Pegmatites of the Crystal Mountain District, Larimer County, Colorado

Trace Elements Investigations Report 139

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology - Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PEGMATITES OF THE CRYSTAL MOUNTAIN DISTRICT, LARIMER COUNTY, COLORADO _/

By

William R. Thurston

April 1952

Trace Elements Investigations Report 139

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_/This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission

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	55

CONTENTS

CONTENTS—Continued

ILLUSTRATIONS

ILLUSTRATIONS—Continued

ILLUSTRATIONS—Continued

TABLES

TABLES —Continued

TABLES—Continued

PEGMATITES OF THE CRYSTAL MOUNTAIN DISTRICT, LARIMER COUNTY, COLORADO

By

William R. Thurston

ABSTRACT

The Front Range of Colorado is composed chiefly of schists of the pre-Cambrian Idaho Springs formation which have been intruded by a variety of granitic batholiths. In the Crystal Mountain district the Mount Olympus granite, a satellite of the Longs Peak batholith, forms sills and essentially concordant multiple intrusions in quartz-mica schist that dips southward at moderate to steep angles. A great number of pegmatites accompanied and followed the intrusion of the sills, and formed concordant and discordant bodies in schist and granite.

Over 1,300 pegmatites in the Hyatt area north of the Big Thompson River are mapped and individually described. There are 27 pegmatites in the area that are made up of a wall zone and a core, and one, the pegmatite at the Hyatt mine, is composed of five zones. The largest pegmatites in the area are discordant in schist and occupy zones that are interpreted to be tear faults and tension fractures produced by the successive intrusions of granite that formed multiple sills. The majority of pegmatites in the large multiple sills were emplaced along the foliation and fractures.

The composition of 96 percent of the pegmatites is granitic, 3.5 percent are quartz-rich pegmatites, and a few are tourmaline-rich. The pegmatites were intruded over a period of time and probably were derived from a granitic magma at different stages during differentiation. Solu-

tions escaping from many of the pegmatites tourmalinized and silicified the wall rocks for a few inches to two feet, but chemical and spectrographic analyses fail to show the transport of any other constituents.

Perthite, plagioclase, and quartz are the essential minerals of the pegmatites, and muscovite is a minor but widespread constituent. Tourmaline, garnet, beryl, and apatite are common accessory minerals, and lithiophillite-triphylite, bismuthinite, uraninite, columbite-tantalite, and chrysoberyl are rare constituents. Beryl is found in 350 or 27 percent of the pegmatites and makes up 0.01 percent or more of 77 bodies. The beryl-bearing pegmatites are richest in two of the three large granite masses, and are somewhat less rich at a distance of more than a thousand feet from the margins of the intrusives, but contain the least beryl in the thousand-foot belt immediately surrounding the intrusives. The Hyatt pegmatite is by far the richest deposit of beryl in the area mapped.

Most of the pegmatites mapped are "unzoned" or homogeneous pegmatites. All gradations are visible between bodies consisting of uniform texture and mineral distribution to zoned pegmatites. The interpretation is made that, for most pegmatites, the initial composition determines whether or not zones will form. Pegmatites containing many zones can form from a magma composed of the elements in perthite, plagioclase, quartz, and muscovite, depending on the proportions of the components crystallizing at any given time. The complexly zoned deposits depend for their formation on the presence of a number of the rarer elements, principally lithium. Replacement textures in zones result from the interaction of the rest-liquid with the earlier-formed solid crystals. No mappable pegmatite in the Crystal Mountain district formed from the replacement of pre-existing pegmatite by solutions escaping from the rest-liquid, or by solutions originating outside the pegmatite.

Three beryl-bearing zoned pegmatites, the Hyatt, Big Boulder, and Buckhorn Mica deposits, were explored by core drilling. Each deposit is mapped and described in detail, and the mineral reserves evaluated. The exploration indicates a total of 2,000 tons of beryl, of which 480 tons is estimated to be recoverable by hand sorting. The mapping of the 3 3/4-square mile Hyatt area indicates beryl in sufficient abundance to infer beryl resources of an additional 1,150 tons.

Small tonnages of scrap mica and perthite may be obtained from the Hyatt and Big Boulder prospects, and columbite-tantalite may occur in sufficient amounts at the Buckhorn Mica mine and Tantalum claim to produce several hundred pounds as a byproduct of beryl mining. Dumps at the various deposits contain 25 to 50 tons of beryl.

INTRODUCTION

In mid-1942 the wartime demand for tantalum, mica, and beryl caused the U. S. Geological Survey to undertake a greatly expanded program of pegmatite investigations, and in the next two and a half years, work was done in most of the important pegmatite mining districts of the country. These studies entailed approximately 68 man-years of work by 39 geologists (Cameron, Jahns, McNair, and Page, 1949). The wartime investigations were focused on deposits containing minerals of strategic importance; limitations on time and manpower precluded examination of deposits not known to contain strategic minerals or to study in detail the regional relationships.

From 1946 to 1950, regional studies were made of the geology and beryl resources of ten pegmatite districts. (See fig. 1.) The work included the preparation of detailed geologic maps of the districts, large-scale maps of individual pegmatites of unusual interest, sampling and diamond-drill exploration of selected deposits, and mineralogic studies. More emphasis was

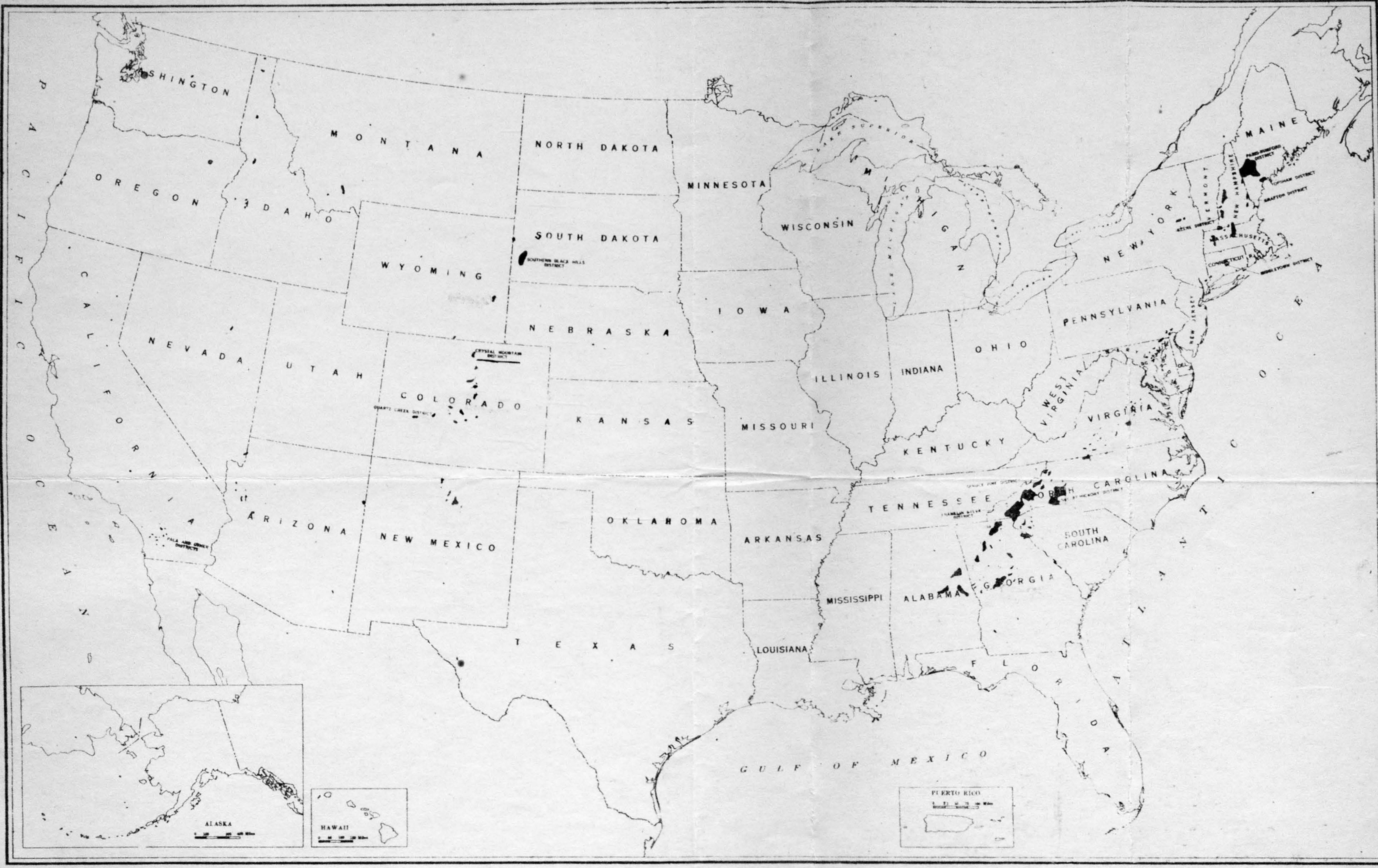

FIGURE 1 —INDEX MAP OF THE UNITED STATES, SHOWING LOCATIONS OF PRINCIPAL PEGMATITE MINING DISTRICTS

placed on regional investigations which included study of the country rock, structure, and economically unimportant pegmatites and their relation to deposits of economic interest. The study of the Crystal Mountain district, Larimer County, Colo., is but one phase of this post-World War II pegmatite program, in part carried out by the Geological Survey on behalf of the Division of Raw Materials of the Atomic Energy Commission.

Description of the area

The Crystal Mountain district is an unincorporated mining district without precise boundaries. In this report the name refers to an area north of the Big Thompson River and south of Buckhorn Creek in Tps. 6 and 7 N., Rs. 71 and 72 W., sixth principal meridian. The district is in the Front Range of the Rocky Mountains, approximately 16 miles west of Loveland and Fort Collins, Larimer County, Colo. The northern part of the district, near Crystal Mountain, is reached by way of unimproved ranch roads that branch southward from the Buckhorn Creek road at a bridge 21 miles west of the town of Masonville. (See fig. 2.) The Hyatt pegmatite area is reached by a private road which branches northward from the Glen Haven road at a bridge 500 yards west of the town of Drake. (See fig. 2.) The ranch roads and the Buckhorn Creek road may be closed for several weeks during severe winters. The road in the steep-walled parts of Buckhorn Creek is washed out occasionally by spring floods.

The topographic sheets which cover the district are the Livermore quadrangle for the northern part and the Mount Olympus quadrangle for the southern part. The lowest altitudes in the Crystal Mountain district are 6,500 on Buckhorn Creek, which bounds the district to the north, and 6,100 feet on the Big Thompson River, which bounds it to the south. Rugged valley walls rise steeply from these streams for about 1,000 feet to a maturely

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REPORT 139

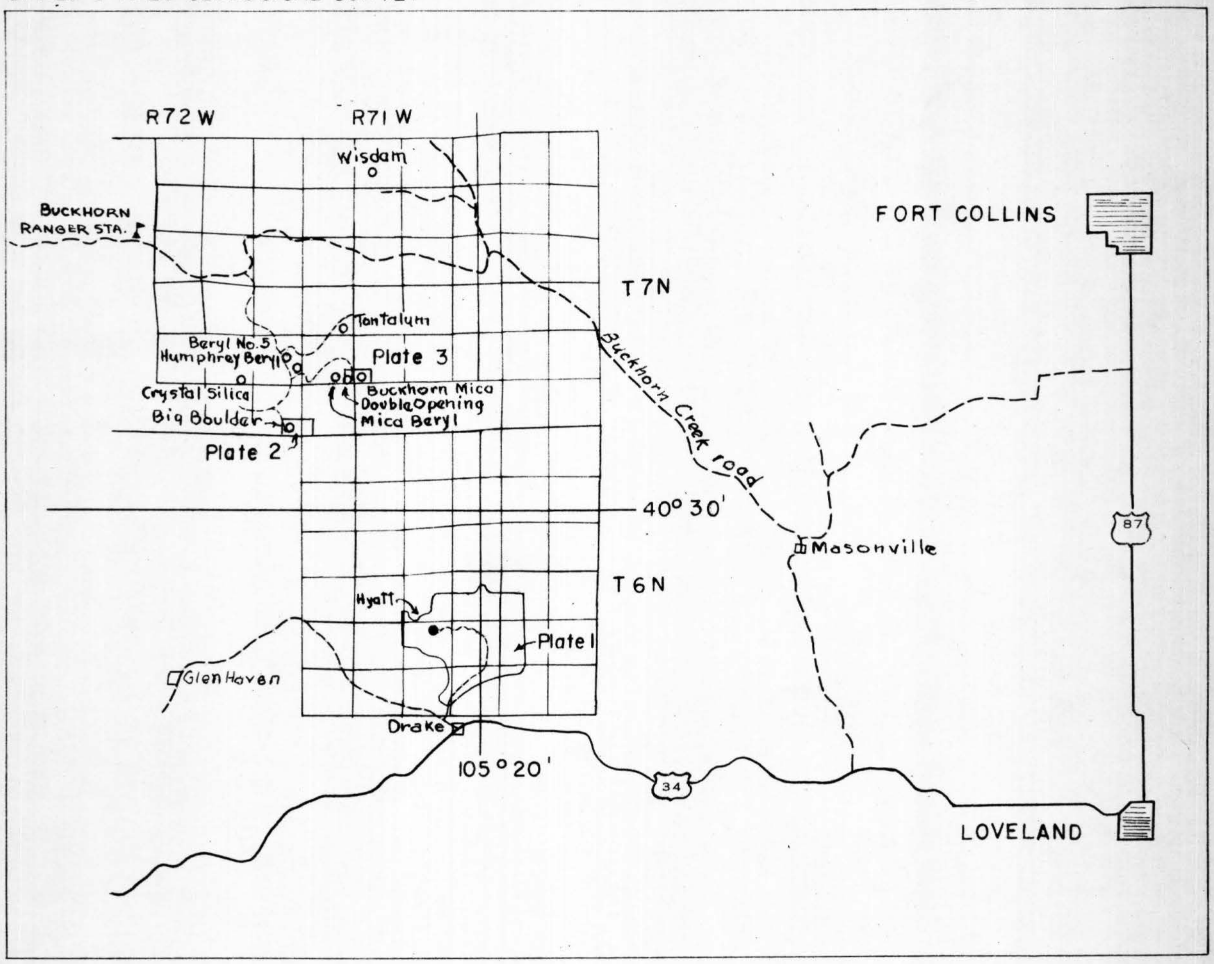

FIG. 2, INDEX MAP OF THE CRYSTAL MOUNTAIN DISTRICT, COLORADO

Scale
0 5 Miles

dissected rolling upland. The highest points on the upland surface are Lookout Mtn. (10,633 feet), Crystal Mtn. (9,952 feet), and Storm Mtn. (9,915 feet). Most of this area is thickly forested with conifers, principally lodgepole pine, but with some ponderosa pine, blue and Engelmann spruce, Douglas fir, and various junipers. Cottonwood, aspen, boxelder, and chokecherry are found along the smaller intermittent streams. There are many small meadows bordered by aspen groves around Crystal Mountain; the Hyatt ranch occupies much of a large meadow called Cedar Park.

The principal economic activities in the area are lumbering and summer grazing. The Dickerson family at a ranch in Box Prairie, and the Hyatt family at a ranch in Cedar Park were the only permanent residents during the time the field work was in progress.

History of mining

Mining has never been an important activity in the region, though the area has been prospected for various commodities since frontier days. Gold mining and milling near Masonville, copper mining just east of the Crystal Mountain district, and various attempts to mine pegmatite minerals have been marginal to submarginal ventures. Scattered throughout the area are caved and weed-covered pits and trenches of unknown date.

The earliest recorded pegmatite mining was at the Buckhorn Mica mine in 1884. It is reported that some time prior to 1900 the Crystal Silica deposit was opened. In 1913 the district was visited by Sterrett (1923, pp. 59-61) who described the Buckhorn Mica mine and "another mica prospect (which) was opened by Parkson and Kitchen about a quarter of a mile west of the Buckhorn mine"; the unnamed deposit may be the one known now as the Double Opening prospect. A claim to the Double Opening prospect was filed in 1934. The Big Boulder prospect and the Hyatt pegmatite were opened in 1936. About a dozen other pegmatite deposits have been prospected, but little or no development work has been done; four of them have been described by Hanley, Heinrich, and Page (1950). Since completion of the wartime studies in 1945 the only production has come from the Hyatt pegmatite in 1948. The production record, insofar as it is known, is compiled in table 1.

Previous work

The geology of the Front Range area of Colorado has been studied because of its many metallic ore deposits and their relation to regional structure and stratigraphy. Burbank and Lovering (1933, pp. 272-311) summarize the general geology of Colorado and part of Wyoming, and list the principal references. In an earlier paper Lovering (1929) describes the geologic history of the Front Range. Pegmatite deposits are not considered, nor are there maps or descriptions which give the relations in the Crystal Mountain district. The reports on the Georgetown quadrangle by Ball (1908) and the Montezuma quadrangle by Lovering (1935) contain abundant information on the schist, granite, and pegmatites of those areas that are helpful in studying similar rocks in the Crystal Mountain district. The descriptions are detailed and precise, and comparisons can be made though the areas are 50 miles apart.

A general map by Lovering (1935, pl. 5) shows the relationships in the area south of the Crystal Mountain district but ends at the southern boundary of the district. The features of the pre-Cambrian structure along the Big Thompson River described by Fuller (1924) and the observations on the granites of the Longs Peak-St. Vrain batholith by Boos and Boos (1934) are too generalized to be applicable to the detailed studies made in the Crystal Mountain district.

Table 1.—Pegmatite minerals produced in Crystal Mountain district, Colorado

Property and location	Commodity and date produced
Hyatt mine, NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 28, T. 6 N., R. 71 W.	Beryl: 1936-1942, 1,500 pounds.
	Do. 1943, 34 tons.
	Do. 1948, 14 tons.
	Potash spar: 1948, 400 tons.
	Scrap mica: 1948, 30 tons.
Buckhorn Mica mine, SW$\frac{1}{4}$ sec. 29, T. 7 N., R. 71 W.	Scrap mica: 1884-1942, 180 tons.
	Sheet mica: 1884-1942, "a few hundred pounds".
	Beryl: 1884-1944, 2 or 3 tons.
	Do. 1944-1950, 1 ton
Big Boulder prospect, SE$\frac{1}{4}$ sec. 36, T. 7 N., R. 72 W.	Beryl: 1936, 10.5 tons.
	Do. 1941, 600 pounds.
Crystal Silica claims, sec. 26, T. 7 N., R. 72 W.	Bismuth minerals: prior to 1900, no data.
	Fusing quartz: no data.
Beryl No. 5 prospect, sec. 25, T. 7 N., R. 72 W.	Beryl: 1942-1944, 1.5 tons.
Total recorded production:	Beryl: 62.8 tons
	Potash spar: 400 tons
	Scrap mica 210 tons

The first description of pegmatites in the Crystal Mountain district was made in 1913 by Sterrett (1923) in the course of an appraisal of mica deposits of the United States. Between September 21 and October 10, 1942, L. R. Page and J. B. Hanley mapped in detail some 20-odd beryl-bearing pegmatites at nine properties in the district, including two described previously by Sterrett. Continued studies at the Hyatt pegmatite resulted in revision and remapping in 1943 and 1944. The results of this work have been described by Hanley, Heinrich, and Page (1950, pp. 86-103).

Field work and acknowledgments

The field and laboratory work on which this report is based started in August 1947 and was completed in December 1950. From August to November 1947 the previously described deposits in the Crystal Mountain district were re-examined and five prospects were remapped with the assistance of A. J. Lang. As a result of this re-examination three beryl-rich pegmatites, the Hyatt, Big Boulder, and Buckhorn Mica deposits, were selected for exploration, and preparations were made during the winter for diamond drilling. The three deposits were core drilled between July 16 and November 7, 1948, by the Fillmore Drilling Company of Deadwood, S. Dak., for the Geological Survey. For seven weeks A. E. Grass and E. V. Dedman were samplers under the supervision of W. I. Finch. For the remaining nine weeks the sampling was done by R. E. Roadifer and the writer. During July and August 1948, H. D. Wright mapped in the vicinity of the Hyatt pegmatite, and Wright and Finch mapped and studied 45 pegmatites in the meadow north of the Hyatt ranch.

While core drilling was in progress, an area of one-quarter of a square mile surrounding the Big Boulder deposit was mapped, and one-eighth of a square mile in the vicinity of the Buckhorn Mica mine was mapped. For two weeks the writer was assisted by C. S. Robinson. From October 4 to November 5, 1948, W. R. Griffitts was associated with the project and mapped in the vicinity of the Big Boulder and Buckhorn Mica deposits. In the winter of 1948-1949, 255 samples of drill core were prepared for analysis; the core data were studied and compiled. In 1949 the Hyatt area was mapped on aerial photographs at a scale of 1:6,000: a total of 12 man-months were spent by E. N. Hinrichs and the writer in mapping over thirteen hundred pegmatites in 3 3/4 square miles.

The topographic maps of the district were of too small a scale for detailed mapping, so aerial photographs were used. The geology was plotted in the field directly on U. S. Forest Service photographs enlarged to a scale of approximately 1:6,000. The topographic relief in the Hyatt area is sufficient to require a contoured base map for the representation of the geology (pl. 1). The base was prepared from photographs of the area, using the Mahan Stereoscopic plotter._/. The work was done by John

_/ Instrument and procedure described in: Topographic Instructions: U. S. Geol. Survey, Chapter 3 C 12 (in preparation).

W. Zydik of the Topographic Division of the Geological Survey and the writer. Vertical control for orientation and contouring was obtained from a six-man altimeter survey between benchmarks. The writer is grateful to J. W. Adams, J. R. Stacy, A. F. Trites, Jr., and D. J. Varnes for their help in making this survey.

Planimetric maps were made directly from the photograph in the small areas of low relief around the Big Boulder prospect (pl. 2), and the Buckhorn Mica mine (pl. 3). Distortion in the photograph has not been corrected, but it is probably not great.

Over 500 determinations were made of the indices of refraction of plagioclase and beryl from the pegmatites, studies were made of other minerals, and 55 thin sections were examined.

The writer is grateful to those who worked with him in the field and to his co-workers in the Geological Survey, particularly to those working on pegmatites for helpful discussions of our common problems. Special thanks are due the members of the Hyatt and Dickerson families for their courtesies and hospitality while working near their homes. Those who visited the writer in the field, bringing fresh outlooks and asking embarrassing questions, particularly C. H. Behre, Jr., J. F. Schairer, N. L. Bowen, O. F. Tuttle, and M. L. Keith, contributed, perhaps more than they realized, by broadening the writer's interest in local and regional problems. The writer also is indebted to L. R. Page for help and guidance.

GEOLOGY

The Crystal Mountain district is such a small part of the Front Range that studies within the district give little direct information on the regional setting. To understand the geologic details and discuss the problems within the district, the broader relations must be considered. Excellent summaries of the geology and history of the Front Range have been written by Lovering (1929) and Burbank and Lovering (1933, pp. 272-316, especially pp. 272-285). A condensation of pre-Cambrian geologic history is taken from these sources.

Summary of the geologic history of the Front Range

The Front Range is a mountainous uplift 30 to 35 miles wide and 175 miles long, composed of pre-Cambrian metamorphic and igneous rocks, cut locally by Tertiary intrusive rocks. Paleozoic and younger sedimentary formations are upturned along the flanks of the range. The metamorphic rocks comprise a thick series of schists, gneisses, and greenstones; they were derived by dynamic and contact metamorphism from dominantly argillaceous and sandy sediments with intercalations of limy and pebbly beds, and probably some eruptive rocks. The schists grade from fine-grained quartz schist on the east through mica-quartz schist to biotite-sillimanite schist on the west. Lime silicate rocks and hornblende-rich rocks are minor components of the schists. Ball (1908, p. 37) gives the name Idaho Springs formation to the succession of metamorphic rocks in the Georgetown quadrangle, Colo. The name has been extended by common usage to include much of the schist of the Front Range, though the continuity of the formation from place to place has not been established. The metamorphic rocks along the Big Thompson River have been called the Big Thompson schist by Fuller (1924), and in the Coal Creek area have been divided into the Coal Creek quartzite and the Ralston schist by Adler (1930). The various units of the schist exposed along the Big Thompson River seem to be conformable.

The schists and gneisses of the Idaho Springs formation are cut by quartz monzonite gneiss, pegmatites, and hornblende-quartz diorite; these are the oldest intrusives recognized in the Front Range. The schists and quartz monzonite gneiss are intruded by a series of granite batholiths and their satellitic stocks, pegmatites, and hornblende-quartz diorite or gabbro bodies. The Archean quartz-monzonite of the Georgetown quadrangle is probably of the same age as the Boulder Creek granite gneiss to the east. The Pikes Peak granite of the central part of the Front Range in Colorado and the Sherman granite in the northern part of the Front Range in southern Wyoming are approximately contemporaneous according to Boos and Boos (1934, p. 307). The Silver Plume, Cripple Creek, and Longs Peak granites are petrographically similar, are younger than the Pikes Peak and Sherman granites, and are probably contemporaneous. The Mount Olympus granite has been designated by Boos and Boos (1934, p. 311, and pp. 323-324) as a satellitic facies of the Longs Peak batholith. The granite intrusives are so related structurally and petrographically that, despite certain marked differences, Lovering (1929, p. 64) believes they belong to one great period of batholithic invasion. Maps by Lovering (1935, pl. 5) and Boos and Boos (1934, fig. 1) show the distribution of the main masses of the intrusives.

Van Hise and Leith (1909, p. 827) date the schists and gneisses as Archean, because their structural and lithologic complexity is similar to the "basal complex" of many other regions, and date the later quartzites and quartz schists as Algonkian. A tentative correlation of the Front Range rock units with the Lake Superior section was made by Lovering (1929, p. 74) on the basis of similarities in history: the Idaho Springs formation may be Lower and Middle Huronian, the Pikes Peak granite may be early Algoman, and the Silver Plume and associated granites may be late Algoman—all included in the Algonkian.

The structural grain of the pre-Cambrian rocks of the Front Range trends generally east-west (Burbank and Lovering, 1933, p. 273 and fig. 11, p. 274) and is bowed locally by the intrusion of batholithic masses. During Paleozoic and Mesozoic time the main lines of deformation gradually rotated clockwise, culminating in the formation of a north-trending highland in the Front Range region during the Laramide orogeny. There are no important Paleozoic or younger rocks in the Crystal Mountain district so the discussion of post-Algonkian rock will be omitted.

Geology of the Crystal Mountain district

Summary

Quartz-mica schists of the Idaho Springs formation are the oldest rocks in the Crystal Mountain district and have been intruded by sills of Mount Olympus granite and by pegmatites that are probably related to the Longs Peak granite batholith. The schist is in open folds in the Hyatt area (pl. 1) that have an average plunge of 60° S. and a general eastward strike. Most of the granite occurs in sheets which are essentially concordant with the foliation of the schist. The two largest granite masses, north and southwest of the Hyatt ranch, are multiple sills. Two smaller granite bodies, one almost surrounding the Hyatt pegmatite and the other about a thousand feet to the east, seem to be plug-like masses, but the contacts are poorly exposed.

Around the Big Boulder prospect, the strike of the schist ranges from north to northeast (pl. 2) and the dip is eastward at steep angles; the plunge of linear structures is steep and to the southeast and south. The strike of the schist in the vicinity of the Buckhorn Mica mine (pl. 3) is about east-northeast, and the dip is steep and to the south. The mile of unmapped country between the two deposits has been traversed without observing unusual changes in structure so it may be inferred that they are on the same broad fold; however, linear elements in the schist near the Buckhorn Mica mine plunge erratically, suggesting that between the Big Boulder and Buckhorn Mica deposits there are concealed structural complexities.

Most of the thirteen hundred-odd pegmatites mapped in the Hyatt area (pl. 1) are concordant, although about 30 of the largest pegmatites in the area are discordant, dipping northward at steep angles.

U.S. Department of the Interior
Geological Survey

Trace Elements Investigation
Report 139

Geology by W.R. Thurston, W.R. Griffitts, and C.S. Robinson 1948

Plate 2. Geology of the Big Boulder prospect area, Crystal Mountain district, Colorado

Scale

0 100 500 1000 feet

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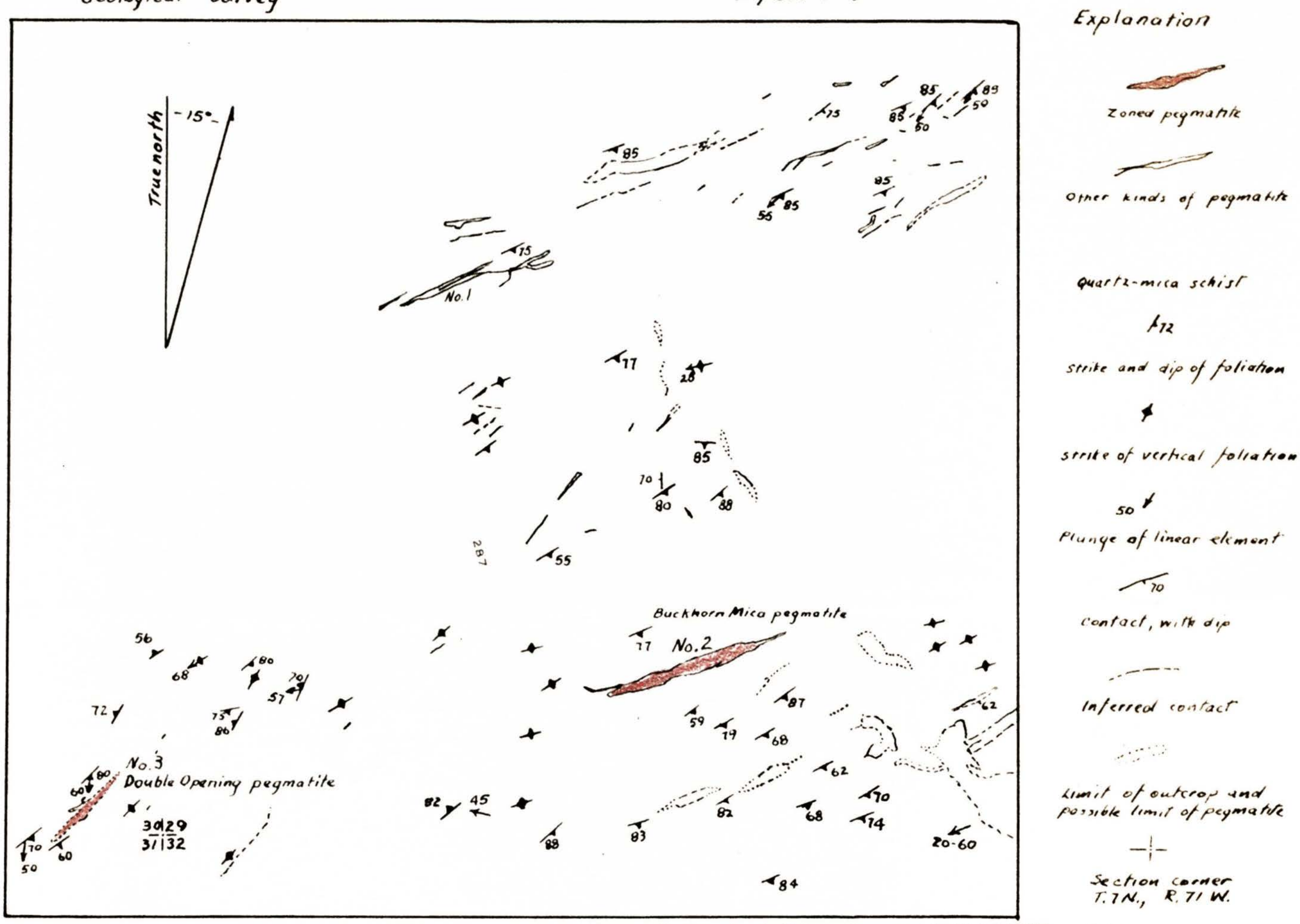
Geological Survey

Trace Elements Investigation
Report 139



Geology by W.R. Thurston and W.R. Griffitts 1948

Plate 3. Geology of the Buckhorn Mica mine area, Crystal Mountain district, Colorado

Scale

0 100 500 1000 feet

Most of the pegmatites in this area are feldspar-rich though some are quartz-rich and a few are tourmaline-rich. The dominant minerals of the pegmatites are, in order of abundance: perthite, plagioclase, and quartz. Muscovite is an everpresent minor constituent. Tourmaline is the commonest accessory mineral and the commonest mineral in the altered wall rock. Beryl and garnet are present in about 27 percent of the pegmatites. The Hyatt pegmatite contains a varied suite of minerals, which are described separately.

Country rocks

Schist

The most common metamorphic rock in the Crystal Mountain district is quartz-mica schist of the Idaho Springs formation. It is fine- to coarse-grained; fresh surfaces are generally light gray and weathered outcrops are dark grayish brown. The facies of the formation range from quartz schist to mica schist, the types grading into each other by changes in the proportions of the dominant minerals, quartz, muscovite, and biotite. The schist is exposed on the steep valley walls in jagged irregular outcrops and on the flatter parts of the upland surface as widely scattered low mounds. In much of the area outcrops are rare, except at the margins of pegmatites.

The foliation of the schist is approximately parallel to the bedding in most places. Wherever recognizable bedding diverges from the foliation at an angle of more than 15°, it has been mapped separately (pl. 1). The linear structures of the schist include: drag folds, ranging from minute crinkles to those 2 feet in cross section; elongation of mineral grains, principally biotite and quartz; and "pencil structure" produced by the intersection of closely spaced planes of fracture. The plunge of the linear elements, with few exceptions, is a reliable indicator of the attitude of the nearby fold.

The most abundant type of schist is characterized by the alternation of thin mica-rich and quartz-rich layers. Commonly, there are from 5 to 50 layers per inch; in places they are thicker. The layers are of differing color, composition, proportions of minerals, or grain size. Quartz, as grains with rounded outlines, is the most abundant mineral. Granulated and strained grains, as well as grains with intricately sutured boundaries are rare. The proportions of biotite and muscovite vary widely. The biotite is coarser grained than the muscovite; some books are as much as 0.3 inch in diameter. Feldspar is not abundant, but in many layers it may constitute 5 to 15 percent of the granular material. Orthoclase, microcline, and plagioclase have been identified; orthoclase is the most common.

Tiny euhedral to subhedral crystals of apatite, zircon, and magnetite or ilmenite are present in all thin sections of schist that were examined. Chlorite, as large flakes and as felted masses of small shreds, is a common accessory. Staurolite, andalusite, and garnet are widely distributed throughout the quartz-mica schist but are rarely abundant. Staurolite crystals range from 0.02 to 1.1 inches in length; equant grains of andalusite range from 0.02 to 0.3 inch in diameter; and garnet crystals average 0.02 inch in size—the largest is about 0.2 inch. Sillimanite is a rare accessory mineral in the Hyatt area except in a few small lenticular beds west of the Hyatt ranch. Sillimanite needles, intergrown with quartz, are abundant in clumps which form white button-like masses in the mica schist. On Buckhorn Creek sillimanite clusters, oriented with the long dimension parallel to the schistosity, are conspicuous in some outcrops. Mappable beds of staurolite-mica schist and garnet-mica schist occur in a few places (pl. 1). Minor quantities of staurolite, garnet, and other accessory minerals are widespread in other types of schist in the Hyatt area.

Small needles of black tourmaline are plentiful in some schist layers, but quantitatively are a minor constituent. Tourmaline crystals up to one inch long, however, are in the schist bordering some pegmatites. The tourmaline decreases in size and abundance away from the pegmatite borders, and the tourmalinized zone rarely exceeds 2 feet in thickness.

Textural facies of the quartz-mica schist are conspicuous in places. Several beds in the area are characterized by closely spaced, roughly ellipsoidal "knots". The "knots" are from one-eighth of an inch to 1 inch in longest dimension, are oriented with the shortest dimension normal to the schistosity, and are composed of essentially the same minerals as the schist, though not necessarily in the same proportions. They are spaced irregularly, from half an inch to 4 inches apart. In some exposures the folia of the schist seem to pass through the "knots" and in others to pass around the "knots". The material composing the "knots" is not uniform, but it is always different from the enclosing schist. The component grains may be finer or coarser, they may be aggregated in a different manner, the proportions of minerals may be different, and invariably the "knots" weather differently. The "knots" have irregular and in some cases gradational boundaries. A thin section across several "knots" shows them to be composed almost entirely of medium-grained muscovite in flakes of random orientation; the surrounding schist is made up predominantly of fine- to medium-grained quartz, with subordinate quantities of fine-grained biotite, muscovite, and chlorite, and accessory magnetite, zircon, and apatite. The "knots" in another bed contain the same minerals as the schist (principally quartz, micas, chlorite, and staurolite), but the aggregate is outlined by a band rich in interstitial limonite, and the schistosity passes around the limonitic shell. Lovering (1935, pp. 7-8) describes a "knotted schist" in the Montezuma quadrangle which he likens to the schist with "ellipsoidal masses" described by Ball (1908, p. 41) and to the "pebble-bearing gneiss" of Spurr (1908, p. 177). Lovering states the "knots" consist of medium-grained quartz with small amounts of sillimanite, and attributes them to extreme metamorphism attended by the migration of siliceous and aluminous material. The "knots" in the schist of the Hyatt area are more varied in composition but may be, nevertheless, the result of the migration of material during metamorphism; the muscovite in the "knots" may have been formed by retrograde metamorphism of original andalusite or sillimanite.

Quartz schist is less common than the quartz-mica schist, though the varieties are gradational and have not been mapped separately. Massive quartzites are rare, but directly south of pegmatite 504 a quartzite with a maximum width of two feet trends westward for 430 feet (pl. 1). Between the Hyatt pegmatite and pegmatite 631, a seven-foot quartzite bed trends approximately N. 15° W. for 120 feet.

A few rounded boulders of a rock composed of lime silicate minerals have been found in the Crystal Mountain district. These apparently were derived from thin limy beds but none have been recognized in the abundant outcrops along the steep valley walls. The dominant minerals are plagioclase (labradorite, An_6Ab_4), epidote, and quartz; abundant accessory minerals are hornblende and garnet. Magnetite, siderite, zircon, and sericite are present in minor quantities.

The schist has undergone no serious deformation since the schistosity was formed and recrystallization was completed. Shredded and bent mica flakes, and strained quartz grains are very rare. Andalusite, staurolite, sillimanite, and tourmaline grains and needles are intact despite their susceptibility to dislocation. Retrograde metamorphism has caused the local degeneration of some andalusite to quartz and mica, and of biotite to chlorite, and biotite to muscovite. There is no record, however, of large-scale retrogressive metamorphism. The metamorphism of the schists, as indicated by andalusite and sillimanite, is high grade in places, although the more widespread and abundant staurolite and garnet suggest that most of the rocks are middle grade. The well-developed schistosity and foliation,_/, as well as the widely distributed and well-developed linear arrangement of biotite and, to a lesser extent, of quartz, indicate that these rocks recrystallized under great stress characteristic of the middle grade of metamorphism of Harker (1932, pp. 198-199).

_/ Harker (1932, p. 203) distinguishes between schistosity and foliation: schistosity is the result of the orientation of minerals into plane parallelism, foliation is due to segregation of minerals into planes or thin layers of contrasting composition.

Granite

The granite in the Crystal Mountain district is a medium- to coarse-grained biotite granite that has many textural and color variations. It is correlated with the Mount Olympus granite because of its similar composition, its mode of occurrence, and its closeness to areas of Mount Olympus granite described by Boos and Boos (1934, pp. 323-324, and fig. 2, p. 308, and 1948, p. 1398). The typical Mount Olympus granite forms irregular masses, large sheets, and sills. It is not confined to a single more or less regular mass as are the larger and better known granites of the Front Range. With two possible exceptions, the granite in the Hyatt area forms essentially concordant bodies. Isolated sills range from 1 to perhaps 200 feet in thickness; the average is about 15 feet. The marginal members of multiple sills have approximately the same range of thickness, but the central members may be much thicker. The two largest granite masses, to the north and southwest of the Hyatt ranch, are multiple sills. The full extent of the northern mass has not been mapped but the part shown in plate 1 has been demonstrated to be a multiple sill by the flow structures and schist partings that parallel the contacts and structure of the country rock. The southern mass, though smaller, has a more massive core of granite flanked by marginal sills, and many satellitic sills to the south. The granite in both masses is intricately interfingered with the schist; the majority of the relatively smooth contacts shown on plate 1 are concealed contacts.

The schist partings are in some places pendants of wall rock, in others they appear to be isolated slabs or screens. The partings range from slabs of schist 20 feet thick to mere films having the dark color, fine grain, and oriented quartz and micas typical of schist. They range from 20 feet to several hundred feet in length. Schist partings in the granite masses are distinctly weak zones, readily etched out by weathering and erosion, that becomes steps or notches which gather talus or a thin stony soil capable of supporting trees and shrubs. More schist partings probably exist than were observed, but they could not be discriminated readily from joint-controlled features.

The isolated sills are consistently concordant. Discordance of any part of the large multiple sills is not obvious in the field but the shapes of the two large granite masses indicate some discordant contacts.

The granite is composed principally of orthoclase, microcline, and quartz, with lesser amounts of biotite, muscovite, and plagioclase, and minor quantities of apatite, magnetite, and zircon. A few minute crystals of tourmaline are present in one thin section, and another contains siderite along the edges of magnetite grains. A red-brown mineral, probably hematite, clouds the orthoclase of one sill. Orthoclase commonly has been sericitized along fractures and cleavage lines, and generally the orthoclase shows pronounced zoning and twinning. The biotite is partially chloritized, and it ranges in texture from very fine-grained to coarse-grained. The margins of the sills in some places show a border zone, one-eighth to one-half inch wide, of finer grain than the bulk of the sill.

The Mount Olympus biotite granite has a different appearance in different sills. It is light gray to medium gray, depending upon the size and abundance of biotite flakes. One brick-red sill owes its color to the myriad of red-brown specks, probably hematite, that cloud the orthoclase. In another sill a tapioca-like effect is caused by large rounded grains and aggregates of orthoclase in a fine-grained dark matrix of quartz and accessory biotite, muscovite, magnetite, and apatite. The orthoclase grains in some sills are larger than the rest of the minerals and give the rock an irregular mottled appearance. In sills where the major constituents are of roughly equal size the rock has the speckled "salt-and-pepper" appearance of typical granite. Longitudinal fractures, thin pegmatites, and biotite flakes in many exposures are parallel to the sill wall, and appear to be related to flowage at the time of intrusion.

Straight parallel-sided quartz veins, ranging from knife-edge width to 3 inches, cut the granite and are in turn cut by pegmatite. Quartz veins intersected by pegmatites are in some instances displaced as much as 6 inches. The relative displacement is always in the same direction: the northwest wall moved northeastward on northeast-trending pegmatites.

Diorite

Scattered boulders of porphyritic fine-grained black diorite are found in a small area between pegmatites 77 and 80 _/ in the northern part of the

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_/ Individual pegmatites are identified by number in plate 4, Index map of pegmatites in the Hyatt area, Crystal Mountain district, Colorado, for location on plate 1.

Hyatt area. Judging from the fineness of grain the boulders probably came from a dike similar to many dikes known in the Front Range. The rock is composed of plagioclase and hornblende with accessory magnetite and minor amounts of apatite and quartz. There are two distinct ages of plagioclase: the large laths are andesine (Ab_6An_4) and the small interstitial grains are andesine-oligoclase (Ab_7An_3). The andesine phenocrysts and the hornblende are slightly sericitized. Only a few grains of quartz and apatite are present.

Surficial deposits

The rolling upland surface has a fairly deep soil which is presumably Pleistocene in age. The steep valleys of the latest cycle of erosion are strewn with boulders, talus cones, and rock slides. In the intermediate zone between the new valleys and the old upland the old soil is being removed by slope wash and soil creep, and by gullying of the meadows and mountain parks. The stream valleys are reducing the area of upland surface, in the process of developing a mature drainage system at the new base level for the Front Range.

Structure

The schist of the Hyatt area strikes approximately east and dips southward. Folds in the schist plunge southward at angles ranging from 25° to 75°. The schist in the vicinity of the Hyatt pegmatite dips about 75° southward and forms small symmetrical folds that plunge to the south. The schist on the hanging wall of the northern granite mass dips southward at angles of 25° to 60°—locally 75°—and is part of a broad fold. West and north of the northern granite mass the metamorphic rocks dip from 45° to 65° southward and strike uniformly east-northeast. (See pl. 1.) The attitude of the schist in the vicinity of the southern granite mass is more irregular and much of the schist dips more steeply than in the rest of the area.

Granite sills and the majority of pegmatites occurring in schist are concordant with the metamorphic structure, as shown in the structure sections (pl. 5). The granite, intruded as several individual bodies along the schistosity of the metamorphic rocks, formed multiple sills in many places.

About thirty of the widest and longest pegmatites in the area are discordant, dipping northward at angles of 65° to 89°. The exact nature and age of the structures controlling the attitude of the discordant bodies are not known. The discordant bodies are concentrated, with few exceptions, in linear groups having two general trends, eastward and northwestward. (See pl. 5A.)

The major folds and fractures apparently resulted from the intrusion of the large multiple sills. It is assumed that the granite, the pegmatites, and the fractures containing the discordant pegmatites were formed during the same period of intrusive activity. The northern multiple sill was formed in schist of moderate dip and produced a broad fold or asymmetrical dome; the doming produced a few tear faults trending northwestward, and fractures arranged in belts trending eastward. Pegmatites were formed both parallel to the schistosity and flow structure, and across it in faults, fractures, and joints.

Near the middle of the northern mass a few faults displace pegmatites. The faults do not exceed 500 feet in length and the maximum displacement is about 20 feet. The fault planes are straight, narrow, and without gouge, breccia, or marginal fractures; they are little more than joints along which minor movements have taken place. The fault planes dip from 45° to 70° to the northwest, and the relative displacements are everywhere in the same direction; the northwest block moved diagonally upward and to the northeast.

The writer infers from the distribution and refractive indices of beryl that there is probably a granite mass, somewhat larger than the ordinary sills, buried at no great depth in the vicinity of the Hyatt pegmatite. The granite which almost surrounds the Hyatt deposit and the body a thousand feet to the east may be attached or closely related to the hypothetical mass, and the anticlinal fold plunging south-southeastward from the Hyatt pegmatite may represent the bowing of the schist by the intrusion of this hypothetical mass. The shape and attitude of the fold suggest that the mass may be a concordant body about 700 feet wide and 500 feet thick, shaped more like a crude cylinder than a tabular sill; the granite exposed near the Hyatt pegmatite may be a part of its irregular top. The fold flattens out abruptly to the north of the Hyatt pegmatite, and tapers out gradually southeastward.

The area has not undergone important deformation since the consolidation of the pegmatites.

PEGMATITES

Distribution

The pegmatites of the Hyatt area are part of a group that extends about 5 miles east and south, and at least 10 miles north and west of the area. Examination of a few deposits outside the area suggests that they are similar mineralogically and structurally to those mapped in the Hyatt area. Some discordant bodies attain larger size and more irregular shape than the concordant bodies, but otherwise, there is no correlation between the pegmatites and their environment. The different mineralogic and textural types of pegmatites are found in all kinds of country rock and structure. Four types of internal structure are recognized in the pegmatites of the district but they are all widely distributed.

Shape and structure of pegmatites

The shape and structure of the pegmatite body can be approximated from a study of the pegmatite contacts, the zones and zonal boundaries, and the structure of the country rock. The shape of the pegmatite is controlled to a large degree by the nature of the country rock and the kinds of openings that can be developed in that rock. In competent rock such as granite the pegmatites are predominantly tabular, branching with angular bends, and have relatively linear courses. (See pl. 1.) In well-foliated rock such as mica schist, the concordant pegmatites are predominantly lenticular, with smoothly curving outlines, and tapering ends. The discordant pegmatites in schist usually have irregular and serrate margins which reflect the jagged fracture of schistose rock. Pegmatites controlled by intersecting structures (such as several systems of fractures or schistosity cut by fractures) may develop highly irregular shapes but the shapes can be determined if the relation between structure and pegmatite can be established. In well-foliated rock the schistose structure, linear elements, and details of the contact give evidence of the structure of the pegmatite body. Jahns (1951, p. 54) found the plunging structures of pegmatites in New Mexico consistently conformable with the plunge of numerous minor structural elements in adjacent country rock. Cameron and others (1945, p. 372) describe the pitch of rolls in some pegmatites of New England as related to structural elements of the enclosing rock. In certain districts of New Hampshire the types of pegmatites that follow the foliation in schist are inclined to wedge out suddenly but, generally speaking, to conform in strike and plunge with the linear structures of the schist, according to Bannerman (1943, p. 8).

The direction and plunge of linear structures impressed on the schist by the pegmatite furnish data for determining the plunge of contact features. The data will rarely, if ever, provide a single complete solution but it will set limits to the extent, shape, and attitude, from which a reasonable compromise must be evolved. The zones reflect to varying degrees the shape of the pegmatite; data on the attitude and dimensions of a zone contribute to the determination of the shape of the neighboring zones and the body as a whole.

Pegmatites whose shapes are controlled by more than one factor present more problems than those controlled by a single factor such as schistosity. The greater part of the Hyatt pegmatite is in granite but both ends extend beyond the granite into schist (pl. 9). The contacts between schist and granite are not exposed. The contacts between pegmatite and wall rocks give a wide range of possible attitude, but the zonal relationships limit the reasonable interpretations to a somewhat narrower range. The shape and attitude of the Hyatt deposit as finally interpreted from the results of drilling (pl. 10) are reasonably close to that of the "compromise body" postulated in advance of exploration.

In a bulbous pegmatite, such as the Big Boulder deposit, whose lower side is concealed, the exposures of pegmatite indicate the attitude of the roughly convex upper surface, and the dips and plunges do not necessarily relate to the converging lower surface. A small keel-like exposure in the undercut outcrop at the north end of the deposit (pl. 22) was used as the principal basis for predicting the location and inclination of the lower side of the body; two diamond-drill holes based on this interpretation did not intersect the pegmatite because the plunge of that small exposure was more steep than the plunge of the entire body.

The Buckhorn Mica pegmatite has been extensively eroded but the contacts along the western part of the deposit do not indicate the plunge of the west end of the body. Indecisive evidence suggested that a crest might plunge steeply westward or a keel might plunge eastward. (See pl. 29.) Drilling indicated a keel with a moderate eastward plunge, and the Buckhorn Mica pegmatite proved to be smaller than the "compromise body" postulated before drilling. The structures in the schist and the plunge of the line of intersection of the contacts in the eastern part indicated that the keel at the east end plunged about 40° to the west; exploration confirmed this interpretation.

The structure of internal units in many pegmatites reflects the structure of the nearest contact with remarkable fidelity. "Rolls" in the contact (anticlinal or synclinal bends or folds) in some places determine the localization in internal units of shoots or pockets of valuable minerals. The relationship between the two features is well exposed in some districts by mining, and examples have been described by Cameron and others (1945, pp. 377-380, p. 388), Bannerman (1943, pp. 11-12), and Jahns (1951, p. 54). The information obtained by studies in other districts has been useful in projecting external and internal structures below the surface to determine shape and attitude of pegmatites, and to interpret the results of drilling.

The pegmatites of the Hyatt area have a wide variety of sizes and shapes as shown in plate 1 but a few examples to indicate the maximum sizes may prove useful in making comparisons with other districts.

The longest pegmatite completely enclosed in granite is pegmatite 272. It has a length of 1,050 feet, an average width of 8 feet, and a maximum width of 12 feet. Pegmatite 259 in the same area is the widest, ranging from 11 to 24 feet and averaging 15 feet; it is 830 feet long.

The longest concordant pegmatite enclosed in schist is pegmatite 584. It is 2,675 feet long and 2 to 4 feet wide. The widest concordant pegmatite (585) is 2,100 feet long: it ranges from 2 to 18 feet in width and averages 12 feet. The greatest width of concordant multiple pegmatite is 200 feet (pegmatite 846). The discordant pegmatites in schist vary widely in size. Multiple pegmatite 448 is the longest with an over-all length of about 2,500 feet; the maximum width is 130 feet. Pegmatite 1197, which has the greatest width, is as much as 250 feet. If pegmatites 1197 and 1199 should prove to be a continuous body, it would be the largest mass of pegmatite in the Hyatt area.

Despite the relatively small average dimensions of the individual bodies in the western part of the northern granite mass, the myriad of interconnected pegmatites exposed there probably contains the greatest concentration of pegmatitic material in the area.

Textures

The textures of individual units within pegmatites vary widely. The grains commonly attain sizes so much larger than those in other rocks that the ordinary descriptive terms must be redefined. The size classification used in this report is that given by Cameron and others (1949, p. 16):

Term	General grain size
Fine	Less than 1 inch
Medium	1 to 4 inches
Coarse	4 to 12 inches
Very coarse	Greater than 12 inches

Statements with regard to the grain size of a pegmatite or unit indicate the general appearance in exposures; it is a qualitative expression of the size of the grains comprising the bulk of the material. Interstitial grains may be very much smaller, and a few grains or masses may be much larger than the average size or range indicated. (See pl. 8A.) Bastin (1911, p. 10) regards this irregularity of grain of pegmatites as more distinctive than the coarseness that is so widely emphasized.

The texture and range of grain size of the principal zones of the explored pegmatites are summarized in table 2. All the minerals increase in average grain size toward the center of the pegmatite, but each mineral seems to have its own rate of change in grain size. The increase is most spectacular in zoned pegmatites, but the change is apparent in homogeneous pegmatites. Perthite exhibits the most obvious increase in grain size. Quartz, whether in single grains or aggregates, increases in size many-fold from the border zone inward. Muscovite in a few places shows a great increase in size, as for example, from the contact to the inner intermediate zone at the Hyatt pegmatite and from the contact to the outer intermediate zone of the Buckhorn Mica mine, but ordinarily it is less marked than that of perthite and quartz. Plagioclase shows the lowest rate of increase. Though the minerals may be present near the center of a homogeneous pegmatite in approximately the same proportions as near the contact, the increase in size of the perthite and quartz is more conspicuous because the plagioclase is in part interstitial to the larger grains and in part masked by weathering, staining, and vegetal matter. The changes in grain size for the minerals of a well-exposed zoned pegmatite and a typical homogeneous pegmatite are summarized in table 3.

Boundaries between pegmatite units are more generally gradational than abrupt because of the over-all coarseness of the component minerals. The boundaries between well exposed fine- and medium-grained units of contrasting composition can be fixed ordinarily within a foot or two, but the boundaries between coarse- and very coarse-grained units are less well

Table 2.--Grain sizes of three-zoned pegmatites in Crystal Mountain district, Colorado

	Texture	Range in size of the majority of grains (inches)	Range in size of all grains (inches)
Hyatt pegmatite:			
Border zone	Fine	<1	0.01- 4
Wall zone, upper and lower	Coarse	4-12	0.01- 36
Inner intermediate zone	Coarse	4-12	0.01- 60
Core	Very coarse	>12	0.01-120
Big Boulder pegmatite:			
Border zone	Fine	<1	0.01- 1
Wall zone	Fine	<1	0.01- 3
Upper intermediate zone	Medium	1-4	0.01- 8
Lower intermediate zone 1/	Coarse	4-12	0.01-30?
Hood	Very coarse	>12	0.01-72
Core 1/	Very coarse	>12	0.01-60?
Buckhorn Mica pegmatite:			
Border zone	Fine	<1	0.01- 5
Wall zone	Fine	<1	0.01- 3
Outer intermediate zone	Medium	1-4	0.01- 12
Inner intermediate zone	Medium	1-4	0.01- 24
Core	Coarse	4-12	0.01- 36

1/ Maximum dimension inferred from drill core.

Table 3.--Comparison of changes in grain size in a zoned pegmatite and homogeneous pegmatite, Crystal Mountain district, Colorado

	Hyatt pegmatite		Homogeneous pegmatite	
	Range of grain size in wall zone (inches)	Range of grain size in or near core (inches)	Range of grain size within 5 inches of contact (inches)	Range of grain size near center of pegmatite (inches)
Perthite	0.01 - 4	0.01 - 120	0.01 - 1	0.01 - 10
Quartz	0.01 - 3	0.01 - 48	0.01 - .7	0.01 - 10
Plagioclase	0.01 - 1	0.01 - 8	0.01 - .4	0.01 - 1
Muscovite	0.01 - 2.5	0.01 - 15	0.01 - .4	0.01 - 2.5
Beryl	0.01 - 1.75	0.01 - 48	0.01 - .8	0.01 - 2
Tourmaline	0.01 - 2	0.01 - 4	0.01 - 1	0.01 - 2
Garnet	0.01 - .2	0.01 - .6	0.01 - .2	0.01 - 1

marked, especially if the mineralogy is closely related. The general sequence of mineral assemblages (table 6) shows that most assemblages are closely related mineralogically to those earlier and later in the sequence. The average composition and texture of a zone may contrast sharply with the average for those adjacent to it but the boundaries are in most places gradational. In the Big Boulder deposit the boundary between the hood of perthite-quartz pegmatite and the core of quartz pegmatite (pl. 22) must be drawn between zones with a common mineral and also across a texture featuring the interlock of grains as much as 6 feet in size. The boundary is drawn so that the average composition of the core does not include more than 5 percent of perthite, although a trench along the boundary as drawn might show that some perthite grains overlap the boundary or some isolated perthite crystals were present in the quartz core. In all the maps of zoned pegmatites the boundaries between zones have been drawn as relatively smooth lines whereas development work will inevitably show an intricate serrate relationship of the individual mineral grains.

Internal structure of zoned pegmatites

The lithologic and structural units found within pegmatite bodies differ in mineralogy, or texture, or both. Three basic types of units are distinguished and are defined by Cameron and others (1949, pp. 13-24) as follows:

1. Fracture fillings are units, generally tabular, that fill fractures in previously consolidated pegmatite.
2. Replacement bodies are units formed primarily by replacement of pre-existing pegmatite, with or without obvious structural control.

3. Zones are successive shells, complete or incomplete, that reflect to varying degrees the shape or structure of the pegmatite body. Where ideally developed they are concentric about an innermost zone or core. Some concentric units, however, are not zones but belong in the categories above.

The term "unit" includes all three types of bodies defined above.

Fracture fillings

Fracture fillings are common although minor features of pegmatites in the Crystal Mountain district. Quartz-filled fractures are the most abundant and rarely exceed 30 feet in length. They commonly are from 1 to 12 feet long and from knife-edge to 3 feet wide. Pegmatitic fracture fillings in homogeneous pegmatites are apparent because of differential weathering; they invariably differ in texture from the enclosing body, and are etched out by weathering.

Fracture fillings may be homogeneous or zoned and may occur within homogeneous or zoned pegmatites. Pegmatite 645 (pl. 1) is not zoned but one fracture filling is a zoned unit containing a wall zone of plagioclase-perthite-quartz-muscovite pegmatite, and a core of perthite-quartz-plagioclase pegmatite. At the Big Boulder prospect a fracture filling composed of perthite-quartz pegmatite extends from the hood-shaped inner intermediate zone across the outer intermediate and the wall zones. (See pl. 22.) The fracture filling has a gently curved trace and steep dip, but its vertical extent is not known. It can be traced into the hood for about 4 feet where it merges with the minerals of the inner intermediate zone.

The margins of fracture fillings are fine grained and in some places contain oriented muscovite flakes and quartz grains. Beryl crystals in the wall zone of the fracture filling in pegmatite 645 (pl. 1) are oriented with the long axis normal to the wall of the fracture. Pegmatite 448 (pl. 1) contains two beryl-bearing fracture fillings at the east end. Both are nearly flat lying and occur near the top of the body. In one fracture filling 161 beryl crystals are exposed, and the beryl content is about 0.28 percent. In the other fracture filling 52 crystals are exposed and the beryl content is 0.3 percent. Pegmatite 645 (pl. 1) contains many fractures with an average strike and dip of N. 60° W., 40° S., but only a few contain beryl-bearing pegmatite; the best exposed fracture filling has over 500 small beryl crystals, and the rock has a beryl content of 0.9 percent. The beryl-bearing fracture fillings rarely exceed 3 feet in thickness, the maximum being about 5 feet. The average dimensions of fracture fillings are about 1 foot thick, 60 feet long, and 15 feet wide, and the tonnage of contained beryl is small.

Replacement bodies

No mappable replacement bodies have been recognized in the pegmatites of the Crystal Mountain district. Cameron and others (1949, pp. 83-97) have described replacement bodies in other parts of the country.

Zones

A zoned pegmatite is one consisting of two or more successive shells, and may or may not contain fracture fillings or replacement bodies. Zoned pegmatites are comparatively rare in the Crystal Mountain district. Of the 1,300 bodies mapped in the Hyatt area, 28 have been designated as zoned pegmatites. Of these, 27 consist of two zones and are listed in table 4; one, the Hyatt deposit, has five zones.

Table 4.—Pegmatites consisting of two zones, Hyatt area, Crystal Mountain district, Colorado

Pegmatite number	Mineralogic composition 1/ Wall zone	Core	Beryl content
405	P, Pg, Q	Q	0.09 percent
441	Pg, P, Q	P, Pg, Q	None
442	P, Pg, Q	P, Pg, Q	Trace
443	P, Q, Pg	P, Pg, Q	Trace
464	Pg, P, Q	P, Pg, Q	None
512	Pg, Q, P	P, Pg, Q	Trace
527	Pg, P, Q	P, Q, Pg	0.10 percent
563	Pg, Q, P	Pg, P, Q	None
565	Pg, Q, P	P, Pg, Q	0.02 percent
566	Pg, P, Q	P, Q, Pg	0.07 percent
567	Pg, P, Q	P, Q, Pg	0.31 percent
571	Pg, P, Q	P, Q, Pg	Trace
642	P, Pg, Q	P, Pg, Q	Trace
748	P, Pg, Q	Q	Trace
766	P, Pg, Q	Q	Trace
773	P, Pg, Q	Q	None
774	P, Pg, Q	Q	None
779	P, Q, M	Q	0.56 percent
2/ 781	P, Pg, Q	Q	Trace
827	P, Q, Pg	Q	0.15 percent
859	P, Pg, Q, M	Q	None
939	P, Pg, Q	Q	None
1017	Pg, P, Q	P, Pg, Q	Trace
1039	P, Pg, Q	P, Q, Pg	None

Table 4.--Pegmatites consisting of two zones, Hyatt area, Crystal Mountain district, Colorado (continued)

Pegmatite number	Mineralogic composition 1/ Wall zone	Core	Beryl content
1068	P, Pg, Q	Q	0.02 percent
2/ 1111	Pg, Q, P	P, Pg, Q	Trace
1284	P, Q, Pg	Q	None

1/ Essential minerals are stated in order of decreasing abundance, perthite (P), plagioclase (Pg), quartz (Q), muscovite (M).

2/ Zoned pegmatite is one member of a multiple pegmatite.

Zones have been classified by Cameron and others (1949, p. 20) as (1) border zones, (2) wall zones, (3) intermediate zones, and (4) cores.

Border zones

The border zone is the outermost zone of a pegmatite and constitutes a fine-grained selvage that is not more than a few inches thick in most pegmatites. In most border zones the minerals, especially muscovite and quartz, show a preferred orientation normal to the contact. Minerals with an elongate habit, such as tourmaline and beryl, exhibit preferred orientation to a marked degree when present in the border zone.

Quartz and muscovite, and in some places plagioclase, are the dominant minerals of border zones adjacent to schist; the texture of these border zones is universally fine-grained, the minerals averaging less than one-quarter of an inch. The cleavage between schist and border zone is invariably sharp and distinct.

Border zones of pegmatites in contact with granite are somewhat less regular and not so well defined. The minerals of the border zone interlock noticeably with those of the granite even where there is a seemingly sharp contact between the two rocks. Quartz and feldspars are the dominant minerals and muscovite is a minor accessory; plagioclase is subordinate to perthite in most border zones in contact with granite. The margins of many pegmatites grade into granite over a width of an inch or two. Gradational contacts are ordinarily irregular and it is impossible in some places to fix the precise limits of the border zone. Perhaps, in a strict sense, there is no border zone in these places.

Wall zones

The wall zone is inside the border zone, and is generally coarser-grained and thicker. In describing the zoning of some pegmatite deposits in Brazil the term "border zone" has been used by Pecora and others (1950a and 1950b) to include both the border zone and wall zone as here used. A common practice in pegmatite mining districts of the United States is to include border zone and wall zone, as defined here, in the term "wall zone."

Wall zones of pegmatites in the Crystal Mountain district are invariably composed of feldspars and quartz; in some deposits perthite is much more common than plagioclase, and in others the reverse is true. Quartz is subordinate to the feldspars, and muscovite is a minor constituent. Beryl, tourmaline, and garnet are present in many wall zones as accessory minerals. In a few deposits the beryl content is about 1 percent.

The texture of most wall zones is medium- to fine-grained, and the minerals have a random orientation. Some minerals in wall zones exhibit a preferred orientation with the long dimension normal to the wall of the pegmatite, for example, the beryl crystals in the wall zone of the fracture filling of pegmatite 645 (pl. 1). Tourmaline crystals, though uncommon in the wall zone in the Crystal Mountain district, are oriented similarly in some deposits.

<u>Intermediate zones</u>

Any zone between the core and wall zone is an intermediate zone; if there are two or more, they can be designated by letter, number, or such terms as "inner," "middle," and "outer." Most intermediate zones are shells around a core, but some as in the Hyatt pegmatite are discontinuous and lenticular. The Hyatt, Big Boulder, and Buckhorn Mica pegmatites all contain more than one zone between the wall zone and the core. Perthite-rich intermediate zones of some pegmatites are discontinuous and show a marked tendency to be concentrated in the upper part of the pegmatite; such a dome-like deposit, concave inward and downward, is referred to as a "hood". The Big Boulder pegmatite contains a prominent hood of perthite-quartz pegmatite. The other zoned pegmatites described in this report contain only wall zones and cores, in addition to the very thin border zones. In each of the polyzonal deposits the texture and mineralogy are sufficiently distinctive and well exposed that more than two mappable units can be distinguished.

Cores

The core is the innermost zone and occurs at or near the center of the pegmatite, commonly as an elongate lens or a series of disconnected segments. Cores of pegmatites in the Crystal Mountain district are, for the most part, quartz or perthite, or both. The core of the Hyatt deposit is perthite pegmatite (pl. 9) and that at Big Boulder prospect (pl. 22) is quartz pegmatite. The core of the Buckhorn Mica pegmatite (pl. 29) is the only exception in this district and it is composed of cleavelandite-quartz-spodumene (?) pegmatite. The texture of the cores is very coarse. The cores of thin pegmatites are invariably thin and may be discontinuous. The core of the Buckhorn Mica deposit has the shape of a flat lens with a maximum width of 12 feet and a length of 160 feet. Bulbous bodies like the Hyatt and Big Boulder pegmatites have somewhat ovoid cores consistent with the shape of the entire body. Pegmatite 464 is a narrow pegmatite with a pronounced bulge near the middle, and a quartz core is present only in the bulge (pl. 1). A similar relationship has been described by Cameron and others (1945, p. 383) at the United Mine, Grafton, N. H., and E. E. Smith mine, Alexandria, N. H., and other deposits. There is no fixed ratio between the size of the pegmatite and the size of the core; in some bodies the core constitutes a small percentage of the pegmatite, and in others, such as the Crystal Silica deposit described by Hanley, Heinrich, and Page (1950, pp. 93-96), the core seems to make up over half of the pegmatite.

Telescoped zones

Two or more zones that are clearly defined in parts of a given pegmatite may appear elsewhere to merge along their dip or strike into a single unit whose composition corresponds to the bulk composition of the two zones. Such "telescoped" zones bear the same relationship to the adjacent zones as that occupied jointly in other parts of the pegmatite by the zones into which the single unit can be traced. Telescoping may present the reverse impression to the one described above: a zone continuous around the core may show a local segregation of minerals so marked that two mappable units are formed. The bulk composition of the segregated units corresponds to that of the full zone into which they can be traced. At the Hyatt pegmatite the hanging wall side of the intermediate zone of plagioclase-quartz-perthite-muscovite pegmatite shows such a segregation of minerals into two mappable units: an outer intermediate zone of perthite-quartz pegmatite and an inner intermediate zone of plagioclase-quartz-muscovite pegmatite.

Shoot

The terms "shoot," "streak," "pocket," and "lens," are used to describe local concentrations of particular minerals or textures within a zone and carry the connotations established by general use in mining. The minerals of a particular zone may be uniformly disseminated but commonly are more irregularly distributed; this is especially true of the minor constituents. Tourmaline, beryl, garnet, and the rare minerals commonly occur within a zone as local concentrations separated by relatively barren rock. The beryl in the inner intermediate zone of the Hyatt pegmatite is found in pockets of coarse-grained crystals and masses. The pockets discovered by past mining (pl. 9) have been 6 to 12 feet long, generally extended the full width of the zone, and have been 10 to about 35 feet apart. The fine-grained beryl in the wall zones of the Hyatt, Big Boulder, and Buckhorn Mica pegmatites is not segregated into pockets or shoots but the distribution is sufficiently irregular to necessitate extensive sampling in order to obtain a representative analysis. Large books of muscovite are scattered irregularly throughout the inner intermediate zone of the Hyatt pegmatite, but much of the fine-grained muscovite has been found concentrated in streaks 1 to 30 feet long, and from 1 inch to 5 feet wide. The mica streaks overlap the beryl pockets to some extent, but do not everywhere coincide with them. At the Big Boulder prospect garnet occurs in pockets of closely packed euhedral and subhedral crystals. The individual crystals are as much as one inch in diameter and the pockets are ½ to 3 feet in size.

Homogeneous pegmatites

A pegmatite that consists of a single zone enclosed between border zones, i.e., is uniform from wall to wall, except for the selvages, was designated as a "homogeneous pegmatite" by Johnston (1945, p. 1,025). Most of the pegmatites of the Crystal Mountain district are of this type, and differ from zoned pegmatites in grain size and degree of segregation of the essential minerals. Bodies exhibiting uniform texture and proportions of minerals from wall to wall are almost as unusual in the Crystal Mountain district as those made up of sharply contrasted zones. Even the zones within zoned pegmatites may show widely differing proportions of the essential minerals in short distances.

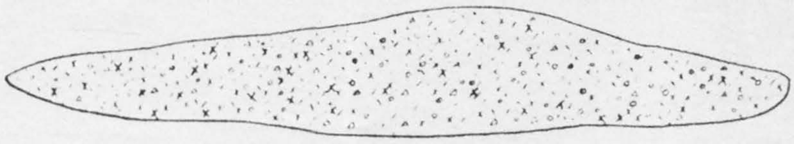
Perthite, plagioclase, quartz, and muscovite are the most common minerals in homogeneous pegmatites of the Hyatt area. Perthite has the most variable grain size. Quartz grains increase in size and form aggregates in progressively larger clots or pods toward the center of the pegmatite.

Muscovite, though a minor constituent, forms distinct books in the interior of the bodies in contrast to the tiny flakes near the walls. Plagioclase grains increase in size toward the center, but the increase is less than that of the other minerals.

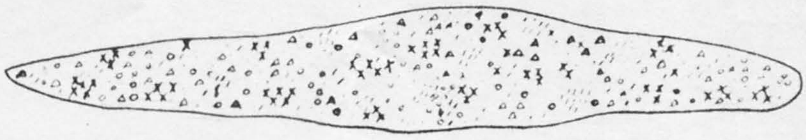
The relative proportions of the various minerals may change as well as the grain size, generally perthite and quartz increasing in abundance at the expense of the plagioclase. The texture and mineral distribution in a great many pegmatites is irregular because perthite, and quartz, or both, occur in clots scattered throughout the perthite-plagioclase-quartz pegmatite which forms the bulk of the deposit. In other bodies the clots are more or less centrally located. A group of pegmatites could be selected to show gradation from homogeneous bodies to pegmatites consisting of a wall zone and core, similar to the diagrammatic sequence of plate 6. In discussing pegmatites in New England, Cameron and others (1945, p. 373) note that there is no sharp distinction between zoned and "unzoned" or homogeneous bodies. For purposes of this report an arbitrary limit has been drawn between homogeneous pegmatites containing scattered clots of minerals and zoned pegmatites containing cores. If the more or less centrally located concentrations of clots are continuous for at least one-quarter of the length of the pegmatite, and have a width of at least one-fifth of the width of the pegmatite, they are considered cores and the pegmatites in which they occur are designated as zoned bodies. This definition of the lower limit of zoning places about 2 percent of the pegmatites of the Hyatt area in the zoned class. Over 1,300 pegmatites are plotted in plate 1; of these 1,234 or 94 percent are classed as homogeneous.

U. S. Department of the Interior
Geological Survey

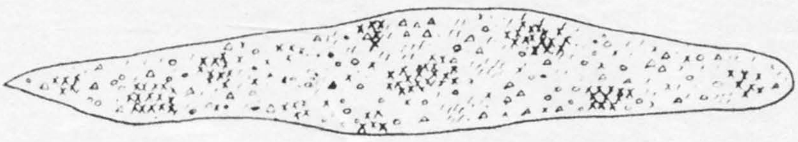
Trace Elements Investigation
Report 139



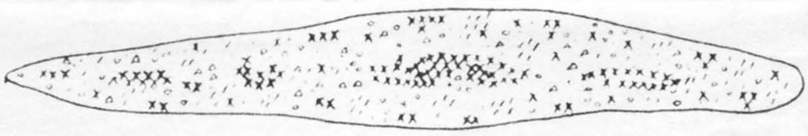
A. Uniform texture and dissemination of minerals.



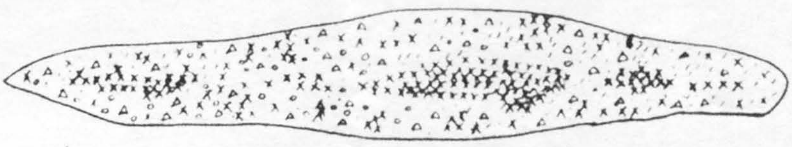
B. Irregular texture and distribution of minerals.



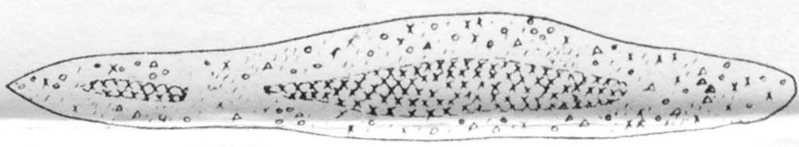
C. Irregularities accentuated by formation of clots.



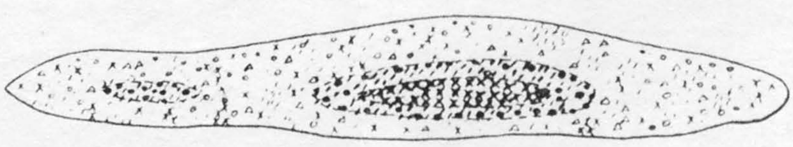
D. Clots arranged symmetrically with respect to the walls.



E. Intermediate stage between central clots and discontinuous core.



F. Discontinuous core of zoned pegmatite.



G. Discontinuous core in pegmatite containing three zones.

Plate 6 . Idealized plans of pegmatite bodies showing sequence of types between homogenous pegmatites and zoned pegmatites.

Multiple pegmatite

The term "multiple intrusion" is credited to Holmes by Stokes and Varnes (in preparation) and defined as:

> "A term applied to sills, dikes, laccoliths, and other intrusions formed by two or more successive injections of approximately the same magma."
> (Holmes, 1928)

The term "multiple pegmatite" is used in this report to designate bodies mapped and described as one pegmatite which consists of two or more pegmatitic masses separated by screens or partings of country rock, or by border zones. In many parts of the Crystal Mountain district there are clusters of pegmatites so narrow and so closely spaced that they can not be plotted individually at a scale of 1:6,000. The members of multiple pegmatites are, with few exceptions, homogeneous bodies. Pegmatite 846 is a continuous mass of pegmatite but is made up of a number of individual members. Between pegmatites 723 and 746 (pl. 1) are about 75 individual intrusions forming a series of 24 multiple pegmatites.

Banded pegmatite

The term "banded" is used to describe the appearance and internal structure of a few pegmatites in the Hyatt area composed of alternating bands of light and dark minerals. Feldspar and quartz predominate in the light bands, and muscovite and quartz predominate in the dark bands. Tourmaline is abundant in the dark bands of a few banded pegmatites and greatly intensifies the contrast between bands. In pegmatite 629 (pl. 1), tourmaline constitutes about 1 percent of the dark bands. The banding is most sharply defined in pegmatites of very fine-grained texture where the grains average less than one-quarter of an inch in diameter. With increasing grain size the banding becomes less distinct. Banding is roughly parallel to the walls whether the pegmatite is in schist or in granite, or whether concordant or discordant. Pegmatite 625 is partly discordant but the banding parallels the walls throughout the body. No pegmatite is known to be uniformly banded throughout its length; banded portions merge with homogeneous material either along the strike or across the width. Within a single exposure banded pegmatite may appear to cut and be cut by typical unbanded pegmatite. The narrow east-trending offshoot of pegmatite 432 is discordant and is crudely banded. The banding is parallel to the contact, but is separated from the contact by a 2-foot, fine-grained, feldspar-rich layer. A fracture filling, 3 inches wide, cuts across the feldspathic layer from the banded layer to the wall. The fracture filling is not banded but is of the same composition and grain size as the banded rock. The fracture filling is neatly outlined by garnet grains and muscovite flakes.

This use of the term "banded" differs from that of Ball (1908, p. 63) who states:

> "..... granular pegmatites grade along their strike into rudely banded dikes, quartz being commonly segregated in the center (fig. 17). . . . ."

The description and figure 17 in Ball's report refer to a pegmatite that the writer would describe as a pegmatite with a feldspar-rich wall zone and a quartz- and biotite-rich core.

Mineralogy

The internal units of pegmatites are designated by names that express composition in terms of essential minerals. The order of mineral names in the designation is in approximately the decreasing order of abundance, and in most cases includes those that are present in the unit in excess of 5 percent. The essential minerals of a majority of the pegmatites in the district are perthite, plagioclase (albite and cleavelandite), and quartz. Muscovite is an essential constituent in the inner intermediate zone of the Hyatt deposit. Tourmaline is an essential mineral in a few small bodies. In order to distinguish the core from the innermost intermediate zone at the Buckhorn Mica mine it is necessary to include the name of a relict mineral in the designation: the inner intermediate zone is quartz-cleavelandite pegmatite and the core is quartz-cleavelandite-spodumene (?) pegmatite, though the spodumene is represented only by aggregates of fine-grained albite and sericite, pseudomorphous after spodumene. In the field the difference in the units is very apparent, but the mineralogy is approximately the same, except for the pseudomorphs.

Proportions of minerals were determined in the field by inspection and noted as percentage composition.. The beryl content of each outcrop was determined by measuring the area of every discernible grain of beryl and calculating the percentage with respect to the area of the exposure. In pegmatites that contain over 0.1 percent beryl, the total area of rock studied by grain counting was at least 1 percent of the calculated surface area of the deposit. Experience has shown that careful grain counting is an accurate measure of percentage composition: estimates of ore grades at the Hyatt, Big Boulder, and Buckhorn Mica pegmatites based on grain counts made by Hanley, Page, and the writer between 1942 and 1948 were confirmed by mine productivity at the Hyatt mine in 1948, and by bulk assays made in 1949 and 1950. Similar confirmations have been obtained for the work in South Dakota.

Mineralogic types of pegmatites

Six mineralogic types of pegmatites, based on bulk mineralogic composition, are recognized in the Hyatt area. Five of the types are mineralogic assemblages common in many pegmatite districts, but the sixth is an anomalous assemblage in which tourmaline is a major constituent. The types and the number of pegmatites included in each type are given in table table 1.

The descriptions of individual pegmatites in the Hyatt area are arranged in table 17 by mineralogic types in the same order as in table 5. The individual bodies are numbered to correspond with the index map (pl. 4), from which they can be identified on the geologic map (pl. 1). A few small pegmatites are shown without numbers or corresponding descriptions.

Sequences of mineral assemblages as units of zoned deposits have been determined for many districts and the assemblages in four districts have been summarized by Cameron and others (1949, pp. 59-70); the assemblages in the Black Hills, S. Dak., have been described in detail by Page and others (in preparation). The mineralogic types of pegmatites in the Hyatt area are analogous to mineralogic units recognized in pegmatites of the Black Hills. Page's tabulation of mineral assemblages is reproduced as table 9, with the addition of small arrows to indicate the mineralogic types of pegmatites observed in Hyatt and other areas in the Crystal Mountain district.

Comparison of table 5 with table 6 shows that the pegmatites of the Hyatt area have a relatively limited range of composition. Those of the first four types (table 5) contain perthite, plagioclase, and quartz, and comprise 96 percent of the bodies in the area. These are all variants of assemblage 3 (table 6). Those of the fifth type are representatives of assemblage 12 (table 6).

The dominant units of zoned pegmatites in the Hyatt area consist of assemblages 3 and 4, or 3 and 12. The border zones are quantitatively in-significant; many have the composition of assemblage 1, and some, principally those in granite, are of assemblage 3. Many homogeneous pegmatites contain clots of perthite or quartz, or both, which may be regarded as incipient development of assemblages 3 and 4. The Hyatt pegmatite is the only body with more complex zoning and is considered separately.

Lithium minerals are not abundant in the district and, therefore, assemblages 5, 7, 8, 9, and 11 are not represented. The presence of trace quantities of lithium at the Hyatt, Big Boulder, and Buckhorn Mica pegmatites is indicated by minor amounts of Li-Mn-Fe phosphates and by relict spodumene; in these three bodies assemblage 6, plagioclase-quartz pegmatite, is well developed. This is the assemblage that Cameron and others (1949, pp. 67-69, and table 5) list as a variant of plagioclase-quartz-spodumene pegmatite.

Table 5.--Mineralogic types of pegmatites in the Hyatt area, Crystal Mountain district, Colorado

Mineralogic type			Number of pegmatites
I. Feldspar-rich pegmatites			1,259
A. Plagioclase-perthite-quartz pegmatite		144	
B. Perthite-plagioclase-quartz pegmatite		1,115	
1) Ratio of perthite to plagioclase is approximately 1:1	198		
2) Ratio of perthite to plagioclase is approximately 3:2	614		
3) Ratio of perthite to plagioclase is approximately 2:1	303		
II. Quartz-rich pegmatites			45
III. Tourmaline-rich pegmatites			3

Table 6 . General sequence of mineral assemblages[1]

MINERALS OF ZONES		OBSERVED LITHOLOGIC TYPES IN PEGMATITES OF SOUTH DAKOTA	
Essential minerals	Common accessory minerals	Essential minerals in order of relative abundance	
		Dominant	Minor
1. Muscovite (M)	Tourmaline	→[2] a. Q, M	Pg
Quartz (Q)	Beryl	→ b. M, Q	Pg
Plagioclase (Pg)	Biotite	→ c. Q, M, Pg	
a. Albite	Perthite	d. Pg, Q	M
b. Oligoclase	Apatite	e. Q, Pg	M
	Cassiterite	f. Q, Pg, M	
	Columbite	g. Pg, M, Q	
		h. Pg, Q, M	
2. Quartz (Q)	Tourmaline	a. Pg, Q	
Plagioclase (Pg)	Beryl	→ b. Q, Pg	
a. Albite	Perthite		
b. Oligioclase	Apatite		
	Muscovite		
	Cassiterite		
	Columbite-tantalite		
3. Perthite (P)	Tourmaline	a. Pg, M, Q, P	
Quartz (Q)	Beryl	b. Pg, Q, M, P	
Muscovite (M)	Li, Mn, Fe, Phos-	c. Pg, Q, P, M	
Plagioclase (Pg)	phates	d. Pg, Q, P	M
a. Albite	Columbite-tantalite	e. Pg, P, Q, M	
b. Oligoclase	Apatite	f. Pg, P, M, Q	
	Lollingite	→ g. Pg, P, Q	M
	Biotite	h. P, Pg, Q, M	
		→ i. P, Pg, Q	M
		j. Q, Pg, M, P	
		k. Q, Pg, P, M	
		l. Q, Pg, P	M
		m. Q, P, Pg, M	
		n. Q, P, Pg	M
		o. Q, P, M	Pg
		p. P, Q, Pg	M
		q. P, Q, M	Pg
		r. Q, Pg, P	M
		s. Q, Pg, M	P
4. Perthite (P)	Tourmaline	→ a. Q, P	
Quartz (Q)	Beryl	→ b. P, Q	
	Plagioclase	→ c. P	Q
	Li, Mn, Fe, Phos-		
	phates		
	Muscovite		
	Columbite-tantalite		
	Apatite		
	Lollingite		
5. Perthite (P)	Tourmaline	a. A	
(or microcline)	Beryl	b. Q, P, A	Pg
Quartz	Cassiterite	c. Q, P, Pg, A	
Plagioclase (Pg)	Tantalite-Columbite	d. Q, Pg, A, P	
(usually cleave-		e. Pg, Q, A	P
landite)	Muscovite	f. P, Q, A, S	Pg
Amblygonite (A)	Apatite	g. P, Pg, Q, A, S	
Spodumene (S)			
		h. Q, P, S	Pg
		i. P, Q, S	
		j. Q, Pg, P, S	
6. Plagioclase (Pg)	Tourmaline	→ a. Q, Pg	
a. Cleavelandite	Beryl	→ b. Pg, Q	
Quartz (Q)	Cassiterite	c. Pg	Q
	Tantalite		
	Muscovite		
	Apatite		
	Amblygonite		
7. Plagioclase (Pg)	Beryl	a. Q, Pg, S	
a. Cleavelandite	Tourmaline	b. Pg, Q, S	
Quartz (Q)	Muscovite		
Spodumene	Cassiterite		
	Tantalite		
	Apatite		
8. Quartz (Q)	Plagioclase	a. Q, S	
Spodumene (S)	Lepidolite		
	Microcline		
	Beryl		
9. Plagioclase (Pg)	Microlite	a. Q, Pg, L	
a. Cleave-	Spodumen	b. Pg, Q, L	
landite	Beryl	c. Pg, L	Q
Quartz (Q)	Amblygonite	d. L	Pg, Q
Lepidolite (L)	Tantalite-columbite		
	Cassiterite		
	Microcline		
	Tourmaline		
	Apatite		
10. Quartz (Q)	Spodumene	a. Q, P	
Microcline (P)	Muscovite	b. P, Q	
	Plagioclase		
	Apatite		
11. Microcline (P)	Cassiterite	a. Pg, P, LiM, Q	
Plagioclase (Pg)	Apatite		
Lithia-Micas (LiM)			
Quartz (Q)			
12. Quartz (Q)	Microcline	→ a. Q	
	Muscovite		
	Plagioclase		
	Beryl		

1/ From Page, L.R., and others, Pegmatite investigations in the Black Hills, South Dakota 1942-1945: U. S. Geol. Survey Prof. Paper (in preparation).

2/ Arrows indicate lithologic types observed in the Crystal Mountain district, Colorado.

TEIR 139

Fersman (1940) classifies pegmatites by the mineral assemblages (though they are not designated as such) and by the characteristics of certain diagnostic minerals. The individual groups are called "geophases" and labelled A to L. The paragenetic diagrams by Fersman (1940) and the illustrations and descriptions in reports by Tscherbakov (1936), Labuntzov (1939), and Sinegub (1943) show that essentially the same mineral assemblages found in American pegmatites are recognized in Russian deposits and in the same sequence as shown in table 6. The pegmatites of the Hyatt area have been assigned tentatively to Fersman's geophase E, the descriptive group, without accepting his genetic and geochemical-geophysical interpretation of that group.

<u>Feldspar-rich pegmatites</u>

The average composition of the feldspar-rich pegmatites, type I of table 5, of the area approximates that of granite. This type has been subdivided into three classes in which the ratios of perthite to plagioclase are approximately 1:1, 3:2, and 2:1. The members of each class are distributed at random throughout the area and there is no clear correlation between mineralogic composition of the pegmatites and structural control, beryl content, indices of refraction of beryl or plagioclase, accessory mineral content, country rock, or relation to intrusive masses.

The feldspar-rich pegmatites predominate in the area and exhibit the widest range in size and shape. Perthite makes up as little as 20 percent of the plagioclase-rich pegmatites and as much as 65 percent of the perthite-rich pegmatites. Plagioclase generally composes from 15 to 60 percent of the same types of deposits, and the quartz content ranges from 5 to 35 percent.

Quartz-rich pegmatites

The quartz-rich pegmatites, type II, tables 5 and 17, are minor bodies rarely consisting of more than lenses of massive quartz containing scattered feldspar and muscovite crystals. Quartz-rich pegmatites are generally 6 inches to 3 feet wide, and 5 to 85 feet long. They are more commonly concordant than discordant and consist of either single continuous bodies or closely spaced lenses separated by 1-inch to 2-foot schist partings. The largest of the quartz-rich pegmatites is pegmatite 1,033 (pl. 1) which has an inferred length of 650 feet.

Quartz-rich pegmatites are gradational with the other types of pegmatites (table 5). Pegmatite 1,023 is 55 percent quartz, pegmatite 1,145 is 60 percent quartz, and pegmatites 525 and 598 are each 85 percent quartz; they comprise a connecting series between the feldspar-rich pegmatites and the typical quartz pegmatite containing over 95 percent quartz. Perthite and plagioclase are both common in quartz-rich pegmatites, but the proportions range widely. Only a few grains of feldspar and flakes of muscovite are identifiable in most pegmatites of this type.

Gradation between the quartz-rich and tourmaline-rich types of pegmatites is illustrated by pegmatites 260 and 404: both tourmaline and quartz are essential constituents, and perthite is an accessory constituent.

Tourmaline-rich pegmatites

The classification and interpretation of the tourmaline-rich pegmatites, type III in table 5, are much in doubt. They are poorly exposed and have a maximum width of 1 foot and a maximum inferred length of 30 feet. Only three, pegmatites, 260, 398, and 404, are of mappable size, but about five other bodies are known. The tourmaline content ranges from 12 to 90 percent, and it may occur as a marginal or as a central segregation. In these bodies tourmaline is associated with quartz, with quartz and perthite, and with plagioclase, perthite, quartz, muscovite, and garnet (table 17). There are all gradations in mineralogy from a typical pegmatitic assemblage to a quartz-tourmaline vein. The tourmaline-rich bodies may be classified either as variants of assemblages 1, 2, or 3 (table 6), in which the tourmalinizing and silicifying fractions (that ordinarily escape and alter the wall rock) were retained in the pegmatitic liquid, or as the early fugitive fractions from a granitic or pegmatitic magma that were concentrated and trapped as fillings of fractures. They also may be considered deposits transitional between pegmatites and hydrothermal veins; if so, they would be similar to the chalcopyrite-bearing tourmaline-quartz veins found near Pecos, N. Mex., described by Kreiger (1932, p. 463); the tourmaline-rich silver, lead, and gold veins of the Helena region, Mont., described by Knopf (1913, pp. 45-54); and the tourmaline-bearing tungsten veins of the Isla de Pinos, Cuba, described by Page and McAllister (1944, pp. 177-246).

Descriptions of minerals

The minerals observed in the pegmatites of the Crystal Mountain area are described in approximately their decreasing order of abundance, and the properties of a group of minerals found in a miarolitic cavity are described at the end of the section.

Perthite, plagioclase, and quartz are the most abundant, muscovite is rarely an essential mineral, beryl, tourmaline, and garnet are the commonest accessory minerals, and apatite is a less common accessory.

Trace amounts of biotite, columbite-tantalite, microcline, lithiophillite-triphylite, sillimanite, bismuthinite, hematite, magnetite, limonite, chrysoberyl, bertrandite, fluorite, and uraninite and related minerals are found in one to eight pegmatites. For convenience in reference the description of microcline follows that of perthite, and the description of biotite is included with that of muscovite, though both microcline and biotite are very rare in these pegmatites.

Perthite

Perthite is the dominant mineral in 85 percent of the pegmatites in the Hyatt area and is an essential mineral of assemblages 3 and 4 (table 6). The perthitic structure, an intergrowth of albite in microcline from which the name "perthite" is derived, is generally visible without the aid of a hand lens. The microcline ranges in color from milky white to deep salmon but is usually a dull pinkish white; the albitic stringers form an anastomosing network and are lighter in color than the microcline.

Perthite is an abundant and readily identifiable constituent of most pegmatites, both as small grains near the walls and large masses and aggregates in the interior. It is closely associated with quartz in most occurrences. Perthite is the principal constituent of the hood at the Big Boulder prospect, and it is the only essential constituent of the core of the Hyatt deposit, where it contains innumerable minute inclusions of muscovite, plagioclase, and quartz. Perthite grains range in size from microscopic (in border zones, banded pegmatites, and the matrix interstitial to large crystals) to 10 feet across. The mineral varies in abundance from less than 1 percent in some quartz pegmatites to about 96 percent in the core of the Hyatt pegmatite.

In zones where both perthite and plagioclase are essential minerals, perthite is almost invariably more abundant in the upper part of the zone than in the lower part. The causes or methods of this segregation have not been determined, but it is a widespread phenomenon, recognized in many districts. Some zones of the explored deposits are divided into an upper perthite-bearing zone and a lower plagioclase-rich zone. (See pls. 10, 23, and 30.) The upward segregation of perthite is not confined to the wall zones; the formation of a perthite-rich hood, such as that of the Big Boulder deposit (pl. 23) is another example of the same phenomenon wherein the potash feldspar of an interior zone is segregated toward the top or roof of the pegmatite. Another example is the perthite-rich outer intermediate zone of the Hyatt pegmatite (pl. 10), which is developed only on the hanging-wall wide of the deposit. Page and others (in preparation) and Staatz (in preparation) describe similar perthite occurrences.

Graphic intergrowths of perthite and quartz are common in many pegmatites but never abundant in any of them. It is not recorded separately in table 17 because graphic granite does not seem to have any consistent relationship to the composition or structure of the pegmatites in the Crystal Mountain district.

Microcline

Non-perthitic microcline has been recognized only in a few scattered occurrences. It occurs as a few light salmon-colored grains about 1 inch in diameter in the plagioclase-quartz pegmatite of the lower wall zone from diamond-drill hole BB-5 in the Big Boulder pegmatite. Only a small part of the grains exhibit gridiron twinning and the indices of refraction are somewhat lower than for most specimens: the beta index, determined by W. T. Pecora of the U. S. Geological Survey, is 1.519.

Microcline is an essential constituent of assemblages 10 and 11 (table 6) and is present in assemblage 5 in some pegmatites. However, assemblages 5, 10, and 11 are directly related to lithium-rich units. The Crystal Mountain district is a lithium-poor region, and microcline is not found as an essential mineral. In its few occurrences it constitutes only a rare accessory mineral.

Plagioclase

Although plagioclase is the dominant feldspar in the 144 pegmatites of Type 1A (tables 5 and 17) it is less abundant in the district than perthite. It is milky white to pale pink and generally shows polysynthetic twinning under the hand lens. The grains are usually smaller than those of the associated perthite and quartz, even where plagioclase is the most abundant mineral, and it is found more as ground mass and interstitial material than as distinct crystals or aggregates. Plagioclase forms small equidimensional grains in most pegmatites, but in some bodies the grains become elongate and platy toward the center of the deposit. The grains become large and the plates are well formed in the central units of the larger zoned deposits, and the name cleavelandite is applied to this variety of plagioclase. Plagioclase is a persistent associate of muscovite and beryl, and can be found around or intergrown with them wherever they occur.

The ranges in indices of refraction and composition of 237 plagioclase specimens from the Hyatt area are given in figure 3. The determinations are of the minimum index of refraction (N_2) on (010) cleavage fragments. The ratio of albite to anorthite is taken from a table by Grout (1932, p. 468) which correlates the variation in index of refraction with changes in composition. The composition ranges from Ab_{78} to Ab_{99}, but 91 percent of the determinations are between Ab_{94} and Ab_{99}. The cleavelandite variety of albite has a compositional range of Ab_{94} to Ab_{99}.

The writer has attempted to correlate the variations in composition of the plagioclase in the Hyatt area with (1) the composition of the enclosing pegmatite, (2) the structural position of the pegmatite, (3) the type of country rock, (4) distance from the granite masses, and (5) association with other minerals, especially beryl, but without success. The range of composition of the majority of specimens is so limited that no systematic varia-

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Trace Elements Investigation
Report 139

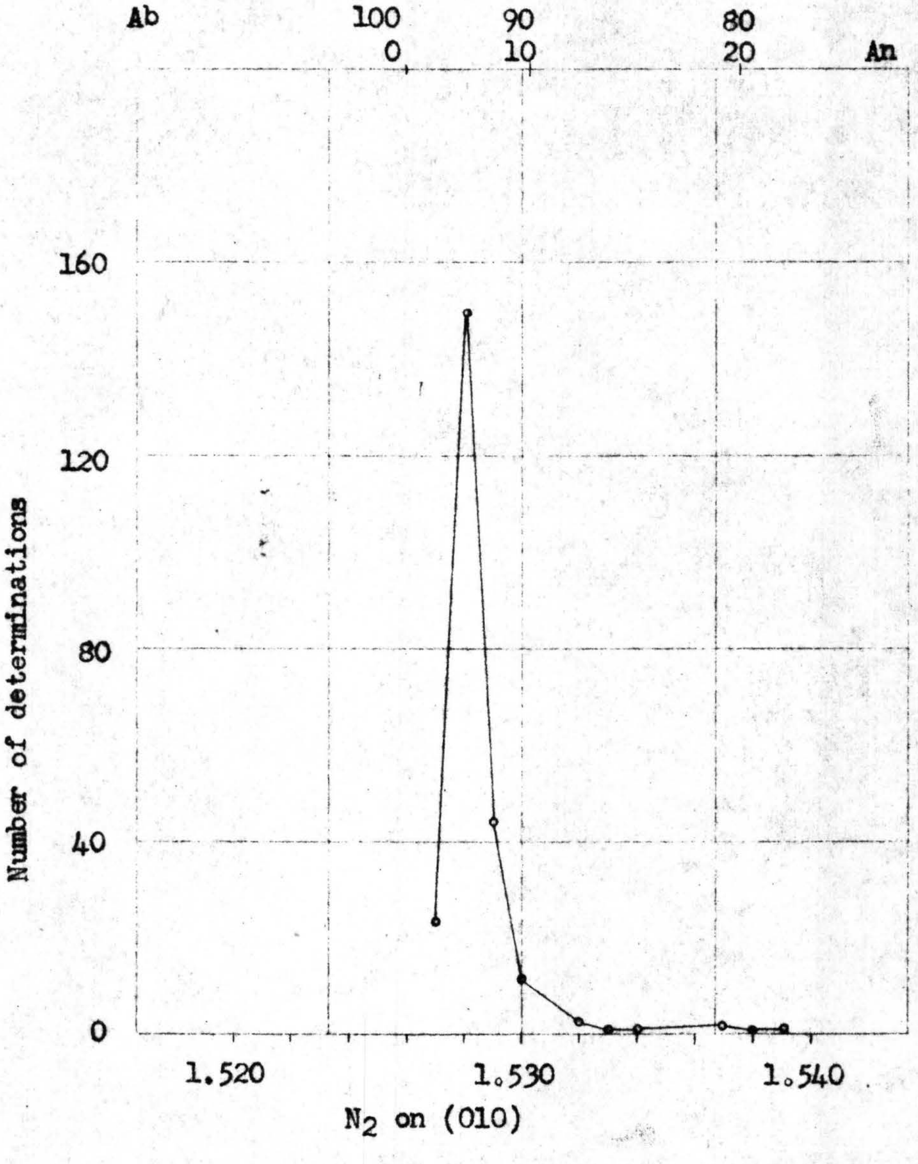

Figure 3 . Distribution of plagioclase indeces

tion is discernible; and the few specimens with compositions outside the dominant range are scattered seemingly at random throughout the area.

Several hundred determinations of index of refraction of plagioclase from the drill cores are not included in figure 3. The exploration furnished 14 excellent cross sections through three well-zoned deposits. The composition in these bodies ranges from Ab_{92} to Ab_{99}, with an average of about Ab_{96}. The composite results for the three deposits show a slight decrease in the anorthite content from the wall to the core of the pegmatite. Several holes show no systematic change in index, and in others the change is confined to the outermost few feet of the pegmatite.

Plagioclase is the dominant mineral in the lower part of the wall and intermediate zones of the Hyatt, Big Boulder, and Buckhorn Mica pegmatites. Cleavelandite is an essential constituent of the core and inner intermediate zone of the Buckhorn Mica deposit and the lower intermediate zone of the Big Boulder pegmatite. The abundance of plagioclase is not easily determined in all outcrops. Because the plagioclase grains are generally smaller than their associates, they weather more rapidly to form hollows that are invariably stained and crusted, and masses of the mineral, even where large, are not conspicuous beside perthite and quartz. Plagioclase and quartz are found in graphic intergrowth in many small areas, and in places make up sizable parts of a zone, as in drill hole BB-5, Big Boulder prospect, where the inner part of the plagioclase-quartz pegmatite contains 7 feet of rock of which about half is composed of graphic material.

Quartz

Quartz is the dominant and in some places almost the only mineral in the quartz-rich pegmatites but in the other types it is subordinate to the feldspars. Quartz, as milky-white to light-gray anhedral grains, most commonly forms from 5 to 35 percent of the pegmatite. Glassy chips are not common, and according to Hanley (1950, p. 95), even the clearest material at the Crystal Silica property (fig. 2) is slightly milky. Smoky to black quartz is found in contact with radioactive minerals.

Quartz ranges in size from microscopic grains in border zones and interstices between other minerals to large masses in the interior zones. The difficulty in recognizing the precise boundaries of anhedral grains precludes giving exact measurements, but continuous masses (that may be aggregates of grains) of quartz are as much as 5 feet across in the core of the Big Boulder pegmatite. The perthite core of the Hyatt deposit contains, in addition to minute inclusions of quartz, rounded masses as much as 1½ feet wide and 4 feet long.

Some of the quartz in the perthite-quartz pegmatite of the hood in the Big Boulder pegmatite has the appearance of a "quartz breccia" with a perthite matrix. This "breccia-like" material occupies irregular but somewhat rounded areas 1 to 6 feet in cross section. There is no continuity between the areas, nor any semblance of linear or planar alinement to suggest it is a tectonic feature. The quartz is separated by a network of irregular fractures into sharply angular fragments, the pieces gradually increasing in size so that the "breccia" grades outward into normal massive quartz cut by a few joints and fracture planes. The central parts are made up of dark-gray pieces ranging in size from 0.01 to 0.2 inch, the color becomes lighter as the fragments increase in size. The dark color of the quartz suggests that radioactive minerals might be present, and that perhaps the fracturing might be related to their presence. The interstices are filled by material that would normally be available during crystallization but not likely to be transported into the fractures after consolidation of the hood.

<u>Muscovite and biotite</u>

Muscovite is a minor, but universal, constituent of pegmatites in the Crystal Mountain district. Despite the abundance of biotite in the related granite intrusives and in the schist wall rock, it has been found in trace quantities in only three bodies, pegmatite 1014, 1225, and 1244. The Crystal Silica pegmatite described by Hanley and others (1950, pp. 93-96) contains both muscovite and a mass of lodestone of large but undetermined size, but no biotite is found. Staatz (in preparation) finds that biotite supersedes muscovite in the Quartz Creek district as the iron content of the pegmatites increases and magnetite becomes an accessory mineral.

The principal deposit of muscovite in the Crystal Mountain district is in the outer intermediate zone of the Buckhorn Mica pegmatite. It has been described by Sterrett (1923, pp. 59-60), and Hanley and others (1950, pp. 88-90), and is reported to have yielded some sheet mica, but most of the muscovite is suitable only for grinding. About 30 tons of scrap mica is reported to have been mined from the inner intermediate zone of the Hyatt deposit. The books attain sizes as much as 15 inches long and 6 inches thick, but are wedge-shaped and show ruling, "A" structure, and abundant mineral inclusions. The muscovite shoots are found in plagioclase-rich zones but the pegmatites, as a whole, are rich in perthite and such deposits generally yield muscovite with little or no sheet mica, according to Cameron and others (1945, pp. 383, 392) and Jahns (1951, p. 55). Bannerman (1943, p. 12) and Cameron and others (1945, p. 382) also note that beryl and phosphatic minerals are associated in many places with imperfect mica; beryl is a common associate of muscovite in the Crystal Mountain district.

In the majority of pegmatites mapped in the Hyatt area, muscovite ranges from microscopic size to three-quarters of an inch in diameter, and rarely attains 2 inches. The average size is about one-quarter of an inch. It rarely exceeds 1 percent of the pegmatite, and is present in excess of 5 percent in only the two zones mentioned previously.

Muscovite is associated with tourmaline in fracture fillings in the Big Boulder pegmatite and in late networks of fine yellow and white scales, some of which is lithium-bearing. The lithium-bearing muscovite fills fractures cutting all previous structures and minerals, and is interesting because of its relation to relict spodumene. The scales of fine mica are in large part slightly curved and many of them have one index below 1.55, which, based on findings in South Dakota, is interpreted as indicating the inclusion of lithium in the composition of muscovite. Sericite present in a miarolitic cavity is described in a later section.

Tourmaline

Columnar crystals of black tourmaline with well-developed prism faces are present in the schist, granite, and pegmatites of the Crystal Mountain district. The tourmaline crystals range from microscopic in size to a maximum of 4 inches in length, but the tourmaline in pegmatites of type III (tables 5 and 17) occurs in masses as much as 4 inches by 4 inches by 6 inches in size. Much of the tourmaline in the schist and granite is derived from solutions escaping from the pegmatites, but some of it is native to the country rock. In granite the tourmaline of replacement origin is markedly poikilitic and 10 to 100 times larger than the minute delicate needles of primary crystallization. Tourmaline in the schist is commonly alined in the plane of foliation, and in some places there is a linear parallelism concordant with drag folds and other lineation. Crystals in the country rock do not exceed three-quarters of an inch in length, and invariably have parallel sides. Tourmaline in pegmatites generally forms long columnar crystals, but a number of irregular skeletal and tapering crystals have been found. (See pl. 8A.) One tapered crystal, about 3 inches long, measures one-quarter of an inch in diameter at one end, and 1 inch at the other, and contains veins and inclusions of groundmass material. A small pegmatite 3 feet southwest of pegmatite 137 is only 5 inches wide but contains tourmaline crystals as much as 2½ inches long and 1½ inches in diameter which are uniformly oriented normal to the walls of the body.

Tourmaline in pegmatites of type III (tables 5 and 17) constitutes 12 to 90 percent of the rock and in altered wall rocks it comprises as much as 40 percent of the schist. Tourmaline grains observed in the drill core of the Hyatt and Big Boulder deposits indicate that this mineral is present in all zones, including the quartz core. Tourmaline and muscovite fracture fillings occur in the Big Boulder pegmatite. Tourmaline also was found in a miarolitic cavity.

Beryl

The Crystal Mountain district is one of about a dozen beryl-rich pegmatite areas in the country, and this study was made primarily to determine the distribution and quantity of beryl. Beryl occurs as an accessory mineral only in the pegmatites; none has been recognized in the granites or schist, though spectrographic assays indicate the presence of traces of beryllium in the wall rocks of the three explored deposits (table 13). Beryl is widely distributed throughout the area in pegmatites that contain from traces to about 2 percent. It occurs in homogeneous and banded as well as zoned pegmatites, but has not been found in quartz pegmatites or tourmaline-quartz pegmatites of the Hyatt area. Its general associations do not seem to preclude the possibility that better exposure or more extensive examination of these bodies might disclose the presence of beryl.

Beryl is difficult to recognize in many parts of the Crystal Mountain district. It is usually a dull greenish gray to light bluish green, but white, yellowish, and blue varieties have been found. Beryl associated with lithium-bearing minerals is a dull white mineral that is particularly difficult to distinguish from milky quartz and feldspar. Only two tiny, much-fractured chips of clear aquamarine-blue beryl were found. Crystals of a wide variety of shades of blue green occur in close proximity, and there is no discernible external control of the color. Fersman (1940, pp. 97-98) states that this pale grayish- and bluish-green beryl, distinct from the yellow, golden, brown, rose, green, and aquamarine varieties, is typical of the beryl of his "geophase E."

Beryl generally forms euhedral crystals on which the only common face is the hexagonal prism (110), but anhedral grains have been found in many bodies, and are especially abundant in the zoned deposits (pls. 11-16, 27-28, and 31-35). Commonly the prismatic crystals are tapered, in some places producing strikingly conical shapes. In other places crystals are broken along the basal cleavage and the parts recemented with the enclosing minerals. One specimen exhibits a series of step-like offsets along the basal cleavage, similar to that described by Johnston (1945, pp. 1032-1033). Such beryl indicates movement within the pegmatite after the formation of that particular crystal but before complete crystallization of the material forming the nearby groundmass.

The largest beryl crystal found in a homogeneous pegmatite or the wall zone deposits of zoned pegmatites was 8 inches long and 3 inches in diameter, but the common range is from 0.01 to 2 inches. Beryl grains are considerably larger in interior zones: in the inner intermediate zone of the Hyatt pegmatite the range is from 2 inches to 5 feet; the average is about 1 foot. It is reported that one crystal at the Big Boulder prospect, mined from the inner side of the hood, yielded 10.5 tons of beryl; the dimensions of that crystal, reconstructed from the weight, the known depth of the pit, [illegible]

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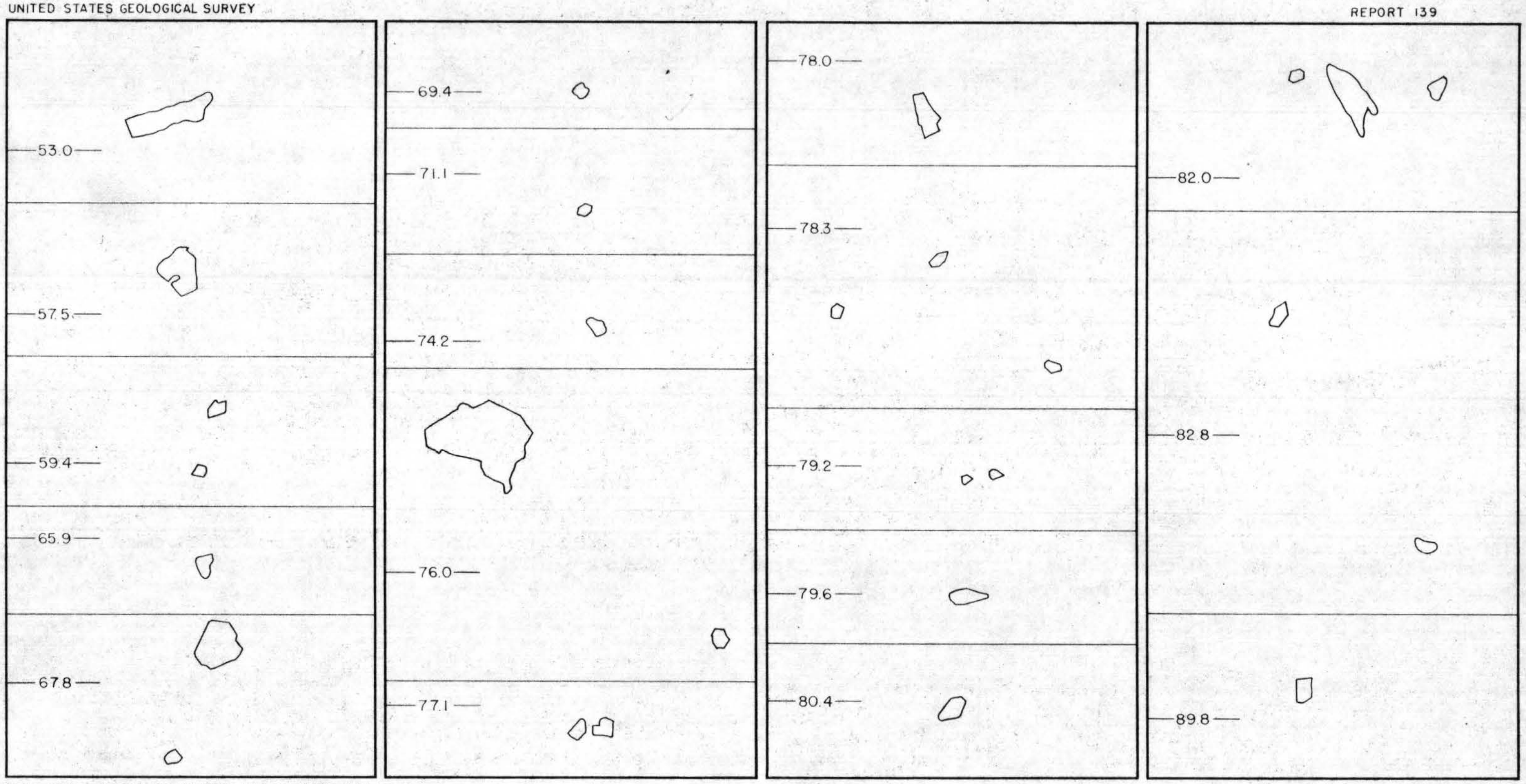
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R Thurston, November, 1948

PLATE II, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-1, HYATT PEGMATITE, LARIMER COUNTY, COLORADO

Scale in inches
0 1 2 3 4 5 6
0 1 2 3 4 5
Scale in tenths of feet

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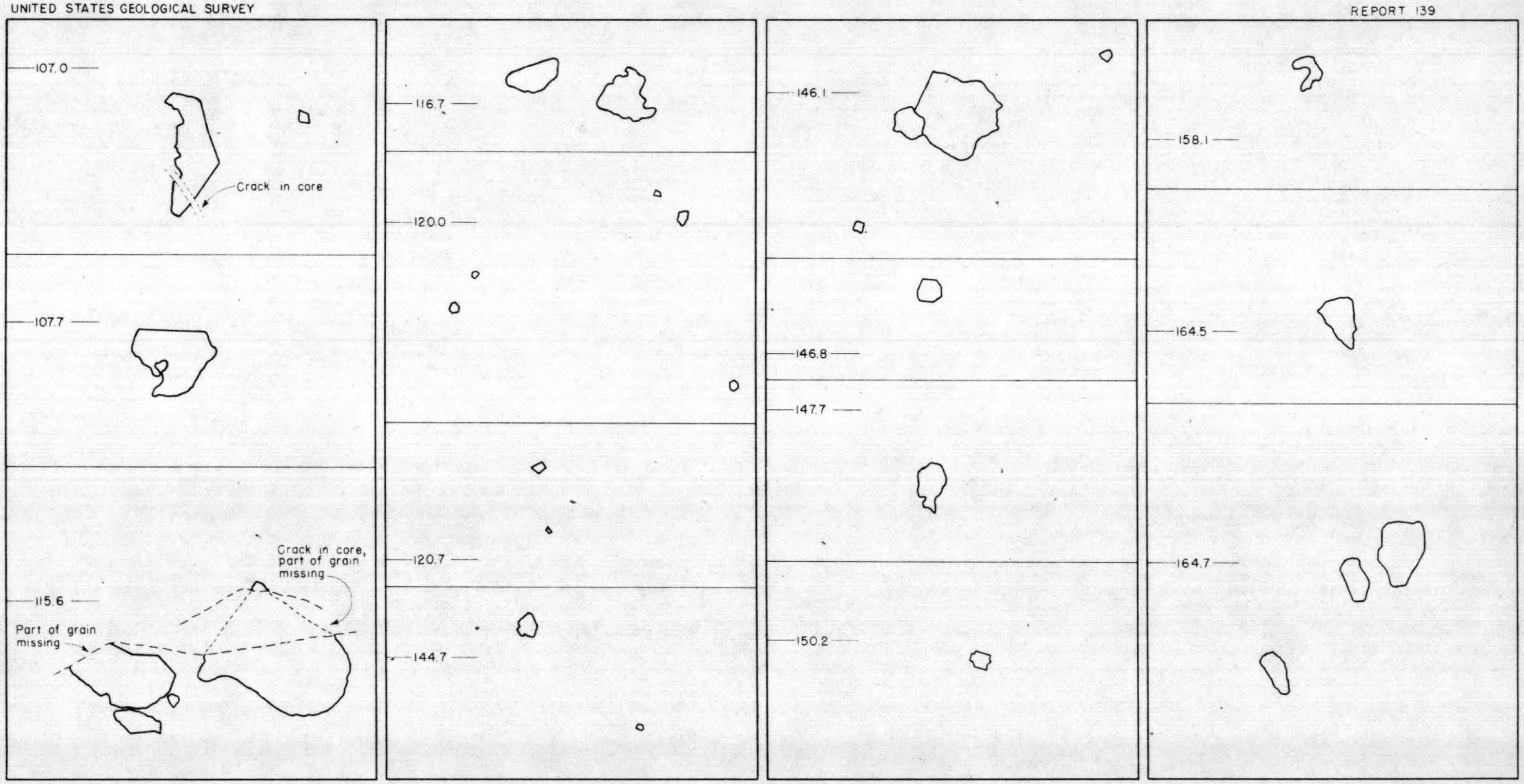
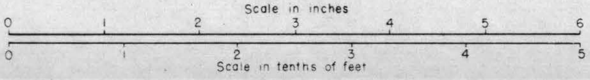


Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 12, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-2, HYATT PEGMATITE, LARIMER COUNTY, COLORADO



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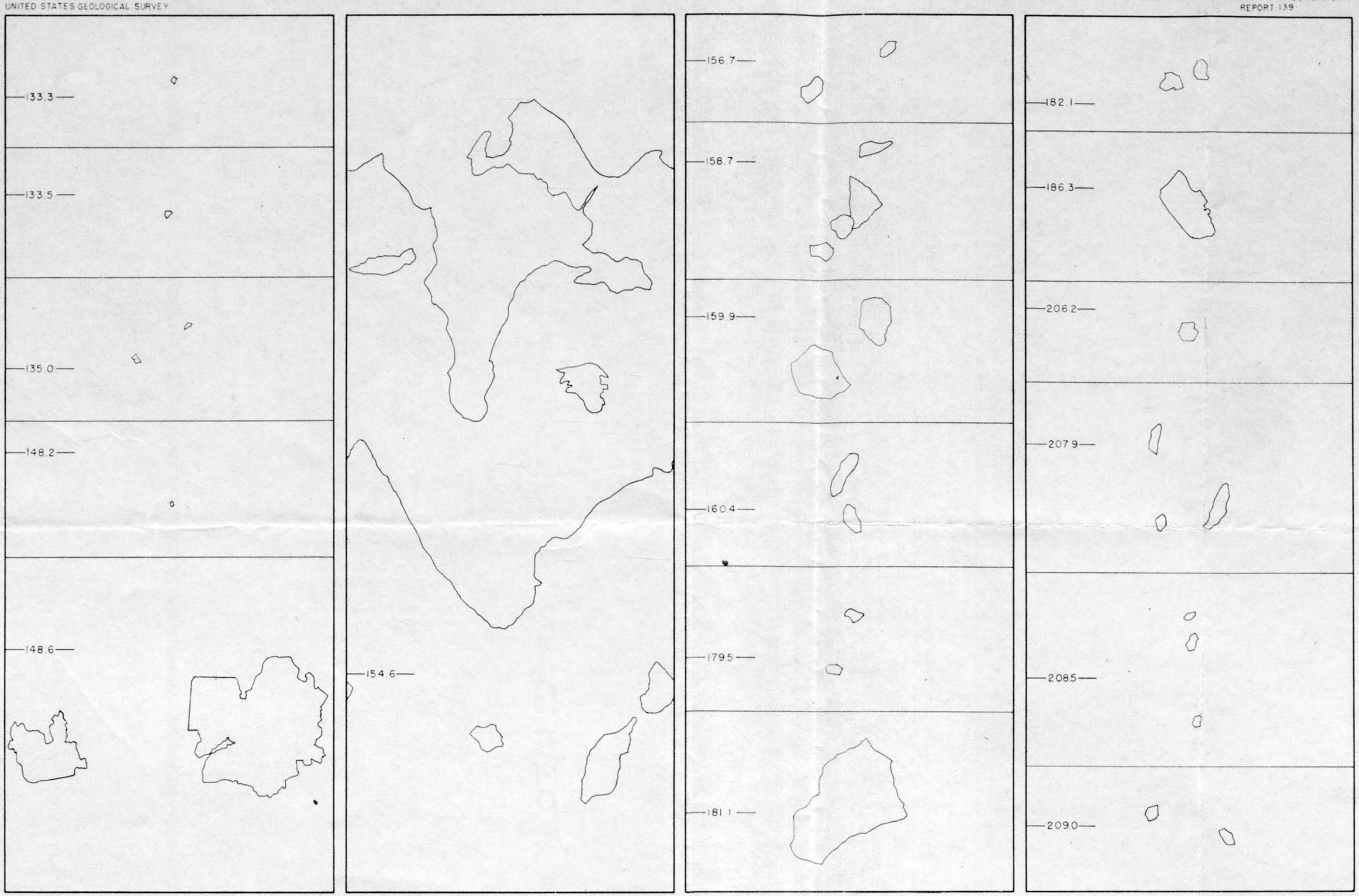
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 13, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-3,
HYATT PEGMATITE, LARIMER COUNTY, COLORADO

Scale in inches
0 1 2 3 4 5 6
0 1 2 3 4 5
Scale in tenths of feet

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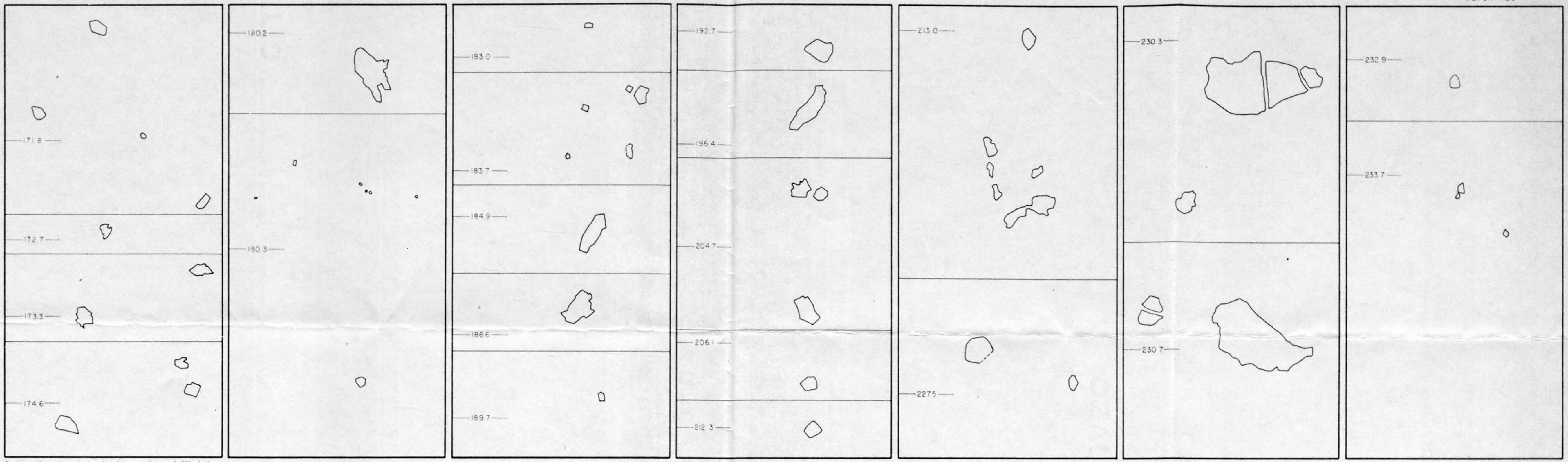
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 14, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-4, HYATT PEGMATITE, LARIMER CO., COLORADO

Scale in inches
0 1 2 3 4 5 6
0 1 2 3 4 5
Scale in tenths of feet

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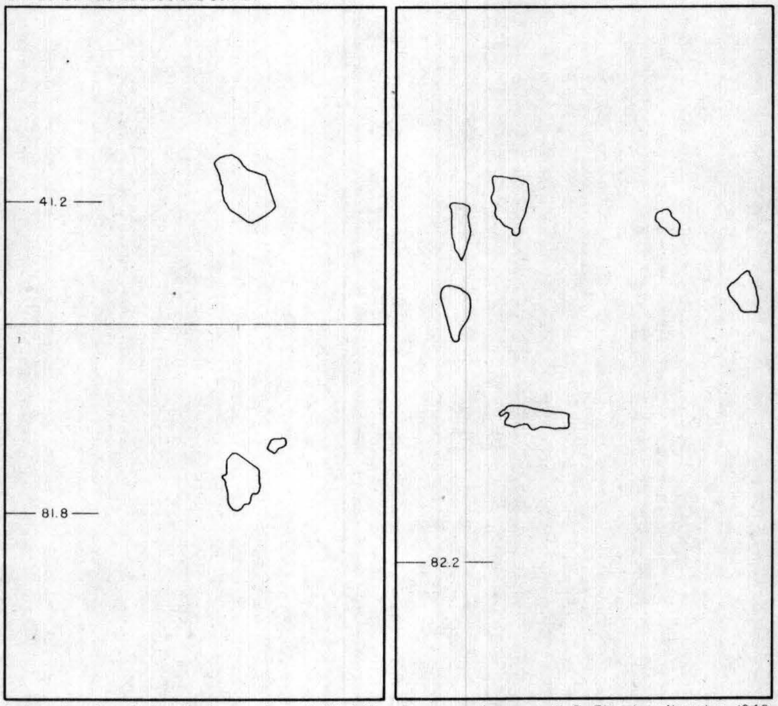
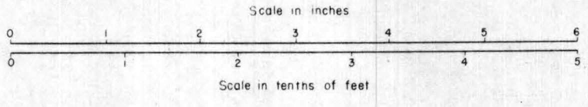
REPORT 139

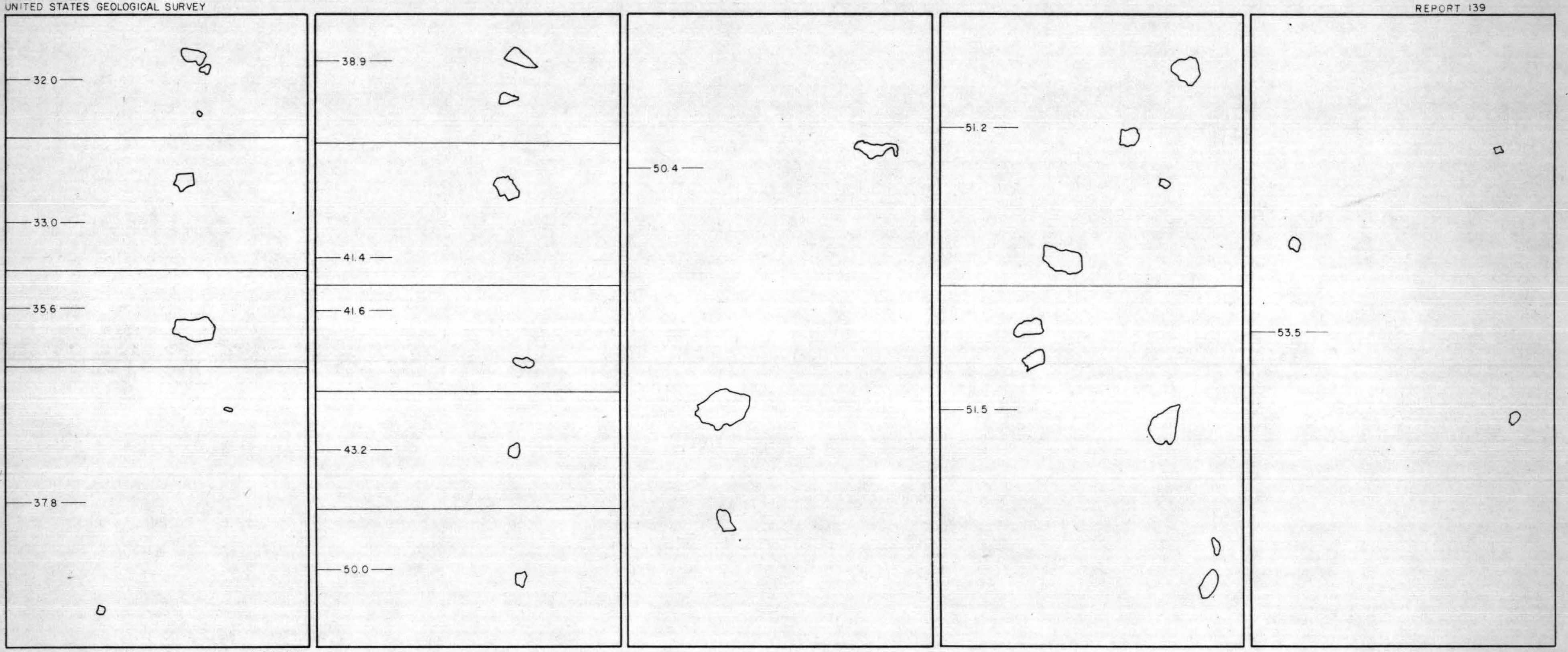


Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 15, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-5, HYATT PEGMATITE, LARIMER CO., COLORADO





Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 16, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE HY-6, HYATT PEGMATITE, LARIMER COUNTY, COLORADO

Scale in inches: 0 1 2 3 4 5 6

Scale in tenths of feet: 0 1 2 3 4 5

80

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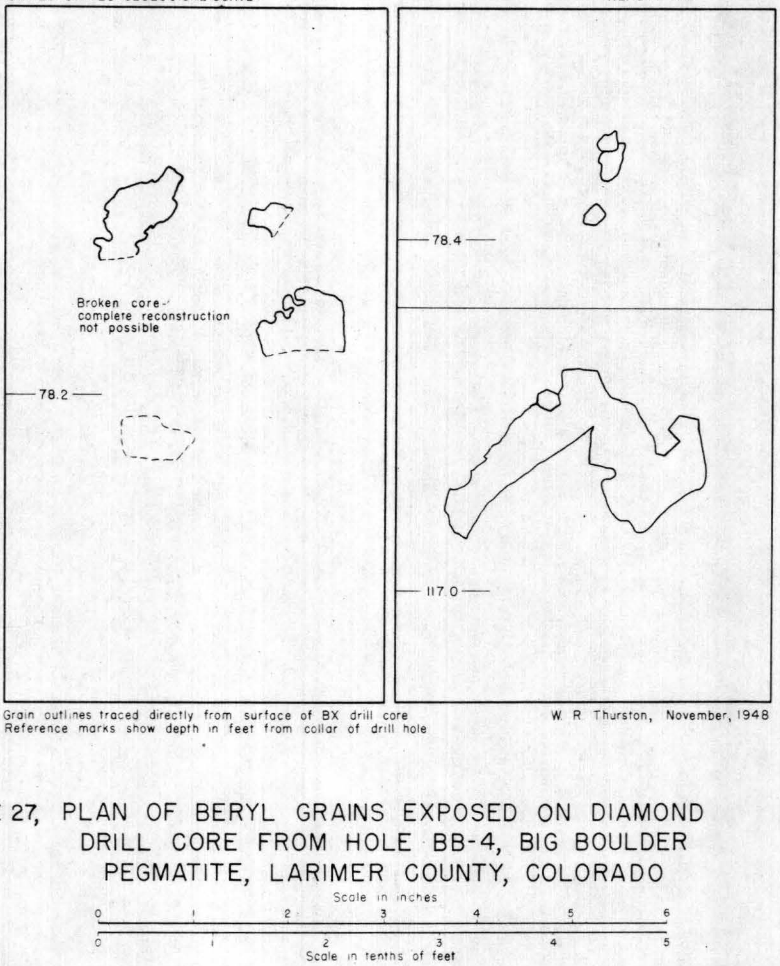
UNITED STATES GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATION
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 27, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BB-4, BIG BOULDER PEGMATITE, LARIMER COUNTY, COLORADO

Scale in inches: 0, 1, 2, 3, 4, 5, 6

Scale in tenths of feet: 0, 1, 2, 3, 4, 5

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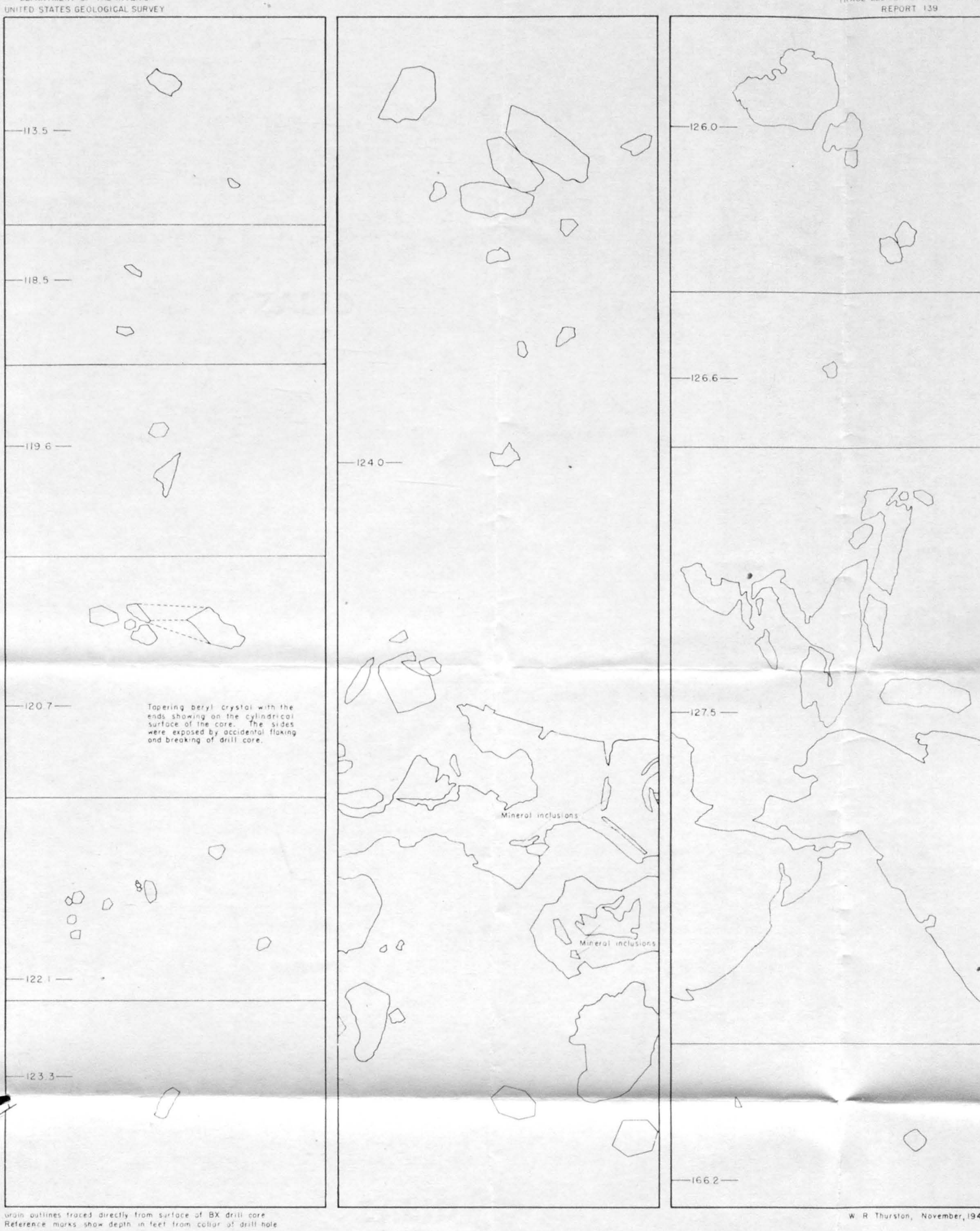
TRACE ELEMENTS INVESTIGATION
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 28, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BB-5, BIG BOULDER PEGMATITE, LARIMER COUNTY, COLORADO

Scale in inches
0 1 2 3 4 5 6
0 1 2 3 4 5
Scale in tenths of feet

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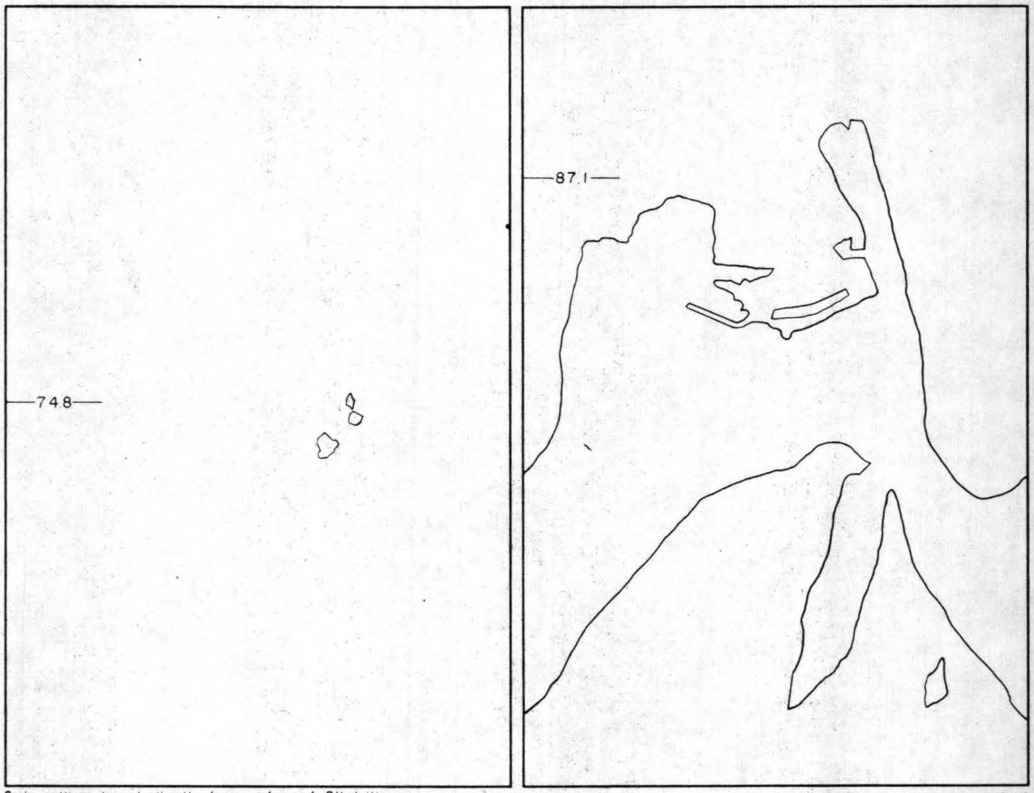
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 31, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BH-1, BUCKHORN MICA MINE, LARIMER COUNTY, COLORADO

Scale in inches: 0 1 2 3 4 5 6

Scale in tenths of feet: 0 1 2 3 4 5

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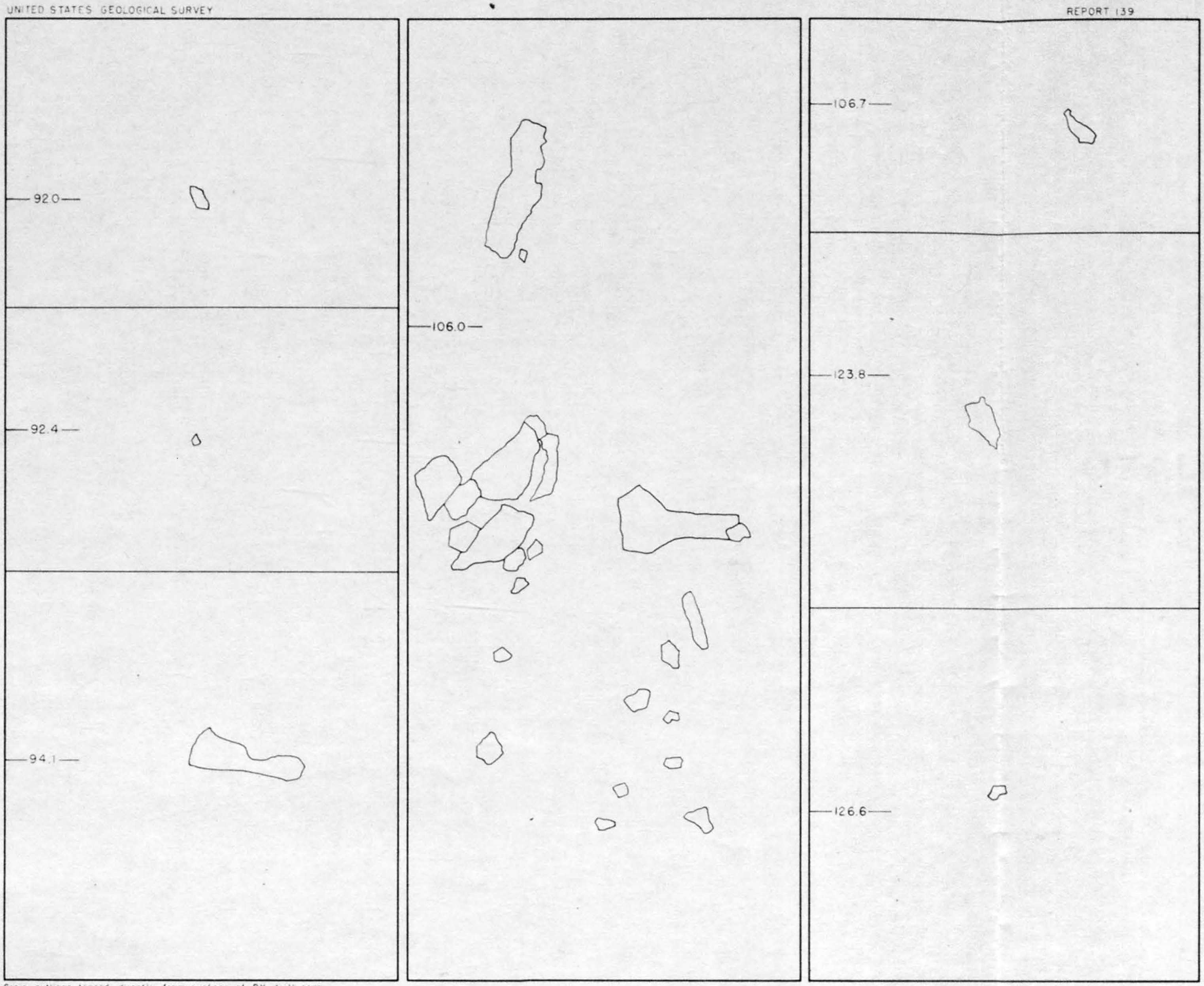
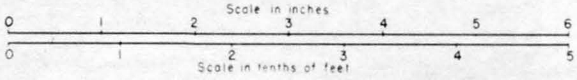
TRACE ELEMENTS INVESTIGATION
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 32, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BH-2, BUCKHORN MICA MINE, LARIMER COUNTY, COLORADO



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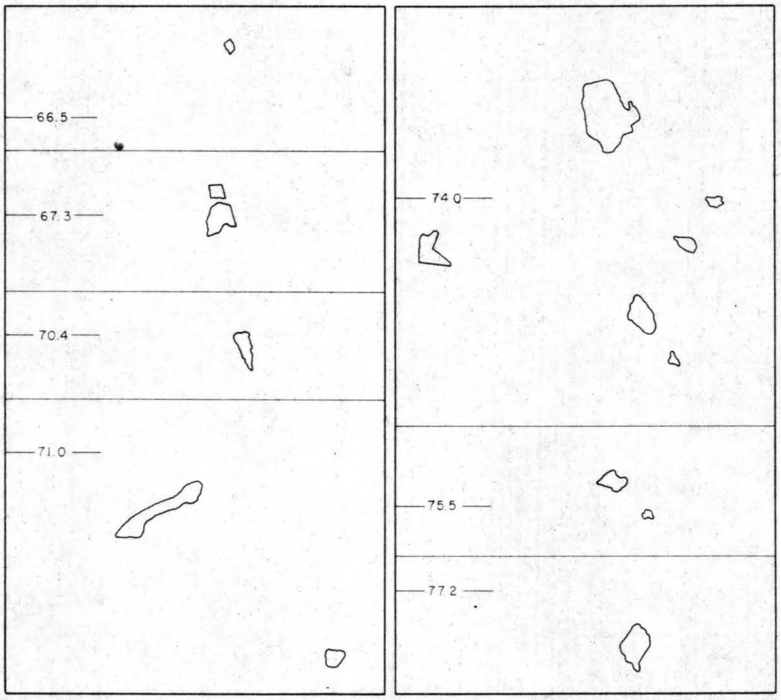
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 33, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND CORE FROM HOLE BH-3, BUCKHORN MICA MINE, LARIMER COUNTY., COLORADO

Scale in inches: 0 1 2 3 4 5 6

Scale in tenths of feet: 0 1 2 3 4 5

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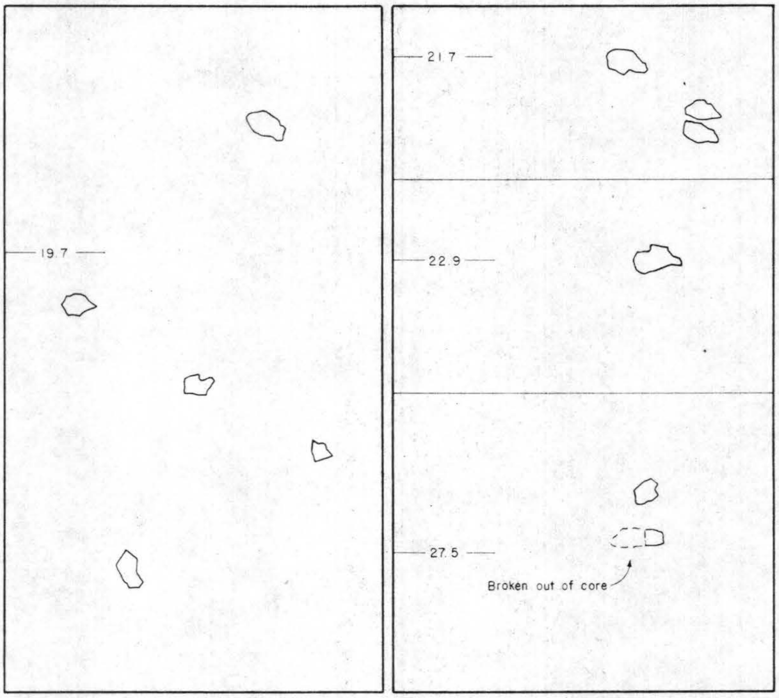
UNITED STATES GEOLOGICAL SURVEY

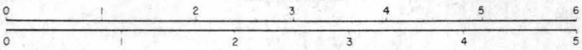
TRACE ELEMENTS INVESTIGATION
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 34, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BH-4, BUCKHORN MICA, LARIMER COUNTY, COLORADO



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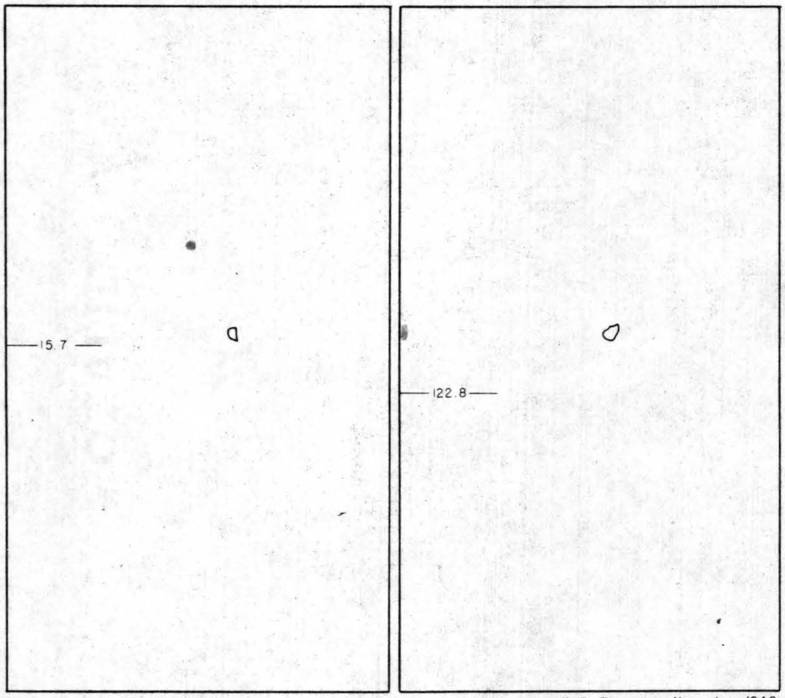
REPORT 139



Grain outlines traced directly from surface of BX drill core
Reference marks show depth in feet from collar of drill hole

W. R. Thurston, November, 1948

PLATE 35, PLAN OF BERYL GRAINS EXPOSED ON DIAMOND DRILL CORE FROM HOLE BH-5, BUCKHORN MICA, LARIMER COUNTY, COLORADO

Scale in inches
0 1 2 3 4 5 6
0 1 2 3 4 5
Scale in tenths of feet

and part of the cast of the crystal remaining in the rock are approximately 6 to 7 feet long and 1.8 feet in average diameter. It is also reported that the crystal tapered toward both ends. The other minerals in the associated perthite-quartz pegmatite are as much as 6 feet in cross section, so the size of the beryl crystal was proportional to the surrounding crystals.

In zoned pegmatites the plagioclase- and muscovite-rich units are the most likely to be beryl-bearing, though other units may contain beryl if the deposit is beryl-rich. Even in homogeneous pegmatites the plagioclase- and muscovite-rich areas in or surrounding the clots or cores of perthite and quartz are more likely places to find beryl than in the clots themselves. No beryl is exposed in the Hyatt deposit in either the perthite of the core or the perthite-quartz pegmatite of the outer intermediate zone, although the spectrographic assays (pls. 19 and 20) indicate the presence of a small percentage of BeO. The beryl-bearing hood of perthite-quartz pegmatite in the Big Boulder deposit contains interstitial plagioclase and muscovite. Most beryl contains abundant inclusions of plagioclase, muscovite, quartz, and perthite and, in addition, a thin layer of fine-grained muscovite may coat the crystal.

The theoretical formula of beryl, $Be_3Al_2(SiO_3)_6$, contains 14.0 percent BeO but natural beryl contains varying amounts of Na_2O, Li_2O, Cs_2O, and combined water. Unpublished studies by W. T. Schaller of the Geological Survey show that the indices of refraction of beryl increase as the alkali content increases. The increase in alkali is made almost entirely at the expense of beryllium, so the variation in the omega index of refraction is also a measure of beryllium content. The results of almost 300 determinations of the omega index and corresponding BeO content of beryl from pegmatites in the Hyatt area are shown in figure 4. The dotted line superposed

U. S. Department of the Interior
Geological Survey

Trace Elements Investigation
Report 139

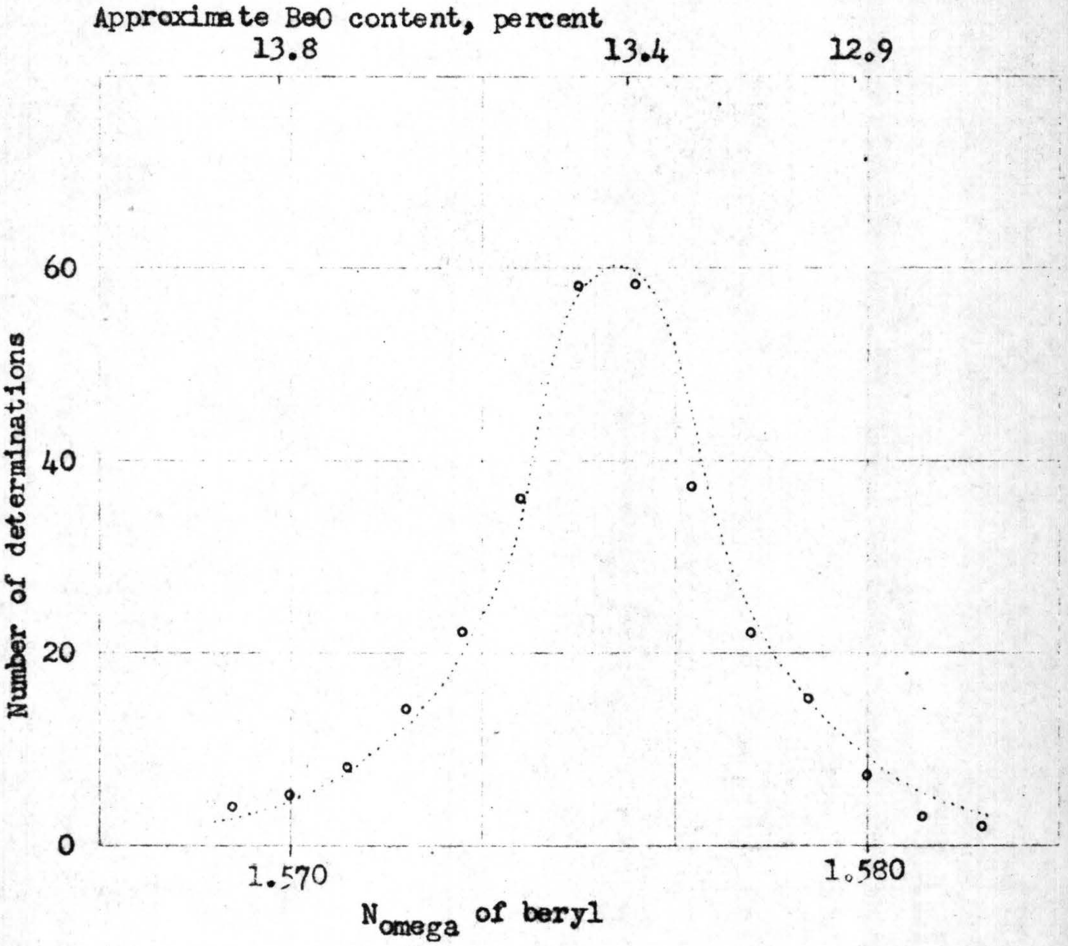


Figure 4. Distribution of beryl indices

on the distribution graph represents the symmetrical curve that could be derived by smoothing out the irregularities in the graph of actual determinations. It is the sort of curve produced by deviations which are free to fall in either direction from a mean value. The curve indicates that the beryl of the Hyatt area contains an average of about 13.4 percent BeO. The geographic position and index of each specimen, plotted in plate 7, show a systematic distribution of the variations in alkali and beryllium ratio that can be contoured with relatively smooth lines. The highest indices are in the areas of the two large granite masses and in the vicinity of the Hyatt pegmatite where there are two small plug-like masses of granite.

A high proportion of pegmatites in the Crystal Mountain district contain beryl as an accessory mineral, the abundance in different bodies ranging from about 2 percent in a particular zone to a single crystal in an entire pegmatite. Commonly several crystals or grains occur in close proximity even in small bodies; therefore, an arbitrary distinction has been made between a "rare accessory" and an "abundant accessory." If the estimated beryl content is less than 0.01 percent it is considered a rare accessory and reported in table 17 as a trace amount. If the estimated quantity of beryl contained in a pegmatite is less than 1 ton it is not considered a potential source of the mineral. The beryl resources considered in tables 7 and 8, therefore, represent the deposits where beryl is an "abundant accessory," and contains an estimated 1 ton or more of beryl in rock with an estimated grade of 0.01 percent or more.

In the Hyatt area 350 pegmatites are known to contain beryl (pl. 8). The number of deposits in which beryl is an abundant accessory probably would not be increased appreciably by further search.

A total of 77 pegmatites (tables 7 and 8) contain over 1 ton of beryl

Table 7.—Distribution of beryl with respect to granite intrusives in Hyatt area, Crystal Mountain district, Colorado

	Number of pegmatites	Percent of pegmatites	Percent of beryl
Pegmatites in granite mass:			
Northern mass	30	26	20.0
Southern mass	1	1	0.05
Mass at Hyatt mine	1	1	42.0
Pegmatites in 1,000-foot belt around mass:			
Northern mass	4	5	2.0
Southern mass	1	1	0.3
Mass at Hyatt mine	3	3	0.4
Pegmatites in belt 1,000 to 2,000 feet around mass:			
Northern mass	19	25	9.0
Southern mass	2	2	9.0
Mass at Hyatt mine	6	8	6.0
Pegmatites in the remainder of the area:	10	13	11.0

Table 8.—Distribution of beryl-bearing pegmatites according to country rock and structure, Hyatt area

Range of inferred resources (tons)	Pegmatites concordant in schist and isolated sills		Pegmatites discordant in schist		Pegmatites in granite	
	Number of pegmatites	Total beryl (tons)	Number of pegmatites	Total beryl (tons)	Number of pegmatites	Total beryl (tons)
1 to 5	12	25	10	32	16	38
5 to 50	7	171	15	323	11	145
Over 50	None	None	2	209	4	1,070

in rock with a grade of 0.01 percent or more. Two deposits, the Hyatt pegmatite and the small body to the south (pl. 1), were known before the present study was undertaken. An analysis of the distribution of beryl deposits shows that the Hyatt pegmatite is the most important source of beryl in the area. The Hyatt deposit contains 42 percent of the known beryl resources, 27 discordant pegmatites in schist contain 28 percent, 30 pegmatites in granite contain 20 percent, and 20 concordant pegmatites in schist contain 10 percent of the beryl. The northern granite mass is much richer in beryl deposits than the southern mass—20 percent as compared to 0.05 percent of the known beryl.

The three principal areas of granite, the two large masses and the plug which almost encloses the Hyatt pegmatite, are each surrounded by belts a thousand feet wide in which beryl deposits are small: the thousand-foot belt around the northern mass contains 2 percent of the beryl resources, the belt around the southern mass contains 0.3 percent, and the one around the Hyatt plug contains 0.4 percent. By contrast, the next thousand-foot belt, concentric to the first belt, contains, in the same order, 9 percent, 9 percent, and 6 percent of the beryl resources. The 13 deposits that are not within the masses and their concentric belts contain 11 percent of the resources of the area (table 7).

These comparisons suggest that beryl deposits occur with somewhat greater frequency in granite masses which contain both large and small pegmatites than in granite masses with only small pegmatites, that discordant bodies are more commonly beryl-bearing than concordant ones, and that beryl deposits are least abundant in pegmatites immediately adjacent to granite masses.

Next in importance to deposits in granite are the discordant pegmatites; the pegmatites concordant in schist are the least important group.

The comparisons are given in table 8.

Garnet

Garnet is a common accessory mineral in the schist but is relatively uncommon in pegmatites, and has not been found in the granite. The crystals in schist range from microscopic in size to one-quarter of an inch in diameter; the average is about 0.01 inch. The garnet in pegmatite has about the same average size, but a crystal as much as 1¼ inches in diameter can be found in a few bodies. Most garnet crystals are reddish brown, but a few minute trapezohedral crystals are bright red and transparent. Garnet usually occurs in scattered groups of a few individual crystals and, more rarely, in rows near the pegmatite contact. Pockets one-half to 3 feet in diameter of closely-packed euhedral to anhedral grains are found in the hood of perthite-quartz pegmatite at the Big Boulder deposit. The grains are as much as an inch in diameter, and heavily stained with manganese oxides. Associated with this garnet are quartz, muscovite, plagioclase, tourmaline, and iron and manganese phosphates.

The specific gravity of individual fragments was calculated from weighings on a Berman microbalance, and the specific gravity of entire suites of grains from single localities were obtained by use of the pycnometer. The microbalance indicates that the specific gravity of garnet varies within single layers of schist and within individual pegmatite outcrops. The overall range is from 3.72 to 4.31, but there is little correlation between the specific gravity of individual grains and the bulk specific gravity of entire suites. Records of previous determinations do not exceed 4.25, so it is assumed the higher readings signify the presence of heavy impurities. The results of 24 microbalance determinations are given in table 9; the compositions are stated in terms of the percentages of theoretical end members: pyrope ($Mg_3Al_2Si_3O_{12}$), almandite ($Fe_3Al_2Si_3$-

Table 9.—Approximate composition of garnet in Hyatt area

Pegmatite number	Mn	Sp. G. individual grain	Index	Proportion					Sp. G. entire suite
				PY	AL	SP	GR	AN	
144	+	4.06	1.81			76	11	13	
185	+	3.80	1.81			30	35	35	
316	+	4.06	1.81			76	11	13	
397	-	3.86	1.81	33	38			29	
483	+	4.06	1.81			76	11	13	
495	+	3.75	1.81			21	41	38	4.10
584	+	4.07	1.81			77	10	13	4.22
584	+	3.77	1.805			26	38	36	
827	+	4.00	1.80			86	8	6	
863	+	4.22	1.81		36	64			4.06
972	+	4.15	1.81		20	77		3	
1050	-	4.06	1.81	21	71			8	
1054	-	3.95	1.81	28	53			19	
1068	+	3.72	1.81		15		48	37	3.90
1128	+	4.14	1.81	16	84				
1131	-	3.87	1.81	34	37			29	
1157	-	4.02	1.81	23	65			12	
1164	+	4.00	1.81			83	4	13	
1194	+	3.91	1.81			66	14	20	3.71
1201	-	4.14	1.81	16	84				
1285	+	3.98	1.805			82	7	11	
Pegmatite: not numbered	+	3.94	1.81			72	10	18	
Schist	+	3.97	1.795	27	53			20	
Schist	-	3.87	1.81	34	37			29	

O_{12}), spessartite ($Mn_3Al_2Si_3O_{12}$), grossularite ($Ca_3Al_2Si_3O_{12}$), and andradite ($Ca_3Fe_2Si_3O_{12}$) (abbreviated PY, AL, SP, GR, and AN, respectively). The compositions are approximate, and are taken from the data tabulated by Winchell (1947, pp. 174-183).

The index of refraction was measured by immersion in liquids of known index of refraction. A few indices are equal to 1.81, but most are slightly below 1.81 and above 1.805, and a few others are as low as 1.795.

The presence or absence of manganese was tested with borax beads. Garnets from some pegmatites contain manganese and others do not. Two specimens from pegmatite 584, selected from different parts of the body, indicate widely differing compositions. Many garnets from schist, not included in table 9, were tested for manganese and the results were consistently negative. A thorough study of garnet compositions and their distribution will require much more extensive sampling.

Apatite

Deep-green, bluish-green, and lilac apatite has been found in the explored deposits and in pegmatites 807, 1212, and 1246 as grains ranging from 0.1 to 0.6 inch in diameter. Apatite is commonly dark and distinctive, but a few grains of light bluish-green material were mistaken at first glance for beryl, for example, in the outer part of the wall zone at the Big Boulder deposit. Lilac-colored apatite occurs in the inner intermediate zone of the Hyatt deposit. It is a very rare constituent of the pegmatites and is recognized principally because of its distinctive color. Apatite is present also in a miarolitic cavity. Apatite is more abundant in the country rocks, but is visible only under the microscope.

Sillimanite

The schist contains sillimanite in fine acicular crystals, but the only specimen found in pegmatite consists of a cluster of parallel columnar crystals 0.5 to 1.5 inches long and averaging 0.1 inch in diameter. The crystals are a translucent grayish white, have a vitreous luster, and are somewhat fibrous. Sillimanite is associated with quartz, plagioclase, muscovite, and perthite, and occurs within 2 inches of the contact of pegmatite 1146. There are no indications that the sillimanite was derived by alteration of an argillaceous inclusion; if it is the result of contamination, the material was thoroughly digested before crystallization of the sillimanite and surrounding pegmatite.

Lithiophillite-triphylite

The phosphatic minerals lithiophillite and triphylite are end members of a continuous series between $LiMnPO_4$ and $LiFePO_4$. Ordinarily the phosphates of Fe, Mn, and Li are coated with dark-brown to dull-black products of oxidation and hydration. The alteration products constitute a number of minerals of which only purpurite is readily identifiable in the field. Members of the lithiophillite-triphylite series were found only in the three explored and one unexplored deposits.

A member of the lithiophillite-triphylite series was exposed in the upper part of the inner intermediate zone of the Hyatt pegmatite by mining operations in 1948. The fresh material is medium blue, and the lowest index is about 1.675. According to Winchell (1947, fig. 78, p. 150) this indicates an approximate composition of $lithiophillite_{80}$ $triphylite_{20}$. It is associated with quartz, pyrite, and lithia mica, and the aggregate forms blocky masses from 1 inch square to about 2 inches by 2 inches by 5 inches. Cinnamon-brown lithiophillite-triphylite was found in the lower part of the inner intermediate zone of the Hyatt deposit. The beta index of refraction is about 1.69 indicating a composition of about $lithiophillite_{45}$ $triphylite_{55}$. It is estimated that the lithiophillite-triphylite content of the workings made in the inner intermediate zone in 1948 was of the order of 0.00X percent. Workings driven before 1948 yielded about 300 pounds of the brown to black altered material, and the content of that part of the zone may have been as high as 0.01 percent.

Columbite-tantalite

A single block of rock found on the dump of the Buckhorn Mica mine contains more columbite-tantalite than has been found in the remainder of the Crystal Mountain district. The mineralogy of this sample indicates that it came from the core of the deposit. Three clusters of tabular crystals have an aggregate volume estimated to be about 11 cubic inches. The plates are from 0.01 to 0.23 inch thick, 0.2 to 3 inches long, and 0.1 to 2 inches wide. A block of what appears to be "massive" columbite-tantalite is about 1 inch by 1 inch by 0.7 inch. The Tantalum claim and the Crystal Silica claims described by Hanley and others (1950, pp. 93-96, 98-99) and the Beryl No. 5 claim, the Big Boulder deposit, the Hyatt pegmatite, and two small bodies not included in the areas mapped contain from a single crystal to three crystals of columbite-tantalite. The mineral dimensions range as follows: 0.02 - 0.1 inch in thickness, 0.3 - 0.9 inch in width, and 0.5 - 1.1 inches in length. From determinations of specific gravity it is possible to estimate the Ta_2O_5 and Cb_2O_5 content of columbite-tantalite: specific gravity of specimens from the Crystal Mountain district ranges from 6.2 to 7.3, indicating a range in Ta_2O_5 content from about 39 to 76 percent and in the Cb_2O_5 content of from about 10 to 48 percent. A specimen from the Tantalum claim has the highest reported specific gravity and tantalum content (Hanley and others, 1950, p. 99). The columbite-tantalite content of the Buckhorn Mica pegmatite and the Tantalum claim deposit may amount to a few hundred pounds; however, the columbite-tantalite found in the other pegmatites is negligible.

Bismuthinite

Bismuthinite (Bi_2S_3) and its alteration product, bismutite, a bismuth carbonate, occur in the inner intermediate zone of the Hyatt pegmatite. The writer estimates the content in the zone exposed by mining in 1948 amounted to 0.00X percent. In one place the bismuthinite formed a mass interstitial to large grains of perthite and quartz but with thin branches following fractures into other minerals. The main mass of bismuthinite was intergrown with plagioclase, muscovite, and quartz. The field determination of bismuthinite was verified chemically and the bismutite was identified by J. J. Glass of the Geological Survey. The bismutite is very fine grained but has the following characteristics: some grains are isotropic and others biaxial negative; mean index of refraction of biaxial grains is 2.20; the mineral occurs as square plates, is yellowish to light green; gives positive bismuth test; and effervesces with acid. X-ray examination by J. M. Axelrod of the Survey confirms the identification. A related alteration mineral also has been found: it is a greenish-gray, amorphous or cryptocrystalline bismuth carbonate.

It is reported that bismuth minerals were mined at the Crystal Silica property prior to 1900, but the amount and source are unknown.

Uraninite and related minerals

The inner intermediate zone of the Hyatt pegmatite contains uraninite and its alteration products in minute quantities. Smoky quartz and reddish-brown feldspar are found in the vicinity of radioactive minerals. It is reported that masses of uraninite as large as a walnut were found in the inner intermediate zone when the deposit was first opened. Still visible are masses of quartz as much as 4 feet in diameter which darken inward from gray edges to jet black centers and indicate that uraninite was once present. Fractures in the quartz contain scales and flakes of yellow autunite, gray metatorbernite and orange gummite. A specimen from the mine dump contains a dozen grains of dull black uraninite, ranging from 0.03 to 0.15 inch in diameter, embedded in perthite. Though not in actual contact with the uraninite, quartz grains in the specimen are black.

Autunite and gummite are present in pegmatite 824 but no uraninite is exposed.

Metatorbernite was identified in a specimen submitted to the Geological Survey Trace Elements Laboratory, and is reported to have the following properties: radioactive and faintly fluorescent; small 2V, uniaxial positive; beta and gamma indices of refraction close to 1.632; anomalous blue and purple interference colors in anisotropic sections; qualitative chemical tests show the presence of P, Cu, and U; it occurs as small green flakes.

No uraninite can be seen at the Big Boulder pegmatite but the intermediate zone contains the alteration products and smoky to black quartz. The associations are similar in the two deposits. The zones contain beryl, scrap mica, phosphatic minerals, columbite-tantalite, smoky quartz, and perthite. The Hyatt deposit contains, in addition, bismuth minerals.

Despite the variety of uranium-bearing minerals in pegmatites the total quantity of uranium obtainable from them is probably minor or negligible. The subject has been reviewed by Page (1950, pp. 12-34). The writer estimates that the uraninite content of the exposed parts of the intermediate zones at the Hyatt and Big Boulder deposits is of the order of 0.000X percent.

Relict spodumene

No unaltered spodumene has been found in the Crystal Mountain district but there is evidence that spodumene crystallized in the interior zones of the Hyatt, Big Boulder, and Buckhorn Mica pegmatites. The spodumene was altered to an exceedingly fine-grained aggregate of albite and sericite which has preserved the lath-like shape and the lamellar structure parallel to (100). Some pseudomorphs are 3 feet long and 2 to 4 inches thick. Spectrographic analyses of two specimens of the aggregate were made by A. T. Myers, Trace Elements Section Denver Laboratory, U. S. Geological Survey. Each specimen contains lithium of the order of 0.X percent, the specimen from the Big Boulder pegmatite is slightly richer than the one from the Buckhorn Mica pegmatite.

The field relations indicate that during the crystallization of the Big Boulder pegmatite, perthite crystallized in the outer and upper parts of the wall zones and as a hood in the intermediate zones, albite formed in these units (cleavelandite in the inner parts), and lithium crystallized as spodumene in the inner part of the intermediate zone. The spodumene, however, was not in equilibrium with the rest-liquid during later crystallization and was altered by reaction to albite and sericite. The resorbed lithium was redeposited, partly with iron and manganese phosphates as lithiophillite-triphylite, and partly as a minor element in lithium-bearing muscovite and sericite.

The sequence at the Buckhorn Mica pegmatite is similar, and simpler mineralogically. Albite and quartz grade inward into cleavelandite and quartz, and the spodumene that crystallized with cleavelandite and quartz was later altered by reaction; the freed lithium was incorporated in micas.

Hematite and magnetite

Hematite and magnetite were found in pegmatite 899. This quartz pegmatite contains tourmaline crystals, as much as 0.2 inch in diameter and 1.1 inches long, and one small mass of hematite and magnetite, 0.3 inch by 0.4 inch, and 0.03 inch thick. No feldspar or mica was found. Lodestone occurs intergrown with quartz and muscovite near the east margin of the quartz core of the Crystal Silica pegmatite.

Chrysoberyl

Pegmatites 1039, 1148, 1155, and 1158 contain asparagus-green to yellowish-green chrysoberyl in plates, masses, and imperfect crystals. The crystals are found in groups of 3 to 8 crystals per pegmatite and are 0.05 to 0.1 inch thick and 0.2 to 0.6 inch long. The chrysoberyl in pegmatite 1039 occurs in the core of perthite-quartz-plagioclase pegmatite. At the Beryl No. 5 prospect (fig. 2) a fracture in quartz is filled with many small plates of chrysoberyl which form an almost solid layer 0.02 inch thick, 4 inches long, and 2½ inches wide. Many of the plates are stellate twins showing fine feather-like striations on the (100) face.

Chrysoberyl is a rare mineral in the Crystal Mountain district but 5 miles to the north at the Wisdom Ranch prospect(S½ sec. 5, T. 7 N., R. 71 W.) described by Hanley and others (1950, pp. 102-104) numerous plates and masses of chrysoberyl have been found; however, it is quantitatively rare, even at the Wisdom Ranch prospect.

Miarolitic minerals

An irregular miarolitic cavity in the Hyatt pegmatite contained a compact mass of yellowish-green micaceous mineral, and minute crystals of a variety of minerals. The cavity was about 0.4 inch in average diameter and occurred in a fine-grained aggregate of quartz, plagioclase, and muscovite that fill the interstices between large perthite masses. The material was identified by J. J. Glass of the U. S. Geological Survey.

The micaceous material is sericite and the associated minerals, in the order of their abundance, are bertrandite, apatite, fluorite, tourmaline, hematite, and limonite.

The sericite is dominantly platy, but a small portion is fibrous, has a waxy luster, and does not yield a lithium flame. It is biaxial negative, 2V variable from 30° to 70°, the finer-grained material having the smaller optical axial angle. The gamma index is 1.577. A quantitative spectrographic analysis of the sericite, made by J. D. Fletcher of the Survey, is given in table 10.

The bertrandite is colorless, exhibits twinning, and perfect cleavage in three directions. The mineral is biaxial negative, angle 2V is 78° to 80°, extinction is parallel, and the indices of refraction are: N alpha 1.590; N beta 1.603; and N gamma 1.614. Bertrandite is a rare hydrous beryllium silicate (H_2O . $4BeO$. $2SiO_2$).

The apatite has the properties of fluorapatite: uniaxial negative, specific gravity near 3.3, the pale grayish sapphire-blue fragments have indices of refraction N epsilon 1.630 and N omega 1.633, and the colorless fragments have indices N epsilon 1.632 and N omega 1.635.

Tourmaline is present as small columnar crystals on albite at the edge of the cavity. It is black in hand specimen, but brown to greenish gray in thin grains. It is uniaxial negative with the indices N epsilon 1.626 and N omega 1.646.

Hematite and limonite are present as crust-like specks on the cleavage planes of the albite and as pale pink and pale yellow stains throughout the specimen.

Relation of pegmatites to wall rocks and structure

Wall-rock alteration

The alteration of schist and granite wall rock in contact with pegmatites of the Crystal Mountain district is in most places inconsequential. Black tourmaline has been added to schist and granite in quantities ranging from negligible to 40 percent; intense alteration is unusual and

Table 10.—Quantitative spectrographic analysis of sericite from the core of the Hyatt pegmatite, Crystal Mountain district, Colorado

J. D. Fletcher, Spectrographer

Be	0.04
Cu	0.002
Sn	0.01
Bi	0.004
Mn	0.3
Ga	0.008
Cr	0.0002
Sc	0.001
Ti	0.02
Zr	0.0007
Sr	0.01
Ba	0.04
B	0.02
Fe_2O_3	0.3 - 0.6
CaO	0.1 - 0.3
MgO	0.1 - 0.3

Plate examined for Ag, Mo, W, Ge, Pb, As, Sb, Zn, Cd, Tl, Co, Ni, V, La, Th, Cb, Ta, and U, but not found.

rarely extends more than 5 inches from the contact. Tourmaline crystals range from microscopic to 1 inch in length. Intensely altered mica schist contains about 20 percent tourmaline. Tourmalinization decreases outward from the contact and disappears at a distance of about 2 feet. As tourmaline is a common accessory mineral in some schist layers, as well as being widespread around most pegmatites, it has been recorded as a wall-rock alteration product only where it is especially concentrated. Bannerman (1943, p. 9) describes black tourmaline as a particularly common mineral in the contact zones in many districts in New Hampshire.

Tourmaline forms rosettes of acicular crystals in minute fractures between pegmatite and granite in the northern multiple granite sill. The needles are 0.1 to 1 inch long, as much as 0.05 inch in diameter, and the rosettes or clusters are no more than one-tenth of an inch thick. The tourmaline is attached to the pegmatite but not to the granite. Tourmaline rosettes have been found in only a few places; their exposure depends on fortuitous breakage.

The granite in contact with pegmatite is almost invariably silicified sufficiently to increase its resistance to erosion. The silicified wall rock forms low ridges flanking recessed pegmatites on the bare surfaces of the northern multiple sill. Narrow ridges of resistant granite are found along joint-like cracks which are in some places connected with pegmatites.

Granite in direct contact with the Hyatt, Big Boulder, and Buckhorn Mica pegmatites was analyzed for BeO, and the determinations are given in tables 11 and 12. Most samples represent about 1 foot of rock at the pegmatite contact, but samples from drill holes HY-4, HY-6, BB-4, and BH-2 represent greater distances. The locations of the samples are given in plates 17-21, 24-26, and 36-40. The range of BeO content in the granite is from

Table 11.—BeO content of granite near Hyatt pegmatite, Crystal Mountain district, Colorado

Drill hole	Sample number	Footage	BeO content (percent) _/	Material included in the granite
HY-1	C 223	56.8 - 57.4	0.011	Few quartz veins and pegmatitic blebs
HY-1	C 231	85.0 - 95.0	0.015	Aplite and pegmatitic stringers
HY-2	C 201	104.0 - 104.9	0.008	None
HY-2	C 218	165.6 - 166.8	0.009	Quartzose patches
HY-3	C 175	131.8 - 132.5	0.004	Pegmatitic blebs
HY-3	C 200	209.6 - 210.6	0.008	None
HY-4	C 145	169.0 - 170.0	0.009	None
HY-4	C 159	213.4 - 214.5	0.001	None
HY-4	C 160	217.5 - 218.7	0.009	Pegmatitic patches
HY-4	C 163	220.9 - 221.8	0.001	None
HY-4	C 165	222.2 - 224.4	0.01	Quartzose and pegmatitic patches
HY-4	C 167	227.8 - 228.2	0.001	None
HY-4	C 173	234.3 - 235.0	0.006	None
HY-5	C 144	83.6 - 85.0	0.01	One slickensided quartz vein
HY-6	C 123	54.0 - 55.0	0.0033	Quartz vein

_/ Quantitative spectrographic analyses of C 123 and C 144 by Saratoga Laboratories, and the rest by National Spectrographic Laboratories.

Table 12.—BeO content of schist near the explored deposits, Crystal Mountain district, Colorado

Drill hole	Sample number	Footage	BeO content (percent) _/	Nature of the schist
HY-1	C 222	55.0 - 56.8	0.001	Granitized and pegmatitic
HY-1	C 225	60.0 - 62.0	0.001	Pegmatitic impregnations
HY-6	C 111	29.0 - 30.0	0.0180	Tourmalinized; weathered
HY-6	C 113	34.0 - 34.4	0.034	Tourmalinized and silicified
HY-6	C 116	39.2 - 40.5	0.0055	Do
BB-3	C 110	82.4 - 83.2	0.0027	Not visibly altered
BB-4	C 79	56.0 - 57.0	0.0027	Do
BB-4	C 95	130.8 - 133.0	0.0045	Pegmatitic stringers and blebs
BB-4	C 96	133.0 - 134.1	0.0088	Do
BB-5	C 63	107.7 - 109.0	0.0019	Not visibly altered
BB-5	C 78	178.1 - 179.1	0.0046	Do
BH-1	C 56	72.5 - 73.5	0.0028	Do
BH-2	C 40	84.0 - 86.8	0.041	Pegmatitic impregnations
BH-2	C 41	86.8 - 90.5	0.0078	Not visibly altered
BH-2	C 48	112.7 - 114.4	0.015	Pegmatitic stringers and blebs
BH-2	C 50	115.1 - 120.0	0.0029	Do
BH-2	C 55	132.0 - 133.2	0.0038	Not visibly altered
BH-3	C 26	64.0 - 65.2	0.0028	Tourmalinized
BH-3	C 39	89.0 - 90.0	0.0021	Not visibly altered
BH-4	C 11	17.8 - 18.8	0.0016	Tourmalinized
BH-5	C 10	131.5 - 132.4	0.0028	Silicified

_/ Quantitative spectrographic analyses of C 222 and C 225 by National Spectrographic Laboratories, and the rest by Saratoga Laboratories.

a trace to 0.015 percent; the average of samples without visible alteration is 0.005 percent and the average of all granite samples (table 11) is 0.007 percent. As the limit of accuracy of the analytical method is about ± 0.001, there is no significant difference between the averages, and it is apparent that addition of BeO to granite is not important.

The range of BeO content in altered schist at the contact with pegmatite is from a trace to 0.041 percent. Schist that is not visibly altered contains an average of 0.003 percent BeO. The average BeO content of all samples in table 12 is 0.008 percent. Pegmatitic stringers and impregnations add BeO to the schist but there is no simple and consistent relationship between the addition of pegmatitic material and the beryllia content. The average of all schists, 0.008 percent, and of all granites, 0.007 percent, indicates that both types of country rock are about equally enriched in beryllia, though the content in schist is more variable.

Wall-rock control

Pegmatites concordant with the foliation of the schist have simple lenticular shapes. The exact ends of concordant pegmatites are rarely exposed, but from the steady narrowing of the exposed parts of the bodies and the diminution of the size of float it is inferred that the ends of the pegmatites are more or less wedge-shaped.

Pegmatites that are discordant to the foliation of the schist usually occupy simple fractures. The contacts may be irregular in detail but the general shapes of the discordant pegmatites are remarkably regular in comparison with those in other districts. For abundant maps and descriptions of pegmatites of more complex shape the reader should refer to papers by Bannerman (1943), Cameron and others (1949), Hanley, Heinrich, and Page (1950), Jahns (1946), Olson (1942), and Smith and Page (1941). Some of the more irregularly shaped bodies in the Hyatt area (pl. 1), such as pegmatites 448 and 645, are multiple bodies whose members are moderately straight and simple. The branching patterns of pegmatites 645, 673, 674, and 675 are produced by concordant offshoots of discordant bodies. Pegmatite 1108 follows intersecting fractures, and pegmatite 1045 is concordant in the eastern half and discordant in the western half. Irregular pegmatites 442, 463, 196, 248, 249, 898, and 900 have been but little eroded and might present more regular outlines if they were more completely exposed.

Pegmatite 432 seems to be the feeder for the flat-lying pipelike body which constitutes pegmatite 430. Pegmatite 432 is a steeply dipping body that trends eastward; pegmatite 430 branches northward from pegmatite 432. The lower contact of pegmatite 432 is an irregular surface with an average southerly dip of 20°, exposed in small outcrops for 200 feet north of the junction. The structure controlling the emplacement of pegmatite 430 is not exposed, but it may have been the low-angle line of intersection of two nearly parallel joints with opposed directions of dip. Other pegmatites in the area show apophyses following planes of weakness that diverge from the structure localizing the main body: the southwestern end of the concordant branch of pegmatite 645 follows a plane dipping 45°-55° NE.; the southwest-trending discordant branch of pegmatite 846 rests in part on a plane striking N. 70° W. and dipping 25° NE; along the south side of pegmatite 695, the pegmatite bulges outward for a few inches to rest on a joint in schist striking N. 31° W. and dipping 6° NE.

Pegmatites that occupy joints in granite are tabular bodies with straight courses and angular bends. Some joint-controlled pegmatites end abruptly and squarely against other joint surfaces, and some taper to a knife-edge as the walls converge. Most joint-controlled pegmatites lose their identity in a network of other joint-controlled bodies. Pegmatites form a veritable maze of interconnected bodies at the western end of the northern multiple granite sill: in the western part, (pl. 1) are shown all the pegmatites over 5 feet in width and as many of the remaining bodies over 1 foot wide as can be plotted at a scale of 1:6,000. Eastward from pegmatite 300 all bodies over 1 foot wide and many of the persistent narrower ones are mapped. North and east of pegmatite 105 bodies less than 3 inches wide and less than 50 feet long are common but were not mapped.

The relation of many bodies to wall-rock structure is not apparent in the field and only those that are clearly joint-controlled are so designated in table 17. The various networks of pegmatites centering around pegmatites 278, 375, 332, and 384 are similar to the more extensive and intricate networks made up of narrower bodies.

Many pegmatites within granite sills are parallel to the flow structure or are along the hanging wall or footwall of the sills. These bodies have the same structural characteristics as pegmatites concordant with the schist. Pegmatites 85, 87, and 88 dip southward parallel to the footwall contact of the northern granite mass, and give the impression of being concordant in the longitudinal fractures of marginal sills.

There are small irregular patches of pegmatitic material in parts of the large multiple granite sills that are not fracture controlled pegmatites. They are amoeboid in shape, with intricately embayed outlines and gradational contacts; but they are clearly fine-grained pegmatites. The material has the minerals typical of the granitic pegmatites of the district, perthite, plagioclase, quartz, and muscovite and contrasts sharply with the biotite granite host rock. These bodies range from a few inches to 2 feet in maximum width and from 1 to 5 feet in maximum length. They are not alined in any recognizable pattern with respect to the structure of the enclosing granite. Comparison of the mineralogy of the pegmatite with the host indicates that the pegmatitic material contains more plagioclase and muscovite, less potash feldspar, and no biotite or magnetite; the pegmatite therefore must have crystallized from material higher in alkalies and water and lower in iron than the surrounding granite.

These pegmatitic patches are so small, irregular, and rare that they are quantitatively unimportant but they pose an interesting genetic problem. The writer interprets these pegmatitic patches as segregations of material rich in hyperfusibles which probably originated by differentiation of the granite after emplacement as a sill. The hyperfusibles apparently accumulated in pockets as the sill solidified. These irregular patches would correspond, according to this interpretation, to the early generation of pegmatites discussed by Grout (1932, pp. 220-221). The origin proposed for these pegmatites is similar to that postulated by Kelley and Branson (1947, p. 708) for the pegmatites of Rabb Canyon, N. Mex.

Six broad mineralogic types of pegmatites are recognized in the area, but no single type is restricted to any particular lithologic or structural environment. Garnet does not occur more abundantly in pegmatites under one condition than any other. The distribution of moderate to intense tourmalinization of country rock shows no preference for association with a mineralogic type of pegmatite. Tourmalinization does seem more prevalent in granite than in schist, but the writer hesitates to draw conclusions from this simply because tourmalinized granite is so much more striking to the eye than tourmalinized schist; equivalent tourmalinization in schist might go unrecorded, particularly because the granite is usually better exposed than schist. Only beryl exhibits a discernible preference in distribution. It is slightly more abundant in discordant than in concordant pegmatites in schist, and is found in more deposits away from the large multiple granite sills than immediately adjacent to them. (See table 7.)

Throughout the Georgetown quadrangle, Ball (1908, p. 64) finds a fairly constant relation between the mineralogy of the country rock and that of the pegmatites. There are many exceptions, but the following correspondence is noted:

1) Biotite-bearing pegmatites in biotite-bearing older granites.

2) Hornblende-bearing pegmatites in quartz diorite and hornblende gneiss.

3) Muscovite-bearing pegmatites in the Idaho Springs formation.

4) Pegmatites in quartz monzonite areas are characteristically without ferromagnesian minerals, and many of them contain, instead of an alkali feldspar, a soda-lime feldspar.

5) Allanite-bearing pegmatites in allanite-bearing quartz monzonite.

Ball (1908, p. 64) concludes that in the Georgetown area the pegmatite fluid abstracted, prior to solidification, sufficient material from the enclosing rock to modify the chemical composition of the pegmatite. Ball infers that magnetite was an original constituent of the pegmatite magma because it alone of the ferromagnesian constituents of the pegmatites is not influenced by the rock intruded. In the Montezuma quadrangle Lovering (1935, pp. 15-16) found the same general relationship between the composition of the country rock and the pegmatites; he adds that quartz-sillimanite-tourmaline-bearing pegmatites occur in quartz-sillimanite-tourmaline-bearing schist. Lovering describes a pegmatite transgressing the contact between biotite granite and muscovite schist: the pegmatite contains biotite between granite walls, muscovite between schist walls, and both biotite and muscovite in the vicinity of the contact between granite and schist.

The sills of Mount Olympus granite in the Hyatt area are everywhere rich in biotite despite their irregularities in texture, fabric, and color. The schist contains biotite in all exposures. With three minor exceptions muscovite is the only mica in the pegmatites. No biotite has been found as an essential constituent or even as an important accessory in any deposit. Sillimanite is a common minor accessory in the schist, but only one small cluster of sillimanite (in pegmatite 1146) has been found. Garnet and tourmaline are common accessories in the schist, are abundant in and near pegmatites, and tourmaline, at least, is native to the granite, and therefore these minerals do not offer a means of correlating mineralogy of pegmatite with wall rock. The widespread tourmalinization of granite and schist and the moderate silicification of granite indicate that solutions escaped from the pegmatite magma and contributed material to the country rock, but the compositions of the pegmatites do not indicate significant or even any detectable assimilation of wall rock.

Minor elements in wall rocks

Analyses of 24 samples of wall rock show small, but generally consistent amounts of rare elements. In the course of the exploration, the drilling of some holes furnished cores of virtually unweathered granite and schist. Samples of wall rock for spectrographic analyses were cut from cores at the Hyatt, Big Boulder, and Buckhorn Mica deposits. Each sample is one-half of the drill core split from a 5-foot section; the sections are taken at 15-foot intervals from the pegmatite contact, but do not include wall rock within 10 feet of the pegmatite. The positions of the 24 wall rock samples are marked in plates 17, 18, 25, 26, 36, and 38, and the semiquantitative spectrographic analyses are given in table 13.

The analyses indicate that the granite contains small and erratic quantities of silver, molybdenum, and a trace of bismuth not found in the schist, and the schist contains small but consistent amounts of yttrium and lanthanum not present in the granite. The schist is also richer in cobalt, chromium, vanadium, zirconium, boron, and magnesium than the granite. The granite seems to have a somewhat greater amount of lead, calcium, strontium, and barium. The differences, however, are not striking, and are no more than one unit in the order of magnitude scale. In samples taken more than 10 feet from the contact there is no indication of a systematic increase or decrease in the content of any component in either the schist or the granite outward from the wall of the pegmatite.

If there were such systematic variations it might indicate that the emplacement and crystallization of the pegmatite had effected some changes in the surrounding rock by the addition or subtraction of material. The absence of discernible systematic variation means that either (1) the contact aureole is so large that the samples represent rocks that have been affected equally, or (2) the wall rocks have been so little altered chemically that the change is not detectable with the methods used. The first alternative seems so improbable that the writer believes the analyses in table 13 are truly representative of the trace elements in the normal country rock at each deposit. If there is a contact aureole, it must extend less than 10 feet from the pegmatite.

Age relations of pegmatites

The sills of Mount Olympus granite were intruded over a period of time, probably from a magma source to the south that might have been subsidiary to the Pikes Peak batholith. Minor variations in composition and major variations in texture and fabric of the granite, and the structural relations of the sills to the schist and to each other, are evidence that the sills were emplaced as successive injections. Quartz veins, less than 3 inches in width and not more than a few tens of feet in length, were deposited in fractures that formed late in the cooling history of the sills.

After the granite was well crystallized, joints developed which in some places cut across the margins between members of the multiple intrusives and across the contacts between schist and granite. Pegmatites were emplaced in the joints, the walls moving apart so as to cause a few inches displacement of the quartz veins.

The pegmatites were also emplaced over a period of time. The mineralogic types, limited in number as they may be, correspond to the progressive changes in composition of a granitic magma during crystallization. The mineralogic types are unsystematically intermingled throughout the area, apparently indicating that the pegmatitic materials were fed sporadically into the area from an underlying source-magma undergoing fractional crystallization. From the relations in the Georgetown area, Ball (1908, p. 64) concluded the pegmatite magmas left the cooling mass of granite at widely differing times and differed in chemical composition. Lovering (1935, p. 15) states that the structural relations of the pegmatites to themselves and to other rocks in the Montezuma quadrangle indicate that their intrusion took place over a long period. Few of the intersecting pegmatites in the Hyatt area show conclusive age relations. Pegmatite 1192 is younger than the northwest branch of pegmatite 1197 and is probably younger than pegmatites 1190, 1191, and 1193 (pl. 1). Pegmatites 117 and 116-b are parallel; they are cut by pegmatite 116-a. Pegmatite 263 is a multiple body, made up of an anastomosing network of pegmatites 2 to 18 inches thick; it intersects several pegmatites, but only its relations with pegmatite 264 are well exposed. The continuity of the network comprising pegmatite 263 across pegmatite 264 is indicated by fine-grained border-zone material along two of its branches, and by a consistently greater resistance to erosion of most parts of pegmatite 263.

Origin

At one time there seemed to be little question that pegmatites were true eruptive rocks formed by crystallization of a magma derived from a source within the earth's crust. In 1925 this view was changed by three independent papers by Schaller, Hess, and Landes. Each advocated that part or all the zonal and related internal structures of complex pegmatites were developed by hydrothermal or pneumatolytic replacement of earlier-formed pegmatite or aplite. These ideas have been used and elaborated since by a number of geologists, notably Landes (1928, 1933), Gevers (1929), Anderson (1931), Fersman (1931), Bjorlykke (1937), Quirke and Kremers (1943), and possibly Uspensky (1943). In these papers there is the tacit assumption that the pegmatite magma and the later fluids of replacement, if any, are derived from granitic magma. By any hypothesis of the formation of granite--whether by the melting of a deep section of the sialic crust, by the differentiation of a basaltic substratum, or by the transformation and mobilization of rock without a magmatic stage--a fraction with granitic composition rich in hyperfusibles can be derived which will serve for pegmatite magma.

Cameron and others (1949, pp. 97-106) have reviewed the literature and the field evidence offered by a large number of zoned pegmatites in many parts of the country. Additional reviews and evaluations of field evidence are contained in district studies by Bannerman (1943), Cameron and others (1945), Hanley and others (1950), Jahns (1946), Olson (1942), Page and others (in preparation), and Staatz (in preparation). The mode of origin of internal structures agreed upon by these men is summarized below but no attempt is made to review their evidence or arguments.

Pegmatitic magmas are derived as a byproduct of the differentiation of granitic magma. They are formed over a period of time and vary somewhat in composition, depending on differences in place as well as time of escape from the parent chamber. Granitic pegmatite magma is composed of the same essential elements as granite: sodium, potassium, aluminum, silicon, and oxygen in large quantities; magnesium, calcium, iron, and manganese in relatively small quantities; and beryllium, fluorine, boron, phosphorus, lithium, and many less common metallic and rare-earth elements in widely differing, but, generally small, quantities. Water is an important part of the solution and is present in relatively large proportions as compared with the water content of the parent granitic magma.(See Ingerson, 1950.)

The pegmatite magma invades the country rock in much the same manner as other eruptive rocks: it moves under pressure, follows the path of least resistance,accommodates itself to pre-existing structures, and is capable of deforming its wall rocks. With declining pressure, and loss of heat and some of the more fugitive mineralizers (boron and water, for example), viscosity increases and eventually the magma comes to rest. In some magmas crystallization starts before the last movements are completed, and gneissic and flow structures develop.

Solidification proceeds from the walls inward and follows the normal order of crystallization of the minerals of igneous rocks. Fractional crystallization of pegmatite solutions rich in mineralizers and trace elements produces zones characterized by distinctive mineral assemblages arranged in a constant sequence. The process may be interrupted by deformation and fracturing, by escape of hyperfusibles, or by intense reaction between earlier-formed pegmatite minerals and the rest-liquid. The systematic variation in composition of persistent or recurring minerals in the zonal sequence indicates that fractional crystallization produces a rest-liquid progressively richer in hyperfusibles. As stated by Bastin (1950, p. 8)

> "A crystallizing magma is a system characterized by changing conditions of equilibrium in the still liquid portions. Such changes in equilibrium may lead to changes in the composition of the minerals deposited and/or to resolution of minerals already formed."

The unceasing attempt to establish equilibrium between the solid phases and the residual liquid phase of the complex system produces a host of replacement textures. In the final stages of the process of fractional crystallization the rest-liquid becomes so rich in mineralizers by residual concentration that it has more of the characteristics of a hydrothermal than a magmatic solution. Movement of the rest-liquid (or fractions thereof) into solidified parts of the pegmatite or into the wall rock produces replacement bodies. There is no evidence that zones or replacement bodies in pegmatites are formed from solutions that invaded the pegmatite body from outside sources.

The papers referred to in the preceding paragraphs and the theory of origin outlined above are concerned almost exclusively with the internal structure of zoned pegmatites. There does not seem to be any question that "simple" "unzoned" bodies, the homogeneous pegmatites, are deposits of orthodox magmatic origin. About 98 percent of the pegmatites in the Hyatt area are not zoned; of the 28 zoned bodies 43 percent show only rudimentary zoning. Only one pegmatite in the Hyatt area is sufficiently well zoned to rank with those discussed in previous papers. The study of the Crystal Mountain district has not disclosed new data concerning zoned pegmatites, but it provides supplementary information on a number of points:

1) The district provides examples that confirm the nature and sequence of 6 of the mineral assemblages described by Cameron and others (1949, p. 61).
2) There is independent verification that plagioclase-quartz pegmatite should be included as a distinct assemblage pre-

ceding plagioclase-quartz-spodumene pegmatite in the general sequence of mineral assemblages as proposed by Page and others (in preparation).

3) Where there is a systematic variation in the composition of beryl it consistently indicates an inward increase in the alkali content of the solution from which it was deposited.

4) The fracture filling at the Big Boulder deposit shows that the shell of partly solidified pegmatite was broken after the border zone, wall zone, outer intermediate zone, and a 4-foot thickness of the hood were formed; a portion of the solution from which perthite-quartz pegmatite was being deposited was drawn into the fracture; the liquid continued normal crystallization and perthite-quartz pegmatite was deposited which is continuous with and indistinguishable from the material composing the hood (pl. 22).

The writer believes the principal contribution that the study of the Crystal Mountain district can make to the problem of the origin of internal structures of pegmatites is in the relation of homogeneous to zoned deposits. What seems like a monotonous array of "unzoned" pegmatites contains many variations in texture, mineral proportion, and distribution. There is an insensible gradation from (1) pegmatites composed of uniformly disseminated grains of small size, through (2) bodies containing crudely segregated clots of minerals in a homogeneous matrix, and (3) two-zoned pegmatites whose cores are coalescing clots, to (4) multi-zoned deposits of contrasting mineral assemblages and grain sizes in gradational units composed of the same essential minerals as the preceding groups in the series.

(See pl. 6.) No member of the series contains evidence of the action of solutions coming from outside the pegmatite body. All members of the series show the same kinds of changes in grain size and distribution of minerals, and the changes are of the same kinds exhibited by common eruptive rocks.

The relation between homogeneous and zoned pegmatites gives some basis for speculation on the factors that control or promote zoning. A series of hypothetical cases will illustrate one set of conditions visualized by the writer which will be compared with a different set discussed later:

1) A pegmatite magma containing the same elements as granite and in the same proportions as granite, with the addition of the barest essentials of mineralizers (perhaps water, boron, and phosphorus) to promote supragranitoid grain size, will crystallize as the simplest type of homogeneous pegmatite with the composition of assemblage 3 (table 6).

2) A magma with the same elements but in different proportions will crystallize with rudimentary zonal structure.

   a. A slight excess of silica will produce quartz clots; a marked excess will produce a quartz core, as in assemblage 12.

   b. Lesser amounts of silica will leave perthite as the dominant mineral crystallizing at the last, forming clots or a core of assemblage 4.

   c. An excess of the elements of plagioclase will promote early saturation of the magma with respect to plagioclase and a plagioclase-rich wall zone will form of the composition of assemblage 1 or 2.

These hypothetical cases are believed to be representative of the processes that formed the zoned pegmatites of the Hyatt area, with the exception of the Hyatt pegmatite. The mineral assemblages developed hypothetically are the same as those actually found in the area, and the list is limited to assemblages 1, 2, 3, 4, and 12. Assemblage 4 is closely related to assemblage 10, and 1 and 2 are akin to 6, but 6 and 10 have not been found except in the association discussed below. The recurrence of minerals in nearly identical assemblages but with different structural positions within the pegmatites must require conditions not commonly met even by those unusual pegmatites that develop two zones.

Variations in proportions of the elements of common granite-forming minerals can produce a limited variety of zones. Other factors control or promote the development of the complex patterns of internal structure typical of well-zoned deposits: the wide range of textures, the recurrence of certain essential minerals in more than one assemblage, the marked segregation of accessory minerals, and the development of special units such as perthite-rich hoods, and replacement bodies. In the Crystal Mountain district the homogeneous pegmatites have the widest range of shape, size, type of country rock, and structural environment; therefore, it is not the amount of magma, nor the cooling rate, nor the pressure conditions that determine whether or not zones will develop. The well-zoned deposits, Hyatt, Big Boulder, the Buckhorn Mica pegmatites, are distinctive by comparison with nearby pegmatites only by reason of their content of such elements as bismuth, tantalum, columbium, lithium, uranium, phosphorus, fluorine, and the rare earths. The writer infers that the initial composition of the pegmatite magma, particularly the content of minor constituents, determines in most magmas whether or not it will become a complexly zoned deposit.

There is no evidence that zoning is developed through the action of one of the elements listed nor does it seem likely that all are necessary. All the well-zoned pegmatites do not contain the same elements. There must also be a lower limit to the concentration and combination of minor elements effective in promoting the development of zonal structure because recognizable crystals of minerals containing rare or mineralizer elements are found in a few places in homogeneous pegmatites. Lithium-bearing compounds are essential constituents in four mineral assemblages and are present, at least in trace quantities, in so many complexly zoned deposits that the presence of lithium is considered a major factor in promoting extensive zoning. The concentration of beryllium does not seem to be important in promoting zonal structure. Pegmatites 132, 357, 387, 402, and 606 contain approximately the same percentage of beryl as the Big Boulder and Buckhorn Mica deposits but they are not zoned; pegmatites 441, 563, 773, 774, 859, and 1039 are zoned bodies but contain no beryl.

The quartz-rich bodies are classed as pegmatites rather than quartz veins because most of them contain at least trace quantities of feldspar and muscovite, and resemble the quartz cores of pegmatites of type I (tables 5 and 17). But, as in the case of the tourmaline-rich bodies of type III, they may be transitional genetically between pegmatites of magmatic origin and veins of hydrothermal origin, or may actually be products of crystallization from hydrothermal solutions.

MINERAL RESOURCES OF THE CRYSTAL MOUNTAIN DISTRICT

Beryl, perthite, scrap mica, and columbite-tantalite are the principal resources of the pegmatites of the Crystal Mountain district. These minerals are not being mined at the present time because the grain sizes and the concentrations are too small to be recovered at a profit by hand sorting. The future of the district depends upon the development of milling methods which will profitably separate beryl, perthite, mica, and columbite-tantalite from the associated minerals. The irregularity of the shapes and grain boundary relationships of beryl and other minerals (pl. 8A) may necessitate elaborate milling to effect high recovery of clean beryl.

Beryl is the most important mineral in the district. It is present in 78 pegmatites in quantities of 1 ton or more, and occurs as a minor constituent of at least 271 pegmatites. The beryl grains range from microscopic in size to 7 feet long, but the majority are less than 3 inches. The beryl content ranges from trace quantities in many pegmatites to about 2 percent in some units of zoned deposits. It is present in all types of feldspar-rich pegmatites. Beryl-bearing pegmatites are not restricted to any special structural environment or type of country rock, but there appear to be fewer rich deposits in the thousand-foot belts immediately adjacent to granite masses of the Hyatt area than in the masses themselves, or in the areas farther than 1,000 feet from the masses. Discordant beryl-bearing pegmatites in the Hyatt area contain richer deposits than the concordant pegmatites.

Beryl has been produced from fortuitous exposures, and there has been comparatively little waste rock to move. The top of the Hyatt pegmatite has been eroded to the level of the inner intermediate zone and many large crystals were exposed before mining. Greater-than-average thicknesses of beryl-rich rock were available for mining in the gentle folds of the crest of the same zone in the upper opencut (pl. 9). Future mining will undoubtedly expose large crystals, but the principal reserves of beryl are in grains less than 3 inches in size. The pegmatites will have to be milled to recover the beryl, and the reserves of potash feldspar, scrap mica, and columbite-tantalite will constitute byproducts of value.

Perthite constitutes as much as 70 percent of some pegmatites, but more commonly ranges from 20 to 60 percent. It makes up 96 percent of the core of the Hyatt pegmatite. The perthite grains in most pegmatite range from microscopic in size to 15 inches; only in zoned pegmatites are there perthite crystals as much as 10 feet in diameter. The average size of perthite grains in the district probably does not exceed 3 inches. Perthite of such small average size and intergrown with other minerals is not exploitable at this time.

Muscovite is a minor constituent of the pegmatites, but it would probably be recovered by almost any milling process and is therefore of potential byproduct value.

Columbite-tantalite is a rare constituent of the pegmatites at the Buckhorn Mica mine and Tantalum claim, and is present in trace quantities in five other deposits in the district. Several hundred pounds of columbite-tantalite may be obtained from the Buckhorn Mica mine and the Tantalum claim, and small quantities might be recovered from other deposits if they were milled for beryl, perthite, and scrap mica.

The plagioclase and quartz of the Crystal Mountain district have no present value. The plagioclase is dominantly albite and could be used in commerce, if recovered by milling. The albite is generally fine grained, grayish white to pink, and intimately intergrown with other minerals; it seems improbable that this material could compete in the near future with the coarse-grained feldspar mined in other districts. The current market for soda spar is more limited than that for potash spar. Light-gray to smoky quartz has no special properties that make it a salable product.

The pegmatites of Tps. 6 and 7 N., and Rs. 71 and 72 W. have been prospected intermittently since about 1934 and it is improbable that outcrops of coarse-grained beryl, perthite, or mica have been overlooked.

Concealed zones may contain hand-cobbable crystals. Albite which increases markedly in size and developes a plate-like habit toward the interior of the pegmatite suggests that it is a zoned body. Stringers and patches of fine-grained curved muscovite, and fine-grained aggregates of sericite and albite cutting all other minerals also suggest that the pegmatite is zoned. Many of the pegmatites that contain an unusually high proportion of fine-grained beryl in the outer part of the body also contain medium-grained beryl in the interior.

Beryl is generally associated more intimately with plagioclase and muscovite than with quartz and perthite; therefore, the plagioclase- and muscovite-rich units of zoned deposits and clots of homogeneous pegmatites should be examined with care.

The beryl of some pegmatites and fracture fillings is concentrated close to the margin, and gives a false appearance of abundance. A beryl-bearing fracture filling that cuts across a large barren pegmatite may give the impression that the large pegmatite is rich in beryl.

DESCRIPTIONS OF INDIVIDUAL PEGMATITES

Over 1,300 of the pegmatites mapped in the Hyatt area have been individually examined and described, and the essential information is given in table 17. Pegmatite numbers correspond with those on the index map (pl. 4), and the descriptions are arranged in groups according to mineralogic composition as outlined in table 5. Such pegmatites as exhibit special features or constitute nearly ideal examples of some typical relationship have been discussed in the appropriate sections of this report. Most of the pegmatites have characteristics that fall well within the types that have been discussed in preceding sections.

Hundreds of pegmatitic patches, small pegmatites, and quartz veins were cored in the course of drilling the three zoned deposits; some are satellites and offshoots of the main body, some are barely more than pegmatitic impregnations of the wall rock, but others are individual pegmatites distinct from the deposits being explored.

The small bodies are mineralogically like the homogeneous deposits mapped in the Hyatt area, and many are also like the wall zones of the zoned deposits. Analysis of 32 samples shows that BeO is present in amounts ranging from 0.001 to 0.50 percent, and averages about 0.03 percent. Some of the small bodies are as rich or richer than the wall zones of the adjacent zoned deposits. Samples C 21 to C 25 (table 14) are taken from a concealed zoned body; it is closely related mineralogically to the nearby Buckhorn Mica pegmatite, but the structural relations are unknown. It is interpreted as an independent pegmatite, not connected directly with the larger zoned body.

Deposits explored by core drilling

Hyatt pegmatite

The Hyatt pegmatite is about 23 miles by road west of Loveland, Colo., in NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 28, T. 6 N., R. 71 W., sixth principal meridian. It is reached from Drake on U. S. Highway 34 by going west on the Glen Haven road for 500 yards and then turning northward on to a private road (fig. 2). The private road goes to the Fred Hyatt ranch on which the deposit is found.

The deposit was discovered in 1936 by Roy Hyatt, but little work was done until September 1942 when it was leased to the United Beryllium Ores and Metals Corporation of Denver. The pegmatite was mined intermittently during the fall of 1942, and was operated steadily from June to December 1943 under a financial arrangement with the Reconstruction Finance Corpora-

Table 14.--BeO content of concealed zoned pegmatite cored in drill hole BH-3, Crystal Mountain district, Colorado

Sample number	Footage	BeO content (percent) 1/	Internal structure and mineralogy
C 21	47.5 - 48.4	0.0014	Wall zone of quartz-plagioclase-muscovite pegmatite.
C 22	48.4 - 48.9	0.0043	Intermediate zone of cleavelandite-quartz pegmatite.
C 23	48.9 - 50.4	0.0011	Core of quartz pegmatite.
C 24	50.4 - 51.2	0.058	Intermediate zone of cleavelandite-quartz pegmatite.
C 25	51.2 - 51.8	0.036	Wall zone of quartz-plagioclase-muscovite pegmatite.

1/ Quantitative spectrographic analyses by Saratoga Laboratories.

tion. The mine was idle from 1944 to 1948. In the spring of 1948 a lease was granted to the Beryl Ores Company who operated the Hyatt mine from May to October 1948. The mine was inactive during 1949 and 1950. Since 1936 about 50 tons of beryl, 30 tons of scrap mica, and 400 tons of potash spar have been produced. The potash spar was mined from the core of the pegmatite, and the other minerals from the inner intermediate zone. The deposit has been opened by three opencuts and a number of shallow prospect trenches. One of the opencuts has been back filled and all but one of the trenches have been destroyed by later workings. The Hyatt pegmatite is shown both prior to mining and after the 1943 operations in two maps and two photographs by Hanley and others (1950, pls. 13 and 14). The extent of the mine after the activities of 1948 is shown in plate 9.

The Hyatt pegmatite was mapped by Hanley and Page in October 1942, and additional studies and maps were made in September 1943 and June 1944 (Hanley and others, 1950, pp. 99-102). In September 1947 the writer and A. J. Lang remapped the deposit.

Geology

The Hyatt pegmatite cuts across a small plug-like mass of gray biotite granite which crops out along the crest of a small anticline in quartz-mica schist (pl. 1). Pegmatites are abundant in the vicinity but none are zoned bodies though a few of them are beryl-bearing. The contact between the granite plug and the schist is not exposed, and the contact between the Hyatt pegmatite and the granite is visible only in the workings on the northwest (hanging-wall) side.

The contact between granite and pegmatite is gradational and somewhat irregular. The feldspars and quartz interlock and are indistinguishable even under the microscope, but biotite is restricted to the granite. Viewed under the microscope the quartz and feldspars of the granite exhibit strain shadows and the biotite flakes are bleached for a fraction of an inch beyond the limits of definitely recognizable pegmatitic material. The force of intrusion of the pegmatite magma probably deformed the grains, and solutions escaping from the pegmatite altered the biotite. The pegmatite has no border zone in many places at the contact with granite, and though the position of the contact can be fixed within a few inches, the attitude of the contact can only be approximated. At the contacts with schist the border zone is well developed and the attitude is readily determinable.

The Hyatt pegmatite is 365 feet long and has a maximum width of 70 feet. It is a roughly lenticular asymmetrical body whose long axis trends N. 60° E; it has an average dip of 60° NW. The northeast end has a flat plunge to the southwest which steepens in the granite (pl. 10). The southwest end plunges about 42° northward so the pegmatite has approximately the shape of half a lens tapering downward and to the northwest. The core of the pegmatite is crossed by a curving and branched fracture filled with granular friable gouge about 4 inches thick. The fracture has a general trend of N. 50° E., dips steeply southeast, and seems confined to the core of the deposit. A few 1- to 4-inch irregular aplite dikes cut all zones of the pegmatite.

The Hyatt pegmatite is divided into the following zones: a wall zone of plagioclase-perthite-quartz pegmatite, an outer intermediate zone of perthite-quartz pegmatite, an inner intermediate zone of plagioclase-quartz-muscovite pegmatite, and a core of perthite pegmatite. The wall zone and inner intermediate zone are continuous around the deposit, but the outer intermediate zone is restricted to the hanging-wall side of the body. Drilling disclosed that in the lower part of the body the wall zone contains almost no perthite, and confirms that the outer intermediate zone is not present on the footwall side. The average composition of the entire pegmatite, calculated from the composition of the individual zones, is plagioclase 50 percent, perthite 35 percent, quartz 15 percent, and muscovite less than 1 percent.

The concentration of perthite in the upper part of the pegmatite is so marked that zonal boundaries have been drawn (pl. 10) on the basis of its distribution.

The upper wall zone consists of about 50 percent plagioclase (albite), 25 percent perthite, and 25 percent quartz. The zone has an average width of about 25 feet, but ranges from 1 to 60 feet. The texture is fine grained and the grains average slightly less than 1 inch in diameter, though perthite grains are as much as 4 inches in length. Muscovite is a common accessory in flakes and books from microscopic in size to 2½ inches in length. Beryl occurs as irregularly disseminated euhedral to anhedral blue-green crystals. The sizes and shapes of the beryl grains found in the drill core are shown in plates 11 to 16. Tourmaline is present near the contact as crystals 0.01 to 0.7 inch long, and in the southwestern end of the pegmatite as clusters of columnar crystals up to 2 inches long.

A sample of the wall zone, weighing almost 300 pounds, was taken from the southwest trench (pl. 9). The BeO content determined by quantitative spectrographic analysis is 0.078 percent, and by the nuclear reaction method it is 0.066 percent. An average of the determinations of index of refraction of beryl in this zone indicates that the beryl contains about 12.4 percent BeO. The analyses, therefore, indicate about 0.6 percent beryl in the sample; this is higher than the average for the entire zone but confirms the measurement of beryl grains made in and near the trench.

The results of chemical analysis and semiquantitative spectrographic analysis of the same sample are given in tables 15 and 16, respectively. The proportions of "standard mineral molecules" or "normative minerals"

Table 15.—Chemical analysis and norm of plagioclase-perthite-quartz pegmatite, wall zone of Hyatt pegmatite, Crystal Mountain district, Colorado

A. M. Sherwood, analyst

Analysis

SiO_2	72.61
Al_2O_3	15.60
Na_2O	5.85
K_2O	3.88
Fe_2O_3	0.24
FeO	0.43
CaO	0.35
MgO	0.12
V_2O_5	0.04
TiO_2	0.01
MnO	0.04
BaO	0.05
U	0.004
H_2O-	0.04
H_2O+	0.45
	99.714

Norm

Quartz	22.5
Orthoclase	22.8
Albite	49.8
Anorthite	1.7
Hypersthene	0.8
Corundum	1.0
Magnetite	0.2
	98.8

Table 16.—Semiquantitative spectrography of plagioclase-perthite-quartz pegmatite, wall zone of Hyatt pegmatite, Crystal Mountain district, Colorado

Helen Worthing, spectrographer

Limits of concentration, percent	Elements
Over 10.0	Si
1.0 to 10.0	Al, Na
0.1 to 1.0	K, Fe
0.01 to 0.1	Mn, Ba, Mg, Pb, Ca, Cu, Ca, V
0.001 to 0.01	Sr, B, Ti, Bi, Cr

calculated from the chemical analysis according to the system of Cross, Iddings, Pirsson, and Washington (Washington, 1917) are: orthoclase 23, albite 50, anorthite 1.7, corundum 1.0, magnetite 0.2, hypersthene 0.8, and quartz 23. The differences between the hypothetical norm and the actual mode are minor: the muscovite present in the rock and not included in the norm is represented by corundum, water, and part of the quartz and magnetite; the hypersthene in the norm (but not in the rock) reflects the presence of a small amount of MgO, and FeO in excess of Fe_2O_3, which are probably incorporated in minute quantities in the feldspars or in the muscovite.

Comparison of the analysis in table 16 with the analyses of the granite, samples C 232 to C 241 of table 13, indicates that there has been little interchange of trace elements between the pegmatite and its wall rock. Manganese, barium, strontium, and chromium are present in similar proportions in the wall zone of the pegmatite and in the adjacent granite, but the other elements, magnesium, lead, calcium, gallium, vanadium, titanium, and bismuth are higher or lower by at least one unit in the order-of-magnitude scale.

The lower part of the wall zone consists of about 60 percent plagioclase (albite) and 40 percent quartz with accessory perthite, muscovite, and beryl. Except for the decrease in perthite content, it resembles the upper part of the wall zone, including concentrations of the same types of beryl. The lower wall zone has a maximum thickness of about 40 feet in the keel and narrows upward along both walls to a feather edge. This trough-like body is shown in plate 10.

The outer intermediate zone is made up of perthite (55 percent) and quartz (45 percent). The grains average between 4 and 12 inches in size, but are as much as 3 feet in diameter. Minor amounts of fine-grained plagioclase, muscovite, and quartz fill interstices and fractures in the large grains. Assays of drill core from this zone show small amounts of

BeO, which probably indicate small grains of beryl in the interstitial filling; no beryl has been observed in the perthite-quartz pegmatite exposed in the drill core or the upper opencut. The zone extends about 130 feet along the hanging-wall side of the deposit, and for a distance of about 110 feet down the dip. Its width ranges from less than an inch to 7 feet.

The inner intermediate zone of coarse-grained plagioclase-quartz-muscovite pegmatite contains coarse-grained beryl and scrap mica that has been mined intermittently since 1942. This pegmatite consists of 50 percent plagioclase, 40 percent quartz, 7 percent muscovite, and 3 percent beryl and other accessories. The inner intermediate zone pinches and swells, ranging from 2 to 8 feet wide. A series of gentle folds plunge at low angles to the southwest (pl. 9), and probably reflect irregularities in the crest of the pegmatite.

Beryl occurs typically in clusters of large and small crystals. A few small grains are scattered at random in the rock between clusters. Pockets 6 to 12 feet long and extending the full width of the zone have been discovered 10 to about 35 feet apart during mining. There are poorly exposed parts of the pegmatite, as much as 70 feet long, in which beryl shoots are not exposed, but which have not been prospected. The beryl ranges in size from 1 inch to 1 foot in diameter, and as much as 5 feet long. Both anhedral and euhedral beryl are common.

Estimates of rock moved from the inner intermediate zone compared to the tons of beryl produced indicate a beryl content of 2.3 percent recoverable by hand sorting.

The inner intermediate zone also has yielded scrap mica from shoots and streaks of fine- to very coarse-grained muscovite. The streaks are from 1 inch to 5 feet wide, and from 1 to 30 feet long. The largest books are as much as 15 inches long and 6 inches thick but no sheet mica has been obtained from them; the books are heavily ruled, wedged, have "A" structure, and many mineral inclusions. The zone is estimated to contain an average of 7 percent muscovite, and perhaps one-quarter of it is recoverable by hand sorting. The fine-grained material consists of flakes and books from microscopic to 3 inches in diameter, intimately intergrown with quartz, plagioclase, tourmaline, and beryl, and oriented at random.

The plagioclase of the inner intermediate zone is of medium texture. It is albite, somewhat platy in habit but is not cleavelandite throughout the zone. The cleavelanditic parts form white curving plates as much as 6 inches in long dimension.

Minor accessory minerals approximately in order of decreasing abundance are tourmaline, microcline, garnet, apatite, lithiophillite-triphylite, and other phosphates, bismuthinite and its alteration products, and uraninite and its alteration products. The accessory minerals constitute less than 1 percent of the zone, and no attempt has been made to estimate the abundance of tourmaline, microcline, garnet, and apatite. The rarer minerals exposed during mining operations in 1948 were estimated to be of the following orders of magnitude: phosphates other than apatite 0.00X to 0.0X percent; bismuth compounds 0.008 percent; and uranium-bearing minerals 0.000X percent.

The core of the Hyatt deposit is about 96 percent perthite, 3 percent quartz and 1 percent of plagioclase, muscovite, tourmaline, and garnet. The perthite is very coarse grained, attaining sizes as much as 10 feet in length. Quartz occurs in very coarse masses as much as 4 feet in size, and as fine-grained inclusions in the perthite, and as interstitial fillings. In addition, plagioclase, muscovite, and tourmaline are included in the perthite and fill the spaces between perthite grains. Beryl has been found along the margins of the core, but not in the interior; however, it may be present in the center either as small grains in the interstitial material or as inclusions in the perthite, because small amounts of BeO are found in spectrographic analyses of the drill samples. The miarolitic cavity from the core of the Hyatt deposit contained bertrandite, indicating that a beryllium-bearing mineral was deposited at a late stage in the crystallization of the pegmatite.

The maximum dimensions of the core are: 240 feet long, 25 feet wide, and 100 feet in the plane of dip.

Exploration

The Hyatt deposit was explored by six holes drilled from the hanging wall side of the pegmatite (pl. 9). The elevation of the collar, inclination of the hole, and depth drilled are indicated on the map (pl. 9), the drill logs (tables 16a-16f), the assay plans (pls. 17-21), and the cross sections (pl. 10). For analysis, 58 sludge samples and 121 core samples of pegmatite including the immediately adjacent country rock were taken together with 10 core samples for a spectrographic study of the wall rocks.

Mineral deposits

The Hyatt pegmatite contains about 170,000 tons of rock including 850 tons of beryl. The beryl is present in the wall zones, both upper and lower, and in the inner intermediate zone. The wall zones contain about 360 tons of beryl in 105,000 tons of rock, or about 0.35 percent beryl, all in grains less than 3 inches in size and averaging less than 1 inch. The drill samples from the inner intermediate zone indicate 25,500 tons of rock containing slightly over 1 percent beryl. Production of beryl from the same zone at the surface indicates a recoverable grade of about 2.3 percent beryl. The drill sampled the zone in three places, but only cut one rich shoot of beryl such as those from which most of the production of beryl has been derived. The drilling, however, does indicate that shoots of beryl are present in the lower parts of the zone and are not restricted to the exposed parts. The inner intermediate zone is estimated to contain 450 tons (1.7 percent) beryl, of which 60 percent or 270 tons might be recovered by hand sorting.

The core of the pegmatite is estimated to contain 40 tons of beryl along its margins. If this beryl is enclosed as fine grains in perthite it may not be recovered except by milling the perthite.

The Hyatt pegmatite also contains scrap mica and perthite resources. The inner intermediate zone contains about 1,800 tons of scrap mica of which 450 tons may be recoverable. The core contains about 33,000 tons of perthite of which 20,000 tons are recoverable, but inclusions and interstitial materials are abundant and the potash spar is not of the best grade. Minor constituents that are of byproduct value are bismuthinite and uraninite; there might be 1,000 to 3,000 pounds of bismuthinite, and 100 to 300 pounds of uraninite in the inner intermediate zone which might be recoverable.

The dumps at the Hyatt mine are not large but are estimated to contain considerable beryl and potash spar. Potash spar could be recovered by hand sorting, but not much of the beryl could be recovered economically by this method. The large dump between the road and the lower opencut (pl. 9) is estimated to contain 2,000 tons of pegmatite from which 1,000 tons of potash spar could be recovered. The residue of the large dump after the removal of the perthite and the small dump are estimated to contain between 15 and 30 tons of beryl in about 2,000 tons of rock.

The milling of pegmatite to recover beryl and associated minerals of economic value is not within the scope of this report, but it should be pointed out that the fine-grained beryl of the wall zones, the existing dumps, and the residue of future hand-cobbing operations in the inner intermediate zone all constitute accessible mill feed. Milling of the pegmatite would undoubtedly yield higher recoveries of potash spar and mica than those calculated for the resources of recoverable minerals. Milling of the perthite of the core might also improve the grade of the potash spar by reducing the content of interstitial minerals. The talus slope below the cliff that formed the outcrop before mining was estimated to contain at least 5 tons of recoverable beryl.

Big Boulder prospect

The Big Boulder prospect is about 37 miles by road southwest of Fort Collins, Colo., in the SE$\frac{1}{4}$ sec. 36, T. 7 N., R. 72 W., sixth principal meridian. The prospect is reached from the town of Masonville by going west on the Buckhorn Creek road for 21 miles to a bridge and then turning west on an unimproved ranch road to the property (fig. 2). The prospect is on State land and is under the jurisdiction of the Colorado Board of Land Commissioners with offices in the State Capitol, Denver.

The Big Boulder pegmatite was opened in 1936 by Roy Hyatt and H. A. Snider; they mined 10.5 tons of beryl from one crystal in the perthite-quartz hood. In 1941 about 600 pounds of beryl was mined and stockpiled by the United Beryllium Ores and Metals Corp. but the mine was idle from 1942 to 1950.

The workings on the property consist of four shallow pits, a small cut, and a 10-foot discovery shaft. The large beryl crystal was mined from the round pit northwest of the discovery shaft (pl. 22).

The wartime investigations of the Geological Survey included mapping the Big Boulder pegmatite by Hanley and Page on October 2, 1942, and the results of this study are described by Hanley and others (1950, pp. 92-93). In August 1947 the deposit was remapped by A. J. Lang and the writer.

Geology

The Big Boulder pegmatite is concordant throughout most of its length in quartz-mica schist which has a northerly strike and steep dip.(See pl. 22.) The southern end of the Big Boulder pegmatite is in contact with a perthite-plagioclase-quartz pegmatite, but the structural relations are poorly exposed; a scale of fine-grained muscovite-rich pegmatite which is continuous with the border zone of the east-trending pegmatite (pl. 22) leads the writer to regard the perthite-plagioclase-quartz pegmatite as intrusive into the Big Boulder pegmatite along a plane dipping eastward at an angle of about 25°.

Most of the Big Boulder pegmatite is weathered and eroded to the level of the surrounding terrain, but the north end forms a prominent knob standing about 30 feet above the flat hilltop (pl. 22). A considerable amount of the border zone is exposed on the northern half of the knob indicating that the present exposure closely approximates the original shape of the north end of the pegmatite. In some places where the border zone has been removed, the muscovite books of the wall zone show a preferred orientation so the position and attitude of the contact can be inferred within a few inches of the border.

The Big Boulder pegmatite is a zoned deposit about 245 feet long and with a maximum width of 80 feet. It strikes N. 10° E., has an over-all dip to the east, and plunges southward—the crest more steeply than the keel (pls. 22 and 23).

The deposit consists of five zones in addition to the border zone: a wall zone of plagioclase-quartz pegmatite, an upper intermediate zone of plagioclase-perthite-quartz pegmatite, a lower intermediate zone of cleavelandite-quartz pegmatite, a hood of perthite-quartz pegmatite, and a core of quartz pegmatite.

The border zone is well developed along most of the exposed contact but rarely exceeds an inch or two in thickness. It is rich in muscovite, and is essentially a muscovite-quartz-plagioclase pegmatite with grains ranging in size from 0.01 to 1 inch. In a few exposures the schist at the contact with the pegmatite has been converted to granulite and the border zone is unusually thin or absent.

The wall zone is composed of 55 percent plagioclase and 45 percent quartz with accessory perthite, muscovite, tourmaline, beryl, garnet, and apatite. The texture is fine grained but the grains range from 0.01 to 3 inches in length. Anhedral and euhedral beryl crystals average 0.7 inch in length, but are as much as 2.5 inches long. Muscovite books are more abundant in the outer few inches of the zone than in the inner part, and are roughly oriented normal to the contact. The zone is as much as 25 feet wide and averages about 12 feet wide, but is absent in some places. The zone thickens along the keel and toward the south end of the deposit. Although perthite is only an accessory mineral in the zone, it occurs principally in local concentrations rather than uniform disseminations: perthite composes 10 to 25 percent of the material in elongate clots at or close to the contact, for example, along the east contact south of the intruding pegmatite, and at an offshoot from the west contact west of drill hole BB-3 (pl. 22), and at the west contact in drill hole BB-4. The perthite is not abundant enough to be classed as an essential mineral in this zone.

The intermediate part of the deposit is essentially an aggregate of albite, perthite, and quartz in two zones. Plagioclase-perthite-quartz pegmatite forms the upper intermediate zone and plagioclase-quartz pegmatite the lower zone. In both intermediate zones the plagioclase has the composition of albite but in the lower part it has a platy habit and is designated cleavelandite. The upper intermediate zone is well exposed only in the knob, and the lower intermediate zone is poorly exposed and only crops out in the weathered southern part of the pegmatite.

The upper intermediate zone is composed of plagioclase (50 percent), perthite (30 percent), and quartz (20 percent) with accessory muscovite, tourmaline, beryl, apatite, relict spodumene (?), and uranium minerals. The zone is present in the upper part of the body (pl. 23), and attains a maximum thickness of 50 feet in the northern bulbous part; the average is about 15 feet. The texture is medium grained, but the grains are as much as 8 inches in size. Beryl crystals range in size from 0.1 to 4.5 inches, and average about 1.5 inches in length. An area 4 feet wide and 25 feet long between the knob and the east contact is composed principally of fine-grained albite with some perthite and quartz, which weathers more rapidly than the surrounding material and has a different appearance, but grades imperceptibly into material typical of the zone. It seems to be an integral part of the unit that crystallized under some locally anomalous conditions. The relict spodumene (?) and uraninite and its alteration products are exposed on the east wall of the discovery shaft along the boundary between the intermediate zone and the hood. The amounts of each are negligible.

The lower intermediate zone of cleavelandite-quartz pegmatite is composed of about 65 percent cleavelandite and 35 percent quartz. Muscovite, perthite, beryl, tourmaline, and garnet are accessory minerals. Two minute plates of tantalite-columbite were found in a core sample. Muscovite occurs as large flakes and books, and also as minute scales with low refractive indices indicating the presence of some lithium. The zone forms a trough-like body with a maximum thickness of 25 feet at the south end and tapering upward to a knife edge. The texture is coarse because the common plates of cleavelandite range between 4 and 12 inches in length, though a few in the drill core may be as much as 30 inches long.

The inner edge of the lower intermediate zone contains relict spodumene (?). It is exposed in the eastern end of the northwest-trending trench (pl. 22), and in two places in the drill core of hole BB-5. In all places it is within a few feet of the quartz pegmatite of the core. The relict spodumene (?) is composed of a very fine-grained aggregate of albite and sericite which contains almost 1 percent lithium. Veinlets of fine-grained albite with a few euhedral garnet crystals and some dark phosphatic material cut the cleavelandite-quartz pegmatite.

A hood in the northern part of the Big Boulder pegmatite is composed of 70 percent perthite and 30 percent quartz. It has a maximum thickness of 60 feet (pl. 23). The rock is coarse grained, for the minerals average over 1 foot in diameter and some perthite grains are as much as 6 feet in diameter. Beryl, muscovite, plagioclase, tourmaline, garnet, alteration products of lithiophillite, and traces of gummite, autunite, and torbernite are present in the hood. A 10.5-ton crystal of beryl was mined from the small pit in this unit northwest of the discovery shaft. In addition to this large crystal, a number of beryl crystals 12 inches in diameter have been found. Some of the quartz in the large shallow pit south of drill hole BB-3 is dark gray and minutely fractured but it is not believed to be a tectonic breccia. The "breccia-like" material is found in masses 1 to 6 feet in diameter that grades outward into typical light-gray to white quartz cut by a few widely spaced joints. The fractures are filled with fine-grained perthite. Streaks of fine-grained muscovite, from an inch to a foot wide and 1 to 5 feet long, cut the perthite and quartz. Irregular pockets, $\frac{1}{2}$ to 3 feet across, containing garnet as the principal mineral, are scattered through this unit. The garnet is euhedral to anhedral, closely packed, dark colored and stained with manganese oxides; associated with the garnet are quartz, muscovite, tourmaline, plagioclase, and iron and manganese phosphates.

A fracture filling of perthite-quartz pegmatite extends from the northern part of the hood, across the upper intermediate zone and wall zone to the contact, and possibly beyond the pegmatite into the schist (pl. 22). It is as much as 4 feet wide, has a sinuous trace, and probably dips steeply. The fracture filling can be traced about 4 feet inward from the boundary between the upper intermediate zone and the hood, and there it merges with the perthite-quartz pegmatite of the hood.

The core of the deposit is essentially quartz pegmatite with minor amounts of cleavelandite, muscovite, tourmaline, and garnet. Spectrographic analyses of drill core from this zone reveal the presence of BeO but no beryl has been recognized. The long axis of the core plunges 45° S. and is 200 feet long; the maximum width is 35 feet and the greatest thickness is 100 feet. The size of the quartz grains is not known but continuous masses of quartz 5 feet in length can be seen in the drill core.

Small grains of tourmaline and muscovite form fillings in steeply dipping fractures that cut all minerals and zonal boundaries of the northern part of the Big Boulder pegmatite (pl. 22). The muscovite-tourmaline fillings are as much as half an inch wide, are discontinuous along the strike, and occur singly, or in groups a foot wide and 6 feet long. The long groups of fractures exhibit a "horsetail pattern" of gently curving planes diverging from a central line. The single fractures rarely exceed six inches in length and are generally straight. The horsetail groups are largest and most abundant directly north of drill hole BB-3 and decrease in length and abundance northward and outward to the walls of the deposit. The relations of the fractures to the mineral boundaries of the intermediate and wall zones show the fractures formed after these zones had solidified. The fracture fillings are not found in the hood or core. The fractures could have formed any time between the solidification of the outer zones and the final solidification of the core. The fractures are radially arranged and restricted to the northern quarter of the pegmatite so it does not seem likely that they are of tectonic origin. It may be presumed they are contraction or cooling cracks, as suggested by Cameron and others (1949, fig. 52, p. 71), which formed in the northern lobe of the body because it solidified first and lost heat faster than the main mass of the pegmatite. The zoning as shown in plate 23 indicates that the lobe was fully crystallized before the core in the main part of the pegmatite solidified. The presence of tourmaline crystals 2½ inches in diameter in the core of the pegmatite indicates that material was available at the last stages of crystallization for the formation of tourmaline.

Exploration

The Big Boulder prospect was explored by five core holes totalling 682 feet. The elevation of the collar, inclination of the hole, and depth drilled are indicated on the map (pl. 22); the drill logs,(tables 16g-16i); the assay plans (pls. 24 to 26); and the cross sections (pl. 23). The drilling provided 32 sludge samples, 48 core samples of pegmatite including the immediately adjacent country rock, and 7 core samples for a spectrographic study of the wall rock.

Mineral deposits

The Big Boulder prospect contains about 560 tons of beryl in 110,000 tons of pegmatite, or approximately 0.5 percent beryl; the core is almost barren, but the wall zone contains a greater-than-average amount.

The wall zone contains 47,000 tons of pegmatite with a grade of 0.75 percent or about 350 tons of beryl less than 3 inches in maximum size. The lower intermediate zone consists of 24,000 tons of rock with 0.37 percent or about 85 tons of beryl, in grains less than 5 inches in size. The core and upper intermediate zone have about 0.06 and 0.07 percent beryl, respectively, and have combined resources of 15 to 20 tons; beryl is visible in the outcrop of the upper intermediate zone but neither the drill core nor the outcrop of the core reveal any beryl, so the reserves are probably less than 10 tons.

Only one drill hole cut through the hood of the deposit and it did not core any beryl crystals. The analyses show 0.04 percent beryl in the drill sample, but the production data show a grade of about 1.68 percent beryl; the drill data indicate 5 tons of beryl in the hood, and the production results combined with drilling data indicate 110 tons of beryl may be found. With 60 percent of the beryl recoverable by hand sorting the yield should be about 60 tons. The remaining 500 tons of beryl in the Big Boulder pegmatite is in grains too small to be recovered economically by hand sorting. (See pls. 27 and 28.)

No other economic mineral resources are present in the Big Boulder deposit. Muscovite is scarce and of scrap grade; perthite is intimately intergrown with other minerals; and tantalite-columbite is rare and fine grained.

Buckhorn Mica mine

The Buckhorn Mica mine is reached from the town of Masonville by going west on the Buckhorn Creek road for 21 miles to a bridge and turning west on an unimproved ranch road to the property (fig. 2). The Buckhorn Mica mine is in SW$\frac{1}{4}$ sec. 29, T. 7 N., R. 71 W., sixth principal meridian.

The mica deposit was discovered in 1884 and was mined for a short period by the Buckhorn Mica Mining and Milling Co. The mine is now owned by Roy Hyatt, who relocated it in 1942 as the Emerald Gem claim. The records of past production are not available but it is reported that at least 180 tons of ground mica, a few hundred pounds of sheet mica, and 2 or 3 tons of beryl have been produced during different periods of operation. In recent years beryl has been hand picked from the dump and the amount is estimated at about 1 ton.

The mine has been described by Sterrett (1923, pp. 59-60), and by Hanley and others (1950, pp. 88-90). It was mapped by L. R. Page and J. B. Hanley on September 29 and 30, 1942, and was re-examined by the writer in September 1947, but was not remapped. The map by Page and Hanley is reproduced with minor modifications by the writer as plate 29.

The workings consist of three shafts, a series of shallow, more or less interconnected opencuts, and five trenches. The eastern shaft is reported to have been 50 feet deep and according to Sterrett (1923, p. 59) drifts were made from this shaft, but the underground workings are inaccessible. The observable parts of the caved and backfilled shafts are vertical and undoubtedly they were sunk in the mica-rich part of the pegmatite. Most of the pegmatite is eroded to the level of the surrounding terrain, but the contacts are well exposed at the east end and the interior zones can be examined in the larger workings.

Geology

The Buckhorn Mica pegmatite is a multiple intrusion consisting of the main body 530 feet long, a smaller member with an angular trace at the west end, and a poorly exposed member south of the workings in the eastern part of the deposit. The main body and the south member are vertical and concordant in the quartz-mica schist of the area that strikes N. 70° E. The western member is partly concordant as a western extension of the main body and partly discordant, lying in a plane striking N. 50° W., dipping

45° NE. The main body has a maximum width of 32 feet and probably averages about 20 feet in width. The western member has an average width of about 10 feet and reaches a maximum of 16. The full extent of the south member is not known, but it is at least 100 feet long and has a maximum width of 9 feet, probably tapers to a knife edge at both ends, and extends to a depth of 120 feet or more.

The outer part of the main body contains plagioclase, quartz, and perthite, but the perthite is concentrated in the upper and outer parts of the deposit as at the Hyatt and Big Boulder pegmatites. The pegmatite forming the outer part of the deposit is divided into two zones on the abundance of perthite: the wall zone exposed at the surface is plagioclase-perthite-quartz pegmatite which grades inward and downward into the outer intermediate zone of plagioclase-quartz pegmatite (pl. 30). The inner intermediate zone is cleavelandite-quartz pegmatite, and the core is cleavelandite-quartz-spodumene (?) pegmatite.

The plagioclase-perthite-quartz pegmatite has a maximum width of 15 feet and extends to a maximum depth of 110 feet below the surface. The average grain size is less than 1 inch, but some grains are as much as 3 inches in long dimension. The texture and appearance of this zone are unusual: the bulk of the material is exceedingly fine grained and encloses coarser-grained minerals in streaks and patches elongated roughly parallel to the walls. The matrix has a grain size of less than 0.3 inch, but the minerals in the streaks are as much as 3 inches in length though the same minerals are common to both parts. The fine-grained matrix is somewhat darker colored than the common types of fine-grained pegmatite and the color is irregular giving a blotchy appearance to the rock.

The 70-foot east-trending tongue at the east end of the main body is a zoned fracture filling. The pegmatite was fractured after most of the wall zone had solidified and pegmatite solutions escaped from the unconsolidated interior. The material crystallized to form zones continuous with the rest of the body. The fracture which breached the wall zone is a conspicuous surface coated with fine-grained green muscovite which separates the wall zone from the intermediate zone on the north side of the large opencut. The wall zone has an average width of about 7 feet in most of the main body, but is only 0.2 to 1 foot wide in the fracture filling. This interpretation has been proposed previously by Cameron and others (1949, p. 76); the writer concurs and adds the data regarding the thin perthite-bearing wall zone to restrict more closely the relative chronology, and eliminate the possibility suggested by Hanley and others (1950, p. 89) that the interior zones were formed by a separate injection of magma distinct from the pegmatite forming the wall zone.

The wall zone contains about 0.4 percent beryl according to the drilling data, but only a few crystals less than 1 inch in size are visible in the outcrop. The proportions of minerals in the fine-grained wall zone are difficult to estimate but appear to be about 55 percent plagioclase, 30 percent perthite, and 15 percent quartz. Muscovite forms less than 1 percent of the wall zone. Other accessory minerals are tourmaline and garnet.

The outer intermediate zone of plagioclase-quartz pegmatite is as much as 10 feet wide, but is missing in many places along the outcrop; it extends to the keel of the pegmatite, a maximum depth of 155 feet below the surface. The outer intermediate zone is composed of 65 percent plagioclase and 35 percent quartz in grains ranging from 0.01 to 12 inches in size. Most of the grains, however, range from 1 to 4 inches. Muscovite is abundant in local concentrations: the old workings were sunk on one or more muscovite shoots, but existing exposures do not indicate that muscovite is an essential constituent of the remainder of the zone. Undoubtedly mica-rich pockets and streaks exist in concealed parts of the deposit, but mica probably constitutes less than 5 percent of the total rock. Many muscovite books from the dump are 1 to 8 inches across and as much as 3 inches thick, but all are ruled, wedged, and stained. Perthite in grains 2 to 20 inches across is present in this zone. Tourmaline, and purpurite and related phosphatic compounds are minor accessory minerals.

Beryl makes up about 0.5 percent of the outer intermediate zone and occurs in anhedral and euhedral crystals 0.1 to 5 inches in length. Many of the euhedral crystals enclose a large amount of quartz, plagioclase, and muscovite, and some are hardly more than hexagonal rims of beryl around a core of other minerals (see pls. 31 to 35).

The plagioclase of the outer intermediate zone is albite with an average composition of Ab_{94}. It becomes coarser and somewhat platy inward toward the inner intermediate zone, and passes gradually into cleavelandite. The boundary between the two intermediate zones is drawn more on average texture and decline of muscovite content than on differences in the essential minerals.

The inner intermediate zone of cleavelandite-quartz pegmatite is exposed for 490 feet on the surface and extends out in the eastern tongue of the main body; it is well exposed in the trench at the east end as well as in the main workings. It has a maximum width of 16 feet and is interpreted to have a maximum depth of 110 feet below the outcrop. The inner intermediate zone contains about 55 percent cleavelandite, 43 percent quartz, and 2 percent accessory minerals. The cleavelandite has an average albite content of Ab_{95} to Ab_{96}, and forms plates as much as 0.3 inch wide and 12 inches long. Muscovite, beryl, columbite-tantalite, and perthite are accessory components. Muscovite forms thin books, 1 to 6 inches in diameter, and minute scales. Columbite-tantalite occurs in plates and blades, 0.01 to 0.6 inch thick and

0.02 to 1 inch in length.

The beryl of the inner intermediate zone is white to pale greenish blue, occurs in grains and crystals 0.1 to 10 inches long and as much as 6 inches in diameter. Assays of drill samples indicate the zone contains at least 0.8 percent beryl and locally contains as much as 2 percent beryl.

The core crops out in the workings for a distance of 85 feet. It has a maximum width of 10 feet and an average width of about 4 feet, tapers downward, and extends about 75 feet below the surface. The core was intersected in drill hole BH-1 but not in the other holes. It is interpreted to have a maximum length of 180 feet in the direction of plunge, i.e., 22° S. 68° W.

The core of the main body contains 50 percent cleavelandite, 45 percent quartz, 3 percent relict spodumene (?), and 2 percent accessory minerals. Were it not for the relict spodumene (?), this zone would differ from the zone surrounding it only in being somewhat coarser grained. The spodumene is represented by lithium-bearing pseudomorphous aggregates of albite (Ab_{97}) and sericite, and by cleavelandite. The fine-grained aggregate preserves in many places the lamellar structure of spodumene, but cleavelandite growing inward into the space occupied by the spodumene preserves only the outline of the lath. Some of the relict laths are 3 feet long and 2 to 4 inches thick. The cleavelandite of the groundmass ranges in composition from Ab_{96} to Ab_{99}, and forms plates as much as 20 inches long.

Quartz in the core occurs in larger masses than in the inner intermediate zone, some of the clots attaining a length of 5 feet. The quartz is cut by streaks and veinlets of fine-grained pale scaly mica. Beryl is an important accessory and in the workings is estimated to constitute 1 percent or more of the zone. The beryl crystals are white to pale blue, are commonly coated with very fine-grained muscovite and albite, and enclose fewer grains of other minerals than beryl in the surrounding zones. Columbite-tantalite occurs in plates which range from 0.01 to 0.23 inch thick, 0.2 to 3 inches long, and 0.1 to 2 inches wide. One block of rock from the core contains an estimated 11 cubic inches of columbite-tantalite in three clusters of tabular crystals.

The south member of the Buckhorn Mica pegmatite branches from the main body along the westward extension of the schist parting exposed on the south side of the main workings. It is made up of plagioclase-perthite-quartz pegmatite like the wall zone of the main body with which it merges. It is also fine grained, tan to cream, and mottled. It contains plagioclase (55 percent), perthite (30 percent), and quartz (15 percent). It is known to extend westward to drill hole BH-2, and it may connect with the two small pegmatites farther west. Assays indicate a beryl content of about 0.5 percent, but beryl is not readily discernible in the outcrop so it is probably very fine grained. Muscovite and tourmaline are minor accessory minerals.

The west member branches from the main body at the end of a schist parting exposed in the westernmost pit. Much of the pegmatite in this part of the deposit is concealed and some of the relations are obscure. The northeast-trending part of the member parallels the main body and is concordant in the schist. The northwest-trending part is in a plane striking N. 50° W., dipping 45° NE. According to the data obtained by drilling, the strike and dip of the discordant branch changes slightly to the northeast (Compare cross sections in pl. 30). The concordant part of the west member forms the connecting link between the main body and the discordant part. The northwestward extent of the discordant part may be greater than is shown in the sections (pl. 30), and its northeastward extent in the plane of dip may also be somewhat greater. The intersection of the northeast-dipping plane with the plane of the main body may modify the shape of the keel of the main body; the shape suggested in the sections (pl. 30) assumes that there has been no modification, but the dotted areas are not included in the calculations of reserves.

At the surface the west member consists of a perthite-bearing wall zone of plagioclase-quartz pegmatite and a core of cleavelandite-quartz pegmatite. In drill holes BH-4 and BH-5 the wall zone does not contain perthite. In hole BH-3 there are relicts of schistose structure which are interpreted as pegmatized material at the junction of the west member with the main body.

Drill holes BH-4 and BH-5 pass beneath the main body at such points that the possibility of a westward-plunging crest is eliminated, and a narrow limit set on the probable extent of the main body.

The zonal boundaries shown in plate 29 differ in detail from those on the original map by Hanley and others (1950, pl. 11). The drilling reveals that the zones are more uniform and symmetrical than the weathered outcrop suggests and the float has been re-examined and re-interpreted accordingly.

Exploration

The Buckhorn Mica deposit was explored by five holes. The elevation of the collar, inclination of each hole, and depth drilled are indicated on the map (pl. 29), the drill logs (tables 16j-16n), the assay plans (pls. 36 to 40), and the cross sections (pl. 30). The drilling provided 15 sludge samples, 62 core samples of pegmatite and the immediately adjacent country rock, and 7 core samples for a spectrographic study of the wall rocks.

Mineral deposits

The Buckhorn Mica deposit contains a total of about 600 tons of beryl in 100,000 tons of pegmatite. The wall zone and outer intermediate zone of the main body, the south member, and the west member contain about 380 tons of fine-grained beryl in 82,000 tons of rock. The inner intermediate zone and core of the main body contain about 220 tons of coarse-grained beryl in 21,000 tons of rock, and it is estimated that 135 tons of this beryl is recoverable by hand sorting.

The most important beryl-bearing zones are the core and inner intermediate zone of the main body. The core is relatively small and is estimated to have the same beryl content as the surrounding zone so they are considered as one deposit in the calculations of tonnage and grade. The drilling indicates that beryl-rich pockets are present below the workings, but there is no evidence to assume that they are present in the western part of the deposit. Assays of the drill samples are combined with assays of samples taken at the surface to arrive at estimates of beryl content west of the workings. Samples of the dumps from the main workings confirm the high beryl content indicated by drilling beneath the workings. The beryl content calculated from the drilling data ranges from 0.01 to 1.97 percent and averages 0.86 percent; when combined with other sample data the range is from 0.29 to 1.97 percent and the average is 1.06 percent beryl. The beryl is estimated to amount to 220 tons, of which 135 tons is recoverable by hand sorting.

The remainder of the deposit contains 380 tons of beryl in grains that average less than 3 inches in size. A small amount of beryl would be recoverable by hand picking the few larger pieces, but probably at comparatively high cost.

Other resources of the Buckhorn Mica mine are scrap mica and columbite-tantalite. It is possible that the unexposed parts of the outer intermediate zone of plagioclase-quartz pegmatite might contain 3,500 tons of muscovite in 35,000 tons of rock because past mining of the zone indicated a mica content of 10 percent. Milling of the deposit to extract fine-grained beryl could produce 1,000 to 3,000 tons of scrap mica from the outer intermediate zone.

The columbite-tantalite content of the core and inner intermediate zone has not been tested analytically, but an examination of the workings and dumps suggests that the mineral is present in concentrations of the order of 0.00001 percent and the interior zones may be expected to produce about 400 pounds of columbite-tantalite.

The dumps at the Buckhorn Mica mine have been partly reworked and the larger pieces of beryl removed, but they are estimated to contain 6 tons of beryl too small to recover by hand sorting.

Perthite grains and crystals might be hand sorted as a byproduct, but the deposit could not be mined for potash feldspar alone. Possibly 1,000 tons of salable potash feldspar of No. 2 grade or lower might be recovered.

The relict spodumene (?) contains less than 1 percent lithium and is not a merchantable product.

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	45

Part II

CONTENTS

ILLUSTRATIONS

TABLES

Part II

TABLES--Continued

Part II

EXPLORATION

The Hyatt, Big Boulder, and Buckhorn Mica deposits were explored by core drilling. The reserves of beryl in each deposit are summarized in tables 21, 22, and 23, and in plates 41, 42, and 43. Tonnage was calculated by planimetry of the sections (pls. 10, 23, and 30). The grade calculations are shown in tables 24 to 37. The samples of core do not in all cases match the samples of sludge, and the combined assays are calculated by apportioning the BeO content of the sludge to the corresponding core samples in proportion to the BeO content of the cores.

RESERVES

The pegmatites of the Crystal Mountain district were studied primarily to determine the content and distribution of beryl. Of the 1,300 bodies mapped in the Hyatt area, about 350 contain beryl, and of these the 77 deposits described in table 18 contain at least 1 ton of beryl in rock having at least 0.01 percent beryl. Five pegmatites in the Big Boulder area (table 19) and three in the Buckhorn Mica area (table 20) also contain beryl as an important accessory.

The tonnage and grade of the beryl resources listed in tables 18, 19, and 20 are distributed as shown in table 38. The beryl content of pegmatites, catalogued according to country rock and structure in the Hyatt area (table 39), supplements table 7 (p. 91) which suggests that pegmatites in granite masses are most likely to yield the greatest quantities of beryl.

Table 21.—Beryl reserves of the Hyatt pegmatite, Crystal Mountain district, Colorado

Structural unit: Pegmatite	Tons pegmatite	Indicated grade of pegmatite, percent beryl	Beryl short tons, indicated	Tons recoverable by hand sorting 1/
Upper wall zone: plagioclase-perthite-quartz pegmatite.	28,500	2/ 0.35	101	None
	Do.	3/ 0.37	105	Do.
Lower wall zone: plagioclase-quartz pegmatite.	76,800	0.34	260	Do.
Outer intermediate zone: perthite-quartz pegmatite.	3,600	Trace	None	Do.
Inner intermediate zone: plagioclase-quartz-muscovite pegmatite.	25,400	2/ 1.08	275	164
Do.	25,400	3/ 1.77	450	270
Core: Perthite pegmatite	34,250	0.12	40	None
Total 2/	168,600		675	164
Total 3/	168,600		850	270

1/ Assumes 60 percent of efficiency in recovery by hand sorting.

2/ Grade determined from drilling data, plate 10.

3/ Grade determined from production data combined with drilling data.

Table 22.--Beryl reserves of the Big Boulder prospect, Crystal Mountain district, Colorado

Structural unit: Pegmatite assemblage	Tons of pegmatite	Indicated grade of pegmatite, percent beryl	Beryl, short tons, indicated	Tons recoverable by hand sorting 1/
Wall zone: plagioclase-quartz pegmatite.	46,900	0.75	350	None
Upper intermediate zone: plagioclase-perthite-quartz pegmatite.	10,700	0.07	5	Do.
Hood: perthite-quartz pegmatite.	13,300	2/ 0.04	5	Do.
Do.	13,300	3/ 0.78	110	60
Lower intermediate zone: cleavelandite-quartz pegmatite.	23,500	0.37	85	None
Core: quartz pegmatite.	17,200	0.06	10	Do.

1/ Assumes 60 percent efficiency in recovery by hand sorting.

2/ Grade determined from drilling data, plate 23.

3/ Grade determined from drilling data combined with production data.

Table 23.--Beryl reserves of the Buckhorn Mica mine, Crystal Mountain district, Colorado

Structural unit: Pegmatite assemblage	Tons of pegmatite	Indicated grade of pegmatite, percent beryl	Beryl, short tons, indicated	Tons recoverable by hand sorting 1/
Main body:				
Wall zone: plagioclase-perthite-quartz pegmatite.	22,700	0.41	95	None
Outer intermediate zone: plagioclase-quartz pegmatite.	35,300	0.54	190	Do.
Inner intermediate zone and core: cleavelandite-quartz pegmatite, and cleavelandite-quartz-spodumene pegmatite.	21,000	2/ 0.86	180	110
Do.	Do.	3/ 1.06	220	135
Total main body	79,000	2/	465	110
Do.	79,000	3/	505	135
West member:				
Wall zone: plagioclase-quartz pegmatite.	14,100	0.38	50	None
Core: cleavelandite-quartz pegmatite.	2,000	0.18	5	Do.
Total west member	16,100		55	Do.
South member:				
Homogeneous body: plagioclase-perthite-quartz pegmatite.	8,000	0.5	40	Do.
Total, entire deposit	100,000	2/	570	110
Do.	Do.	3/	600	135

1/ Assumes 60 percent efficiency in recovery by hand sorting.

2/ Grade determined from drilling data, plate 30.

3/ Grade determined from drilling data combined with surface sampling data.

Table 38.--Distribution of beryl resources according to tonnage and grade

	Beryl, short tons				
Grade, percent beryl	0.01 to 0.1	0.1 to 0.5	0.5 to 1.0	Over 1.0	
Indicated reserve					
Hyatt pegmatite					
Wall zone		365			
Inner intermediate zone				450	
Core		40			
Big Boulder prospect					
Wall zone			350		
Upper intermediate zone	5				
Hood			110		
Lower intermediate zone		85			
Core	10				
Buckhorn Mica mine					
Main member					
Wall zone		95			
Outer intermediate zone			190		
Inner intermediate zone and core				220	
West member					
Wall zone		50			
Core		5			
South member		40			
Indicated reserve	15	680	650	670	
Total					2,015
Inferred reserve, plates 1, 2 and 3					
517 pegmatites	921				
18		212			
5			58		
1				1	
Inferred reserve	936	892	708	671	
Total					1,192
Inferred reserve, miscellaneous					
Double Opening prospect					
Wall zone	15				
Intermediate zone	15				
Core	1				
Tantalum claim	1				
Crystal Silica property		61 to 210			
Total	32	61 to 210			
Total resources	968	953	708	671	
Grand total					3,300

Table 39.—Distribution of beryl-bearing pegmatites according to country rock and structure, Hyatt area, Crystal Mountain district, Colorado

Pegmatites concordant in schist and isolated sills		Pegmatites discordant in schist		Pegmatites in granite masses	
Pegmatite number	Tons of beryl	Pegmatite number	Tons of beryl	Pegmatite number	Tons of beryl
		185	14	54	3
424	8	200	2	64	2
454	1	243	9	113	1
500	1	246	1	125	1
514	1	249	23	128	6
530	2	252	3	129	8
535	6	426	43	132	6
544	3	477	15	137	60
628	1	503	18	140	8
1/ 675	50	511	1	145	4
676	2	519	17	272	13
677	39	521	3	276	1
683	32	523	4	279	1
706	3	526	27	280	5
779	4	527	11	301	20
824	4	565	19	306	1
				330	4
827	2	566	4	331	1
				351	2
1068	1	567	5	357	6
1128	30	568	5	377	11
1260	6	606	6	387	7
		641	4	394	18
		649	7	395	63
		1/ 675	50	397	97
		835	67	399	4
		1131	19	400	1
		1157	45	401	1
		1160	142	402	5
				405	42
				654	850
				1299	1
19	196	27	564	31	1253

1/ Pegmatite 675 is about one-half concordant and one-half discordant; tons of beryl apportioned accordingly.

FUTURE WORK

Additional mapping would determine the extent of the pegmatite-bearing region and might indicate the limits of the beryl-bearing part or parts. The three areas mapped in the Crystal Mountain district are considered to be representative of a larger pegmatite-bearing region which extends at least 5 miles to the east and south and possibly 10 miles to the north and west. Beryl occurs in pegmatites 15 miles north of the district, north of the Cache la Poudre River, and 15 miles south near the town of Lyons. They may be distinct pegmatite-bearing regions, or they may be separate beryl-bearing districts within a continuous pegmatite region, or they may be part of a continuous beryl-bearing area.

Amblygonite has been found in pegmatites near Lyons and may indicate a lithium- as well as a beryllium-bearing district. Perhaps there are lithium-rich localities within the pegmatite region that could be exploitable.

More extensive mapping may contribute to the understanding of the relation of pegmatite to granite, and thereby suggest other areas worthy of study and furnish assistance in exploration. Additional study might show more conclusive structural or petrologic control to guide exploration.

Amblygonite and other lithium-bearing minerals, and columbite-tantalite have not been produced commercially in the district and it is unlikely that prospectors are aware of their value and identification. It is possible that deposits of these minerals may be found by continued detailed study. Detailed study may point to concealed deposits of beryl in pegmatites that have not been eroded very much.

Extensive detailed mapping of areas like the Hyatt, Big Boulder, and

Buckhorn Mica areas may be expected to disclose beryl resources of roughly 500 tons per square mile, and perhaps one complexly zoned deposit per two square miles of area. Detailed mapping in the Hyatt area has shown that 77 out of 1,300 pegmatites, or about 1 in 16, contain beryl as an important accessory. The 77 deposits are inferred to contain 1,163 tons of beryl, or almost 1 ton per total number of pegmatites mapped, exclusive of the Hyatt deposit. Reconnaissance in the Crystal Mountain district suggests that about one pegmatite per 1,000 is a complexly zoned deposit containing over 100 tons of beryl, and that there are roughly 500 pegmatites per square mile.