Geology and Pegmatites of Part of the Fourmile Area, Custer County, South Dakota

Trace Elements Investigations Report 155

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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

By

A. J. Lang, Jr., and J. A. Redden

March 1952

Trace Elements Investigations Report 155

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

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

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

ABSTRACT

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

Three new formations of metamorphic rocks are described that have a total thickness of at least 7,700 feet. The oldest of these formations, the Ruby Creek quartz-mica schist, is more than 6,500 feet thick. The overlying Raver formation, 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 rock. The youngest formation, the Ruddock quartz-mica-feldspar schist, is more than 1,000 feet thick. The presence of kyanite, staurolite, cordierite, and sillimanite in the rocks indicate that they have been subjected to high-grade metamorphism.

About 420 pegmatites were mapped in the Ruby Creek quartz-mica schist and the Ruddock quartz-mica-feldspar schist. A few thin pegmatites in the Raver formation were not mapped. Most of the pegmatites 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 are classified as heterogeneous pegmatites. The remainder are homogeneous pegmatites that are poorly zoned. The major constituents of the pegmatites are plagioclase, quartz,

perthite, and muscovite. The accessory minerals are tourmaline, apatite, garnet, and biotite. Beryl was observed in 15 of the pegmatites.

The heterogeneous pegmatites contain commercial deposits of potash feldspar, mica (sheet and scrap), and beryl.

INTRODUCTION

A part of the Fourmile area, approximately 2 miles southwest of Custer, S. Dak. (fig. 1), was mapped in the summers of 1948 and 1949 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, 21, 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 the remaining area to the west. Mapping was done on aerial photographs enlarged to a scale of 1/12,000.

Although additional mapping was done to the west and south by the Geological Survey during the summers of 1950 and 1951, 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 mapping was under the supervision of J. J. Norton, who gave valuable assistance in the field and in the preparation of this report. D. H. Kupfer offered suggestions in the preparation of the manuscript.

The general geology of the south Black Hills has been described by Newton and Jenney, _/ Van Hise, _/ Darton and Paige, _/ and Connolly and O'Harra. _/

_/Newton, Henry, and Jenney, W. P., Report on the geology and resources of the Black Hills of Dakota: U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

_/Van Hise, C. R., The pre-Cambrian rocks of the Black Hills: Geol. Soc. America Bull., vol. 1, pp. 203-244, 1890.

_/Darton, N. H., and Paige, Sidney, U. S. Geological Survey Atlas, Central Black Hills folio (no. 219), 1925.

_/Connolly, J. P., and O'Harra, C. C., The mineral wealth of the Black Hills: South Dakota School of Mines Bull. 16, 1929.

The Fourmile area is approximately 6 miles southwest of the center of the main mass of granite and pegmatite which surrounds Harney Peak in the southern Black Hills uplift (fig. 1). 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

Three major units of metamorphic rocks are designated as new formations. They have been named the Ruby Creek quartz-mica schist, the Raver formation, and the Ruddock quartz-mica-feldspar schist. The exposed thickness of these three formations is at least 7,700 feet.

Graded bedding in arkose layers within the Ruddock quartz-mica-feldspar schist and the relative position of schistosity and bedding indicate that the beds are upright. The oldest formation is the thick

Ruby Creek quartz-mica schist; the youngest is the Ruddock quartz-mica-feldspar schist formation. The thin Raver formation is intermediate in age and contains many different rock types.

Ruby Creek quartz-mica schist

Most of the northern and eastern part of the area is underlain by the Ruby Creek quartz-mica schist, named after Ruby Creek, which flows south across the formation. The bottom of the formation is not exposed in the mapped area. The known exposures indicate that the formation is at least 6,500 feet thick.

Most of the formation consists of light- to dark-gray, fine-grained quartz-mica schist containing about 70 percent quartz and 25 percent mica. In general muscovite 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 be concentrated in the outer part of the ellipsoids. The plagioclase composition ranges from An_{60} to An_{90}. Runner and Hamilton _/ have described these structures as metamorphosed calcareous

/Runner, J. J., and Hamilton, R. G., Metamorphosed calcareous concretions and their genetic and structural significance: Am. Jour. Sci., 5th ser., vol. 28, pp. 51-64, 1934.

concretions. Although the ellipsoids have been found throughout the formation, there is a tendency for them to be concentrated in certain zones.

Raver formation

A unit of interbedded rocks of various types, named the Raver formation, overlies the Ruby Creek quartz-mica schist. The formation is named for the Raver Ranch which is in the southeast part of the Fourmile area. The outcrop width of the formation ranges from 150 to 1,500 feet, depending on the degree of folding and topography. The true thickness is probably between 100 and 200 feet. The formation contains amphibolite, lime-silicate rock, cordierite-biotite schist, microcline-biotite schist, quartz-mica schist, and quartzite. Many gradational rock types exist between the amphibolite, lime-silicate rock, cordierite-biotite schist, and microcline-biotite schist.

Amphibolite and hornblende schist.--Structureless amphibolite and hornblende schist are the most abundant rocks of the Raver formation. They occur as individual beds or groups of beds separated by other rock types.

The amphibolite is dark green and medium to coarse grained. The dominant minerals are hornblende, plagioclase, and quartz. The accessory minerals are sphene, apatite, graphite, magnetite, and tourmaline. Zoisite, garnet, chlorite, biotite, diopside, and calcite occur in a few specimens. Hornblende-bearing rocks which are associated with lime-silicate rock may contain as much as 50 percent calcite. Locally, the

amphibolite is very dark colored and contains no megascopically visible light-colored minerals.

In general the plagioclase content of the rock ranges from 5 to 30 percent. The plagioclase ranges in composition from An_{22} to An_{80}; probably there are all variations between these extremes. The anorthite-rich plagioclase is usually found in hornblende gneisses that contain abundant calcite, biotite, or diopside.

The hornblende schist is composed of the same minerals as the amphibolite but is much finer grained and is lighter green.

Thin lenticles of sugary-grained quartzite occur in part of the amphibolite. Similar lenticles of nearly pure calcite occur in the calcite-rich specimens. Cummingtonite-tourmaline-graphite schist is associated with hornblende schists at the Newark mine.

Lime-silicate rock.--Lime-silicate rock, containing alternating light and dark layers ranging from 0.2 inch to 12 inches thick, forms a bed of variable thickness near the middle of the Raver formation. The dark-colored bands are composed chiefly of fine-grained biotite and a small amount of hornblende and quartz. A few of the dark layers contain cordierite. The light-colored bands 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 a centimeter in diameter, but the remaining minerals are fine grained. The plagioclase (An_{70-90}) tends to be concentrated along the contact with the biotite-rich bands.

Cordierite-biotite schist.--A cordierite-biotite schist bed, less than 40 feet thick, occurs near the upper contact of the formation. The schist has a dark gray-brown groundmass that encloses light-colored grains

of cordierite. The cordierite grains are equidimensional and have an average diameter of 1 mm. They are surrounded by a network of biotite flakes and fine-grained microcline, which causes the schistosity to be very obscure except in those specimens that contain abundant mica. The schist contains about 40 percent cordierite, 35 percent biotite, 10 percent microcline, and 10 percent plagioclase. Part of the schist contains graphite which makes up as much as 10 percent of the rock.

Microcline-biotite schist.--Microcline-biotite schist, less than 40 feet thick, is associated with cordierite-bearing schist, and may grade vertically and laterally into the cordierite-rich rock. The schist is dark grayish-black to black. It is very fine grained, averaging 0.02 mm 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 beds of quartz-mica schist with variable amounts of accessory minerals occur within the Raver formation. A few outcrops of the schist contain 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 formation 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 mm 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.

Ruddock quartz-mica-feldspar schist

The uppermost stratigraphic unit is a quartz-mica-feldspar schist formation that is named for the Ruddock Ranch in the southeast part of the area. The formation also contains, here and there, small quantities of quartz-mica schist, garnet-staurolite schist, and lime-silicate ellipsoids. The total thickness of the formation 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}) and minor microcline. Near the contact with the Raver formation the schist contains as much as 30 percent feldspar. Recrystallized quartz and feldspar grains as much as 4 mm in diameter are visible in 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 mm thick, occur in the more feldspar-rich schist.

The feldspar content decreases away from the contact with the Raver formation. 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 approximately 300 feet stratigraphically above the lower contact of the formation. Dark bands within the bed have as much as 60 percent of biotite. Euhedral crystals of staurolite, as much as 1 inch long, constitute as much as 30 percent of the rock. The

garnet crystals average 1 mm 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 cut across the schistosity of the Ruby Creek quartz-mica schist apparently are metamorphosed 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 mm in diameter, that are intergrown, giving the rock a speckled appearance that differs from the amphibolite of the Raver formation. The plagioclase characteristically shows reverse zoning. An indistinct foliation is visible in the outer edges of the dikes.

Pegmatites

Approximately 420 pegmatites were mapped in the Fourmile area. Those pegmatites that are less than 1 foot thick were not mapped. The pegmatites are as much as 2,600 feet long and 250 feet thick. Four hundred and eleven of the mapped pegmatites are concordant sill-like bodies; 394 of these are less than 20 feet thick. All of the mapped pegmatites are in the Ruby Creek quartz-mica schist and the Ruddock quartz-mica-feldspar schist.

Following the terminology of Johnston, _/ the pegmatites of the

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_/Johnston, W. D., Jr., Beryl-tantalite pegmatites of northeastern Brazil: Geol. Soc. America Bull., vol. 56, pp. 1024-1025, 1945.

Fourmile area are divided into the following groups: (1) homogeneous

pegmatites or pegmatites that are essentially uniform in texture and mineralogy from wall to wall, and (2) heterogeneous pegmatites or pegmatites that contain distinct textural and mineralogic units. It is probable that all gradations exist between homogeneous and heterogeneous pegmatites.

Homogeneous pegmatites

All but 9 of the mapped pegmatites were considered to be homogeneous pegmatites. The homogeneous pegmatites 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, which has a thickness commonly of less than 3 inches and a grain size of less than one-eighth inch. A gradual increase in grain size toward the center of the pegmatite 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 of the 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 (fig. 3, 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. Most of the plagioclase content tends to decrease and the perthite content increase toward the center of the pegmatite.

Table 1.--Mineralogy of pegmatites

HOMOGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3) 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	Texture (inches)	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/
1	Ruby Creek 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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	< 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.	< 1	1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	0.3	----
																								Apatite.	< 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.	0.1	----
																								Lollingite.	< 1	1/4
																								Biotite.	< 1	< 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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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.	< 1	< 1/16
																								Biotite.	< 1	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

1/ The number of individual pegmatites designated by one number on figure 3 is given in parentheses.

2/ Average grain size.

Table 1.--Mineralogy of pegmatites--Continued

HOMOGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3) 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	Texture (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/
22 (8)	Ruby Creek quartz-mica schist.		Conformable.	Tabular.	Unzoned.	1 to 4	35	< 1	20	4 to 12	10	4 to 12	30	< 1	2	< 1			2	< 1				Apatite. Biotite.	< 1 < 1	1/8 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 porphyroblasts.	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. Biotite.	< 1 < 1	< 1/16 < 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 porphyroblasts.	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. Biotite.	< 1 < 1	< 1/16 1/8
32 (25)	do.	Microcline porphyroblasts.	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. Biotite.	< 1 < 1	< 1/16 < 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 porphyroblasts.	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.	Tourmalinization.	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)	Ruddock 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 pegmatites--Continued

HOMOGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3) 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	Texture (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/	Mineral	Percent	Size (inches)
44	Ruddock 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)	Ruby Creek 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. Beryl.	< 1 Trace.	< 1/16 < 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. Beryl.	< 1 < .01	< 1/16 < 1/2

Table 1.--Mineralogy of pegmatites--Continued

HOMOGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3) 1/	Wall rock		Pegmatite																							
	Type and formation	Alteration	Relation to wall rock	Shape	Internal structure	Texture	Mineralogy																			
							Plagioclase		Perthite		Graphic granite		Quartz		Muscovite		Garnet		Tourmaline		Lithium minerals			Other minerals		
						(inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Percent	Size (inches) 2/	Mineral	Percent	Size (inches) 2/	Mineral	Percent	Size (inches)
77	Ruby Creek quartz-mica schist.		Conformable.	Tabular.	Unzoned.	1 to 4	15	1/2	20	4	30	10	25	1	5	3/4	< 1	1/4	4	1				Apatite.	< 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)	Ruddock 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

In some pegmatites, as pegmatites 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 pegmatite, such as pegmatites 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 of them are thin, sill-like bodies. The largest body, pegmatite 20 (fig. 3), has a length of 2,350 feet and a thickness of 100 feet. A pegmatite in pegmatite group 4 (fig. 3) is 2,600 feet long, but is less than 15 feet thick.

Heterogeneous pegmatites

Heterogeneous pegmatites in the Fourmile area contain as much as 4 distinguishable zones, which, using the terminology of Cameron, et al., _/

_/Cameron, E. N., Jahns, R. H., McNair, A. H., and Page, L. R., Internal structure of granitic pegmatites: Econ. Geology, Monograph 2, pp. 14, 20, 1949.

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may be called border, wall, intermediate, and core zones. Zones were 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. The zones in the Fourmile area pegmatites 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

Table 2.--Mineralogy of pegmatites

HETEROGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3)	Wall rock		Pegmatite																							
							Mineralogy																			
	Type and formation	Alteration	Relation to wall rock	Shape	Internal structure	Texture 1/	Plagioclase		Perthite		Graphic granite		Quartz		Muscovite		Garnet		Tourmaline		Lithium minerals			Other minerals		
							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)	Ruby Creek 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
					"Bull mica" unit.	F	10	1/2					20	1/2	70	1					Yellow mica.		1/4	Apatite.	< 1	1/16
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
					"Bull mica" unit.	F	15	1/2					25	1/2	60	3/4								Apatite.	< 1	1/16
68 (Highland Lode)	do.		Conformable and locally disconformable.	do.	Wall zone.	M	50	1	< 5	24			40	2	3	2			3	3				Beryl.	0.2	3/4
					Upper Core	C	< 5	1	75	36			15	6	1	1/2										
					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.

the assemblages correspond to the generalized assemblages (1), (3), and (4) of Cameron, et al. /

/Cameron, et al., op. cit. p. 61.

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 mineral. Pegmatite 24, however, contains a border zone of plagioclase-quartz-perthite pegmatite. Pegmatite 12-B is in a wall rock of 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 pegmatite 65 to 5 feet in pegmatite 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 (pegmatite 12-B) or muscovite (pegmatite 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 have 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. A few of the pods may be a series of small fracture fillings. The two most abundant minerals of

the cores are quartz and perthite. Plagioclase or muscovite may be the third most abundant mineral. Tourmaline, apatite, and beryl commonly occur as accessory minerals. Perthite is coarse grained as in the intermediate zones. Quartz is massive or in finer grained aggregates with plagioclase and muscovite.

Heterogeneous pegmatites also contain fracture filling units which were defined by Cameron, et al. _/ as units, generally tabular, that fill

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_/Cameron, et al., op. cit. p. 14.

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fractures in previously consolidated pegmatite. Pegmatite 12A (fig. 3) could be classified as a heterogeneous pegmatite because it contains a large fracture filling (?). This fracture filling, however, is distinctly zoned and is described separately as pegmatite 12-B. (See section on mines and prospects.)

A few of the pegmatites listed as homogeneous pegmatite 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 thick, are found throughout the area. The largest vein is 300 feet long. In general the larger veins are concordant, but many of the smaller veins are discordant.

In addition to quartz, the veins 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 veins 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 Ruby Creek quartz-mica schist and the Ruddock quartz-mica-feldspar schist. 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 of this dark mineral concentration, but small quantities of chlorite, quartz, apatite, and muscovite are also present. All of these minerals are normal to the schists, but biotite, graphite, and tourmaline are much more abundant than in the average schist.

Sedimentary rocks

Deadwood formation (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 of the pebbles are quartzite. They are arranged in poorly defined beds approximately parallel to the present surface of the ground.

The Deadwood formation crops out about 5 miles west of here and is very similar lithogically to this outcrop. Also, pegmatites in the vicinity of this outcrop are beveled off at approximately the same elevation as the outcrop. This concordance of pegmatite outcrops probably resulted from the pre-Cambrian erosion surface over which the Deadwood formation was deposited.

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 of sand and pebbles, but some pegmatite boulders are as much as 6 feet in diameter.

STRUCTURE

Folds and linear structures

The part of the Fourmile area that has been mapped lies on the western 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 east of the mapped area and is visible on aerial photographs of the ground to the north and east of the area. The 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 from the entire area have about the same average plunge, 30° S. 10° E. The trend of the bedding on the fold limbs is relatively constant, having strikes of N. 30° - 60° W. and dips of 25° - 60° SW. Bedding and schistosity are generally parallel, but locally diverge both in strike and dip. Locally the bedding may have a more westerly trend than the schistosity which commonly strikes about N. 40° W. In places the bedding 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 bedding differs, 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. Generally these small faults 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 (fig. 2). The lineaments are approximately parallel and strike N. 35° E. The western lineament can be traced on aerial photographs for approximately 4 miles and the eastern lineament for 6 miles and possibly for 9 miles to where it apparently disappears under the Paleozoic rocks. They are clearly marked on aerial photographs by a gentle 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 Raver formation. As the contacts of the Raver formation are located only approximately at the points where the lineaments cross the formation, it is impossible to find the total displacement accurately. It is safe,

however, from the approximate location of the contacts, to infer 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 pegmatites of group 11 (fig. 3) all of the mapped pegmatites are concordant with the 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 (pegmatite group 4, fig. 3).

Small rolls in the pegmatite contacts and the ends of pegmatites indicate three general directions of plunge of the pegmatites. 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. 10° - 45° E.; and a third plunges S. 45° W. It appears that in general the pegmatites were intruded along structural features formed by the deformation that produced folding in the area.

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, gneisses, 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 Ruby Creek quartz-mica schist and the Ruddock quartz-mica-feldspar schist, 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 Ruddock quartz-mica-feldspar schist. Lime-silicate ellipsoids, originally carbonate beds or concretions, now are composed of diopside, garnet, and anorthite-rich plagioclase.

The Raver formation, originally carbonate-rich rocks of different compositions, now 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. /

/Harker, Alfred, Metamorphism: 2nd ed., revised, Metheum and Co., London, pp. 235-235, 256, 1939.

It is believed that 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 Raver formations that have sillimanite apparently replacing kyanite and muscovite. The absence of sillimanite throughout the area, except in the Raver formation, is mainly a result of the composition of the different rocks, but its development there may have been affected by the presence of abundant

CO_2 in certain beds in the Raver which might permit the attainment of equilibrium faster there than elsewhere 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 rock. 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 show no noticeable metamorphism. The general lack of metamorphism, either in forming new minerals or the coarsening of grain size of original minerals, is more striking than the actual contact metamorphism. The usual contact effect of the pegmatites is the development of coarser grained, excess tourmaline for a few inches thick, or at the most, a few feet thick, in the schist along the contact. In addition, microcline, albite, and apatite appear to have been added to the schist, but, lacking definite chemical proof, may have merely recrystallized into coarse, easily visible crystals. At a few contacts there is so much tourmaline developed in the schist that boron must have been added, since the normal schist contains only a percent or less of tourmaline. Probably a little potash, soda, and phosphorous 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 of the homogeneous pegmatites are noncommercial with respect to present prices and mining practices. Many of the pegmatites contain potash feldspar that is recoverable by hand cobbing, but the grade is too low for commercial production. Furthermore, in many of the homogeneous pegmatites the potash feldspar occurs as graphic granite and contains too much quartz to be commercially acceptable.

Small quantities of scrap mica, crude sheet mica, and beryl occur in many of the homogeneous pegmatites, but are not of economic grade at the present 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 have better possibilities for development. Recoverable quantities of potash feldspar occur in the intermediate zones and core of the heterogeneous pegmatites. Beryl and mica may be present in any zone.

Beryl and mica occur only in small quantities in the heterogeneous pegmatites and it is impossible to mine these pegmatites for beryl or mica alone. At present beryl and mica are produced as byproducts of potash feldspar mines.

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 are considered to be cobbable.

Pegmatite 68 contains more recoverable beryl than any of the 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 to be recoverable by present mining methods.

Beryl may occur in the wall zone, intermediate zone, and core of the heterogeneous pegmatites. The average grade of the 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. Pegmatites 13-B and 15 were estimated to contain about 41 tons of beryl of which 8 tons are cobbable. 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 appeared to be 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. Pegmatite 80 contained more than 12 small crystals ranging from 0.15 to 1 inch in diameter.

Although beryl was found in only seven of the homogeneous pegmatites, the authors believe that it occurs in most of them. The reason for the failure to observe more beryl in the homogeneous pegmatites is probably a result of the small size of the crystals, the occurrence of the beryl in anhedral crystals that are easily mistaken for quartz and other minerals, and the failure to be able to investigate the interior 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_/ in the Harney Peak area which is considered

_/Personal communication.

to be the source rock of the pegmatites. 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 along with potash feldspar and scrap mica would make large homogeneous pegmatites as 15 and 80 (fig. 3) possible beryl producers. Any such milling process would enable the recovery of 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 of the heterogeneous and homogeneous pegmatites contain scrap mica. With the exception of pegmatites 14 and 67, (table 2) all of the heterogeneous pegmatites contain sheet and punch mica.

Sheet and punch mica occur in the wall zone of pegmatites 24, 54, 57, and 67, and in the intermediate zones of pegmatite 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 grade 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 approximately 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 byproduct of feldspar mining.

The sheet and punch mica reserves of the mapped area (excluding pegmatite 68-Highland lode) are estimated at 31 tons. Pegmatites 24 and 67 contain nearly one-third of 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 pegmatites 10 and 8 (fig. 3) 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 the pegmatites, however, the quantity of feldspar that could be recovered by present mining methods is too small to permit the mining of the pegmatites. In addition, much of the 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 10, 18, and 20 (fig. 3) were estimated to contain over 1,500,000 tons of potash feldspar. Most of the feldspar is not cobbable, but flotation 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 operations have been carried on 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 on the amount of recovered gold are not available.

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 in the veins exposed in the prospect pits is too low to warrant further development. In 1938 Allsman _/ sampled the

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_/Allsman, P. T., Reconnaissance of gold mining districts in the Black Hills, South Dakota: U. S. Bur. Mines Bull. 427, p. 132, 1940.

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 Raver formation. Whether or not the gold content is greater in these quartz veins than in those in the Ruddock and Ruby Creek formations 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. (fig. 3). It is owned by the Consolidated Feldspar Company 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 was described in a Geological Survey report by J. W. Adams, _/ who visited the property in June 1945. This report

_/Adams, J. W., Big Spar No. 1 mine, in Page, L. R., et al., Pegmatite investigations 1942-1945, Black Hills, South Dakota: U. S. Geol. Survey Prof. Paper, in preparation.

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 the pegmatite 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 thick, 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 consists 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.

Mineral deposits

Beryl occurs in the intermediate zone as light-green crystals. The maximum observed 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 were recovered during feldspar mining.

Most of the mica produced from the Big Spar No. 1 mine is of scrap quality. About 150 pounds of sheet mica, of which 74 percent was No. 2 quality and 26 percent No. 2 inferior, were 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 SW$\frac{1}{4}$ sec. 21, T. 3 S., R. 4 E. (fig. 3). The mine workings include two open cuts: a large cut measuring 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 approximately 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 of the pegmatite is 45° S. 40° W.

The pegmatite is crudely zoned, containing a border zone of fine-grained quartz-plagioclase-muscovite pegmatite, a wall zone of plagioclase-quartz-perthite pegmatite, and a core of perthite-plagioclase-quartz pegmatite.

Quartz-plagioclase-muscovite pegmatite (border zone)

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

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, up to 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.

Mineral deposits

Beryl crystals in the wall zone average a quarter of an inch in diameter and three-quarters of an inch in length. A mineral count over an area of 27 square feet 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. (fig. 3).

The pegmatite is a tabular body, striking N. 45° W. and dipping 44° SW. The approximate plunge is about 36° S. 24° E. The pegmatite 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-perthite pegmatite, and a core of quartz-perthite-plagioclase pegmatite.

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

Plagioclase-quartz-perthite pegmatite with a grain size of about a quarter of an inch 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 constitutes 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.

Mineral deposits

Scrap mica occurs in both the wall zone and core. The wall zone on the hanging wall of the pegmatite contains an estimated 3.0 percent of ruby-colored crude sheet mica in books approximately 3 inches in diameter. A small quantity of sheet mica occurs elsewhere in the pegmatite.

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

Pegmatite 53

Pegmatite 53 is in the NE¼ sec. 29, T. 3 S., R. 4 E. (fig. 3). 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. It strikes N. 30° W. and dips 40° SW. The approximate plunge is 35° S. 27° W.

The pegmatite contains a border zone of plagioclase-quartz-muscovite pegmatite, a wall zone of plagioclase-quartz-perthite pegmatite, and a discontinuous core of quartz-perthite pegmatite.

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

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 are present as much as 2 inches in diameter.

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 biotite, 5 percent muscovite, and accessory tourmaline, garnet, apatite, and beryl. Approximately 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 occur 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. Half an inch muscovite books constitute about 2 percent of the zone. The perthite is in light-pink crystals that average 1.5 feet in diameter.

Mineral deposits

Beryl is found in the intermediate zone in crystals large enough to be recoverable by hand cobbing. A measurement of beryl crystals gave 0.01 percent 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, but 20 percent is in graphic granite and, therefore, is not acceptable for grinding at the present time. Approximately 40 percent of the core is cobbable perthite, but the total recovery would be 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. (fig. 3). 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-muscovite pegmatite, a wall zone of plagioclase-quartz-perthite pegmatite, and a core of quartz-perthite-plagioclase pegmatite.

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 thick 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 approximately of 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 of 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.

Mineral deposits

Beryl occurs in the core in crystals large enough to be recoverable 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 of 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 SW¼ sec. 20, T. 3 S., R. 4 E. (fig. 3). The property is owned by R. A. Schull of Custer, S. Dak. The mine workings consist of two small open cuts along the west side of the pegmatite.

The pegmatite is a tabular body, 150 feet in length and averaging 25 feet in thickness. 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-muscovite pegmatite, a wall zone of plagioclase-quartz-perthite pegmatite, an intermediate zone of perthite-quartz-plagioclase pegmatite, and a core zone of quartz-perthite-muscovite pegmatite.

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

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

A 2-foot thick wall zone 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 percent of beryl in the zone was estimated at 0.1.

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 finer grained 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 of the pods. The largest crystal was 13 inches long and 6 inches in diameter.

Mineral deposits

Beryl occurs in all of the zones. In general, it is 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

grade of the beryl for the entire pegmatite was estimated at 0.1 percent on the basis of measurement of beryl crystals over 1,500 square feet.

Mica, throughout most of the pegmatite is of 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 NW¼ sec. 20, T. 3 S., R. 4 E. (fig. 3). No prospecting work has been carried out.

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-muscovite pegmatite, a wall zone of quartz-plagioclase-perthite pegmatite, an intermediate zone of quartz-plagioclase-perthite pegmatite, and a core consisting of disconnected pods of quartz-perthite pegmatite.

Quartz-plagioclase-muscovite pegmatite (border zone)

A 1-inch thick border zone 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, with 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.

Mineral deposits

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 of 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. 3). It is owned by Consolidated Feldspar Corporation of 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 _/ who visited the property

_/Hall, W. E., Dorothy lode prospect, in Page, L. R., et al., Pegmatite Investigations 1942-1945, Black Hills, South Dakota: U. S. Geol. Survey Prof. Paper, in preparation.

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 of the pegmatite 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-muscovite pegmatite, an intermediate zone of perthite-

quartz-muscovite pegmatite, and a core of perthite-quartz-plagioclase pegmatite.

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 2-foot thick wall zone 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.

Mineral deposits

Beryl occurs in the core zone in crystals up to 3 inches in diameter, but 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 of 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.

Approximately 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, but 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. 3). The pegmatite has been described in detail by Page and Stoll./ The following brief

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/Page, L. R., and Stoll, W. C., Highland lode (John Ross mine), in Page, L. R., et al., Pegmatite investigations 1942-1945, Black Hills,

South Dakota: U. S. Geol. Survey Prof. Paper, in preparation.

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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-quartz pegmatite, and a core made up of two units, namely, perthite-quartz pegmatite and quartz-perthite-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.

Mineral deposits

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

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	7.5	
1943	15.75	886	57	21.7	---	100
1944	5.75	?	?	1.1	---	
1945-50	3.0	?	?			
Totals	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 1½ 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 of scrap quality, though 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 of 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 Cb_2O_5 content of 63 percent.

Feldspar has been the main economic mineral produced in the past. Past overall 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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CONTENTS

TABLES

ABSTRACT

The Fourmile area, Custer County, S. Dak., defined as an area of 30 square miles, was partly mapped (8 square miles) in the summers of 1948 and 1949 on behalf of the Atomic Energy Commission. Mapping is being continued under Geological Survey funds. This area of 30 square miles contains 60 percent (3,300 tons) of the beryl resources of the Custer district. The beryl resources of the 8 square miles mapped are estimated to be 350 tons of which about a quarter can be recovered by hand cobbing. The area mapped in 1950 contained additional beryl resources of 36.5 tons.

INTRODUCTION

The Fourmile area as originally designated, was to include 30 square miles in an area 5 by 6 miles (fig. 4). Approximately a quarter of this project was completed under the auspices of the Atomic Energy Commission and is reported here. Mapping of the area was continued in 1950 and 1951 by the Geological Survey, but complete results of this work have not yet been compiled.

The Fourmile area was chosen because of the rich beryllium pegmatites found in the area. Nearly 60 percent, or about 3,300 tons, of the total beryl reserves of the Custer district are included in the area.

The following named pegmatites are included in the area (fig. 4): Highview, Wright, Tin Mountain, Warren Draw, Gayle (Dubuque), Royal Flush, Rainbow Beryl, Pleasant Valley, Big Tom, Helen Beryl, Tiptop, New York, Michaud, Big Spar No. 1, Dorothy, Highland lode (John Ross), and Silver

Top. All of these pegmatites have been mined in the past or are being mined at present. All have produced beryl, mica, and feldspar, and in addition, the Tin Mountain pegmatite has produced spodumene, amblygonite, lepidolite, microlite, and columbite-tantalite.

The Helen Beryl, New York, and Tin Mountain pegmatites are in the southwest part of the Fourmile area (fig. 4). These three pegmatites contain 86 percent of the beryl reserves. It appears from the location of these three pegmatites that the richer beryl-bearing pegmatites tend to occur southwest of the present mapped area. This has been apparently substantiated by the small amount of additional mapping carried on by the writers during the latter part of the summer of 1950.

The tonnage of beryl in the area to the southwest probably will be greater than in the present mapped area.

RESOURCES

The accompanying tables 3 and 4 contain computed reserves of pegmatites in the mapped area. Only the larger homogeneous pegmatites are listed in table 3. The reserves of beryl, mica, and feldspar from the homogeneous pegmatites cannot be recovered profitably by present mining and milling methods. It is possible that milling operations could recover large quantities of feldspar and scrap mica from the larger homogeneous pegmatites as pegmatites 10, 18, and 20 (table 3).

The estimated tonnage of beryl in the pegmatites examined in the mapped area (fig. 2) is 350 tons of which about 85 tons are cobbable. Since the completion of work on behalf of the Atomic Energy Commission, the authors have mapped additional areas to the southwest. Three small

Table 3.--Pegmatite mineral resources
(in short tons)

HOMOGENEOUS PEGMATITES 1/

Number and name of pegmatite (Fig. 3)	Internal structure	Size and shape of deposit					Beryl				Feldspar				Mica								Other minerals			
		Shape	Average length (feet)	Average thickness (feet)	Depth (feet)	Tons	Percent	Composition	Tons	Percent cobbable	Percent	Composition	Tons	Percent cobbable	Percent crude sheet and punch	Percent sheet and punch in crude	Size of sheet and punch	Quality of sheet and punch	Tons sheet and punch	Total tons of scrap	Total tons of mica	Percent cobbable	Mineral	Percent	Composition	Tons
1	Unzoned.	Tabular.	1,000	20	125	200,000					20	Perthite and graphic granite.	40,000	20						6,000	6,000	10				
8 A	do.	do.	450	20	75	54,000					30	do.	16,000	10						1,600	1,600	5				
B	do.	do.	250	60	100	120,000					30	do.	36,000	35						3,600	3,600	5				
C	do.	do.	300	90	100	216,000					30	do.	65,000	30						6,500	6,500	5				
D	do.	do.	400	35	100	112,000					30	do.	33,000	30						3,500	3,500	5				
E	do.	do.	300	40	100	96,000					30	do.	29,000	25						2,900	2,900	5				
9	do.	do.	300	20	150	70,000					40	do.	28,000	40	0.3	2	< 3		4	2,000	2,004	15				
10	do.	do.	1,200	100	200	1,900,000					10	do.	192,000	10						57,000	57,000	3				
11 A	do.	Cross-cutting.	200	60	50	48,000					30	do.	14,000	20						2,400	2,400	10				
B	do.	do.	450	100	50	180,000					30	do.	54,000	20	0.25	1			5	9,000	9,005	10				
12 A	do.	Tabular.	200	30	100	48,000					35	do.	17,000	50						2,400	2,400	10				
C	do.	do.	300	70	100	220,000					30	do.	66,000	50	0.25	1	< 3		3	11,000	11,003	10				
13 A	do.	do.	650	10	100	52,000					30	do.	15,000	30						520	520	10				
B	do.	do.	250	30	150	90,000	0.3 2/		1 2/	30	30	do.	27,000	30						900	900	10				
15	do.	do.	1,200	30	125	360,000	0.1 2/		10 2/	10	35	do.	83,000	50						11,000	11,000	10				
18	do.	do.	1,500	40	250	1,200,000					30	do.	360,000	15						36,000	36,000	10				
20	do.	do.	2,350	100	200	3,760,000					30	do.	1,100,000	20						188,000	188,000	5				
56	do.	do.	550	20	150	132,000					20	do.	33,000	20						7,000	7,000	<5				
79 A		do.	550	30	100	132,000					40	do.	53,000	40						4,000	4,000	15				
B		do.	500	40	100	160,000					40	do.	64,000	40						4,800	4,800	15				
80		do.	360	30	100	86,000	0.02		17	15	45	do.	38,000	50						3,200	3,200	20				
Totals									41	8			2,363,000	535,450						363,000	363,312	20,341				

1/ Resources computed only for the larger homogeneous pegmatites that may have potential value for bulk mining and milling.

2/ Beryl limited to coarser grained pods in the unzoned pegmatite.

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Table 4.--Pegmatite mineral resources
(in short tons)

HETEROGENEOUS PEGMATITES

Number and name of pegmatite (Fig. 3)	Internal structure	Size and shape of deposit: Shape	Average length (feet)	Average thickness (feet)	Depth (feet)	Tons	Beryl: Percent	Composition	Tons	Percent cobbable	Feldspar: Percent	Composition	Tons	Percent cobbable	Mica: Percent crude sheet and punch	Percent sheet and punch in crude	Size of sheet and punch (inches)	Quality of sheet and punch	Tons sheet and punch	Total tons of scrap	Total tons of mica	Percent cobbable	Other minerals: Mineral	Percent	Composition	Tons
12-B (Big Spar No. 1)	Wall zone.	Shell.	138	1	100	2,000														100	100	5				
	Intermediate zone.	Shell.	90	15	90	19,000	0.2		38	20	20	Perthite and graphic granite.	4,000	60	0.5	1	2	No. 2, 74% No. 2 inferior, 26%.	1	970	971	50				
	Core.	Lenticular.	50	20	60	5,000					40	do.	2,000	40						250	250	25				
14	Wall zone.	Shell.	440	5	100	35,000	0.01		3	20	5	Perthite.	2,000	10						1,000	1,000	5				
	Core.	Tabular.	420	15	100	50,000					40	Perthite and graphic granite.	20,000	70						1,000	1,000	5				
24	Wall zone.	Shell.	267	1	100	4,000					10	Perthite.	400	10	3.0	4	1 to 3		5	240	245	60				
	Core.	Tabular.	260	6	90	11,000					30	Perthite and graphic granite.	4,000	40						330	330	20				
53	Wall zone.	Shell.	160	1	100	1,300					20	Perthite.	300	10						60	60	5				
	Intermediate zone.	Tabular.	155	12	96	28,000	0.05		14	50	30	Perthite and graphic granite.	9,000	50	0.75	2	2-1/2		4	850	854	50				
	Core.	Several pods. 1/					0.1		2 2/	75	40	Perthite.														
	"Bull mica" unit.	Irregular.	3	2	1/															1/	1/					
54	Wall zone.	Shell.	108	< 1	50	3,800					15	Perthite.	130	10	3.5	3	1-1/2		1	56	57	60				
	Core.	Tabular.	105	7.5	45	3,000	0.8		24	30	30	Perthite and graphic granite.	900	40						300	300	50				
57 (Silver Top Lode)	Wall zone.	Shell.	148	2	120	6,000	0.2		12	30	20	Perthite.	1,300	10	2.5	2	1 to 3		3	300	303	60				
	Intermediate zone.	Shell.	142	18	110	23,000	0.05		12	70	45	Perthite and graphic granite.	10,000	60						690	690	40				
	Core.	Several pods. 1/																								
65	Wall zone.	Shell.	178	0.5	75	1,000					10	Perthite.	100	10						100	100	40				
	Intermediate zone.	Tabular.	175	8	70	8,000	0.1		8 2/	30	20	do.	1,600	50						400	400	50				
	Core.	Several pods. 1/			1		0.1		2 2/	25																
67 (Dorothy Lode)	Wall zone.	Shell.	145	1.5	130	4,500									2.5	4	1 to 3		5	225	230	70				
	Intermediate zone.	Shell.	142	8	125	12,000 3/					80	Perthite.	8,800	70						440	440	60				
	Core.	Tabular.	125	12	100	12,000	0.01		1	20	40	do.	5,000	80						600	600	25				
	"Bull mica" unit.	Several pods.	4	2	1/																					
68 (Highland Lode)	Wall zone.	Shell.	250	10	125		0.2		84 3/	1					Trace.			No. 1, 20% No. 2, 65% No. 2 inferior, 15%.	1/	1/	1/					
	Core.	Lenticular.	150	7	90		0.7 to 1.0	12.5 to 13.5% BeO	50 to 75 3/	75	42	Perthite.	3,000	90						1/	1/		Columbite.	< 1	17% Ta_2O_5 63% Cb_2O_5	
	Dump.	Irregular.		10					60-150	1																
	Totals								310	77 (tons)			72,500 4/						19	7,911	7,930	2,715 (tons)				

1/ Unknown.

2/ Estimated.

3/ Part of unit mined out.

4/ Estimated: 33,000 tons of cobbable perthite.
15,000 tons of cobbable graphic granite.

pegmatites, the Royal Flush, Gayle, and Pegmatite 115 (number from field notes of A. J. Lang), have been mapped and beryl tonnage computed. The Royal Flush pegmatite is estimated to contain 6.5 tons of cobbable beryl to a depth of 25 feet and the Gayle pegmatite, 30 tons to a depth of 30 feet. Pegmatite 115 contains 1 ton of beryl in the wall zone, 80 percent of which is cobbable.

The total beryl reserves of the area mapped to date (both for the AEC and USGS) is 388 tons. Of this, 115 tons are considered to be cobbable. However, beryl is mined largely as a byproduct of feldspar mining and it is very doubtful that all of the cobbable beryl could be profitably recovered at present prices.

The heterogeneous pegmatites (table 4) are estimated to contain 310 tons of beryl, 31 tons of sheet and punch mica, and 2,700 tons of cobbable scrap mica. In addition, the heterogeneous pegmatites contain approximately 33,000 tons of cobbable perthite and 15,000 tons of cobbable graphic granite. Present prices and mining methods, however, will not permit the recovery of much of this beryl, mica, and feldspar. Pegmatite 68 will probably be mined at existing prices and most of the beryl will be recovered.

The larger homogeneous pegmatites listed in table 3 are estimated to contain 41 tons of beryl, 12 tons of sheet and punch mica, 20,000 tons of cobbable scrap mica, and 500,000 tons of cobbable perthite and graphic granite. It is certain, however, that these reserves cannot be mined until successful milling plants are developed.