near the peak crest were constructed during this time (Boos 1959). The last mining surge of mining and prospecting activity was during the late 1970's to early 1980s, led by King Koenig of Fort Collins. After his passing, most claims lapsed with only a few claims for mineral specimens.

Regional Geology

The Crystal Mountain pegmatite field is found within high-grade Proterozoic metamorphic schists and quartzite, formerly known as the Idaho Springs Formation, which is sandwiched from the south and west by the Longs Peak-St.Vrain Granite and a minor variant, the Mount Olympus Granite, and from the north by plutons of the Boulder Creek Granodiorite. The regional, orogenic metamorphism which formed the metamorphic rocks essentially ended 1.75 billion years ago. The plutons of the Boulder Creek Granodiorite were emplaced at the end of this metamorphic event (Braddock and Cole, 1979). The Mount Olympus Granite and Longs Peak-St. Vrain Granite were intruded approximately 1.4 billion years ago (Braddock and Cole, 1979) during the anorogenic Silver Plume thermal event. Traditional thought is that this pegmatite field formed during the 1.4 by thermal anorogenic event and were derived from either the Longs Peak-St. Vrain Granite or the Mount Olympus Granite. No known age dating of the pegmatites is known. A complete geologic description of the individual pegmatite prospects and mines with their exact locations can be found in Jacobson (1986).

The metamorphic rocks are quartz-biotite schists and quartzites. The wall rock of all the pegmatites is a dark-gray quartz-biotite schist that commonly is highly crumpled and folded. The regional structure of the metamorphic rocks strikes northeast, and the folds plunge steeply to the southwest.

Pegmatite Geology

A pegmatite zonation is suggested for the entire field. In this region, barren pegmatites containing quartz, plagioclase, muscovite, and microcline are found adjacent to the Longs Peak-St. Vrain Granite and Mount Olympus Granite, followed by beryl-bearing pegmatites further away. The lithium-bearing pegmatites are the most distal from the interpreted parental granite. This conforms with the often observed relationship that the most fractionated pegmatites, those richest in rare elements (lithium, niobium, etc.) and volatile components, have been intruded furthest away from the parental granite (Jacobson, 1986).

The zoned pegmatites in the field typically contain a wall zone of plagioclase-microcline-quartz with minor amounts of muscovite, and a quartz core. Less frequently, the pegmatites contain intermediate units of cleavelandite (either as a core-margin zone or a replacement unit), spodumene-cleavelandite, and rarely a microcline (perthite) hood. The most common accessory minerals are black tourmaline, garnet, beryl, and apatite. The rarer accessory minerals are iron-manganese phosphate minerals and columbite-tantalite. There appears to be no preference for the zoned pegmatites to be either concordant or discordant. The larger zoned pegmatites reach up to 100 feet wide and 400 feet long.

The zoned pegmatites of the field are similar in internal structure and mineralogy, although most of the pegmatites are unzoned. In pegmatites that contain beryl, the beryl is found as euhedral crystals along the margins of the quartz or quartz-microcline cores and as anhedral masses, sometimes fine grained, in the fine grained quartz-albite-microcline-muscovite pegmatite of the wall zones.

Three of the pegmatites, the Buckhorn, Big Boulder, and Sheep Creek (Kings Kanyon pegmatites) either do or did contain spodumene. The Tantalum pegmatite contains tantalite with cleavelandite and fine-grained muscovite. Several pegmatites in the field, including the Double Opening, Bull Elk Beryl Crystal no. 1, and the Big Boulder pegmatites, contain traces of uranium minerals. Phosphate minerals are also abundant in many of the pegmatites, particularly the Storm Mountain, Big Boulder, Crystal Snow, Double Opening and Hyatt pegmatites. Such generalizations for the field is misleading, since there are almost as many exceptions. The Kings Kanyon pegmatites are unzoned and lithium-bearing. The Hyatt pegmatite has a microcline core. One unique feature of the field is that the muscovite occurs in small books, rarely exceeding three inches in width. Additional details on pegmatite geology are in Jacobson (1986) and Thurston (1955).

Wisdom Ranch pegmatite

Location and mining history

The Wisdom Ranch pegmatite, in the present-day Paradise Valley subdivision, is located in the S 1/2 of section 5, T 7 N, R 71 W, sixth principal meridian. It is 15.5 miles by air line and 29 miles by road west of Fort Collins. The location of the mine dump in front of the abandoned adit is at 469,150 m E, 4,493,953 m N, 7592 feet elevation, UTM 13, NAD27 datum.

Although the pegmatite was on a ranch formerly owned by C. C. Wisdom, the mineral rights in 1942 were held by the United Beryllium Ores and Metals Corp. of Denver. The pegmatite was discovered and first worked by Leslie Barker in the spring of 1941 and in August 1941 was acquired by Eugene Bruell for the United Beryllium Ores and Metals Corp. About 15 or 20 tons of beryl mixed with chrysoberyl was produced by their mining.

The prospect on the westernmost exposure of the elongated pegmatite was examined by L. R. Page assisted by J. B. Hanley, and part of it was mapped by plane table and telescopic alidade during 4 days in September 1942. At that time other pegmatites in the vicinity were examined, but no beryllium-bearing minerals were found in them.

The openings in this prospect include one large open pit that has an average length of 70 feet, an average width of 10 feet, and an average depth of 5 feet; a 33 foot drift from this open-cut; and eight small prospect pits and trenches. Since 1942 no additional excavations have been done nor have researchers or mineral collectors visited this pegmatite. This field trip group will be the first to inspect the moss-covered dumps and outcrop since 1942.

Geology

The Wisdom Ranch pegmatite and the other pegmatites in the vicinity intrude dark-colored, Proterozoic biotite-sillimanite schists and injection gneisses, which were formerly named the Idaho Springs formation. In general they strike east and dip 50° to 75° N. The contact between the Wisdom Ranch pegmatite and schist or gneiss is obscure because of poor exposures. Outcrops of the gneiss are indicated on the pegmatite map and most of the area between these outcrops is probably underlain by pegmatite. Only a few outcrops of schist to which little or no igneous material has been added can be found.

The gneisses are composed of granulose layers of pink to red feldspar and quartz that are separated by schistose layers of biotite, muscovite, sillimanite, and quartz. The individual layers show a wide range of composition and thickness. The granulose layers in places contain large quantities of sillimanite, magnetite, and hematite, which were probably derived from the assimilation of the adjacent schistose material. The schists are intruded by pink to gray granite, of Proterozoic age, about half a mile north of the prospect. Diabase dikes of unknown age cut both the schists and the pegmatites.

Pegmatite Geology

The Wisdom Ranch pegmatite, of which only the beryllium-bearing part was mapped by Hanley et al. (1950), may be followed for more than a mile in an easterly direction. Beryllium minerals occur only at the workings and are confined to one small area. The pegmatite is parallel in general to the gneiss in strike and dip, although locally it cuts across the gneiss structure. In the adit-drift, the pegmatite contacts dip 45° N., but elsewhere the dips are probably only slightly greater than the surface slope. The pegmatite is very irregular, both in plan and in cross section.

The pegmatite contains four distinct zones, of which only the quartz pegmatite zone is shown separately in the geologic map. The microcline-quartz-muscovite pegmatite zone, the albite-quartz-muscovite pegmatite zone, and the microcline pegmatite zone were grouped together by Hanley et al. (1950) because they are too poorly exposed to be mapped accurately at the scale of the map. A few of the large microcline crystals at the outer edge of the quartz pegmatite are shown on the map, but the microcline pegmatite zone is more continuous than the mapping indicates.

The largest part of the pegmatite is a pink to red, granitic-textured microcline-quartz-muscovite pegmatite that contains large quantities of sillimanite, magnetite, and hematite near schist inclusions and the contacts. Microcline occurs in subhedral crystals that are as much as 6 inches in diameter, but the average size is 2 inches. Graphic intergrowths of pink microcline and gray quartz are common in this zone. Muscovite flakes rarely make up more than 5 percent of the pegmatite. Sillimanite locally may make up 50 percent of the zone but generally occurs as scattered masses of fibrous aggregates 1 to 3 inches across. These masses are partly altered to sericite. Magnetite crystals partly altered to hematite also occur near the contacts. The average size of these crystals is about three-eighths of an inch, but they may be as much as 1 inch in diameter. Locally magnetite makes up 15 to 20 percent of the pegmatite. Both sillimanite and magnetite probably formed as the result of assimilation of the wall rock. The microcline-quartz-muscovite pegmatite grades imperceptibly into a lighter-colored albite-quartz-muscovite pegmatite that contains beryl, chrysoberyl, and garnet near the margin of the quartz pegmatite zone. The albite-quartz-muscovite pegmatite is composed of pink albite that has a composition near Ab_{95}, gray quartz, and small books of muscovite. Pale bluish-green beryl, yellowish-green to dark-green chrysoberyl, and brown manganese garnet are the accessory minerals. Muscovite books are rare, but some highly ruled mica books with "A" structure occur in the pegmatite. Most of the mica occurs in aggregates of small flakes associated with the chrysoberyl. The brown garnet occurs in masses as much as 12 inches in diameter that are made up of individual crystals or aggregates. Many of these masses are intergrown with quartz, beryl, chrysoberyl, and albite. Alteration of the garnet has produced manganese oxides, which have stained the surrounding minerals.

A zone of very large microcline crystals occurs between the albite-quartz-muscovite pegmatite and the quartz pegmatite. One microcline crystal is 11 feet long, and crystals 3 to 4 feet across are not uncommon. The albite-quartz-muscovite pegmatite and the microcline pegmatite together form a zone with an average thickness of about 5 feet.

The quartz (core) pegmatite is composed almost entirely of massive milky-white to rose quartz. This quartz typically has an intricate pattern of crisscrossing streaks of more opaque quartz; these streaks may represent healed fractures. The quartz pegmatite is well exposed, although heavy quartz float hides the actual limits and contacts with the other zones. The individual masses of quartz pegmatite are very irregular in shape but probably are relatively thin and roughly parallel to the surface slope. Their irregular outcrop pattern is probably caused by a combination of structure and erosion.

Diabase

Two poorly exposed diabase dikes cut across the gneisses and pegmatite in the area mapped. The eastern dike is offset by an east-trending fault. The northern segment of the dike strikes N. 40° W. and is exposed for a width of about 30 feet. The southern segment strikes about N. 10° W. and has a maximum width of 23 feet. The dip of the dike is unknown. The diabase is a black, fine- to medium-grained rock that contains a few plagioclase crystals as much as 6 millimeters in length. Aggregates of biotite and hornblende give the rock a mottled appearance. The western dike strikes N. 25° to 30° W., dips about 40° SW., and is about 30 feet thick. The diabase is black and slightly porphyritic and has a fine- to medium-grained groundmass. Plagioclase phenocrysts as much as 1 inch in length project as knobs above the weathered surface of the dike.

Mineral Deposits

Only at one location on the Wisdom Ranch pegmatite have beryllium-bearing minerals been found. It is possible that additional deposits may occur adjacent to the three other quartz pegmatite masses in the pegmatite.

Beryl, the chief beryllium-bearing mineral, occurs in the albite-quartz-muscovite pegmatite in pale bluish green crystals that are as much as 8 inches in diameter. Part of one crystal, which was 3 inches in diameter and 12 inches in length, was observed in place. The indices of the beryl were determined to be Ne=1.567±.003 and No =1.572±.003, indicating that the beryl has a low alkali content. The beryl is usually associated with albite but occasionally is found in contact with microcline.

Chrysoberyl also is an important beryllium-bearing mineral in the deposit. It is yellowish green to dark green in color and occurs with beryl, albite, quartz, and garnet in plates as much as 3 inches long and 13 millimeters thick. It also occurs associated with muscovite in quartz nodules that are 3 to 6 inches in diameter. These nodules are commonly enclosed in light-pink albite. Chrysoberyl makes up as much as 50 percent of some of the nodules. A few plates of chrysoberyl were seen in albite, but the albite generally appears to have formed after the chrysoberyl.

The size of the deposit is not known because exposures are poor and little development work has been done. The deposit is exposed only in the large open-cut, and so far as is known the maximum length is 70 feet and the width 5 feet. The grade of the deposit is based only on past production, as only one beryl crystal and a few chrysoberyl crystals have been found in place. The grade indicated by past production may be as much as 10 percent beryl and chrysoberyl. No estimate of reserves or resources of beryllium-bearing minerals can be made until more development work is done.

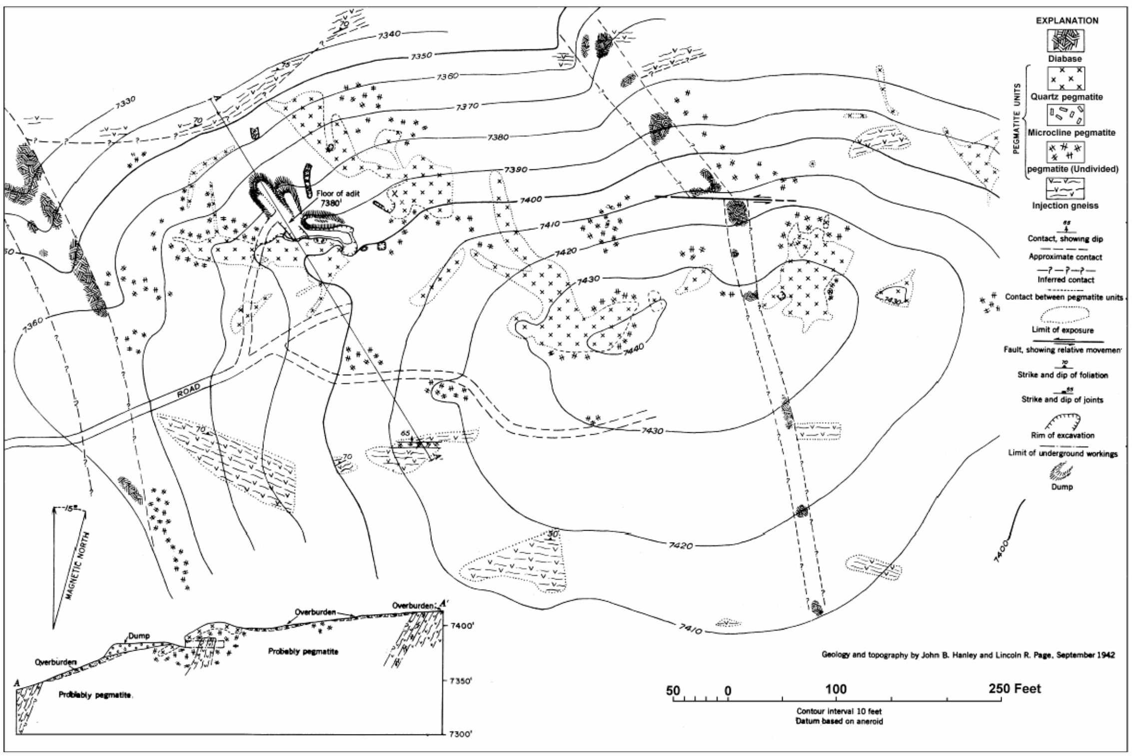

Figure 2. Geologic map of the Wisdom Ranch pegmatite, Larimer County. Modified after Hanley, et al. (1950).

Bull Elk Beryl Crystal no. 1 pegmatite

Location and mining history

The pegmatite is located in the NE 1/4 of the SW 1/4 of section 25, T 7 N, R 72 W. It is located 1,750 feet east of the west line and 2,200 feet north of the south line of section 25, T. 7 N., R. 72 W or 464,811 m E, 4,487,588 m N, 8677 feet elevation, UTM 13, NAD27 (GPS measured). The prospect can be reached from the Buckhorn Creek road 44H by the Crystal Mountain road, also known as fire road 344.

The Bull Elk Beryl Crystal no. 1 prospect was first claimed by King Koenig, Frank Koenig and J. M. Johnston on November 11, 1954. King Koenig relocated the claim in December 1, 1977 and filed the claimed on January 27, 1978, and had continued to do minor excavation up until 1982, when he sold the claim to Gary Stout. Circa 1990, the claim was allowed to lapse. Chrysoberyl was discovered in the pegmatite in July 1980 by Nathaniel Tilander and Mark Jacobson. The pegmatite was later mapped by S. Douglas Hartman and Mark Jacobson.

The prospect workings include an open cut on the southern half of the pegmatite, and a minor shallow cut and bulldozing at the northern edge. The open cut is approximately 15 feet deep, 20 feet wide and 40 feet long.

Pegmatite geology

The Bull Elk Beryl Crystal no. 1 prospect is in a zoned pegmatite that is 75 feet long and as much as 15 feet wide. The pegmatite is disconformable within laminated, dark gray quartz-biotite schists which are presumably of Proterozoic age. The pegmatite strikes N 40° W and dips from 60° to 80° to the west. Although the country rock is altered adjacent to the pegmatite in several places, the contacts are sharp.

The pegmatite contains four units. A one to two inch thick border zone of fine-grained plagioclase-quartz-muscovite forms the outermost unit. Muscovite is variable in the border zone. At some places the muscovite forms a crudely layered pattern parallel to the pegmatite contact with the schist. A four to six feet thick wall zone is composed of medium grained plagioclase-quartz-muscovite. Sheet mica is found along the inner part of the plagioclase-quartz-muscovite wall zone adjacent to the cleavelandite unit. The quality and quantity of the muscovite are inadequate to be an economic ore. Chrysoberyl in this zone is found adjacent to plagioclase and between coarse books of muscovite.

The cleavelandite unit is composed of cleavelandite, coarse to medium-grained black and smoky quartz, black (?) tourmaline crystals that have been replaced by muscovite, and muscovite books. Accessory minerals are light-green chrysoberyl, columbite-tantalite, and beryl. Coarse books of muscovite found in the cleavelandite unit adjacent to the sheet mica of the wall zone have a shredded appearance along the edges of the crystals. Clusters of irregular-shaped muscovite books in cleavelandite may have been part of an older single muscovite book. This evidence suggests that the cleavelandite unit is a replacement body, even though exposures show that the cleavelandite unit is approximately concentric around the quartz core. The quartz core is composed of milky to smoky quartz, It is three feet wide and was exposed only on the floor of the main pit in 1984. After more than 30 years the exposures on the floor of the quarry are buried under rock debris. The core seems to be a larger aggregate of quartz than normally found in the cleavelandite unit. Crystal cavities either as wall zone vugs or cleavelandite replacement vugs have not been observed.

Mineralogy

Light green chrysoberyl occurs as contact twinned crystals up to 1-1/4- inch long by 1 inch wide and as pseudo-hexagonal twins up to 1-1/4- inch in diameter. Both crystal types are flattened to less than ¼ inch. Contact twins occur both as V-shaped and triangular-shaped twins. Pseudo-hexagonal twins are usually poorly shaped without sharp outlines. Chrysoberyl occurs most frequently in the cleavelandite unit as clusters of crystals along the edges of muscovite after tourmaline, and in the immediately adjacent smoky quartz and cleavelandite. Rarely, chrysoberyl is found in the wall zone interlayered between muscovite books and adjacent to plagioclase. Crystals found within muscovite books and smoky quartz are sometimes transparent but highly fractured. The largest gemmy piece is only 3/16 inch thick.

Almost all of the tourmaline occurs in the cleavelandite unit. Rarely, replaced crystals were seen in the outer part of the wall zone. All the tourmaline crystals have been altered to fine-grained muscovite. The crystal shape has been faithfully preserved as a bulging triangular cross section, striated prism faces and trigonal pyramid termination. It is presumed that these were black tourmaline crystals, but no evidence was observed to support this conclusion. The tourmaline pseudomorphs are found up to three inches wide and occasionally over six inches long. A very fine-grained exterior zone and a coarser core of ¼ inch muscovite plates compose the tourmaline pseudomorphs. The chrysoberyl occurs only in the exterior zone and just adjacent to it.

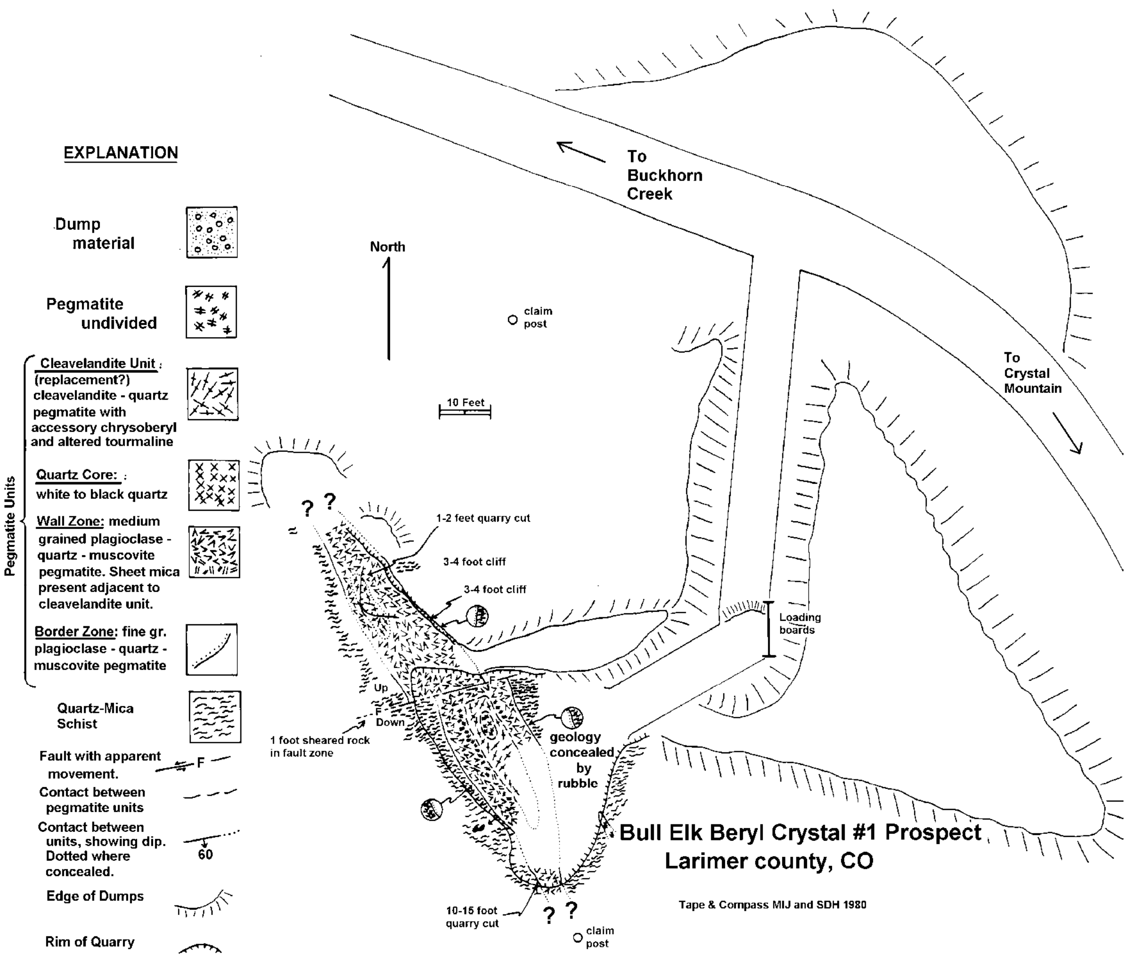

Figure 3. Geologic map of the Bull ElK Beryl Crystal #1 pegmatite, Larimer County, Colorado. Most of the chrysoberyl is found in the cleavelandite unit.

Beryl is rarely found in the wall zone as subhedral pale green crystals. The largest was only slightly over two inches long. Rarely, in the cleavelandite and wall zone were observed large 4 to 5 inch masses of white beryl with columnar striations. Thin plates of columbite-tantalite, none larger than an inch in length, were observed in the cleavelandite unit. Sometimes adjacent to and on the columbite plates was a florescent yellow crust, moderately radioactive, of presumed autunite. Zircon as 1 to 4 mm in length were also found in the cleavelandite.

Big Boulder pegmatite

Location

The Big Boulder pegmatite is in the SW 1/4 of the SE 1/4 of section 36, T 7 N, R 72 W, sixth principal meridian, which is 465,360 m E, 4,485,688 m N, 8708 feet elevation, UTM13, NAD83 datum (map measured) or 465,410 m E, 4,485,478 m N, 2655 m elevation, UTM13, NAD27 datum. It is about 2 miles by air line southeast of Crystal Mountain. In 2016, the pegmatite can be reached from the north via the National Forest Service road in Buckhorn Canyon to the Crystal Mountain road, also known as Fire Road 344 and then past a gated, sometimes open, National Forest road that bypasses private land and goes to the pegmatite The prospect is located in section 36 where the surface and mineral rights are owned by Colorado State and are administered by the Colorado State Land Board.

History

The mineral rights prior to 1936 are said to have been optioned to Walter J. Lee of the United Beryllium Ores and Metals Corp., but Harold L. Flinn of the Mountain States Minerals Production Co. claims the property by right of location. Roy Hyatt and H. A. Snider produced 10.5 tons of beryl from one crystal in the prospect in 1936, and in 1941 about 600 pounds of beryl was mined and stockpiled by the United Beryllium Ores and Metals Corp.

In September-October 1942, the Big Boulder prospect was visited and geologically mapped by Lincoln R. Page and John B. Hanley of the United States Geological survey. The excavations at that time consisted of four small pits and a 10-foot discovery shaft. Mining done by unknown parties since 1942 has created a NE-SW trending quarry with a connected central pit that exposed altered spodumene in the cleavelandite-spodumene zone. No mining has occurred since at least 1980.

Geology

The beryl-bearing pegmatite of the Big Boulder pegmatite has a lensoidal shape at the western end of a large, irregular quartz-microcline-muscovite-plagioclase pegmatite. The lenticular, beryl-bearing pegmatite is 260 feet long and as much as 100 feet wide. It probably plunges 60° to 65° to the south and may be expected to pinch out 75 to 125 feet below the present surface. It is essentially conformable to the Proterozoic quartz biotite schist except at the southern end where it joins the quartz-microcline-muscovite-plagioclase pegmatite, which cuts across the structure of the schist. Poor exposures make it impossible to study the actual connection between the two pegmatite bodies.

The Big Boulder pegmatite contains two zones, both of which contain beryl. A fine-grained outer zone of quartz-albite-microcline-muscovite pegmatite surrounds a central core of coarse-grained quartz-microcline pegmatite. The outer zone is a granitic intergrowth with an average grain size of about an inch. Most of the zone is composed of white to pink albite, pink to red microcline, quartz, and muscovite with accessory beryl, black tourmaline, and apatite. Radial to platy clusters of black tourmaline and some blue apatite are associated with the beryl.

The core of the pegmatite contains crystals several feet across. It is composed mainly of milky quartz and large crystals of microcline, which makes up at least 30 percent of the pegmatite. In the shaft (see pl. 12) a few powdery, "rotten" spodumene crystals are exposed associated with small quantities of the uranium minerals, autunite and gummite, in albite, microcline, and smoky quartz.

An offshoot, 1.5 to 8 feet wide, of core material cuts across the outer zone to the wall-rock contact on the northwest side of the pegmatite. This offshoot is composed chiefly of white quartz and a small quantity of microcline.

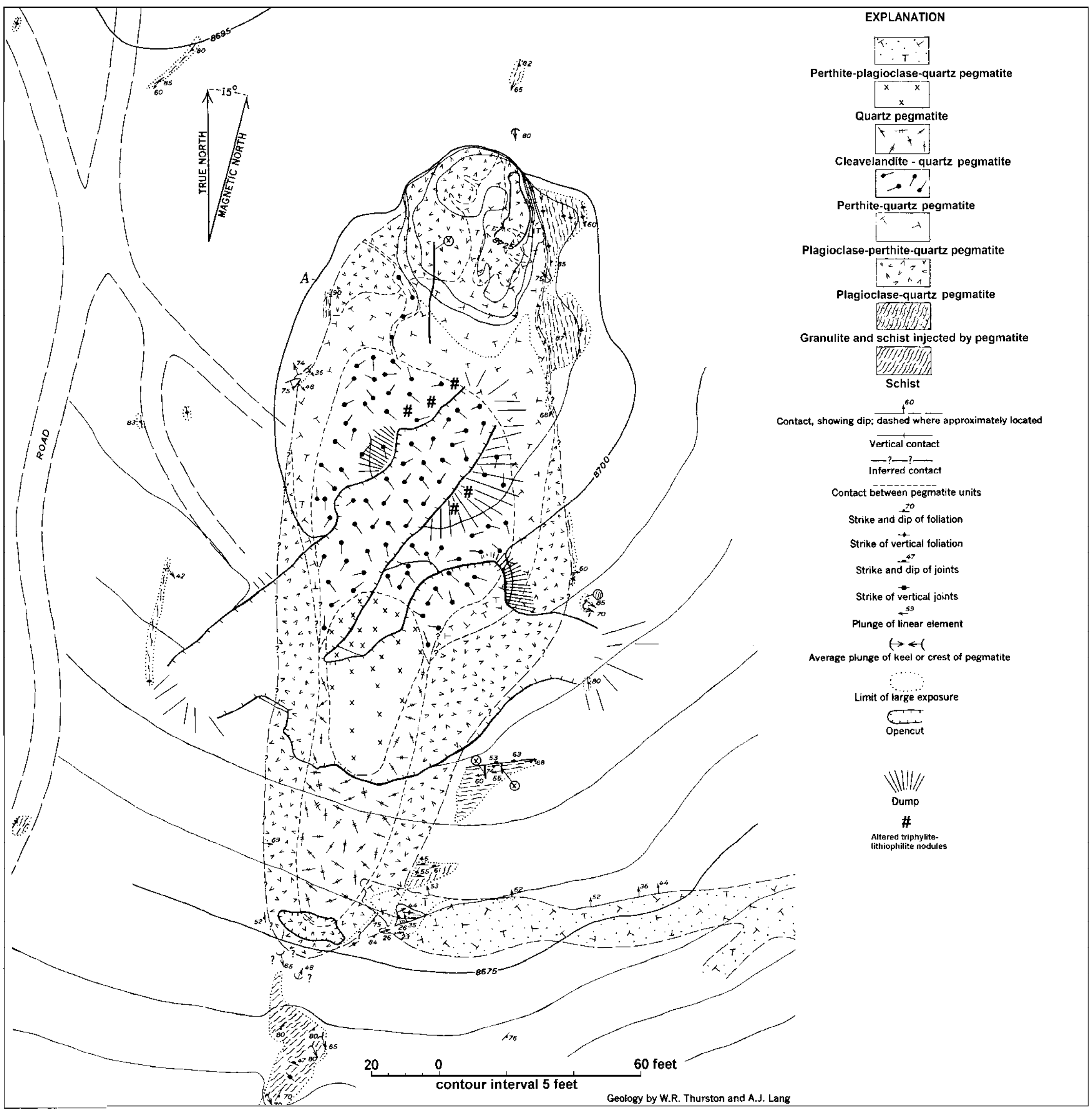

Figure 4. Geologic map of the Big Boulder pegmatite, Larimer County, Colorado. Modified after Thurston (1955).

Mineral deposits

Beryl occurs in both zones of the pegmatite. In the quartz-microcline pegmatite one crystal was 6 to 7 feet long by 5.5 feet in diameter and tapered toward both ends. At least two other crystals more than 12 inches in diameter were mined in 1941. The beryl is green to slightly bluish green and contains few mineral inclusions. Only a few small crystals were seen in place in the core. Blue, green, and white beryl occurs in crystals and anhedral grains that are 1 inch or less in diameter in the quartz-albite-microcline-muscovite pegmatite. In the cliff at the north end of the pegmatite body, solid beryl grains or crystals appear to be distributed uniformly throughout the pegmatite. At the south end, where albite is more abundant, the beryl occurs both as solid crystals and as skeletal crystals around albite and quartz.

The beryl deposit in the outer quartz-albite-microcline-muscovite pegmatite is from 5 to 60 feet wide and is estimated to contain 600 tons of pegmatite in each foot of depth over the exposed area. The maximum vertical exposure is 50 feet. Visual estimates suggest that this zone will contain 1 to 2 percent beryl, which can be recovered only by milling.

The beryl deposit at the outer edges of the quartz-microcline pegmatite core is lenticular; it has a maximum length of 160 feet and a possible width of 85 feet. The average length is 140 feet, and the average width may be 60 feet. This core probably extends 50 to 80 feet below the present surface. The grade of the deposit is estimated, on the basis of past production, to be comparable to the grade of the outer zone. In addition to beryl, this deposit contains at least 30 percent large microcline crystals that are probably of marketable grade.

The reserves of fine-grained beryl in the quartz-albite-microcline-muscovite pegmatite are roughly estimated to be 450 tons of beryl in 45,000 tons of rock. The reserves in the core are estimated to be about 25 tons of beryl, separable by hand cobbing, and about 10,000 tons of recoverable feldspar.

Crystal Snow pegmatite

Location

The Crystal Snow pegmatite is located 175 feet east of the west line and 2,700 feet north of the south line of section 31, T 7 N, R 71 W in the NW 1/4 of the SW 1/4 of section 31, T 7 N, R 71W. The edge of the pit is at 465,952 m E, 4,486,167 m N, 8830 feet elevation, UTM 13, NAD27 datum (GPS measured). The pegmatite can be accessed from a well defined 4WD road heading northeast from the Big Boulder pegmatite.

Mining History

The Crystal Snow prospect was first claimed by Mrs. H. A. Snider of Masonville, on June 18, 1941. No mining has been done since the original excavation of many years ago, which produced an 80 foot by 20 foot by 20 foot deep pit. As best as can be determined the pegmatite was mined either for beryl or feldspar.

Geology

The Crystal Snow pegmatite is an almost vertical dike approximately 150 feet long by 25 feet wide. It is concordant with the quartz-mica schist. The pegmatite contains a border zone of fine grained plagioclase-quartz-muscovite, a wall zone of plagioclase-quartz-muscovite and a smoky to white quartz-microcline core. Phosphate minerals are found on the edge of the core.

The surrounding dumps in 1984, as well as exposures on the western wall of the pit, contain an abundant assemblage of phosphate minerals. The phosphates identified by x-ray diffraction are: 1) heterosite as rich purple masses in a matrix of triplite, 2) blackish-brown triplite masses, the most abundant phosphate in the pegmatite, 3) alluaudite as fine-grained green masses (with an appearance similar to varulite) intermixed with heterosite and as borders surrounding a core of laminated graftonite-heterosite, both present in a triplite matrix, 4) laminated gray to blackish-brown graftonite-heterosite masses and, 5) chalk-white to tan masses of hydroxylapatite intermixed with other phosphate minerals.

In the pit walls are subhedral triplite crystals in smoky quartz and graftonite-heterosite masses in microcline. The green alluaudite appears to have replaced the graftonite-heterosite masses and also possibly some of the triplite. The phosphate minerals in the Crystal Snow prospect are typically found in large nodules composed predominantly of triplite with intermixed clumps of graftonite, heterosite, green alluaudite and hydroxylapatite.

This is the second richest known phosphate pegmatite in the field. The abundance of phosphates on the dumps and quarry walls indicates that additional phosphate minerals may be present.

Hyatt beryl pegmatite

Location

The Hyatt pegmatite is in the NE 1/4 of the NW 1/4 of section 28, T 6 N, R 71 W, sixth principal meridian, or 469790 m E, 4478924 m N, 8147 feet elevation, UTM 13, NAD83 (map measured) or 469,840 E, 4,478,714 m N, NAD27. The pegmatite was on the former Fred Hyatt ranch but today is shown as National Forest land after purchase by the Bureau of Mines. In 2016, there is a 50 foot disagreement between the location of the eastern property boundary between the county records (further east) and local property owners (further west).

The pegmatite is about 1 mile by air line north of the North Fork Big Thompson River and about 1.5 miles by air line north-northwest of the town of Drake on U. S. Highway 34. The mine can be reached from Drake by a bitumen paved road that becomes a graded direct road. In 2015, access by 2WD vehicle was uneventful.

Mining History

The Hyatt Mine was discovered by Roy Hyatt in 1936. The pegmatite was quarried intermittently for beryl until Eugene Bruell, representing United Beryllium Ores & Metals, made a deal with Fred Hyatt, the surface owner, to mine this and other nearby pegmatites on September 25, 1942. It was operated steadily from June 1943 to December, 1943 by United Beryllium Ores & Metals Corporation (Hanley et al., 1950) under a financial arrangement with the Reconstruction Finance Corporation (financed by the U. S. Federal government during World War II). During 1944 the mine was inactive.

The operations since 1936 has resulted in the production of 34.75 tons of hand-cobbed beryl that contained an average BeO content of 11.04 percent. Thirty-four tons of beryl was produced during the operations from June to December 1943.

The mine was first visited by J. B. Hanley on September 21, 1942, and was mapped by him and L. R. Page by plane table and telescopic alidade on October 9 and 10, 1942. It was remapped from September 7 to September 13, 1943, by J. B. Hanley and Roswell Miller III and from June 17 to June 21, 1944, by J. B. Hanley, A. F. Trites, Jr., and J. E. Husted. A 3,000-pound sample of the fine-grained beryl pegmatite was collected by James F. Piquette of the Metals Reserve Company with the assistance of the Geological Survey in September 1943.

In 1948, the property was leased to Michael D. Lyons who mined 400 tons of feldspar and 30 tons of scrap mica (Gilkey, 1960). In late 1948, the U.S. Geological Survey explored the pegmatite by core drilling as reported by Thurston (1955). For one year after September, 1950, the U. S. Bureau of Mines further investigated the pegmatite to determine the extent and economic feasibility of mining beryl and other minerals. They developed an adit 272 feet long completely through the lower part of the pegmatite, thus penetrating and exploring all the zones in the pegmatite. They also drilled 297 feet of core below the adit level. Surface quarrying has resulted in a 20 foot highwall cut along almost the entire north flank (hanging wall).

Mine workings

The mine workings on the Hyatt pegmatite comprise two large open-cuts, a third open-cut that is buried beneath dump material, and three prospect and sample trenches. The largest cut is 118 feet in length and as much as 47 feet in width and has a maximum depth of at least 35 feet. The other cut is 65 feet in length, as much as 45 feet in width, and at least 25 feet in depth. The backfilled cut was 472 square feet in area with an average depth of 10 feet. The adit that was made by the U. S. Bureau of Mines circa 1948 has been buried under the mine dump as it slide southward.

Pegmatite geology

In the vicinity of the Hyatt pegmatite numerous pegmatite and gray granite bodies intrude dark-gray schists, which probably belong to the Proterozoic formerly known as the Idaho Springs formation. In some exposures the granites are cut by the pegmatites and hence are older, but both rocks are probably Proterozoic in age.

Two large and two small pegmatites crop out in the area mapped. The Hyatt pegmatite, which is the largest, is zoned and contains beryl, as does one of the small pegmatites. The other pegmatites do not contain beryl.

The Hyatt pegmatite is roughly lenticular but discordant, that has been intruded across a small projection of a gray biotite granite (tonalite) and quartz-mica schist. It is at least 350 feet in length and as much as 60 feet in width and, prior to the mining, was exposed for a vertical height of 50 feet in a natural cliff. The general trend of the pegmatite is N 60° E, and the dips of the contacts range from 30° to 45° NW except at the southwest and northeast ends where locally they dip 45° S to vertical. The plunge of the pegmatite is about 25° SW.

The contacts with the wall rock are well exposed at the northeastern and southwestern ends and prior to the mining were well exposed along most of the southeast side. Along the northwest side the contact is obscured by granite float from the ridge above the pegmatite.

In the largest open-cut the pegmatite is crossed by a fracture that strikes N. 50° E., dips southeast, and branches downward. The fracture is marked by a 4 inch thickness of soft and very friable gouge, which is composed of brecciated quartz, feldspar, beryl, and mica. Despite the thick layer of gouge no displacement can be found.

The Hyatt pegmatite contains, besides a discontinuous border zone, a wall zone of fine-grained microcline-quartz-muscovite-beryl pegmatite, a discontinuous and highly irregular intermediate zone of quartz-albite-muscovite pegmatite that contains beryl, and a core of coarse-grained microperthite pegmatite. A large body of quartz pegmatite was exposed at the hanging-wall contact prior to the mining, but the relationship of this unit to the zones is not known since it was removed prior to the earliest investigation by Hanley et al. (1950)

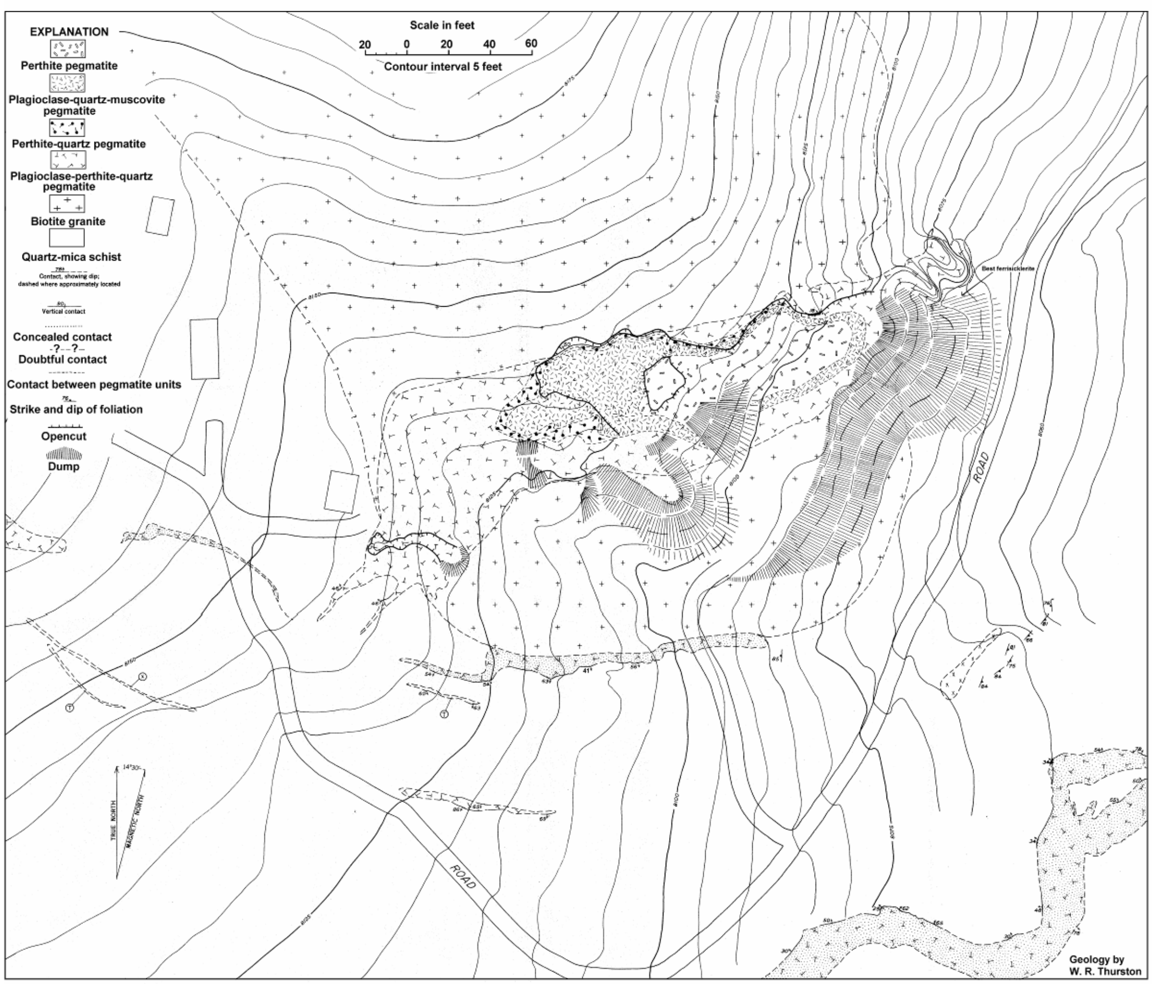

Figure 5. Geologic map of the Hyatt pegmatite, Larimer County, Colorado. Modified after Thurston (1955).

Border zone pegmatite - In many places, where the granite pegmatite is in contact with the granite, there is no border zone. But where the pegmatite is in contact with the quartz-mica schist, the border zone is well-developed (Gilkey, 1960).

Microcline-quartz-muscovite-beryl pegmatite - The wall zone of the pegmatite is composed of pink microcline, white to pink plagioclase, grayish quartz, and small books of muscovite, with minor quantities of light bluish-green to blue beryl that occurs in euhedral crystals with an average size of 6 millimeters. This zone is exposed over an area of 10,150 square feet and makes up the bulk of the pegmatite at the surface. The average grain size of this pegmatite is about 1 inch, although some of the microcline crystals are several times this size. The grain size decreases toward the contact with the schist wall rock, but no change in grain size was observed near the contact with the granite wall rock. Beryl is uniformly distributed throughout the zone and is visually estimated to compose 1 to 3 percent of the pegmatite.

Quartz-albite-muscovite pegmatite - The intermediate zone is a series of disconnected lenticular pods between the wall zone and the core. It is composed chiefly of quartz, white albite, and greenish-white muscovite with accessory beryl, black tourmaline, lithiophilite - triphylite, sicklerite-ferrisicklerite, purpurite-heterosite, uraninite, torbernite, autunite, bismuthinite, and pyrite (found in the triphylite). The albite commonly forms in small anhedral crystals with a composition indicated by the indices of refraction as about Adm. Muscovite occurs in wedge shaped books that are as much as 1 foot long, are reeved, and have "A" structure. No punch nor sheet mica has been found; the muscovite is suitable only for scrap mica. Light bluish-green to blue beryl occurs in euhedral crystals and bundles of crystals as much as 1 foot in diameter and 4 feet in length. This beryl commonly is fractured subparallel to the basal cleavage, and the fractures have been healed by grayish-white quartz or by a fine-grained quartz-albite-muscovite pegmatite that has a typical aplitic texture. Narrow stringers of this aplitic pegmatite occur as healing material along fractures in all zones of the pegmatite except the core. When the pegmatite was first examined, seven separate clusters of beryl crystals were exposed in the cliff face. The largest of these clusters contained 31 beryl crystals in 30 square feet of pegmatite.

Black tourmaline occurs in the muscovite and albite as euhedral crystals that range from less than 3 to 25 millimeters in diameter. It commonly occurs on the crystal faces of the beryl. The lithiophilite-triphylite minerals, as well as its associated alteration minerals and the uranium minerals occur in lenticular patches that are oriented parallel to the structure of the intermediate zone near the contact between the intermediate zone and the core. These patches are commonly associated with the albite-rich parts of the zone rather than with the muscovite-rich parts. Bismuthinite and its alteration products occur at the inner edge of the intermediate zone.

Microperthite pegmatite — The microperthite pegmatite of the core is composed chiefly of white microperthite in masses several feet in size. Milky quartz and black tourmaline are minor accessories. Some of the microperthite, particularly near the surface, is iron stained, but this staining does not continue in depth except along fractures. Adjacent to the intermediate zone the microperthite pegmatite contains albite, beryl, and muscovite in small quantities.

The smaller beryl-bearing pegmatite is about 40 feet south of the Hyatt pegmatite and is exposed for 180 feet. It ranges in width from less than 1 foot to 6 feet. Its general strike is N. 70° E., and its dip is 60° SE. The western end of this pegmatite has been displaced 10 feet horizontally to the south by a small fault that trends N. 10° E. The dip of the fault could not be determined.

This pegmatite is composed chiefly of quartz, microcline, plagioclase, and muscovite with accessory beryl and has an average grain size of 3 inches. Quartz pegmatite occurs as small, discontinuous pods along the center of the dike. About 30 feet east of the fault 84 beryl crystals with an average size of 10 millimeters are exposed in an area of 32 square feet. This pegmatite is similar to the wall zone of the Hyatt pegmatite but is small and contains little beryl.

The larger of the two quartz-microcline-plagioclase-muscovite pegmatites ranges in width from 12 to 50 feet and is at least 400 feet long. Its average grain size is 2 inches. Near the west end it has been displaced by a minor fault that strikes N 76° W and dips 80° NE. The displacement on the fault is mainly rotational. No beryl is exposed in the pegmatite.

The smaller quartz-microcline-plagioclase-muscovite pegmatite is exposed only for a length of 48 feet. It is as much as 4 feet wide, strikes N. 70° E., and dips 60° NW. The pegmatite is similar to the larger quartz-microcline-plagioclase-muscovite pegmatite and has an average grain size of about 18 millimeters. No beryl is exposed in it.

Mineral Deposits

Beryl

The Hyatt pegmatite contains an appreciable quantity of beryl in the wall and intermediate zones. The beryl produced has been mined from the intermediate zone beryl deposit. A mica deposit in the intermediate zone and a feldspar deposit in the core of microperthite pegmatite are large enough to repay mining operations.

The wall-zone beryl deposit is exposed over 10,150 square feet of the surface of the pegmatite. The thickness of this zone is variable, and its average thickness is not known. It probably extends at least 50 feet below the original surface of the pegmatite. The beryl content was visually estimated to be between 1 and 3 percent. A spectrographic analysis by the Chemical Laboratory of the Geological Survey of a part of the Metals Reserve Company-s bulk sample from this zone showed a BeO content of 0.07 percent, or 0.5 percent beryl that contains 13 percent BeO. However, the sampling was not representative of the zone and is significant only in that it shows beryl is present.

The intermediate-zone beryl deposit is exposed as a series of lenticular pods over a surface area of 1,100 square feet. The thickness of this zone is variable, and the average thickness cannot be determined. The probable extent of this deposit in depth is 50 feet. The past production figures indicate that the beryl content of the zone is about 2 percent. Prior to the mining, seven clusters of beryl crystals were exposed in the natural cliff face. The beryl crystals in these clusters, which projected above the surface of the surrounding rock, were measured, and the quantity of beryl thus exposed totaled 3,300 pounds.

Gilkey (1960) observed that the largest and most abundant beryl crystals are found in clusters of several crystals in the inner intermediate zone. Some of them range up to 30 cm in diameter and 1.6 m in length. Large beryl crystals are still exposed on the outcrop in the inner intermediate zone at the west end of the pegmatite. The core and outer intermediate zones are essentially barren of beryl.

Muscovite

The greenish-white muscovite of the intermediate zone mica deposit occurs in large wedge-shaped books as much as 1 foot in length. It is wedged and reeved, has "A" structure, and is suitable only for scrap mica. Small black tourmaline crystals are commonly associated with the muscovite. The muscovite deposit occurs in the same zone as the beryl deposit. Its grade is visually estimated to be 10 to 15 percent scrap mica.

Feldspar

White microperthite occurs in the core in masses that are several feet in size. Milky quartz and black tourmaline occur in minor quantities in the microperthite, and very small quantities of muscovite, albite, and beryl occur near the outer edges of this deposit.

The feldspar deposit is exposed over a surface area of 3,825 square feet and to a vertical depth of 30 feet. It probably continues for 20 feet more in depth. It is visually estimated to contain about 50 percent microcline.

Storm Mountain pegmatite

Location

The Storm Mountain pegmatite is located almost at the summit of Storm Mountain; the open pit quarry and dump faces eastward in the SE 1/4 of the NE 1/4 of section 18, T 6 N, R 71W. On a map, the pit is located 650 feet west of the east line and 3,050 feet north of the south line of section 18, T. 6 N., R. 71 W or at 467,463 m E, 4,481,575 m N, 9773 feet elevation, UTM 13, NAD27 datum (GPS measured) or 467,414 m E, 4481,786 m N, UTM13, NAD83 (map measured).

Mining History

The Storm Mountain pegmatite was discovered on July 1, 1952 by Ed Wild and others, who claimed it on September 25, 1952. The pegmatite was reclaimed by Wayne and Marvin Milner on March 15, 1955. Ore Research & Laboratories, Inc. of Dallas, Texas later purchased control of the property and initiated mining in June 1957. The result of their core drilling and quarrying is an open cut on the eastern end of the dike. Approximately 300 feet west of this opening is a bulldozer trench on another pegmatite parallel to the Storm Mountain pegmatite. They also built a steep 4-wheel drive road to the quarry (Boos 1959).

Geology

The pegmatite is exposed along the summit as a westerly trending sill with almost vertical concordant contacts with mica-quartz schist of the former Idaho Springs formation. Schorl-muscovite schist is present at some locations along the northern contact. The pegmatite has a border zone of fine-grained quartz-plagioclase-muscovite, a wall zone one to three feet thick of coarse-grained plagioclase-quartz-muscovite with accessory beryl, schorl and garnet, and a core of very coarse-grained, segregated pods of gray to smoky quartz and microcline. Within the composite core are black manganese oxide-coated phosphate pods.

The Storm Mountain Mine is the richest phosphate-bearing pegmatite in the field.

Exposed in the open pit and in the dumps are large pods of phosphate minerals, from which the following assemblages have been identified (all phosphates, except for heterosite, have been identified by x-ray diffraction). Fine grained alluaudite nodules have been found up to one foot in diameter. The nodules exhibit three colors — yellow-brown as from Varutrask, Sweden (Quensel 1957, p. 50), deep red-brown, and olive-green as varulite from Varutrask, Sweden (Quensel 1957, p. 45). Occasionally the exterior of the alluaudite nodules are coated by chalk-white to tan hydroxylapatite. Heterosite masses to two feet are especially common. Graftonite has been observed either as a blackish-colored phosphate that is laminated with heterosite or as salmon-colored masses to 20 pounds. Vivianite is present as a thin film along the fractures in the salmon-colored graftonite masses and as less than 1.5 mm crystals in yellow-brown alluaudite and gray laminated graftonite-heterosite.

Buckman (1969) also reported ferrisicklerite (because of the identification of ferrisicklerite, it is assumed the other minerals in the alteration series are triphylite and heterosite), triphylite-lithiophilite and triplite. As has been argued by Moore (1971) in general, the alluaudites appear to have replaced the original triphylite-ferrisicklerite-heterosite minerals. In addition, the alluaudites also seem to have replaced graftonite as suggested by green alluaudite surrounding graftonite-heterosite intergrowths and also yellow-brown alluaudite with faint heterosite lamella traversing through the specimen.

Other accessory minerals are light green beryl, garnet, schorl and zircon, variety cyrtolite. Buckman (1969) reported the uranium-bearing minerals, phosphuranylite, meta-autunite, uraninite-thorianite, uranophane and vandendriesscheite.

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Field Trip guide to the pegmatites of the South Platte pegmatite field

The following description of the pegmatites from the South Platte district is reprinted with the permission of the authors from: Field Trip Guidebook from the Eugene E. Foord Memorial Symposium on NYF-Type Pegmatites, Denver, Colorado, September 11-14, 1999, p. 1-22.

Anorogenic, NYF-Type Pegmatites of the South Platte District, Pikes Peak Batholith, Colorado

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ABSTRACT

Pegmatites of the South Platte district, Jefferson County, Colorado, constitute one of the world's classic NYF pegmatite districts. The district is located within the Precambrian core of the Rocky Mountain Front Range in central Colorado, near the northern margin of the Pikes Peak batholith. More than 75 pegmatites belong to this district and all are enriched in Niobium, Yttrium and Fluorine. Samarskite-(Y) is abundant throughout the district and many tons were mined from several pegmatites, Synchysite-(Y), and xenotime-(Y) are abundant in several pegmatites and fluorite is abundant in most. Several contained mappable zones of fluorite. The whole pegmatite-granite system is extremely REE enriched and the pegmatites are well known for their contents of relatively abundant rare-earth minerals (Simmons and Heinrich 1980, Simmons et al 1987). Boron is virtually absent and beryllium is present only in rare gadolinite (Ce) and gadolrnite-(Y). Only a few samples of beryl have been found in the entire district. All of the mica occurs as biotite and the feldspars are pink. The pegmatites are enriched in Fe and pods of metallic hematite occur in some pegmatites and there is abundant secondary hematite replacement. In addition to the common rock-forming minerals such as quartz, microcline, sodic plagioclase, and biotite, the following accessory minerals are prevalent hematite, fluorite, zircon (cyrtolite), muscovite, siderite, calcite, pyrolusite, and widespread rare-earth minerals which include yttrian fluorite, cerian fluorite, monazite- (Ce), xenotime-(Y), allarnte-(Ce), samarskite-(Y), fergusonite-(Y), yttrotantalite-(Y), gadolinite-(Ce), gadolinite-(Y), molybdenite, thorite, thalenite-(Y), synchysite-(Y) or bastnaesite-(Ce). In some deposits one or more of these minerals may be very abundant in secondary units. Very rarely, minerals such as sellaite and autunite have been found.

The pegmatites are characterized by an extraordinarily well-developed internal zonation which is spectacularly well displayed in three dimensions, owing to selective mining techniques, which have completely removed the intermediate zones leaving quartz cores standing in bold relief. The structure of these pegmatites, from the outer margin to the core consists of. 1) a poorly developed thin border zone (rarely present), 2) a wall

zone of biotite graphic granite, 3) an outer-intermediate zone of giant biotite crystals (rarely present), 4) an intermediate zone of microcline-perthite, 5) a core-margin zone of green fluorite, 6) a large core of massive quartz (quartz-core pegmatites) or quartz-microcline (composite-core pegmatites), and 7) secondary replacement units superimposed on the primary zonal sequence, containing albite, fluorite, REE minerals, and hematite.

Quartz-core pegmatites are roughly circular in plan and contain four or more well-developed, mappable zones, including a wall zone, an intermediate zone of microcline-perthite, a core-margin zone of green fluorite, and a large core of nearly pure, monomineralic quartz. Typically, quartz-core pegmatites are more extensively replaced by secondary mineralization that is more complex and variable than that of composite-core pegmatites. Composite-core pegmatites are distinctly zoned, but generally display only a core and a wall zone and lack an intermediate zone. Composite-core pegmatites tend to be more irregular in shape and commonly have elliptical horizontal cross sections. The cores are characteristically large in proportion to the rest of the pegmatite compared to the quartz-core pegmatites. Within the South Platte district, the quartz-core and the composite-core pegmatites cluster into two geographical groups. The quartz core pegmatites cluster in the northern part of the district, whereas composite-core pegmatites occur in the southern part of the district.

All the pegmatites in the South Platte district are contained within the parental Pikes Peak batholith and are thus unambiguously genetically related to the Proterozoic A-type Pikes Peak granite. U-Pb zircon crystallization ages for the Pikes Peak granite range from 1092 to 1074 Ma (Unruh et al. 1995). Geochemically, granitoids from the South Platte district have high Ga/Al ratios and high K20+ Na20 compared to M-, S-, and 1-type granites and plot in the A-type field of Whalen et al. (1987) South Platte granitoids can be classified as within-plate granite (WPG) using the Nb-Y discrimination diagram of Pearce et al. (1984). A ternary plot of Nb, Y and Ga* 3 reveals that the South Platte granitoids can be classified as A2-type (postcollisional, postorogenic and anorogenic environments) granitoids according to Eby (1992).

INTRODUCTION

The South Platte pegmatite district lies within the Precambrian core of the Colorado Front Range in the northernmost lobe of the Pikes Peak batholith near the former town of South Platte, Colorado (Figures 1 and 2). U-Pb zircon crystallization ages of the Pikes Peak granite range from 1092 to 1074 Ma, and ^{40}Ar /^{30}Ar plateau dates on biotite indicate the deeper-level pegmatites of the South Platte district cooled through 300 °C between 1077 and 1066 Ma (Unruh et al. 1995). The pegmatites of the district are well known for their, strong enrichment in rare-earth elements, yttrium, niobium, fluorine, and iron, manifested by the abundance and variety of rare-earth-element (REE), niobium. and fluorine minerals found in the secondary replacement units of the pegmatites. The REE are extremely enriched in these pegmatites, and the only other pegmatites that have similar concentrations are those in Llano County, Texas and those near, Osterby, Ytterby, and Finbo, Sweden.

The central portion of the South Platte district encompasses an area of about 10 km^2 and is defined by a cluster of more than 50 large, complex, concentrically zoned pegmatites, all contained within the parental Pikes Peak pluton. However, unlike pluton-interior pegmatites from other districts, South Platte pegmatites exhibit extensive replacement of primary mineral phases by secondary phases produced during late-stage hydrothermal alteration and most display exceptionally well-developed internal zonation.

The first report of this district was by Hanley et al. (1950). Heinrich (1958) reported on the REE mineralogy and mining activity, which had begun in the mid-1950s. Peterson (1964) mapped the Platte Canyon quadrangle and Haynes (1965) published an interpretation of the White Cloud and related pegmatites. Simmons and Heinrich (1975, 1980) discussed the geology, mineralogy, and petrology of the district. Wayne (1986), Brewster (1986), and Lee (19860 completed additional mineralogical and geochemical studies of the district which were summarized in Simmons *et al*. (1987).

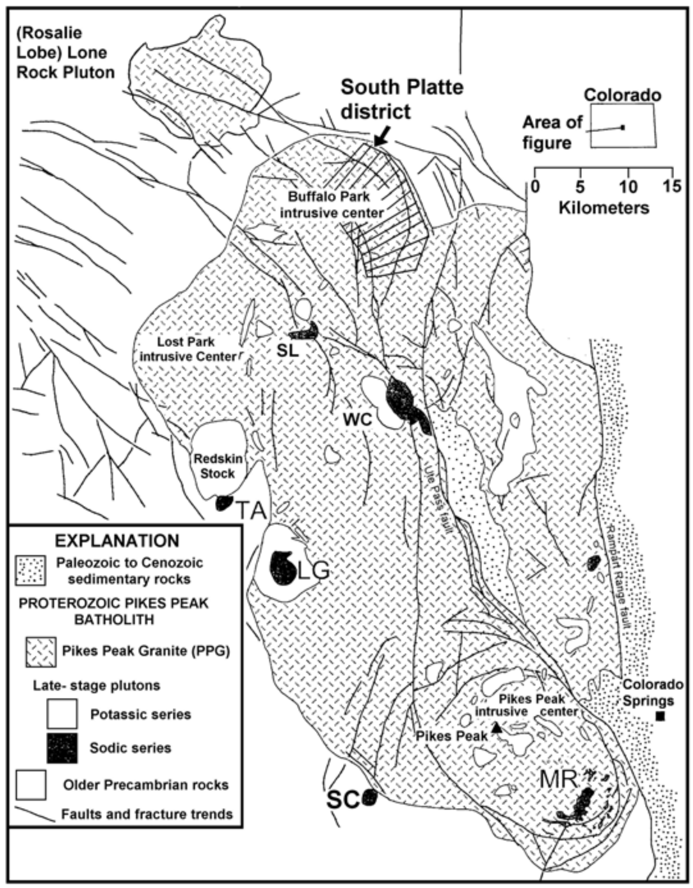

Figure 1. Geologic map of the Pikes Peak batholith showing the Buffalo Park intrusive center and the location of the South Platte pegmatite district (Modified from Barker *et al*. 1976, and Hawley & Wobus, 1976).

DISTRICT GEOLOGY

Host batholith

Hutchinson (1976) and Hawley and Wobus (1977) demonstrated that the Pikes Peak batholith is composite in nature with at least three clearly defined intrusive centers. The South Platte pegmatite district lies within the northern part of the Buffalo Park intrusive center near the town of Buffalo Creek, Colorado (Figure 1). Here the batholith is in contact with the 1750 Ma Idaho Springs Formation. Flow structures in the granite parallel the contact between wall rocks and the batholith. Contacts are sharp and dip steeply away from the batholith, but gradational contacts and migmatization occur locally. Gneissic xenoliths of metamorphic rock and migmatite, which closely resemble rocks of the Idaho Springs Formation, occur in this portion of the batholith. Their presence suggests that the present level of exposure is dose to the roof of the pluton. The Buffalo Park Pluton is reversely zoned, with a more siliceous outer zone and a more mafic center. It is similar to reversely zoned plutons of the Bottle Lake complex described by Ayuso (1984). Its outer zone is composed of biotite granite, which is in gradational contact with the inner zone of porphyritic quartz monzonite (Figure 2). The granite consists of perthite, quartz, oligoclase, biotite, and hornblende, with accessory magnetite, apatite, zircon, allanite (Ce), and fluorite. The quartz monzonite contains megacrysts of perthite in a matrix of oligoclase, quartz, biotite, and hornblende, with accessory magnetite, zircon, apatite, and sphene. Numerous aplite dikes crosscut the granitic rocks and, in places, grade into pegmatite.

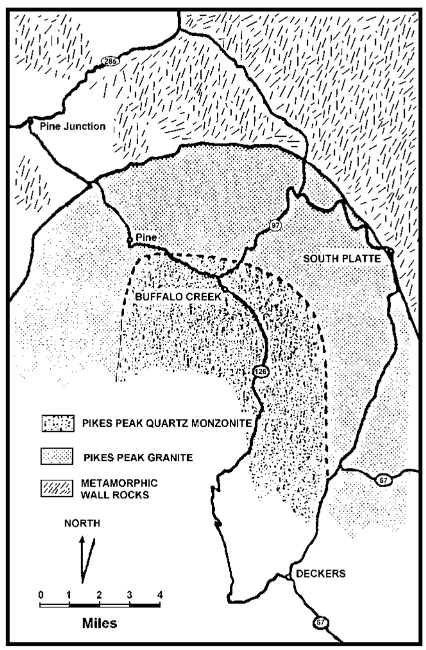

Figure 2. Generalized geolgic map of the northeastern end of the Pikes Peak batholith (Modified from Hutchinson, 1960).

Pegmatites

More than 50 large pegmatites occur in an area just southwest of the former town of South Platte, after which the district is named. Typically, their large "bull quartz" cores stand up as resistant knobs above the surrounding granite Early feldspar mining, chiefly by hand, also left the much harder quartz cores standing in bold relief as the enveloping microcline was removed. The pegmatite bodies are roughly circular to elliptical in plan with well-developed concentric zoning The major axes of elongation of the few elliptical bodies show no systematic alignment with flow structures, joints, aplite dikes, or faults within the batholith.

Several other mineralogically simple types of 'mini-pegmatites' also crop out in this area. Some aplite dikes contain pegmatitic zones that are generally small and compositionally similar to the aplite. Typically, these are never more than a meter in their maximum dimension. The larger bodies may contain miarolitic cavities. Pegmatitic material is also locally present along fractures, fissures, or tensional joints, but these are small and limited in areal extent.

The main cluster of pegmatites is restricted to elevations between 2100 and 2400 meters within the granite, forming a clearly defined pegmatite niveau. Similar vertical zonation has not been described in other districts and this represents an unusual feature of the South Platte district. Concentric internal zonation is conspicuously developed, particularly in pegmatites with nearly circular horizontal cross sections. An idealized zonal sequence from outer margin to the center is: 1) Thin, poorly developed aplitic to graphic quartz-perthite border zone; 2) Biotite graphic granite wall zone, 3) Outer intermediate zone of microcline-perthite with giant biotite crystals; 4) Microcline perthite intermediate zone; 5) Core margin zone of green fluorite; and 6) Quartz, or quartz-microcline core.

Secondary replacement units, consisting principally of albite, fluorite, hematite, REE minerals, or sericite, are superimposed on the primary zonal sequence. Replacement units are more abundant along the core margin, but they may replace any primary zone.

Two end ember pegmatite types can be distinguished on the basis of external shape and the number and type of internal zones (Figure 3). The first is the quartz-core type. These have an inverted teardrop shape and are circular in plan view. They are characterized by four or more mineralogically distinct zones 1) wall zone, 2) intermediate zone of microcline-perthite, 3) core - margin zone of green fluorite; and 4) large core of nearly pure, monomineralic quartz. Typically, the quartz-core types are more extensively replaced by secondary minerals that are more complex and variable than those found in the other zonal type. The second zonal type is the composite-core type These pegmatites are vertical to steeply dipping ellipsoidal bodies consisting of only a wall zone and a composite quartz-microcline core. They tend to be more irregular in their external shape and commonly have elliptical horizontal cross sections. The cores are characteristically larger in proportion to the rest of the pegmatite.

Quartz-core pegmatites exhibit a pronounced vertical asymmetry, with internal zones dipping away from the core near the top of the pegmatite and zones dipping toward the core near the bottom of the pegmatites (Figure 3). Field evidence indicates a correlation between the size of the replacement units and their relative vertical level within the pegmatite. Large replacement units are found where primary zones are inclined at shallow angles away from the center of the pegmatite, whereas replacement bodies are smaller where dips are steeper or inclined toward the center of the pegmatite. The asymmetric displacement of the replacement units toward the tops of pegmatites indicates that the more volatile-rich components rose during crystallization (Simmons and Heinrich 1980).

The two pegmatite structural types occur in two different geographic areas The quartz-core pegmatites cluster in a group just west of Raleigh Peak and north of Spring Creek. The composite-core bodies are found to the south of Spring Creek.

Secondary mineralization in this district is complex and varied Generally, one or, two phases are dominant and the replacement mineralogy of an individual pegmatite can be categorized by these dominant phases. The details of the replacement mineralogy are discussed by Simmons and Heinrich (1980). The five categories of mineralization, which characterize the replacement units are: albite, fluorite, hematite, REE minerals, and sericite. Virtually every replacement unit contains one or more of these minerals as a principal constituent. A list of replacement minerals common in South Platte pegmatites can be found in Table 1.

RARE -EARTH ELEMENT MINERAL ZONATION

Notable occurrences of the REE silicate, allanite-(Ce), are restricted to the southern group of composite-core pegmatites Within these, allanite-(Ce) is found exclusively in an intermediate or core margin position between the wall zone and composite core. It occurs as red-brown to black, earthy to vitreous, pod-like masses ranging in diameter from a few centimeters to large masses greater than 50 cm across. Typically, allanite-(Ce) pods are intergrown with biotite and in some cases are associated with minor late-stage purple fluorite. In thin section, the most noticeable characteristic is the pervasive fracturing and alteration. Most samples exhibit a red-brown alteration rind of bastnaesite-(Ce) and

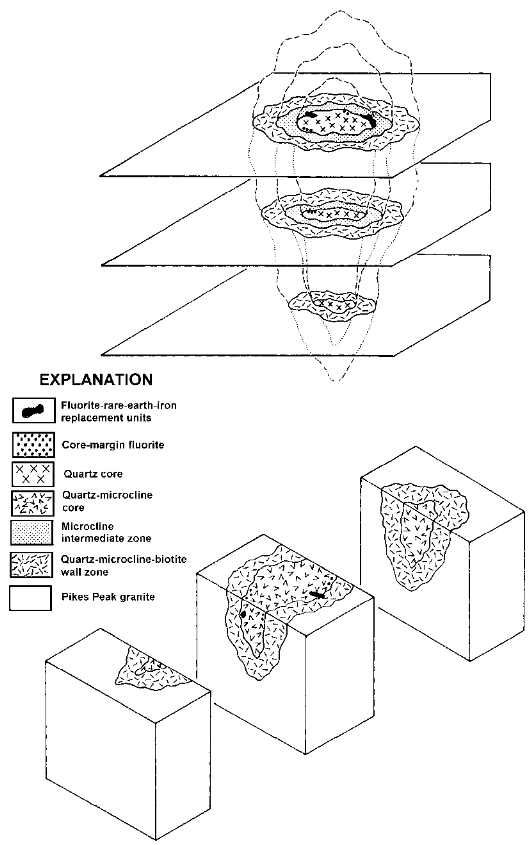

Figure 3. Idealized block diagrams of the internal structure of the quartz core and composite quartz-microcline core pegmatites.

extensive bastnaesitization along fractures X-ray diffraction patterns typically 'contain only peaks for bastnaesite-(Ce). Under crossed nicols, the bastnaesite-(Ce)-free portions range from partially to completely isotropic, corresponding to their degree of metamictization. Allanite-(Ce) samples from the Shuttle Run and Madonna Eastern pegmatites were chosen for analysis (Figure 4). Within each sample, regions showing various degrees of metamictization were selected for microprobe analysis.

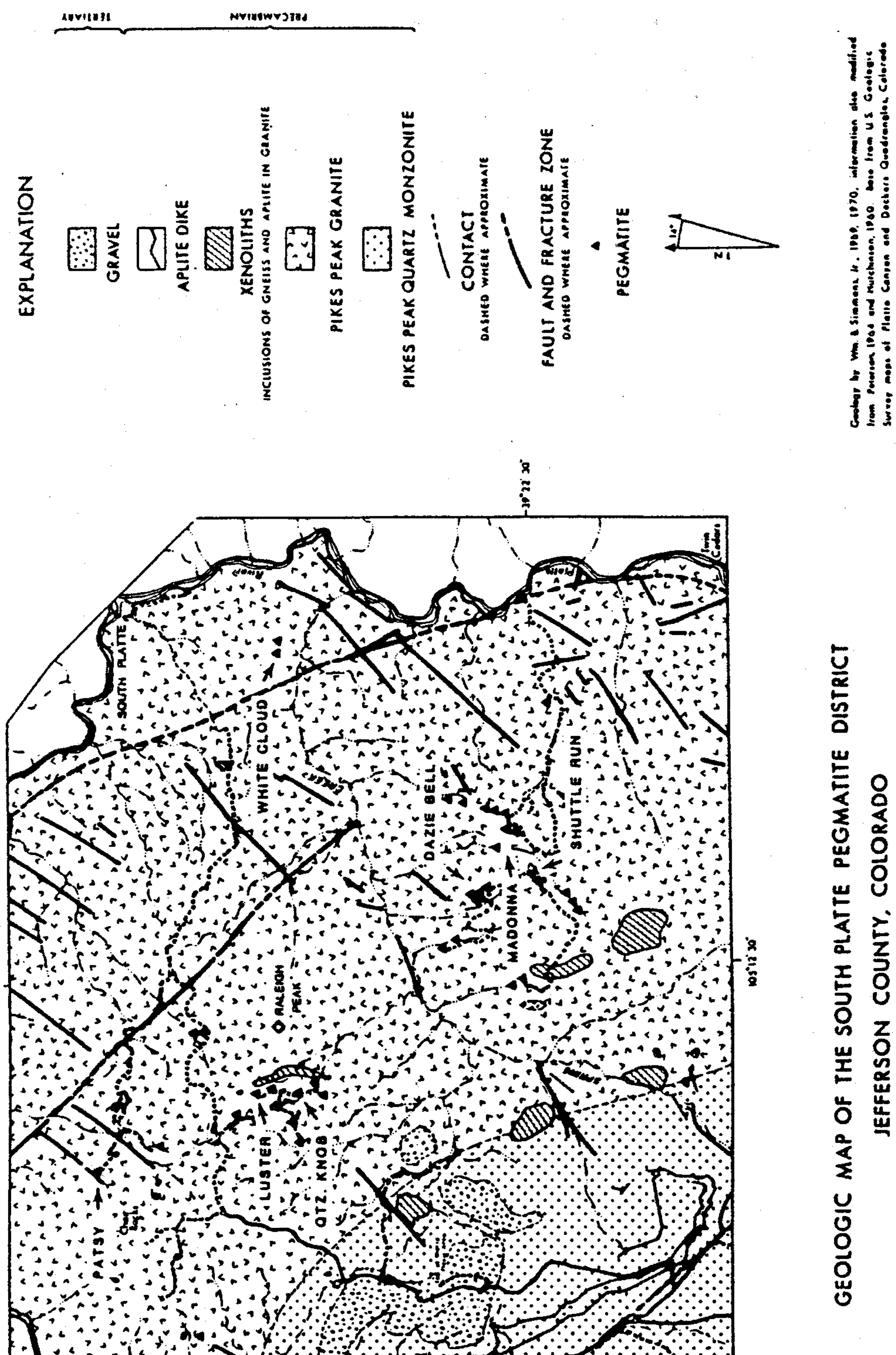

FIGURE 4. Geologic map of the South Platte pegmatite district, showing location of selected pegmatites (modified from Simmons & Heinrich, 1975).

Classification	Main Elements	Mineral
Simple Oxides	Fe	Hematite
-	Fe	Limonite
	Mn	(Pyrolusite)
Multiple Oxides	Y, Nb, Fe	Samarskite-(Y), -(Yb)
	Y, Ta, Fe	(Yttrotantalite-(Y))
Halides	Ca	Fluorite
	Mg	(Sellaite)
	REE	REE Fluorite
Carbonates	Fe	(Siderite)
	Ca _	(Calcite)
	Y, Ce, F	(Synchysite-(Y)-(Y))
	Ce, F	Bastnaesite-(Ce)
Sulfide	Fe	(Pyrite)
Sulfate	Ca	(Anhydrite).
Phosphates	Ce	Monazite-(Ce)
	Y	Xenotime-(Y)
	U	(Autunite)
Silicates	K, Al	Sericite
	Na	Albite
	Th	Thorite
	U, Th	(Thorogummite)
	Zr, Y	Cyrtolite
	Y, Fe, Be	Gadolinite-(Y).
	Ce, Fe, Be	Gadolinite-(Ce)
	Y	(Thalenite-(Y))
	Ca, Ce, Fe	AIIanite(Ce)
	Be	(Beryl, bertrandite)

Table 1. Replacement Mineralogy of the South Platte Pegmatites (very rare species in parenthesis)

MINERAL CHEMISTRY

All analyses were conducted in the wavelength dispersive mode on the University of New Orleans' ARL-EMX-SM three-spectrometer electron microprobe operating with an accelerating voltage of 15 kV, a beam current of approximately 25 nA, and counting times of approximately 30 s Errors resulting from the inherently complicated overlap interferences for the REE L-series spectra were eliminated using a modified version of the correction scheme developed by Wayne (1986). Data were reduced with a version of the ZAF program EMPADR (Rucklidge and Gasparnni 1969) which has been modified in our laboratory to analyze up to 30 elements simultaneously. Standards used were synthetic REE glass standards (Drake and Weill 1972), synthetic REE fluorides (Wayne 1986), synthetic REE-Ga garnets, synthetic REE-A1 garnets, synthetic REE silicates (U.S. National Museum numbers S-65, S679 S-693, S-875 S-92, S-90, S-529, S-516, S-846, S-847), thorianite (U.S.N.M. 106961) and an analyzed samarskite(Y) from Afghanistan (E. E. Foord, pers. comm).

A representative formula for a Shuttle Run allanite.-(Ce), calculated on the basis of three silicons, twelve oxygens, and one (OH, Cl, F) is shown in Table 2. Fe^{+2} and Fe^{+3} are calculated on the basis of charge balance South Platte allanite-(Ce) consistently show a strong affinity for the light rare earth elements (LREE) and generally conform to the abundance trend Ce > Nd> La > Pr > Sm > Y. The trend for the five White Cloud specimens differs slightly with Ce > La> Nd > Pr > Sm > Gd (Wayne 1986). Thorium, although a relatively minor constituent, displays approximately a two-fold enrichment in the metamict areas relative to the partially metamict areas. Uranium was not detected in the analyzed allanite-(Ce). Chlorine concentrations of 0.5 to 1.0 wt % were detected in both allanite-(Ce) and associated biotites Normalized structural formulas indicate a small deficiency in the A-site which may be attributed to either Ca^{+2} depletion or possible site vacancies resulting from the extensive substitution of REE^{+3} into the A. site.

The REE-bearing niobium-tantalum oxide, samarskite-(Y), occurs principally in the quartz core pegmatites which are clustered just west of Raleigh Peak and north of Spring Creek. Large radiating samarskite-(Y) nodules, as much as 30 cm in diameter, are found in the albite - rich core-margin replacement units which also contain relict primary green fluorite and late-stage purple fluorite. Unlike allanite-(Ce), which exhibits various degrees of metamictization, these highly radioactive samarskite-(Y) specimens are completely isotropic under crossed nicols. Typically, samarskite-(Y) is extensively fractured and contains abundant inclusions of fine-grained hematite. Microprobe analyses of samarskite-.(Y) from the Quartz Knob, Luster, and Little Patsy pegmatites (Figure 4), reveal an A-site cation abundance trend of heavy-rare-earth-elements (HREE),+ Y > Fe > U > Ca > LREE > Pb> Th. Of the HREE group, Yb is the dominant cation. For seven of the ten analyzed samples, the concentration of Yb exceeds that of Y. Yb_20_3 concentrations range from approximately 1.6 to 6.0 wt %, which makes this South Platte "samarskite" highly enriched in Yb (samarskite-(Yb» relative to samarskite-(Y) from other areas. Dysprosium and erbium are the next most abundant HREE and occur in nearly equal proportions, with concentrations ranging from approximately 1 to 3 wt % oxide. A representative microprobe analysis of a particularly Yb-enriched "samarskite" from the Little Patsy is shown in Table 3. The formula is calculated on an anhydrous basis and on the basis of 8 cations and 16 oxygen atoms as proposed by Sugitam *et al*. (1985). The low analytical total is due in part to adsorbed water and also to oxidation of Fe^{+2} to Fe^{+3} and U^{+4} to $U.^{+6}$.In addition, the presence of pervasive fine-grained hematite inclusions further contributes to analytical error. These results and the distribution of replacement minerals described by Simmons and Heinrich (1980) clearly show that there are significant differences in chemistry between the two pegmatite groups. The northern group near Raleigh Peak is enriched in fluorine, HREE, Nb, and Ta relative to the southern group, which is relatively enriched in LREE. These differences, as well as the differences in structure, mineralogy, and late-stage chemistry, suggest that the two pegmatite groups have a fundamentally different origin.

Oxide	Wt.%	Cations	For M_8O_{16}
Nb2O5	27.59	Nb	2.657
Ta2O5	24.77	Ta	1.435
TiO2	1.96	Ti	0.313
ThO2	0.24	Th	0.012
UO2	2.54	U	0.120
La2O3	0.00	La	0.000
Ce2O3	0.42	Ce	0.032
Pr2O3	0.04	Pr	0.003
Nd2O3	1.13	Nd	0.086
Sm2O3	0.80	Sm	0.059
Eu2O3	0.30	Eu	0.150
Gd2O3	0.53	Gd	0.037
Tb2O3	0.23	Tb	0.016
Dy2O3	1.96	Dy	0.134
Ho2O3	0.46	Ho	0.031
Er2O3	2.29	Er	0.153
Tm2O3	1.21	Tm	0.080
Yb2O3	5.48	Yb	0.356
Lu2O3	0.84	Lu	0.220
Y2O3	1.06	Y	0.120
FeO*	4.60	Fe	0.820
MnO	0.80	Mn	0.144
ZrO2	3.02	Zr	0.313
CaO	2.27	Ca	0.518
Sc2O3	0.25	Sc	0.047
SnO2	0.00	Sn	0.053
PbO	0.00	Pb	0.091
		M	8.000**
H2O	4.96	(L.O.I.)	

TABLE 3. Chemical composition and formula of South Platte samarskite-(Y)
*** Total Fe as FeO **Normalized to 8 cations**

Oxide	Wt.%	Ion	
CaO	7.97	Ca	0.840
Ce2O3	10.85	Ce	0.391
La2O3	4.28	La	0.156
Pr2O3	1.55	Pr	0.056
Nd2O3	5.69	Nd	0.200
Sm2O3	0.95	Sm	0.032
Eu2O3	0.13	Eu	0.030
Gd2O3	0.00	Gd	0.000
Tb2O3	0.13	Tb	0.004
Dy2O3	0.25	Dy	0.008
Ho2O3	0.15	Ho	0.005
Er2O3	0.00	Er	0.000
Tm2O3	0.00	Tm	0.000
Yb2O3	0.16	Yb	0.005
Lu2O3	0.06	Lu	0.007
Y2O3	1.02	Y	0.053
ThO2	0.97	Th	0.022
MnO	1.17	Mn	0.098
Na2O	0.07	Na	0.013
		SUM A	1.920
Al2O3	13.93	Al	1.617
FeO	14.49	Fe2+	1.040
		Fe3+	0.398
TiO2	0.23	Ti	0.017
MgO	0.00	Mg	0.000
		SUM M	3.072
SiO2	31.04	Si	3.000
		OH	0.938
Cl	0.37	Cl	0.062
Total	97.92		

TABLE 2. Chemical composition and formula of South Platte allanite-(Ce)

WHOLE ROCK GEOCHEMISTRY

Thirty-three representative samples were chosen for whole-rock major- and trace element analyses by X-ray fluorescence (XRF) employing a Siemens SRS 200 automated X-ray. spectrometer. Eighteen samples were analyzed by instrumental neutron activation analysis (INAA) at the Phoenix Memorial Laboratory, University of Michigan. The XRF results and partial CIPW norms are presented in Table 4. The INAA results are given in Table 5. Silica contents range from 65 to 77 wt % for the sequence quartz monzonite to granite to aplite to pegmatite wall zone.

	Granite												Quartz Monzonite						
	SPG-1	SPG-5	L3-B	SER 106	MW 2	L3-A	SPG 30	SPG-9	DB 4A	SPG 55	SPG 16	AVG	SPG-34	L2-A	SPG-15	TWG-1	TWM-1	SPG-8	AVG
Wt. %																			
SiO2	72.78	71.68	72.02	72.07	73.93	72.01	72.98	71.83	74.49	71.89	72.19	72.53	70.54	66.88	67.94	67.79	71.11	65.21	68.24
TiO2	0.29	0.24	0.30	0.40	0.20	0.32	0.30	0.32	0.22	0.30	0.31	0.29	0.53	0.98	0.92	0.7	0.62	1.04	0.8
Al2O3	13.49	13.85	13.76	13.47	12.90	13.25	12.88	13.11	13.87	13.07	13.01	13.33	13.28	14.14	14.23	14.26	13	13.84	13.79
FeO*	2.96	2.57	2.98	3.27	2.04	3.02	2.82	3.43	1.80	3.18	2.92	2.82	3.6	5.03	4.8	4.49	3.64	5.53	4.52
MnO	0.07	0.10	0.07	0.06	0.06	0.09	0.07	0.10	0.03	0.05	0.06	0.07	0.07	0.05	0.06	0.11	0.05	0.06	0.07
MgO	0.12	0.14	0.15	0.36	0.13	0.12	0.43	0.39	0.23	0.13	0.33	0.23	0.92	1.8	1.36	1.1	0.92	1.7	1.3
CaO	1.13	1.09	1.21	1.39	0.94	1.16	0.89	1.03	0.54	1.12	1.13	1.06	1.67	3.4	3	2.14	1.93	3.37	2.58
Na2O	3.34	3.51	3.44	3.36	3.19	3.45	3.22	3.60	3.32	3.29	3.27	3.36	3.14	2.81	3.21	3.11	3.43	3.09	3.13
K2O	6.01	6.09	6.08	5.53	5.70	5.79	5.64	5.71	6.44	6.11	5.94	5.91	5.58	4.89	4.86	5.03	4.76	4.42	4.92
P2O5	0.03	0.03	0.04	0.12	0.02	0.03	0.07	0.04	0.03	0.05	0.08	0.05	0.34	0.78	0.55	0.53	0.33	1.07	0.6
Total	100.22	99.30	100.05	100.03	99.11	99.24	99.30	99.56	100.99	99.18	99.24	99.66	99.66	100.76	100.91	99.26	99.78	99.34	99.95
(ppm)																			
Y	142	138	151	164	115	148	142	174	73	128	147	138	127	88	110	78	106	114	104
Sr	64	47	73	95	49	64	74	69	78	67	64	68	163	323	274	231	202	313	251
Rb	193	227	184	227	196	203	197	183	164	182	209	197	185	129	154	174	173	119	156
Zr	541	429	531	530	432	590	407	628	248	506	427	479	437	462	452	493	375	467	448
Zn	113	123	115	97	53	118	92	121	85	97	84	100	64	113	102	106	82	77	91
CIPW																			
Q	25.83	24.28	24.62	26.49	30.50	26.02	28.82	24.86	27.74	25.74	26.60		25.80	22.37	22.36	24.29	27.49	21.97	
Or	35.38	36.23	35.87	32.63	33.98	34.46	33.54	33.85	37.69	36.36	35.37		33.03	28.62	28.39	29.87	28.17	26.27	
Ab	29.06	30.07	29.17	28.50	27.37	29.54	27.56	30.71	27.96	28.19	27.96		26.75	23.67	26.95	26.61	29.15	26.39	
An	3.57	3.97	4.10	5.28	4.00	3.52	3.97	2.68	2.42	2.81	3.23		5.60	11.35	9.91	7.23	5.96	9.73	
D. I.	90.26	90.59	89.66	87.62	91.85	90.01	89.91	89.42	93.39	90.28	89.94		85.58	74.66	77.69	80.76	84.81	74.62	

	Aplite Dike				Pegmatite Wall Zone													
	MCG-1	L1	SPG-47	AVG	TC-2	RP3-2	JL-1	LP-3	RP4-2A	DB-6	SR-1	ME-1	QK-1	WC-4	SGP-7	SPG49	SER100	AVG
Wt. %																		
SiO2	73.71	74.75	72.40	73.62	75.29	75.03	75.68	75.89	76.94	75.16	76.12	75.91	75.95	76.26	75.54	75.27	74.19	75.63
TiO2	0.34	0.05	0.21	0.20	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.09	0.15	0.04
Al2O3	13.40	14.32	14.51	14.08	13.87	13.97	13.55	13.42	14.43	13.38	13.29	13.43	13.55	13.66	14.13	13.51	12.98	13.63
FeO*	2.01	0.24	1.87	1.37	0.08	0.07	0.08	0.14	0.02	0.31	0.09	0.02	0.05	0.03	0.33	1.00	1.87	0.31
MnO	0.03	n.d.	0.07	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	0.05	0.01
MgO	0.36	0.11	0.48	0.31	0.04	0.04	0.08	0.05	0.04	0.08	0.05	0.02	0.05	0.02	0.03	0.12	0.09	0.05
CaO	0.80	0.96	0.78	0.85	0.18	0.15	0.15	0.25	0.12	0.12	0.13	0.12	0.13	0.04	0.06	0.31	0.91	0.20
Na2O	2.87	3.61	3.15	3.21	3.43	3.70	3.56	3.53	3.14	4.59	3.33	3.27	3.23	3.24	2.81	2.67	3.92	3.41
K2O	5.76	5.64	6.94	6.11	7.36	7.11	6.78	6.64	8.16	5.66	7.19	7.16	7.26	7.24	7.82	7.22	5.19	6.98
P2O5	0.07	0.03	0.35	0.15	n.d.	0.01	n.d.	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	0.01	0.01	0.01	0.01	0.00
Total	99.34	99.71	100.75	99.93	100.26	100.09	99.84	99.94	102.88	99.32	100.20	99.94	100.24	100.51	100.76	100.22	99.36	100.27
(ppm)																		
Y	117	19	67	68	32	26	43	94	27	37	21	30	30	34	24	52	162	47
Sr	85	205	111	134	38	13	46	45	33	9	39	28	29	17	46	31	56	33
Rb	423	155	231	269	309	335	293	219	296	465	279	281	382	396	291	362	181	315
Zr	364	n.d.	148	171	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	19	n.d.	n.d.	14	109	11
Zn	40	21	48	36	11	7	7	14	6	15	12	5	4	7	8	15	14	10
CIPW																		
Q	32.61	29.98	25.36		26.61	25.86	28.61	29.24	26.31	27.30	28.86	29.11	28.84	29.38	28.63	30.55	28.88	
Or	34.22	33.41	40.64		43.38	41.99	40.11	39.27	46.87	33.68	42.37	42.36	42.79	42.59	45.86	42.57	30.87	
Ab	24.54	30.78	26.55		29.03	31.38	30.29	30.00	25.92	37.56	28.22	27.82	27.41	27.37	23.71	22.65	33.50	
An	3.56	4.59	1.57		0.65	0.44	0.71	1.09	0.55	0.00	0.04	0.59	0.62	0.12	0.24	1.47	2.44	
D. I.	91.37	94.17	92.56		99.03	99.23	99.01	98.50	99.11	98.54	99.05	99.29	99.04	99.34	98.21	95.77	93.25	

TABLE 4. Whole Rock Major- and Trace-Element XRF Analyses with Partial CIPW Norms

Estimated errors in XRF analyses based on counting uncertainties and precision in reproducing USGS standards, expressed as a percentage of the amount present, are as follows: SiO_2 (0.8 %), TiO_2 (2 %), Al_2O_3 (2 %), FeO* (0.9 %), MnO (5%), MgO (3 %), CaO (0.7 %), Na_2O (3 %), K_2O (0.6 %), P_2O_5 (3 %), Rb (8 %), Sr (5%), Y (10 %), Zr (4 %), Zn (10 %) (from Nelson and Livieres, 1986).

Average silica contents are 68 wt % for quartz monzonite, 73 wt % for. Granite, 74 wt % for aplite, and 76 wt % for pegmatite wall zones. These bulk compositions fall in the calc-alkaline field on an AFM diagram and show a calcalkaline enrichment trend. The differentiation index (D.I.) increases systematically from the least differentiated quartz monzonite to the most differentiated pegmatite wall zones. Major element silica-variation diagrams show generally smooth, coherent trends of oxide enrichment or depletion from quartz monzonite through pegmatite wall zones with a systematic decrease in CaO, FeO* (total iron as FeO), MgO, TiO_2, and P_2O_5 with increasing SiO_2 (Simmons *et al*. 1987). K_2O and Na_2O are positively correlated with SiO_2. The Na_2O values show considerable scatter for the pegmatite wall zones, probably as a result of minor late-stage albitization. The colinear decrease of CaO, MgO, FeO, TiO_2, and P_2O_5 from the center to the outer margin of the pluton demonstrates that the Buffalo Park pluton is reversely zoned chemically as well as petrologically. The generally smooth chemical variation trends suggests that fractional crystallization may have been an important process in the evolution of this granitic rock suite.

Trace element concentrations were determined by XRF and INAA Y, Sr, Rb, Zr, and Zn were analyzed by XRF and the remainder by INAA (Tables 4 and 5). Several trace elements show systematic variation with silica similar to that exhibited by the major elements Sr, Ba, and Sc show a nearly linear decrease with increasing silica. Rb and Ta increase with increasing silica (Simmons *et al.* 1987). The strong depletion of the compatible elements and enrichment of the incompatible elements from the quartz monzonite to the granite is further evidence of the reverse chemical zonation of the pluton and cogenetic nature of the rocks. The antithetic behavior of Rb and Sr, over the entire range of silica contents from quartz monzonite to granite to pegmatite wall zones, can be seen in variation diagrams with CaO, K_2O, and Rb vs. Sr (Simmons *et al*. 1987). This systematic variation strongly implies that all three rock types are related by some process of differentiation, such as fractional crystallization. Contrary to what might be expected in light of the above relationships, the remaining trace elements exhibit a sharp departure from the regular variation with silica described above. Zn, Zr, Th, Y, Cs, and Hf are all strongly depleted in the pegmatite wall zones relative to the granite and quartz monzonite. Y, Hf, and Cs are enriched in the granite relative to the quartz monzonite, whereas Th, Zr, and Zn are roughly the same in both. Chondrite normalized whole-rock REE abundances show considerable overlap in values for the quartz monzonite and the granite, but overall granites are slightly enriched relative to quartz monzonite in all REE except europium. Pegmatite wall zones are strongly depleted in REE. The granite and the quartz monzonite are LREE enriched with moderately negative slopes. The average pegmatite wall zone slope is flatter with a small positive europium anomaly (Simmons et al 1987).

TECTONIC DISCRIMINATION

All the pegmatites in the South Platte district are contained within the parental Pikes Peak batholith and are thus unambiguously genetically related to the Proterozoic A-type Pikes Peak granite. Geochemically, granitoids from the South Platte district have high Ga/AI ratios and high K_2O+ Na_2O compared to M-, S-, and 1-type granites. According to the Ga* 10000/Al vs K_2O + Na_2O discrimination diagram of Whalen et al. (1987), South Platte samples fall within the A-type granitoid field (Figure 5). South Platte samples show a clear within plate granitoid (WPG) signature (Figure 6) using the Nb-Y discrimination diagram of Pearce *et al.* (1984). A ternary plot using Nb, Y and Ga*3 is useful for differentiating between Al-type WPG granitoids (rift, plume, and hot spots environments)

	Granite											
(ppm)	SPG-1	SPG-2	SPG-3	SPG-4	SPG-5	SPG-9	SPG-16	SPG-30	SPG-48	SPG-55	SER-106	AVG
La	112	72	168	131	204	207	187	144	181	178	138	157
Ce	277	181	414	326	481	523	345	268	326	343	273	342
Nd	151	103	214	155	234	255	183	186	187	210	151	184
Sm	20	17	27	24	30	34	26	24	23	26	24	25
Eu	2	3	2	3	2	3	2	2	2	2	2	2
Tb	3	3	4	4	5	6	3	3	2	3	3	4
Yb	12	9	11	11	14	14	25	22	20	23	22	17
Lu	2	2	2	2	2	2	2	2	1	2	2	2
Cs	1	1	<1	3	2	2	2	1	1	2	1	1
Ba	642	1612	478	967	460	634	541	673	736	739	922	764
Th	21	11	34	27	28	37	35	28	23	30	23	27
U	3	2	4	3	3	3	4	3	3	4	3	3
Hf	16	24	15	18	18	20	12	14	12	17	14	16
Ta	9	5	7	8	6	6	9	6	7	12	8	8
Sc	6	7	5	6	8	7	7	6	5	7	8	7
Co	21	12	13	19	13	13	15	12	16	18	15	15

	Quartz Monzonite					Aplite	Pegmatite Wall Zone			
(ppm)	SPG-8	SPG-34	SPG-15	TWG-1	AVG	SPG-47	SPG-7	SPG-49	SER-100	AVG
La	88	107	131	170	124	55	4	9	29	14
Ce	222	214	263	379	270	112	15	18	78	37
Nd	95	136	149	138	130	66	22	n.d.	70	31
Sm	19	20	23	18	20	12	1	2	11	5
Eu	4	3	4	4	4	1	1	1	2	1
Tb	5	2	3	3	3	1	<1	<1	2	1
Yb	10	22	21	7	15	7	3	12	13	9
Lu	2	2	2	1	2	<1	<1	1	3	1
Cs	1	2	1	1	1	1	1	1	1	1
Ba	1512	1184	1201	1485	1345	444	121	74	259	151
Th	9	20	25	33	22	37	6	12	347	122
U	2	4	4	3	3	3	2	4	23	10
Hf	15	15	15	14	15	5	1	2	6	3
Ta	4	10	8	4	7	5	7	11	11	10
Sc	17	8	15	13	13	6	0	1	1	1
Co	16	19	21	15	17	15	19	23	23	22

TABLE 5. Whole Rock Trace- and Rare-Earth-Element INAA Analyses
Estimated errors in INAA analyses based on eight replicate analyses of USGS standard G-2, expressed as percentages of the amount present, are as follows: La (7 %), Ce (9 %), Nd (18 %), Sm (2 %), Eu (6 %), Tb (28 %), Yb (17 %), Lu (11 %), Cs (13 %), Ba (6 %), Th (9 %), U (36 %), Hf (6 %), Ta (12 %), Sc (6 %), Co (6 %). (Personal communication from R. M. Owen, Univ. of Michigan, and Lee, 1986)

and A2-type WPG granitoids (postcollisional, postorogenic and anorogenic environments) (Eby 1992). South Platte granitoids can be classified as A2-type grarntoids (Figure 7).

CONCLUSIONS

Pegmatites of the South Platte district record striking evidence of REE zonation between structurally distinct groups of pegmatites. The replacement phases of the district can be subdivided into two well-defined assemblages, with allanite-(Ce) representing the LREE-dominant group and samarskite-(Y) representing the HREE-dominant group. Further, major occurrences of allanite-(Ce) are restricted to the less differentiated composite-core pegmatites, whereas samarskite-(Y) is restricted to the more differentiated quartz-core pegmatites. With increasing silica, from quartz monzonite to granite to pegmatite wall zones, there is a systematic enrichment in K_2O, Na_2O, and Rb and corresponding depletion in CaO, Al_2O_3, FeO, MgO, Ti_2O, P_2O_5, Sr, Sc, and Ba. These trends strongly suggest that fractional crystallization was an important process in the generation of the granite and the pegmatites. The removal of plagioclase, biotite, and apatite from the original melt could produce the observed trends. Thus, all three rock types are genetically related and the pegmatites represent the most evolved final residual products. The REE, except for europium are enriched in the granite relative to the quartz monzonite. However, the pegmatite wall zones are depleted in REE relative to the granite. This abrupt depletion of REE along with Y, Zr, and Th in pegmatite wall zones is contrary to the expected systematic enrichment of incompatibles, which would be predicted from the behavior of the major elements and compatible trace elements. A closer examination, however, of the replacement mineralogy reveals that these elements were not depleted from the pegmatites as a whole, but were instead concentrated into the very last fluids to crystallize. This indicates that there is a significant difference in the behavior of these elements in the pegmatitic melts. Within such pegmatitic melts, these elements are strongly partitioned out of the primary pegmatite zones and into the final residual fluids, which ultimately produce the mineral assemblages of the replacement units These are the minerals that contain almost all of the REE, Y, Nb, Zr, and Th for the pegmatite as a whole. The abundance of fluorite in the replacement units indicates that fluorine played an important role in the observed partitioning of these elements out of the pegmatite wall zones and into the final residual fluids. Significantly, the abundance of fluorite is greatest in pegmatites containing the most extensive replacement units characterized by HREE-, Y-, Nb-, Zr-, and Th-rich replacement mineral assemblages. INAA analyses of mineral separates of the major rock forming minerals reveal that their total contribution of REE is up to an order of magnitude less than the whole-rock chondrite values. Therefore, the rnajority of the REE present in the whole-rock samples must be contributed by accessory REE minerals such as sphene, zircon, apatite, and allanite-(Ce). Two-feldspar geothermometry suggests that the quartz monzonite formed at higher temperatures than the granite and the pegmatite wall zones, which formed at about the same temperature (Simmons et al. 1 987). Compositional trends of the district are interpreted to be the result of a process of fractional crystallization and diffusive differentiation which produced a chemically stratified magma chamber with a cooler, more felsic SiO_2-rich granitic magma near the top and a hotter more mafic SiO_2-poor quartz monzonitic magma near the base. Roofward diffusion of volatiles and fluorine-complexed HREE and Y left the lower level magma relatively depleted in HREE and Y. Resurgence of more mafic lower level quartz monzonitic magma into the felsic upper level granitic magma produced the reverse

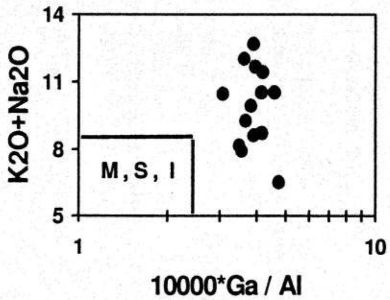

FIGURE 5

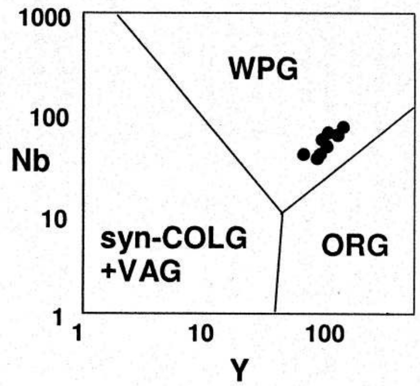

Figure 6

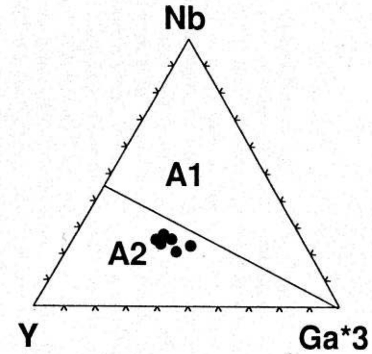

Figure 7

Figure 5. Ga*10000/Al vs $K_2O + Na_2O$ discrimination diagram of Whalen *et al.* (1987). South Platte granitoids plot in the A-type field and have high Ga/Al ratios and high $K_2O + Na_2O$ compared to the field of M-, S-, and I-type granites.

FIGURE 6. Y vs. Nb tectonic discrimination diagram of Pearce *et al.* (1984), showing the within-plate signature for South Platte district granitoids.

FIGURE 7. Ternary plot for differentiating between A1-type WPG granitoids (rift, plume, and hotspots environments) and A2-type WPG granitoids (postcollisional, postorogenic and anorogenic environments) (Eby 1992), showing the A2-type character of the South Platte granitoids.

zonation apparent in the petrologic and geochemical relationships. This resurgence could not have been induced by volcanic tapping of the chamber without depleting the chamber of its pegmatitic fluids Thus, the presence of numerous pegmatites and aplite dikes suggests that this resurgence was caused by an influx of new magma into the base of the magma chamber, and not by volcanic tapping Separation of the pegmatitic fluids from the juxtaposed magmas took place after resurgence. The pegmatitic fluids coalesced into bubble4ike masses, which rose until their vertical ascent was halted by the more completely solidified magma near the roof of the batholith. The quartz-core pegmatites, which contain abundant fluorite and HREE minerals, were generated from the HREE-, F-, Y- enriched pegmatitic fluids derived from the granitic magma. The quartz monzonite magma produced LREE-enriched pegmatitic fluids, which gave rise to the composite-core pegmatites that contain the LREE minerals.

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The Big Bertha pegmatite, Jefferson County

The Big Bertha pegmatite is exposed in the NW 1/4 of the SW 1/4 of section 22, T8S, R70W, or 481,244 m E; 4,354,200 m N, 7472 feet elevation, UTM 13, NAD83 (same as 481,305 m E; 4,354,000 m N, UTM 13, NAD27) Jefferson County. The land is accessed by national forest road 530, from route 126, the Buffalo Creek to Deckers road.

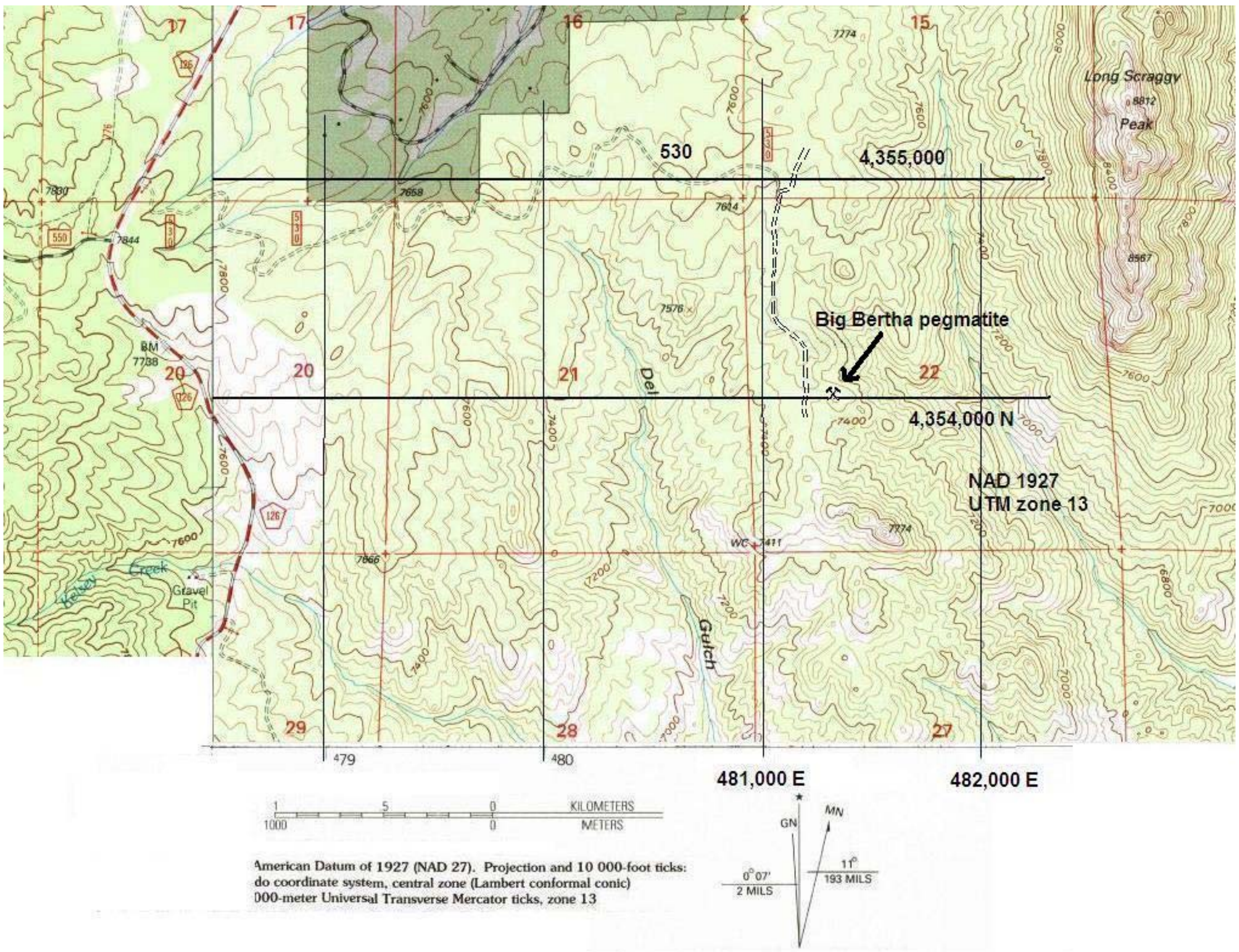

Figure 8. The topographic map showing the location and route to the Big Bertha pegmatite, Portion of the Deckers 7.5 minute quadrangle map.

The Big Bertha pegmatite is an irregular shaped composite core pegmatite about 285 by 120 feet in surface exposure. When it was mapped by Simmons (1973), the exposures indicated a thin wall zone, an almost insignificant intermediate zone and a dominant composite quartz-microcline core with minor replacement units, that were not mappable. The significant feature of the pegmatite was the recovery of huge football-sized allanite masses with minor fluorite-xenotime replacement pods. The pegmatite was mined for its rare earths (Simmons and Heinrich 1980, 98).

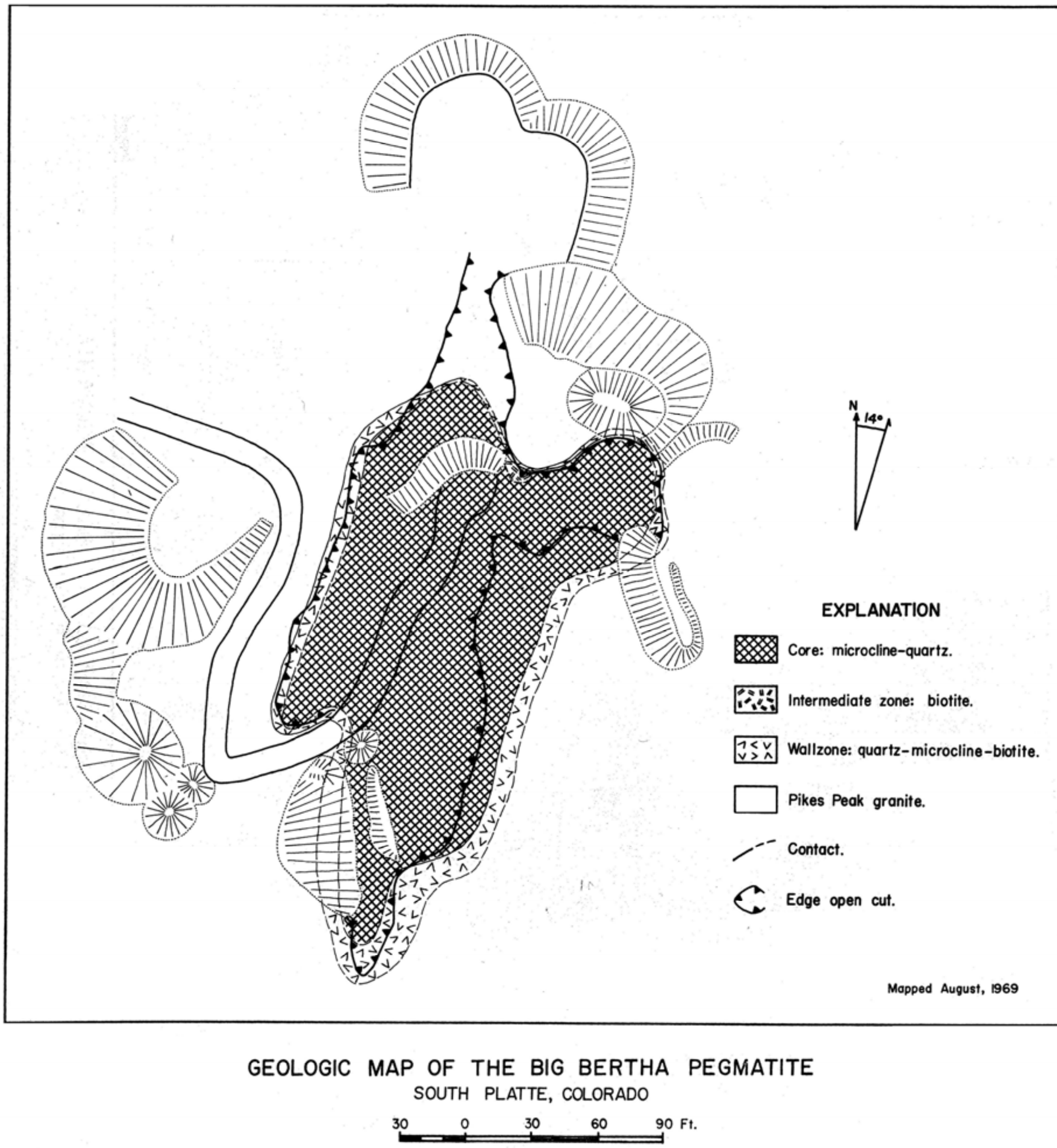

Figure 9. Geologic map of the Big Bertha pegmatite. From Simmons and Heinrich (1980, 125).

Field Trip guide to the pegmatites in the St. Peters Dome area, El Paso County

Pegmatites and related rocks of the Mesoproterozoic Mount Rosa Peralkaline Granite Complex, El Paso County, Colorado (USA)

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Overview

Located in the central Front Range of Colorado, the 1.08 Ga A-type Pikes Peak Batholith (fig. 1) is host to numerous REE-enriched late-stage peraluminous to peralkaline granitic plutons (Barker et al. 1976; Gross and Heinrich 1965, 1966; Smith et al., 1999). The ~1.04 Ga peralkaline ((Na_20/K_20) > Al_2O_3) Mount Rosa granite (MRG), ~15 km west of the city of Colorado Springs, is composed of multiple sheet-like masses, dikes, and ovoid bodies covering an area of ~50 km^2 with numerous spatially-related mafic dikes, aplite dikes, and fayalite-bearing granite bodies (fig. 2). The Mount Rosa Complex is enriched in rare earth elements (REE) and other high field strength elements (HFSE, e.g. Th, Ti, Zr, Nb and Ta) and also hosts numerous simple to complex-type Niobium-Yttrium-Fluorine (NYF)-type pegmatites. Additionally, pegmatites of the Mount Rosa complex show zonation with respect to their distance from the inferred parental Mount Rosa granite main body, with simple or residual melt type pegmatites hosted close to or within this body of Mount Rosa granite, and more complex pegmatites hosted in Pikes Peak granite or fayalite granite 3-10 km from the MRG. Simple type pegmatites typically contain alkali feldspar, quartz, Na-amphibole, biotite, zircon, thorite, and fluorite, whereas complex-type pegmatites contain aluminofluoride minerals, REE minerals (typically fluorocarbonates and Na-F-REE phases). columbite-tantalite, and sulfides.

Geology of the Mount Rosa Complex & Pikes Peak Batholith

The Mount Rosa granite is the southernmost (Fig 1) of 7 studied late-stage plutons within the Pikes Peak Batholith, a 1.08 Ga anorogenic, ‘A-type’ composite pluton with ~3300 km^2 of surface expression dominated by coarse-grained biotite ± amphibole syenogranite with minor monzogranite (Smith et al. 1999). The Pikes Peak batholith is considered a ‘classic’ example of an A-type granite and features 3 large (20-25 km. diameter) intrusive centers in addition to the aforementioned late-stage plutons, and exhibits a diversity of rock types including gabbro, diabase, syenite, and fayalite and riebeckite granite (Smith et al. 1999). The late-stage plutons of the Pikes Peak batholith are divided into two populations, a sodic series (SiO_2 = ~44-78 wt%; K/Na = 0.32-1.36, includes the Mount Rosa granite), and a potassic series (SiO_2 = ~70-77 wt%; K/Na = 0.95-2.05), which likely have different petrogenetic histories, as indicated by their geochemical and Nd isotope data (Smith et al. 1999). More than 90% of the late-stage rocks in the Pikes Peak batholith belong to the potassic group (Na_20/K_20) <1), which is dominated by biotite granite (Hanson & Zito 2014).

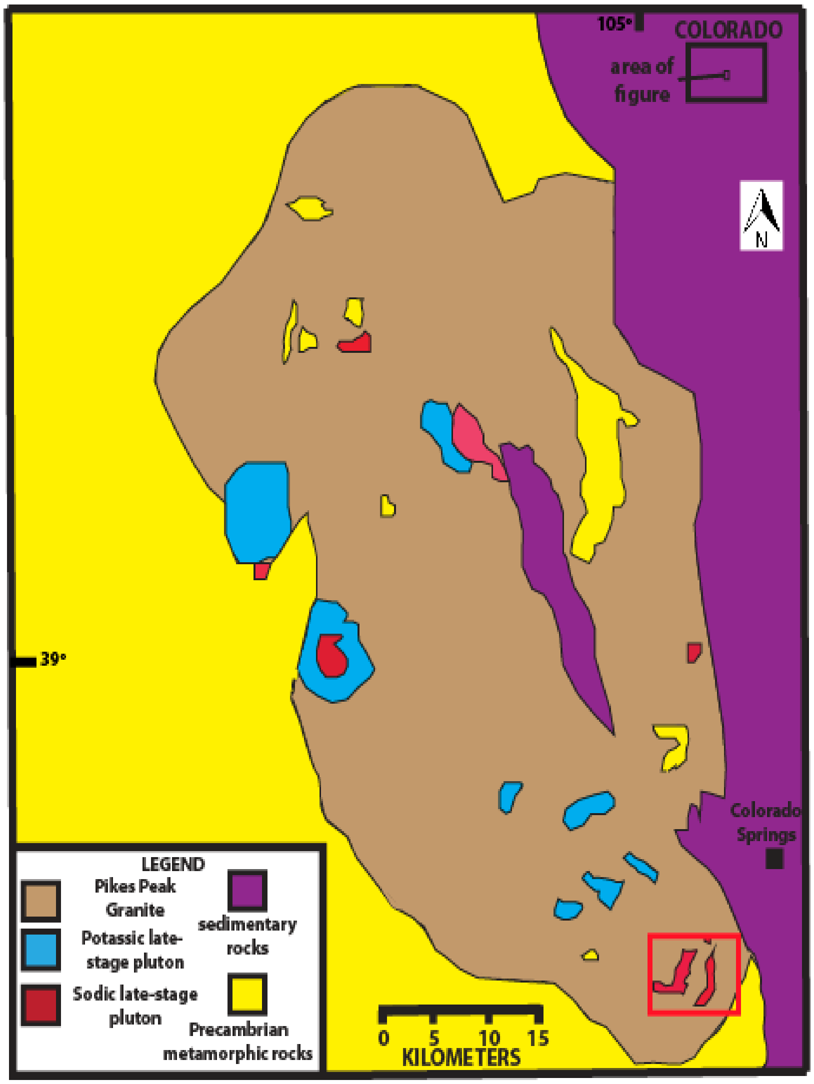

Figure 1. Overview of the Pikes Peak Batholith, showing late-stage plutons of the potassic and sodic groups and the location of the Mount Rosa Complex [red box] (after Smith et al. 1999).

The Mount Rosa granite and related Pikes Peak batholith rocks were emplaced at ~1.08 Ga into the Yavapai province, a ~500 km. wide belt which was accreted onto the southern edge of the Archean Wyoming craton around ~1.7 Ga (Smith et al. 1999). Gross (1962) obtained several K^{40}/Ar^{40} dates on rocks of the Mount Rosa granite ranging from 1020-1045 Ma, and unpublished dates from the U.S Geological Survey (Unruh & Premo; personal communication) also cluster around 1040 Ma, making it distinctly younger (but temporally-related to) the 1.08 Ga age obtained from an average of recent geochronological work on the Pikes Peak batholith main phase by Smith et al. (1999).

Some workers have proposed that the Pikes Peak batholith evolved from extreme fractionation of an upper mantle-derived basaltic melt which ascended through underplated crust in an intra-plate extensional tectonic setting, which may have been due to post-orogenic collapse and 'localized' trans-tension and extension following the proposed ~1.4 Ga Berthoud orogeny (DePaulo 1981, Frost & Frost 1997, Smith et al. 1999). The melt generated during this crustal extension likely interacted with metasomatised middle to lower crust which had been affected by a preceding alkaline fluid which 'fertilized' it, a process that may explain the mixed geochemical patterns seen in some studies of the Mount Rosa and Pikes Peak granites (DePaulo 1981, Martin 1999). While some have proposed an upper mantle origin for the Mount Rosa Complex (Barker et al. 1975; DePaolo 1981), it may also represent the transition from a peraluminous (Pikes Peak batholith) to peralkaline (Mount Rosa granite) melt, as has been suggested for other peralkaline granite complexes (Thomas et al. 2006; Costi et al. 2009). This melt evolution from peraluminous to peralkaline, aided by fluids rich in F, OH, CO_2, and other volatiles, may explain the patchy, irregular distribution of Mount Rosa granite, as well as the spatial relationship between cogenetic rocks including pegmatites. Average F content increases from ~.30% in the relatively early fayalite granite & associated quartz syenite to ~.63% in the Mount Rosa granite, and reaches much higher levels within the more evolved pegmatites (Bailey 1980; Smith et al. 1999).

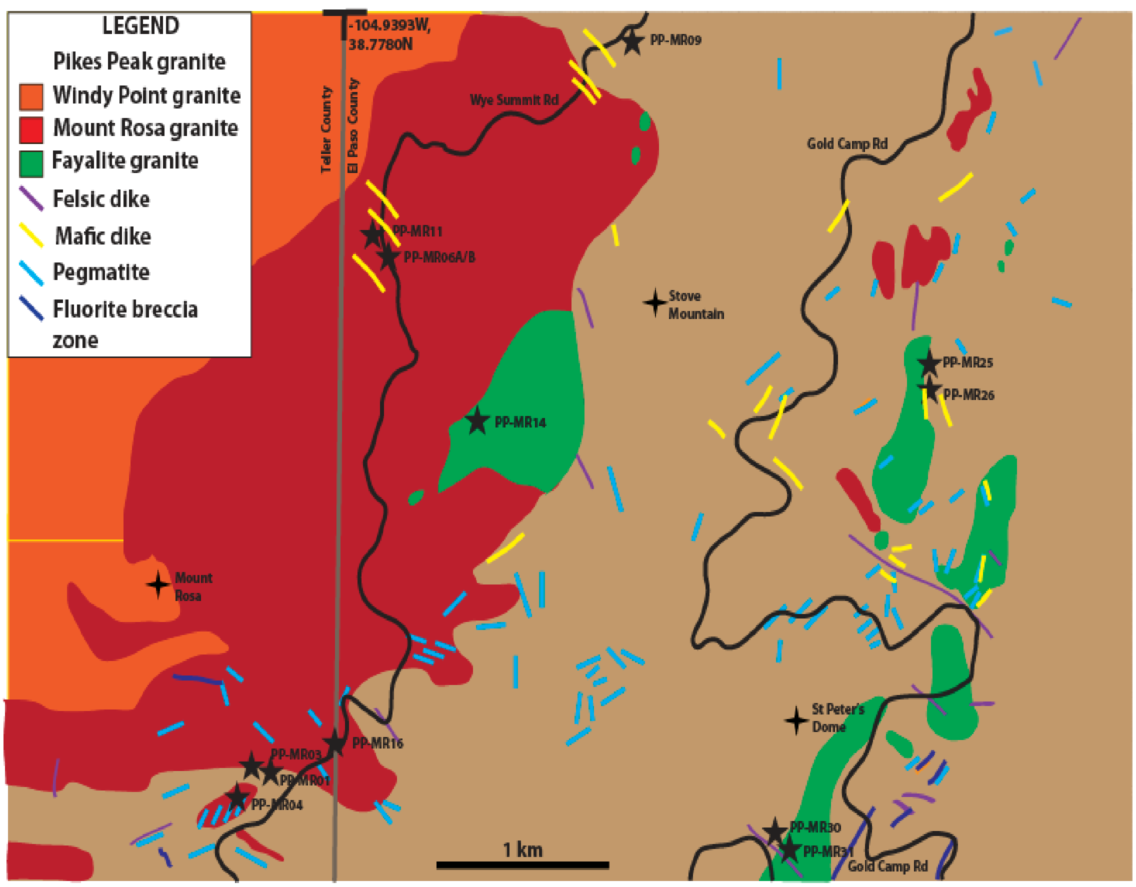

Figure 2. Overview of the Mount Rosa Complex showing major rock units and pegmatites (synthesis of mapping by Persson 2014-2016, Keller et al. 2004; and Gross 1962).

Petrology

The Pikes Peak Batholith in the Mount Rosa area is a medium to coarse-grained, allotriomorphic biotite syenogranite to monzogranite containing ~70% feldspar, with some samples containing only perthitic orthoclase/plagioclase, and others containing primary orthoclase crystals (~50%) mantled by plagioclase (~20%) in typical Rapakivi texture. Moreover, Pikes Peak granite samples contain ~25-35% quartz, ~4-8% biotite and accessory fluorite, Fe/Ti-oxides, apatite, and zircon. Opaque phases and zircon crystallized first, followed by plagioclase, alkali feldspar, quartz, and finally biotite. The Pikes Peak batholith is generally a hypersolvus granite, with one (perthitic) primary feldspar indicating crystallization at relatively low H_2O fugacity and overall volatile content.

The Mount Rosa granite is a medium to fine-grained, allotriomorphic to aplitic granite containing ~40-60% albite, ~25-40% quartz, 0-10% orthoclase, ~5-10% Na-amphibole, <3% biotite, and minor amounts of Na-pyroxene, fluorite, opaques, zircon, REE minerals, and astrophyllite. Opaques and zircon crystallized earliest, followed by orthoclase and later quartz and albite, commonly forming micrographic and other granophyric textures. Poikilitic Na-amphibole (commonly rimmed by Na-pyroxene), fluorite, REE minerals, and astrophyllite crystallized last. Fluorite & REE minerals (fluorocarbonates & phosphates) are commonly associated and occur as late interstitial segregations between major mineral grains, along with possible hydrothermal zircon showing abundant inclusions (fig 3). The Mount Rosa granite is a subsolvus granite, with primary albite and orthoclase as well as abundant granophyric textures indicating crystallization at relatively high H_2O fugacity and volatile content.

Fine-grained to porphyritic mafic dikes and mafic enclaves cut Mount Rosa granite, Pikes Peak granite and fayalite granite and contain ~40% orthoclase, ~20% quartz, ~15% calcic plagioclase, ~12-30% biotite, <25% pyroxene, <5% amphibole and minor amounts of opaques, fluorite, apatite, zircon, REE minerals, and rare accessory phases of alkali association such as bafertisite. Opaques, apatite and zircon were the first minerals to crystallize, followed by pyroxene, biotite, amphibole, alkali feldspar, quartz, and finally interstitial fluorite and REE minerals.

Fayalite granite occurs as isolated ovoid bodies of coarse-grained greenish-gray syenogranite in the Pikes Peak granite and is composed of ~35% perthitic orthoclase, ~30% albite, ~30% quartz, ~3% biotite, and accessory Na-pyroxene, opaques, zircon, and fayalite. Opaques, zircon and fayalite crystallized first, followed by biotite, plagioclase, alkali feldspar, quartz, and finally Na-pyroxene.

Pegmatites

The Mount Rosa Complex is noteworthy for its large number of pegmatites, ranging from small unzoned miarolitic cavities 10-50 cm. across to large zoned Niobium-Yttrium-Fluorine (NYF)-type bodies over 40 meters long (Gross & Heinrich 1966). Cerny & Ercit (2005) classified the pegmatites of the Mount Rosa granite as belonging to the Peralkaline NYF-type and Na-amphibole subtype, similar to pegmatites on Hurricane Mountain, New Hampshire, or the Franklin Mountains of western Texas.

Pegmatites of the Mount Rosa Complex can be generally assigned into three different groups. The first are the miarolitic-type pegmatites, which are hosted in pink to white medium to coarse-grained biotite syenogranite of the Pikes Peak batholith and generally occur from ~4-10 km from the main body of Mount Rosa granite. These were described as 'Pikes Peak granite-type' pegmatites by Gross & Heinrich (1966) and are generally small (<2 meters), irregular, poorly-zoned bodies, and often containing miarolitic pockets with euhedral crystals. These are genetically-similar to other miarolitic pegmatites of the Pikes Peak granite, but differ in their rare mineral content, including euhedral crystals of rare species such as the Zn-Be silicate genthelvite, REE-F carbonates (e.g.; bastnäsite, fluocerite), and REE phosphates (e.g., xenotime-(Y) & monazite-(Ce); Hanson & Zito 2014). Many of these minerals replace or overgrow primary minerals such as feldspars, pyroxenes/amphiboles, and micas (Hanson & Zito 2014). In this regard, these miarolitic-type pegmatites show geochemical similarities to those of the Mount Rosa-type, and may have been affected by fluids associated with the Mount Rosa granite.

The second group of pegmatites are the 'simple-type' pegmatites hosted within or on the margins of the main body of Mount Rosa granite on the eastern and northern slopes of Mount Rosa proper. These pegmatites, classified as 'interior-type' by Gross & Heinrich (1966), are generally typically smaller is size, poorly-zoned, and less mineralogically-complex than the complex or 'exterior' type pegmatites, and are enriched in Zr, Th, Ti, with Nb>Ta, and Ce>Y (Gross 1962). Their mineralogy and chemistry is close to that of their host rocks, and their genetic connection to the Mount Rosa granite appears less ambiguous than the 'exterior' type bodies (Foord et al. 1984). A somewhat distinct sub-class of the 'interior type' pegmatites are the 'hydrothermal thorite veins' of Gross (1962) which occur near Rosemont on the eastern slopes of Mount Rosa proper. These pegmatites, up to 50 m. long and several meters wide, consist of highly-altered quartz, alkali feldspar and riebeckite as well as abundant zircon, thorite, thorogummite, uranothorite, and REE phases; generally fluorocarbonates (Gross & Heinrich 1966). Recent analyses also show the presence of minor aluminofluoride minerals including prosopite associated with and replacing interstitial fluorite in irregular blebs <500 um across in simple-type pegmatites from within the Mount Rosa granite. This confirms that these unusual phases are not unique to the evolved pegmatites of the complex and likely represent Na & F-rich autometasomatic fluids associated with the main body of Mount Rosa granite. Many of the simple-type pegmatites hosted within the Mount Rosa granite show irregular borders and preferential alignment of minerals suggesting they may represent residual melt during the late magmatic evolution of the MRG.

The third group of pegmatites in the Mount Rosa granite complex are the complex pegmatites, called 'exterior-type' by Gross & Heinrich (1966). These occur as generally tabular, sub-horizontal bodies ranging from ~.2 x 5 m to ~6 x 50 m in size, and cut fayalite granite, aplite dikes, and Pikes Peak granite. They often have intruded along the margins of fayalite granite bodies, and also show anastomosing and irregular contacts with parallel to sub-parallel mafic dikes and Mount Rosa granite dikes, suggestion contemporaneous emplacement in the larger exocontact of the MRG. Complex-type pegmatites generally occur 3-10 km from the main Mount Rosa granite body and are larger, more structurally-uniform, and more mineralogically-complex than either the simple or miarolitic-type pegmatites. Zonation is often strong and generally consists of an 'endocontact' of albitized host rock enriched in fine-grained zircon, fluorite & REE minerals, a wall zone with large prismatic riebeckite and Na-pyroxene crystals aligned perpendicular to the contact, and intermediate zone with large microcline-perthite and quartz crystals with interstitial albite, and a core zone with aluminofluoride minerals or dissolution holes formerly occupied by such phases, microcline, albite, REE minerals, zircon, and rare accessory phases. These pegmatites contain significant Be, Rb, Y, F, Zr, & Ce, with Ta>Nb, and sometimes contain 'exotic' minerals such as Al-Fluoride minerals (e.g.; cryolite, weberite, prosopite, pachnolite, thomsenolite; elpasoite) found only in a few other localities in the world such as Ivigtut, Greenland and the Pitinga Mine, Madeira Granite, Brazil (Gross & Heinrich 1966, Costi et al. 2009). Indeed; aluminofluoride minerals are endemic to a group of

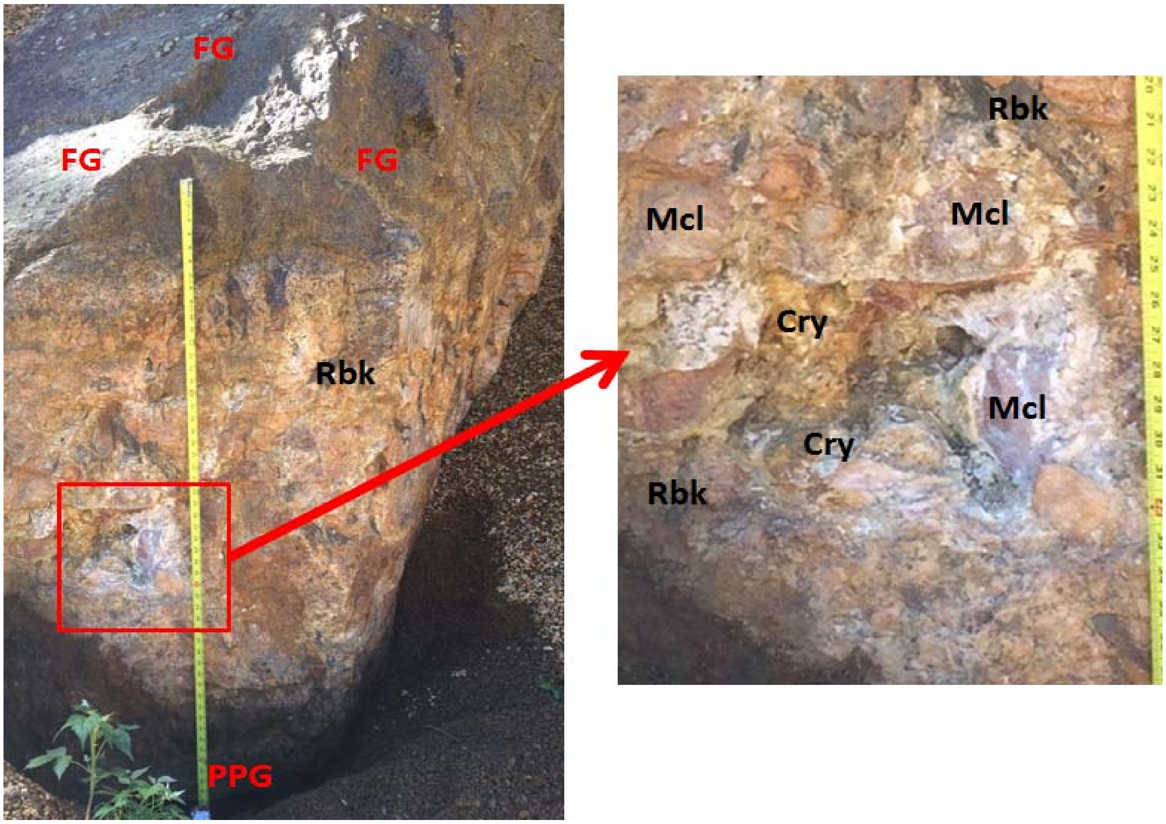

Figure 3. Typical complex-type pegmatite exposed along Gold Camp Road on St. Peter's Dome, showing contact with fayalite granite (FG) and Pikes Peak granite (PPG). Pegmatite contains large riebeckite crystals (Rbk) oriented perpendicular to contact, with core zone composed of large microcline crystals (Mcl), quartz, riebeckite, and interstitial cryolite (Cry) and other aluminofluoride phases which have largely dissolved away leaving boxy cavities.

complex-type pegmatites centered on St. Peter's Dome ~5 km southeast of the Mount Rosa granite, and help define their presence in this area (figure 3). Other unusual accessory minerals containing REE, HFSE, F, Na, and OH occur in the complex-type pegmatites, including murataite-(Y), Zn & Y-bearing senaite, pyrochlore (Pb-rich), cerianite-(Ce), and bastnäsite-(Ce) (Foord et al. 1984). Many of the complex-type pegmatites also show evidence for two generations of zircon, an earlier magmatic population and a later hydrothermal population (Ephraim 2013). Psuedomorphs are abundant in complex-type pegmatites and include Fe-oxides and clays after biotite, fluorite after riebeckite, various 'secondary' aluminofluoride minerals after fluorite and cryolite. Some of these pegmatites show also evidence for intense metasomatic alteration and their mineralogy may have been overprinted by late fluids associated with the intrusion of Mount Rosa granite (Foord et al. 1984, Gross & Heinrich 1966).

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Field Trip guide to the Platt (Uranium King) pegmatite, Carbon County, Wyoming

The Big Creek Pegmatite Area, Carbon County

Robert S. Houston*[1]

Introduction

The Big Creek pegmatite area is located in T 13 N, and R 80 and 81 W. along the west slope of the Medicine Bow Mountains in southeastern Wyoming, only 12 miles north of the Colorado state line. The area covers the northeastern half of T 13N, R 81W and includes five sections along the western edge of T13 N, R 80 W, (Figure 1). It is bounded on the east by the North Platte River and on the southwest by Wyoming State Highway 230.

The Platt pegmatite is located in the SE 1/4 of SW 1/4 of section 3, T13N, R81W, at 375,228 m E, 4,552,950 m N, 8010 feet elevation, UTM 13, NAD83 (map measured) or 375,277 m E, 4,552,738 m N, UTM 13, NAD27 (GPS measured).

The area is readily accessible from the paved, all-weather highway 230 and is traversed throughout by graded dirt roads that are best traveled by pick-up truck, high clearance vehicles or four wheel drive vehicles. Access to the Platt pegmatite can be done by a 2WD vehicle if the roads are dry.

Topography and vegetation

Elevations in the area are in excess of 8,000 feet, but in most of the area relief is not great. The only part that is rugged topographically is the land that descends into the North Platte River canyon where the relief is in the order of 1,000 feet, with elevations rising from 7,500 feet at the river to 8,500 feet in less than a mile.

Vegetation is not abundant except along minor streams and the North Platte River. Most of the streams have small groves of aspen along them, and dense forests of coniferous trees and aspen are found along the valley adjacent to the North Platte River. Most of the area though is covered by a sparse growth of sage brush and native grasses, especially on west and south facing slopes. The Platt pegmatite is only vegetated by sage brush. Rain fall is classified as semi-arid. Rock outcrops are abundant or only superficially covered by topsoil.

General Geology

The Proterozoic rocks can be divided into three general units: a metamorphic layered

*[1] This article was abstracted and modified from: Houston, R. S. (1961) The Big Creek Pegmatite Area, Carbon County, Wyoming.. *Wyoming Geological Survey Preliminary Report* **1**, 11 p. Reprinted with permission of the Wyoming Geological Survey.

sequence consisting of interlayered feldspar-quartz-biotite gneiss, hornblende gnieiss and schist; mafic intrusive rocks consisting principally of rocks of gabbroic composition; and a foliated granite.

The layered sequence is folded into a series of northeast trending folds with nearly vertical limbs. The axes of these folds plunge to the northeast. The folds are displaced along east-west

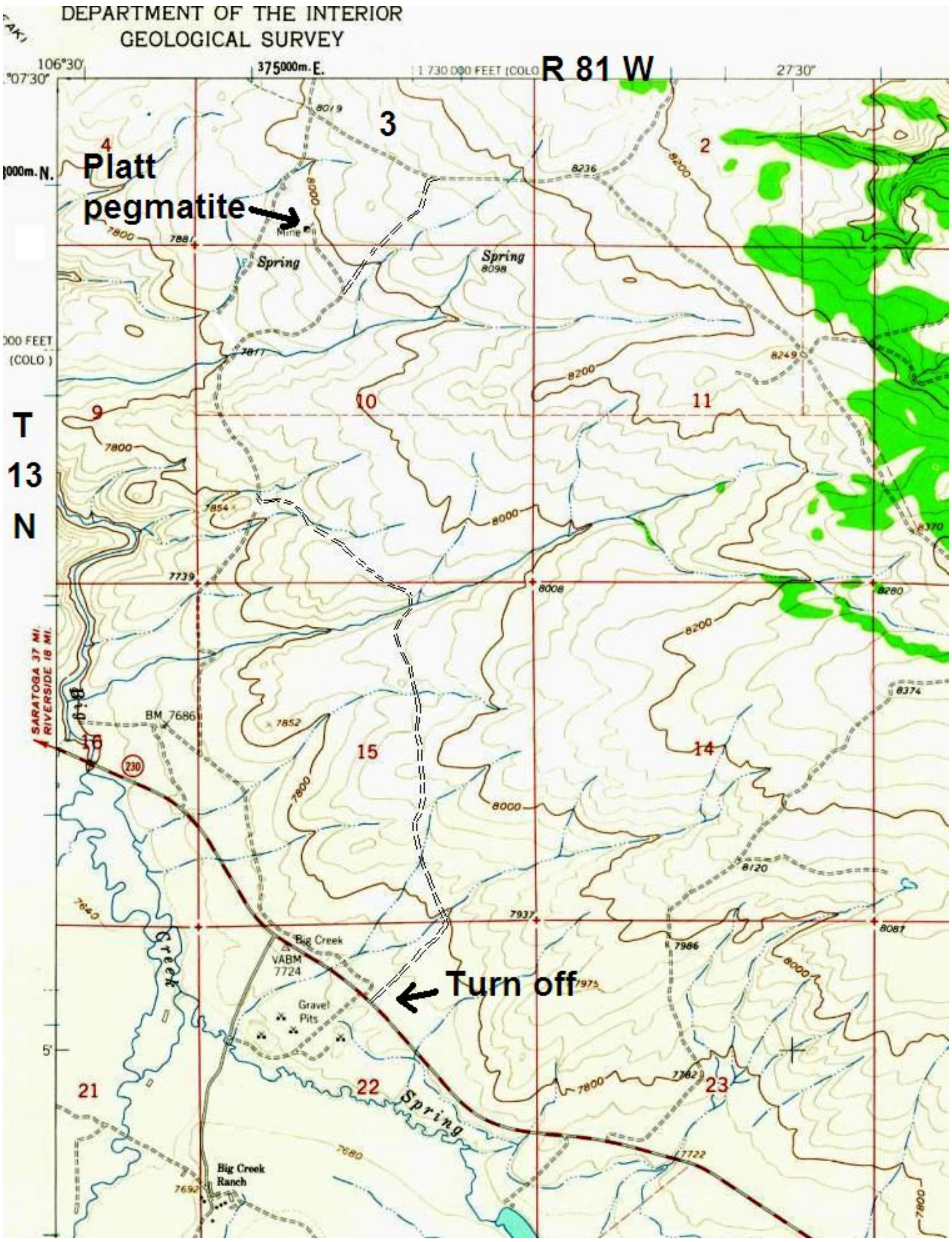

Figure 1. Road map of route from paved State highway 230 to the Platt pegmatite. United States Geological Survey Elkhorn 7-1/2 minute quadrangle topographic map.

and northeast-trending faults and shear zones. The mafic intrusive rocks in the northeastern part of the map area are a southern extension of a large body of meta-igneous rock that ranges in composition from norite to quartz diorite. Foliated granite is found in a large body in the northwestern part of the area and in a number of sills and dikes throughout the area.

Tertiary sedimentary rocks of Miocene age and younger occur in the southeastern area and along the river bottoms as alluvium.

Layered Sequence

This unit is the most widespread in the area, is made up of alternating layers of feldspar-quartz-biotite gneiss and amphibole gneiss and schist. In some areas, such as along Big Creek, these two rock types occur in alternating layers 2 to 50 feet in thickness. In general, units composed principally of feldspar-quartz-biotite can be distinguished from units composed principally of amphibole gneiss, a distinction made in mapping. The area underlain principally by hornblende gneiss is best exposed in the vicinity of the Big Creek mine and the area underlain principally by feldspar-quartz-biotite gneiss is best exposed in the core of an antiformal structure in the southeastern part of the area.

The feldspar-quartz-biotite gneiss is the more resistant of the two units and occurs as low ridges and subdued hillocks. Fresh outcrops are gray; weathered surfaces are pink or reddish. The rock weathers into gravel composed of crystals of feldspar and quartz. Mineralogical and textural variations of this rock can be recognized in hand specimens. The most common type is composed of plagioclase, quartz, biotite, and microcline. Layering caused by alternations of light-colored minerals and biotite, is poorly developed, but distinct alignment of biotite crystals give the rock a well-developed foliation. Locally the feldspar-quartz-biotite gneiss is massive in appearance. A different textural variety of the gneiss is an augen gneiss found along the northwestern border of the area. This gneiss is characterized by large eye-shaped potash feldspar crystals in a fine-grained biotite-rich matrix. It has gradational contacts with foliated granite and may be an intermediate phase between amphibole gneiss and foliated granite.

The amphibole gneiss and schist is bluish gray to black depending on the percentage of dark-colored minerals in the rock. It ranges from types rich in amphibole that contain minor amounts of quartz and plagioclase and best classified as amphibole schist or amphibolite, to layered types composed of alternating plagioclase-quartz layers and amphibolite-rich layers.

The structural relationship between the two rock types of the layered sequence is conformable. The units cannot be followed for long distance in single outcrops, but in limited exposures the attitude of the foliation and the attitude of the contacts between the two different rock types are parallel. Contacts between the two unite are generally sharp. Replacement of the amphibole-rich unit by more felsic constituents is common. The transformation is toward a biotite-rich microcline gneiss, and it is difficult or impossible to be certain how much of the felsic gneiss was formed by transformation of amphibole gneiss and how much was primary, especially in areas where the felsic gneiss is the principal rock type.

Mafic Igneous Rock Series

The mafic igneous rock series crops out in the northern part of the area. It consists of a variety of mafic igneous rocks that may or may not be related to each other in space and time. Only a small part of this rock series is exposed in the Big Creek area. The series extends for a distance of approximately three miles north of the Big Creek area and for an undetermined distance in an easterly direction.

Rocks of the mafic series are dark colored and fairly resistant to erosion. They underlie low rounded hills for the part. Soil developed from these rocks is dark colored, making it possible to distinguish the unit readily on air photographs.

The southern border of the mafic rock series in the Big Creek area is underlain by diorite, but northwest trending of norite, gabbro, and related rocks are present in the northwestern part of the area. The relationship between the different types of mafic rocks has not been established, but the variation in grain size, texture, and degree of metamorphism suggests that hey have been emplaced at different times.

Foliated Granite

The largest outcrop of foliated granite is in the northwestern part of the area where it underlies approximately one square mile. It is also found in northeasterly trending sills in the layered sequence in the southeastern part of the area and as cross-cutting bodies in the mafic rock series.

The foliated granite is similar to the feldspar-quartz-biotite gneiss in color and resistance to erosion. It does not have the layering that is common in the gneiss, however, and it is not as well foliated as the gneiss. It is composed chiefly of microcline, and biotite and is, in general, a coarse-grained rock.

The foliated granite of the northwestern part of the area grades into augen gneiss that is in turn gradational into hornblende gneiss. Contacts of this type are especially common along the northwestern border of this body. In this area the granite has well developed jointing that strikes in two directions roughly parallel to and perpendicular to the strike of the foliation, Many of these joints are filled with quartz, and quartz veins of this type can be considered characteristic of the rock.

The foliated granite sills are similar in mineralogy and texture to the larger unit, but are finer grained. These units are relatively narrow bodies with s thickness of 2 to 50 feet, but they commonly extend for long distances along strike. They are very similar in appearance to the layers of feldspar -quartz: -biotite gneiss but are not banded and do not contain much biotite as this unit. These sills may or may not be of igneous origin. They are in sharp contact with units of the layered series, but they do not have stringers or veinlets cutting the host rock.

The foliated granite dikes in the mafic igneous rock series are unquestionably cross - cutting igneous rock. These dikes found in part in joint spaces in the mafic igneous rock and have interconnected stringers and veinlets cutting the country rock. They are composed of microcline, quartz, and biotite and are similar in texture to the granite sills. Many of the dikes are more highly foliated than the mafic units that they cut, and were it not for the stringers of granite cutting the mafic rock in contact with them they might be considered inclusions of felsic gneiss.

Pegmatite

Granite pegmatites are found throughout the area. They are especially abundant in the amphibole gneiss and schist unit of the layered sequence, are less abundant in the felsic gneiss, and are uncommon in the foliated granite. The most common type of pegmatite is unzoned feldspar -quartz pegmatite that is approximately conformable in strike and dip with the country rock. Those pegmatites are not much over 10 feet wide and probably average less, but they may extend for distances 5 to 10 times their width along strike, with some of them being over one-half mile long. They have sharp contacts with the country rock but do not show a decrease in grain size at the contact. They are characterized by simple mineralogy and contain chiefly feldspar with minor and accessory biotite, garnet, muscovite, magnetite, and ilmenite.

A second type of pegmatite has cross -cutting relationships with the country rock and is generally more elliptical in plan. The length of these pegmatites may average three times their width. These pegmatites also have sharp contacts with the country rock and do not show a decrease in grain size at the contact, but they may have poorly developed zoning such as a concentration of quartz pods near the center of the pegmatite or a poorly developed quartz core and a graphic granite outer border. They are generally more complicated mineralogically and in addition to feldspar and quartz, contain such minerals as tourmaline [schorl], biotite, muscovite, fluorite, and rarely monazite, allanite, euxenite, and columbite.

This basic distinction between pegmatites is arbitrary, and there are gradations between the two types. For example, the Big Creek mine is in a pegmatite containing a unique assemblage of copper minerals and a relatively complex mineralogy, but it is basically a comformable pegmatite.

Most of the pegmatites are strongly sheared. Many of the conformable pegmatites have a crude foliation caused by closely spaced joints that cut all minerals in the rock. This extensive fracturing may indicate that the pegmatites were folded along with the rocks in which they were emplaced, or at least subjected to a period of stress after emplacement.

Structure

The layered sequence has been folded into a series of northeast trending folds. The limbs are steep and the axes northeast. These folds have been displaced along east-west and northeast trending faults and shear zones. In an area of this sort where key beds or marker beds are lacking, and where no definite stratigraphic succession has been established, it is very difficult, to interpret the structure. The faults and shear zones have been established by recognition of abrupt changes in foliation, by extensively sheared, silicified, crenulated, or brecciated zones, and by photo-geologic evidence. It is possible that the folds are the result of drag along the fault systems or that the faults displace previously formed folds. The latter interpretation is favored because northeast-trending folds in similar rocks have been established in less deformed roc to the south (Myers 1958) and because the axes of most of the minor folds plunge northeastward.

Foliation of the rocks is a combination of a preferred orientation of platy minerals and compositional layering. In general there is no divergence in strike and dip between mineral foliation or compositional layering and the contacts between the units of the layered sequence. On the other hand, isolated exposures of highly deformed hornblende gneiss have been found, especially where this unit is the dominant one, that have very complex minor folds developed in the compositional layering. The gneiss has been folded into tight chevron folds with an amplitude of one inch and a wave length of one and one-half inches. The limbs of many of the folds have been faulted, and the planes of he faults are parallel to the axial planes of the folds. The attitude of amphibole crystals is parallel to the axial planes of the folds rather than to the compositional layering. This type of structure suggests that the compositional layering may have originally been bedding and that the minerals were oriented during deformation parallel to the axial planes of the folds. The attitude of the minerals would then define an axial plane foliation, and as this type of foliation is folded along with the rest of the units it may be considered a folded axial plane foliation.

Linear features of three types have been recorded: 1) plunge of the axes of minor fold, 2) plunge of biotite streaks in the plane of foliation, and 3) plunge of amphibole crystals.

Pegmatite economic geology

Pegmatites contain all the minerals of economic value that have been found in this area. From an economic viewpoint, two types of pegmatites occur -- a copper-bearing type and a rare earth-bearing type. The rare earth pegmatites contain such minerals as euxenite, columbite, and monazite in addition to common pegmatite minerals. Five pegmatites containing one or more of these minerals have been noted in the field and others are probably present, but the only pegmatite that contained these minerals in economic quantities was the Platt pegmatite.

The Platt pegmatite is a zoned cross-cutting type that is 70 feet wide and 160 feet long. The central part of the pegmatite is a quartz-mica-feldspar-rare earth mineral pegmatite, and the outer part is feldspar pegmatite. The rare earth minerals occur as large individual euhedral crystals and intergrown crystal aggregates in the central part of the pegmatite and in gash fractures, some of which are filled with mica and rare earth minerals and some with quartz and rare earth minerals. Euxenite is believed to be the most abundant rare mineral, monazite is second and columbite is the least abundant.

X-ray fluorescence studies of euxenite, done prior to 1961, showed that the mineral contains, in order of abundance, niobium, yttrium, iron, tantalum, uranium, and zirconium, as well as minor amounts of lead, manganese, zinc, erbium, europium, actinium, holmium, titanium, thorium, samarium, and radon. Compared to normal euxenite (Palache, Berman and Frondel 1944, 789) this mineral is low in titanium and cerium and perhaps high in iron. It is metamict and does not give an X-ray diffraction pattern. Samples fired to 1,100 degrees centigrade give an X-ray pattern that is closer to yttrotantalite than euxenite, and the general chemical composition of the mineral in closer to yttrotantalite, but inasmuch as the name euxenite has been generally applied to the mineral, it will be used here until more detailed studies have been made.

X-ray fluorescence studies of monazite, done prior to 1961, showed that the mineral contains, in order of abundance, cerium, neodymium, yttrium, thorium, and lanthanium, as well as minor amounts of praseodymium, samarium, and gadolinium. This type of analysis does not show the presence of phosphorous which is undoubtedly present as a major constituent.

No work has been done on the reported columbite, allanite, zircons, nor for that matter on any other minerals from this pegmatite.

The Platt pegmatite is exceptionally rich in the rare earth minerals. From 1956 to 1958 approximately 10,000 pounds of euxenite were recovered from this relatively small pegmatite by the part-time mining operations of Ralph Platt and his assistant during the winter months. The mining by Ralph Platt in the now covered shaft was only recovered from mining vertically. According to Ron Platt, his son, no drifts were ever created and mined. Some of the minerals from the mine were sold as mineral specimens with

Encampment, Wyoming sometimes given as the locality. Specimens from this mine are on exhibit in the Saratoga pioneer museum.

The Big Creek copper-bearing pegmatite conforms in strike and dip to the surrounding country rock and is exposed continuously on the surface for a distance of 2,400 feet, averaging approximately 15 to 20 feet in width. Surface exposures, with one exception, are feldspar pegmatite without any evidence of copper mineralization. A cross section of this pegmatite is exposed along Big Creek at the eastern limit of the body, however, and at a depth of about 70 feet below the canyon rim the pegmatite contains numerous gash veins composed of quartz and chalcopyrite. Locally, the chalcopyrite is replaced by secondary copper minerals, including bornite, chalcocite, malachite, and chrysocolla. These minerals are also found in veinlets in brecciated pegmatite and brecciated country rock adjacent to the pegmatite. The quartz and sulphide mineralization is invariably later than the pegmatite, but it could be late stage pegmatite mineralization. Adits driven into the pegmatite from along the canyon of Big Creek extend for a distance of 400 feet to the west and are in mineralized pegmatite most of the distance.

No definite age relationships between the different types of pegmatite have been established because they have not been found in contact with each other, but certain differences between them suggest that they may have had a different source. The replacement type has gradational contacts with the country rock, is not exceptionally coarse grained, is uneven texturally, is unzoned, and is characterized by simple mineralogy. According to Steven {1957, p. 350-351) most of these pegmatites are simple aggregates of quartz and feldspar and are not mineralized. The conformable type of pegmatite has sharp contacts with the country rock and a few pegmatites of this type have poorly developed zoning and may have a complex accessory mineral suite including some rare earth minerals, but, in general, they have a simple mineralogy similar to the replacement type. The cross- cutting pegmatites noted in the Big Creek area generally are zoned and contain a more complex accessory mineral suite, including rare earth minerals.

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Field Trip guide to the Brown Derby pegmatites, Gunnison County

The text written below was extracted from both Hanley, Heinrich and Page (1950) and Staatz and Trites (1955), merged together, and updated as needed to provide this guidebook text.

Location

The Quartz Creek pegmatite field is located 17 miles almost due east of Gunnison, in Gunnison County, north and south of the road connecting Parlin and Ohio City, State route 76 (bitumen). The entire pegmatite field is north of U. S. Highway 50. The 1,803 mapped pegmatites are centrally located around the Black Wonder pegmatitic granite and cover an area of 26 square miles (Hanley, Heinrich, and Page 1950; Staatz and Trites 1955). The exposed pegmatites form an example of a zoned field where the pegmatites closest to its source pluton are geochemically less evolved with the most distal pegmatites being the most geochemically evolved. The minerals found in these pegmatites are among the most rare in Colorado.

The Quartz Creek pegmatite field is on the western slope of the Sawatch Range in Townships 49 and 50 N, Range 3 E, New Mexico principal meridian, Gunnison County, Colorado. Access into the southern part of the pegmatite field is from county road 44 and not State Route 76. The field trip will travel to the pegmatites starting from County road 44, and then onto National Forest Service (NFS) road 802 (dirt, 4WD or high clearance vehicles) along Woods Gulch. Low Clearance 2WD vehicles will be able to be parked at the junction of County road 44 and NFS road 802.

Pegmatite field mining history

Between September 1942 and December 1944 the U. S. Geological Survey had several field parties mapping in Colorado, under E. W. Heinrich in 1942, and under John B. Hanley in 1942-44 (Hanley, Heinrich, and Page, 1950, p. 63-80). In the Quartz Creek district these parties mapped in detail—on scales ranging from 1:240 to 1:600 - the Opportunity No. 1 claim, the Brown Derby No. 1 claim, the Brown Derby Ridge pegmatites, the Brown Derby No. 5, the White Spar No. 1, the White Spar No. 2, and the Bazooka pegmatites. In all, 25 pegmatites were mapped with plane table and telescopic alidade. Several other pegmatites were visited and described.

From September 1943 to the spring of 1945 the Brown Derby property was leased by the Hayden Mining Co. Prior to February 1945, 3,155.67 pounds of beryl (J. B. Hanley, oral communication) were sold to the Metals Reserve Company and 283 tons of lepidolite to the Corning Glass Co. In addition, 4,000 pounds of microlite concentrate containing 52 percent microlite, an ore of tantalum, was stockpiled at the mill and later sold. Though the final production figures are not available, they are not greatly in excess of these figures as mining was stopped in the spring of 1945.

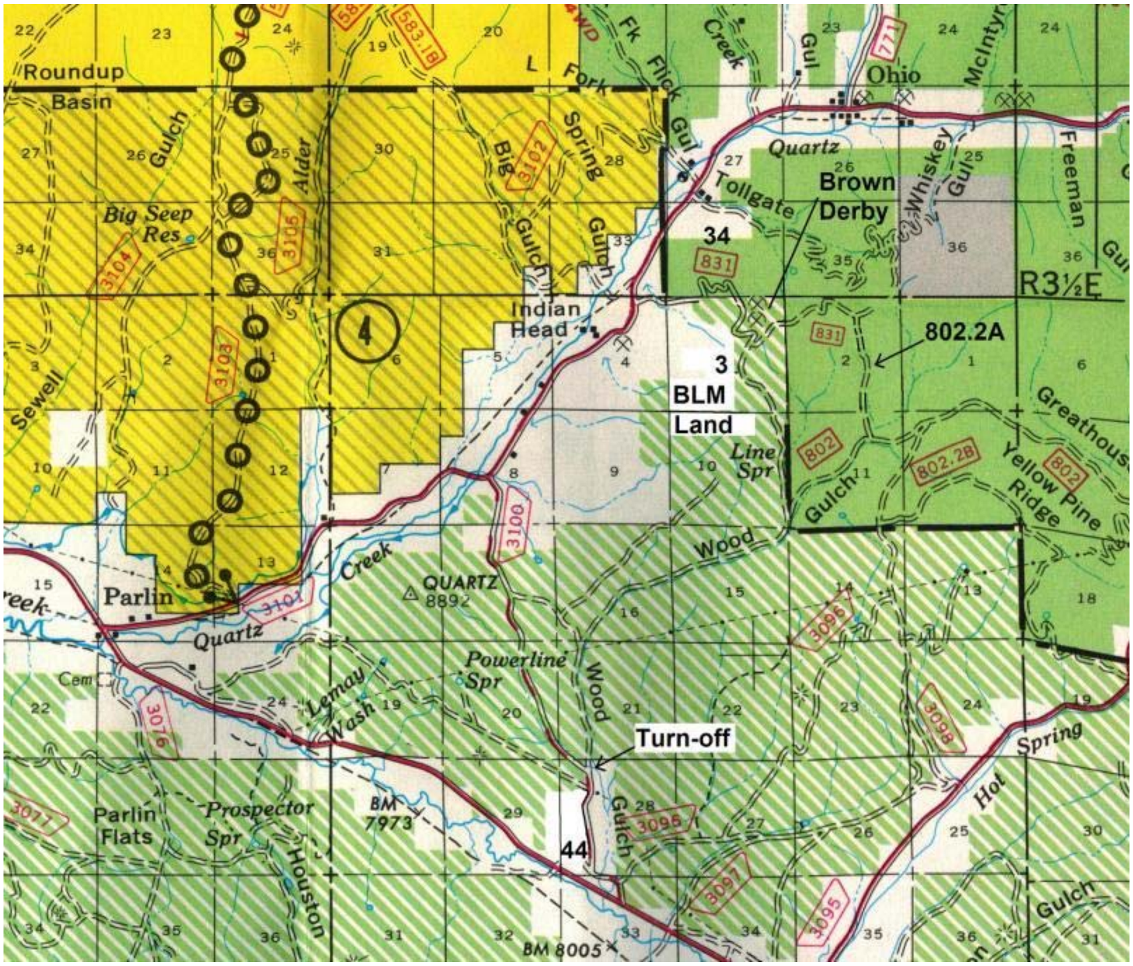

Figure 1. Road and land map of the Quartz Creek pegmatite field showing the dirt road route to the Brown Derby pegmatites. Map modified from the Gunnison National Forest Service map.

The White Spar No. 1 and No. 2 pegmatites, which are 0.8 mile north of the Brown Derby mine, for a short time during World War II were mined by the Colorado Feldspar Company. The production of lepidolite with its associated microlite and feldspar is not known but was small.

There was no mining in the district from 1945 to 1947. Mr. Rod Fields located the Bucky claim on the east side of Willow Creek and started to mine beryl in the spring of 1948. Mr. Fields produced 17 tons of beryl and in November 1948 sold the property to the Beryllium Mining Company, Inc., which produced, up to May 1950, 32.0 tons of beryl, 139.6 tons of scrap mica, 1,020 pounds of columbite-tantalite, 15 pounds of monazite, and 13 pounds of a mineral resembling samarskite. The last two minerals were sold to Ward's Natural Science Establishment, Inc.

Two teams of U. S. geological survey geologists began mapping on July 10, 1948. M. H. Staatz and P. T. Flawn mapped on the east (south) side of Quartz Creek whereas A. F. Trites and F. L. Klinger mapped on the west (north) side of the creek. Field work was recessed September 7, 1948. It was resumed on June 12, 1949, and completed December

10, 1949. Staatz and Trites were assisted for 3 months during 1949 by F. L. Klinger and for 2 months by J. D. Vogel. Mapping was done by pace and Brunton compass.

Since 1948, the Brown Derby pegmatites have been under claim by different companies. These companies on an irregular basis would do some mining or prospect work. The most significant activity has been the construction of metal screen gates to close off the underground portions of the Brown Derby no. 1 pegmatite.

General Geology

The Proterozoic country rock of the Quartz Creek pegmatite field formed during the Routt orogenic event that spanned the age range of 1,770 to 1,670 million years including post-orogenic granitic plutons. Extensive age dating, however, shows that the Quartz Creek pegmatite field was intruded during the Berthoud anorogenic event at 1,390 $\pm$ 40 million years. Most of the pegmatites crystallized within fractures that crosscut the foliation of a hornblende gneiss and less frequently within the older granitic and volcanic rocks.

The Proterozoic 1,770 million year rocks consist of metasedimentary rocks, predominantly quartzites, surrounded by younger and more abundant hornblende tonalite and hornblende gneiss (a metatonalite). Included in this series are two small bands of dacitic pillow lava and one of hornblende-biotite tonalite. A post-orogenic, coarse-grained porphyritic granite, dated at 1670-1700 my, intruded the older Proterozoic metamorphic rocks in the south-central part of the district. The hornblende gneiss, granite, and quartz monzonite are in turn intruded by many fine-grained pink granite dikes and by a large number of pegmatites. In general, the Proterozoic metamorphic rocks dip steeply and have a northwesterly trend, which is shown by the bedding of the metasedimentary rocks and the trend of the dacitic pillow lava.

Černý (1982, 422) was the first to suggest that the Black Wonder pegmatitic granite was the parental source to the pegmatite field, based solely on a rough mineralogical zoning of the surrounding pegmatites. Most of the pegmatites are simple, and frequently unzoned (comprising 78 % of the total). They are located northeast of the Black Wonder and contain biotite and magnetite. The beryl-bearing pegmatites are found close to the Black Wonder as well as more distally to the south and west. The lithium-rich pegmatites, the Brown Derby, Bazooka, White Spar and Opportunity pegmatite groups, are the most distal, being found only to the south and southwest. The zoned pegmatites tend to be zoned in layers (as opposed to concentrically zoned), which is interpreted (but unproven) to reflect the influence of gravity during crystallization on moderately dipping pegmatite dikes.

At least twenty-seven minerals have been identified from this field (Elder 1998). Specimen quality lepidolite, non-gemstone elbaite, beryl, monazite, and columbite-tantalite have been found. Rarer minerals of microlite, rynersonite, gahnite, zircon, allanite, spodumene, amblygonite and stibiotantalite can also be found but are often unattractive. The Brown Derby pegmatite remains the best source of elbaite specimens in this district. Lepidolite is known from several other pegmatites in flat and curved crystals as well as the more common fine-grained masses that are ideal for polishing. Although beryl occurs at the Brown Derby, other pegmatites in the field contain better crystallized specimens.

The Brown Derby no. 1 pegmatite is the most highly geochemically evolved pegmatite in Colorado. The premier indication of chemical evolution is the presence of pollucite, a cesium-bearing zeolite which has been found as a small pod exposed underground in the southern wall of the large gallery at the southeastern end of the Brown Derby no. 1 pegmatite. This lithium-cesium-tantalum (LCT) geochemical family, complex pegmatite class, sub-class lepidolite-topaz, formed at approximately 2.5 kilobars pressure (approximately 10 km below the surface) and 550º C.

Brown Derby No. 1 pegmatite

The Brown Derby mine is a property that originally was composed of two claims that covered 4 exposed pegmatite dikes. These dikes are in the NE 1/4 of section 3, T 49 N, R 3 E, New Mexico principal meridian.

Mining History

The Brown Derby No. 1 and No. 2 claims, on which the mine is situated, were located by William Disberger and O. F. Werner on September 17, 1930. Extensive development work was done by these owners until their deaths, when the property was inherited by Mrs. Marie M. Disberger of Gunnison. For several years no work was done, but in September 1943 the Hayden Mining Co., which had leased the property, started operations. The production to the end of 1944 was 3,155.67 pounds of beryl, which was sold to the Metals Reserve Company, and 243 tons of lepidolite concentrate. In addition, a few thousand pounds of microlite concentrates had been recovered but had not been cleaned up and sold.

The Brown Derby pegmatites were first investigated by J. B. Hanley and E. Wm. Heinrich November 3-6, 1942, and at that time dike 1 and part of dike 2 were mapped at a scale of 1 inch to 50 feet by plane table and telescopic alidade. In July and August 1943, this map was extended by J. B. Hanley, E. Wm. Heinrich, and Roswell Miller III to include nine other pegmatites in the adjoining area. From July 25 to August 8, 1944, following the start of the mining operations, dikes 1, 2, and 3 and also a small, previously unmapped pegmatite in this group were mapped by transit and stadia at a scale of 1 inch to 20 feet by J. B. Hanley, A. F. Trites, Jr., and J. E. Husted. During December 6-8, 1944, the new underground workings were mapped by J. B. Hanley.

Pegmatite geology

The Brown Derby no. 1 pegmatite is non-concentrically zoned, in layers. These zonal layers also vary laterally along strike with a mono-mineralogic, quartz unit cross-cutting other layered zones. Pegmatite no. 1 has a total surface length of 913 feet and contains lepidolite for 319 feet of this length. The thickness of the lepidolite-bearing part is 12 feet at the surface and about 20 feet at the bottom of the incline. The surface width ranges from 1 foot to 43 feet along the length of the dike. The dike narrows rapidly to the north of the incline and in pit 1 is not more than 5 feet thick. About 100 feet south of tunnel 2 the dike splits into an eastern and a western branch; this split probably occurs between the lithia-rich zones and the quartz-albite-mica-microcline pegmatite.

The eastern branch is very poorly exposed at the surface but by means of the pits and trenches and tunnel 3 can be traced for a distance of 142 feet south of the point where the dike branches. The western branch can be traced by means of pits and trenches for 160 feet to the southwest of that point.

The structure can be determined readily from the contacts, rolls, and lineations. At least a 1-foot thickness of the pegmatite adjacent to the footwall contact is fine-grained and resistant to erosion. A similar fine grained pegmatite occurs along the hanging wall, although here it is not more than 2 inches thick. The fine-grained pegmatite has preserved the external structure of the pegmatite body.

The dip of the pegmatite changes from place to place along the length, but the dip throughout the minable part is from 10° to 35° SE. Locally, particularly in close proximity to the axes of minor rolls, the dip on the contact may range from 5° to vertical. Reversals of dip are uncommon. However, the upper 6 feet of the outcrop above tunnel 2 forms a dip slope controlled by a longitudinal roll in the pegmatite.

The pitch of the axes of the rolls ranges from S. 5° E. to S. 67° E. in direction and from horizontal to 44° in angle of pitch. Of the 12 axes measured, only one was found that pitched northwest. The general plunge of the pegmatite is probably 22°, S. 28° E., the average of the pitch measurements.

Internal pegmatite zonation

Dike 1 contains a group of units that can be recognized by diagnostic minerals and by differences in mineral proportions. Boundaries between units are gradational and irregular. The units are markedly discontinuous, and any given unit is commonly found on only one side of the pegmatite. The major units are a wall zone of quartz-albite-muscovite-microcline pegmatite, a possible intermediate zone of albite-quartz pegmatite, and a core that probably is made up in turn of a unit of cleavelandite-quartz-lepidolite-topaz pegmatite, a second unit of lepidolite-quartz-cleavelandite pegmatite, and a third unit of cleavelandite-quartz-curved lepidolite pegmatite. A pod of quartz pegmatite occurs along the hanging wall in part of the dike, but its position in the sequence is not known.

In the western branch two units occur that have not been found in the main part of the dike. They are a unit of cleavelandite-quartz pegmatite and a unit of albite-quartz-biotite pegmatite.

The lepidolite-quartz-cleavelandite pegmatite, the quartz pegmatite and the albite-quartz-biotite pegmatite occur only as lenticular pods, the distribution of which appears to be controlled by the local structure. All the other units have great lateral extent and are nearly constant in composition and sequential position throughout the dike, although in places one or more units of the sequence are lacking. The units, except the wall zone and the possible intermediate zone, thin out markedly both to the north and the south of the incline.

The **quartz-albite-muscovite-microcline pegmatite** is the hanging-wall zone for most of the length of the dike and is the footwall zone except in the lithia-rich part. It is the only zone in the eastern branch. The thickness of the zone is highly variable, but the maximum in the lithia-rich part is not over 4 feet. The chief minerals are quartz, albite, and muscovite, with accessory microcline, beryl, topaz, black tourmaline, and lepidolite. Muscovite commonly occurs in the upper part of the zone just below the hanging wall. Beryl occurs in blue anhedral to subhedral crystals, one of which yielded 1,600 pounds of the mineral.

The **wall zone** is absent along the footwall from the point where the dike branches to a point 66 feet north of the incline. In this part of the dike the albite-quartz pegmatite occurs along the footwall. The absence of the wall zone in the lithia-rich part can be explained in three ways. One explanation is that a peculiar local set of conditions may have prevented the formation of the wall zone in this part of the dike. The second

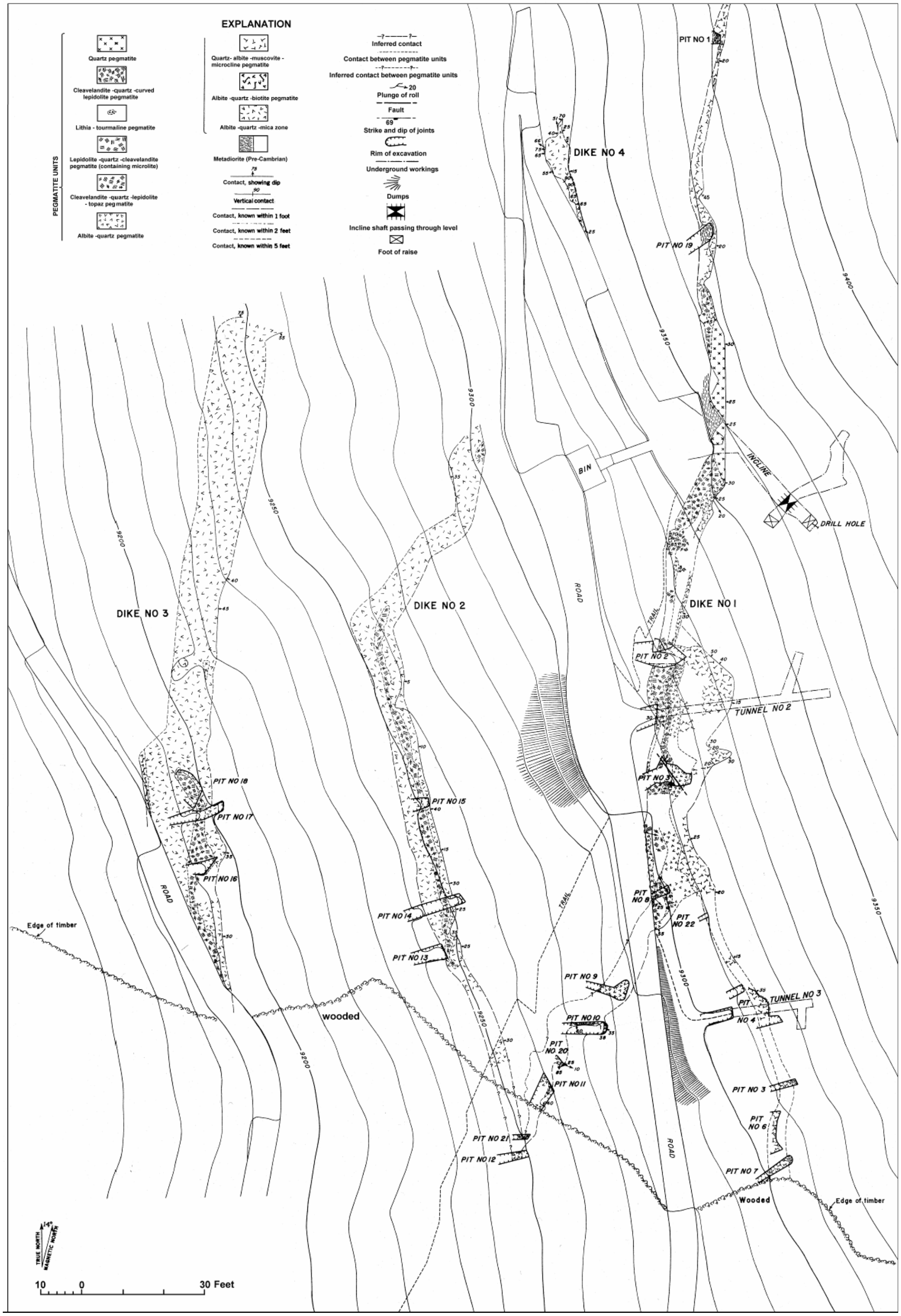

Figure 2. The Brown Derby mine containing pegmatites dikes 1 through 4. Map modified from Hanley, Heinrich and Page (1950).

explanation is that the wall zone formed but was later partly removed by corrosion of the liquid that formed the lepidolite-bearing units and that the albite-quartz pegmatite was deposited in its place. The third explanation is that the wall zone was hydrothermally replaced after it had formed. The available data do not indicate which is the correct explanation, but the occurrence of lepidolite, cleavelandite, microlite. topaz, and fluorite in the other units indicates that if these minerals are of primary origin, the liquid from which the pegmatite formed was strongly corrosive, so that the second explanation may well be the correct one, particularly as no definite evidence of hydrothermal replacement of preexisting pegmatite has been found.

The **albite-quartz pegmatite** along the footwall in the lithia-rich part of the dike has an average thickness of 1.5 feet. In the upper part of the dike it has an average thickness of about a foot. The chief mineral constituents are albite—or locally cleavelandite—and quartz, with accessory lepidolite, beryl, and black tourmaline. The average grain size in the footwall part is about 5 millimeters, but in the upper part it is larger. This unit contains no concentrations of commercially valuable minerals.

The **cleavelandite-quartz-lepidolite-topaz pegmatite** in the core is best exposed in the incline. It has an average thickness of 2 feet. It consists of cleavelandite. quartz, lepidolite, and topaz, with accessory beryl and lithia tourmaline. Lepidolite occurs in deep lavender books as much as 10 inches in size in a distinct 8- to 10-inch band just below the overlying unit. Topaz occurs in subhedral crystals as much as 12 inches across and 4 feet long and is associated with the coarse-grained lepidolite band, but individual crystals extend into the overlying unit. Most of the crystals are milky white, but some are greenish or bluish white. Cleavelandite occurs in radial aggregates below the band of lepidolite books and grades downward into the fine-grained albite-quartz pegmatite. Bluish-green and pale-rose beryl crystals occur in the cleavelandite and also in the lepidolite band.

The **lepidolite-quartz-cleavelandite pegmatite** in the core is likewise best exposed in the incline but is also exposed in tunnel 2 and in the pits and trenches between these tunnels. It has a maximum thickness of 8 feet in the underground workings. The mineral constituents are lepidolite, cleavelandite, and quartz, with accessory microlite and lithia tourmaline. In most of the unit the lepidolite is very fine grained, ranging in size from 1 millimeter to 3 millimeters, but it occurs also as medium grained aggregates in which the lepidolite flakes have an average diameter of 15 millimeters. The fine-grained lepidolite occurs in irregular pods that contain the high grade microlite shoots. This type of lepidolite contains microlite only in the incline, as far as is known. The fine-grained pods are visually estimated to contain 75 to 95 percent lepidolite. The rest of the unit is composed of coarse-grained lepidolite and contains larger quantities of quartz and albite.

A concentration of lithia tourmaline crystals occurs in a rod-shaped body between the lepidolite-quartz-cleavelandite pegmatite and the cleavelandite-quartz-curved lepidolite pegmatite in tunnel 2. The red, green, and variegated crystals are as much as 4 inches in diameter and 14 inches long, but all the exposed crystals are highly flawed and friable. Associated minerals are quartz, cleavelandite, and lepidolite.

The **cleavelandite-quartz-curved lepidolite pegmatite** is distinguished from the other units by pale-lavender lepidolite that occurs in curved plates. Cleavelandite and quartz are the other abundant minerals, and red or green lithia tourmaline is the only prominent accessory. The thickness of the unit is unknown but is probably about 2 feet.

The **quartz pegmatite** occurs only in an irregular pod beneath a roll in the contact above the incline. Its thickness directly above the incline is 2 feet. It is nearly pure quartz but has minor quantities of microcline. It forms the hanging-wall zone for 66 feet north and 18 feet south of the incline.

The **cleavelandite-quartz pegmatite** is the most widespread unit in the western branch and is composed chiefly of white cleavelandite that occurs typically in ball-shaped masses of plates that are as much as 6 inches long. Cleavelandite is visually estimated to make up 70 to 80 percent of the rock. Quartz is the only other abundant mineral. Accessory minerals are red and green lithia tourmaline and lepidolite. This unit in most of the western branch is next to the hanging wall, and the outer 2 inches is much finer grained than the rest of the unit. Its thickness is not known.

The **albite-quartz-biotite (zinnwaldite) pegmatite** is exposed only in pit 11 and in dike 4. In pit 11 it occurs in a pod beneath a structural roll in the hanging-wall contact. The pegmatite is fine-grained and brownish white and is composed of albite, quartz, and biotite, with accessory monazite, columbite, black tourmaline, gahnite, betafite, garnet, and fluorite. Albite occurs in the same manner as in the other units, but the size of the masses is less than 2 inches. Monazite occurs in reddish-brown euhedral crystals as much as 2 inches long, 1 inch wide, and 0.4 inch thick. The columbite, which has a specific gravity of 5.61 and contains 72 percent Cb_2O_5 and 6 percent Ta_2O_5,, occurs in crystals that are as much as 4 inches long, 3 inches wide, and 0.3 inch thick. Betafite occurs as small, flattened, diamond-shaped crystals with resinous luster and is closely associated with columbite. The identification of the betafite has not been confirmed by later investigators. Gahnite occurs as octahedrons and masses up to 10 millimeters in size and can be recognized by its green color. The maximum thickness of this unit is 1 foot, and the lateral extent is probably less than 20 feet.

This pegmatite locally grades upward into a layer, 4 to 6 inches thick, of biotite-black tourmaline pegmatite at the hanging wall, but it may form the hanging wall unit.

Brown Derby no. 2 pegmatite

Dike 2 has a total length of 437 feet and contains lepidolite for 210 feet of this length. Its average thickness is 10 feet, and its surface width ranges from 8 to 21 feet. Only four shallow pits, none revealing much of the geology, have been made in this dike. The hanging wall is well exposed for 110 feet of the total length, but the footwall is not well exposed and cannot be located definitely. The structure of the dike is therefore not known in detail, but its general dip is about 30° SE. Locally the dip is as gentle as 5° or as steep as 40°. The border zone is not resistant to erosion, and the contacts of the dike are not well preserved. The surface shape indicates that rolls occur in the contact.

Dike 2 probably connects with the western branch of dike 1. The point of connection is not known, but the structure of the two dikes, the converging course of the contacts of both, the pronounced lateral lithologic gradation from dike 1 toward dike 2, and the occurrence of a small lepidolite pegmatite pod where the dikes are believed to join suggest that they do connect. A possible point of connection is exposed in pit 21, but the exposure is too poor to be sufficient proof.

Dike 2 is composed of four major units. The contacts between the units are gradational. In order from footwall to hanging wall these units are albite-quartz-biotite (zinnwaldite) pegmatite, quartz-albite-muscovite pegmatite, cleavelandite-lepidolite pegmatite, and quartz-albite- muscovite pegmatite.

The albite-quartz-biotite(zinnwaldite) pegmatite is composed mainly of albite and quartz with accessory biotite(zinnwaldite), black tourmaline(schorl), and garnet. Typically, this rock is banded near the contact, showing an alternation of garnet-rich layers with black tourmaline-rich layers. The unit ranges from a few inches to 1 foot in thickness.

The two quartz-albite-muscovite pegmatite units are identical in mineral composition and may be parts of the same zone. Their thicknesses are not known accurately, but the lower unit is about 3 feet thick and the upper unit about 3.5 feet thick. Near the central cleavelandite-lepidolite pegmatite both of these units may contain either green or red tourmaline, or both, as accessory minerals. The outer 1 or 2 inches of the upper unit is usually finer-grained than the rest and forms the border zone at the hanging wall.

The cleavelandite-lepidolite pegmatite of the core is visually estimated to contain about 80 percent cleavelandite, 15 percent lepidolite, and 5 percent accessory tourmaline and topaz. It typically contains a large quantity of ball-shaped aggregates of cleavelandite plates. Lepidolite occurs in books as much as 6 inches in size and in fine- to medium-grained aggregates. The fine-grained lepidolite aggregates occur in lenticular pods where the core is thicker beneath minor rolls in the contact. Only three or four of these pods were found. No microlite was observed, although this type of lepidolite aggregate is the microlite host rock in dike 1.

Brown Derby no. 3 pegmatite

The Brown Derby no. 3 pegmatite is 680 feet long, but only 110 feet of it near the southern end contains lepidolite. In the lepidolite bearing part it is 32 feet thick; the thickness of the northern part is unknown. The average thickness is probably about 25 feet, and the surface width ranges from 20 to 33 feet. The outcrops are poor in general except in the central part of the dike, and only three small pits explore the dike. The wall-zone pegmatite is resistant to erosion and forms a steep slope. Talus from this zone has collected along the break in slope at the footwall contact and conceals this contact. The hanging-wall contact is fairly well exposed over much of the dike, but the northern part is obscure.

The structure of this dike is not known in detail. Its general dip is about 30° SE; locally the dip ranges from 25° to 55°. The contacts are marked by a fine-grained pegmatite, but it is not resistant enough to preserve the external structure. Neither structural rolls nor faulting was observed.

The pegmatite is very similar to pegmatite no. 2 in structure and lithology. Both pegmatites bear a much closer resemblance to each other than to dike 1. Dike 3 contains four units in the southern 110 feet of its length, but the remainder consists of one unit. The units are identical in mineral composition with those of dike 2 and occur in the same sequence. The fine-grained lepidolite pods in the cleavelandite-lepidolite pegmatite contain small quantities of microlite. The largest of these pods, which is exposed in pit 18, contains microlite, and a small quantity of lepidolite and microlite was recovered in enlarging this pit. Microcline occurs in the upper quartz-albite-mica pegmatite as an accessory mineral. Beyond the northern end of the core the lower and upper parts of the quartz-albite-mica pegmatite zone merge and occupy the full thickness of the pegmatite. The average grain size of this pegmatite is about 1 inch.

Mineralogy

Of the minerals that occur in these pegmatites only lepidolite, microlite, and beryl are commercially valuable and beryl is important only as a byproduct.

Lepidolite occurs in a variety of forms, chiefly in platy books that are as much as 10 inches in size, in plates and aggregates of medium-grained flakes, and in fine-grained aggregates in which the size of the individual flakes ranges from 1 millimeter to 7 millimeters. The physical and optical properties of all these varieties are similar, and the only chemical difference is that the manganese content of the large plates is slightly higher than that of the smaller flakes.

Analyses have been published by Stevens (1938, p. 615), Hanley, Heinrich and Page (1950, p. 72), and Heinrich (1967, p. 1116, sample 504) of large plates of pale-purple lepidolite from Ohio City, Colo. (U. S. National Museum, specimen 97893). The only occurrence near Ohio City where lepidolite is found in large plates is in these three Brown Derby dikes. An average formula from these analyses is $K_4Li_7Al_5Al_2Si_{14}O_{40}(F,OH)_8$.where F>OH. The analysis and formula probably hold for all the lepidolite in these pegmatites, except that the manganese content is lower in the smaller plates.

Microlite occurs in the fine-grained aggregates of lepidolite as spherical masses and octahedrons that range from microscopic grains to 13 millimeters in diameter. The mineral is usually rosin-brown although some honey-yellow microlite has been found. It can be recognized easily by the waxy luster, conchoidal fracture (suggesting that it is metamict), and alteration halos in the lepidolite. A detailed analysis by Fairchild (Eckel and Lovering 1935) on a selected, purified sample of this microlite indicated that the mineral is a calcium tantalate close to microlite in composition. The specific gravity determined on the analyzed sample was 5.604.

The **beryl** from the quartz-albite-muscovite-microcline pegmatite in dike 1 contained 12.62 percent BeO, according to analyses made for the Metals Reserve Company. The BeO content of the beryl in the cleavelandite-quartz-lepidolite-topaz pegmatite in this dike is not known. The mineral occurs in blue, bluish-green, or pale-rose anhedral to euhedral crystals that are as much as 8 inches in diameter and 1.5 feet in length in the cleavelandite-quartz- lepidolite-topaz pegmatite and 2.5 feet by 4 feet in size in the quartz-albite-mica-microcline pegmatite.

Size and grade.—The lepidolite deposit in dike 1 is made up of the three units in the core and is the core in dikes 2 and 3. It is the major deposit in the dikes and also contains the microlite shoots in dikes 1 and 3. The microlite shoots do not occur throughout the lepidolite deposit but are in scattered, isolated pods.

In dike 1 the deposit is exposed for a surface distance of 319 feet, of which the northern 232 feet was thick enough to be mined profitably prior to 1946. The central block has been explored in depth by the incline and adjoining level and by tunnel 2. The dividing lines between the blocks are a line down the dip 24 feet north of the incline and a line down the dip 40 feet south of tunnel 2.

Mineral counts of two chip samples, across all the lepidolite-bearing units, taken in 1912, gave a lepidolite content of 48.0 percent and 45.0 percent, but chemical analyses by the Chemical Laboratory of the Geological Survey gave 41 percent and 20 percent, respectively. The reasons for the differences between the mineral counts and the chemical analyses are not known. A spectrograph analysis made for the Hayden Mining Co. of the richest lepidolite concentrations within the deposit gave a content of 74 percent lepidolite, and mill tests on samples for this company from the same concentrations indicated a lepidolite content of 73 percent. In order to balance the tested parts of the deposit against the untested parts, the visually estimated grade of 40 percent is used.

The largest microlite concentration is a lenticular pod that is probably controlled by local structures. It has a surface length of 104 feet, an average thickness of about 3 feet, and a depth down the dip of 61 feet at the incline, in which the bottom of the shoot probably has been reached. A few other microlite shoots occur in the lepidolite deposit, but these are so small that the quantity of microlite that might be recovered is negligible. A poorly exposed, low-grade microlite concentration occurs as a lateral extension of the major shoot. Its size and shape are not known definitely.

The grade of the largest microlite shoot is based on four analyses, two of which were made by the Chemical and Petrographic Laboratories of the Geological Survey. The microlite content of a chip sample, determined by a mineral count in the heavy mineral concentrate, was 1 percent. A spectrographic analysis of a channel sample gave 0.24 percent Ta_2O_5, or 0.35 percent microlite, on the basis of Fairchild's analysis. Two other analyses gave 0.95 percent Ta_2O_5, or 1.3 percent microlite, and 0.36 percent Ta_2O_5, or 0.68 percent microlite, on the basis of this analysis. The grade of 0.35 percent, or 7 pounds per ton, of microlite determined spectrographically in the channel sample probably is most representative of the deposit.

In dike 2 the core has a length of 183 feet and an average thickness of 1.5 feet and extends down the dip at least 20 feet. It is visually estimated to contain 15 percent lepidolite. No microlite is exposed in this pegmatite.

In dike 3 the core has a length of 108 feet and an average thickness of 1 foot and probably extends down the dip at least 15 feet. The lepidolite deposit in the core is visually estimated to contain 15 percent lepidolite. The one microlite shoot in the core is not more than 15 feet in length. 1.5 feet in average thickness, and 15 feet in depth. Its grade is not known, but it is estimated to be 0.1 percent microlite.

Beryl occurs in the lepidolite deposit only in dike 1. It is concentrated in the lower foot of the deposit, of which it is visually estimated to form not more than 0.5 percent.

Topaz occurs throughout the core in dike 1 but is most abundant in the cleavelandite-quartz-lepidolite-topaz pegmatite unit. On the basis of mineral counts and visual estimates a topaz content of 25 percent can be expected in the unit and a topaz content of 3 percent in the whole core.

Brown Derby no. 3B (Dike 4) pegmatite

Hanley et al. (1950) did not describe in their text a Brown Derby no. 3B pegmatite but on plate 9 they did illustrate a small pegmatite as dike 4. The pegmatite is located northeast of dike 2 and due east of the north end of dike 1. This pegmatite has the shape of a tadpole swimming northward. Its outcrop width is 13 feet at the northern end and 48 feet long. It is composed only of albite-quartz-mica without any observed zoning. No excavations have been made on the dike.

Brown Derby no. 4 pegmatite

The Brown Derby No. 4 pegmatite is in section 34, T 50 N, R 3 E, The prospect in 1942 was claimed by Mrs. Marie Disberger of Gunnison and leased to the Hayden Mining Co. It was examined by E. Wm. Heinrich in November 1942.

Two poorly exposed pegmatites, 250 feet apart, occur on the leased claim. The eastern one has been explored by only a shallow cut at the southern end. The western pegmatite has been explored by a narrow adit that is 5 feet long. Both pegmatites are composed chiefly of quartz, pink microcline, and muscovite with accessory beryl. Dull blue beryl crystals as much as 3 inches in diameter are exposed in the workings.

Brown Derby no. 5 pegmatite

The Brown Derby No. 5 pegmatite (pegmatite 535 of Staatz and Trites [1955]) is in a small gulch on the west side of the Brown Derby ridge at an elevation of 8,900 feet. It is in the south central part of sec. 34, T. 50 N., R. 3 E.

The property was claimed by Mrs. Disberger in 1942 and was leased to the Hayden Mining Co. The production through 1944 was 10 to 15 tons of lepidolite. The prospect was examined by J. B. Hanley and Roswell Miller III on September 3, 1943, and at that time was mapped by plane table and telescopic alidade. The description of the internal structure of the pegmatite was revised by Staatz and Trites (1955) in September 1949.

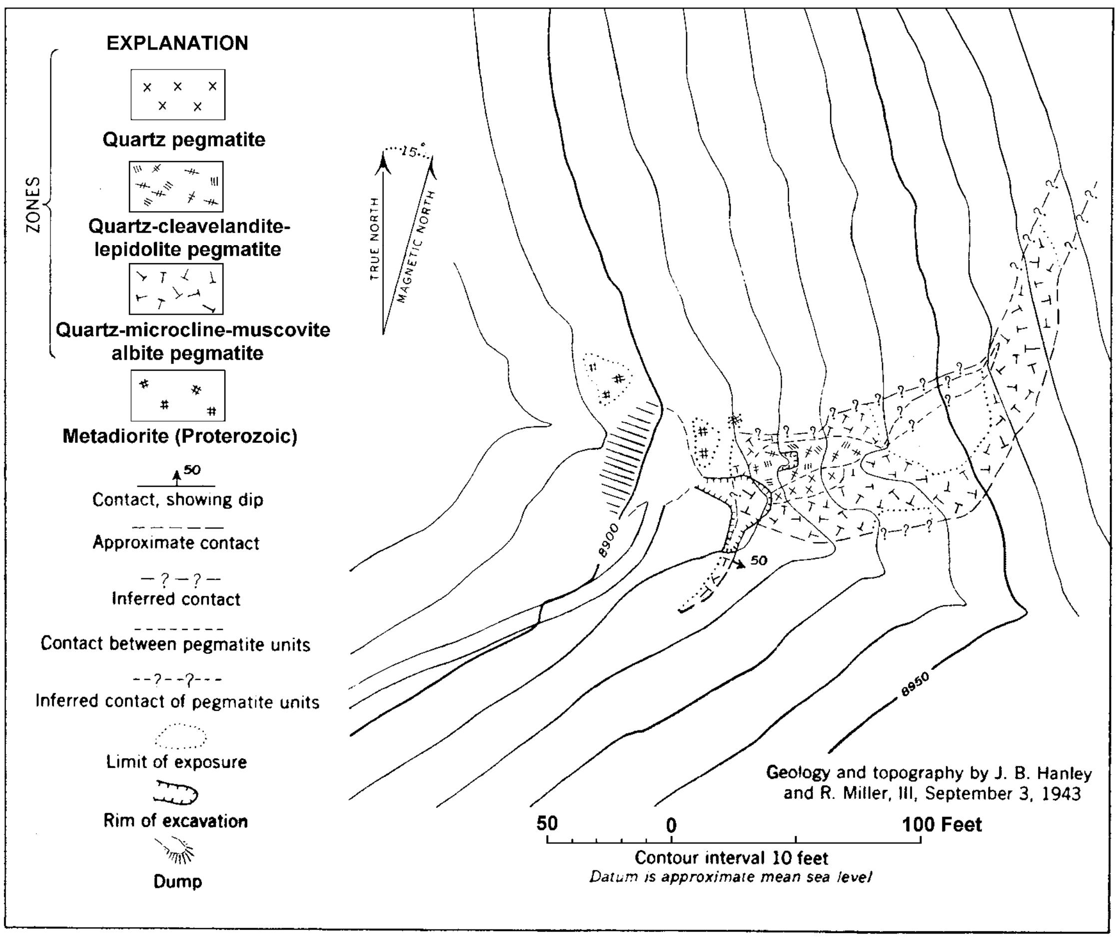

Figure 3. Geologic map of Brown Derby. no. 5 pegmatite. Modified from Hanley, Heinrich and Page (1950).

The mine workings are in a small gulch on the side of the ridge containing the Brown

Derby no. 1 pegmatite at an altitude of 8,900 feet. (See fig. 13.) A branch road from the Brown Derby no. 1 pegmatite road leads to the workings. The workings consist of two small opencuts and an adit. The larger cut has a main part, 32 feet long, 15 feet wide, and 18 feet deep at the eastern face. The southern branch of this cut is 12 feet long, 6 feet wide, and 6 feet deep at the northeast face. An adit, approximately 10 feet long, was driven from the eastern end of this cut. A second shallow cut, 10 feet long and 8 feet wide, is northeast of the main cut.

Pegmatite geology

The Brown Derby no. 5 pegmatite is a crudely lenticular body that is at least 210 feet long and as much as 60 feet wide. It trends N 54° E and the dip is probably 50° to 55° SE. The pegmatite was intruded into a greenish black hornblende tonalite. The pegmatite is distinctly zoned with a discontinuous border zone, a wall zone of quartz-microcline-muscovite-albite pegmatite, an intermediate zone of quartz-cleavelandite-lepidolite pegmatite that contains beryl and microlite, and a core of quartz pegmatite.

The wall zone is 2.5 feet thick where exposed in the large opencut, has a range in grain size of from 0.12 to 0.25 inch, and consists of albite (61 percent), quartz (25 percent), perthite (10 percent), muscovite (4 percent), black to greenish-black tourmaline (less than 1 percent), lepidolite (trace), garnet (trace), and beryl (less than 0.1 percent). One exposed area of the wall zone, about 3 feet square, contains 17 beryl crystals ranging in size from 0.5 by 0.5 inch to 1 by 1.3 inches. This unusually rich area averaged 1.13 percent beryl in blue-green euhedral crystals, but contained only three crystals that could be hand cobbed.

The intermediate zone is in the southeastern part of the pegmatite, and is approximately 50 feet long and 14 feet wide. It has an average grain size of 4 inches and consists of quartz (55 percent), white cleavelandite (35 percent), lepidolite (5 percent), white massive perthite (4 percent), muscovite (1 percent), beryl (0.1 percent), topaz (less than 1 percent), garnet (less than 1 percent), greenish-black tourmaline (less than 1 percent), apatite (trace), microlite (trace), and columbite-tantalite (trace). Lepidolite occurs both as fine-grained aggregates and as large flat sheets up to 6 inches in diameter. The workings are on this zone, and mining was directed toward the recovery of the fine-grained lepidolite; most of the large sheets were thrown out on the dump. The beryl is in blue-green euhedral crystals from 0.5 to 3.5 inches in diameter. The beryl content increases in the northern part of the zone and appears richest in the small northern pit. In this upper pit, a beryl count made on an area 4 feet by 5 feet indicated 0.43 percent beryl by volume. About 15 pounds of beryl was also found lying on the dump from this pit. The topaz is milky white and forms euhedral crystals, 4 to 6 inches long, adjacent to the lepidolite. The garnet forms crystals as much as 1.5 inches in diameter, and commonly is surrounded by coronas of muscovite. It is most common near the contact with the underlying wall zone. The apatite is in widely scattered, light-blue crystals 0.5 inch in diameter. Microlite was not seen in place but was found on the dump in distorted octahedra, 0.12 to 0.25 inch in diameter. The olive-green microlite is faintly radioactive and is found between plates of cleavelandite. One crystal of columbite-tantalite, 0.06 by 0.75 inch, was found between plates of cleavelandite.

The core consists of milky-white quartz with accessory microcline and muscovite with a gradational contact to the intermediate zone. The core consists of white massive quartz (40 percent), white perthitic microcline (39 percent), albite (20 percent), muscovite (1 percent), lepidolite (trace), blue-green beryl (only 1 crystal, 4 by 6 inches), and columbite-tantalite (2 thin pieces, 0.5 by 0.06 inch). The grains of the core average 6 inches in diameter.

Brown Derby Ridge pegmatite

The Brown Derby Ridge pegmatite is in sec. 3, T 49 N, R 3 E, New Mexico principal meridian, about 1,200 feet above the floor of Quartz Creek valley at an altitude of 9,550 feet. It is on the crest of the hill on which the Brown Derby mine is located, about 1,000 feet by air line southeast of the mine. The claim in which the prospect is located was formerly known as the Ventura claim, owner unknown, but is now owned by the Hayden Mining Co. of Colorado Springs. This prospect was investigated on August 19, 1943, by J. B. Hanley and Roswell Miller III and at that time was mapped by pace-and-compass methods except for the southern 100 feet of the western dike.

One small discovery hole, 4 feet wide, 15 feet long, and 10 feet deep at the face (fig. 16), is the only opening in this prospect. Two thin, elongate, beryl- bearing pegmatites crop out on this claim. The eastern one is 40 feet higher than the western. They strike N 14° E, dip 10° to 50° SE, and cut across the foliation of the Proterozoic dioritic schist and amphibolite wall rock. The contacts with the wall rock are well exposed except in the few areas where the pegmatite is not resistant to erosion. The lower pegmatite is about 445 feet long and averages 3 feet in thickness. The upper pegmatite is about 440 feet long and averages 4 feet in thickness. Each is thin and tabular at its northern end but is much wider at the southern.

A rotational fault cuts the lower dike, and two others cut the upper dike. The northern fault in the upper dike strikes N 60° E. The southern fault in the upper dike appears to connect with the northern in the area between the two dikes; it strikes N. 80° E. The dips of these faults cannot be determined, but the maximum horizontal displacement on the northern fault is 20 feet and, on the southern fault, 18 feet.

Both dikes are indistinctly zoned and contain a narrow border zone of fine-grained pegmatite that has an average grain size of an eighth of an inch and a central part composed of quartz-microcline-plagioclase pegmatite that has an average grain size of 6 inches. Quartz pegmatite pods as much as 1.5 feet in diameter occur along the center of each dike. In general neither pegmatite contains much muscovite, although a small quantity occurs around the edges of the quartz pods.

The most abundant mineral is pinkish to white microcline. Quartz and a small quantity of plagioclase are the only other abundant minerals. Euhedral crystals of white to pale-blue beryl occur in the central parts of both dikes. The largest beryl crystal seen was 1.5 inches in diameter, and the average size is 0.5 inch. Dark-red garnet, in crystals as much as 1 inch in diameter, and muscovite, in small books and aggregates, are the only other accessory minerals. Columbite in association with a radioactive, black metamict mineral has been found along the hanging wall of the pegmatite.

In both pegmatites the average ratio of beryl to pegmatite is 1:10,000, but on the hanging-wall side of the large northernmost roll at the south end of the upper dike (see fig. 16) is an area of quartz-plagioclase-microcline pegmatite, about 30 feet long and 6 feet wide, that is rich in beryl. An area of 20 square feet in this beryl-rich pegmatite contained 195 beryl crystals with an average size of .05 foot, or 2 percent beryl. However, this part of the pegmatite appears to be too insignificant in size to contain an appreciable tonnage of beryl. The crystals are too small to be recovered without milling.

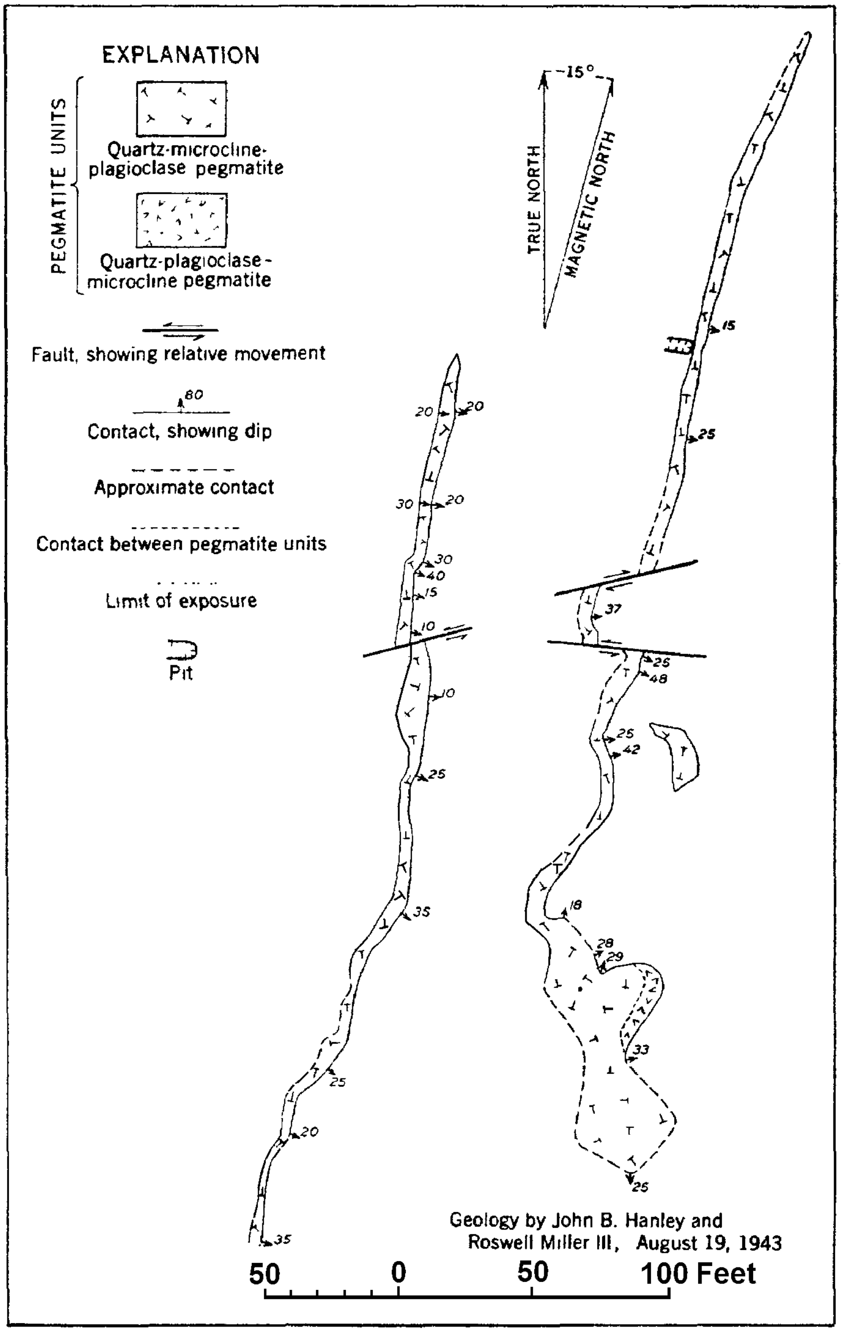

Figure 4. Geologic map of the Brown Derby Ridge pegmatite. Map modified from Hanley, Heinrich and Page (1950).

Bazooka (Nesbit) spodumene pegmatite

The Bazooka spodumene pegmatite, in section 11, T. 49 N, R. 3 E., New Mexico principal meridian, is near the head of Wood Gulch at an altitude of 9,300 feet. The prospect can be reached from the national forest road just to the west that connects Wood Gulch with the Brown Derby pegmatites to the north. The prospect was owned by briefly by Leonard Nesbit of Parlin, who relocated the claim in July 1943. It was examined by E.

Wm. Heinrich assisted by Roswell Miller III on July 20, 1943, and at that time was mapped by plane table and telescopic alidade.

Two circular pits were the only openings in the two pegmatites. Later bulldozer work since 1945 has trenched the southern pegmatite along most of its length. The pit in the northern pegmatite is about 5 feet in diameter and 3 feet deep. The pit in the southern pegmatite was larger, about 20 feet in diameter and at least 10 feet deep. Since 1945, most of this pit has been filled in by slumping rock.

The Bazooka pegmatites have intruded Proterozoic metamorphic rocks across the contact between a hornblende gneiss and a quartzite. The hornblende gneiss is a blue-gray, massive rock that is composed of hornblende and feldspar, and the quartzite is reddish, fine grained, uniform in texture, and highly stained by iron oxide along joints and fractures. Neither the general structure of these rocks nor their relationship to one another could be determined.

Two lenticular pegmatites that trend N. 35° E. and appear to be vertical crop out on the Bazooka claim. The southern pegmatite is 175 feet long and has a maximum width near the central part of 35 feet, but the average width is only 10 feet. The northern pegmatite is 55 feet long and has an average width of 5 feet. These two pegmatites may be connected in depth. No other pegmatites were found in the vicinity of the Bazooka prospect.

Both pegmatites are zoned, although the zones are highly discontinuous. The southern pegmatite contains a wall zone of quartz-albite-lepidolite pegmatite, also pods of quartz pegmatite and a unit of quartz-albite-spodumene pegmatite. The northern pegmatite is similar to the southern one but contains no quartz-albite-spodumene pegmatite.

The **quartz-albite-lepidolite wall zone** is composed of a fine- to medium- grained intergrowth of quartz, albite, and lepidolite. Masses of fine-grained lepidolite as much as 2 feet in diameter occur in it. The lepidolite content of the zone in both pegmatite bodies is visually estimated to be less than 5 percent.

The **quartz core pegmatite** occurs as a large pod in the southern part of the southern pegmatite and as a smaller pod near the northern end. A small pod of quartz pegmatite occurs near the center of the northern pegmatite. One contact of this pod strikes N. 35° W. and dips 25° SE.

The **quartz-albite-spodumene intermediate zone pegmatite** occurs as a roughly circular pod about 15 feet in diameter. It is in the widest part of the pegmatite and at the place where the pegmatite crosses the contact between the hornblende gneiss and the quartzite.

The pegmatite of this pod is a medium- to coarse-grained mixture of quartz and albite with scattered flakes of lepidolite; scattered anhedral montebrasite masses that are 3 inches in size; patches of highly sericitized pink feldspar (microcline?); crosscutting veins and masses of spodumene: and accessory sericite, cookeite, microlite, and prochlorite, as well as several unidentified alteration products.

The spodumene occurs in thin lathlike crystals, many of which are extremely friable. Individual spodumene crystals are as much as a foot in length, and these crystals commonly occur in masses as large as 1 foot by 1.5 feet. A thin coating of bright-green sericite is common on the spodumene crystals. One honey-yellow microlite crystal found in this deposit had an index of refraction of 2.06. The reported amblygonite of Hanley, Heinrich and Page (1950) (AF-43, USNM. specimen 117,775) from this pegmatite was analyzed by Černá, Černý and Ferguson (1973) and had 0.15 ratio of F/(F+OH) indicating it is montebrasite.

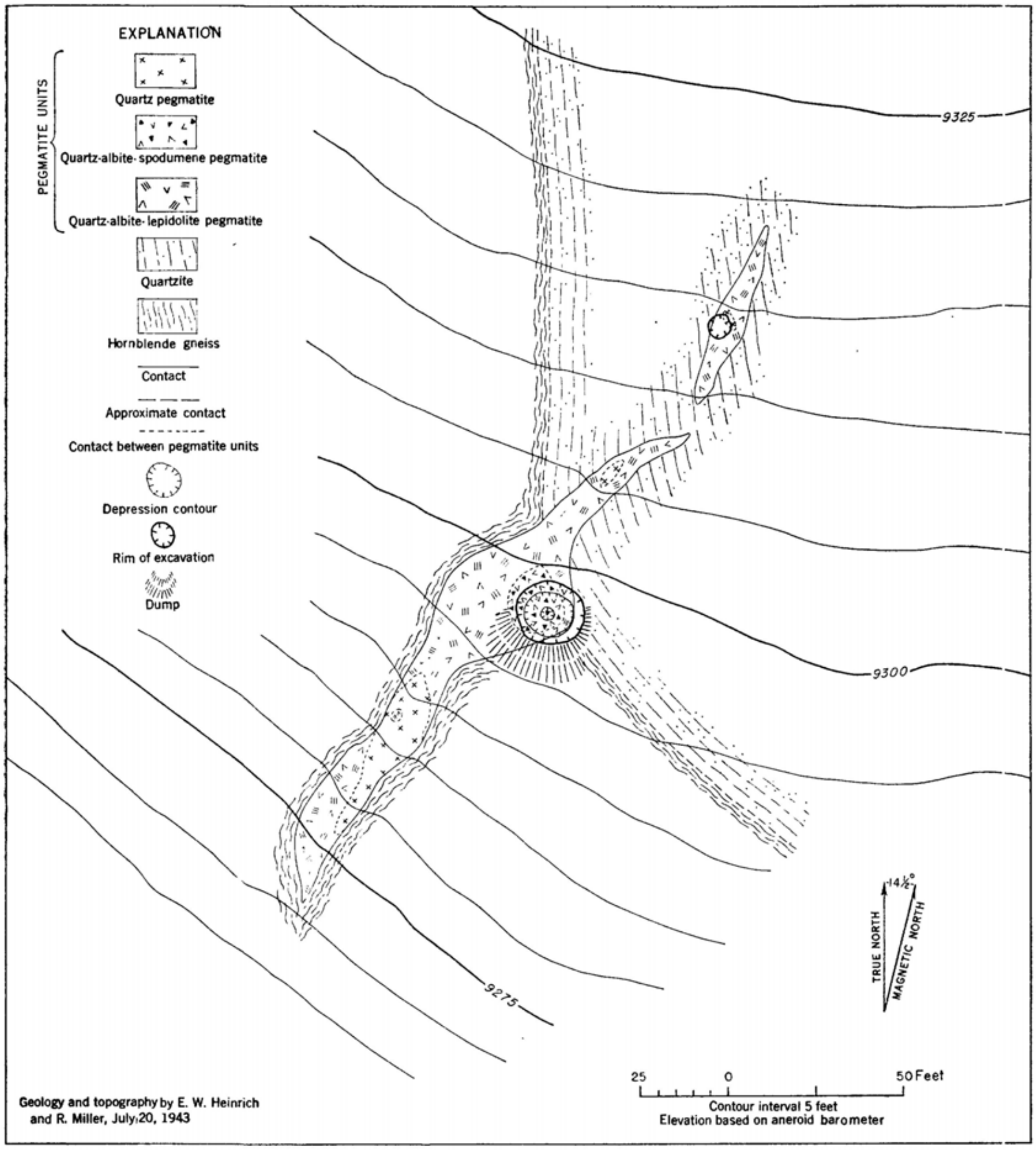

Figure 5. Geologic map of the Bazooka pegmatite. From Staatz and Trites (1955).

Spodumene in the of quartz-albite-spodumene zone of the southern pegmatite was observed to make up 12 percent of a face in the pit with an area of 25 square feet, amounting to possibly 800 tons of gross rock. The montebrasite content of this zone is not known, but it is estimated to be 5 to 10 percent montebrasite.

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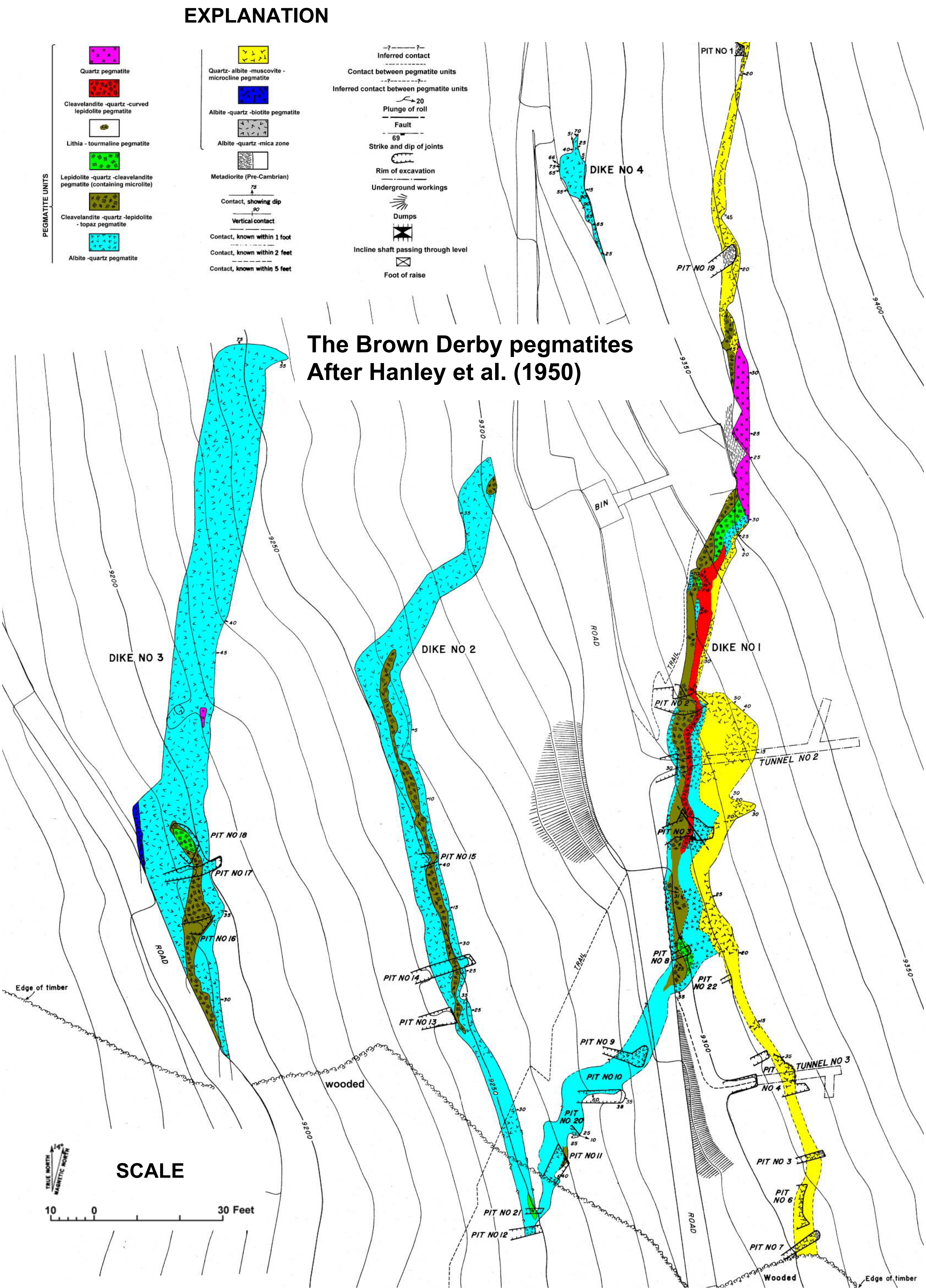

EXPLANATION
PEGMATITE UNITS
Quartz pegmatite
Cleavelandite -quartz -curved lepidolite pegmatite
Lithia - tourmaline pegmatite
Lepidolite -quartz -cleavelandite pegmatite (containing microlite)
Cleavelandite -quartz -lepidolite - topaz pegmatite
Albite -quartz pegmatite
Quartz- albite -muscovite - microcline pegmatite
Albite -quartz -biotite pegmatite
Albite -quartz -mica zone
Metadiorite (Pre-Cambrian)
Contact, showing dip
Vertical contact
Contact, known within 1 foot
Contact, known within 2 feet
Contact, known within 5 feet
Inferred contact
Contact between pegmatite units
Inferred contact between pegmatite units
Plunge of roll
Fault
Strike and dip of joints
Rim of excavation
Underground workings
Dumps
Incline shaft passing through level
Foot of raise
The Brown Derby pegmatites
After Hanley et al. (1950)
DIKE NO 4
DIKE NO 3
DIKE NO 2
DIKE NO 1
PIT NO 1
PIT NO 19
BIN
ROAD
TRAIL
PIT NO 2
TUNNEL NO 2
PIT NO 3
PIT NO 18
PIT NO 17
PIT NO 16
PIT NO 15
PIT NO 14
PIT NO 13
PIT NO 8
PIT NO 22
PIT NO 9
PIT NO 10
TUNNEL NO 3
PIT NO 4
PIT NO 20
PIT NO 11
PIT NO 3
PIT NO 6
PIT NO 21
PIT NO 12
PIT NO 7
Edge of timber
wooded
Wooded
9200
9250
9300
9350
9400
SCALE
TRUE NORTH
MAGNETIC NORTH
10
0
30 Feet