GEOLOGICAL SURVEY CIRCULAR 245

GEOLOGY AND PEGMATITES OF PART OF THE FOURMILE AREA CUSTER COUNTY SOUTH DAKOTA

By Andrew J. Lang, Jr. and Jack A. Redden

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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Washington, D. C., 1953

Free on application to the Geological Survey, Washington 25, D. C.

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ABSTRACT

The Fourmile area, Custer County, S. Dak., is underlain by pre-Cambrian metamorphic rocks that surround the granitic core of the Black Hills. The main structure in the area is the upright limb of an overturned anticline that plunges about 30° S. 10° E.

Three units of metamorphic rocks are described that have a total thickness of at least 7,700 feet. The oldest of these units, a quartz-mica schist, is more than 6,500 feet thick. The overlying unit, about 200 feet thick, is composed of thin beds of amphibolite and hornblende schist, lime-silicate rock, cordierite-biotite schist, microcline-biotite schist, and other types of rocks. The youngest unit, a quartz-mica-feldspar schist, is more than 1,000 feet thick. The presence of kyanite, staurolite, cordierite, and sillimanite in the rocks indicates that they have been subjected to high-grade metamorphism.

About 420 pegmatites were mapped in the quartz-mica-schist and the quartz-mica-feldspar schist. A few thin pegmatites in the third unit were not mapped. Most of these are concordant with the schistosity and relict (?) bedding of the enclosing metamorphic rocks. They are as much as 250 feet thick and range from 10 to 2,600 feet in length. Nine pegmatites are zoned and classified as heterogeneous. The remainder are homogeneous and are poorly zoned. The major constituents are plagioclase, quartz, perthite, and muscovite. The accessory minerals are tourmaline, apatite, garnet, and biotite. Beryl was observed in 15 pegmatites. The heterogeneous pegmatites contain commercial deposits of potash feldspar, mica (sheet and scrap), and beryl.

INTRODUCTION

A part of the Fourmile area, about 2 miles southwest of Custer, S. Dak. (fig. 1), was mapped in the summers of 1948-49 as part of the beryllium program of the Geological Survey, carried out on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. About 7.8 square miles were mapped in secs. 19, 20, 27, 28, 29, 30, 32, 33, T. 3 S., R. 4 E., and sec. 24, T. 3 S., R. 3 E. A. J. Lang, Jr., mapped the eastern 6.2 square miles and J. A. Redden mapped the remaining area to the west. Mapping was done on aerial photographs enlarged to a scale, 1:12,000.

Although additional mapping was done to the west and south by the Geological Survey during the summers of 1950-51, only the work on the area mapped under the auspices of the Atomic Energy Commission is reported here. Therefore certain conclusions in this report should not be considered final and may be revised upon completion of the field work.

The general geology of the Black Hills has been described by Newton and Jenny (1880)[1], Van Hise (1890), Darton and Paige (1925), and Connolly and O'Harra (1929).

The Fourmile area is about 6 miles southwest of the center of the main mass of granite and pegmatite that surrounds Harney Peak in the southern Black Hills uplift (fig. 2). Many pegmatites and quartz veins intrude the folded pre-Cambrian metamorphic rocks that make up most of the bedrock. Paleozoic formations crop out as cuestas about 3 miles to the west.

The area has a mature topography with a maximum relief of 700 feet. It is drained by French Creek and its intermittent tributaries, Ruby Creek and Crow Creek. A thin mantle of alluvium covers the creek valleys.

The bedrock is well exposed in the western part but not in the eastern part of the area. Pegmatites and quartz veins are very resistant to weathering and generally project above the weathered country rock.

DESCRIPTIVE GEOLOGY

Metamorphic rocks

The metamorphic rocks are divided into three major units: a quartz-mica schist, a unit predominantly amphibolite, and a quartz-mica-feldspar schist. The exposed thickness of these three units is at least 7,700 feet.

Graded bedding in arkose layers within the quartz-mica-feldspar schist, and the relative position of schistosity and bedding indicate that the beds are vertical. The oldest unit is the thick quartz-mica schist; the youngest is the quartz-mica-feldspar schist. The thin amphibolite unit is intermediate in age and contains many different rock types.

Quartz-mica schist unit

About three fourths of the area—all except a northwest-southeast trending belt along the southern limits of the region mapped—is underlain by the quartz-mica schist. The bottom of the unit is not exposed in the mapped area. The known exposures indicate that the unit is at least 6,500 feet thick.

Most of the unit consists of light- to dark-gray, fine-grained quartz-mica schist containing about 70 percent quartz and 25 percent mica. Muscovite

[1] See Literature cited.

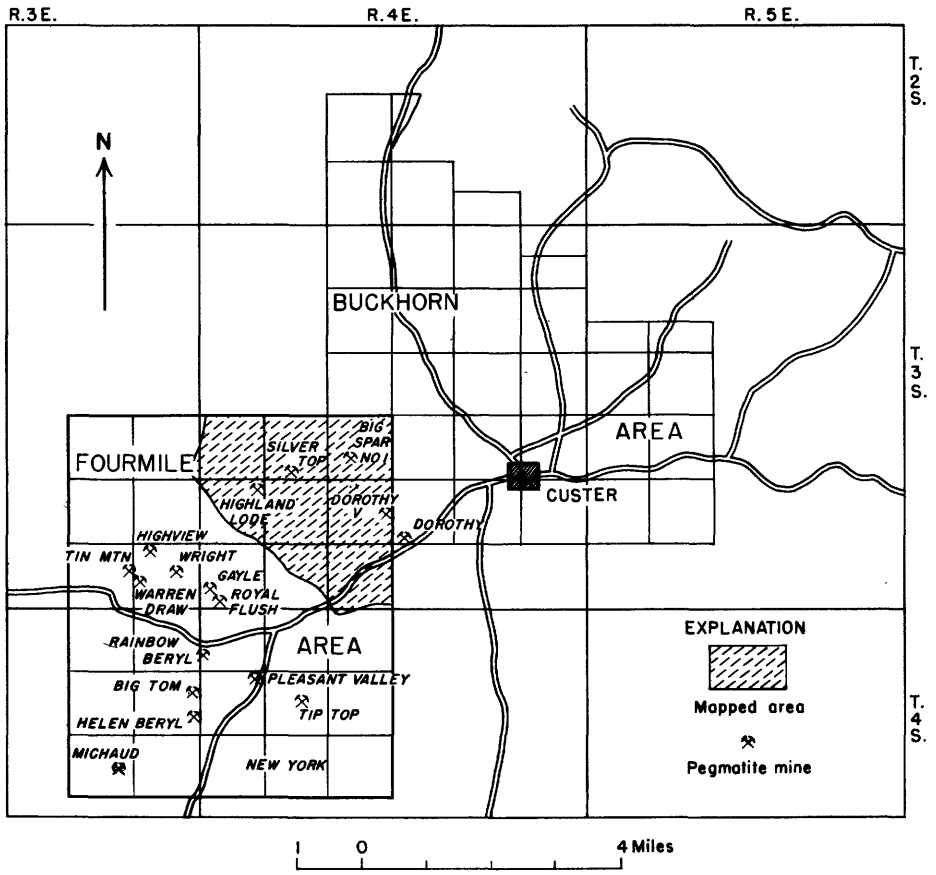

Figure 1.--Fourmile area, Custer County, S. Dak.

generally exceeds biotite in abundance. The accessory minerals include plagioclase, tourmaline, graphite, sphene, apatite, zircon, rutile, and magnetite.

Thin beds of mica-rich schist containing 50 to 95 percent mica occur within the more massive quartz-mica schist. In these beds biotite generally exceeds muscovite in abundance. The biotite-rich beds commonly contain small garnet crystals.

Many ellipsoidal structures of lime-silicate rock occur within the quartz-mica schist. The ellipsoids have a short axis ranging from 1 to 6 inches, an intermediate axis ranging from 4 to 12 inches, and a long axis ranging from 12 to 60 inches. They contain quartz, garnet, diopside, calcite, epidote, plagioclase, hornblende, biotite, and sphene. Biotite and hornblende tend to concentrate in the outer part of the ellipsoids. The plagioclase composition ranges from An_{60} to An_{80}. Runner and Hamilton (1934) have described these structures as metamorphosed calcareous concretions. Although the ellipsoids have been found throughout the unit, they have a tendency to concentrate in certain zones.

Amphibolite unit

A unit of interbedded rocks of various types, called the amphibolite unit, overlies the quartz-mica schist. The width of the outcrop ranges from 150 to 1,500 feet, depending on the degree of folding and topography. The true thickness is probably not less than 100 feet and not more than 200 feet. The unit contains amphibolite, lime-silicate rock, cordierite-biotite schist, microcline-biotite schist, quartz-mica schist, and quartzite. Many intermediate rock types represent gradations between the amphibolite, lime-silicate rock, cordierite-biotite schist, and microcline-biotite schist.

Amphibolite.--Amphibolite occurs predominantly in the lower portion of the unit, but is also associated with lime-silicate rocks near the middle.

Locally, the amphibolite in the lower portion of the unit is in excess of 50 feet thick, but this probably represents an exaggerated thickness due to folding or flowage. The amphibolite associated with the lime-silicate rocks is generally less than 30 feet thick, and in some places is missing entirely.

The lower amphibolite is schistose and rather fine-grained. It is dark green and is commonly stained with iron. The dominant mineral is hornblende, although considerable plagioclase and quartz are also present. The plagioclase forms from 5 to 30 percent of the rock, and its composition ranges from An_{22} to An_{50}. Sphene, apatite, graphite, magnetite, and tourmaline are the most common accessory minerals: zoisite, garnet, chlorite, biotite, diopside, and calcite are present in a few specimens.

The upper amphibolite is more variable in composition and appearance than the lower amphibolite. It contains zones rich, respectively, in biotite; biotite and plagioclase; calcite; calcite and

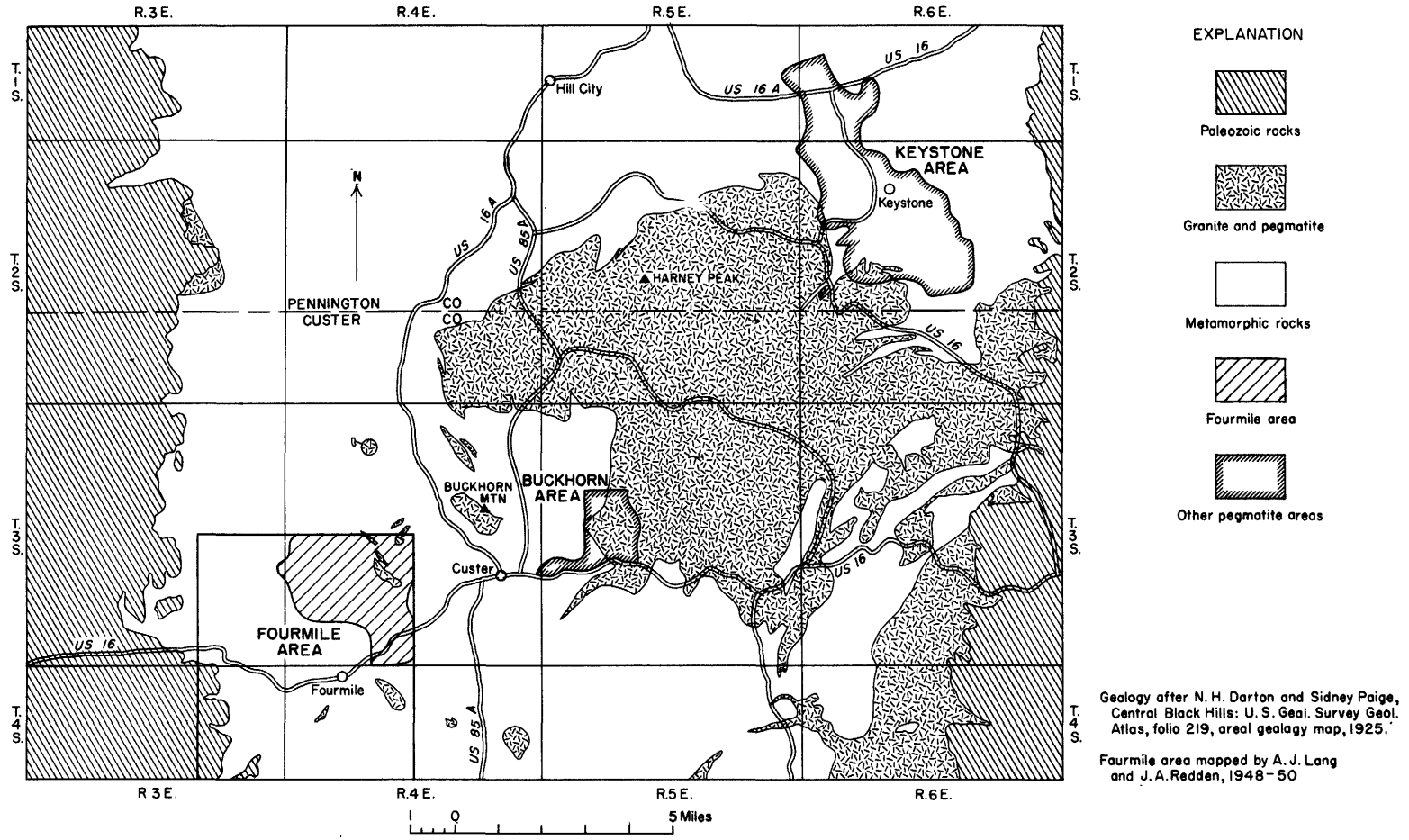

Figure 2. --Map of the southern Black Hills, South Dakota.

plagioclase; and cummingtonite and tourmaline. All these types of amphibolite have poorly developed schistosities.

The biotite- and biotite-plagioclase-rich amphibolites contain stubby green hornblende crystals more than 0.2 inch in diameter. These crystals are relatively unoriented and appear to "knit" the biotite-rich matrix together.

The calcite in the calcareous amphibolite is disseminated throughout the rock in variable amounts up to 50 percent, and also occurs in veinlets and thin layers that apparently are beds. Thin lenses of quartzite are associated with the layers of calcite. Hornblende generally occurs as thin needles having a well-developed lineation—a sharp contrast to the hornblende in the biotite-bearing amphibolites.

Schistose cummingtonite-tourmaline amphibolite occurs only at the Newark gold mine near quartz veins in biotite-bearing amphibolite and may represent an alteration of the original rock. The presence of graphite in this rock is also indicative of a secondary origin associated with the quartz veins.

Plagioclase from the upper amphibolite unit ranges in composition from An_{60} to An_{80}. The most calcic plagioclase is concentrated in the calcite-bearing amphibolites that also contain accessory diopside.

Lime-silicate rock.—Lime-silicate rock, containing alternating light and dark layers ranging from 0.2 inch to 12 inches in thickness, forms a unit of variable thickness near the middle of the amphibolite unit. The dark-colored layers are composed chiefly of fine-grained biotite and a small amount of hornblende and quartz. A few dark layers contain cordierite. The light-colored layers are coarser grained and have a distinct greenish color. They consist of diopside, calcite, microcline, plagioclase, scapolite, sphene, and hornblende. The diopside, microcline, and scapolite form grains as much as 1 centimeter in diameter, but the other minerals are fine-grained. The plagioclase (An_{70-90}) tends to concentrate along contacts with the dark layers.

Cordierite-biotite schist.—A layer of cordierite-biotite schist less than 40 feet thick, occurs near the top of the unit. The schist has a dark gray-brown groundmass that encloses light-colored equidimensional grains of cordierite that have an average diameter of 1 millimeter. The grains of cordierite are surrounded by a network of biotite flakes and fine-grained microcline, that cause the schistosity to be obscure except in those specimens that contain abundant oriented mica. The schist contains about 40 percent cordierite, 35 percent biotite, 10 percent microcline, and 10 percent plagioclase. In some places the schist contains as much as 10 percent graphite.

Microcline-biotite schist.—Microcline-biotite schist in a layer less than 40 feet thick, is associated with cordierite-bearing schist, and locally grades vertically and laterally into the cordierite-rich rock. This schist is dark grayish-black and is very fine grained, averaging 0.02 millimeter in grain size. The average composition is about 60 percent microcline, 25 percent biotite, 10 percent muscovite, and less than 5 percent plagioclase. Much of the schist contains graphite that makes up as much as 10 percent of the rock.

Quartz-mica schist.—A few thin layers of quartz-mica schist with variable amounts of accessory minerals occur within the amphibolite unit. At a few outcrops, the schist contains fuchsite and cordierite. In other small outcrops, kyanite and sillimanite occur in quartz-biotite-feldspar schist.

Quartzite.—Quartzite beds near the upper and lower contacts of the amphibolite unit range in thickness from 5 to 30 feet. Most of the quartzite is light gray to flesh colored. Quartz grains, ranging from 0.02 to 0.5 millimeter in diameter, make up about 90 percent of the rock. Much of the quartzite contains bluish-gray bands rich in graphite. The other accessory minerals are mica, tourmaline, zircon, and rutile. Locally, the quartzite is granulated and has a sugary texture.

Quartz-mica-feldspar schist unit

The uppermost unit is a quartz-mica-feldspar schist. Locally it contains small quantities of quartz-mica schist, garnet-staurolite schist, and lime-silicate ellipsoids. The total thickness is unknown, but it probably exceeds 1,000 feet.

The quartz-mica-feldspar schist is fine-grained and generally light to dark gray. It contains about 65 percent quartz, 20 percent mica, and 15 percent feldspar. Biotite and muscovite are equal in abundance. The feldspar consists predominantly of plagioclase (about An_{30}) with minor amounts of microcline. Near the contact with the underlying amphibolite unit the schist contains as much as 30 percent feldspar. Recrystallized quartz and feldspar grains as much as 4 millimeters in diameter are visible in metamorphosed coarse-grained arkosic beds near this contact. Part of the schist contains small, slightly flattened pebbles, a quarter of an inch thick and three-quarters of an inch long, consisting of quartz and feldspar. Biotite lenticles, 1 millimeter thick, occur in the more feldspar-rich schist.

The feldspar content decreases upward away from the contact with the amphibolite unit. Beds of quartz-mica schist are interbedded with the quartz-mica-feldspar schist farther from the contact. As the feldspar content decreases, the mica content increases and the grain size becomes smaller.

A bed of schist, less than 40 feet thick, that is rich in biotite, staurolite, and garnet, occurs about 300 feet stratigraphically above the lower contact of the unit. Dark layers within the bed have as much as 60 percent of biotite. Euhedral crystals of staurolite, as much as 1 inch long, locally constitute 30 percent of the rock. The garnet crystals average 1 millimeter in diameter. A small quantity of kyanite was found in one outcrop. The remainder of the rock is chiefly quartz and feldspar.

Amphibolite dikes

Two small bodies of massive amphibolite that apparently cut across the schistosity of the Ruby Creek schist are interpreted as being metamorphosed mafic dikes. The dikes have an average thickness of 20 feet and a length of about 100 feet. They are composed

mainly of hornblende and plagioclase (An_{30}) grains, averaging about 1 millimeter in diameter, that are intergrown, giving the rock a speckled appearance that differs from the amphibolite of the amphibolite unit. The plagioclase characteristically shows reverse zoning. An indistinct foliation is visible near the outer edges of the dikes.

Pegmatites

About 420 pegmatites were mapped in the area: the only unmapped ones were those less than 1 foot thick. The length of a single pegmatite is as much as 2,600 feet and the thickness as much as 250 feet. Of the mapped pegmatites 411 are concordant sill-like bodies and of these 394 are less than 20 feet thick. All are in the quartz-mica schist and the quartz-mica-feldspar schist.

Following the terminology of Johnston (1945), the pegmatites of the Fourmile area are divided into the following groups: (1) homogeneous pegmatites or those that are essentially uniform in texture and mineralogy from wall to wall, and (2) heterogeneous pegmatites or those that contain distinct textural and mineralogic units. It is probable that all gradations exist between homogeneous and heterogeneous pegmatites.

Homogeneous pegmatites

Except for nine, the mapped pegmatites were considered homogeneous pegmatites. These are similar in their mineralogy and texture to the pegmatitic phases of the granitic rock near Harney Peak, northeast of Custer. Distinct textural and mineralogic units in these pegmatites are confined to a fine-grained selvage at the contact, that has a thickness commonly less than 3 inches and a grain size less than one-eighth inch. A gradual increase in grain size toward the center is noticeable in many of the homogeneous pegmatites; others have no noticeable textural changes.

Most of the homogeneous pegmatites contain plagioclase, quartz, perthite, and muscovite in decreasing order of abundance. All homogeneous pegmatites more than 20 feet in thickness are composed of plagioclase, quartz, and perthite. The variability in the proportions of these minerals in the smaller pegmatites is shown in table 1. Many neighboring pegmatites have similar compositions, textures, and shapes, and are designated as pegmatite groups (pl. 1, table 1). Plagioclase (An_4 to An_{15}) ranges from 15 to 50 percent; quartz, 15 to 45 percent; perthite, 0 to 40 percent; muscovite, 1 to 15 percent; and tourmaline, 1 to 5 percent. In most homogeneous pegmatites the plagioclase content tends to decrease and the perthite content to increase toward the center.

In some pegmatites, as nos. 23, 49, and 50 (table 1), more than half of the perthite is in graphic granite. Most of the perthite and graphic granite is coarser grained than the other minerals. The largest crystals, as much as 5 feet in diameter, are graphic granite. Finer grained quartz and plagioclase have an average grain size of about half an inch. Plagioclase-rich pegmatites, such as nos. 19, 41, and 72 (table 1), have an average grain size that is considerably smaller than the perthite-rich pegmatites. The perthite and graphic granite content varies considerably in different parts of a single homogeneous pegmatite.

These pegmatites have a wide range in size and shape. Most are thin, sill-like bodies. The largest, no. 20 (pl. 1), has a length of 2,350 feet and a thickness of 100 feet. One pegmatite in group 4 (pl. 1) is 2,600 feet long, but is less than 15 feet thick.

Heterogeneous pegmatites

Heterogeneous pegmatites in the Fourmile area contain as many as 4 distinguishable zones using the terminology of Cameron, and others (1949), may be called border, wall, intermediate, and core zones. Zones are defined as successive shells, complete or incomplete, that reflect to varying degrees the shape and structure of the pegmatite body. Where ideally developed they are concentric about an innermost zone or core. Border zones commonly have the same general composition as the wall zone. The zones in pegmatites of the Fourmile area contain plagioclase, quartz, and muscovite; quartz, perthite, and plagioclase; and perthite and quartz (table 2). The relative order of abundance of these minerals varies, but the assemblages correspond to the generalized assemblages (1), (3), and (4) of Cameron, and others (1949).

The border zone occurs at the contact of the pegmatite and the country rock. It is fine-grained, averaging slightly less than a quarter of an inch in grain size. Quartz and plagioclase are the most abundant minerals and muscovite is usually the third most abundant. Pegmatite 24, however, contains a border zone of plagioclase, quartz, and perthite. Pegmatite 12-B is a pod within a homogeneous pegmatite and does not possess a border zone. Tourmaline, apatite, and garnet are the accessory minerals in the border zones.

Wall zones occur inside of the border zone and are thicker, ranging from half a foot in no. 65 to 5 feet in no. 14. As in the border zone, the two most abundant minerals are plagioclase and quartz. The third most abundant mineral is commonly perthite, but may be tourmaline (no. 12-B) or muscovite (no. 67). Wall zones average about half an inch in grain size. They contain the same accessory minerals as the border zone, and in addition may contain beryl.

Intermediate zones are any zones between the wall zone and core. They range in thicknesses from a few feet to as much as 20 feet. They contain perthite, plagioclase, and quartz in varying proportions. Tourmaline, garnet, muscovite, and beryl may occur as accessory minerals. Quartz and plagioclase are fine-grained, averaging about 1 inch in diameter, and perthite is coarse-grained, averaging 1 foot or more.

The cores of the heterogeneous pegmatites have a variable thickness and may be a series of small disconnected pods. The two most abundant minerals of the cores are quartz and perthite. Plagioclase or muscovite may be the third most abundant. Tourmaline, apatite, and beryl commonly occur as accessory minerals. Perthite is coarse-grained as in the intermediate zones. Quartz is either massive, or in fine-grained aggregates with plagioclase and muscovite.

Heterogeneous pegmatites also contain fracture-filling units that were defined by Cameron, and others (1949) as "units, generally tabular, that fill fractures in previously consolidated pegmatite." Pegmatite 12A (pl. 1) could be classified as heterogeneous because it contains a large fracture filling (?). This

Table 1.--Mineralogy of homogeneous pegmatites

No. and name of pegmatite (pl. 1)[1]	Wall rock		Pegmatite																									
							Mineralogy																					
							Plagioclase		Perthite		Graphic granite		Quartz		Muscovite		Garnet		Tourmaline		Lithium minerals			Other minerals		
	Type and formation	Alteration	Relation to wall rock	Shape	Internal structure	Average grain size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Per-cent	Size (inches)	Mineral	Per-cent	Size (inches)	Mineral	Per-cent	Size (inches)
1	Quartz-mica schist.	----	Conformable--	Tabular---	Unzoned---	1 to 4	45	< 1	15	4 to 12	5	4 to 12	30	< 1	3	1/2	< 1	1/16	1	1	----	----	----	Apatite----	< 1	< 1/16
2 (11)	---do---	----	---do---	---do---	--do---	1 to 4	50	1/2	15	6	5	6	25	1/2	3	1/2	< 1	1/16	2	1	----	----	----	---do--- Biotite----	< 1 < 1	< 1/16 1/4
3 (21)	---do---	----	---do---	---do---	--do---	1 to 4	40	1/2	20	5	5	5	30	1/2	3	1/2	< 1	1/16	2	1	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 < 1/16
4 (12)	---do---	----	---do---	---do---	--do---	1 to 4	40	1/2	15	5	5	5	35	1/2	3	1/2	< 1	1/16	2	1	----	----	----	Apatite---- Biotite----	< 1 < 1	1/16 1/8
5 (12)	---do---	----	---do---	---do---	--do---	1 to 4	40	1/2	20	5	5	5	30	1/2	3	1/2	< 1	1/16	2	1	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
6 (24)	---do---	----	---do---	---do---	--do---	1 to 4	30	< 1	15	4	5	4	40	< 1	5	3/4	< 1	1/16	3	1	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
7	---do---	----	---do---	---do---	--do---	1 to 4	35	< 1	20	4 to 12	5	4 to 12	30	< 1	5	1/2	< 1	1/16	3	3/4	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/4
8 (5)	---do---	----	---do---	---do---	--do---	1 to 4	40	< 1	15	4 to 12	5	4 to 12	35	< 1	3	1/2	< 1	1/16	2	1/2	----	----	----	Apatite----	< 1	< 1/16
9	---do---	----	---do---	---do---	--do---	1 to 4	30	3/4	20	12	20	12	25	3/4	3	3/4	< 1	1/16	2	1	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
10	---do---	----	---do---	---do---	--do---	1 to 4	50	1/2	5	4 to 12	5	4 to 12	30	1/2	3	1/4	1	1/16	2	1/4	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
11 (2)	---do---	----	Cross-cutting.	---do---	--do---	1 to 4	35	1/2	20	4 to 12	10	4 to 12	25	1/2	5	3/4	< 1	1/16	2	1/2	----	----	----	Apatite----	< 1	< 1/16
12a(2)	---do---	----	Conformable--	---do---	--do---	1 to 4	45	1	20	12	10	12	15	1	5	3/4	2	1/8	3	1	----	----	----	Apatite----	< 1	< 1/16
13 (2)	---do---	----	---do---	---do---	--do---	1 to 4	40	3/4	20	12	10	12	25	3/4	1	1/2			2	3/4	----	----	----	Beryl---- Apatite----	0.3 < 1	---- < 1/16
15	---do---	----	---do---	---do---	--do---	1 to 4	30	3/4	25	12	10	12	25	3/4	3	3/4	< 1	1/8	3	1	----	----	----	Beryl---- Lollingite Biotite----	0.1 < 1 < 1	---- 1/4 < 1/16
16 (s)	---do---	----	---do---	---do---	--do---	1 to 4	35	< 1	20	4 to 12	10	4 to 12	30	< 1	2	1/2			2	3/4	----	----	----	Apatite----	< 1	< 1/16
17	---do---	----	---do---	---do---	--do---	1 to 4	40	3/4	15	6	5	6	35	3/4	3	1/2	< 1	1/16	2	1/2	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
18	---do---	----	---do---	---do---	--do---	1 to 4	40	< 1	20	4 to 12	10	4 to 12	25	< 1	3	1/2	< 1	1/16	2	1	----	----	----	Apatite---- Biotite----	< 1 < 1	< 1/16 1/8
19	---do---	----	---do---	---do---	--do---	1 to 4	45	< 1	15	4 to 12	5	4 to 12	30	< 1	2	1/2			3	1/2	----	----	----	Apatite----	< 1	< 1/16
20	---do---	----	---do---	---do---	--do---	1 to 4	35	3/4	10	6	20	12	25	3/4	5	1/2	< 1	1/16	3	1/2	----	----	----	---do--- Biotite----	< 1 < 1	< 1/16 1/8
21 (3)	---do---	----	---do---	---do---	--do---	1 to 4	35	3/4	10	4	20	12	25	3/4	5	1/2	< 1	1/16	3	1/2	----	----	----	Apatite----	< 1	1/8

22 (8)	---do---	----	---do---	---do---	---do---	1 to 4	35	< 1	20	4 to 12	10	4 to 12	30	< 1	2	< 1			2	< 1	----	----	----	Apatite----	< 1	1/8
																								Biotite----	< 1	1/8
23	---do---	----	---do---	---do---	---do---	1 to 4	35	1	10	8	15	12	30	3/4	5	1/2	1	1/8	2	1	----	----	----	Apatite----	< 1	< 1/16
25 (20)	---do---	Microcline porphyro-blasts.	---do---	---do---	---do---	1 to 4	45	3/4	5	5	15	8	30	3/4	3	1/2	< 1	1/16	2	1/2	----	----	----	---do---	< 1	< 1/16
																								Biotite----	< 1	< 1/16
26 (8)	---do---	---do---	---do---	---do---	---do---	1 to 4	30	3/4	10	4 to 12	20	4 to 12	30	3/4	5	1/2			3	1/2	----	----	----	Beryl----	Trace---	1/2
27 (5)	---do---	----	---do---	---do---	---do---	1 to 4	45	2	10	4 to 12	5	4 to 12	25	1/2	10	3/4			2	1	----	----	----	Apatite----	< 1	< 1/16
28 (4)	---do---	----	---do---	---do---	---do---	1 to 4	35	3/4	10	6	10	10	30	1/2	10	3/4	< 1	1/16	3	3/4	----	----	----	---do---	< 1	< 1/16
29 (8)	---do---	----	---do---	---do---	---do---	1 to 4	35	1	10	12	5	12	35	1/2	10	3/4			4	1	----	----	----	---do---	< 1	< 1/16
30 (2)	---do---	Microcline porphyro-blasts.	---do---	---do---	---do---	1 to 4	30	1	10	4	30	5	25	3/4	5	1/2	< 1	1/8	3	1	----	----	----	---do---	< 1	< 1/16
31 (14)	---do---	----	---do---	---do---	---do---	1 to 4	30	1/2	30	6	5	4	25	1/2	5	1/2	< 1	1/16	2	1/2	----	----	----	---do---	< 1	< 1/16
																								Biotite----	< 1	1/8
32 (25)	---do---	Microcline porphyro-blasts.	---do---	---do---	---do---	1 to 4	30	1	25	5	5	1 to 4	30	1/2	5	1/2	< 1	1/16	2	1/2	----	----	----	Apatite----	< 1	< 1/16
																								Biotite----	< 1	< 1/16
33 (30)	---do---	---do---	---do---	---do---	---do---	1 to 4	20	3/4	20	4	25	6	25	1/2	5	3/4	< 1	1/8	2	1/2	Yellow mica.	----	< 1	Apatite----	< 1	< 1/16
34 (7)	---do---	---do---	Cross-cutting.	---do---	---do---	< 1	35	1/4	10	1 to 4	20	1 to 4	25	1/4	5	1/8	< 1	1/16	2	1/4	---do---	----	< 1	---do---	< 1	< 1/16
35 (2)	---do---	---do---	Conformable	---do---	---do---	1 to 4	35	1/2	5	4	10	6	35	1/2	10	1	< 1	1/8	3	1	----	---	----	----		
36 (31)	---do---	---do---	---do---	---do---	---do---	1 to 4	25	1/2	10	4	20	6	35	1/2	5	1			3	1	Yellow mica.	----	< 1	----		
37 (18)	---do---	----	---do---	---do---	---do---	1 to 4	25	3/4	15	6	15	6	35	1/2	5	3/4			3	3/4						
38 (27)	---do---	Microcline porphyro-blasts.	---do---	---do---	---do---	1 to 4	35	1/2	20	4 to 12	10	4 to 12	25	1/2	< 1		1/16		2	1/2	----	----	----	Apatite----	< 1	< 1/16
39	---do---	----	---do---	---do---	---do---	1 to 4	25	1/2	20	8	10	12	35	1/2	5	1/2			3	1/2	----	----	----	---do---	< 1	< 1/16
40 (2)	---do---	Tourmalin-ization.	---do---	---do---	---do---	1 to 4	35	1/2	10	12	25	12	20	1/2	5	1/2			4	1/2	----	----	----	---do---	< 1	< 1/16
41	---do---	----	---do---	---do---	---do---	1 to 4	45	3/4	5	1 to 4	15	1 to 4	20	1/2	10	1/2			2	1/2	----	----	----	---do---	< 1	< 1/16
42 (13)	Quartz-mica--feldspar schist.	----	---do---	---do---	---do---	1 to 4	30	1/4	20	2	5	4	40	1/4	5	1/2	< 1	1/16	3	1/2	----	----	----	---do---	< 1	< 1/16
43 (3)	---do---	----	---do---	---do---	---do---	1 to 4	30	1/2	25	6			35	1/2	10	1/2			< 2	1/2	----	---	----	---do---	< 1	< 1/16

Table 1.--Mineralogy of homogeneous pegmatites--Continued

No. and name of pegmatite (pl. 1)[1]	Wall rock		Pegmatite																								
							Mineralogy																				
							Plagioclase		Perthite		Graphic granite		Quartz		Muscovite		Garnet		Tourmaline		Lithium minerals			Other minerals		
	Type and formation	Alteration	Relation to wall rock	Shape	Internal structure	Average grain size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Mineral	Percent	Size (inches)	Mineral	Percent	Size (inches)
44	Quartz-mica-feldspar schist.	----	Conformable	Tabular	Unzoned	1 to 4	25	1/2	30	1 to 4	20	1 to 4	15	1/2	5	1/2			5	1/2						
45	---do---	----	---do---	---do---	---do---	1 to 4	35	< 1	30	1 to 4	10	1 to 4	20	< 1	3	1/2			2	1/4						
46 (5)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	20	8	5	8	30	1/2	5	1/2	< 1	1/16	3	1/4	Yellow mica.	----	< 1	Apatite----	< 1	< 1/16
47 (3)	Quartz-mica schist.	----	---do---	---do---	---do---	1 to 4	40	1/4	15	12	5	12	30	1/4	5	1/4			3	1/4	----	----	----	----		
48 (2)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	10	10	10	10	30	1/2	10	1/4	< 1	1/16	2	1/4	----	----	----	Apatite----	< 1	< 1/16
49 (4)	---do---	----	---do---	---do---	---do---	1 to 4	30	1/2	10	10	20	14	25	1/2	10	1/4			2	1/4	----	----	----	---do---	< 1	< 1/16
50	---do---	----	---do---	---do---	---do---	1 to 4	35	< 1	10	6	20	10	25	< 1	5	1/4	< 1	1/16	2	1/4	----	----	----	---do---	< 1	< 1/16
51 (2)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	10	8	20	12	25	1/2	5	1/4	< 1	1/16	2	1/4	----	----	----	---do---	< 1	< 1/16
52 (2)	---do---	----	---do---	---do---	---do---	1 to 4	25	3/4	5	10	25	14	35	1/2	5	1/2	< 1	1/16	3	1/4	----	----	----	---do---	< 1	< 1/16
55 (9)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	5	8	20	12	30	1/2	5	1/2			2	1/4	----	----	----	---do---	< 1	< 1/16
56	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	5	8	20	14	30	1/2	5	1/2	< 1	1/16	2	1/4	----	----	----	---do---	< 1	< 1/16
58 (5)	---do---	----	---do---	---do---	---do---	< 1	30	1/4	5	8	15	12	40	1/4	5	1/8			2	1/4	----	----	----	---do---	< 1	< 1/16
59 (2)	---do---	----	---do---	---do---	---do---	1 to 4	25	3/4	5	4	25	6	30	3/4	10	1			2	1/2	----	----	----	---do---	< 1	< 1/16
60	---do---	----	---do---	---do---	---do---	< 1	30	1/4	20	1 to 4	5	4 to 12	35	1/4	5	1/4			3	1/4	----	----	----	---do---	< 1	< 1/16
61 (3)	---do---	----	---do---	---do---	---do---	1 to 4	20	1/2	15	4 to 12	25	4 to 12	30	1/2	5	1/2			3	1/2	----	----	----	---do---	< 1	< 1/16
62 (2)	---do---	----	---do---	---do---	---do---	1 to 4	35	< 1	15	4 to 12			40	< 1	5	< 1			2	< 1	----	----	----	---do---	< 1	< 1/16
63 (2)	---do---	----	---do---	---do---	---do---	1 to 4	30	< 1	15	4 to 12	5	4 to 12	40	< 1	5	1/4			2	< 1	----	----	----	---do---	< 1	< 1/16
64	---do---	----	---do---	---do---	---do---	1 to 4	30	1/2	15	1 to 4			40	1/2	15	1/4			1	1/4	----	----	----	---do---	< 1	< 1/16
66	---do---	----	---do---	---do---	---do---	1 to 4	25	1/2	10	4	20	6	30	1/2	10	1/2	1	1/4	2	1/2	----	----	----	---do---	< 1	< 1/16
69 (3)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	15	5	20	8	20	1/2	4	3/4			4	1	----	----	----	---do---	< 1	< 1/16
70	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	10	4	20	10	27	1/2	4	1/2			3	3/4	----	----	----	---do---	< 1	< 1/16
71 (2)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	25	4	5	6	25	1/2	5	1/2			2	1/2	----	----	----	---do---	< 1	< 1/16
72	---do---	----	---do---	---do---	---do---	< 1	45	3/4					40	1	15	3/4			< 1	1/2	----	----	----	---do---	< 1	< 1/16
73	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	20	3	20	12	20	3/4	3	3/4			1	3/4	----	----	----	---do---	< 1	< 1/16
																								Beryl------	Trace---	< 3/4
74 (5)	---do---	----	---do---	---do---	---do---	1 to 4	35	1/2	20	4	5	8	30	1	4	1/2			3	1	----	----	----	Apatite----	< 1	< 1/16
75 (2)	---do---	----	---do---	---do---	---do---	1 to 4	40	1/2	15	6	15	12	24	1/2	3	1/2			4	1	----	----	----	---do---	< 1	< 1/16
76	---do---	----	---do---	---do---	---do---	1 to 4	50	1	5	4	10	8	30	1/2	3	1/2	1	1/2	2	1	----	----	----	---do---	< 1	< 1/16
																								Beryl------	< .01	< 1/2

77	----do----------	----	----do-------	---dc------	--do------	1 to 4	15	1/2	20	4	30	10	25	1	5	3/4	< 1	1/4	4	1	----	----	----	Anatite----	< 1	< 1/16
78 (9)	----do----------	----	----do-------	---do------	--do------	1 to 4	40	1/2	20	3	5	6	30	1/2	4	1/2	< 1	1/4	1	3/4	----	----	----	---do------	< 1	< 1/16
79 (6)	----do----------	----	----do-------	---do------	--do------	1 to 4	30	1/2	15	6	25	12	20	1/2	3	1/2	< 1	1/2	3	3/4	----	----	----	---do------	< 1	< 1/16
80 (3)	Quartz-mica-feldspar schist.	----	----do-------	---do------	--do------	1 to 4	25	1/2	15	18	30	20	20	3/4	4	3/4	5	3/4	4	1-1/2	----	----	----	---do------ Beryl------	Trace--- .02	< 1/16 3/4

[1] The number of individual pegmatites designated by one number on plate 1 is given in parentheses.

Table 2.--Mineralogy of heterogeneous pegmatites

No. and name of pegmatite (pl. 1)[1]	Wall rock		Pegmatite																								
							Mineralogy																				
							Plagioclase		Perthite		Graphic granite		Quartz		Muscovite		Garnet		Tourmaline		Lithium minerals			Other minerals		
	Type and formation	Alteration	Relation to wall rock	Shape	Internal structure	Average grain size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Percent	Size (inches)	Mineral	Percent	Size (inches)	Mineral	Percent	Size (inches)
12-B (Big Spar No. 1)	Quartz-mica schist.	----	Pod within granite pegmatite.	Pod------	Wall zone-	M	50	1/4					30	1/4	5	1/4	< 1	1/8	10	3	----	----	----	Apatite----	< 1	1/16
					Intermediate zone.		45	1	15	12	5	12	30	1	5	1			< 1	1/4	----	----	----	---do------	< 1	1/16
						VC	15	1																Beryl------	< 1	2
					Core------						40	24	40	2	5	1/4	< 1	1/8	< 1	1/4	----	----	----	Apatite----	< 1	1/16
14	----do----------	----	Conformable--	Tabular---	Wall zone-	M	60	1	5	1			30	1	3	1/4	< 1	1/8	2	1/4	----	----	----	Beryl------	< 1	3/4
																								Biotite----	< 1	1/8
					Core------	C	35	1	10	18	30	24	20	1	2	1/4	< 1	1/8	1	1/4	----	----	----	Arseno-pyrite.	< 1	1/4
																								Biotite----	< 1	1/8
24	----do----------	----	----do-------	---do-----	Wall zone-	M	50	1/2	10	3			30	1/2	6	3/4			2	1/2	----	----	----	Apatite----	< 1	1/16
					Core------	C	25	1	20	12	10	14	40	1	3	1/2	< 1	1/8	1	1/4	----	----	----	---do------	< 1	1/16
53	----do----------	----	----do-------	---do-----	Wall zone-	F	40	1/2	20	1			30	1/2	5	1/4	1	1/16	2	1/4	----	----	----	---do------	< 1	1/16
					Intermediate zone.	C	30	1	5	24	25	24	35	1	3	3/4	< 1	1/16	1	1/4	Yellow mica.	----	1/4	---do------	< 1	1/16
																								Beryl------	< 1	2
					Core------	C			40	18			60	12	2	1/4					----	----	----	---do------	< 1	1
																								Apatite----	< 1	1/16
					"Bull mica" unit.	"F	10	1/2					20	1/2	70	1					Yellow mica.	----	1/4	----		
54	----do----------	----	----do-------	---do-----	Wall zone-	F	40	1/2	15	2			35	1/2	7	3/4	< 1	1/8	3	1/2	----	----	----	Apatite----	< 1	1/16
					Core------	C	25	1	15	24	15	24	36	1	10	3/4	< 1	1/8	2	1	----	----	----	---do------	< 1	1/16
																								Beryl------	< 1	1
57 (Silver Top lode).	----do----------	----	----do-------	---do-----	Wall zone-	F	40	3/4	20	2			30	3/4	5	3/4	< 1	1/8	3	1/4	----	----	----	---do------	< 1	1
					Intermediate zone.	M	20	1	35	24	10	24	30	1	3	1/2	< 1	1/8	2	1/4	----	----	----	---do------	< 1	2
					Core------	C			30	24	10	24	55	12	5	1/2					----	----	----	----		
65	----do----------	----	----do-------	---do-----	Wall zone-	F	35	1/2	10	2			40	1/2	10	1/2			1	1/4	----	----	----	Beryl------	< 1	1/2
					Intermediate zone.	M	35	3/4	20	12			40	3/4	5	3/4			< 1	1/4	----	----	----	Apatite----	< 1	1/16
					Core------	C			40	12			50	12	10	1					----	----	----	----		
67 (Dorothy lode).	----do----------	----	----do-------	---do-----	Wall zone-	F	55	3/4					35	3/4	5	3/4			1	1/4	----	----	----	Apatite----	< 1	1/16
					Intermediate zone.	C	7	1	80	36			10	1	2	3/4			1	1/4	----	----	----	----		
					Core------	VC	15	3/4	40	36			40	12	5	1/2					----	----	----	Lithiophi-lite.	< 1	3
																								Apatite----	< 1	1/16
					"Bull mica" unit.	"F	15	1/2					25	1/2	60	3/4					----	----	----	----		
68 (Highland lode).	----do----------	----	Conformable and locally discon-formable.	---do-----	Wall zone-	M	50	1	< 5	24			40	2	3	2			3	3	----	----	----	Beryl------	0.2	3/4
					Upper----	C	< 5	1	75	36			15	6	1	1/2					----	----	----	----		
					Core------																					
					Lower----	C	15	1	25	36			55	8	1	4	< 1	1	1	5	----	----	----	Beryl------	.7 to 1.	8
																								Columbite--	< 1	1
																								Lithiophi-lite.	< 1	4

[1] Average grain size: F is < 1 inch; M is 1 to 4 inches; C is 4 to 12 inches; VC is > 12 inches.

fracture filling, however, is distinctly zoned and is described separately as no. 12-B. (See Mines and prospects.)

A few of the pegmatites listed as homogeneous in table 1 contain very small fracture-filling units. In all of these the fracture fillings are of such small size that the pegmatites were included with the homogeneous group.

Quartz veins

Quartz veins, ranging from a quarter of an inch to 6 feet in thickness, are found throughout the area. The largest vein is 300 feet long. The larger veins are generally concordant, but many of the smaller ones are discordant.

In addition to quartz, they contain small quantities of microcline, plagioclase, tourmaline, apatite, and mica. The thick veins contain only a small amount of these other minerals, but a few, less than a foot thick, contain as much as 20 percent feldspar.

A concentration of dark minerals occurs in the schist wall rock, immediately adjacent to the larger quartz veins in the quartz-mica schist unit and the quartz-mica-feldspar schist unit. This concentration of dark minerals forms an "envelope" around the vein, ranging from half an inch to 2 feet thick. Biotite, graphite, and tourmaline are the chief constituents, but small quantities of chlorite, quartz, apatite, and muscovite are also present. All these minerals are normal constituents of the schists, but biotite, graphite, and tourmaline are much more abundant than in most schists of this area.

Sedimentary rocks

Deadwood formation (?) Upper Cambrian

A small outcrop of quartzitic conglomerate in the NW¼SE¼ sec. 33, T. 3 S., R. 4 E. is probably part of the Deadwood formation. The reddish-brown iron-stained quartzite matrix contains well-sorted, coarse sand grains, averaging about half a millimeter in size. Well-rounded and undeformed pebbles average about three-eighths inch in diameter and have a maximum diameter of 1 inch. Nearly all the pebbles are quartzite. They are arranged in poorly defined beds approximately parallel to the present surface of the ground.

The positively identified Deadwood formation that is exposed about 5 miles to the west is very similar to rocks in this outcrop in sec. 33. Also, pegmatites in the vicinity of this probable Deadwood formation are beveled off at about the same elevation as the base of the outcrop. This concordance of pegmatite outcrops probably corresponds to the pre-Cambrian erosion surface, and this single outcrop probably is all that remains of the Deadwood formation in this area.

Alluvium

A thin cover of gravel is found in the valleys of Crow Creek, Ruby Creek, and French Creek. The thickest cover, probably less than 20 feet thick, is along French Creek. The gravels are composed chiefly of sand and pebbles, but some pegmatite boulders as much as 6 feet in diameter are included.

STRUCTURE

Folds and linear structures

The part of the Fourmile area that has been mapped lies on the southwestern limb of a southeast-plunging anticline. The axis of the anticline trends about N. 35° W., and on the basis of minor superimposed folds and linear structures, plunges about 30°S. 10° E.

The axis of the major anticline lies slightly northeast of the mapped area and can be located on aerial photographs of the region to the north and east. A syncline paralleling the anticline has its axis about 2 miles to the southwest of the mapped area. The two folds apparently have the same general plunge, as smaller folds and elongated lime-silicate ellipsoids at many localities throughout area have about the same average plunge, 30° S. 10° E. The attitude of the beds on the fold limbs is relatively constant, having strikes of N. 30° to 60° W. and dips of 25° to 60° SW. Bedding and schistosity are generally parallel, but locally diverge both in strike and dip. Locally the bedding may have a more westerly strike than the schistosity that commonly strikes about N. 40° W. In places the beds and schistosity have the same strike, but the schistosity has a steeper dip, indicating the relative movement of the beds on the limb of the anticline. Where the dip of schistosity and beds differ, there is commonly a poorer bedding-plane schistosity. Elongated biotite grains and small-scale crenulations along the planes of schistosity generally plunge in a direction 10° to 35° west of the plunge direction of the minor folds and have no obvious relation to the general structure of the area. A slight change of stress direction during a late stage in the folding or a much later deformation could produce the second lineation.

Faults and lineaments

No major faults have been recognized in the area. Minor steeply dipping faults with horizontal displacements of less than 30 feet and vertical displacements of less than 5 feet offset several pegmatites. These small faults generally are indicated only by displacement of the resistant pegmatite outcrop and cannot be traced in the metamorphic rocks. Most of the faults strike N. 40° E.

Two linear elements, probably surface expressions of shear zones, which are readily recognizable on aerial photographs, but not so readily recognizable in the field, have been called lineaments (pl. 1). The lineaments are approximately parallel and strike N. 35° E. The western lineament can be traced on aerial photographs for about 4 miles and the eastern lineament for 6 and possible 9 miles, where it apparently disappears under the Paleozoic rocks. They are clearly marked on aerial photographs by a shallow valley averaging about 200 feet wide. Only a small amount of horizontal and vertical movement is indicated by displacement of pegmatites and the contacts of the amphibolite unit. As the contacts of the amphibolite unit are located only approximately at the points

where the lineaments cross the formation, it is impossible to measure the total displacement accurately. It can be inferred, however, from the approximate location of the contacts, that the total horizontal displacement along each lineament is less than 100 feet. Vertical movement, as indicated from displacement of individual pegmatites, is very small, if not lacking entirely.

Structural relation between pegmatites and country rock

Except for seven pegmatites of group 33 and two of group 11 (pl. 1), all the mapped pegmatites are concordant with schistosity and bedding. The larger pegmatites may be locally discordant but in general outline are concordant. Where outcrops of country rock are few or lacking, the attitude of the pegmatites is the main clue to the underlying structure (group 4, pl. 1).

Small rolls in the contacts and the ends of pegmatites indicate three general directions of plunge. One set of plunge directions parallels that of the minor folds, about S. 10° E.; a second parallels the plunge of the biotite lineation, about S. 5° to 35° W.; and a third plunges S. 45° W. It appears that the pegmatites were generally intruded along structural features formed during the folding of the rocks.

METAMORPHISM

The metamorphic rocks of the Fourmile area, originally sandstones, shales, arkoses, conglomerates, and carbonate-rich sedimentary rocks, have been altered by dynamo-thermal metamorphism to schists and lime-silicate rocks containing mineral assemblages characteristic of high-grade metamorphism. In places within a few feet of the pegmatite contacts, minerals, such as tourmaline, have been formed by reactions between the wall rocks and the solutions escaping from the pegmatites.

The quartz-mica schist unit and the quartz-mica-feldspar schist unit, originally mainly aluminum-poor sediments, now consist predominantly of quartz, mica, and feldspar. Garnet occurs only in widely scattered thin biotite-rich beds, and staurolite, garnet, biotite, and minor kyanite in only one thin bed in the quartz-mica-feldspar schist. Lime-silicate ellipsoids, originally carbonate beds or concretions, are composed of diopside, garnet, and anorthite-rich plagioclase.

The amphibolite unit, originally consisting of predominantly carbonate-rich rocks of different compositions, consists of several rock types containing several mineral assemblages, some of which are indicative of high-grade metamorphism. These assemblages include hornblende-plagioclase-quartz; hornblende-plagioclase-calcite; hornblende-biotite-quartz; biotite-muscovite-quartz; microcline-biotite-muscovite-plagioclase; diopside-microcline-plagioclase-quartz-hornblende-calcite; cordierite-microcline-biotite-plagioclase; and kyanite-sillimanite-biotite-muscovite-plagioclase-quartz. The last three of the above assemblages are considered high-grade metamorphism by Harker (1939).

Probably the metamorphic grade of the entire area is on the border between high- and medium-grade metamorphism. Evidence for this is found in thin sections from the amphibolite unit that have sillimanite apparently replacing kyanite and muscovite. The absence of sillimanite throughout the area, except in the amphibolite unit, is mainly a result of the composition of the different rocks, however, its development may have been affected by the presence of abundant CO_2 in certain beds in the unit that may have permitted the attainment of equilibrium faster there than in the quartz-rich rocks.

The plagioclase composition in the metamorphic rocks ranges from An_{20} to An_{85} and is apparently the result of the original composition of the rocks. Plagioclase from a lime-silicate ellipsoid had a composition of about An_{85}, whereas plagioclase from quartz-mica-feldspar schist, 1 foot from the ellipsoid, contained An_{20}.

At the contacts of a few of the pegmatites, there is a small amount of contact metamorphism, but the wall rocks of others do not show any. The general lack of metamorphism, either in forming new minerals or in the coarsening of grain size of original minerals, is more striking than the actual contact metamorphism. When any contact effect of the pegmatites is evident, it usually is the development in the schist along the contact of coarser grained, excess tourmaline in zones a few inches thick, or at the most, a few feet thick. In addition, microcline, albite, and apatite apparently have been added to the schist; but, without chemical analyses, it is impossible to say whether this is true or whether smaller grains of these minerals may have merely recrystallized into coarse, clearly visible crystals. At a few contacts abundant tourmaline in the schist indicates the addition of boron, as the average schist contains only 1 percent or less of tourmaline. Probably a little potash, soda, and phosphorus migrated from the pegmatite into the wall rock to form the coarser grained microcline, albite, and apatite that occur on and near a few of the contacts.

ECONOMIC GEOLOGY

The mineral deposits of economic interest in the Fourmile area are small gold placers, gold-bearing quartz veins, and pegmatite deposits. Pegmatites in the Fourmile area have produced potash feldspar, sheet and scrap mica, columbite, and beryl. The value of the potash feldspar produced exceeds that of all other minerals.

Pegmatites

Nearly all the homogeneous pegmatites are noncommercial in relation to 1952 prices and mining practices. Many of these contain potash feldspar recoverable by hand cobbing, but the grade is too low for commercial production. Furthermore, in many of the homogeneous pegmatites the potash feldspar occurs in graphic granite and contains too much quartz to be commercially acceptable.

Small quantities of scrap mica, crude sheet mica, and beryl occur in many, but were not of economic grade at the 1952 market. Many of the larger homogeneous pegmatites have potential reserves and could be mined upon the development of a successful milling process to recover potash feldspar, mica, and beryl.

Heterogeneous pegmatites contain zones rich in industrial minerals and, therefore, are more likely to be mined. Recoverable quantities of potash feldspar occur in the intermediate zones and the core. Beryl and mica occur in quantities too small to be mined except as by-products of feldspar mining.

Beryl

Heterogeneous pegmatites 12-B, 14, 53, 54, 56, 65, 67, and 68 and homogeneous pegmatites 13-B, 15, 26, 73, 76, 79, and 80 contain beryl (tables 1 and 2). The beryl reserves of the heterogeneous pegmatites are estimated at about 310 tons. Of this total reserve 77 tons is considered recoverable by hand sorting.

Pegmatite 68 contains more recoverable beryl than any other heterogeneous pegmatites listed in table 2. Pegmatite 12-B has a large total beryl reserve, but only 20 percent of the beryl is considered recoverable by present mining methods.

Beryl may occur in the wall zone, intermediate zone, and core of the heterogeneous pegmatites. The average content of beryl in these zones is about 0.1 percent, although pegmatite 68 contains a beryl-bearing portion of the core with a grade of 0.8 percent. Pegmatite 14, however, contains a wall zone with a grade of only 0.01 percent.

A reliable estimate of the beryl in the homogeneous pegmatites is somewhat difficult to make. The beryl is limited to coarser grained pods or segregations. The beryl content of one of these "pods" is 0.3 percent, but the remainder of the pegmatite apparently is barren. The quantity of beryl observed in most of the homogeneous pegmatites in which beryl was found consisted of one or two crystals, commonly less than 1 inch in diameter. More than 12 small crystals of beryl, ranging from 0.15 to 1 inch in diameter were seen in pegmatite 80.

Although beryl was found in only seven of the homogeneous pegmatites, the authors believe that it occurs in most of them. The reasons for the failure to observe beryl in the others are probably that the beryl occurs in small-size crystals and in anhedral crystals that are easily mistaken for quartz and other minerals, and that beryl may occur in unexposed interiors of the pegmatites. The homogeneous pegmatites probably contain about 0.001 percent of BeO. This estimate is based on spectrographic analyses of samples collected by D. H. Kupfer (personal communication) from the granite in the Harney Peak area, which is considered the source rock. The estimate of 0.001 percent of BeO corresponds to approximately 0.01 percent of beryl. An estimate of 0.01 percent beryl may be too high, for it is not certain that all of the BeO is contained in the beryl lattice.

The development of a milling process whereby fine-grained beryl could be recovered with potash feldspar and scrap mica would make large homogeneous pegmatites, as nos. 15 and 80 (pl. 1) potential beryl producers. Any such milling process would also make it possible to recover the fine-grained beryl from the beryl-bearing heterogeneous pegmatites and from homogeneous pegmatites 13-B and 15. The potential beryl reserves of the mapped area would then be at least 350 tons.

Mica

All the heterogeneous and homogeneous pegmatites contain scrap mica. With the exception of nos. 14 and 67, (table 2) all heterogeneous pegmatites contain sheet and punch mica.

Sheet and punch mica occur in the wall zone of nos. 24, 54, 57, and 67, and in the intermediate zones of nos. 12-B and 53. The percent of sheet and punch in the crude sheet in these zones is low, and most of the mica reserves will remain unmined. In actual mining practice only the richer mica shoots are mined and the percent of sheet and punch mica in the mined rock is therefore considerably higher. Pegmatites 24 and 67 (Dorothy lode) are the richest mica-bearing pegmatites in the area.

The other heterogeneous pegmatites contain very small quantities of sheet and punch mica. Pegmatite 12-B (Big Spar No. 1), a feldspar mine, produced 150 pounds of sheet mica from 5,100 tons of pegmatite. Pegmatite 68 (Highland lode) produced about 32 pounds of sheet mica, 150 pounds of punch mica, and 343 tons of scrap mica from 1938 through 1944. With the possible exceptions of pegmatites 24 and 67, it is necessary to recover all mica as a by-product of feldspar mining.

The sheet and punch mica reserves of the mapped area (including pegmatite 68-Highland lode) are estimated at 31 tons. Pegmatites 24 and 67 contain nearly one-third the total sheet and punch mica. The heterogeneous pegmatites are estimated to contain about 2,700 tons of cobbable scrap mica. Homogeneous pegmatites contain only traces of sheet and punch mica. Flotation milling could recover very large quantities of scrap mica from the homogeneous pegmatites. Pegmatite 20 and nos. 10 and 8 (pl. 1) are estimated to contain over 200,000 tons of scrap mica.

Potash feldspar

Very large reserves of potash feldspar are present in the homogeneous and heterogeneous pegmatites of the Fourmile area. In most of these, however, the quantity of feldspar that could be recovered by present mining methods is too small to permit profitable mining. In addition, much of the feldspar (perthite) occurs in graphic granite and is used only in small quantities for glass feldspar.

Pegmatite 67 (table 2) contains the largest recoverable reserves of perthite of any of the heterogeneous pegmatites. The intermediate zone is 140 feet long and 8 feet thick and is composed of 80 percent perthite, 70 percent of which is cobbable. Pegmatites 65 and 67 (table 2) have smaller, but substantial reserves of perthite. Pegmatite 14 (table 2) has larger reserves of potash feldspar, but over 70 percent is in graphic granite.

Homogeneous pegmatites nos. 10, 18, and 20 (pl. 1) were estimated to contain over 1,500,000 tons of potash feldspar. Most of the feldspar is not cobbable, but the flotation process could recover the feldspar and scrap mica. In addition, these three pegmatites are located within a radius of a quarter of a mile. Most of the other homogeneous pegmatites are small and widely scattered and would be of little value for milling.

Gold

Placer deposits

Dredging has been in operation in the valley of French Creek through secs. 19, 20, 28, and 29, T. 3 S., R. 4 E. The dredging was restricted to a narrow belt less than 100 feet wide along the present channel of French Creek. Figures are not available on the amount of gold recovered.

Lode deposits

Many of the larger quartz veins in the area contain a small amount of gold and apparently are the source of the placer gold. Prospect pits and shafts are located on most of the larger veins, but it is probable that the gold content of the veins exposed in the prospect pits is too low to warrant further development. In 1938 Allsman (1940) sampled the Newark mine and obtained assays of $3.00 per ton for the quartz veins and $5.00 per ton for the schist immediately adjacent to the vein. Most of the prospect pits are on quartz veins along the amphibolite unit. Whether or not the gold content is greater in these quartz veins than in those in the quartz-mica schist unit and the quartz-mica-feldspar schist unit is not known.

MINES AND PROSPECTS

Pegmatite 12-B (Big Spar No. 1 mine)

Pegmatite 12-B (Big Spar No. 1 mine) is in the SW¼ sec. 21, T. 3 S., R. 4 E. (pl. 1). It is owned by the Consolidated Feldspar Co., of Trenton, N.J., which operated the mine for feldspar intermittently from 1943 to 1948. The mine workings consist of a single large open-cut, 85 feet long, 25 feet wide, and averaging 30 feet deep.

This pegmatite is described by J. W. Adams (1953?), who visited the property in June 1945. This report includes a brief description of the mine workings and the geology of the pegmatite.

Pegmatite 12-B is a well-zoned, lenticular fracture filling in the southwest part of pegmatite 12-C. Pegmatite 12-C is poorly zoned and is composed of 45 percent plagioclase, 30 percent quartz, 15 percent perthite, and 5 percent muscovite. It is at least 250 feet in length and as much as 60 feet in thickness. The general trend of pegmatite 12-C is N. 45° W., and the average dip is 45° SW. Pegmatite 12-B has an exposed length of 140 feet and a thickness of 50 feet. It strikes N. 35° W. and dips to the southwest. The apparent plunge is to the southwest.

Plagioclase-quartz-tourmaline pegmatite (wall zone)

The wall zone, averaging 1 foot in thickness, is composed of an estimated 50 percent plagioclase, 30 percent quartz, 10 percent tourmaline, 5 percent muscovite, and accessory apatite and garnet. Black tourmaline crystals as much as 12 inches in length and 4 inches in diameter locally may form as much as 80 percent of the rock.

Plagioclase-quartz-perthite pegmatite (intermediate zone)

The intermediate zone is 90 feet long and 15 feet thick. It is composed of an estimated 45 percent plagioclase, 30 percent quartz, 20 percent perthite, 5 percent muscovite, and accessory beryl, tourmaline, apatite, and garnet. Cream-colored perthite crystals average 3 feet in length. About 20 percent of the perthite is in graphic granite. Quartz and plagioclase are fine-grained, averaging about 1 inch in diameter. Light-greenish muscovite books average 1 inch in diameter. Beryl crystals, about 2 inches in length, occur in the outer part of the intermediate zone.

Quartz-perthite-plagioclase pegmatite (core)

The core of the pegmatite is 50 feet long and 20 feet thick. It is composed of an estimated 40 percent quartz, 40 percent graphic granite and perthite, 15 percent plagioclase, 5 percent muscovite, and accessory tourmaline, apatite, and garnet. The zone contains massive quartz and large cream-colored perthite crystals as much as 3 feet in length. The remaining quartz, plagioclase, and muscovite are fine-grained.

Economic minerals

Beryl occurs in the intermediate zone as light-green crystals. The maximum length was about 8 inches. An area of 160 square feet contained 0.1 percent beryl on the basis of a mineral measurement. About 2 tons of beryl was recovered during feldspar mining.

Most mica produced from the Big Spar No. 1 mine is scrap quality. About 150 pounds of sheet mica, of which 74 percent was no. 2 quality and 26 percent no. 2 inferior, was recovered during World War II. This sheet mica was mined from the intermediate zone.

The intermediate zone contains about 15 percent recoverable potash feldspar and most of the past production came from this zone. The potash feldspar in the core is in graphic granite and, therefore, is not acceptable for grinding at the present time.

Pegmatite 14

Pegmatite 14 is in the SW¼ sec. 21, T. 3 S., R. 4 E. (pl. 1). The mine workings include two open-cuts: a large cut 45 feet long, 10 feet wide, and 8 feet deep, and a smaller one 15 feet long, 6 feet wide, and 3 feet deep.

The pegmatite is a tabular body about 450 feet long and 30 feet thick. It is exposed as a dip slope that strikes N. 55° W. and dips 45° SW. The approximate plunge is 45° S. 40° W. The pegmatite is crudely zoned, containing a border zone of fine-grained quartz, plagioclase, and muscovite, a wall zone of plagioclase, quartz, and perthite, and a core of perthite, plagioclase, and quartz.

Quartz-plagioclase-muscovite pegmatite (border zone)

A thin border zone, averaging 1 inch in thickness, occurs at the contact between pegmatite and wall rock. It consists of fine-grained quartz-plagioclase-muscovite pegmatite about one-eighth inch in diameter. Most of the zone on the hanging wall has been removed by erosion.

Plagioclase-quartz-perthite pegmatite (wall zone)

The wall zone, averaging 5 feet in thickness, consists of 60 percent plagioclase, 30 percent quartz, 5 percent perthite, 3 percent muscovite, and less than 2 percent tourmaline, garnet, biotite, apatite, and beryl. The average grain size of the zone is 1 inch. Yellowish-green beryl crystals are unevenly distributed throughout the zone.

Perthite-plagioclase-quartz pegmatite (core)

The core is exposed for a length of 420 feet and an average width of 15 feet. It consists of 40 percent perthite, 35 percent plagioclase, 20 percent quartz, 2 percent muscovite, and 3 percent tourmaline, arsenopyrite, biotite, garnet, and apatite. The average grain size of the core is larger than that of the wall zone. Large perthite crystals as much as 4 feet in length are surrounded by finer grained plagioclase and quartz, the average grain size of which is 1.5 inches. About 75 percent of the perthite is graphically intergrown with quartz. Other perthite crystals contain inclusions of garnet and tourmaline. Large tourmaline crystals, as much as 2 feet in length and 4 inches in diameter, are associated with massive quartz. Muscovite books are very subordinate throughout the core and have an average diameter of less than 1 inch.

Economic minerals

Beryl crystals in the wall zone average a quarter of an inch in diameter and three-quarters of an inch in length. In an area of 27 square feet a mineral count indicated 0.01 percent beryl. About 20 percent of the beryl is cobbable.

The wall zone contains an estimated 3 percent of scrap mica. The larger core contains about 2 percent. The core contains 40 percent of potash feldspar, 65 percent of which is in graphic granite. The quality of the potash feldspar is further lowered by the presence of inclusions of tourmaline and garnet.

Pegmatite 24

Pegmatite 24 is in the SW¼ sec. 21, T. 3 S., R. 4 E. (pl. 1).

The pegmatite is a tabular body, striking N. 45° W. and dipping 44° SW. The approximate plunge is about 36° S. 24° E. It measures 270 feet in length and has an average thickness of 10 feet.

Three zones have been recognized in this pegmatite: a border zone and a wall zone of plagioclase, quartz, and perthite, and a core of quartz, perthite, and plagioclase.

Plagioclase-quartz-perthite pegmatite (border and wall zones)

Plagioclase-quartz-perthite pegmatite has a grain size about a quarter of an inch that makes up a 2-inch thick border zone.

The wall zone, about 1 foot thick, consists of an estimated 50 percent plagioclase, 30 percent quartz, 10 percent perthite, 5 percent muscovite, and less than 3 percent tourmaline, apatite, and garnet. The average grain size is half an inch, although muscovite books, as much as 4 inches in diameter, and tourmaline crystals, as much as 5 inches in length, are present. Medium-grained cream-colored perthite crystals average about 3 inches in diameter.

Quartz-perthite-plagioclase pegmatite (core)

The core is composed of most of the visible pegmatite. It is 260 feet in length and averages 6 feet in thickness. The estimated mineral composition is 40 percent quartz, 30 percent perthite, 25 percent plagioclase, 3 percent muscovite, and 2 percent tourmaline, apatite, and garnet. Small, 1-inch muscovite books occur with quartz and plagioclase of similar size. Blocky perthite crystals, as much as 3 feet in diameter, are in a fine-grained matrix consisting of all the other minerals of the zone. The perthite crystals average 1 foot in diameter. About 25 percent of the perthite is in graphic granite.

Economic minerals

Scrap mica occurs in both the wall zone and core. The wall zone on the hanging wall contains an estimated 3 percent of ruby-colored crude sheet mica in books about 3 inches in diameter. A small quantity of sheet mica occurs elsewhere in the pegmatite.

The wall zone contains 10 percent potash feldspar, mostly too fine grained to be cobbed. Some feldspar, however, could be mined from the core. The quantity would be small, unless the core thickens with depth, as appears likely from the exposed pegmatite contacts.

Pegmatite 53

Pegmatite 53 is in the NE¼ sec. 29, T. 3 S., R. 4 E. (pl. 1). The mine workings consist of a single open-cut 54 feet long, 20 feet wide, and 6 feet deep.

The pegmatite is a tabular body with a strike length of 200 feet and an average thickness of 15 feet, strikes N. 30° W., and dips 40° SW. The approximate plunge is 35° S. 27° W. It contains a border zone

of plagioclase, quartz, and muscovite; a wall zone of plagioclase, quartz, and perthite; and a discontinuous core of quartz and perthite.

Plagioclase-quartz-perthite pegmatite (border and wall zone)

A thin discontinuous border zone of fine-grained plagioclase-quartz-muscovite pegmatite has a maximum thickness of 2 inches and a grain size of a quarter of an inch.

A wall zone, about 1 foot thick, consists of 40 percent plagioclase, 30 percent quartz, 20 percent perthite, 5 percent muscovite, and 3 percent tourmaline, garnet, and apatite. The average grain size is half an inch, but muscovite books as much as 2 inches in diameter are present.

Quartz-plagioclase-perthite pegmatite (intermediate zone)

An intermediate zone, 12 feet thick and 155 feet long, makes up the bulk of the pegmatite. It consists of 35 percent quartz, 30 percent plagioclase, 30 percent perthite, 5 percent muscovite, and accessory tourmaline, garnet apatite, and beryl. About 80 percent of the perthite is in graphic granite. The grain size of the entire zone is about 2 inches. Light-pink perthite and graphic granite crystals average 2 feet in length, but are as much as 4 feet long and 2 feet thick. Quartz and plagioclase are fine-grained. Most of the muscovite occurs as aggregates of small, light yellow-green books. Pale-yellow crystals of beryl, as much as 9 inches in length and 5 inches in diameter, are unevenly distributed throughout the zone.

The zone also contains several pod-shaped mica-rich aggregates as much as 3 feet long and 2 feet wide. These aggregates contain an estimated 70 percent muscovite, 20 percent quartz, and 10 percent plagioclase. The average grain size is three-quarters of an inch.

Quartz-perthite pegmatite (core)

The core is a series of disconnected irregular-shaped pods that are about 4 feet in length and 2 feet in thickness. The pods contain 60 percent massive quartz and 40 percent perthite. Muscovite books half an inch in diameter constitute about 2 percent of the zone. The perthite is in light-pink crystals that average 1.5 feet in diameter.

Economic minerals

Beryl is found in the intermediate zone in crystals large enough to be recoverable by hand cobbing. Measurements of beryl crystals gave 0.01 percent of beryl over an area of 200 square feet.

Scrap mica occurs in the three inner zones of the pegmatite. The intermediate zone contains approximately 3.5 percent of crude sheet mica.

Large reserves of potash feldspar occur in the intermediate zone, however, 20 percent is in graphic granite and is not acceptable for grinding at the present time. About 40 percent of the core is cobbable perthite, but the total quantity is low because of the small size of the core.

Pegmatite 54

Pegmatite 54 is in the SW¼ sec. 20, T. 3 S., R. 4 E. (pl. 1). The mine workings consist of a small open-cut 10 feet long, 8 feet wide, and 5 feet deep.

The pegmatite is a tabular body 110 feet long and 10 feet thick, that strikes N. 43° W., and dips 46° SW. Its approximate plunge is 42° S. 20° W. A shear zone, recognizable on aerial photographs as a part of a lineament, strikes N. 49° E. and offsets the pegmatite at two points. The horizontal displacement is less than 5 feet.

The pegmatite contains three zones: a fine-grained border zone of quartz, plagioclase, and muscovite; a wall zone of plagioclase, quartz, and perthite; and a core of quartz, perthite, and plagioclase.

Quartz-plagioclase-muscovite pegmatite (border zone)

The border zone is about three-eighths of an inch thick but is only discontinuously exposed along the pegmatite contact. It is composed of 50 percent quartz, 35 percent plagioclase, 10 percent muscovite, and 3 percent tourmaline, apatite, and garnet. Muscovite occurs as pale-yellow books about one-eighth of an inch in diameter. The quartz and plagioclase have an average grain size approximately the same as the muscovite.

Plagioclase-quartz-perthite pegmatite (wall zone)

The wall zone averages 1 foot in thickness and consists of 40 percent plagioclase, 35 percent quartz, 15 percent perthite, 5 percent muscovite, and less than 4 percent tourmaline, apatite, and garnet. The grain size is about half an inch. Muscovite books are present as much as 1.5 inches in diameter. Cream-colored perthite crystals are as much as 1 foot in length but the average is about 2 inches.

Quartz-perthite-plagioclase pegmatite (core)

The core, 8 feet thick and 105 feet long, consists of about 35 percent quartz, 30 percent perthite, 25 percent plagioclase, 10 percent muscovite, and 5 percent tourmaline, garnet, beryl, and apatite. The core is much coarser in texture than the outer zones. It contains large pink perthite crystals as much as 4 feet long, surrounded by finer grained quartz and plagioclase. About half the perthite is graphically intergrown with quartz. Tourmaline crystals and muscovite books occur in the outer part of this zone. Beryl crystals were found in the fine-grained quartz-plagioclase matrix. The crystals are yellowish green, and range from 1 to 5 inches in length and half an inch to 3 inches in diameter.

Economic minerals

Beryl occurs in the core in crystals large enough to be recovered by hand cobbing. The beryl content of the core was estimated at 0.8 percent on the basis of a mineral count over an area of 45 square feet. The volume of the core, and hence the beryl-bearing rock, however, is small.

Most of the mica in the pegmatite is scrap quality. The wall zone, however, contains 2.5 percent of crude sheet mica in books ranging from 1 to 3 inches in diameter.

Recoverable potash feldspar occurs in the core zone, but the percent of potash feldspar is low and about half occurs in graphic granite. Feldspar production would be small because of the size of the core.

Pegmatite 57 (Silver Top lode mine)

Pegmatite 57 (Silver Top lode mine) is in the SW$\frac{1}{2}$ sec. 20, T. 3 S., R. 4 E. (pl. 1). The property is owned by R. A. Schull, Custer, S. Dak. The mine workings comprise two small open-cuts along the west side of the pegmatite.

The pegmatite is a tabular body, 150 feet long and 25 feet thick. It is exposed as a dip slope and strikes N. 46° W., and dips 50° SW. The plunge of the pegmatite is 40° S. 26° W.

The pegmatite contains four zones: a border zone of plagioclase, quartz, and muscovite; a wall zone of plagioclase, quartz, and perthite; an intermediate zone of perthite, quartz, and plagioclase; and a core zone of quartz, perthite, and muscovite.

Plagioclase-quartz-perthite pegmatite (border and wall zone)

The border zone is about 3 inches thick and has an average grain size of a quarter of an inch.

A wall zone 2 feet thick has a grain size of about 1 inch. It is composed of 40 percent plagioclase, 30 percent quartz, 20 percent perthite, and 5 percent muscovite. Accessory tourmaline, garnet, biotite, apatite, and beryl constitute less than 5 percent of the zone. Muscovite is in books as much as 3 inches in diameter. Pale-yellow to green beryl occurs in euhedral crystals in the inner part of the wall zone. Although a few crystals are as much as 3 inches long, the average is less than 1 inch. Most of the beryl is fractured and altered to a clay-like material. The content of beryl in the zone was estimated at 0.1 percent.

Perthite-quartz-plagioclase pegmatite (intermediate zone)

An intermediate zone, 18 feet thick and 140 feet long, consists of 45 percent perthite, 30 percent quartz, 20 percent plagioclase, and about 3 percent muscovite. Accessory tourmaline, apatite, garnet, and beryl constitute about 2 percent of the zone. Coarse-grained perthite and graphic granite crystals average 2 feet in diameter, and are enclosed in a matrix of quartz-plagioclase-muscovite pegmatite with an approximate grain size of three-quarters of an inch. Although beryl is unevenly distributed throughout the zone, it is most abundant in the outer part. The largest crystal measured was 11 inches long and 2 inches in diameter. Beryl was visually estimated at 0.1 percent of the zone.

Quartz-perthite-muscovite pegmatite (core)

The core is several disconnected lenticular pods, less than 10 feet in length and 5 feet thick, that are located near the center of the intermediate zone. The pods contain about 55 percent quartz, 40 percent perthite, and 5 percent muscovite. Accessory tourmaline, apatite, and beryl constitute less than 3 percent of the pods. Quartz and perthite are coarse-grained, but the muscovite is fine-grained, occurring in half an inch books. Beryl crystals were observed in two pods. The largest crystal was 13 inches long and 6 inches in diameter.

Economic minerals

Beryl occurs in all the zones. It is generally altered in the wall zone and intermediate zone, and fresh in the core. Beryl in the wall zone is too fine grained to recover by hand cobbing, but most of the beryl from the intermediate and core zones could be recovered. The beryl content of the entire pegmatite, on the basis of measurement of beryl crystals in more than 1,500 square feet of outcrop, was estimated at 0.1 percent.

Mica, in most of the pegmatite, is scrap quality. The wall zone, however, contains about 2.5 percent of crude sheet mica in books as much as 3 inches in diameter.

The intermediate zone contains from 20 to 25 percent of cobbable potash feldspar. The disconnected pods of the core have a similar percentage of recoverable feldspar, but the volume of the core is much less than that of the intermediate zone.

Pegmatite 65

Pegmatite 65 is in the NW$\frac{1}{4}$ sec. 20, T. 3 S., R. 4 E. (pl. 1). No prospecting work has been done.

The pegmatite is a tabular body that strikes N. 38° W., and dips 35° SW. The plunge is probably about 40° S. 26° W. The pegmatite is exposed for 180 feet along the strike and has an average thickness of 10 feet.

The pegmatite contains at least four zones: a thin border zone of quartz, plagioclase, and muscovite; a wall zone of quartz, plagioclase, and perthite; an intermediate zone of quartz, plagioclase, and perthite; and a core consisting of disconnected pods of quartz and perthite.

Quartz-plagioclase-muscovite pegmatite (border zone)

A border zone 1-inch thick occurs at the pegmatite contact. It consists of fine-grained (averaging less than a quarter of an inch) quartz-plagioclase-muscovite pegmatite.

Quartz-plagioclase-perthite pegmatite (wall zone)

The wall zone is 0.5 foot thick and contains approximately 40 percent quartz, 35 percent plagioclase, 10 percent perthite, 10 percent muscovite, and less than 3 percent tourmaline, beryl, and apatite. The grain size of the wall zone is about half an inch. Perthite crystals, having an average diameter of 2 inches, are enclosed in a fine-grained matrix of the other minerals of the zone. The grain size of the muscovite is about a quarter of an inch. Fine-grained light-green beryl crystals are intergrown with quartz and plagioclase.

Quartz-plagioclase-perthite pegmatite (intermediate zone)

The intermediate zone is exposed for 175 feet along the strike and has an average width of 8 feet. It contains an estimated 40 percent quartz, 35 percent plagioclase, 20 percent perthite, 5 percent muscovite, and accessory tourmaline and beryl. Cream- to light-pink perthite occurs in crystals in finer grained quartz and plagioclase. Pale yellowish-green muscovite books and light-green beryl crystals range from half an inch to 2 inches in diameter.

Quartz-perthite pegmatite (core)

The apparent core is a series of disconnected pods, as much as 4 feet thick, consisting of an estimated 50 percent quartz, 40 percent perthite, 10 percent muscovite, and accessory beryl. It can not be determined whether the pods coalesce into a single core at depth. Perthite crystals as much as 2 feet long are found in the core. Muscovite is concentrated along the periphery of the quartz-perthite core in books about 3 inches in diameter. Beryl crystals average 3 inches in length.

Economic minerals

An estimated 0.1 percent of beryl occurs in the two inner zones of the pegmatite. The beryl in the wall zone can be recovered only by milling, but 30 percent of the beryl in the intermediate zone and 25 percent of the beryl in the core can be hand cobbed.

Mica in the wall and intermediate zones is scrap quality. A few sheet mica books, 3 inches in diameter, occur along the periphery of the core.

Pegmatite 67 (Dorothy lode mine)

Pegmatite 67 (Dorothy lode mine) is in the SW¼ sec. 27, T. 3 S., R. 4 E. (fig. 2). It is owned by Consolidated Feldspar Corp., Trenton, N. J. The mine workings consist of an open-cut 100 feet long, 20 feet wide, and about 30 feet deep. This pegmatite was described in a Geological Survey report by W. E. Hall (1953?), who visited the property October 31, 1942. His report includes a brief description of the pegmatite, the muscovite-bearing units, and the feldspar and mica production for September and October 1942.

The pegmatite forms a narrow ridge surrounded by quartz-mica schist. It is a tabular body that strikes N. 70° E., and dips about 46° SE. The plunge is probably 35° S. 23° E. The pegmatite, as exposed, is 150 feet long and averages 25 feet thick.

The pegmatite contains four zones: a border zone and wall zone of plagioclase, quartz, and muscovite; an intermediate zone of perthite, quartz, and muscovite; and a core of perthite, quartz, and plagioclase.

Plagioclase-quartz-muscovite pegmatite (border and wall zones)

The border zone is only a few inches thick and contains plagioclase, quartz, muscovite, and accessory apatite, tourmaline, and garnet. The grain size is about a quarter of an inch.

A wall zone 2 feet thick is composed of an estimated 55 percent plagioclase, 35 percent quartz, and 5 percent muscovite. Accessory tourmaline, apatite, and garnet constitute less than 5 percent of the zone. The grain size is about 1 inch.

Perthite-quartz-muscovite pegmatite (intermediate zone)

The intermediate zone has a length of 142 feet and an average thickness of 8 feet. It is composed of 80 percent perthite, 10 percent quartz, and 7 percent plagioclase. Muscovite, tourmaline, and apatite are accessory. White perthite is in crystals as much as 5 feet in length. These are surrounded by a fine-grained matrix of quartz and plagioclase, that averages three-quarters of an inch in diameter. Locally, either quartz or plagioclase may predominate in this finer grained matrix. Tourmaline occurs in the fine-grained quartz and plagioclase, and may be found as small inclusions in the perthite.

Perthite-quartz-plagioclase pegmatite (core)

The core is 12 feet wide and 125 feet long and is composed of an estimated 40 percent perthite, 40 percent quartz, 15 percent plagioclase, and accessory muscovite, beryl, and phosphate minerals (lithiophilite-triphylite). The core consists mainly of massive quartz and coarse-grained perthite. Perthite occurs in crystals as much as 4 feet in length. Fine-grained quartz and plagioclase form small segregations and may represent replacement bodies within the core. The beryl ranges from 0.5 inch to 2 inches in diameter.

The core also contains mica-rich aggregates or "bull" mica units. These units are as much as 4 feet in diameter and contain about 60 percent of small muscovite books, averaging half an inch in diameter. The remaining minerals are quartz and plagioclase.

Economic minerals

Beryl occurs in the core zone in crystals up to 3 inches in diameter, only about 20 percent is large enough to recover by hand cobbing. The grade was visually estimated at 0.01 percent.

Mica in the intermediate and core zones is scrap quality. Books of sheet mica, as much as 7.5 inches in diameter, were mined from the wall zone. The crude sheet mica content of the wall zone is visually estimated at 2.5 percent.

About 70 percent of the potash feldspar in the intermediate zone is recoverable at present. The core contains only half as much feldspar as the intermediate zone and 80 percent is considered to be recoverable.

Pegmatite 68 (Highland lode, John Ross mine)

Pegmatite 68 (Highland lode, John Ross mine) is a well zoned pegmatite in the NE¼ sec. 30, T. 3 S., R. 4 E. (fig. 2). The pegmatite has been described in detail by Page and Stoll (1953?). The following brief description is taken from that report:

"The Highland lode pegmatite is owned by the New York Holding Association and is leased by John Ross who has operated it intermittently for feldspar, beryl, mica, and columbite since 1938. The mine workings include a large open-cut, an inclined shaft, stope, adit, and a small prospect pit.

"The pegmatite crops out as a roughly oval mass, 220 feet long and 150 feet wide. It appears to have a shape similar to a flattened tear drop. The hanging wall and footwall converge down the plunge to the southwest until the pegmatite is probably only 25 feet thick at the elevation of the lower workings.

"Three units have been mapped in the pegmatite. These are a wall zone of albite and quartz, and a core made up of two units, namely, perthite and quartz and quartz, perthite, and albite pegmatite.

"The wall zone consists of albite and quartz with pink perthite, black tourmaline, yellowish beryl, and muscovite. Perthite crystals are as much as 4 feet long, and on the hanging-wall side of the pegmatite extend to the contact. They are less common on the footwall part of the zone. The other minerals have an average grain size of about 1 inch.

"Both units of the core zone are considerably coarser grained than the wall zone. The perthite-quartz pegmatite unit of the core is primarily perthite with interstitial quartz intergrown with a little albite and muscovite. The quartz-perthite-albite pegmatite is predominantly quartz with about 25 percent perthite. Albite, associated with garnet and tourmaline, replaces many of the perthite crystals and also occurs intergrown with quartz, beryl, columbite, muscovite, and lithiophilite between the perthite crystals."

Economic minerals

The Highland lode is predominantly a feldspar mine as indicated by the following figures on past production:

Year	Beryl (tons)	Feldspar (tons)	Scrap mica (tons)	Sheet mica (pounds)	Punch mica (pounds)	Columbite (pounds)
1938	8.0	560	3.5	----	----	----
1939	11.0	1,877	3.5	----	----	----
1940	8.25	3,563	2.0	----	----	----
1941	26.5	1,880	37.0	8.0	140.0	----
1942	4.0	578	240.0	2.0	7.0	----
1943	15.75	886	57	21.7	----	100
1944	5.75	----	----	1.1	----	----
1945-50	3.0	----	----	----	----	----
Total	82.25	9,344	343.0	32.8	147.5	100

Beryl was produced in the past as a byproduct of feldspar mining. Green beryl crystals as much as 4 feet in diameter and 8 feet in length were found in the quartz-perthite-albite pegmatite, but commonly the crystals range from 6 to 8 inches in diameter. The BeO content of these crystals is about 12.5 percent. The albite-quartz pegmatite of the wall zone has pale-yellow beryl crystals ranging from half an inch to 6 inches in length and from a quarter of an inch to $1\frac{1}{2}$ inches in diameter. Most of these are not recoverable at present.

The beryl-rich pegmatite of the core is a flat lenticular body, 6 to 8 feet thick, 150 feet in length along the strike, and 75 to 100 feet in length along the dip. The body is parallel to the footwall contact of the pegmatite. Measurements of beryl crystals on exposures of the beryl-rich quartz-perthite-albite pegmatite gave values of 0.7 percent and 1.0 percent of beryl. Measurements on the albite-quartz pegmatite gave values of 0.2 percent of beryl.

The mica is mostly scrap quality, although a few pounds of sheet mica were sold during World War II. It occurs as "bull" mica aggregates in the quartz-perthite-albite pegmatite and as book mica, mainly scrap quality "A" mica, in the albite-quartz wall zone.

Columbite occurs with interstitial albite in the core. A few hundred pounds have been recovered during feldspar mining. Specific gravity tests indicate that the columbite has a Ta_2O_5 content of 17 percent and a Nb_2O_5 content of 63 percent.

Feldspar has been the main economic mineral produced in the past. Past over-all recovery has been about 36 percent of the total mined rock. The feldspar deposit decreases in grade down the plunge of the pegmatite as a result of the pinching out of the perthite-quartz unit. The quartz-perthite-albite unit has considerable recoverable feldspar, but it is doubtful if it is rich enough to allow profitable mining solely for feldspar.

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

R. 4 E.

T. 3 S.

T. 4 S.

French Creek

Ruby Creek

Crow Creek

BIG SPAR NO 1

SILVER TOP LODE

HIGHLAND LODE

DOROTHY LODE

NEWARK MINE

Amphibolite dikes

A A'

EXPLANATION

CAMBRIAN QUATERNARY

Alluvium

Upper Cambrian

Ed Deadwood formation

PRE-CAMBRIAN

Quartz vein

Zoned pegmatite

Plagioclase-quartz-perthite pegmatite

Thin pegmatite bodies showing dip

Quartz-mica-feldspar schist unit (Pattern in outcrop area)

Amphibolite unit

E Quartz-mica schist unit (Pattern in outcrop area; letter E shows location of lime silicate ellipsoids)

Contact showing dip, dashed where approximately located

Inferred contact

Limit of outcrop

Lineament

Probable fault

Strike and dip of beds

Strike and dip of foliation

Strike and dip of foliation and plunge of lineation

Plunge of minor fold

Plunge of lime-silicate ellipsoid

A 7 Groups of pegmatites and number (Tables 1-4; letters designate pegmatites referred to in text and tables)

Trench

Mine

Small mine or prospect

15°

TRUE NORTH

MAGNETIC NORTH

1000 0 3000 Feet

Datum is mean sea level

Geology by Andrew J. Lang and Jack A. Redden, 1948-49

Quartz-mica-feldspar schist unit

Amphibolite unit

Quartz-mica schist unit

A

A'

5600′
5400′
5200′
5000′
4800′

GEOLOGIC MAP AND SECTION OF THE FOURMILE AREA, CUSTER COUNTY, SOUTH DAKOTA