PEGMATITES OF EIGHT MILE PARK, FREMONT COUNTY, COLORADO*†

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Abstract

The Eight Mile Park pegmatite district, three to twelve miles west of Canon City, Fremont County, Colorado, includes about 30 square miles that lie at the westernmost end of the Canon City embayment in the Front Range structure. The area is a dissected plateau, 6000 to 7000 feet in altitude, that is bisected by the Royal Gorge of the Arkansas River, which is nearly 1200 feet deep locally. The pre-Cambrian rocks that underlie the

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area are flanked on the east by hogbacks of formations of Paleozoic age and on the south and west by flat lying beds of Mesozoic rocks. Three major pre-Cambrian rock units are present: Pikes Peak granite, Idaho Springs schist, and injection gneiss.

The oldest, the Idaho Springs formation, consists chiefly of muscovite schist with minor biotite schist and quartzite. This series was intruded after metamorphism by irregular sills and lenses of hornblende gabbro. Later the batholith of Pikes Peak granite, a red, coarse-grained, porphyritic, microcline granite, was emplaced. Late differentiates from the granitic magma were aplites followed by pegmatites. The youngest pre-Cambrian rocks are dikes of diabase. Veins are not common. The injection gneiss was formed by large scale lit-par-lit intrusion of Idaho Springs biotite schists by granite, aplite, and pegmatite.

The pre-Cambrian structural elements trend uniformly northeast-southwest. They include (1) the trend of the Idaho Springs schist belt and its contacts, (2) the attitude of the schist foliation, (3) the attitude of the primary granite flow structure, (4) the strikes of aplite sills in granite, (5) the attitudes of pegmatite sills in schist, and (6) the trend of the axis of the major anticline in the injection gneiss.

Three types of pegmatites are present: interior, marginal, and exterior. The interior pegmatites, which are relatively small, tabular dikes within the batholith, tend to occur in swarms. They contain microcline, oligoclase, quartz, muscovite, biotite, and schorl. Not uncommonly a zonal arrangement of petrologic units is present. The marginal pegmatites, which also occur in granite but are restricted to its border, are large, flat lying, sheet-like masses or discoidal bodies that transect the granitic flow structure. Their mineralogy is similar to that of the interior pegmatites. Zonal structure is poorly developed, but locally there occur small concentrations of uncommon minerals. The marginal pegmatites occur in schist near the batholith contact. They vary greatly in size and are moderately dipping, tabular, or lens-like sills along the schistosity. Their zonal structure is well defined, and secondary units containing concentrations of sodic plagioclase, muscovite, and rarer minerals are strongly developed, especially along the footwall contacts of cores.

The zones are primary and appear to have formed by successive crystallization of pegmatite magma inward from the walls. The secondary units follow fractures or zone contacts and are believed to have formed by the replacement of preexisting pegmatite. Two hydrothermal phases can be recognized: an early sodic plagioclase-muscovite stage, and a later, more intense, but more restricted cleavelandite-lepidolite type. The total number of minerals is 35. Among the more unusual pegmatitic species are fremontite (the type locality), beyerite, triplite, and chalcocite.

INTRODUCTION

General

This study is concerned with the pegmatites and geology of Eight Mile Park, Fremont County, Colorado. It is an attempt to interrelate the structure and mineralogy of the pegmatites with the geology of the rocks in which they occur.

The writer, as a member of the U. S. Geological Survey, became familiar with the general aspects of the geology of the area through work done in late 1942 and mid-1943. A study of the detailed mineralogy of the deposits was begun in the Laboratory of Mineralogy of Harvard University in early 1946. Mapping of the individual pegmatite bodies and of the entire area was begun early in June, 1946, and was completed by

mid-September of that year. Additional laboratory work was done in the fall of 1946 at the Montana School of Mines, Butte, Montana.

The writer was visited in the field by Professors E. S. Larsen and C. S. Hurlbut, to whom he is particularly indebted for continuous assistance and careful advice from the inception of the project to its conclusion. Professor Clifford Frondel contributed many valuable suggestions and discussions. The writer is also grateful to Professor C. Wroe Wolfe of Boston University for important assistance in many aspects of the laboratory work. The cost of numerous thin sections was met by the Harvard Department of Mineralogy and Petrography, and a grant from the Brodrick Fund of Harvard University helped to defray the expenses of field work in 1946. The writer also wishes to acknowledge the generous assistance of Professor Walter F. Hunt, Editor of the *American Mineralogist*, in converting the study from thesis form to one suitable for publication, and that of Edith Dunn Heinrich in all aspects of the manuscript preparation. Mr. M. V. Denny kindly made several important photographs.

Previous Work

The earliest record of mica deposits in Fremont County, Colorado, was made by Albert Williams (1883),[1] but no specific deposits are mentioned. Headden (1905) described columbite from the Eight Mile Park pegmatites, and in 1911 Schaller (1911, 1912, 1914, 1916) presented the first of his descriptions of fremontite, a mineral that has been found in only one other locality. Sterrett (1913, 1923) examined many Colorado pegmatites shortly before World War I. No further work was done until 1932 and 1933, at which time Landes (1935, 1939) examined several pegmatite districts in Colorado, including the Eight Mile Park area.

The general geology has been described by Darton (1906) and also by Campbell (1922). Powers (1935) studied the physiography of the Royal Gorge, and in 1941 brief notes on the geology were made by Kessler (1941). Blum (1944, 1945, 1946) has made a magnetic survey of the area. Special studies involving the sedimentary rocks have been completed by Walcott (1891), Washburne (1908), and Tieje (1923).

GEOGRAPHY

Location and Access

The Eight Mile Park area is in Fremont County, Colorado, 3 to 12 miles west and northwest of Canon City (Fig. 1). The area mapped, which consists of about 30 square miles, extends from 105° 15′ to 105° 22′ 30″

[1] References are at the end.

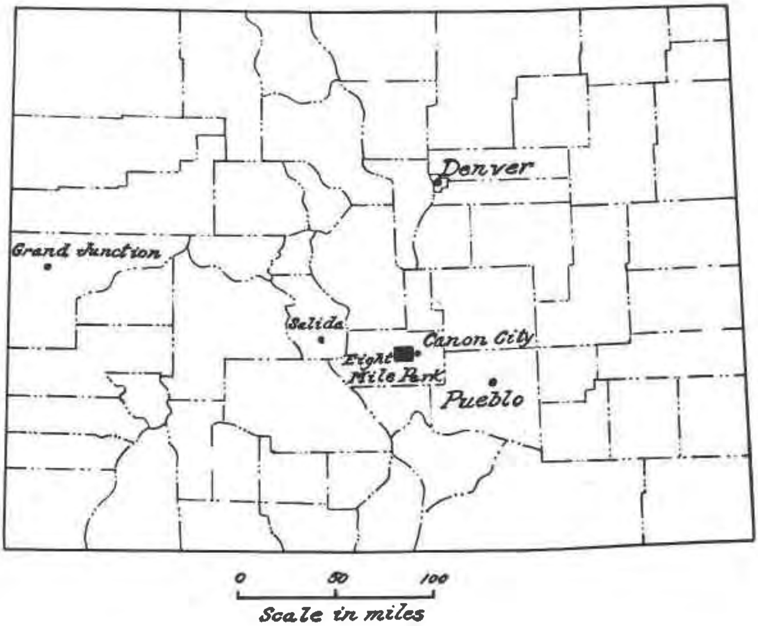

FIG. 1. Index map of Colorado, showing location of Eight Mile Park pegmatite district.

West Longitude and from 38° 26′ to 38° 30′ North Latitude. It lies on both sides of the Royal Gorge of the Arkansas River.

The region is easily accessible over U. S. Highway 50, which parallels the eastern and northern sides. From it the Royal Gorge road extends southward to the Royal Gorge bridge and beyond to the Webster Park road. State Highway 9 and the Webster Park road skirt the western and southern margins. The southern line of the Denver and Rio Grande Western Railroad from Denver to Salt Lake City passes through the Royal Gorge.

PHYSICAL FEATURES

Eight Mile Park is a plateau of resistant rocks bounded except on the north by softer sedimentary formations, which dip away in a quaquaversal manner. The southeastward flowing Arkansas River has cut a deep and narrow gorge through the center of the area. Elevations range from about 7000 feet at the top of Fremont Peak to 5350 feet at river level at the east end of the Gorge.

The highest and most rugged part of the plateau is in the southeastern corner. Westward and northwestward it changes gradually into moderately and gently rolling country with extensive park-like areas that begin at an elevation of about 6100 feet and slope gently westward where they pass into the sharply dissected margin along the sedimentary contacts. Powers (1935, p. 190) states that "The plateau retains parts of two erosion surfaces—the eastern upland about 6800 in altitude and the 6100-foot 'flat area'." However, the two sections are not distinctly separated, and the former is too poorly defined to be easily recognized as the remnant of a separate erosion surface. Probably there is represented only a single, westward dipping erosion surface whose higher eastern part has been more strongly dissected.

PETROLOGY

General Statement

The pre-Cambrian rocks may be grouped into three major units which occur as northeast-trending belts. From northwest to southeast these are:

1. Pikes Peak granite
2. Idaho Springs formation
3. Injection gneiss

The oldest rock is the Idaho Springs formation which was intruded by Pikes Peak granite. Large-scale lit-par-lit injection by granitic material related to the Pikes Peak magma fashioned the injection gneiss from selected parts of the Idaho Springs formation. Closely related to the intrusion of Pikes Peak granite are dikes of aplite, aplitic granite, pegmatite, and diabase. The pegmatites are described in detail in a special section.

Idaho Springs Formation

The name Idaho Springs formation was applied by Ball (Spurr, Garrey, and Ball, 1908) to a highly metamorphosed series of rocks that forms the oldest unit of the pre-Cambrian complex in the Georgetown Quadrangle. Four lithologic units were distinguished: biotite-sillimanite schist, biotite schist, quartz gneiss (impure quartzite), and lime-silicate rocks. Similar rocks had been described previously by Cross (1894A, 1894B) from the Pikes Peak and Crested Butte Quadrangles. Finlay (1916) indicated the presence of small areas of these rocks in the Cripple Creek Quadrangle but did not differentiate them on his map. Later Loughlin and Koschmann (1935) described them in detail. Lovering (1929) correlated the earlier descriptions in his summary of the geologic history of the Front Range.

In the Eight Mile Park area the Idaho Springs formation is chiefly a muscovite schist with variable but generally minor amounts of biotite schist, biotite-muscovite schist, biotite-sillimanite schist, quartz-mica schist, quartzite, and exceedingly rare layers of quartz-epidote rocks.

The most typical phase is a coarse-grained muscovite-rich schist in

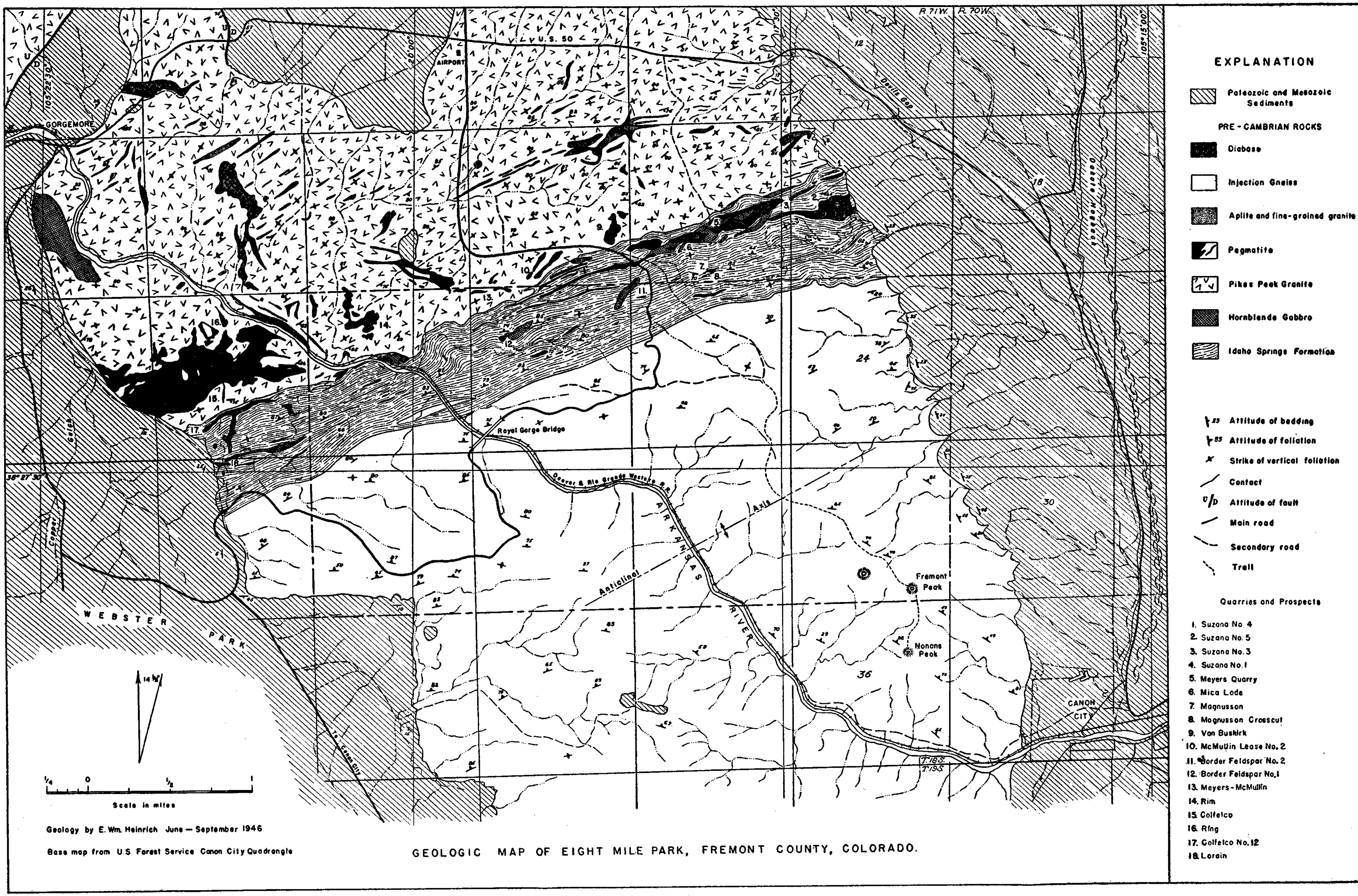
EXPLANATION
Paleozoic and Mesozoic Sediments
PRE-CAMBRIAN ROCKS
Diabase
Injection Gneiss
Aplite and fine-grained granite
Pegmatite
Pikes Peak Granite
Hornblende Gabbro
Idaho Springs Formation
Attitude of bedding
Attitude of foliation
Strike of vertical foliation
Contact
Attitude of fault
Main road
Secondary road
Trail
Quarries and Prospects
1. Suzana No. 4
2. Suzana No. 5
3. Suzana No. 3
4. Suzana No. 1
5. Meyers Quarry
6. Mica Lode
7. Magnusson
8. Magnusson Crosscut
9. Von Buskirk
10. McMullin Lease No. 2
11. Border Feldspar No. 2
12. Border Feldspar No. 1
13. Meyers-McMullin
14. Rim
15. Colfelco
16. Ring
17. Colfelco No. 12
18. Lorain
GORGEMORE
AIRPORT
U.S. 50
Devils Gap
Royal Gorge Bridge
Denver & Rio Grande Western R.R.
ARKANSAS RIVER
Anticlinal Axis
Fremont Peak
Nonans Peak
CANON CITY
WEBSTER PARK
R.71W. R.70W.
T.18S. T.19S.
105°22'30"
105°20'00"
105°17'30"
105°15'00"
38°27'30"
Scale in miles
Geology by E. Wm. Heinrich June — September 1946
Base map from U.S. Forest Service Canon City Quadrangle
GEOLOGIC MAP OF EIGHT MILE PARK, FREMONT COUNTY, COLORADO.

Fig. 2

which the mica flakes may attain a diameter of $\frac{3}{8}$-inch. A similar fine-grained rock is comparatively rare. The color ranges from silver to blue-gray to grayish-green, and the schistosity is commonly well developed. Quartz is the only other common mineral, feldspar occurs sparingly, and biotite may be present in variable quantities. Under the microscope this rock is seen to consist chiefly of muscovite and quartz. Iron-stained sericite is very abundant and replaces both quartz and earlier coarser muscovite. Accessory minerals include abundant magnetite which is commonly fractured and veined by sericite, a little chlorite, traces of sillimanite, and a few grains of zircon. Zircon was noted in quartz-biotite schists in the Cripple Creek Quadrangle (Finlay, 1916, p. 4). Locally this rock with an increase in the amount of quartz grades into quartzite. Schists that contain important quantities of both muscovite and biotite are rare.

The Idaho Springs formation has been intruded by sills of gabbro with the production of quartz-hornblende contact rocks containing plagioclase metacrysts. Other contact schists contain coarse metacrysts of muscovite or $\frac{1}{8}$-inch muscovite "knots" in a fine-grained groundmass of biotite and quartz.

Near bodies of aplite epidote may be abundant, and tourmaline metacrysts have been formed along the margins of some small pegmatite bodies. Ball (Spurr, Garrey, and Ball, 1908, p. 40) states that " . . . large prisms of black tourmaline are embedded at right angles to the schistosity near pegmatite dikes containing similar tourmaline." The larger pegmatities commonly are sheathed in recrystallized and coarsened muscovite schist.

Hornblende Gabbro

Sills and lenses of hornblende gabbro, which range in length from 400 to 2500 feet and in width from 20 to 350 feet, have been intruded into the Idaho Springs formation. The largest body occurs north of the mouth of Copper Gulch, where it apparently forms part of a roof pendant in Pikes Peak granite. This mass, which is 3300 feet long and 1000 feet wide, has been intruded and altered by the granite. Thus the gabbro is younger than the Idaho Springs formation and older than the granite. The foliation is very poorly developed, and the sills were intruded toward the close of or after the metamorphism of the Idaho Springs schists. Mafic hornblende-bearing rocks in the injection gneiss probably represent altered remnants of similar gabbroic sills.

The most common rock type is a dark, coarse-grained hornblende gabbro that contains varying amounts of biotite. The grain sizes ranges from $\frac{1}{8}$-inch to $\frac{5}{8}$-inch, but the coarser phases are of local extent only. In addition to this predominant type there occur:

1. Quartz-hornblende gabbro that resembles the normal type except for the presence of quartz. This rock appears to have been formed by reaction with quartz-rich schist, for it is a marginal phase of some sills.
2. Hornblendite in which plagioclase is a very minor constituent.
3. Biotite-bearing hornblendite in which plagioclase is likewise subordinate.
4. A biotite-rich rock which contains abundant magnetite and apatite. Plagioclase is subordinate and hornblende is absent.
5. A rare biotite-rich rock which contains magnetite, olivine, and traces of hornblende and plagioclase. The grain size averages $\frac{1}{4}$ inch.
6. Local highly schistose phases, which are probably the result of post intrusive fracturing and shearing, contain abundant chlorite and some secondary quartz. Some are marginal to large bodies of pegmatite.

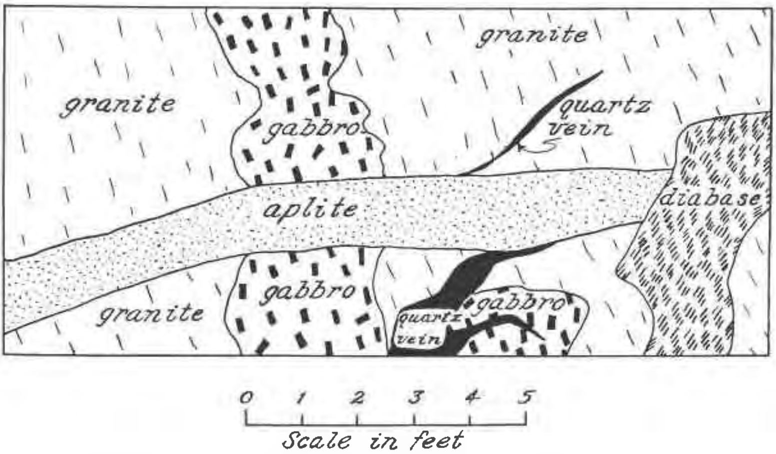

FIG. 3. Age relationships between gabbro, Pikes Peaks granite, aplite, diabase, and quartz veins, Copper Gulch.

Microscopically the gabbro consists of an equigranular aggregate of hornblende, labradorite, and minor biotite. Magnetite and apatite are common accessories. Chlorite and calcite are products of weathering. Some of the hornblendes are poikilitic with plagioclase inclusions. The plagioclase ranges in composition from calcic andesine to calcic labradorite.

Associated with the gabbro are two minor types of pegmatite. The first, which was observed just west of the Border Feldspar No. 1 pegmatite, contains abundant quartz and chlorite and minor microcline. The brownish-green chlorite appears to be primary. The other variety occurs in one- to two-foot pods marginal to the thick sill of gabbro in the gulch northeast of the Lorain quarry in the SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 20. It consists of abundant hornblende in two-inch blades, epidote, albite, apatite, and traces of biotite.

The gabbro has been intruded by Pikes Peak granite, aplite, pegmatite, and diabase (Figs. 3 and 4). Around the margins of aplite dikes it contains abundant epidote, calcite, and red microcline in veinlets and minute blebs.

FIG. 4. Xenoliths of gabbro in Pikes Peak granite, Copper Gulch.

PIKES PEAK GRANITE

The most widespread igneous rock is the Pikes Peak granite, which underlies the northern third of the area. The Pikes Peak granite was first described by Mathews (1894) and then shortly thereafter by Cross (1894A). It was subsequently found to have a wide distribution in the Colorado Front Range, especially in the south-central part where it forms a batholith about 80 miles long and nearly 35 miles wide. Lovering (1929) has correlated the Pikes Peak with the Rosalie granite, and Boos (1934) has indicated that it is also probably identical with the Sherman granite in northern Colorado and Wyoming.

The Canon City body is separated from the main batholith by an arm of Cripple Creek granite on the north and by the down-faulted block of sediments in Garden Park on the east.

The main rock type is a red, coarse-grained, porphyritic granite, which forms the central part of the mass. The groundmass, whose average grain size is about $\frac{3}{16}$-inch, consists of quartz, oligoclase, and abundant biotite. In this matrix are set well formed phenocrysts of red microcline, which range in length from ½ inch to 2 inches, with an average of about 1 inch. Rarely are they less than ½ inch long. Accessory minerals are abundant allanite and sphene, apatite, and magnetite. Fluorite, which is a common accessory mineral of this granite in the vicinity of Pikes Peak (Mathews, 1900), appears to be absent in the Eight Mile Park area. Biotite is commonly partly altered to chlorite, and the feldspars, especially the plagioclase, may be thoroughly sericitized. A small amount of micropegmatite is present.

Table 1 presents Rosiwal analyses of four specimens of Pikes Peak granite.

TABLE 1. ROSIWAL ANALYSES OF PIKES PEAK GRANITES

	A.	B.	C.	D.
Microcline and orthoclase	52%	42%	56%	66%
Quartz	23	29	33	22
Oligoclase	13	8	4	2
Biotite	10	12	4	7
Muscovite	tr	6	tr	tr
Accessory minerals	2	3	3	3
	100	100	100	100

A. Royal Gorge, Mouth of Overshot Gulch, Eight Mile Park, Fremont County, Colorado.
B. U. S. Highway 50, 3 miles west of Parkdale, Fremont County, Colorado.
C. Idem.
D. East side of Litterdale Gulch, near Lake George, Park County, Colorado.

The normal granite has a well-defined foliation characterized by a planar orientation of the tabular phenocrysts and platy biotite. Along the schist contacts a finer-grained, non-porphyritic, gneissic phase is prominently developed. Biotite is more abundant. Local porphyritic patches occur, and the contact with the normal phase is gradational.

The Pikes Peak granite was intruded successively by:

1. Sills, dikes and small stocks of aplite and fine-grained granite.
2. Dikes of pegmatite.
3. Dikes of diabase.

The magmatic activity continued with the formation of several types of veins:

1. Rare allanite veinlets as much as ¾ inch thick.
2. Veinlets of flesh colored feldspar with minor quartz. Younger epidote, which may be coated by fine-grained blue-green chlorite, is also present in many.
3. Veinlets of epidote.

4. Veinlets and lenses of quartz. Large pods of "bull" quartz are restricted to the schist-granite contacts. The quartz veinlets contain plagioclase, black tourmaline, hornblende, chlorite, biotite, and ilmenite as rare constituents.

The formation of these veins was followed by a period of fracturing during which well-defined narrow shear zones were developed in a few places. Elsewhere parts of the granite body were sheared in a wholesale manner with the development of cataclastic structures and minor mineralization. A few unmineralized fractures with slickensides were also noted, but these may be much younger.

Aplite and Fine-Grained Granite

Sills and dikes of aplite and fine-grained granite are the oldest of the minor differentiates that intrude the Pikes Peak granite. Sills along the

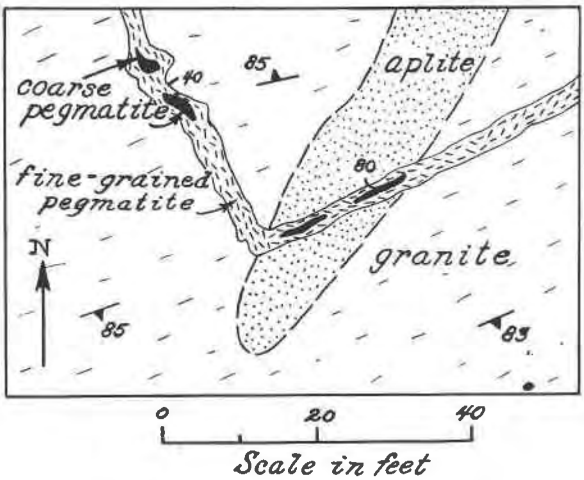

Fig. 5. Pegmatite transecting aplite, Overshot Gulch.

granitic foliation are more common than dikes and these form the larger masses. Some of the smaller aplite dikes were intruded along the contacts of tabular schist xenoliths in granite. A few small stocks, some with concordant apophyses, were also mapped. In addition, aplite sills and dikes have been intruded into the schists of the Idaho Springs formation and into the hornblende gabbro. Several large pod-like bodies of aplite have been localized along the Pikes Peak-Idaho Springs contact. Several generations of aplite are present. The earlier bodies tend to be sills along the granitic foliation, whereas the later ones were injected along fractures.

The most important rock type is a fine-grained aggregate of red microcline and gray quartz. Biotite and plagioclase are very subordinate or absent. A little muscovite may be present, replacing biotite with the formation of magnetite "dust." This type grades into a fine-grained equigranular granite that contains, in addition to abundant quartz and microcline, the essential minerals, plagioclase, orthoclase, and biotite. Muscovite, apatite, zircon, and magnetite are common accessories.

Most of the aplites and aplitic granites are red in color, owing to the predominance of red microcline and orthoclase. Some of these rocks, in which biotite is more abundant, are light gray in color.

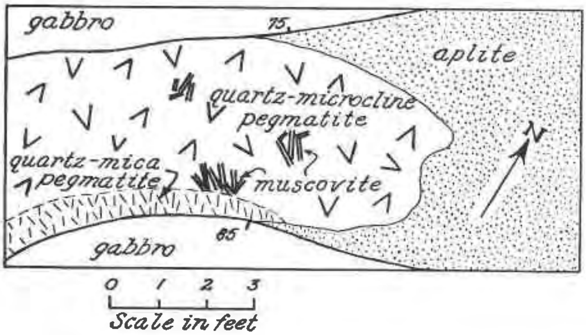

FIG. 6. Composite aplite-pegmatite sill, near Meyers Quarry.

Although the aplites are generally somewhat earlier than the pegmatites, which transect them (Fig. 5), gradations from aplite to pegmatite were noted (Fig. 6). A few aplite dikes contain central pods of massive white quartz, similar in appearance and arrangement to the massive quartz cores of many of the pegmatite bodies.

Some aplitic sills in granite developed strong gneissic structures parallel to their strike and dip. The structures appear to be primary, for the surrounding granite is undeformed as are later diabase dikes which transect the aplite sills.

DIABASE

Dikes of diabase occur throughout the entire area of preCambrian rocks. Several textural varieties are present. The smaller bodies consist of a dense, brown to gray aphanitic type, which may contain conspicuous small needles of plagioclase. The larger dikes are characterized by the typical ophitic texture in which the individual grains may attain a length of $\frac{1}{4}$ inch. The aphanitic type is highly fractured and disintegrates to blocky, angular fragments, reddish gray in color, but the coarse-grained varieties are massive and weather to large spheroidal boulders which are enclosed in thin shells of decomposed, iron-stained material. In some dikes both phases are present.

Diabase dikes are especially abundant in granite but also are numerous in schist and in the injection gneiss complex. In the gneiss they were not mapped individually. The dikes are generally flat-lying, thin tabular bodies, which cut across the primary granite foliation at nearly right angles. Dips are low, ranging from 0° to 25°. One flat-lying dike, which ranged in thickness from one to about ten feet, was traced for over one quarter mile. Some dikes split into one or more arms, each of which may divide into numerous thin stringers. The largest bodies, which contain the coarse-grained phases, are most irregular in shape. Many are flat lying to moderately dipping dikes that vary widely in thickness and attitude over short distances.

A third structural type is represented by steeply dipping dikes rather uniform in attitude. These are generally 5 feet or less in width and several score feet to several hundred feet long. One set strikes N. 10° W. to N. 20° E. and the other strikes nearly east-west. Evidence of some displacement along one of the north-south fractures is found at the West Dell prospect, where an east-west pegmatite in granite has been cut off by a north-trending dike of diabase. The relationship between the steeply dipping and the flat lying dikes is well shown in the main tributary to Catlin Gulch (SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, sec. 20), where a nearly vertical apophyse extends upward from a horizontal body. The vertical sill has weathered away to form a "chimney" along the schistosity.

Injection Gneiss

The most widespread rock is injection gneiss, which underlies the southeastern half of the area. Biotite schists of the Idaho Springs formation first were intruded by sills of gabbro and later, chiefly in lit-par-lit manner, by exceedingly numerous bodies of aplite, fine-grained granite, and pegmatite. In many places the alternation of granitic material with granitized schist is so marked that the composite appears stratified. Numerous dikes of diabase cut across this injection structure. In some horizons the structure is crumpled and very complex, with ptygmatic folds that range in size from a few inches to scores of feet. Here cross-cutting masses of granitic material are more common. A few post-diabase faults were also noted.

The pegmatitic material in the injection gneiss differs from that elsewhere in the area. It occurs in very irregular masses that consist chiefly of microcline and quartz. Small flakes of muscovite may be present, and biotite is abundant locally in plates one inch or less in width. Magnetite is unusually abundant, commonly in well-shaped octahedra as large as one inch. Garnet occurs sparingly. Patches of chlorite and veinlets of specular hematite were also observed. Graphic granite appears to be absent. Associated with the pegmatites are veins of quartz, some of which contain abundant large magnetite crystals; veinlets of quartz and hornblende; and veinlets of quartz, hornblende, and biotite.

The host rock for this large scale injection appears to have been chiefly fine-grained biotite schist with scattered lenses of hornblende gabbro. The biotite rock has been intensively granitized throughout much of the complex, resulting in the formation either of biotite schist or gneiss rich in quartz and feldspar, or of banded biotite-feldspar gneisses. The gabbroic rocks have been converted to biotite-hornblende gneisses which contain varying amounts of magnetite, quartz, and feldspar, but in general they have been altered less than the schists.

The granitic material that constitutes the major part of the injection gneiss is believed to have been derived from the Pikes Peak magma. In appearance, occurrence, and mineralogy the rocks resemble closely the late granitic rocks as they occur in the other rock units of the area—the Pikes Peak granite, the Idaho Springs formation, and the hornblende gneiss. The difference lies largely in the intensity of the injection process and in the amount of material introduced. It seems rather unusual that the most intense injection occurred at some distance from the main body of Pikes Peak granite and thus left an undisturbed belt of schists adjacent to the contacts of the batholith. Yet similar sequences of injection gneiss, schist, and Pikes Peak granite are to be observed in two places along U. S. Highway 50 between Parkdale and Cotopaxi, west of the area. It is possible that further light may be shed on this peculiar distribution when detailed mapping is continued to the south of the area.

Paleozoic and Mesozoic Sediments

The area is bounded on the east by hogbacks of Paleozoic sediments that dip gently to moderately eastward. On the west, northwest, and southwest Mesozoic beds, which begin with the Morrison formation, lie along the margins (Fig. 2). Contacts between the pre-Cambrian and the younger rocks usually are erosional in nature. Small islands of capping Morrison strata occur at several widely scattered places (Fig. 2). Faulted contacts are rare. A few small faults cut sediments and granite in the northwest corner of the area (Fig. 2) where the Mesozoic strata are locally overturned.

STRUCTURE

Pre-Cambrian Structure

The pre-Cambrian rock units are characterized by a uniform structure that strikes N. 50–80° E. and is steeply dipping to vertical. The elements that combine to produce this structural uniformity are:

Idaho Springs Formation
1. Attitude of schistosity.
2. Strike and dip of pegmatite and aplite sills.
3. Attitude of fractures in pegmatites.
4. General trend of entire schist belt and of contacts with flanking rock units.

Hornblende Gabbro
1. General trend of the gabbro sills.
2. Attitude of poorly developed foliation.
3. Strike and dip of pegmatite and aplite bodies.

Pikes Peak Granite
1. Attitude of primary foliation.
2. Attitude of aplite sills.
3. Attitude of primary foliation in the sills of aplitic granite.
4. Strike and dip of fractures in aplite sills.

Injection Gneiss
1. Axis of major anticline.
2. Strike and dip of foliation on northwest flank of anticline.

Laramide Structure

The Eight Mile Park area lies at the extreme western end of the Canon Embayment in the Front Range structure. No important periods of diastrophism occurred in Paleozoic time. During the Laramide orogeny the Eight Mile Park plateau was uplifted as part of the Front Range accompanied by arching of the sedimentary cover. Faulting was confined to the northwest corner of the area, where several small blocks of Mesozoic formations were dropped down relative to the pre-Cambrian rocks.

Geologic History

The schists of the Idaho Springs formation are believed to be sedimentary in origin and probably were formed by the erosion of granitic rocks no longer exposed (Lovering, 1929). Very likely the formation consisted of marine shales and sandstones; very little limestone was deposited in the Eight Mile Park area. If no isoclinal folding is present, the thickness may be as much as 10,000 feet. Lovering (1929) states that it may attain a thickness of 25,000 feet.

Uplift and strong folding followed deposition, and the sediments were transformed into schists and quartzites with a foliation parallel with the original bedding. The sills of gabbro were intruded toward the close of the period of metamorphism.

The emplacement of the Pikes Peak batholith followed, and satellitic dikes and sills of aplite and aplitic granite were injected close to the end of the period of granite crystallization. The pegmatite bodies that followed were intruded along cooling fractures in the granite as dikes (interior and marginal pegmatites), and as sills (exterior pegmatites) along the schistosity of the bordering Idaho Springs formation. The diabase dikes followed fractures both in granite and the metamorphic rocks. During the hydrothermal stage, which was of feeble development, a variety of quartz-rich veins were formed.

Uplift and a long period of erosion followed. The erosion surface may have been largely developed at this time. Minor deposition of Paleozoic sediments began in upper Cambrian time. In the area west of Canon City the Cambrian is largely absent and probably was eroded away before deposition of Ordovician sediments was initiated. The Ordovician overlaps the Cambrian remnants westward. No Silurian or Devonian formations occur in the Canon embayment, and the Mississippian rocks (Millsap limestone) appear to be bounded both at the top and bottom by erosional unconformities. The Fountain formation of Pennsylvanian age probably did not extend far west of Canon City nor did the Permian, Triassic, or Jurassic. The Cretaceous formations overlap far to the west resting on pre-Cambrian rocks on the west side of Eight Mile Park.

During the Laramide orogeny the Eight Mile Park area was uplifted with maximum elevation near the southeastern corner. The Arkansas River began to cut its canyon and stripping of the sedimentary cover was begun.

Table 2 compares the pre-Cambrian geologic history of Eight Mile Park area with other areas in the Front Range.

PEGMATITES

Distribution

Pegmatites occur in all three major rock units: granite, schist, and injection gneiss. The pegmatitic material in the gneiss is characterized by irregular patchy distribution and cannot be represented as distinct map units. It is of no commercial importance and of little mineralogical interest. The other pegmatite bodies in the area can be classified readily into three types: interior, marginal, and exterior. This grouping is analogous to that proposed by Gevers (1936) for the Namaqualand pegmatites. Before comparing the characteristics of each of the groups it is necessary to discuss in some detail the general internal structure of pegmatite bodies.

A magnetic survey of the Canon City Quadrangle has been completed by Blum (1944) who states (p. 557), "The second feature on the magnetic map which is of interest is the set of magnetic highs in the northwest quadrant of the map. The two western highs correlate quite well with the pegmatitic dikes which are here amply exposed. The western high in the group is situated in the sedimentary horizon and probably reflects the existence of these same dikes under the Paleozoic rocks."

TABLE 2. SUMMARY OF PRE-CAMBRIAN GEOLOGY OF SELECTED AREAS IN THE FRONT RANGE OF COLORADO

A. Front Range (general)	B. Longs Peak-St. Vrain	C. Indian Creek	D. Cripple Creek	E. Eight Mile Park
	Mount Olympus granite			
Silver Plume granite (gripple Creek, Longs Peak granites)	Longs Peak granite	Injection gneiss	Cripple Creek granite	
		Indian Creek granite		
Injection gneiss				Injection gneiss
Pikes Peak granite (Rosalie, Sherman granites)		Pikes Peak granite	Pikes Peak granite	Pikes Peak granite
Metamorphism	Metamorphism	Metamorphism		
Granite gneiss				
Quartz-Monzonite gneiss	Boulder Creek granite gneiss	Mount Evans quartz monzonite	Olivine Syenite?	Hornblende gabbro
Metamorphism	Metamorphism	Metamorphism	Metamorphism	Metamorphism
Idaho Springs fm.	Idaho Springs fm.	Idaho Springs fm.	Idaho Springs fm.	Idaho Springs fm.

A. Lovering (1929).
B. Boos and Boos (1934).
C. Boos and Aberdeen (1940).
D. Loughlin and Koschmann (1935).
E. Heinrich (this paper).

With this hypothesis the writer cannot agree. The largest pegmatite bodies flank the Pikes Peak-Idaho Springs contact to form a belt that trends east-northwest. Probably this belt continues eastward beneath the sedimentary cover. The western magnetic high referred to by Blum does not overlie the pegmatite belt nor does it reflect its shape. In all likelihood, therefore, its existence must be ascribed to other factors as yet undeciphered. For similar reasons the eastern high cannot be laid to the influence of pegmatites beneath the sedimentary cover.

General Structural Features of Pegmatites

History

The early history of pegmatite investigation was marked by intensive mineralogical and crystallographic study, wherein suites of specimens were collected in a generally haphazard fashion and subjected to detailed scrutiny in the laboratory. Many of the specimens were selected because of their unusual mineralogy, and in many cases, less spectacular material that constituted the bulk of the pegmatites was ignored. The results of such work were sometimes embodied in a paragenetic history, which, although complete in itself, failed to relate the mineralogy of the rarer constituents to the structure of the pegmatite or to its geologic environment. Thus, "specimen" mineralogy and the lack of pegmatite maps combined to assert the thesis of heterogeneity and irregularity of mineral distribution in pegmatites.

That some pegmatites are characterized by a well-defined and orderly internal arrangement of petrologic units was, however, early recognized. Hitchcock in his report on the geology of Massachusetts wrote (1833, p. 505), "The most noted locality of green and red tourmalines is in Chesterfield on the land of Mr. Clark. They are contained in an enormous vein of granite in mica slate, which corresponds nearly in direction with the layers of slate. This granite is crossed obliquely by a vein, varying in width from six to eighteen inches, of smoky quartz and silicious (sic) feldspar: or rather the quartz forms the central part of the vein, and the feldspar lies on each side of the quartz: the green red and blue tourmalines, with schorl and sometimes beryl passing through the feldspar and the quartz." It is not entirely clear whether his description deals with primary structures in a pegmatite or with banding in a fracture-controlled unit cutting a larger pegmatitic mass.

A systematic distribution of minerals in the Etta (Black Hills) pegmatite was reported by Blake (1884), and a reproduction of a map by Bailey (Blake, 1884, p. 606) shows a marked concentric structure in the deposit. Shortly thereafter banding was noted in a pegmatite on 110th Street, New York City (Kemp. 1888). Van Hise (1904, p. 724), in writing of the pegmatites of the Black Hills, states, "Still farther away (from the granite) the pegmatitic masses begin to have vein-like characters—that is, there is a rough concentration of the material in different layers parallel to the walls. Still farther away a true banded-vein structure is found."

An interesting description of a zoned pegmatite was presented by Holmquist (1910, p. 804) for a pegmatite of the coast region of Stockholm, Sweden: "Such a pegmatite, traversing Archean limestone, has been worked on the little cliff 'Vånkobben.' It is a dike of about 10 *m* in width, composed of pure masses of quartz, microcline and a little graphic felspar and some pegmatite-granite, which different masses appear in regular zones in the dike. The pegmatite-granite is found as a thin layer or crust on both sides of the wall. After this crust followed inward belts of graphic felspar of a somewhat irregular thickness. These passed into pure microcline, which form irregular crystals several decimeters in size. The middle of the dike consists of pure quartz, coarse crystalline and a little smoky in colour."

Bastin (1911), Ziegler (1913), and Sterrett (1913) recognized a degree of orderliness in the mineral distribution of the pegmatites they studied, and in the 1920's this phenomenon was reported by Schwartz (1925), Schaller (1925), Schaller and Henderson (1926), and Landes (1928). Kemp (1924, p. 708) stated, "Quartz certainly is the last of all, and in many dikes forms the central part where it seems to be the last residue and to run along the central part like a residual filling." He also noted (p. 709) the existence of banded structures, finer-grained wall zones, and selvages of mica plates normal to the walls. Vogt (1926), p. 229 presented a sketch of a pegmatite from near Arendal, Norway, that shows the quartz core and an arrangement of (mica?) crystals normal to the walls.

The regular distribution of muscovite in pegmatites was summarized by Mohr (1930) in his book, "Der Nutzglimmer" (pp. 52–57). Kuznezova (1931) reported that the pegmatites of Western Georgia, U.S.S.R., are zoned between their margins and center. Landes (1932) recognized a coarse-grained core of quartz and microcline in the Baringer Hill, Texas, pegmatite. Hess (1933) noted the existence of large, segregated masses of potash feldspar in many pegmatites. Gevers (1936) emphasized the relation of rare mineral distribution to the contacts of quartz cores in Namaqualand pegmatites.

It was not until 1942, under the stimulation of war-time need for pegmatitic minerals, that the internal structures of pegmatite deposits were systematically studied and the units given map representation. A large number of investigations since that year have indicated that pegmatites with mappable internal units are widespread and that by mapping these units results of both economic and scientific importance can be obtained.[1]

Recently there has appeared a short notice on the systematic classification of structural units in pegmatites (Cameron, et al., 1946), and Vlassov (1946) has attempted to classify granite pegmatites on the basis of their internal units.

[1] See for example: Smith and Page (1941); Olson (1942); Pecora (1942); Bannerman (1943); Page, Hanley, and Heinrich (1943); de Almeida, Johnston, et al. (1944); Cameron, Larrabee, et al. (1945); Stoll (1945); Johnston (1945); Griffitts, Heinrich, et al. (1946); Jahns (1946); Shainin (1946A); Cameron and Shainin (1947); and Heinrich (1948).

No matter what detailed version of the origin of pegmatites is ultimately generally accepted, it is certain that two major types of structural units can be recognized in some pegmatites and can be represented accurately on maps and sections. This is not to imply that all pegmatites are marked by a regular internal arrangement of their constituents. However, it has become increasingly recognized in the last seven years that those pegmatites that are of commercial or mineralogical significance generally exhibit this characteristic to a varying degree. The recognition of this systematic distribution of internal elements is of far-reaching significance in the prospecting and mining of pegmatites and in deciphering their genesis.

The two classes of units are (1) primary and (2) secondary. In the following sections definitions of these types are attempted.

Primary Units

Many pegmatite bodies contain well-defined, mappable units of contrasting petrology (i.e., varying mineral content or texture or both) which, in the ideal case, occur as concentric layers around a central unit, or core. Such units, through recent usage, have been termed pegmatite zones (Shainin, 1946B). They are primary in the sense that they represent the original structural elements of the pegmatite body, formed in successive stages of crystallization from the walls inward. The structure and shape of zones reflect the attitude of the pegmatite body as a whole. Not only does their arrangement impart a rough bilateral symmetry in plan but in section as well. Pegmatites containing such units may be termed, *zoned pegmatites*, and those lacking these elements may be referred to as, *unzoned pegmatites*.[2]

Recent usage has also suggested appropriate names for various zones. The outermost zone along the wall rock contacts is the *border zone*. Because these are commonly thin, they generally cannot be mapped separately, and because they are of relatively little practical importance to the pegmatite miner, they have been ignored. On the other hand some operators have distinguished an economically important *wall zone*, which name can conveniently be retained for the zone adjoining the border zone. The central units are known as *cores*, and a zone immediately surrounding a core is often referred to as a *core-margin zone*. Any zone

[2] The terms, unzoned pegmatites and zoned pegmatites, are not identical, respectively, with "simple" and "complex" pegmatites as defined by Landes (1933, p. 95). Landes' simple pegmatites, which he defines "as those in which there has been no hydrothermal replacement," may be either unzoned or zoned. His complex pegmatites, defined as those in which "hydrothermal replacement has taken place and rarer minerals have been deposited," probably are all zoned or were zoned originally.

that falls between the core and the wall zone may be termed an *intermediate zone*, of which the core-margin zone is one variety.

The designation of zones in actual practice is not always easy. Lack of pegmatite exposures, changes in relative position of units on different levels owing to the plunge of central and intermediate zones, incomplete development of zones, and disruption and destruction of zones by secondary material are factors that tend to complicate the deciphering of the zonal structure.

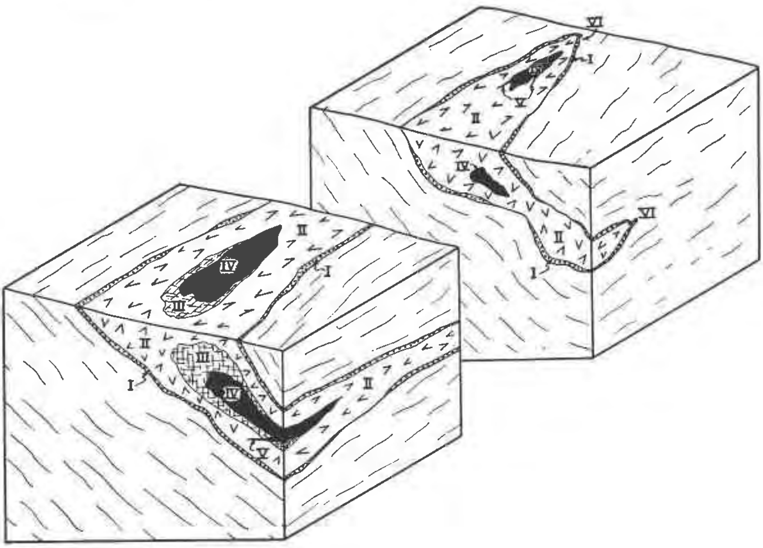

FIG. 7. Idealized expanded block diagram in isometric projection showing pegmatite sill with zonal structure: I—border zone; II—wall zone; III—hood-shaped intermediate zone; IV—core pods; V—transection of intermediate zone by core apophyse; VI—keel of pegmatite, note plunge.

Although, in general, the configuration of zones reflects the over-all shape and attitude of the pegmatite, it should be noted that zones may be imperfectly developed, at least in the horizon under immediate observation. Cores, in particular, may occur as several isolated lenses or pods as well as single central bodies. Some intermediate zones will show a maximum thickness around the end of cores and may pinch out along its sides to form a hood-like unit. Locally within the pegmatite border or wall zones may be discontinuous. These and other features of zones are shown in Fig. 7.

In some flat-lying or moderately-dipping pegmatites the core does not always occur centrally but is displaced toward the hanging wall. Similarly, although a wall zone may be developed along both contacts, one side may show a difference in mineral content. Thus, a wall zone along the hanging-wall contact may be relatively rich in mica as compared to its footwall counterpart.

A conspicuous feature of zones is that they become increasingly coarse-textured toward the center of the pegmatite. Border zones are usually fine-grained; cores are marked by crystals of gigantic dimensions. There is also a tendency toward simplification in mineralogy toward the core. Outer zones are composed generally of more than two essential constituents; cores are bi- or mono-mineralic.

Obviously the detailed mineral composition of zones varies considerably, depending upon the petrologic type of pegmatite. Wall zones of granitic pegmatites do not contain the same proportions or even the same minerals as wall zones of granodioritic or syenitic pegmatites. Zones in general, however, are composed for the large part of the common rock-forming minerals. Thus zones of granitic pegmatites may contain microcline (or less commonly orthoclase), quartz, muscovite, and biotite as major constituents, and sodic plagioclase, magnetite, garnet, apatite, and schorl as minor constituents. Regardless of the bulk composition, however, zones seem to become more siliceous toward the core. For example, in granitic pegmatites the bulk of plagioclase (primary) may be found in wall zones, the intermediate zones are rich in potash feldspar, and the core is commonly massive quartz. Similarly, in granodioritic pegmatites the outer zones contain a higher proportion of plagioclase, whereas inner zones carry increasing quantities of microcline. There is even evidence that suggests the plagioclase in some of these pegmatites becomes progressively more sodic toward the center of the body. In many zoned syenitic pegmatites wall zones are mafic, rich in an alkali amphibole, whereas cores are felsic in composition.

The number of zones in a pegmatite varies considerably. Within the same district pegmatites may range from unzoned to zoned with three or four units. Pegmatites with more than three zones are not common and those with five are very rare.

The characteristics of primary pegmatite units or zones may be tabulated as follows:

TABLE 3. CHARACTERISTICS OF ZONES

1. Their shape and attitude reflect those of the pegmatite as a whole.
2. Their arrangement gives to the pegmatite a rough bilateral symmetry.
3. The grain size of the constituents increases toward the core.
4. They are composed of the common, rock-forming minerals.
5. They tend to become increasingly simple in mineralogy toward the center.
6. They tend to become more siliceous toward the center.
7. They are few in number; generally there are two or three, uncommonly four, very rarely five.

Secondary Units

Secondary units are those which were formed within crystallized pegmatite by the processes of fissure-filling or replacement, or a combination of the two. They range from thin fracture-filled veins to large irregular masses that represent replacement of a zone or parts of several zones. For convenience there may be distinguished:

1. Veins of fracture-filling.
2. Fracture- and contact-controlled replacement masses.
3. Replacement masses of zones.

Fracture-filled veins are generally too small to be represented on a map although their attitudes may be recorded. Replacement bodies that form outward from fractures will, in their initial stages, be controlled in shape by the fissure. As replacement proceeds the guiding channel tends to be obscured and the tabular bodies grade over into irregular replacement masses. Initial replacement from flat-lying or moderately-dipping fissures favors pegmatite on the hanging-wall side of the crack. In many pegmatites with low-angle dips, the well-defined footwall contact of a massive core with an intermediate or wall zone is a favored

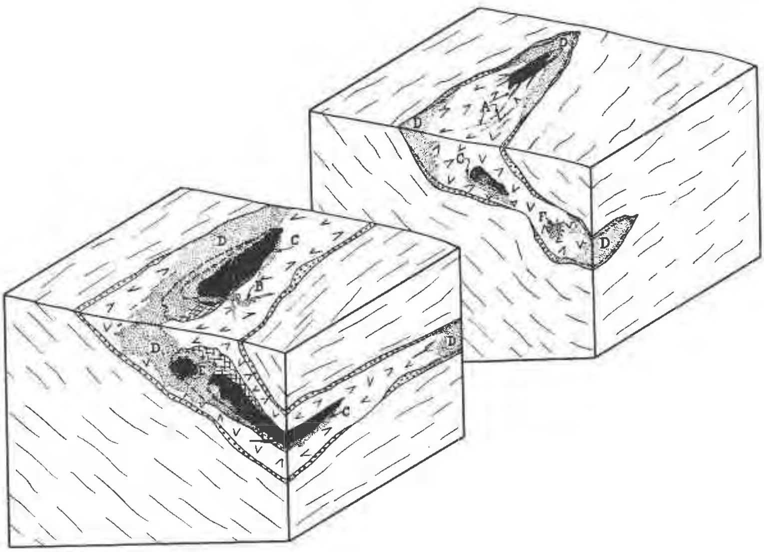

FIG. 8. Idealized expanded block diagram in isometric projection showing pegmatite of Figure 7 with superimposed hydrothermal mineralization: A—filled fractures; B—fracture-controlled replacement vein; C—contact-controlled replacement masses; D—zone replacement masses; E—relict of core and intermediate zone in zone replacement mass: F—radial replacement mass.

channel for localizing replacement. In vertical or more steeply dipping pegmatites both core contacts may show later mineralization. Replacements of a zone or large parts of several zones may themselves show a layered or banded structure, often on a very minute scale. Various types of secondary units are illustrated in Fig. 8.

Secondary units are transgressive and cut across zones and zone contacts. Their shape and attitude do not reflect those of the pegmatite, but are varying and irregular. Their development may destroy the zonal symmetry of the pegmatite. Grain size, texture, and structure are unsystematic and bear no relation to the distance from the contacts. Radial and concentric mineral masses may occur, and corroded and veined relicts of zonal minerals also may be present. Pseudomorphs and vugs of solution are often characteristic.

The rarer mineral species for which some pegmatites are famous are concentrated in the secondary units. In the granitic pegmatites the chief constituents are quartz and sodic plagioclase, commonly sugary albite or cleavelandite. Potash feldspar is rare except as relict material. Lithium micas, alkali tourmalines, and beryl, phosphates, columbium-tantalum minerals, uranium minerals, sulfides, carbonates, zeolites, etc., may be found in these units. Many secondary units may occur in a single pegmatite. For most pegmatites that contain abundant hydrothermal material in secondary units it can be demonstrated that a primary zonal structure is present as well. Unzoned pegmatites containing large or numerous secondary units are not common.

The characteristics of secondary units are enumerated in Table 4:

Table 4. Characteristics of Secondary Units

1. Their shape and attitude are largely independent of those of the pegmatite.
2. They may be cross cutting, and their arrangement tends to destroy zonal symmetry.
3. The grain size is irregular and shows no relation to distance from walls.
4. Corona, rosette and concentric structures, pseudomorphs, relicts, and vugs may be present.
5. Many can be referred to fractures or contacts between zones.
6. The mineralogy is complex, and rare minerals may be abundant. There is no relation of bulk composition to distance from walls.
7. They may be very abundant in any one pegmatite.

Interior Pegmatites

The interior pegmatites, which tend to be in swarms within the batholith, are tabular crosscutting masses that strike N. 50° W to S. 80° W. and commonly dip 45°–85° NE., and 60°–80° NW. They range in thickness from an inch to six feet but probably average about one or two feet. Some are persistent and can be traced for as much as 700 feet; others are only a few score feet long. They are generally well zoned despite their small size, and they consist chiefly of microcline, quartz, muscovite, some biotite, traces of black tourmaline, and variable quantities of plagioclase (commonly oligoclase). The microcline is invariably pink to red; the plagioclase is white.

A well-defined swarm occurs just east of the junction of the Mica Lode road and U. S. 50. The dikes, which range in thickness from 1 to 3½ feet, are well differentiated, with six-inch cores of massive quartz and coarse-grained microcline, and outer zones of fine-grained quartz, microcline, and muscovite. One of the group appears to have had a central cleft. Accessory black tourmaline is present.

In the NW. ¼, SW. ¼, sec. 16 occur several small, well-zoned pegmatites. A section from hanging-wall to footwall shows the following development:

1. Fine-grained light red microcline and quartz; 6 inches.
2. Medium-grained quartz, white oligoclase, and subordinate red microcline; 12 inches.
3. Core of coarse-grained quartz and red microcline; 18 inches.
4. Fine- to medium-grained white oligoclase and quartz; 12 inches.

Just south of this group a pegmatite body, L-shaped in plan, transects a dike of aplite (Fig. 5). The northeastern arm, a sill along the granitic foliation, strikes N. 65° E. and dips 80° NW. However, the northwestern arm, which strikes at nearly right angles to the other and dips 40° NE., appears to have been emplaced along a fracture.

On the north rim of the Gorge, east of the end of the Intake Road, several 6- to 8-inch pegmatites transect reworked xenoliths of hornblende gabbro in Pikes Peak granite. They contain 1- to 2-inch cores of quartz surrounded by zones of fine-grained quartz, red microcline, and white andesine. This is the most calcic plagioclase found in any pegmatite in the area and may be the result of contamination by the mafic host.

A few hundred feet east of this locality on the lip of the Gorge another swarm of small dikes is exposed. One body, which is well exposed on the cliff face, forks with depth and splits into two arms, each of which contains a thin quartz core.

Marginal Pegmatites

All of the larger pegmatites in Pikes Peak granite lie near the contacts with the Idaho Springs formation. These bodies are horizontal to gently dipping, sheet-like or discoidal masses that transect the primary igneous flow structure at nearly right angles. Strikes are very irregular but may be generally to the northwest. Dips, which range from 0° to 25° and average perhaps 10°, are most commonly to the southwest. Changes in thickness and rolls in both contacts are the rule. Included in this group are the largest pegmatites in the district. The Colfelco pegmatite crops out over a length of one mile (northeast-southwest) and is ¼ mile wide.

The sheet-like or discoidal shape of the bodies is clearly recognizable. Contacts with the granite are flat-lying or gently dipping, and in many deposits both footwall and hanging wall are exposed. Erosion of rolls in the footwall contacts has resulted in the exposure of the underlying granite in "windows." Some of these pegmatites are roughly circular in outcrop and send off numerous irregular apophyses.

These sheet-like bodies are very poorly differentiated. Zoning, if present, is irregular and ill defined with intergradations rather than clearly defined contacts. The zones tend to be flat-lying, parallel with the contacts. Generally a discontinuous outer zone of varying thickness, consisting of a fine-grained aggregate of quartz, microcline, and muscovite or biotite, lies along both contacts (Fig. 9a).

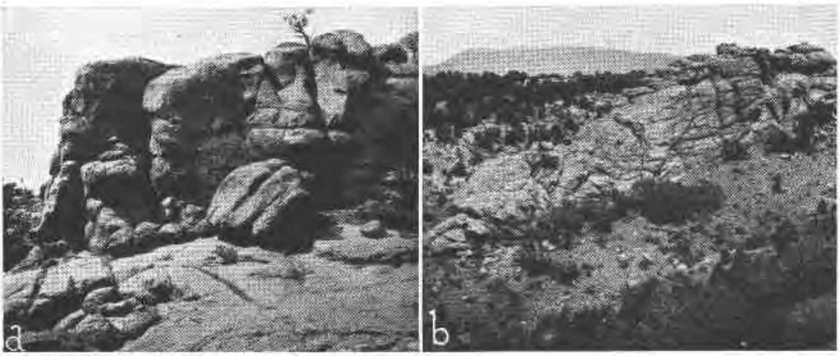

Fig. 9*a*. Rounded erosional form, outer zone, Rim pegmatite, in granite.
9*b*. Unzoned exterior pegmatite sill in schist, MacMullin Ridge.

The bulk of the pegmatite consists of the intermediate zone, a rock composed of two phases. The matrix is a fine- to medium-grained microcline-quartz-muscovite rock in which occur euhedral phenocrysts of graphic granite two inches to two feet across. They resist weathering more than the groundmass and project as knobby, blocky masses (Fig. 10). They consist of a single euhedral microcline crystal as host, with subordinate quartz in an irregular, to subgraphic, to graphic texture. The phenocrysts constitute 10 to 75% of the rock and probably average about 25%. Their cross sections are nearly square and their outlines are as well or better defined than those of the microcline phenocrysts in the Pikes Peak granite. Nearly all of them contain intergrown quartz, but a few of the smaller ones are quartz-free. Like most of the microcline derived from the Pikes Peak magma they are pale pink to deep red in color. Locally red phenocrysts occur in a matrix of white microcline, quartz, and muscovite, which imparts an unusual mottled appearance to the rock.

Flat-lying pods of massive white quartz or of blocky microcline and quartz form the cores. They are small for the size of pegmatite bodies and are irregularly distributed throughout the central parts. The microcline is free of intergrown quartz and occurs in crystals as much as four or five feet across.

Locally around the margins of the cores occur patches of another distinctive rock type that consists of a subgraphic to graphic intergrowth

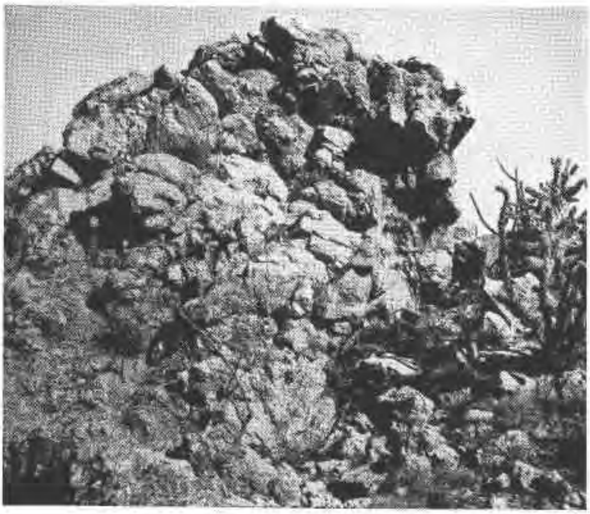

FIG. 10. Phenocrysts of graphic granite in Intake Road pegmatite, matrix of fine-grained pegmatite.

of microcline and quartz intermingled in irregular fashion with a quartz-muscovite aggregate. The latter is made up of a dominant quartz host in which are set abundant flakes of muscovite in a semi-regular pattern. The flakes may tend toward parallelism or approach a dendritic or plumose pattern. A few scattered books of muscovite may also occur along the margins of the core. Rarely do they exceed a width of two inches.

With one major exception, fracture-controlled or replacement units are absent or very subordinate. Thin veinlets of black tourmaline and quartz cut across the zones. The School Section pegmatite, the only major exception, contains small replacement units of plagioclase-muscovite pegmatite along the footwall contacts of many of the core pods. Beryl, tourmaline, garnet, triplite, and other rare minerals occur in these units.

A few marginal pegmatites consist chiefly of quartz with subordinate amounts of other minerals. The largest representative of this type occurs southeast of the School Section quarry. This pod-like body which strikes N. 70° E., consists of 80–90% massive white quartz and very minor amounts of microcline, biotite, and muscovite. Across the valley from the Mica Lode quarry is exposed a quartz-rich pod, 30 feet long and 6 feet wide, with narrow stringers and small patches of microcline. At the mouth of Catlin Gulch along the schist-granite contact lies a mass of pegmatite about 250 feet long that strikes N. 56° E. and dips 65° SE. It is highly quartzose and fractured and has been stained by iron oxides. Abundant small masses and veins of fine-grained oligoclase-quartz-muscovite rock occur in it. Along the schist wall is a selvage of 2-inch muscovite books that tend to be normal to the contact. These pegmatites appear to be similar to the "feldspathized quartz veins" in the Archean of the Grand Canyon, Arizona, as described by Campbell (1937, pp. 441–444).

Exterior Pegmatites

The Idaho Springs schists have been intruded conformably by numerous bodies of pegmatite. The larger masses are close to the Pikes Peak granite contact, but smaller pegmatites occur throughout the entire belt. The pegmatites range in thickness from a few inches to 800 feet and in length from several feet to 3,000 feet. The larger, more irregular masses tend to be concordant but extend numerous apophyses across the foliation. Tabular and pod-like shapes are most common. The strikes range from N. 55–85° E., with generally steep to moderate dips to the northwest. An exception to this general shape and attitude is the Border Feldspar No. 1 pegmatite, which is a very irregular flat-lying lens with offshoots from its crest. Another unusual pegmatite is the Lorain deposit, which is L-shaped in plan.

The intrusion of pegmatite was accompanied by minor wall rock alteration. Mica of the schists has been recrystallized or coarsened, and around some of the smaller sills tourmaline metacrysts have been formed. Some hornblende gabbro has been altered to a muscovite-rich rock by the intrusions.

Many of the larger bodies contain a characteristic zonal structure. Border zones, which are normally narrow and discontinuous, consist either of quartz with small disseminated flakes of muscovite or of coarse books and flakes of muscovite, closely intergrown and normal to the walls. Wall zones may be strongly developed and are composed of a fine-grained, uniform intergrowth of quartz, microcline, and muscovite.

The greater mass of most of the deposits is made up of the intermediate zones. In mineralogy they resemble their counterparts in the marginal pegmatites, but the two differ markedly in texture. Two phases are present: an irregular to graphic intergrowth of quartz and red microcline, and a quartz-muscovite rock in which the mica flakes tend toward parallelism or dendritic and plumose patterns. These two distinct phases are intergrown in extremely irregular fashion. Although the proportions vary somewhat, neither predominates strongly. Contact relations between the two rock types are confused and contradictory, and their periods of formation probably overlapped. In some exposures the quartz-mica rock appears to penetrate and replace graphic granite. Elsewhere the latter appears to be the younger phase. The rock grades into the fine-grained, uniform pegmatite of the wall zones.

Cores are composed of massive white quartz with variable amounts of quartz-free microcline in crystals as much as six feet in width. Locally, with a decrease in the quartz-mica phase, intermediate-zone pegmatite passes into microcline-rich "embryonic" cores in which graphic granite becomes subordinate to blocky, quartz-free microcline. Cores may consist of several unconnected segments as in the Meyers Quarry pegmatite, or they may be a single unit as in the Mica Lode.

Replacement units, which are superimposed on the zonal structure, are relatively strongly developed in many of the larger pegmatites in schist. Most of the units are clearly related to fractures or to footwall contacts between cores and underlying intermediate zones. Plagioclase, either oligoclase or albite, is the dominant mineral with quartz and muscovite next in importance. Locally cleavelandite is important. Muscovite occurs in two ways: as aggregates of tightly intergrown, $\frac{1}{4}$- to 2-inch flakes ("ball mica"); and as long, wedge-shaped blades arranged in comb structure. Other minerals are garnet, black tourmaline, apatite, beryl, triplite, lepidolite, red and green tourmaline, and chalcocite.

The structural elements described above, with variable development of the replacement units, are characteristic of the following exterior pegmatites: Meyers Quarry, Mica Lode, Suzana Nos. 1, 3, and 4, Border Feldspar Nos. 1 and 2, Magnusson Crosscut, as well as other smaller bodies.

Most of the atypically zoned Lorain pegmatite is a poorly differentiated aggregate of microcline and quartz, but the thicker part of the northwest limb contains a microcline-rich core. Massive quartz is almost entirely absent. Finely banded pegmatite occurs in the Suzana No. 5 deposit. The bands form swirls, scallops, and irregular curved patterns (Fig. 11). They appear to represent reworked masses of schist.

Many of the smaller pegmatites (one to six feet in thickness) are poorly zoned or completely undifferentiated (Fig. 9b). Some consist of a fine-

FIG. 11. Banded, fine-grained pegmatite, Suzana No. 5 pegmatite.

to medium-grained mixture of microcline, quartz, and muscovite. In the main tributary of Catlin Gulch there occurs a type which consists of a fine-grained matrix of quartz and microcline stippled by $\frac{1}{2}$-inch crystals of muscovite.

Near the contacts with injection gneiss the pegmatites contain increasingly important quantities of magnetite, which occurs as larger euhedral crystals scattered through a fine- to medium-grained aggregate of microcline and quartz.

Near the sedimentary hogbacks south of the Suzana No. 5 body are exposed a number of 1- to 2-foot pegmatites that consist chiefly of quartz and muscovite and minor microcline. The mica flakes are parallel with the contacts and with abundant elongated wisps of schist. These sills may have formed by the accretion of adjoining lit-par-lit injections through gradual replacement of the intervening metamorphic rock.

Some of the smaller of the zoned pegmatites contain only two units: a core of massive white quartz and an outer zone of abundant muscovite books normal to the walls.

(*To be concluded in the September-October issue*)

Photographed by George Karger
from the Harvard Collection

ADAMITE FROM THE OJUELA MINE, MAPIMI, MEXICO. (Two-fifths natural size.)