Geology of the High Climb Pegmatite Custer County South Dakota

GEOLOGICAL SURVEY BULLETIN 1015-C

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By DOUGLAS M. SHERIDAN

A CONTRIBUTION TO ECONOMIC GEOLOGY

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A CONTRIBUTION TO ECONOMIC GEOLOGY

GEOLOGY OF THE HIGH CLIMB PEGMATITE, CUSTER COUNTY, S. DAK.

By Douglas M. Sheridan

ABSTRACT

The High Climb pegmatite, Custer County, S. Dak., belongs to the series of pegmatitic and granitic rocks that characterize the Harney Peak region of the southern Black Hills. It intrudes pre-Cambrian metamorphic rocks consisting chiefly of quartz-mica schist. Along part of the pegmatite contact the country rock has been altered to a tourmaline-rich schist.

The structure of the pegmatite, in general, is concordant with the westward-dipping schistose structure of the country rock, but locally the pegmatite cuts it. The main part of the pegmatite is an irregularly shaped pipe that plunges 45° N. 40° W., parallel to the average plunge of rolls in the footwall. A small northern extension of the pegmatite has a lenticular shape, and cuts the schist at a low angle. Rolls in this part of the pegmatite have an average plunge of 28° N. 25° W. One large north-trending crestal roll divides the outcrop of the northern segment of the pegmatite into two parts.

The pegmatite has a well-defined internal structure and is made up of five zones. The outer units, a fine-grained wall zone consisting of albite-quartz pegmatite, and a medium-grained first intermediate zone consisting of albite-quartz-muscovite pegmatite, form incomplete concentric shells. The second intermediate zone, perthite-quartz-albite pegmatite, forms a hood-shaped unit between the outer units and the third intermediate zone along the crest and hanging-wall of the pegmatite. The third intermediate zone, a concentric shell of quartz-cleavelandite pegmatite, surrounds a lenticular core of quartz pegmatite containing altered spodumene. In addition to the five zones, a fracture-filling unit of quartz-perthite-muscovite-albite pegmatite and a possible sixth zone (or replacement unit?) of very fine-grained muscovite pegmatite were recognized.

The essential minerals of the pegmatite include microcline-perthite, quartz, albite, and muscovite. Accessory minerals include tourmaline, beryl, amblygonite (variety montebrasite), apatite, columbite-tantalite, loellingite, altered spodumene, many unidentified dark-colored phosphate minerals, a manganese-bearing carbonate, garnet, and chalcopyrite.

A satisfactory explanation of the origin of the pegmatite requires processes of fractional crystallization and incomplete reaction in a restricted system. The concentric zonal structure and the general increase in grain size from the wall

zone to the core suggest that the pegmatite units formed in successive order by crystallization from the walls inward. No true replacement stages occurred.

Beryl, amblygonite, potash feldspar, columbite-tantalite, scrap mica, and sheet mica have been produced as industrial minerals.

INTRODUCTION

The High Climb pegmatite is a zoned pegmatite that has been the source of amblygonite, beryl, mica, feldspar, and columbite-tantalite. Geologic interest has been stimulated not only by the economic possibilities of the pegmatite as a source of beryl and scrap mica, but also by its complex structure and its unusually well developed series of zones containing widely varied mineral assemblages.

LOCATION AND SURFACE FEATURES

The High Climb pegmatite in Custer County, S. Dak., is near the section line between the SE¼, sec. 22 and the NE¼, sec. 27, T. 2 S., R. 4 E., about 6 miles north of the town of Custer, and just south of the Pennington County line (fig. 13). A road log from Custer to the pegmatite is given below:

Miles	
0.0	At Custer County Bank, Custer, South Dakota. Travel north on State Route 16A (fig. 13). Recently changed to U. S. Highway 16.
6.3	Turn right to ungraded road.
6.5	Travel across small intermittent stream in Tenderfoot Gulch, under the Chicago, Burlington, and Quincy Railroad trestle, and across small log-dirt bridge. Proceed north along Tenderfoot Gulch.
6.8	Road crosses small stream and winds northeastward up the slope on the east side of Tenderfoot Gulch.
7.0	Road turns sharply to the right at crest of ridge and winds across small valley.
7.3	High Climb pegmatite.

The pegmatite crops out between altitudes of 5,680 feet and 5,750 feet on the east side of Tenderfoot Gulch and on the west side of a northward-trending ridge approximately 300 feet above the floor of the gulch. The relief of the area is rugged, and the pine-covered slopes drop steeply to the valleys below.

OWNERSHIP AND PRODUCTION

The High Climb pegmatite is on an unpatented claim owned by Mrs. Gladys Wells and Mr. Fred Heidepriem, both of Custer, S. Dak. Mining operations on the claim began in 1932 and have been continued intermittently since then.

Minerals that have been produced from the High Climb pegmatite are amblygonite, beryl, columbite-tantalite, scrap mica, punch and

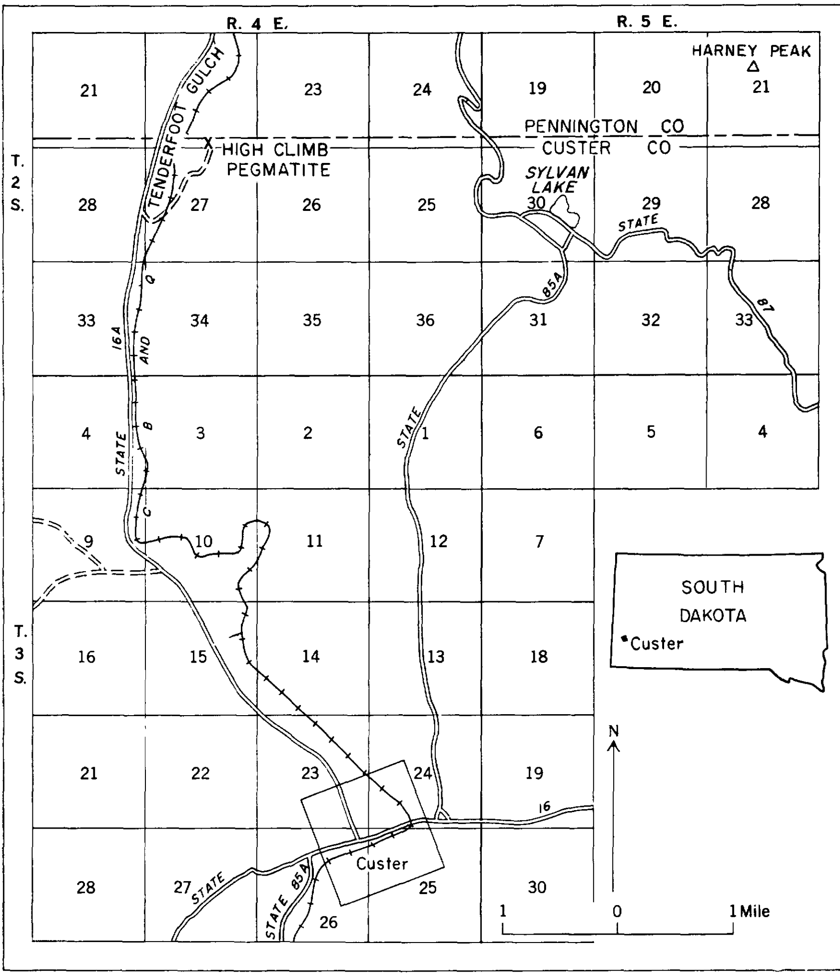

FIGURE 13.—Map showing location of the High Climb pegmatite.

plate mica, and feldspar. W. C. Stoll[1] received the following data from Mrs. Wells on the approximate total production through 1940:

Amblygonite	Estimated 100–350 tons (no accurate figures available)
Beryl	60 tons
Scrap mica	100 tons (including about 150 pounds of punch and sheet mica)
Feldspar	150–180 tons
Columbite	100 pounds

In 1944–45 the mine was worked intermittently for feldspar, but no production figures are available. In 1948 the mine was operated for

[1] Stoll, W. C., 1942, Map and brief accounts of the High Climb pegmatite, Custer, S. Dak. [Unpublished memorandum report in the files of the U. S. Geological Survey.]

beryl and scrap mica. Mrs. Wells and C. K. Koch, the mine operator, have provided the following figures for 1948:

Beryl	4,832 pounds shipped, and approximately 2,000 pounds mined but not cobbed
Scrap mica	25,270 pounds

According to Mrs. Wells (oral communication, 1951), production since 1948 has been negligible, and no production figures are available.

MINE WORKINGS

The High Climb pegmatite has been mined by two opencuts in the southern end of the body and three small opencuts to the north. The main pit extends 140 feet southeast across the southern or main part of the pegmatite (pl. 7); the pit is 50 feet wide and 42 feet deep. The main pit was originally operated from an opening in the southeast side of the pegmatite; a large dump made at that time extends 160 feet southeast from the pegmatite. More recently the lower part of the main pit has been mined through the narrow cut that opens to the northwest (pl. 7) at an altitude of 5,710 feet. A smaller opencut, 40 feet long, 30 feet wide, and 20 feet deep, is 30 feet northeast from the lower entrance to the main pit. The large dump, extending 170 feet to the northwest, consists of rock derived from operations in the lower part of the main pit and in the smaller opencut.

Three small cuts are in the northern part of the pegmatite; the largest of these is only 10 feet deep. One small prospect trench to the northeast of the pegmatite was cut in schist.

PREVIOUS WORK

In 1941 Fisher (1942, p. 17–23) prepared a generalized map of the High Climb pegmatite and the mine workings; Fisher's report includes descriptions of the geology, mineralogy, and paragenetic relations, and also sections showing the mineralogic and textural relations on the walls of the main pit. Fisher (1945, p. 18–20, figs. 4 and 5) later illustrated and described a process of so-called "albitization of microcline", using examples from the High Climb pegmatite. In 1942, W. C. Stoll [2] used Fisher's map as a base for preparing an unpublished memorandum on strategic minerals for the files of the U. S. Geological Survey. The results of Stoll's examinations were revised by J. W. Adams (Adams and Stoll, 1953, p. 131).

PRESENT INVESTIGATION

The purpose of the present investigation was to make a study of the internal structure and the lithologic units in the High Climb pegmatite, as a contribution to the Geological Survey's investigations

[2] See footnote 1, page 61.

of the pegmatites of the Black Hills. Although previous workers had prepared generalized maps and collected descriptive data, no detailed map or systematic study of the internal structure had been made.

The field work was carried out intermittently from July through December 1948. This work was done partly on behalf of the Division of Raw Materials of the Atomic Energy Commission. A detailed map (pl. 7) and geologic sections (pl. 7) were prepared, using planetable methods. R. E. Roadifer, V. R. Wilmarth, J. J. Norton, and L. R. Page assisted the writer during the mapping. A. J. Lang and D. B. Stewart measured beryl crystals on typical exposures.

Microscopic studies of grains and thin sections of pegmatite minerals were carried on at the University of Minnesota from January to June 1949.

The writer is indebted to Mrs. Gladys Wells, Mr. Fred Heidepriem, and Mr. C. K. Koch for providing production figures and information regarding the mineralogical character of mined-out parts of the main pit. The writer appreciates the advice of Professor S. S. Goldich and other staff members of the Department of Geology and Mineralogy of the University of Minnesota during the laboratory investigations.

GENERAL GEOLOGY

REGIONAL SETTING

The Black Hills of South Dakota is a mountainous area resulting from erosion of a domal uplift, the long axis of which strikes north-northwest and is 125 miles long; the uplift is about 60 miles wide. The central part of the Black Hills consists predominantly of igneous and metamorphic rocks of pre-Cambrian age that crop out in an area 60 miles long and 25 miles wide. Paleozoic and younger sedimentary rocks dip away on all sides from the pre-Cambrian area and form inward-facing scarps of hogback ridges.

The southern part of the pre-Cambrian core of the Black Hills contains many intrusives of pegmatitic rocks in a 250-square mile area surrounding Harney Peak. Many of the intrusives approach granite in texture and composition, whereas others are well-zoned pegmatites. The High Climb pegmatite is one of the well-zoned pegmatites. It lies about 5 miles west of Harney Peak (fig. 13).

METAMORPHIC ROCKS

The country rocks of the High Climb pegmatite consist of a series of metamorphosed pre-Cambrian sedimentary rocks, now mainly quartz-mica schists. The schistosity of these rocks, in general, strikes N. 20°-30° E. and dips from 40° to 85° NW. Bedding has approximately the same strike as the schistosity, but usually dips about 10 degrees less than the schistosity.

The country rock has been shown on the map as consisting entirely of quartz-mica schist, with the exception of one outcrop of graphitic schist cut by quartz stringers in the northwest corner of the area (pl. 7). Interbedded with the quartz-mica schist, however, are less abundant beds of lime silicate-quartz rock, micaceous quartzite, and porphyroblastic quartz-mica schist.

QUARTZ-MICA SCHIST

The brownish-gray to silvery quartz-mica schist crops out in well-foliated beds that alternate with micaceous quartzite, lime silicate-quartz rock, and porphyroblastic quartz-mica schist. The beds range in thickness from less than an inch to more than 12 inches. All gradations exist between schist and quartzite.

Study of thin-sections indicates that the quartz-mica schist is composed of quartz, 40 to 50 percent; biotite, 30 to 40 percent; muscovite, 10 to 20 percent; zircon, less than 1 percent; and traces of magnetite, garnet, apatite, microcline, plagioclase, and tourmaline. Most of the individual grains in the schist are about 0.01 inch or less in size. Some of the muscovite occurs in relatively coarse plates that cut across quartz grains.

MICACEOUS QUARTZITE

All gradations exist between massive, blocky micaceous quartzite and schist. In thin sections the micaceous quartzite is seen to consist of quartz, 85 to 90 percent; biotite, 10 percent; muscovite, 1 percent; zircon, less than 1 percent; tourmaline, less than 1 percent; and traces of garnet, apatite, and magnetite (?). The quartz grains have a granoblastic texture, but the platy parallelism of the mica grains gives the rock a definite schistose appearance. Skeletal tourmaline crystals are present in amounts as much as 4 percent in quartzite near small pegmatite stringers. The tourmaline has quartz inclusions and cuts across biotite flakes.

PORPHYROBLASTIC QUARTZ-MICA SCHIST

Part of the quartz-mica schist contains 5 percent or more of porphyroblasts and augenlike lenses. These rocks include quartz-mica-garnet schist, quartz-mica-garnet-chlorite schist, and quartz-mica-garnet-sillimanite schist.

The quartz-mica-garnet schist contains 5 to 10 percent garnet, in reddish-brown to pink euhedral grains ranging from less than 0.05 inch to 0.15 inch in diameter. With the exception of garnet, the proportion of other minerals is the same as in normal quartz-mica schist. The foliation ordinarily bends around the garnet grains, but in some places it is cut by the garnet. Most of the garnet crystals are euhedral and contain numerous poikilitic inclusions of quartz, but some very irregular crystals enclose both quartz and biotite. Zircon, apatite, and magnetite(?) are minor accessory minerals. Some of the apatite is granulated. Minor amounts of tourmaline occur in parts of the quartz-mica-garnet schist.

Quartz-mica-garnet-chlorite schist is similar to the quartz-mica-garnet schist, but characteristically is more crumpled and contains green-black metacrysts of chlorite, 0.2 inch to 0.5 inch in length. Some of the dark-colored metacrysts have the shape of a cross, and thin-section studies suggest that some of these metacrysts may be a result of retrogressive metamorphism of staurolite twins. Most of the garnet grains exhibit euhedral or skeletal forms and appear quite fresh, but one grain observed in thin-section has been altered to a fine-grained mass of chlorite. Pod-shaped aggregates of relatively coarse quartz and muscovite are irregularly distributed in the rock. The muscovite in these aggregates cuts across the elongated quartz grains.

Quartz-mica-garnet-sillimanite schist contains small grayish-white, augenlike lenses, 0.1 to 0.3 inch in length. Thin-section study of this schist indicates that the general composition is much like that of the quartz-mica-garnet schist, but the small lenses contain sericite and relicts of sillimanite. Sericite surrounds and apparently has replaced the sillimanite, and it cuts quartz grains around the margins of the lenses. The sericite is probably younger than the relatively coarse biotite and muscovite in the matrix of the schist.

LIME SILICATE-QUARTZ LENSES

In the northeastern part of the mapped area (pl. 7) lime silicate-quartz lenses, ranging from 1 foot to more than 20 feet in length and from 1 inch to 12 inches in thickness, are interbedded with quartz-mica schist and quartzite. The lenses have a pale reddish-white to greenish-white central layer bordered on both sides by darker colored marginal layers that characteristically have greenish-black grains of amphibole oriented parallel to the surfaces of the lenses.

The light-colored central layer shows no orientation of the minerals and is composed of quartz, 50 percent; plagioclase, 25 percent; garnet, 10 percent; pyroxene, 10 percent; zoisite and/or clinozoisite, 5 percent; and less than 1 percent sphene. The minimum index of refraction ($N\alpha'$) of cleavage fragments (001) of the plagioclase is 1.576 ± 0.001, indicating that the composition is about $Ab_{10}An_{90}$, that is, bytownite-anorthite.[3] Zoisite in irregular grains is intimately associated with the plagioclase. Some of the grains have the slightly greenish yellow interference color characteristic of clinozoisite rather than the anomalous blue color of zoisite. The pyroxene is mainly diopside, but several grains have extinction angles that indicate the variety pigeonite.

[3] The plagioclase curves used for this report are those after Tsuboi, as diagrammed by Winchell (1951, p. 280, fig. 173).

The banded marginal layers of the lenses are composed of quartz, 45 to 50 percent; amphibole, 20 to 25 percent; plagioclase, 15 to 20 percent; garnet, 5 to 10 percent; zoisite and/or clinozoisite, 5 percent; sphene, less than 1 percent; and a trace of rutile. The amphibole is probably hornblende, but was not identified specifically. The plagioclase is highly calcic, as in the central layer.

The occurrence of the lime silicate-quartz rock as conformable lenticular layers in the metamorphosed sedimentary series suggests that it was originally a calcareous sediment, probably a calcareous silt or a calcareous argillaceous sand. The presence of pyroxene in the central layer and amphibole—but no pyroxene—in the well-banded marginal layers is not so easily explained. Runner and Hamilton (1934, p. 51–64) have studied similar rocks in the southern Black Hills, but their report deals mainly with metamorphosed concretions that have similar characteristics. They suggest that there were two periods of metamorphism: an early period in which the lime silicate minerals and quartz were formed, and a later period in which outer layers were altered under stress to a banded amphibole-bearing rock.

GRAPHITIC SCHIST

Dark-colored graphitic schist crops out along the northwestern margin of the mapped area (pl. 7). The schist is cut in an intricate manner by abundant, irregular quartz veins. In thin-sections the graphitic material obscures the other minerals, but there are abundant minute crystals of tourmaline, in addition to graphite, quartz, biotite, and muscovite. The tourmaline may have been introduced at the time of the formation of the quartz veins.

ALTERED ROCKS ADJACENT TO PEGMATITE

The country rock along the pegmatite contacts has been variously altered to tourmaline-rich schist, muscovite-rich schist, and a nonschistose rock consisting of tourmaline, quartz, and plagioclase. The altered rock does not form a complete shell surrounding the pegmatite; along much of the contact no significant alteration was observed. The outcrops of altered rock have not been differentiated from "quartz-mica schist" on the map (pl. 7) because of their small size and irregular distribution. Thin stringers of pegmatite (less than 0.25 inch thick) are common as lit-par-lit injections in the altered rock.

Tourmaline is the characteristic mineral of most of the altered rock; it forms as much as 75 percent of the rock near the pegmatite contact, but decreases in abundance outward from the pegmatite. The thickness of the tourmaline-rich schist rarely exceeds 4 feet. Tourmaline crystals are euhedral and have irregular color zoning—from brown through grayish to light green. Quartz is included in the tourmaline. Quartz generally forms at least 25 percent of the tourmaline-rich schist, and muscovite is an esential constitutent of the outer part of the altered zone. Accessory minerals are zircon, apatite, garnet, plagioclase, and microcline. In some places thin continuous layers of relatively coarse quartz are parallel to the schistosity.

A nonschistose rock, usually less than 6 inches thick and consisting mainly of tourmaline, quartz, and plagioclase, occurs along some of the discordant pegmatite contacts. Although the platy minerals are not parallel, this rock is very similar in character to the tourmaline-rich schist.

A less common type of altered rock, a schist, containing as much as 80 percent muscovite, occurs as a 6-inch layer along part of the pegmatite contact. Clusters of tiny crystals of green apatite are abundant in this schist one-fourth to one-half inch from the pegmatite contact. The muscovite (average grain size, 0.05 inch) is generally coarser than in schist farther from the contact.

PEGMATITE

The High Climb pegmatite is a lenticular, well-zoned body containing quartz, albite, microcline-perthite, muscovite, tourmaline, beryl, amblygonite, apatite, columbite-tantalite, loellingite, spodumene, many dark-colored phosphate minerals, a manganese-bearing carbonate, garnet, and chalcopyrite. Fisher (1942, p. 22) also found a brown mineral resembling strueverite or tapiolite on the dump.

Many small pegmatite stringers intrude the metamorphic rocks in both lit-par-lit and crosscutting relationships. Most of the stringers are from less than one-half inch to 1½ inches thick and commonly show "pinch-and-swell" structure. Some stringers are largely quartz with minor plagioclase; others contain differing proportions of microcline-perthite, quartz, plagioclase, muscovite, apatite, and tourmaline. The texture of the stringers is usually fine grained. The thicker stringers contain muscovite, quartz, and plagioclase in a fine-grained marginal zone, and potash feldspar in a coarser grained central zone.

QUARTZ VEINS

Milky to colorless quartz veins, ranging from less than 6 inches to 3 feet in thickness, are abundant in the High Climb area. For the most part they are concordant, but some cut and distort the schistosity. No complete gradation could be traced from pegmatite to veins consisting solely of quartz, but some of the lit-par-lit pegmatite stringers consist mainly of quartz with only a small amount of plagioclase.

HIGH CLIMB PEGMATITE

SIZE, SHAPE, AND STRUCTURE

The outcrop of the High Climb pegmatite has a tadpole shape (pl. 7), is 335 feet long, trends N. 10° E., and is as much as 180 feet wide

FIGURE 14.—Large outcrop of schist at east corner of main pit, High Climb pegmatite. Schist inside the white and black lines is bounded on both sides by pegmatite. This structure constitutes a major fingerlike roll plunging 57° N. 40° W.

(in the vicinity of the main pit); the maximum thickness is about 85 feet (pl. 7, section *C–C′*). The pegmatite dips to the west and, in general, is roughly concordant with the schistosity. The strike of the schistosity ranges from north to N. 55° E.; the dip is from 38° to 84° W. Locally the pegmatite contact crosscuts the schistosity.

The main or southern part of the pegmatite has a pipelike structure with an elliptical to thickly lenticular cross section (pl. 7, sections *C–C′*, *D–D′*, *E–E′*). The average plunge is about 45° N. 40° W. The shape of the pegmatite is complicated by large fingerlike rolls, most of which are exposed on the eastern or footwall side of the intrusive. Perhaps the most conspicuous of the irregularities is at the east corner of the main pit (fig. 14), where a large arcuate offshoot from the pegmatite extends around the eastern side of an outcrop of schist. The plunge of this structure is 57° N. 40° W., but the angle of plunge

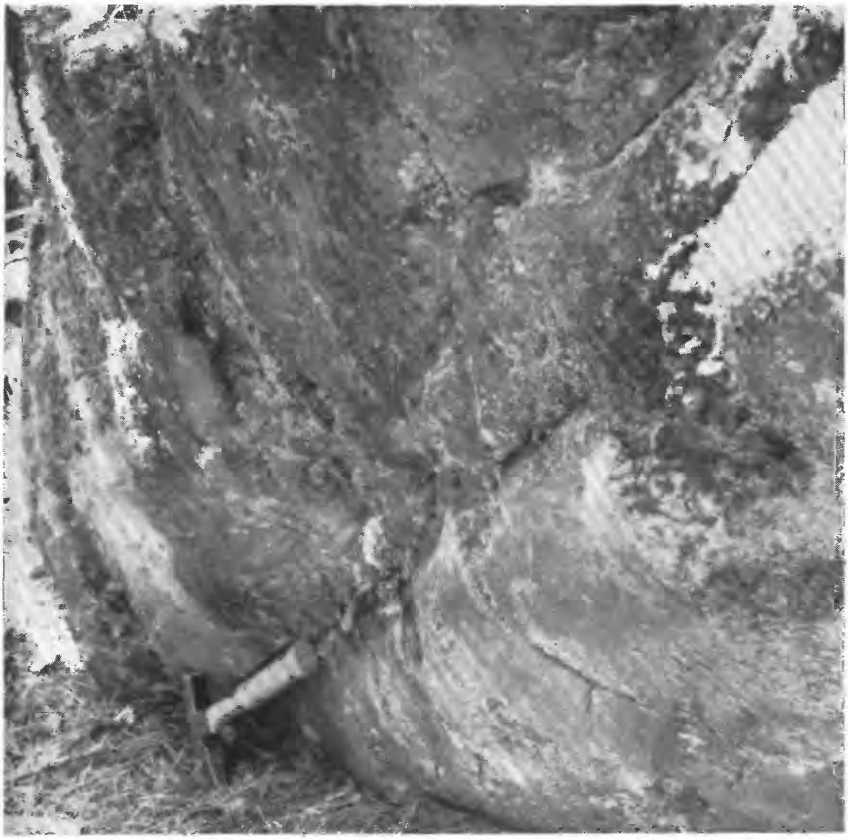

FIGURE 15.—Roll in pegmatite contact, southern end of northern part of High Climb pegmatite. Axis of roll (in line with handle of pick) plunges 46° S. 88° W.

apparently decreases at depth. Another prominent roll in the contact exposed in the southeast end of the main pit (pl. 7) plunges 45° N. 40° W. Other rolls in the south wall of the main pit plunge 30° to 40° N. 32° W. The position of the hanging-wall contact is obscure, and consequently the shape of the pegmatite northwest of section *C–C′* (pl. 7) is not well known. Likewise, the structure of the extreme southern part of the body is imperfectly known; its shape in cross section has been determined by projecting the inferred contacts downplunge. Most of the footwall of the southern half of the pegmatite is concordant with the foliation in the schist, but locally along some of the sharp rolls and in the extreme southern part of the body the footwall contact cuts the foliation.

A small northern extension of the pegmatite is separated at the surface from the larger southern part by a small area of overburden, schist, and a few small outcrops of pegmatite (pl. 7). Although there is no conclusive evidence that the two parts of the pegmatite are joined

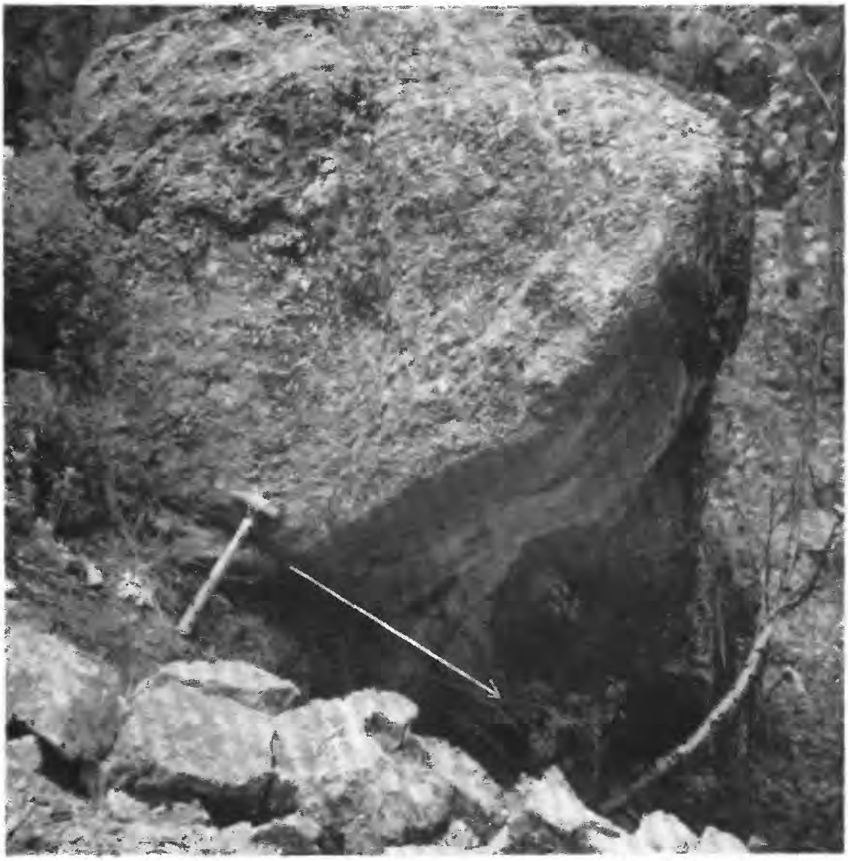

FIGURE 16.—Large roll in pegmatite contact, northeast side of High Climb pegmatite. Axis of the roll (white arrow) plunges 32° N. 20° W.

at the surface, as shown on the map (pl. 7), a roll in the contact (fig. 15) plunging 46° S. 88° W. at the southern end of the northern extension of the pegmatite suggests that they join, at least at depth.

The northern part of the pegmatite is lenticular, but only the crest is exposed. The contacts are complicated by many rolls (pl. 7 and fig. 16). One crestal roll trends north across the central part of the northern extension of the pegmatite; this roll is nearly horizontal and may be a relatively shallow feature. Other rolls plunge 15° to 66° N. 12° W. to N. 60° W.; the average plunge is 28° N. 25° W. The footwall contact, on the northeast side of the outcrop, has an average dip of about 75° SW. Exposures of the hanging wall contact are fewer, but the dips range from 28° to 70° SW. The dike apparently widens slightly below the surface before pinching out in depth. Projections from the surface exposures suggest that the maximum thickness of the concealed part of the northern half of the pegmatite is probably not more than 55 feet.

The High Climb pegmatite is cut by many fractures, most of which are small, very irregular, branching, and discontinuous. None of the fractures, with the exception of a single prominent joint in the southern part of the body, are shown on the map (pl. 7). One poorly exposed fracture in the north wall of the main pit may be a fault with a displacement of about 1 foot. Some of the fractures near phosphate-rich parts of the pegmatite are heavily stained by iron and manganese oxides.

PEGMATITE UNITS

In accordance with the classification of internal structural units in pegmatites as defined by Cameron, Jahns, McNair, and Page (1949, p. 14), 5 units have been mapped in the High Climb pegmatite: a wall zone, 3 intermediate zones, and a central zone or core. In addition to these units a possible sixth zone (or replacement unit?) and a fracture-filling unit were recognized.

A wall zone of albite-quartz pegmatite forms an almost continuous shell around the pegmatite (pl. 7). In some outcrops a very thin discontinuous border zone rich in quartz and muscovite occurs along the pegmatite contact; because of the small volume of this zone, it has not been mapped and its description is included in that of the wall zone. Along some of the rolls the wall zone is locally absent and the first intermediate zone lies adjacent to the schist (for example, pl. 7, section *D–D′*, footwall of the pegmatite). The first intermediate zone, composed of albite-quartz-muscovite pegmatite, is discontinuous along the crest of the pegmatite, but it is rarely, if ever, absent on the footwall side of the pegmatite. The second intermediate zone is an arcuate-shaped unit composed of perthite-quartz-albite pegmatite that is confined to the crest and hanging wall side of the pegmatite (pl. 7). This unit forms a hood above the quartz-cleavelandite pegmatite of the third intermediate zone. The core is quartz pegmatite.

The average mineralogic composition of each of the five zones in the High Climb pegmatite is given in table 1. The size classification for pegmatite textures in this report conforms to the system of Cameron, Jahns, McNair, and Page (1949, p. 16) as follows:

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

Small fracture fillings of quartz-perthite-muscovite-albite pegmatite occur in the wall zone in the southern part of the pegmatite. Some of the waste rock on the dump southeast of the pegmatite suggests that a unit composed of very fine yellowish to grayish mica has been completely mined out. This may have been a discontinuous zone or a replacement body.

309393—55——3

TABLE 1.—*Average mineralogic composition of zones in the High Climb pegmatite, based on visual estimates of all exposures*

Zone	Texture[1]	Average grain size (in.)	Average mineralogic composition (percent)															
			Albite (An_{3-4})[2]	Quartz	Muscovite	Tourmaline	Perthite	Beryl	Amblygonite (var. montebrasite)	Apatite	Unidentified phosphate minerals[3]	Garnet	Loellingite	Manganese-bearing carbonate	Chalcopyrite	Altered spodumene[4]	Chlorite(?)	Columbite-tantalite[5]
Albite-quartz pegmatite (wall zone).	Fine	0.1	63	26	4	3	3	<1	0	<1	<1	<1	0	0	0	0	0	0
Albite-quartz-muscovite pegmatite (first intermediate zone).	Medium	1.0	38	33	22	4	<1	1	<1	<1	1	0	<1	([7])	0	0	0	0
Perthite-quartz-albite pegmatite (second intermediate zone).	Coarse	8.0	19	29	1	<1	50	0	([7])	<1	<1	0	([7])	([7])	0	0	0	0
Quartz-cleavelandite pegmatite (third intermediate zone).	Medium	1.25	[6]44	48	4	1.5	0	<1	<1	<1	1.5	0	<1	([7])	([7])	0	([7])	([7])
Quartz pegmatite (core)	Massive		0	97	0	0	0	0	0	0	0	0	0	0	0	3	0	0

[1] Classification after Cameron, Jahns, McNair, and Page, 1949, p. 16.

[2] The plagioclase curves used for this report are those after Tsuboi, as diagrammed by Winchell (1951, fig. 173, p. 280).

[3] Unidentified phosphate minerals include dark-brown, dark-green, and purplish-brown minerals, probably largely of the lithiophilite-triphylite group, but may also include heterosite (purpurite), triplite, and others.

[4] Altered spodumene is white to yellowish-white, very fine-grained micaceous material, some of which may be eucryptite(?); the largest remnant of an altered spodumene crystal is 3 feet long and 9 inches wide.

[5] C. K. Koch, mine operator, reported that columbite-tantalite had been found only in parts of the quartz-cleavelandite pegmatite in the northwest end of the main pit during mining operations prior to 1948. This mineral was not found by the writer in the present exposures.

[6] All the albite in the third-intermediate zone is the platy variety, cleavelandite.

[7] Trace.

ALBITE-QUARTZ PEGMATITE

The albite-quartz pegmatite or wall zone forms a shell around most of the High Climb pegmatite. Locally, however, the wall zone is absent, and the first intermediate zone is in contact with schist. The thickness of the wall zone is as much as 14 feet along the footwall of the pegmatite (pl. 7, section *B–B′*). The average thickness along the footwall in the southern or main part of the pegmatite is about 4 feet, and in the northern part between 6 inches and 1 foot. The overall average grain size of the wall zone is about 0.1 inch.

Along the crest of the northern part of the pegmatite the wall zone is thin and discontinuous. Albite-quartz pegmatite forms about 60 percent of the exposures mapped as wall zone in the northern area (pl. 7), and the rest is albite-quartz-muscovite pegmatite (first intermediate zone) in patches too small to map.

The mineralogic composition and grain size of the wall zone differ from place to place (table 2). Three main types of wall zone have been mapped as a single structural unit on the basis of texture, because all are fine-grained (average grain size less than one inch) in contrast to the medium-grained intermediate zones. All three types contain albite and quartz as the predominant essential minerals, but the proportions of tourmaline, muscovite, and perthite are variable. Lack of exposures in critical areas prevented the study of possible "telescoping" (Cameron, Jahns, McNair, and Page, 1949, p. 19) of these types of wall zone.

TABLE 2.—*Variations in grain size and mineralogic composition of albite-quartz pegmatite (wall zone), High Climb pegmatite*

Locat on	Average grain size[1] (inches)	Mineralogic composition (percent)								
		Albite	Quartz	Muscovite	Tourmaline	Perthite	Apatite	Garnet	Unidentified phosphate minerals	Beryl
In sugary-textured type, along footwall in main pit (southern part of pegmatite) and in several irregular outcrops in the northern part of the pegmatite	0.03	71	19	1	8	0	<1	0	<1	0
Wall zone in rest of southern part of the pegmatite	.25	66	20	5	<1	8	<1	<1	0	<1
Most of the wall zone in northern part of the pegmatite	.15	59	34	5	<1	0	<1	1	0	<1
Average[2]	0.1	63	26	4	3	3	<1	<1	<1	<1

[1] Average grain size means the average maximum dimension of the grains.

[2] Mineralogic composition—compiled from visual estimates at many exposures of the zone; the percentages for each of the three types were weighted against the estimated volume of each type.

In addition to the three main types of the wall zone, another subdivision could be made on some of the dip slopes and along some of the contacts where the outer 0.5 to 2 inches is relatively rich in quartz and muscovite. Because the total volume of this "border zone" is negligible and because it is irregularly distributed, it was not mapped as a unit, and its mineralogic composition was not computed separately from the rest of the wall zone.

Mineralogical data for the albite-quartz pegmatite (wall zone) are given in table 3. Thin sections of the sugary-textured (0.03 inch grain size) type show that tourmaline crystals have inclusions of quartz and albite and show color zoning from blue at the edge to yellow-brown near the center. Microcline-perthite occurs as blocky grains in part of the wall zone in the southern part of the pegmatite. (All perthite in the High Climb pegmatite is microcline-perthite.) Iron and maganese oxides, resulting from the alteration of phosphate minerals, cause irregular straining of much of the sugary-textured footwall part of the albite-quartz pegmatite. Beryl occurs only along gradational contacts with the first intermediate zone. It is commonly much less than 0.5 percent of the wall zone, whereas it generally constitutes 1 percent of the first intermediate zone. Optical properties of the beryl are the same as those of beryl in the first intermediate zone.

ALBITE-QUARTZ-MUSCOVITE PEGMATITE

Albite-quartz-muscovite pegmatite forms the first intermediate zone in the High Climb pegmatite. On some of the rolls and in places along the footwall of the southern half of the pegmatite, where the wall zone is absent, the first intermediate zone is in direct contact with the schist. The first intermediate zone borders the third intermediate zone in the keelward and footwall parts of the pegmatite and borders the second intermediate zone along the hanging wall side and the crest (pl. 7). The first intermediate zone is as much as 5 feet thick; the average thickness is about 2.5 feet. The zone is thickest along the complex rolls on the footwall of the southern part of the pegmatite. The average size of individual grains is about 1 inch, but the grain size ranges widely.

The average mineralogic composition of the albite-quartz-muscovite pegmatite is shown in table 4. The relative proportions of albite and muscovite range widely. In most of the exposures of the zone, muscovite forms at least 20 percent and in a few it constitutes as much as 50 percent of the zone. In the northern segment of the pegmatite, fine-grained (average 0.5 inch) albite-rich areas are irregularly distributed in the zone. These contain albite (55 percent), quartz (25 to 30 percent), muscovite (10 percent), tourmaline (3 percent), beryl (as much as 3 percent), amblygonite (variety, montebrasite) (1 percent), and accessory apatite and dark-colored phosphate minerals.

TABLE 3.—*Mineralogy of albite-quartz pegmatite (wall zone), High Climb pegmatite*

Mineral	Average composition of zone (percent)	Size of mineral (in.)		Occurrence	Color	Optical data	Remarks
		Range	Average [1]				
Albite	63	0.01–0.5	0.02 (in sugary-textured type); 0.1 (in other types).	Blocky to subplaty grains	White	$N_\alpha'=1.529$ to 1.530 (±0.001) [2] (composition, An_3–An_4).	
Quartz	26	0.01–0.6	0.1 (sugary-textured type); 0.2 (in other types).	Irregular grains and masses intimately intergrown with plagioclase.	Colorless to slightly milky.		
Muscovite	4	0.01–0.75	0.2	Tabular flakes	Yellowish to silvery		
Tourmaline	3	0.02–0.75	.2	Euhedral grains	Black to bluish-black	Bluish-black: $N_\omega=$ 1.659–1.669 (zoned crystals).	Optical data are from the sugary-grained type of wall zone.
Perthite	3	0.3–4.0	1.75	Blocky grains	Buff-white to flesh		
Apatite	<1		<0.1	Rounded grains	Greenish-blue to green	One greenish-blue grain: $N_\omega=1.642$, $N_\epsilon'=1.637$ (probably a hydroxylapatite).	
Garnet	<1	0.01–0.2	.1	Rounded grains irregularly distributed.	Reddish-brown		
Unidentified phosphate minerals.	<1	0.1–3.5	.75	Irregular grains irregularly distributed along inner edge of wall zone near phosphate-rich parts of first intermediate zone.	Brownish to gray-black		Probably minerals of lithiophilite-triphylite group, but may also include heterosite (purpurite), triplite, and others.
Beryl	<1	0.5–2.5	1.0	Euhedral grains	White	(Optical data are included in table 4.)	Occurs only along gradational contacts of wall zone and albite-rich parts of first intermediate zone.

[1] The "average" size is the average maximum dimension of the grains of each mineral.

[2] N_α' is the minimum index of refraction, as determined on cleavage fragments (001). The plagioclase curves used for this report are those after Tsuboi, as diagrammed by Winchell (1951, fig. 173, p. 280).

TABLE 4.—*Mineralogy of albite-quartz-muscovite pegmatite (first intermediate zone), High Climb pegmatite*

Mineral	Average composition of zone (percent)	Size of mineral (in.)		Occurrence	Color	Optical data	Remarks
		Range	Average [1]				
Albite	38	0.1–2.5	0.75	Mostly platy (var. cleavelandite). Blocky to subplaty in the relatively fine grained, mica-poor parts of the zone.	White to grayish-white	$N_{\alpha}' = 1.529$ to 1.530 (± 0.001),[2] (Composition, An_3 to An_4).	Aggregates of platy albite are as large as 5 inches in diameter.
Quartz	33	0.1–5.0	1.25	Irregular grains and masses.	Colorless to milky		
Muscovite	22	0.1–10.0	3.0	Tabular flakes and books.	Silvery, yellowish-silvery, pale ruby, and pale greenish-brown.		Some of the muscovite contains mineral inclusions (tourmaline, cleavelandite, and quartz) and hair cracks; most of the muscovite has varying proportions of "A" and herringbone structures.
Tourmaline	4	0.75–12.0	2.5	Subhedral to euhedral grains.	Black to greenish-black.		Anhedral bluish-black tourmaline forms intimate intergrowths with other minerals in phosphate-rich parts of the zone.
Beryl	1	0.5–10.0 (length).	3.5 (length) 1.5 (diameter).	Euhedral grains	White to greenish-white, generally stained in part by reddish-brown iron oxides.	$N_{\omega} = 1.5794$ to 1.5865 (± 0.0005). Complexly zoned; very small chips from various parts of the crystals have a difference in index (N_{ω}) of as much as 0.0030. Nearly all the crystals have higher indices in outer parts of grains than in centers of grains, but in one grain the higher index is in the center.	Thin sections indicate that many beryl crystals are veined by muscovite and quartz. At the edges of some grains, beryl and albite are intergrown, with evidences of each replacing the other. The prism faces of the beryl grains are commonly grooved where they are in contact with muscovite books. A thin coating of very fine muscovite generally occurs along the contact of beryl with quartz and albite. The beryl commonly carries a network of fine dusty alteration (clay minerals?), associated with varying quantities of iron stain. Liquid and gas inclusions are common.

Unidentified phosphate minerals.	1	0.1–3.5	0.75	Irregular grains	Brown, gray-black, dark-green and purplish-brown.		Some are probably members of the lithiophilite-triphylite group, others may be heterosite and triplite. Alteration products, including vari-colored iron and manganese oxides, occur as heavy stains on other minerals in the immediate vicinity of phosphate mineral concentrations.
Amblygonite, var. montebrasite.	<1	0.5–3.0	1.25	Rounded grains	Grayish-white	$N\gamma'$=1.634 to 1.638 (±0.002). Usually it is coated with a white dusty alteration product, the identity of which is unknown.	Montebrasite is chiefly in the albite-rich parts of the first intermediate zone. In the phosphate-rich pods, it is commonly veined by the dark-colored phosphate minerals and is intimately intergrown with anhedral blue-black tourmaline.
Apatite	<1		<0.1	Rounded grains	Bluish-green to green		A few anhedral grains, intimately intergrown with albite, are as large as 1 inch.
Perthite	<1	4–18	10	Blocky grains	Flesh to buff-white		Distributed irregularly along contacts with second intermediate zone.
Loellingite	<1	0.1–1.5 (length) 0.05–0.3 (diameter).	0.5 (length) 0.1 (diameter).	Euhedral grains, generally prismatic and elongate.	Silvery		Occurs in phosphate-rich pods.
Manganese-bearing carbonate.	(3)			Fine-grained intergrowth in phosphate-rich pods.	Pinkish-buff		Qualitative chemical tests indicated the presence of considerable manganese in the carbonate, which is probably between rhodochrosite and siderite in composition.

[1] Except where specific dimensions are noted, the "average" size is the average maximum dimension of the grains of each mineral.

[2] N_α' is the minimum index of refraction, as determined on cleavage fragments (001). The anorthite content of the albite is based on the curves after Tsuboi, as diagrammed by Winchell (1951, fig. 173, p. 280).

[3] Trace.

Optical data and descriptions of the minerals of the albite-quartz-muscovite pegmatite (first intermediate zone) are included in table 4. In most of the zone the albite is platy (variety, cleavelandite), but in the relatively fine-grained mica-poor parts of the zone, it is blocky to subplaty. The maximum index of refraction ($N\omega$) of the beryl ranges from 1.5794 to 1.5865 ($\pm$0.0005). An unpublished curve[4] compiled by W. T. Schaller of the U. S. Geological Survey shows that the BeO content of beryl having these indices ranges from 13.10 percent for the grains of lowest index to 12.35 percent for grains of the highest index. Unidentified dark-colored phosphate minerals intimately intergrown with other minerals of the zone are commonly concentrated in irregular, heavily-stained pods, from 1 foot to 6 feet in length, along the inner edge of the zone; the pods contain as much as 10 percent phosphate minerals. Some of these minerals are probably members of the lithiophilite-triphylite group. Fisher (1942, p. 19) has reported heterosite and triplite in the phosphate-bearing rocks of the High Climb pegmatite. Amblygonite (variety, montebrasite) commonly occurs in the albite-rich parts of the zone. The maximum index of refraction ($N\gamma'$) of the montebrasite ranges from 1.634 to 1.638 ($\pm$0.002), which, according to Winchell's curves (1951, p. 224, fig. 121), places the mineral at the extreme montebrasite end of the amblygonite-montebrasite series. A partial analysis of the montebrasite, made by C. M. Warshaw and W. W. Brannock of the U. S. Geological Survey, gave the following:

Oxide	*Percent*
Al_2O_3	33.15
Li_2O[a]	9.51
H_2O[b]	4.88
F	.59

[a] Determined with flame photometer by W. W. Brannock.
[b] Averages of three determinations of total H_2O.

In the phosphate-rich parts of the zone, the montebrasite is intimately intergrown with anhedral blue-black tourmaline and commonly is veined by the dark-colored phosphate minerals.

PERTHITE-QUARTZ-ALBITE PEGMATITE

Perthite-quartz-albite pegmatite forms the second intermediate zone in the High Climb pegmatite. In the southern half of the pegmatite this zone is arcuate in cross section (pl. 7, sections *C–C'*, *D–D'*, and *E–E'*) and occurs as a hood above the inner zones. The maximum thickness of the unmined parts of the zone is 26 feet (pl. 7, section *A–A'*). The zone thins away from the crest of the pegmatite, and on the footwall side it pinches out completely. Only the upper parts

[4] Schaller, W. T., Curves showing the relation of the maximum index of refraction (Nw) of beryl to the specific gravity and BeO content. (Unpublished manuscript in files of the U. S. Geological Survey.)

of the second intermediate zone are exposed in the northern half of the pegmatite, and its full extent is not known. The overall, average size of individual grains in the zone is about 8 inches, but the size of grains varies widely. Relatively large perthite crystals are enclosed in a matrix of relatively fine grained quartz and albite.

The average mineralogic composition of the perthite-quartz-albite pegmatite (second intermediate zone) is shown in table 5. Variations in the mineralogical composition of the zone are chiefly in the proportion of perthite. The upper parts, near the crest of the pegmatite, contain as much as 75 percent perthite; the percentage of perthite decreases downward and the lower parts of the zone contain as little as 25 percent perthite. In the northern part of the pegmatite, perthite grains averaging 1 foot in size constitute 60 percent of the visible exposures, and the quartz is probably more abundant in the matrix than in the southern part of the pegmatite.

Optical data and descriptions of the minerals of the perthite-quartz-albite pegmatite (second intermediate zone) are given in table 5. Unidentified dark-colored phosphate minerals are associated with amblygonite (variety, montebrasite), loellingite, manganese-bearing carbonate, and bluish-black anhedral tourmaline. These are distributed in heavily stained aggregates along the zonal contacts with the first and third intermediate zones.

QUARTZ-CLEAVELANDITE PEGMATITE

Quartz-cleavelandite pegmatite of the third intermediate zone underlies the hood-shaped second intermediate zone. In the lower parts of the pegmatite the third intermediate zone is in contact with the first intermediate zone (pl. 7). Quartz-cleavelandite pegmatite forms a shell ranging in thickness from 2 feet to 30 feet—average about 14 feet—around the quartz core. The average size of individual grains is about 1.25 inches, but the average size of aggregates of grains is about 3 inches.

The average mineralogic composition of the quartz-cleavelandite pegmatite (third intermediate zone) is shown in table 6. Several exposures of the innermost 1 to 2 feet of the zone, marginal to the quartz core, contain as much as 70 percent of cleavelandite and 10 percent montebrasite. In other exposures quartz forms 60 percent of the zone, cleavelandite only 35 percent, and montebrasite is absent.

Descriptive data for individual minerals of the third intermediate zone are listed in table 6. All the plagioclase in this zone is the platy variety of albite, cleavelandite. The phosphate-rich parts of the zone are generally in elongate heavily-stained pods, as much as 10 feet in length, and are most common near the zonal contacts with the other intermediate zones.

TABLE 5.—*Mineralogy of perthite-quartz-albite pegmatite (second intermediate zone), High Climb pegmatite*

Mineral	Average composition of zone (percent)	Size of mineral (in.)		Occurrence	Color	Optical data	Remarks
		Range	Average [1]				
Perthite	50	6–60	15	Blocky grains	Flesh-white to buff creamy white.	Most thin sections of perthite grains show albite intergrown with microcline as "vein" and "patch" perthite. For this albite in the perthite, $N_\alpha'=1.5300$ (±0.0005), composition An_4.	The perthite grains are set in a matrix of quartz and albite; the texture of the matrix is very similar to the texture of the third intermediate zone. Some of the perthite grains are rounded and embayed by the matrix. Perthite and the albite of the matrix are mutually intergrown; in some thin sections, albite of the matrix appears to replace microcline in the perthite, but in others microcline veins and replaces albite.
Quartz	29	0.2–4	1.5	Irregular grains and masses.	Colorless to milky		
Albite	19	0.1–3	0.75	Mostly platy grains; minor amounts as blocky to subplaty grains.	White	$N_\alpha'=1.529$ to 1.530 (±0.001) [2] (composition An_3 to An_4).	Aggregates of platy albite as large as 4 inches in size generally occur as irregular intergrowths with quartz.
Muscovite	1	0.05–3	0.75	Tabular flakes and books.	Silvery to yellowish-silvery.		Sparsely distributed in the quartz-albite matrix.
Tourmaline	<1	0.5–5	1.5	Subhedral to euhedral grains.	Black to greenish-black.	Apparently zoned greenish-black tourmaline: $N_\omega=1.653$ to 1.656 (±0.002).	Anhedral bluish-black tourmaline occurs in the heavily stained aggregates of phosphate minerals.
Apatite	<1		<0.1	Rounded grains	Bluish-green to green		
Unidentified phosphate minerals.	<1	0.1–3.5	0.75	Irregular grains	Brown, gray-black, dark green, and purplish-brown.		Some are probably members of the lithiophilite-triphylite group, some may be heterosite and triplite.

Amblygonite (var. montebrasite).	Tr.	0.5–3.0	1.25	Rounded grains	Grayish-white	N_γ' = 1.634 to 1.638 (±0.002).	Montebrasite occurs in the phosphate-rich aggregates; commonly veined by dark-colored phosphate minerals and intimately intergrown with anhedral blue-black tourmaline.
Loellingite	Tr.	0.1–1.5 (length) 0.05–0.3 (diameter).	0.5 (length) 0.1 (diameter).	Euhedral grains, generally prismatic and elongate.	Silvery		Occurs in the phosphate-rich aggregates.
Manganese-bearing carbonate.	Tr.			Fine-grained intergrowth in phosphate-rich aggregates.	Pinkish-buff		Qualitative chemical tests indicated considerable manganese in the carbonate, which is probably between rhodochrosite and siderite in composition.

[1] Except where specific dimensions are noted, the "average" size is the average maximum dimension of the grains of each mineral.

[2] N_α' is the minimum index of refraction, as determined on cleavage fragments (001). The anorthite content of the albite is based on the curves after Tsuboi, as diagrammed by Winchell (1951, fig. 173, p. 280).

TABLE 6.—*Mineralogy of quartz-cleavelandite pegmatite (third intermediate zone), High Climb pegmatite*

Mineral	Average composition of zone (percent)	Size of mineral (in.)		Occurrence	Color	Optical data	Remarks
		Range	Average [1]				
Quartz	48	0.2–12	1.5	Irregular grains and masses.	Colorless to milky		
Albite, var. cleavelandite.	44	0.5–3.5	0.75	Platy grains	White to grayish-white.	N_α' = 1.529 to 1.530 (±0.001) (composition An_3 to An_4).[2]	Aggregates and radiating rosettes of cleavelandite are as much as 12 inches in diameter.
Muscovite	4	0.05–6	1.75	Tabular books and flakes.	Yellowish-silvery to pale greenish-silvery.		
Tourmaline	1.5	0.5–12	4	Subhedral to euhedral Anhedral	Greenish-black to black. Bluish-black		Anhedral grains of bluish-black tourmaline are intergrown with other minerals in the phosphate-rich parts of the zone. Elsewhere in the zone tourmaline is subhedral to euhedral and greenish-black to black.
Unidentified phosphate minerals.	1.5	0.1–3.5	0.75	Irregular grains	Brown, gray-black, dark green, and purplish-brown.		Some of these minerals are probably members of the lithiophilite-triphylite group, but some may be heterosite and triplite. Alteration products of the phosphate minerals, including varicolored iron and manganese oxides, occur as heavy stains on the other minerals of the zone in the immediate vicinity of the phosphate-rich parts of the zone.
Amblygonite, var. montebrasite.	<1	0.5–8	3.5	Rounded grains	White to grayish-white.	Optically (+) N_γ' = 1.634 to 1.638 (±0.002) N_β' = 1.620 to 1.629 (±0.002) N_α' = 1.608 to 1.609 (±0.002) Birefringence of some grains is as much as 0.026.	Most of the montebrasite is in the core-margin parts of the zone, but a few grains are scattered irregularly through the rest of the zone. Visual estimates indicate an average content of 0.25 to 0.5 percent. The specific gravity of one sample was found to be 2.94. In thin section the montebrasite shows multiple lamellar twinning and is cut by quartz veins 0.03 inch thick.

Beryl	<1	0.5–12 (length).	3.5 (length) 1.5 (diameter).	Euhedral grains	White to greenish-white.	(Optical data are included in table 4.)	Beryl occurs only at the extreme outer edge of the zone along contacts with the first intermediate zone.
Apatite	<1		<0.1	Subhedral grains	Green to bluish-green		
		As much as 1.5.		Anhedral masses intergrown with cleavelandite.			
Loellingite	<1	0.1–1.5 (length) 0.05–0.3 (diameter).	0.5 (length) 0.1 (diameter).	Euhedral grains, generally prismatic and elongate.	Silvery		Occurs in the phosphate-rich pods.
Manganese-bearing carbonate.	Tr.			Fine-grained intergrowth in the phosphate-rich pods.	Pinkish-buff		Qualitative chemical tests indicated the presence of considerable manganese in the carbonate, which is probably between rhodochrosite and siderite in composition.
Chalcopyrite	Tr						One polished section of a sample of the phosphate-rich rock contained tiny grains of chalcopyrite associated with loellingite crystals.
Chlorite(?)	Tr.						One thin section of phosphate-rich rock contained traces of a green micaceous mineral with optical characteristics of chlorite, intergrown with dark phosphate minerals and the manganese-bearing carbonate.
Columbite-tantalite.	Tr. (?)			(3)			

1 Except where specific dimensions are noted, the "average" size is the average maximum dimension of the grains of each mineral.

2 $N\alpha'$ is the minimum index of refraction, as determined on cleavage fragments (001). The anorthite content of the cleavelandite is based on the curves after Tsuboi, as diagrammed by Winchell (1951, fig. 173, p. 280).

3 Mr. C. K. Koch (oral communication, 1948) stated that columbite-tantalite occurred in parts of the third intermediate zone that were mined from the northwestern end of the main pit. It was also reported by Fisher (1942, p. 21), but no specimens were found by the author.

QUARTZ PEGMATITE

The quartz core is entirely enclosed by the third intermediate zone. In cross section (pl. 7) the shape of the core is thinly to thickly lenticular. The texture is massive.

The core is composed of milky to colorless quartz (97 percent) and altered spodumene (3 percent). Remnants of altered spodumene crystals, as much as 3 feet in length, are diversely oriented in a matrix of massive quartz in the north wall at the northwest end of the main pit (pl. 7). The alteration products of the spodumene are chiefly white to yellowish-white fine micaceous materials, some of which may be eucryptite. A thin section of part of one spodumene relict shows an aggregate of very fine-grained pale-yellowish micaceous material intergrown with small quantities of fine-grained quartz and albite.

QUARTZ-PERTHITE-MUSCOVITE-ALBITE PEGMATITE

Fracture-filling units of quartz-perthite-muscovite-albite pegmatite cut the wall zone south of the main pit. The largest fracture fillings are only 2 feet long and 6 inches wide, and cannot be shown on the map. The average grain size is about 3 inches.

The fracture fillings are estimated to contain quartz (45 percent), perthite (35 percent), muscovite (10 percent), and albite (10 percent). Colorless to milky quartz and flesh-colored perthite grains are 2 to 8 inches in maximum size. Subplaty to platy albite is intergrown with quartz. Yellowish-silvery muscovite books, averaging about 0.75 inch in size, commonly occur at the margins of the fracture fillings.

MUSCOVITE PEGMATITE

Blocks of very fine-grained muscovite pegmatite were found on the large dump southeast of the main pit, but similar rock was not found in place. The rock is composed almost entirely of yellowish to grayish muscovite flakes, less than 0.2 inch in size, intergrown with a little platy albite and quartz. Some of the muscovite-rich material is associated with coarse perthite blocks that are apparently corroded and embayed by the mica. This fine-grained muscovite pegmatite may have been derived from a discontinuous zone adjacent to the second intermediate zone or from a replacement unit of unknown shape and position. The color of the material suggests that it may be a lithium-bearing mica, but Fisher (1942, p. 22) reports that this mineral is not lepidolite but muscovite.

ORIGIN

The High Climb pegmatite has many of the characteristics that led Page and others (1953, p. 17–24) to conclude that zoned pegmatites of the Black Hills were intruded as a viscous liquid and that the internal units resulted from fractional crystallization in an essentially closed system. Other authors, however, have not arrived at these conclusions, and for this reason a brief statement of the evidence from the High Climb pegmatite and a discussion of what the evidence means are presented herewith.

Geologists are in fairly general agreement that pegmatites are formed by fluids derived from a differentiating granite magma. The principal dissent from this opinion with regard to origin of Black Hills pegmatites has been presented by Higazy (1949, p. 555–581); he believes that the pegmatites were formed by metasomatism of schist. Many of Higazy's arguments rest on the assumption that the Black Hills pegmatites consist chiefly of perthite, whereas perthite actually is less abundant than quartz and plagioclase. The predominance of soda feldspar over potash feldspar in the bulk composition of many of the well-zoned pegmatites in the Black Hills and the presence of notable quantities of lithium, beryllium, and phosphate minerals are not adequately explained by a granitization theory that relies heavily on the movement of potassium ions. Furthermore, Higazy failed to describe such features as island-mainland structure, gradational phases between schist and the different kinds of pegmatite, or the changes in pegmatite composition correlated with changes in composition of the country rock; these features should be present if his theory is correct. The High Climb pegmatite has sharp contacts with the country rock, and evidence for a gradational change from one to the other cannot be recognized.

The close areal proximity of the High Climb pegmatite to the granite of Harney Peak and the similarities in mineralogy and composition strongly suggest that the pegmatite and the granite are genetically related. Both have microcline-perthite, sodic plagioclase, quartz, tourmaline, and muscovite as the dominant constituents. It is not known whether the Harney Peak mass was the actual source of the material of the High Climb pegmatite and other pegmatites in the southern Black Hills or whether the granite and the pegmatites originated in a common deep-seated batholithic source.

The composition of the fluid or magma which formed the High Climb pegmatite is indicated in a general way by its mineralogy. Quartz, albite, perthite, and muscovite are the major minerals, indicating that the pegmatite fluid was rich in silicon, sodium, potassium, and water. Significant amounts of beryl, phosphate minerals, tourmaline, and amblygonite also indicate that the pegmatite fluid contained lithium, beryllium, boron, and phosphorous. This assemblage of elements together with significant amounts of water suggests that the pegmatite fluid was a late stage product resulting from the differentiation of a granitic magma.

The overall general concordance of the High Climb pegmatite with the schistosity in the country rock suggests that the emplacement of the pegmatite was controlled mainly by the regional schistosity. Locally the pegmatite contact cuts the schistosity, indicating that the viscosity of the pegmatite fluid and the force of its movement were sufficient to breach the country rock. A noteworthy example of this breaching occurs along the footwall of the southern part of the pegmatite (pl. 7, section *E–E′*), where a large fingerlike extension of the pegmatite cuts the schist and then extends parallel to the main contact.

Speculation about the history of crystallization of pegmatites after emplacement has brought forth the greatest diversity of opinion among geologists. Many geologists, including Schaller (1925, p. 269–279), Landes (1925, p. 355–411), and Hess (1925, p. 289–298), believed that complex pegmatites are formed in two or more phases: an initial intrusion and crystallization of a magma, simple in composition, followed by one or more hydrothermal phases, during which the original material was partly or completely replaced by hydrothermal minerals. Quirke and Kremers (1943, p. 571–580) supported the idea that pegmatites were formed by crystallization of solutions moving through open systems. Recently many writers (Cameron, Jahns, McNair, and Page, 1949, p. 104; Page and others, 1953, p. 20–24; Hanley, Heinrich, and Page, 1950, p. 8; Jahns, Griffitts, and Heinrich, 1952, p. 45) have shown that the internal structure of pegmatites supports the concept that pegmatite zones developed by fractional crystallization and incomplete reaction in a restricted system. Stockwell (1933, p. 38–39) had earlier expressed essentially this same concept to explain the origin of Manitoba pegmatites, which, he believes, show a definite order of solidification progressing inward from the walls.

Fisher (1942, p. 23) has postulated a three-fold sequence for the genesis of the High Climb pegmatite: originally, the pegmatite was formed as a small mass consisting of the "soda aplite"; subsequently the "quartz-microcline-microperthite aggregate" was introduced; finally "most of the later components were formed by replacement from solutions that continued to penetrate the already solidified pegmatite". Fisher's initial "soda aplite" is apparently the same rock described in the present report as a sugary-grained type of albite-quartz pegmatite (wall zone). In a later report Fisher (1945, p. 14–20, fig. 4, fig. 5) used textural studies showing "albitization" of microcline at the High Climb pegmatite as evidence for replacement to support a general genetic theory consisting of several stages. In Fisher's "igneous" stage, a light fluid portion of a deeply buried magma was forced up into the schist and yielded the bulk of the pegmatite material (mainly potash feldspar, quartz, and minor muscovite and black tourmaline). Fisher postulated that during later "hydrothermal" stages residual water-rich portions of increasingly fluid nature were forced out of the magma at depth, and they moved upward to replace some of the earlier formed pegmatite. He further postulated that a final stage of alteration was effected in some pegmatites by meteoric waters, after a period of considerable erosion.

The textural phenomena cited by Fisher are of value in determining the detailed paragenetic sequence of minerals within an individual zone. In the present investigation, for example, detailed thin section studies of material from the second intermediate zone show that the albite of the matrix appears to replace microcline-perthite in some specimens, and in others the microline replaces and veins the albite of the matrix and poikilitically includes crystals of cleavelandite. Textural studies alone, however, do not determine which process caused the embaying, veining, and corroding; the overall structural and mineralogic relations in the pegmatite must also be considered. The so-called replacement textures can be caused by several processes, including hydrothermal replacement, pneumatolytic action, and the incomplete reaction between rest liquids and crystals during fractional crystallization.

The well-developed zonal structure, the general increase in grain size inward, the concentration of mineral assemblages in definite zonal positions, and the similarity of the zonal sequence with that of other pegmatites constitutes evidence in favor of fractional crystallization in situ. The internal structure of the High Climb pegmatite strongly indicates that the so-called replacement textures were actually formed by incomplete reaction between newly-formed crystals and a progressively crystallizing rest liquid, and that the process operated in an essentially closed system with no addition of hydrothermal fluids from outside the system after the original emplacement.

The concentric zonal arrangement could not have been formed in successive stages by deposition in an open system, as in the process suggested by Quirke and Kremers (1943, p. 571–580), because the combination of wall zone and first intermediate zone completely encloses the other zones in the High Climb pegmatite at all exposures except where mining or erosion has cut through the outer zones. The concentric zonal arrangement and the concentration of certain mineral assemblages in definite zonal positions suggest that processes of differentiation, fractional crystallization, and segregation were operating throughout the time of the solidification of the High Climb pegmatite.. The internal structure and zonal sequence in the High Climb pegmatite is compatible with the internal structure and zonal sequence in many other pegmatites in the United States (Cameron, Jahns, McNair, and Page, 1949, p. 59–70) and is best explained by fractional crystallization. It seems very improbable that either the open system of Quirke and Kremers (1943, p. 571–580) or the successive stages of hydrothermal replacement of preexisting pegmatite, as proposed by Landes (1925, p. 355–411), could cause such a uniformity of sequence of the dominant mineral assemblages in concentric lithologic zones in so many districts. Consequently, it seems most probable that the solidification of the pegmatite magma was an orderly process involving differentiation and fractional crystallization in a restricted system. Crystallization started at the walls and progressed inward, forming concentric zones differing in mineralogic composition and texture. The entire process of fractional crystallization was accompanied by incomplete reaction between the rest liquid and the newly formed crystals.

An outer zone of fine-grained albite-quartz pegmatite formed at the contact and is separated from the schist only by a very thin, discontinuous chilled margin, or border zone, rich in quartz and muscovite. Along the footwall of the southern part of the body, rapid loss of volatile material probably was the cause of the formation of the sugary-grained facies of the wall zone. The escape of volatile material is indicated by alteration of the adjacent schist. Probably most of the volatile material, however, streamed inward and upward along the major structural rolls in the footwall and by retarding the rate of crystallization at these sites caused the crystallization of medium-grained albite-quartz-muscovite pegmatite adjacent to schist. The crystallization of this medium-grained first intermediate zone occurred in part simultaneous with and in part subsequent to the formation of fine-grained albite-quartz pegmatite elsewhere along the contact (for example, pl. 7, section *E–E′*).

It is possible that the sugary-grained facies of the wall zone may actually be a replacement body formed by solutions rich in sodium aluminum silicate escaping from the rest liquid at the time the first intermediate zone was crystallizing. If so, these escaping solutions should have replaced a preexisting wall zone or schist to form the sugary-grained unit. However, because no consistent cross-cutting relations and no pseudomorphic textures either of schist or of a preexisting wall zone were recognized, the sugary-grained rock is best considered to be a facies of the wall zone.

As crystallization proceeded, the distinctive mineral assemblages of the first, second, and third intermediate zones were deposited as quasi-concentric shells. The distribution of minerals in these units suggests a certain degree of segregation in the liquid prior to crystallization or during crystallization. The best development of the mica- and beryl-rich first intermediate zone was in the lower part of the pegmatite and a fraction rich in potash and poor in water segregated near the crest to form the hood-shaped second intermediate zone. Fractures formed after crystallization of the wall zone in the southern part of the pegmatite were filled by liquid that crystallized and formed some of the essential minerals of both the first and second intermediate zones. Phosphate-rich materials containing some lithium, arsenic, copper, and carbonate, were segregated along the inner edge of the first intermediate zone, where it is in contact with the second and third intermediate zones, and also along the contact between the second and third intermediate zones. Other fractions of fluid rich in water reacted elsewhere along the underside of the perthite-rich second intermediate zone to form a discontinuous unit of fine-grained muscovite rock. It is possible that some of these segregations may be replacement units, but no evidence of relict pegmatite was found.

When the process of crystallization was nearly completed, the residual material became sufficiently concentrated in lithium to form a mesh of spodumene crystals. The spodumene, however, subsequently was altered almost completely to fine micaceous material. The alteration was not the result of late weathering processes, because other silicate minerals in the pegmatite exhibit very little alteration. The alteration of the spodumene could not have been caused by the introduction of hydrothermal solutions after the crystallization of the pegmatite, because there is no evidence to indicate that such solutions passed through other units of the pegmatite. It seems very likely that the spodumene crystals altered simply by their reaction with the rest liquid. The cause of this reaction, however, is not entirely clear. It is not readily apparent why the rest liquid, so soon after crystallization of spodumene, should change in composition sufficiently to replace the spodumene pseudomorphically. A possible explanation is that the crystallization of the spodumene may have occurred before the completion of crystallization of the third intermediate zone. Then, reaction between the progressively crystallizing inner part of the third intermediate zone and the rest liquid may have changed the composition of the rest liquid enough to cause it, in turn, to react with and to alter the spodumene.

If the alteration of the spodumene was accomplished by simple reaction between the crystals and the rest liquid, as the field evidence seems to indicate, there still remains the problem of the disposal of the lithium. It is important to note that the actual exposure of the quartz core is rather small and that the altered spodumene crystals were observed only near the upper and outer edge of this exposure. Altered or "rotten" spodumene crystals have also been reported at the Edison and Etta pegmatites in Pennington County, S. Dak. (Page and others, 1953, p. 112 and p. 118) ; in these pegmatites the altered crystals generally occur in the outer, spodumene-bearing units or in the outer parts of central units, whereas unaltered spodumene generally occurs in the inner parts of the pegmatites. According to Page (oral communication, 1953), the lithium from the altered crystals at the Edison and Etta pegmatites probably was taken into the rest liquid and then formed the unaltered crystals of the relatively younger, inner parts of these pegmatites. If unaltered spodumene occurs in the unexposed inner part of the core of the High Climb pegmatite, Page's explanation would also apply in the genetic sequence there. If, however, all the spodumene in the core of the High Climb pegmatite is altered, a possible explanation may be that the lithium is now disseminated in the molecules of the micas and the quartz that make up the core. The altered spodumene forms only 3 percent of the exposure of the core. If this percentage applies to the entire core, then the total quantity of lithium present in the original crystals was rather small, and dissemination of this small quantity throughout the entire volume of the core does not seem unreasonable.

The final product of crystallization at the High Climb pegmatite was a silica-rich fluid that crystallized as a quartz core, enclosing the mesh of altered spodumene logs. There is no evidence that at any time during the entire process of crystallization, from the formation of the outermost zones through the crystallization of the core, was material added to the pegmatite by open system hydrothermal solutions. The pegmatite fluid crystallized in essentially a closed system, although a minor amount of violatile material escaped into and altered the adjacent schist.

In its late stages the pegmatite fluid may well have been more nearly hydrothermal than magmatic. The boundary between processes which have been termed "magmatic," or "igneous," and processes which have been termed "hydrothermal" has long been a controversial problem. It is true that many minerals, such as beryl and muscovite, occur not only in pegmatites but also in quartz veins. Adams (1953, p. 98–100), for example, has reported beryl both in pegmatites and in quartz veins of the Mount Antero region, Colorado. The fact that some minerals occur in hydrothermal quartz veins does not necessarily mean that the occurrence of these same minerals in pegmatites should demand a separate stage in the genetic sequence, as postulated by Landes (1925, p. 355–411) and Schaller (1933, p. 144–151). Landes (1933, p. 55) later recognized the possibility that the hydrothermal solutions may be "residua" of the crystallization of pegmatite magma in the larger pegmatites. The process of fractional crystallization of a pegmatite magma in an essentially closed system, as postulated by Cameron, Jahns, McNair, and Page (1949, p. 97–106), is entirely compatible with the so-called hydrothermal character of some of the younger minerals in pegmatites. During the process of fractional crystallization the proportion of mineralizers in the rest liquid tends to increase, and the solution may change from a viscous liquid essentially magmatic in character to one that is essentially hydrothermal. The exact nature of the change from magmatic to hydrothermal conditions has been difficult to study in the laboratory because extreme difficulties are encountered in working with concentrations of mineralizers under combined conditions of heat and pressure. However, the change in character of the solution during fractional crystallization is indicated in many pegmatites by the increase in grain size from the walls to the center of the pegmatite, by the increase in abundance of reaction replacement textures inwards in the pegmatite, and by the presence, in some pegmatites, of true replacement bodies that extend outward from inner zones and replace parts of older zones.

The High Climb pegmatite contains no evidence that there have been any significant changes since the original crystallization of the pegmatite, although there has been minor alteration of the phosphate minerals. Certainly there is no evidence of carbonate veins cutting the pegmatite. The carbon in the manganese-bearing carbonate in the phosphate-rich assemblage of minerals could easily have been a primary constituent of the source magma or could have been derived by partial assimilation of carbonaceous metasediments as the pegmatite fluid moved through the schists to its present site.

MINERAL DEPOSITS

The industrial minerals that have been produced at the High Climb pegmatite are amblybonite; beryl; columbite-tantalite; potash feldspar; scrap, punch, and sheet mica. The pegmatite still has significant quantities of all these minerals except columbite-tantalite.

AMBLYGONITE

The amblygonite in the High Climb pegmatite is the high hydroxyl and low fluorine variety, montebrasite. It is mainly in quartz-cleavelandite pegmatite (third intermediate zone), especially in a 2-foot thickness of cleavelandite-rich rock marginal to the core. It occurs as rounded nodules that average about 3.5 inches and range from 0.5 inch to 8 inches in size.

The percentage of montebrasite in the third intermediate zone is estimated to be between 0.25 percent and 0.5 percent. The distribution, however, is very spotty. The montebrasite content of the other zones is negligible.

BERYL

Beryl is confined almost entirely to the first intermediate zone of albite-quartz-muscovite pegmatite; this zone is also the main mica deposit in the High Climb pegmatite. Minor quantities of beryl (less than 1 percent) occur in the innermost part of the wall zone and in the extreme outer part of the third intermediate zone, where these zones are adjacent to albite-quartz-muscovite pegmatite.

The beryl in the High Climb pegmatite is white to greenish white, but generally carries considerable reddish-brown iron stain. Beryl from areas rich in phosphate minerals is stained brown to gray-black by alteration products of the phosphate minerals. The length of crystals ranges from 0.5 inch to 12 inches; the average crystal is about 3.5 inches long and 1.5 inches in diameter. Most of the beryl is in euhedral crystals, but some is in subhedral intergrowths with albite and muscovite. Refractive indices indicate that the BeO content of the beryl ranges from 12.35 to 13.10 percent.

The average beryl content of the albite-quartz-muscovite pegmatite (first intermediate zone) is estimated to be about 1 percent. This estimate was obtained by measuring the area of beryl on three rich faces and estimating the beryl content of many other exposures of the zone. On the north wall of the main pit 17.5 square feet of albite-quartz-muscovite pegmatite was found to contain 31 crystals of beryl totaling 0.88 square foot in area, for a grade of 5.03 percent beryl; the exposed area of individual crystals in this rich face ranges from 0.0025 square foot to 0.1 square foot. Measurements of beryl crystals were made by Lang and Stewart[5] on two exposures of the first intermediate zone in the northern extension of the pegmatite. An area of 21 square feet of this zone in the south wall of the northernmost pit (pl. 7) contained 2.3 percent beryl in 22 beryl crystals with a total area of 0.48 square foot. In the south wall of the southern cut (pl. 7) in the northern half of the pegmatite a grade of 0.8 percent beryl was indicated in an area of 40 square feet that had 50 crystals of beryl having a total area of 0.31 square foot. Visual estimates of several other exposures of the zone indicate beryl contents of less than 0.5 percent.

The beryl content of those parts of the wall zone and the third intermediate zone immediately adjacent to the main beryl deposit (first intermediate zone) is less than 1 percent, and beryl has not been found elsewhere in the pegmatite. The beryl from both the wall zone and the third intermediate zone can be mined at the same time as the beryl is mined from the main deposit.

The percentage of beryl that can be hand-cobbed from the albite-quartz-muscovite pegmatite differs from place to place. Lang and Stewart estimated 96 percent and 41 percent in the 2 exposures they measured. Probably the average percentage of cobbable beryl in the entire zone is in the order of 40 to 50 percent. The rest of the beryl would have to be recovered by some other method.

COLUMBITE-TANTALITE

Columbite-tantalite was not observed by the writer in the present workings, but according to descriptions by C. K. Koch, mine operator, the 100 pounds that were produced occurred mainly in the part of the

[5] Lang, A. J., and Stewart, D. B., 1948, Estimated beryl reserves in the small pegmatite just north of the main pegmatite on the High Climb claim. [Unpublished report in the files of the U. S. Geological Survey.]

quartz-cleavelandite pegmatite (third intermediate zone) that was mined from the northwestern end of the main pit. It was also reported by Fisher (1942).

POTASH FELDSPAR

The only minable deposit of potash feldspar in the High Climb pegmatite is the second intermediate zone of perthite-quartz-albite pegmatite. Only very small quantities of this mineral occur in other zones.

The potash feldspar is flesh white to buff creamy-white microcline-perthite which for the most part is clean and free from excessive iron stain except near irregular fractures. The size of the individual crystals of the perthite in the second intermediate zone ranges from less than 1 foot to 5 feet, but the average size is probably about 1.5 feet in the southern part of the pegmatite and 1 foot in the northern part.

The average perthite content of the second intermediate zone in the southern part of the pegmatite is about 50 percent. The grade in the uppermost parts of the zone is as much as 75 percent, and in the lower parts of the zone, as little as 25 percent. In the northern part of the pegmatite the average grade of the exposures of the zone is about 60 percent perthite.

MICA

Muscovite occurs in all the units of the High Climb pegmatite, but it is most abundant in albite-quartz-muscovite pegmatite (first intermediate zone), which is also the main beryl deposit in the High Climb pegmatite. The muscovite in this zone is silvery, yellowish-silvery, pale ruby, and pale greenish-brown in color. Books range in size from less than 0.25 inch to 10 inches; the average size is about 3 inches. Most of the mica contains varying amounts of "A" structure and herringbone structure, and some contains mineral-inclusions and hair cracks. In parts of the zone near phosphate-rich pods, the mica is badly stained. Muscovite from elsewhere in the zone is sold as white scrap mica.

The average muscovite content of the first intermediate zone is estimated to be about 22 percent. The amount of sheet mica in present exposures is negligible. Adams and Stoll (1953, p. 131) estimated that about 10 percent of the small quantity of sheet mica recovered was of No. 1 and 2 qualities.

Muscovite also occurs in the wall zone, in the second and third intermediate zones, and in fracture fillings of quartz-perthite-muscovite-albite pegmatite, but the grade in these units is too low for economic recovery of scrap mica by hand sorting. Furthermore, the small quantity of other economic minerals in these units decreases the possibility that the mica will be extracted even as a by-product.

RESERVES

AMBLYGONITE

The main deposit is the third intermediate zone of quartz-cleavelandite pegmatite, which is estimated to contain between 0.25 and 0.5 percent amblygonite (montebrasite). The average thickness of the third intermediate zone in the southern part of the pegmatite is about 14 feet, but most of the exposed montebrasite is in the inner 2 feet of the zone. The length of the third intermediate zone, measured normal to the plunge, is about 125 feet; the depth of the zone, measured down the plunge (pl. 7, sections *A–A′*, *B–B′*), is at least 110 feet and may be as much as 250 feet. This zone is not exposed in the northern part of the High Climb pegmatite.

BERYL AND MICA

The principal reserves of both beryl and mica are in albite-quartz-muscovite pegmatite (first intermediate zone), which is estimated to contain 1 percent beryl and 22 percent mica. Not more than about half of the beryl and less than half of the mica can be recovered by cobbing.

The average thickness of the first intermediate zone is about 2.5 feet in the southern half of the High Climb pegmatite, but the zone is as much as 5 feet thick; the thickest exposures occur along the footwall. The depth of the deposit, inferred down the plunge along the footwall (pl. 7, sections *A–A′* and *B–B′*), is at least 105 feet but may be as much as 250 feet. The total length of exposures of the first intermediate zone in the southern half of the pegmatite is about 200 feet, but the shape is very irregular, reflecting the many rolls in the pegmatite contact.

In the dikelike northern extension of the pegmatite the first intermediate zone is exposed for a total of 60 feet along the strike of the pegmatite and averages about 2 feet in thickness. The depth of this beryl deposit is not known but is probably at least 50 feet.

POTASH FELDSPAR

Reserves of potash feldspar are in the second intermediate zone, perthite-quartz-albite pegmatite. The grade ranges from 25 to 75 percent; the average is about 50 percent.

In the southern part of the pegmatite, the maximum thickness of the perthite-quartz-albite pegmatite is about 26 feet. The zone pinches out on the footwall side and thins down-dip on the hanging-wall side. The maximum depth, measured down the plunge (pl. 7, section *A–A′*), is 190 feet and the length, measured normal to the plunge, is about 110 feet.

In the northern part of the pegmatite, the second intermediate zone is exposed for a total of 75 feet along the strike of the dike. Exposures are too poor to allow accurate determination of the thickness and depth in this part of the pegmatite.

The low grade, small size, and erratic distribution of perthite in the wall zone, in the first intermediate zone, and in the fracture-filling unit are unfavorable to mining of these units for potash feldspar.

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