Geology and beryl deposits of the Peerless pegmatite, Pennington County, South Dakota

By D. M. Sheridan, H. G. Stephens, M. H. Staatz, and J. J. Norton

Trace Elements Investigations Report 226

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GEOLOGICAL SURVEY

Geology and Mineralogy

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GEOLOGICAL SURVEY

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By

Douglas M. Sheridan, Hal G. Stephens,
Mortimer H. Staatz, and James J. Norton

February 1955

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GEOLOGY AND BERYL DEPOSITS OF THE PEERLESS PEGMATITE, PENNINGTON COUNTY, SOUTH DAKOTA

By Douglas M. Sheridan, Hal G. Stephens
Mortimer H. Staatz, and James J. Norton

ABSTRACT

The Peerless pegmatite, half a mile south of Keystone, Pennington County, S. Dak., has been a large source of scrap mica and beryl. Feldspar, amblygonite, tantalite-columbite, and cassiterite also have been recovered.

The pegmatite is intrusive into Precambrian quartz-mica schist. Much of the schist contains staurolite and chlorite. Staurolite has been partly altered to mica, quartz, and chlorite, especially near pegmatite contacts. The pegmatite is generally discordant with the schist, but in many places secondary schistosity has been developed parallel to the contact. Tourmaline and muscovite, presumably introduced by pegmatitic solutions, are characteristic of the wall rock near discordant contacts.

At the surface the pegmatite is tadpole-shaped and is 580 feet long and 360 feet wide. In cross-section the pegmatite has an anticlinal form that suggests control of the intrusion by fractures bearing N. 30° W. and dipping 45°NE. and SW. Dike-like apophyses extending from the main pegmatite have various attitudes.

The Peerless pegmatite is a complex pegmatite consisting of seven zones, two replacement units, and two types of fracture-fillings. These are: Zone 1, quartz-muscovite-plagioclase pegmatite (border zone); Zone 2, albite-quartz-muscovite pegmatite (wall zone); Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone); Zone 4, perthite-cleavelandite-quartz pegmatite (second intermediate zone); Zone 5, cleavelandite-quartz pegmatite (third intermediate zone); Zones 6a and b, quartz-microcline pegmatite and quartz pegmatite (fourth intermediate zone); Zone 7, lithia mica-cleavelandite pegmatite (core); lithia mica-cleavelandite-quartz replacement unit; muscovite-cleavelandite replacement unit; quartz fracture-fillings; and tourmaline-quartz fracture-fillings.

Zones 1 and 2 consist of alternating layers of different texture and mineralogy that are parallel to the contact. The layers contain differing proportions of quartz, plagioclase, muscovite, perthite, and accessory minerals. Sugary albite-quartz aggregates are important constituents of some layers. Layers of similar composition may occur two, three, or perhaps more times. The overall mineralogic composition of Zones 1 and 2 is similar to the composition of wall zones in many other Black Hills pegmatites. Zones 3 to 7 are in the normal sequence of zones in Black Hills pegmatites.

The structural, textural, and mineralogic data confirm previously published evidence from other Black Hills pegmatites that indicates crystallization of a magma-like fluid from the wall inward. Repetition of layers in Zones 1 and 2 indicates changes in composition of the fluid at the crystallizing face. These changes may have been caused by addition of new material from below, by loss of material to the wall rocks, or by failure of convection to maintain equilibrium throughout the fluid in the pegmatite chamber. Zone 3 to 7 are in the normal sequence of zoned pegmatites that indicates crystallization from a restricted or nearly closed system. The lithia mica-cleavelandite replacement unit, which extends outward from the core, shows that in the very late stages of crystallization a pneumatolytic or hydrothermal fluid escaped outward and replaced previously crystallized pegmatite.

Accessory minerals of the pegmatite include tourmaline, beryl, apatite, amblygonite (variety, montebrasite), lithia mica, cassiterite, tantalite-columbite, garnet, spodumene, svanbergite, loellingite (?), vivianite (?), triploidite (?), dahllite, and vari-colored phosphate minerals of the lithiophilite-triphylite group and their alteration products.

The chemical composition of the pegmatite has been determined by estimating the mineral constitution of the various units and by calculating the tonnage of these units by use of successive geologic sections. The principal constituents are: SiO_2 (77.0 percent), Al_2O_3 (13.7 percent), Na_2O (5.0 percent), and K_2O (1.7 percent).

Chemical composition has also been determined for four subdivisions of the pegmatite: (A) Zones 1 and 2, (B) Zones 3 and 4, (C) Zone 5, and (D) Zones 6 and 7 and the replacement units. The content of SiO_2 increases and the content of Al_2O_3 decreases from the outer part of the pegmatite inward. Na_2O forms only 0.4 percent of the inner subdivision (D), but 4.7 to 6.5 percent of the other subdivisions. K_2O forms 4.0 percent of subdivision (B), but only 0.7 to 1.3 percent of the other subdivisions.

Zone 3, the principal minable unit, contains 1.7 percent beryl and 28 percent scrap mica. Beryl also constitutes more than 1 percent of parts of the wall zone, especially albite-rich layers of the inner part of the unit in the upper part of the pegmatite. Beryl is a less important constituent of other units of the pegmatite.

Potash feldspar is mined chiefly from Zone 4. Cleavelandite that can be hand-cobbed and sold as soda-feldspar occurs in Zones 3, 4, and 5. Amblygonite forms between 0.5 and 1.0 percent of Zone 5.

Reserves of beryl, scrap mica, potash feldspar, and amblygonite are one to six times past production.

INTRODUCTION

Location

The Peerless pegmatite is in the Keystone district, Pennington County, S. Dak. This district is near the northeast edge of the large area of granitic rocks surrounding Harney Peak in the southern Black Hills. Pegmatites also have been mined in the Hill City district, northwest of Harney Peak, and in the Custer district, southwest of Harney Peak.

The Peerless pegmatite is one of a group of zoned pegmatites, within an area of less than one square mile, which have been the source of the greater part of the pegmatite mineral production of the Keystone district. Other major pegmatites in this group are the Hugo, Etta, White Cap, and Edison (fig. 1).

The Peerless mine is in sec. 8, T. 2 S., R. 6 E., Black Hills principal meridian, about half a mile south of Keystone (fig. 1). The pegmatite crops out along the crest of a ridge that trends southeast from the junction of Battle Creek and Grizzly Bear Creek. The crest of the ridge is approximately 350 feet above the valley floor. Relief is rugged, and the pine-covered slopes drop steeply to the valleys below.

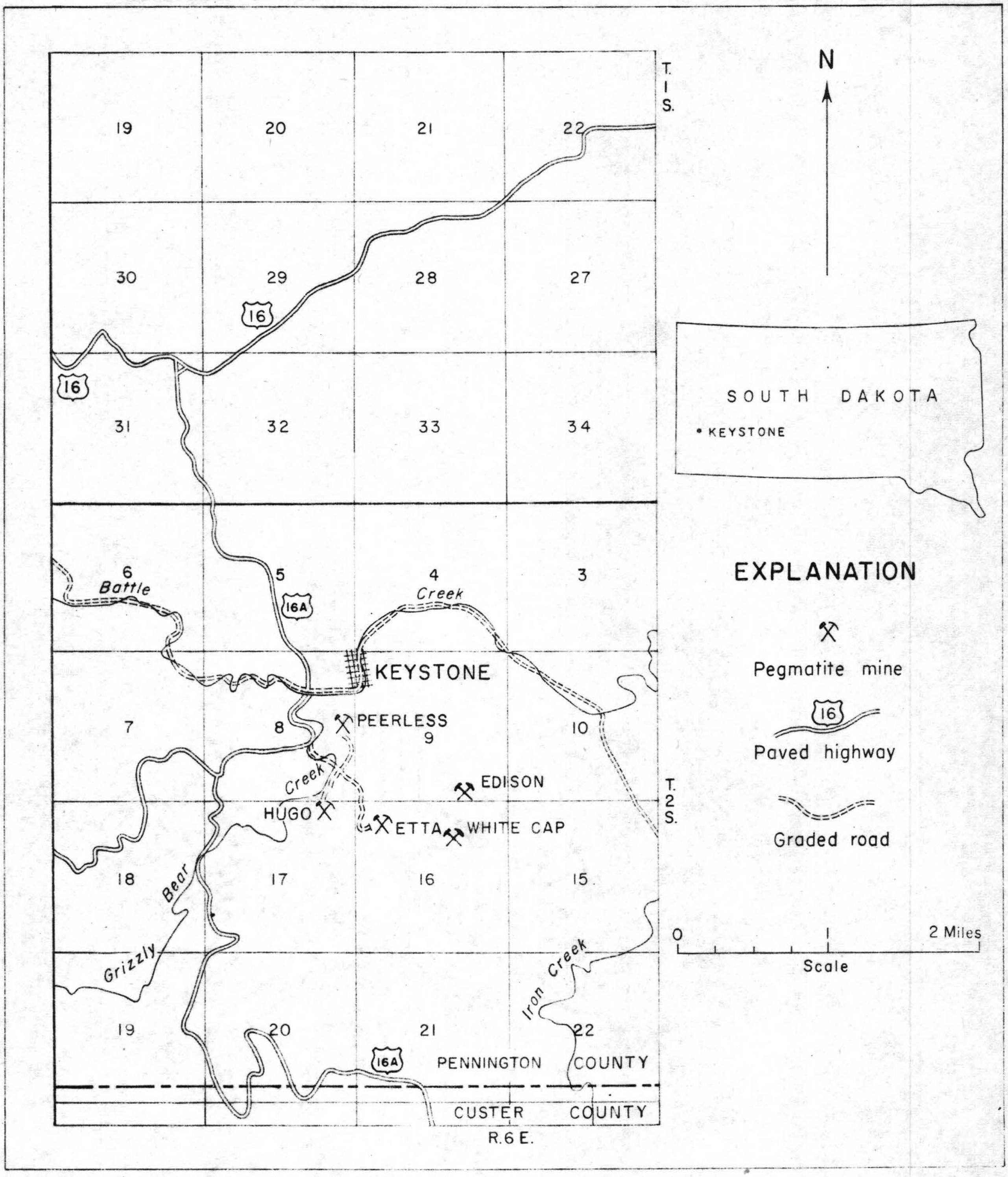


FIGURE 1.- INDEX MAP SHOWING LOCATION OF THE PEERLESS PEGMATITE,
PENNINGTON COUNTY, SOUTH DAKOTA

The Peerless mine can be reached from Keystone, the nearest railhead, by 1.1 miles of paved and dirt road in accordance with the following log.

Miles	
0.0	Keystone, at intersection of Chicago, Burlington, and Quincy Railroad and U. S. Highway 16A. Travel south on U. S. Highway 16A.
0.6	Turn left on graded road.
0.6-0.8	Cross three bridges over Grizzly Bear Creek.
0.8	Turn left.
1.1	Compressor house, Peerless mine.

History

The pegmatite was first mined about 1907 for amblygonite by the Harney Peak Tin Mining, Milling, and Manufacturing Company, and probably it had been prospected earlier for tin by the same company. Most of the early work for amblygonite, however, was done by the Reinbold Metallurgical Company. Since 1924 the Keystone Feldspar and Chemical Company has mined the property. Ernest Reckitt of Chicago is president, J. A. Schreiber of Chicago is general manager, and A. F. Walker of Keystone is resident superintendent.

Production

The Peerless pegmatite has been a source of scrap mica, beryl, potash feldspar, soda feldspar, punch and sheet mica, amblygonite, tantalite-columbite, and cassiterite. Production records from 1907 to 1950 are given in tables 1 and 2. In recent years scrap mica and beryl were the principal minerals recovered.

The total recorded production of minerals from the Peerless pegmatite to September 11, 1950, is 8,747 tons of muscovite, 511.25 tons of beryl, 9,649 tons of potash spar, 1,772 tons of soda spar, 1,013 tons of amblygonite, 930 pounds of tantalite-columbite, and 1 ton of cassiterite (table 1). This material would have a gross value at 1953 prices of approximately three-quarters of a million dollars.

Scrap mica has been the chief product of the Peerless pegmatite since 1924. In 1950 the scrap mica was being sold to the U. S. Mica Company, Chicago, Ill., and used as artificial snow for Christmas decorations. Small quantities of punch and sheet mica were produced from 1943 to 1947 (table 2), but the total value was trivial in comparison with the value of the scrap mica.

The Peerless mine has been a major source of beryl. The production through 1950 was about 17 percent of all domestic production and 1 percent of the total world production._/ The Peerless beryl production through 1949 was 26 percent of the total beryl production cited by Smith (1950, p. 6) for South Dakota.

Both potash and soda feldspar have also been major products of this mine. The demand for soda feldspar, however, is so small that it is ordinarily stockpiled so that it can be sold whenever orders are received.

_/ Data based on: Staff of the U. S. Bureau of Mines and Geological Survey, 1953, Materials Survey Beryllium: Table IV-1.

Table 1.--Production of mica, potash feldspar, soda feldspar, beryl, amblygonite, tantalite-columbite, and cassiterite, Peerless pegmatite, Keystone, Pennington County, South Dakota, 1907-September 1950. 1/

Year	Mica (tons)	Potash feldspar (tons)	Soda feldspar (tons)	Beryl (tons)	Ambly-gonite (tons)	Tantalite-columbite (pounds)
1907-1908	---	---	---	---	900	---
1911-1916	---	---	---	---	2/	---
1917-1919	---	---	---	3	3/	---
1924	46	354	---	---	---	---
1925	178	512	---	---	---	---
1926	543	262	---	---	---	270
1927	571	121	---	---	---	200
1928	314	534	---	---	---	---
1929	257	267	---	157	---	320
1930	257	61	---	39	---	---
1931	47	708	---	---	---	---
1932	423 4/	160	42	---	---	---
1933	127	---	---	28	---	---
1934	159	290	18	---	12	---
1935	281	328	58	---	94	---
1936	429	---	49	---	---	---

1/ The tonnages shown in table 1 are for sales in the years 1907 through September 1950, and are not necessarily the amounts actually mined in such years. For this reason, the figures for beryl differ slightly from the production figures cited by Stoll (in page and others, 1953, p. 175-176).

2/ The amblygonite production from the Keystone district during 1911-1916 totalled 1,502 tons, part of which probably came from the Peerless pegmatite.

3/ The amblygonite production from the Peerless pegmatite and the Hugo pegmatite totalled 387 tons between 1917 and 1919 inclusive.

4/ The 423 tons of mica sold in 1932 and 8 tons of the 1947 production were designated "mica schist", the miner's term for scrap-mica, that occurs in fine-grained (< 0.5 inch) aggregates.

Table 1.--Production of mica, potash feldspar, soda feldspar, beryl, amblygonite, tantalite-columbite, and cassiterite, Peerless pegmatite, Keystone, Pennington County, South Dakota, 1907-September 1950. 1/ --Continued

Year	Mica (tons)	Potash feldspar (tons)	Soda feldspar (tons)	Beryl (tons)	Ambly-gonite (tons)	Tantalite-columbite (pounds)
1937	451	---	60	36	---	140
1938	417	---	151	---	---	---
1939	297	---	174	28	---	---
1940	534	---	78	31	---	---
1941	725	---	---	25	---	---
1942	390	2,221	---	43	---	---
1943	218	1,080	385	45	---	---
1944	175	1,269	99	9	7	---
1945	311	947	---	12	---	---
1946	433	490	60	6	---	---
1947	331 4/	45	113	8	---	---
1948	289	5/	233	10	---	---
1949	344	5/	178	22	---	---
1950 (through September 11)	200	5/	79	9 1/4	---	---
Totals 6/	8,747	9,649	1,772	511 1/4	1,013	930

5/ Feldspar production in the years 1948, 1949, and 1950 was recorded as "spar". A. F. Walker stated that the sales were predominantly soda-spar in these years.

6/ In addition, approximately 1 ton of cassiterite has been accumulated by the Keystone Feldspar and Chemical Company since 1924, but no sales of this mineral have been recorded.

Table 2.--Production of punch and sheet mica, Peerless pegmatite, Keystone, Pennington County, South Dakota, 1943-1947.

Year	Punch Mica (pounds)	Sheet mica (pounds)
1943	312.50	279.99
1944	---	127.58
1945	22.31 1/	---
1946	255.00	29.88
1947	279.00	---
Totals	868.81	437.45

1/ Not stated whether punch or sheet mica.

The total amblygonite production may be several hundred tons more than the 1,013 tons recorded in table 1. Most of the amblygonite was mined prior to 1924 by the Reinbold Metallurgical Company, which mined rich areas in the upper part of the main pit and in the old cut northwest of the main pit (fig. 2). The Keystone Feldspar and Chemical Company sold 106 tons between 1924 and 1935, but only 7 tons were produced from 1935 to September 1950.

Tantalite-columbite, the only other mineral that has been sold, has been a minor byproduct. Approximately 1 ton of cassiterite has been accumulated since 1924 (table 1), but no sales have been recorded.

Past and present investigations

The Peerless pegmatite was mentioned in several early geologic publications, but the first extensive report was by F. L. Hess (1925). He discussed mineralogical relationships and textures in the Peerless pegmatite and briefly described the shape of the outcrop. K. K. Landes (1928) described the Peerless pegmatite and discussed the sequence of mineralization. G. M. Schwartz (1928, p. 61-62) described this pegmatite briefly. W. C. Stoll (in Page and others, 1953, p. 175-176) and W. E. Hall examined and mapped the Peerless pegmatite in 1942 during reconnaissance investigations for strategic minerals by the U. S. Geological Survey.

More detailed investigations of the Peerless pegmatite were started by the U. S. Geological Survey in July 1947. The first work was done by W. R. Thurston and A. J. Lang, Jr. Between August and December 1947, M. H. Staatz and H. G. Stephens, assisted at various times by J. W. Adams and L. R. Page, completed the surface mapping and part of the underground mapping, and prepared preliminary geologic sections (Stephens and Staatz, 1948, p. 1400).

In January 1949, Stephens prepared proposals for diamond drilling and developmental mining at the Peerless pegmatite at the request of the U. S. Bureau of Mines. On August 30, 1949, a core-drilling program began, and the work was completed on December 15. Seven holes totalling 1,573.5 feet were drilled under the supervision of Stuart Ferguson and Eugene O. Binyon of the U. S. Bureau of Mines. Geological work during the drilling, including revision and extension of existing maps and sections, was done by D. M. Sheridan, R. E. Roadifer, and J. J. Norton of the U. S. Geological Survey. D. M. Sheridan logged the core.

The U. S. Bureau of Mines conducted an experimental mining project at the Peerless pegmatite during 1950-1951. This work consisted of driving an adit along diamond drill hole 5 (figs. 2, 3, and 4) to test the results obtained from the drill hole. The coarse material from the adit was hand-sorted on a picking belt to gather data on mineral content, and the fine material was saved for metallurgical treatment (Runke, Mullen, and Cunningham, 1952, p. 21-22, 23, 30-31). The adit was mapped by Staatz and Sheridan in January and April 1951. L. R. Page and J. A. Redden in April 1954 examined layering of the border and wall zones; their results were used to compile table 4.

Acknowledgments

The writers wish to thank Ernest Reckitt, J. A. Schreiber, and A. F. Walker of the Keystone Feldspar and Chemical Company for their kind cooperation in providing production data. Appreciation is also extended to members of the U. S. Bureau of Mines for their assistance and cooperation in obtaining geological information during their diamond-drilling and experimental mining programs.

This investigation was done partly on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

MINE WORKINGS

The Peerless pegmatite has been worked by both open-cut and underground mining methods. Most of the recent mining has been conducted in the underground workings (fig. 3), in the main pit (fig. 2), and in two new open cuts started after the surface map was made. The main pit (fig. 2) is in the southeastern part of the pegmatite. It is about 220 feet long, 105 feet wide, and a maximum of 115 feet deep. A 100-foot access cut extends southward from the main pit, and another cut extends westward 160 feet from the southwestern edge of the main pit to a point above the portal of the adit. A small cut northwest of the adit portal is 60 feet long and 50 feet in maximum depth. Older workings in the northern and western parts of the pegmatite consist of five small open cuts (fig. 2) 10 to 110 feet long and 4 to 55 feet wide. Two new open cuts were started on the northeast part of the pegmatite by the Keystone Feldspar and Chemical Company in 1950, at the same time that the U. S. Bureau of Mines was driving an adit for experimental mining tests along drill hole 5 from the southwest side of the pegmatite.

Underground workings having a length of 735 feet are in the southern and eastern parts of the pegmatite (fig. 3) at an altitude of 4,540 feet. Stopes to a maximum height of 20 feet have been made in the pegmatite along the first intermediate zone. After the geologic map (fig. 2) was made, the underground workings were extended into the main pit through two glory holes having dimensions of 40 by 20 feet and 25 by 30 feet at the adit level.

The U. S. Bureau of Mines experimental adit (fig. 3), as of July 1, 1951, extended 165 feet northeast along diamond drill hole 5. The altitude of the new adit is approximately 4,580 feet.

Four large dumps southwest of the Peerless pegmatite are all more than 80 feet wide and 120 feet long. The material in the three largest dumps came from the main pit; each dump represents a different stage in the mining. In addition, there are at least seven smaller dumps on the pegmatite itself and along its northeast side; most of the material in these dumps came from the smaller pits. Calculations made in 1947 indicated a total of 113,000 tons of rock in the Peerless dumps. Since that time there has been a slight increase in the size of the large dump southwest of the pegmatite (fig. 2) and a new dump has been added on the northeast side of the pegmatite.

GEOLOGY

Metamorphic rocks

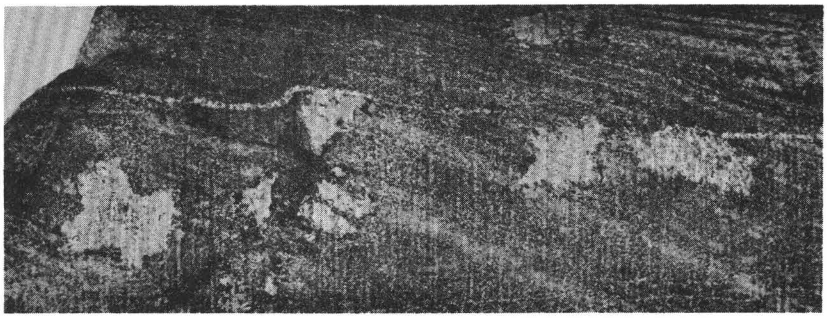
The Precambrian country rock consists predominantly of gray to brownish-gray schists consisting of quartz, mica, chlorite, staurolite, and garnet. The predominant facies is quartz-mica schist, but many beds contain essential staurolite or chlorite, and others are so deficient in mica that they are best termed micaceous quartzites. Because these beds are generally too thin--mostly less than 2 inches thick, but as much as 10 feet thick--to be mapped on a scale of 1:480, they are not distinguished on figures 2 and 3.

The most abundant type of country rock, quartz-mica schist, that has an average grain size of about 0.02 inch, contains quartz (45 to 65 percent), muscovite (15 to 30 percent), biotite (10 to 25 percent), chlorite, (0 to 3 percent), and garnet ($<$ 1 percent). Feldspar also occurs in the schist, but the quantity was not estimated. All minerals have tabular shape that cause the rock to have a strong schistosity.

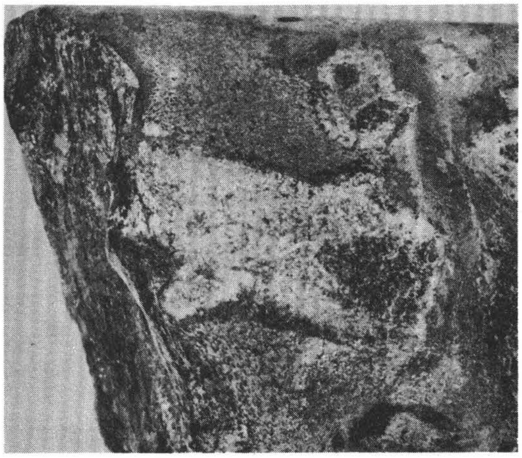
Some beds of quartz-mica schist contain as much as 4 percent muscovite and biotite pseudomorphs after staurolite. Beds of micaceous quartzite contain quartz (75 to 85 percent) and muscovite and biotite (15 to 25 percent); chlorite and garnet are absent.

The beds of quartz-mica-staurolite schist are similar to the quartz-mica schist except for the presence of metacrysts of staurolite (2 to 10 percent) and andalusite ($<$ 1 percent). Staurolite occurs commonly as cruciform twins. The length ranges from 0.1 inch to 2 inches; the average is about 0.4 inch. Indices of refraction are : $N\gamma$ = 1.75; $N\alpha$ = 1.74. Less abundant, pink prismatic metacrysts of andalusite average about 1 inch in length. Optical data for the andalusite are: $N\gamma$ = 1.64; $N\alpha$ = 1.62; 2V near 90°. Red to reddish-brown crystals of garnet (average size, 0.05 inch form 1 to 2 percent of the quartz-mica-staurolite schist. The matrix of this type of schist averages about 0.02 inch in grain size.

Some of the quartz-mica-chlorite schist is similar to the quartz-mica schist but contains more chlorite (5 to 10 percent) in the form of tabular metacrysts, 0.1 to 0.3 inch in diameter. Other beds of quartz-mica-chlorite schist are almost identical with quartz-mica-staurolite schist except that the staurolite and andalusite are present only as relicts, and chlorite forms 3 to 10 percent of the rock (pl. 1).



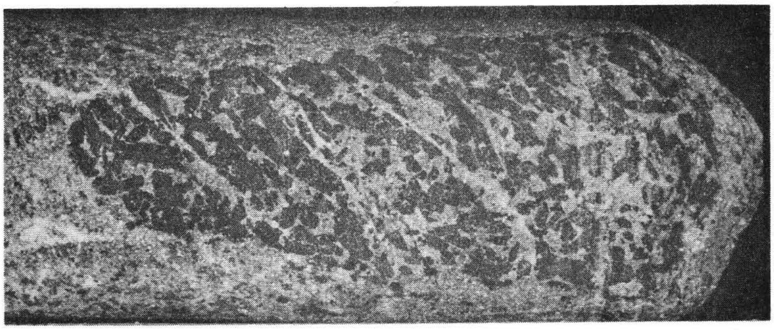
A. Quartz-mica schist containing staurolite partially changed to muscovite, chlorite (ripidolite), quartz, and biotite. (Photograph is 1-1/2 times natural size.)



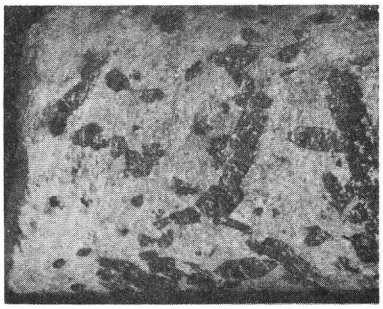
B. Schist in which staurolite has been completely replaced by muscovite, quartz, and biotite. Beds in the upper specimen are as much as 1/8 in. thick. (Photograph is 1-1/4 times natural size.)

PLATE 1. WALL ROCK, PEERLESS PEGMATITE

GPO 836752



C.



D.

C. and D. Tourmalinized schist. (Photograph is natural size.)

PLATE 1. WALL ROCK, PEERLESS PEGMATITE

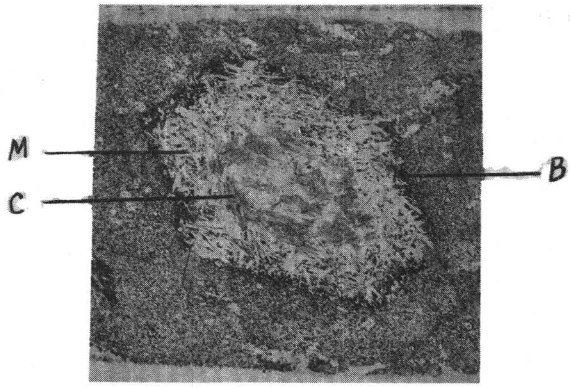
Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite comprise about 5 percent of this schist. The mica flakes in the pseudomorphs average 0.05 inch in diameter, compared to the average grain size of 0.02 inch in the schist matrix. Some of the pseudomorphs contain relicts of brown staurolite; others have chlorite centers and muscovite or biotite rims (pl. 2); still others are wholly muscovite. These pseudomorphs are more abundant near pegmatite contacts.

Garnet is more abundant along contacts of quartz-mica-chlorite schist with more quartzose beds.

The country rock adjacent to the pegmatite contact commonly is altered to a quartz-muscovite-tourmaline schist, especially where the pegmatite cuts across the bedding and schistosity (pl. 1). The thickness of the altered rock ordinarily is less than 4 feet, but may be as much as 9 feet. This rock contains quartz (30 to 55 percent), muscovite (30 to 45 percent), tourmaline (5 to 40 percent), and apatite (<1 percent). The tourmaline (N_W = 1.67) is in black euhedral needles that range in length from 0.1 to 1.1 inch. Bluish-green grains of apatite (N_W = 1.63) 0.05 inch or less in diameter are common only within a few inches of the pegmatite contact. The average grain size of the altered schist is about 0.04 inch which is somewhat coarser than that of the unaltered rock. In some places the only visible alteration of the schist has been the destruction of biotite with only negligible additions of tourmaline; in other places there has been no apparent alteration.

The average strike of bedding is almost directly east, and the average dip is 85° S. The structure of the schist is not known completely, although the schist has been studied not only in the area shown on figure 2, but also in adjacent areas. Probably the tops of beds are generally to the north, but there may be some reversals caused by folding. Minor folds in the schist have not been studied in detail.

The schistosity near the edges of the mapped area (figure 2) is nearly parallel to the bedding, but the average dip may be at a lower angle to the south than the bedding dip. As the pegmatite is approached, however, the attitude of the schistosity turns until it is parallel or nearly parallel to the contact. This relationship is shown especially well on the 4,540-foot-level (fig. 3) and east of the open pit (fig. 2). Nonetheless, schistosity at the contact may be discordant by as much as 20°.



Quartz-mica-chlorite schist at depth of 34.8 feet in drill hole 5, and 35.5 feet from the pegmatite contact. The groundmass contains quartz (50 percent), biotite (25 percent), muscovite (20 percent), chlorite (3 percent), and titanite (trace). Pseudomorphs of euhedral staurolite crystals forming 5 to 10 percent of the schist are composed of muscovite (50 percent), quartz (20 percent), chlorite (20 percent), and biotite (10 percent). In the pseudomorph shown in the thin section, biotite, (B) forms the outer rim, muscovite (M) forms the next layer, and chlorite (C) is concentrated near the center of the pseudomorph.

PLATE 2. PSEUDOMORPH OF A STAUROLITE CRYSTAL
(photomicrograph 2-1/3 times natural size)

GPO 836752

[illegible]

[illegible]

All types of schists are cut by numerous quartz stringers that range in thickness from 0.05 inch to more than 12 inches. Some of the stringers are parallel to the foliation, but many crosscut the foliation at various angles. Most of the stringers consist entirely of colorless to slightly milky, massive quartz; a few contain as much as 20 percent plagioclase. The minimum index of refraction (N_q ') of (001) cleavage fragments of the plagioclase in one of these stringers is 1.543, indicating that the plagioclase is oligoclase, An_{29}. _/ Some of the quartz veins and the adjacent schist contain small specks of chalcopyrite, pyrite, and pyrrohotite.

_/ Throughout this report the determination of the anorthite content of plagioclase is based on Grout, 1932, p. 468, fig. 264.

Quartz-plagioclase-muscovite pegmatite, undivided

Undivided quartz-plagioclase-muscovite pegmatite cuts the schist in the southwest part of the mapped area (fig. 2). This pegmatite has a variable texture but is generally fine-grained. The maximum grain size is about 1 inch. Part of the albite and quartz occurs as sugary-textured aggregates.

Peerless pegmatite

The Peerless pegmatite is a large northwest trending complex pegmatite anticlinal in cross-section (figs. 4, 5 and 6) and irregularly elongate in plan view (fig. 2). The pegmatite contains seven zones, two replacement units, and two types of fracture-fillings. These units consist chiefly of differing proportions of quartz, plagioclase, perthite, muscovite, and lithia mica. Chemically this pegmatite has a relatively simple composition; it consists almost entirely of four oxides: SiO_2, Al_2O_3, Na_2O, and K_2O. Available evidence suggests that this pegmatite crystallized from a magma-like fluid consisting chiefly of these constituents together with an unknown quantity of water.

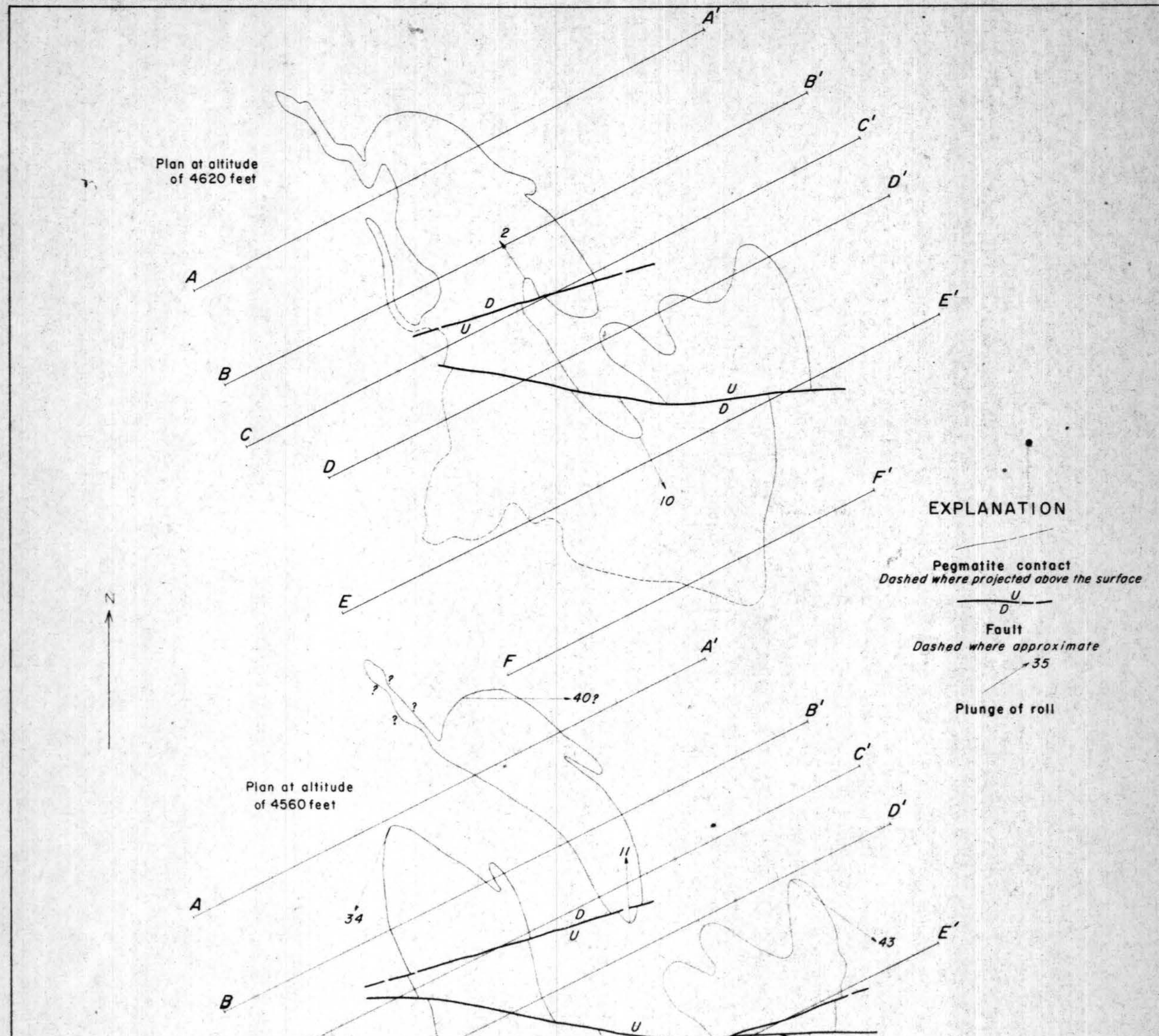


FIGURE 6—GEOLOGIC PLANS, PEERLESS PEGMATITE AT ALTITUDES OF 4560 AND 4620 FEET ABOVE SEA LEVEL

Geology by D.M. Sheridan and J.J. Norton

0 100 200 Feet

Datum approximate

Size, shape and structure

The long axis of the pegmatite outcrop trends northwest over a distance of about 580 feet; the maximum width of exposed pegmatite is about 360 feet. The anticlinal structure of the pegmatite and its discordance with the schist suggest control of the intrusion by fractures striking about N. 30°W. and dipping about 45° E. and W. (figs. 2 and 6). The axis of the anticlinal structure has a low angle of plunge (fig. 6 and pl. 3); on the underside of the southern part of the pegmatite it is 10° S. 27° E; northward it changes to 2° N. 34° W., and still farther north it is 5° N. 49° W.

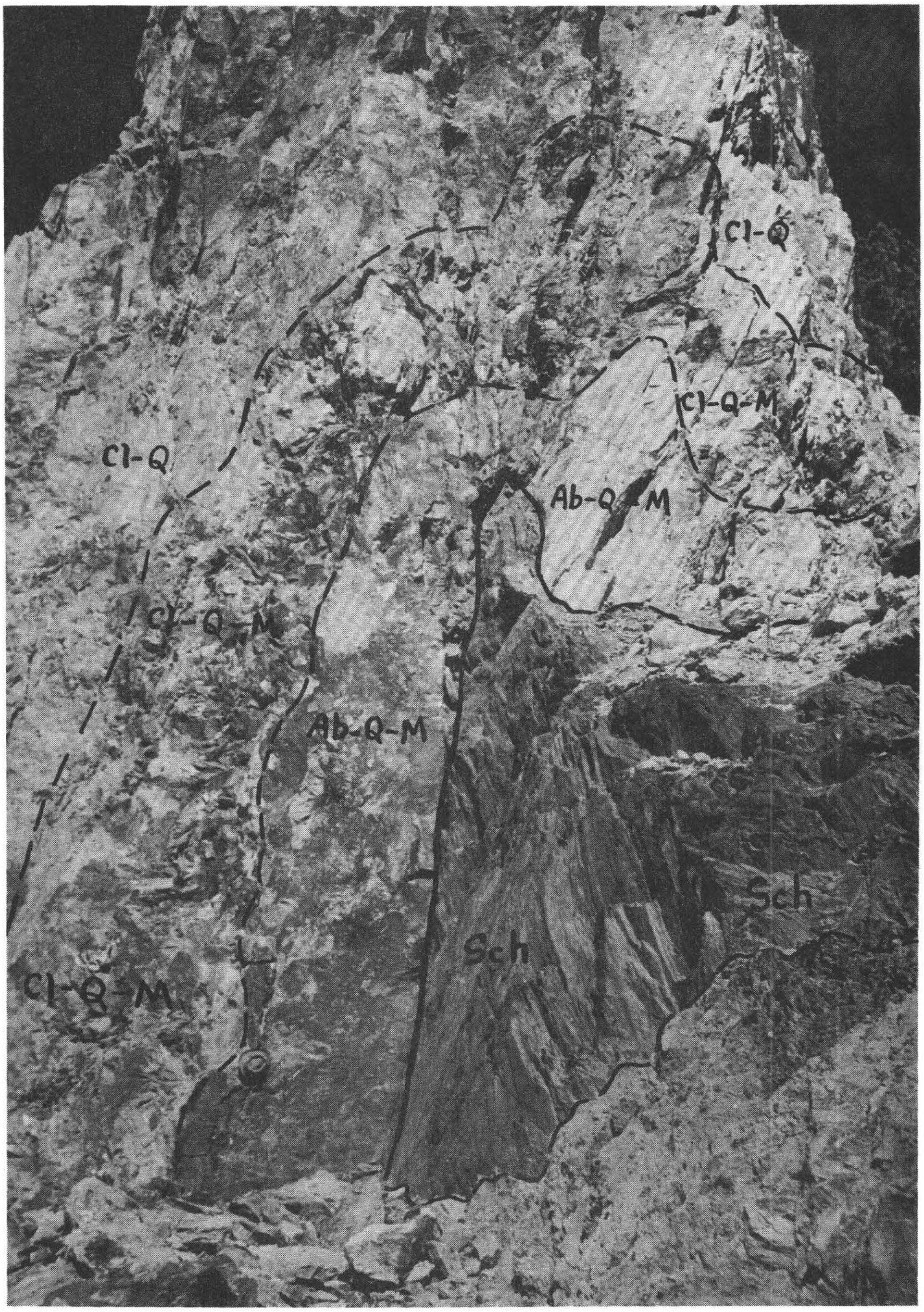
Geologic plans at 4, 560 and 4, 620 feet in altitude (fig. 6) show the changes in shape of the pegmatite. At the 4, 560-foot level the pegmatite is divided into three segments: two on the northeastern limb and one on the southwestern limb. At the 4, 620 foot level the southwestern limb is joined to both segments of the northeastern limb. The two segments of the northeastern limb may also join each other at this level, even though they are separated (fig. 2) and (fig. 6).

The keels of the southwest limb and each segment of the northeast limb are doubly plunging, having a north plunge at the south end and a south plunge at the north end (fig. 6). The geologic sections (fig. 4) indicate that from section AA' to section BB' the keel of the southwest limb plunges 34° S. 23° W. From section BB' to DD' the plunge is probably nearly horizontal. Further south the underside of the pegmatite has three large rolls, rather than one simply defined keel. These rolls plunge 5° to 25° N. 5° E. to N. 35° W. The pattern of these rolls on the 4, 560-feet level (fig. 6) suggests that these are two coalescing pegmatites.

The two segments of the northeastern limb are structurally similar to the southwest limb. Both have rolls that suggest coalescing structure. The south segment is simple at its south end, but it has at least three major rolls at the north end. The keel is probably horizontal just south of section EE'.

The keel of the north segment of this limb plunges northerly from section CC' to AA'. Further north it probably curves upward to join the crest. This conclusion is supported by 65° to 80° dips and easterly plunges at the north end of the outcrop (fig. 2).

In addition to these three large structures and their various minor rolls, there are several dike-like apophyses that extend outward from the main body of the pegmatite. The two chief ones are on the west



A. The main axis of the Peerless pegmatite; northeast limb on the right and southwest limb on the left. Location is between sections EE' and FF' (fig. 2). Sch --quartz-mica schist. Ab-Q-M--Zone 2, albite-quartz-muscovite pegmatite (wall zone). Cl-Q-M--Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone). Cl-Q--Zone 5, cleavelandite-quartz pegmatite (third intermediate zone). Upper parts of the exposure contain unlabeled central units of the pegmatite. Scale is given by hat in lower left.

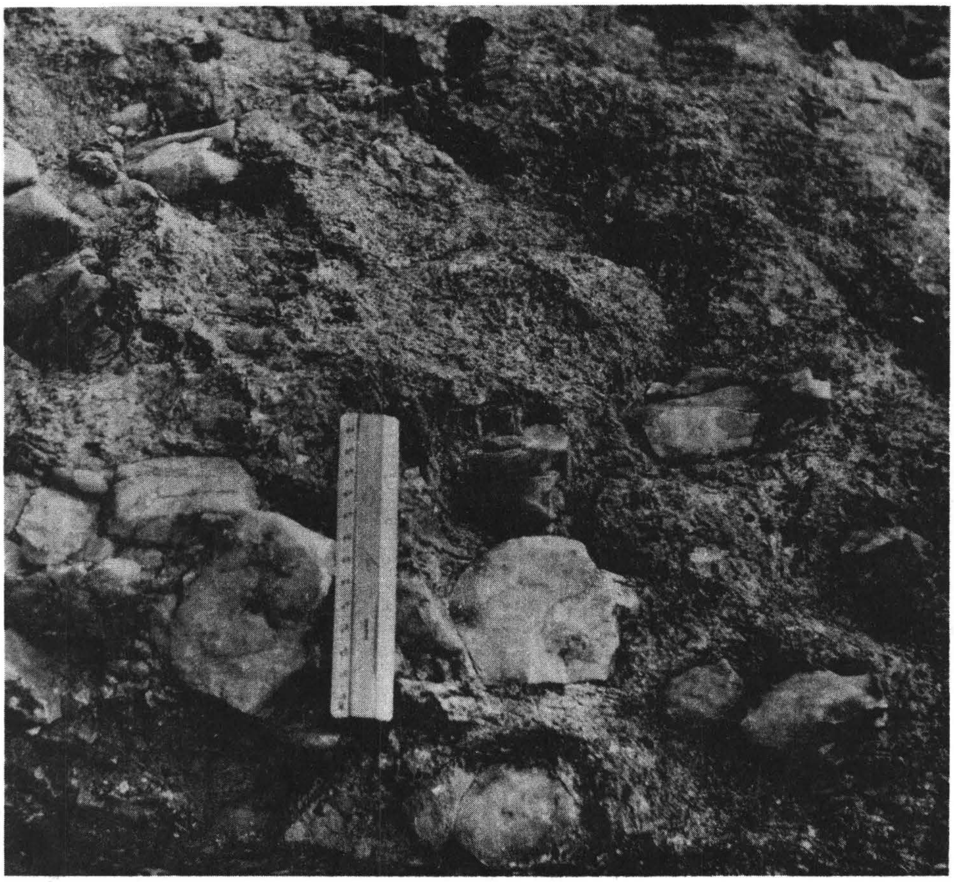
PLATE 3. PEERLESS PEGMATITE

B. Layering in the wall zone. Sugary albite-quartz pegmatite on the left. Coarser-grained albite-quartz-muscovite pegmatite on the right.

PLATE 3. PEERLESS PEGMATITE

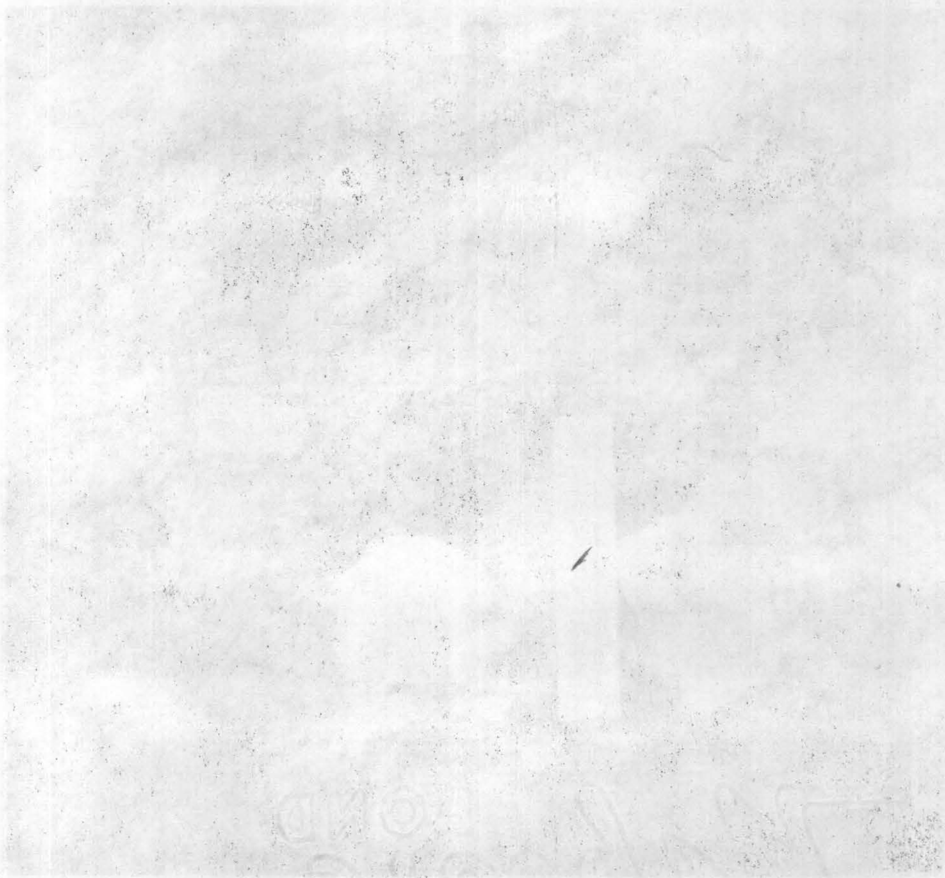
C. Layering in the wall zone. Schist contact on the right. South of A.

PLATE 3. PEERLESS PEGMATITE



D. Beryl in albite-rich pegmatite near the contact of Zones 2 and 3.

PLATE 3. PEERLESS PEGMATITE



b. [illegible] in albite-rich pegmatite near the contact of zones 2 and 3.

side of the pegmatite near the north end (figs. 2, 4, and 6). These are irregular and discordant with the schist; the principal attitude is a strike of N. 20°W. and a dip of 70°E. A footwall roll in drill hole 6 (fig. 4) may be similar in structure.

Internal units

The Peerless pegmatite has a sequence of seven zones, two replacement units, and two varieties of fracture-filling units. The outermost unit is a 1/2-inch-thick border zone consisting predominantly of quartz, but also containing muscovite and blocky albite-oligoclase. Blocky to subplaty albite becomes predominant in the wall zone, at the expense of quartz and muscovite (table 3). Both the border and wall zones consist of a series of layers that differ greatly in texture and in content of quartz, feldspars, and muscovite. In Zone 3, the first intermediate zone, albite is still the chief mineral, but it is predominantly cleavelandite. Zone 3 contains more muscovite than any other zone. Zone 4 is a hood-shaped zone at the top of the pegmatite in which very coarse-grained microcline-perthite is the principal mineral; muscovite is minor, and the cleavelandite-quartz groundmass is much the same as in zone 3. Zone 5 is similar to the groundmass of Zone 4. Sharp changes take place at the contact with Zone 6. This zone consists chiefly of quartz, but a subsidiary unit containing non-perthitic microcline forms a hood at the top of this zone. The core consists principally of lithia mica, but it also contains cleavelandite. The core is bordered by a replacement unit. The introduced minerals of the replacement unit are the same as the minerals of the core, but relicts of Zones 3 through 6 can also be recognized. Minor units of the pegmatite include fracture-fillings containing quartz and tourmaline, and also a mass of muscovite-cleavelandite-pegmatite that probably is a replacement unit.

The minerals of the Peerless pegmatite include: albite, quartz, muscovite, microcline-perthite, non-perthitic microcline, tourmaline, beryl, apatite, amblygonite (variety, montebrasite), lithia mica, cassiterite, stannite, tantallite-columbite, garnet, loellingite (?), chalcopyrite, limonite, spodumene, svanbergite, vivianite (?), dahllite, triploidite (?), an unidentified bluish-green to dark-green mineral, and vari-colored phosphate minerals (probably largely members of the lithiophilite-triphylite group)-and

Table 3.--Approximate mode of internal structural units, Peerless pegmatite. 1/

Internal structural unit	Average grain size 2/ (inches)	Plagioclase (percent)	Plagioclase (variety)	Quartz	Muscovite	Microcline-perthite	Microcline (non-perthitic)	Tourmaline	Beryl	Apatite	Amblygonite, var. montebrasite	Lithia mica	Varicolored 2/ phosphate minerals	Cassiterite	Tantalite-columbite	Garnet	Spodumene	Other minerals (all in traces)
				Approximate mode (percent)														
Zone 1. Quartz-muscovite-plagioclase pegmatite (border zone).	0.1	10	Blocky albite-oligoclase.	65	23	-	-	< 1	Trace.	< 1	-	-	-	-	Trace.	< 1	-	-
Zone 2. Albite-quartz-muscovite pegmatite. (wall zone).	.4	58	Blocky to subplaty albite.	28	8	3	-	1.5	1.08 4/ (outcrops) .09 (drill core).	< 1	Trace.	-	< 1	Trace.	Trace.	Trace.	-	Loellingite(?). Svanbergite. Dahllite Triploidite(?) Unidentified bluish-green to dark-green mineral.
Zone 3. Cleavelandite-quartz-muscovite pegmatite. (first intermediate zone).	2.25	40	Cleavelandite.	29	28	< 1	-	< 1	1.46 4/ (outcrops) 1.93 (drill core).	< 1	Trace.	-	Trace.	< 1	< 1	Trace	-	Loellingite(?). Vivianite(?). Dahllite.
Zone 4. Perthite-cleavelandite-quartz pegmatite. (second intermediate zone).	10 5/	30	Cleavelandite.	23	6	40	-	< 1	< .5	< 1	-	-	-	-	-	-	-	--
Zone 5. Cleavelandite-quartz pegmatite. (third intermediate zone).	1.5	45	Cleavelandite.	45	6	-	-	< 1	.5 6/ (outcrops) .12 (drill core).	< 1	.5 to 1.	-	1	< 1	< 1	-	-	--
Zone 6a. Quartz-microcline pegmatite. (fourth intermediate zone).	180	-	---	59	-	-	40	-	--	-	--	< 1	-	-	-	-	-	--
Zone 6b. Quartz pegmatite. (fourth intermediate zone). 7/	Very coarse.	-	---	99	-	-	-	-	Trace.	-	--	-	< 1	-	-	-	< 1	--
Zone 7. Lithia mica-cleavelandite pegmatite (core, and replacement unit). 8/	.1	15	Cleavelandite.	1	-	-	-	-	--	-	--	82	1	< 1	< 1	-	-	--
Muscovite-cleavelandite pegmatite (replacement unit). 8/	.2	30	Cleavelandite.	-	69	-	-	< 1	Trace.	< 1	--	< 1	-	Trace.	< 1	-	-	--
Tourmaline-quartz pegmatite. (fracture-filling).	.15	-	---	10	-	-	-	90	--	-	--	-	-	-	-	-	-	--

1/ Based on visual estimates of the composition of drill core and surface exposures. The magnitude of errors in these estimates is not known.

2/ The "average grain size" of each unit is the average of the lengths of the grains in the unit.

3/ Includes grayish-brown, yellowish-brown, clove-brown, bluish-gray, pinkish-buff, greenish-gray, purple, and brownish-black minerals, most of which are probably lithiophilite-triphylite group and its alteration products.

4/ Obtained by measuring beryl grains.

5/ Aggregates of the cleavelandite-quartz matrix are as much as 4 ft in size, and the average length of perthite grains is about 2 ft.

6/ Visual estimates were used to determine the beryl content of outcrops, and measurements of beryl grains were used for the drill core.

7/ Accessory minerals were found only in the fourth intermediate zone; the quartz fracture-fillings consist entirely of massive quartz.

8/ Excludes partially replaced relict masses of pegmatite of other units.

their alteration products. Other minerals that have been reported in the literature but not observed during the present investigations, include struverite (strueverite) (Ziegler, 1914a, p. 115), alteration products of stannite (Headden, 1893, p. 105-110), autunite and torbernite (Ziegler, 1914a, p. 206-207), and possibly rare chrysoberyl (Page and others, 1953, p. 11).

Table 3 gives detailed data concerning the mineralogy of the various pegmatite units. The percentages of the various minerals listed in table 3 have been compiled from visual estimates at numerous exposures, both at the surface and in underground workings, and from visual estimates of the drill cores. Beryl figures are based partly on grain measurements.

Pegmatitic textural terms in this report are adapted from the classification by Cameron, Jahns, McNair and Page (1949, p. 16). The terms "very fine-grained" and "sugary-grained" have been added. The terms and grain sizes used in this report are as follows:

Term	Average grain size
Sugary	Less than 0.1 inch
Very fine	0.1 to 0.25 inch
Fine	0.25 to 1 inch
Medium	1 to 4 inches
Coarse	4 to 12 inches
Very coarse	Greater than 12 inches.

Quartz-muscovite-plagioclase pegmatite (Zone 1, border zone) and albite-quartz-muscovite pegmatite (Zone 2, wall zone).--The overall composition of the border zone is quartz-muscovite-plagioclase pegmatite, and the wall zone is albite-quartz-muscovite pegmatite. These zones can be further subdivided into a series of pegmatite lenses or layers (pl. 3). These structures have been defined from studies of this and other Black Hills pegmatites, as differing in mineral composition, texture, or both; they are parallel to the pegmatite contact and may or may not be continuous around the entire body. The layers may be cut by fracture-fillings or replacement units; they may or may not be zoned.

Figure 7 shows the sequence of layers and probable correlations where the pegmatite was cut by diamond drill holes. Table 4 shows a somewhat similar sequence in the main open pit.

Table 4. --Sequence of layers in the border and wall zones, northeast part of the main open pit , Peerless pegmatite. Geology by L. R. Page and J. A. Redden.

Order of layers inward from pegmatite contact	Correlative layer in drill holes (fig. 7)	Thickness	Approximate mode (percent)	Average grain size (inches)	Known age relations
11	Q-Ab	3 ft	Quartz-65	1 1/2	Younger than 10.
10	Variant of Upper Ab-Q-M	4 ft	Quartz-45 Albite-40 Muscovite-15	1 1/2	Younger than 8.
9	Variant of Ab-Q-P	0 to 6 in.	Perthite-40 Quartz-30 Albite-10 Muscovite-10 Tourmaline-10	3	Younger than 8 and 10. Segregation or fracture-filling.
8	Middle Ab-Q-M	5 to 6 ft	Albite-65 Quartz-25 Muscovite-5 Perthite-trace	3/8	Younger than 7.
7	None	3 ft	Quartz-60 Muscovite-25 Albite (cleavelandite)-15	2	Younger than 6.
6	Ab-Q	2 ft	Albite-80 Quartz-20	Sugary.	Younger than 5.
5	Lower Ab-Q-M	1 ft	Albite-55 Quartz-30 Muscovite-10 to 15	1	Younger than 2.
4	None	1 ft	Quartz-45 Albite-35 Muscovite-20	2	Younger than 3 and 5. Segregation or fracture-filling.
3	Lower Ab-Q-M	1 ft	Albite-55 Quartz-30 Muscovite-10 to 15	1	Younger than 2.
2	Q-Ab-M	3 in.	Quartz-45 Plagioclase-35 Muscovite-20	1	Probably the oldest unit in the sequence.
1	Q	0 to 1/2 in.	Quartz--100	Massive	Probably younger than 2.

The border zone is very fine grained; the average grain size is 0.1 inch. The thickness is generally about 0.5 inch, but the maximum thickness is 2.5 inches. The largest exposures of border zone occur as dip slopes along the northern and northeastern flanks of the pegmatite (fig. 2); elsewhere the zone is exposed along more steeply dipping contacts where it is too thin to constitute a mappable unit.

The border zone consists of quartz (65 percent), muscovite (23 percent), albite-oligoclase (10 percent), tourmaline (< 1 percent), apatite (< 1 percent), garnet (<1 percent), beryl (trace), and tantalite-columbite (trace). Locally the border zone ranges from quartz pegmatite with accessory muscovite to pegmatite composed of albite (50 percent), quartz (35 percent), and muscovite (15 percent); several outcrops have as much as 35 percent muscovite. Detailed mineralogic data are presented in table 5.

Quartz is the dominant mineral in nearly all exposures of the border zone. At many places the outermost layer of the pegmatite is a thin sheet of massive quartz that may be a fracture-filling unit.

Plagioclase is sparse at the outer contact, but it increases in abundance inward. The anorthite content of the plagioclase is as much as 13 percent at the outer contact and decreases to 4 percent at the inner contact.

The wall zone is as much as 20 feet thick, but the average thickness is about 5 feet. It is thickest on the footwall sides of the pegmatite limbs and is thinnest near the crest of the body and near some of the structural rolls (figs. 4 and 5). Locally the wall zone is absent and either the first or second intermediate zone is in direct contact with the border zone.

The wall zone exhibits a great diversity in mineralogy and texture, as shown by the data on layering in table 4 and figure 7. Most of the wall zone has a fine-grained pegmatitic texture; the average size of individual grains is about 0.4 inch but the size ranges widely. The minerals are albite (58 percent), quartz (28 percent), muscovite (8 percent), perthite (3 percent), tourmaline (1.5 percent), beryl (0.6 percent), apatite (< 1 percent), varicolored phosphate minerals and their alteration products (<1 percent), garnet (trace), amblygonite (variety montebrasite) (trace), svanbergite (trace), tantalite-columbite (trace), cassiterite (trace), loellingite (?) (trace), triploidite (?) (trace), dahlite (trace), and an unidentified bluish-green to dark-green mineral (trace). Detailed mineralogic data are presented in table 6.

Table 5.--Mineralogy of quartz-muscovite-plagioclase pegmatite (Zone 1, border zone), Peerless pegmatite

		Grain size (inches)				
Mineral	Percent	Range	Average 1/	Shape	Color	Optical date
Quartz	65	0.02-0.5 or Massive	0.1	Irregular grains. Discontinuous massive quartz as much as .5 in. thick, at contact	Colorless to slightly smoky and milky	- - -
Muscovite	23	.01- .4	.05	Tabular flakes	White to yellowish-silver	- - -
Plagioclase	10	.01- .5	.1	Mostly blocky. Some subplaty to platy at inner edge of zone.	White, pale buff, and grayish-white	The minimum index of refraction (N_{α}') on cleavage fragments (001) ranges from 1.533 (An_{13}) for grains near contact to 1.528 (An_4) for grains at inner edge of zone. 2/
Tourmaline	< 1	.05- .3	.15	Euhedral	Black, bluish-black, greenish-black	N_{ω} = 1.67 (blue-black).
Apatite	< 1	.01- .15	< .05	Rounded	Bluish-green	- - -
Garnet	< 1	.02- .25	.1	Rounded	Reddish-brown	N = 1.82
Beryl	Trace.	.1- .5	.25	Subhedral to euhedral	White to colorless	N_{ω} is 1.577 to 1.581 (13.3 to 13.0 percent BeO. 3/)
Tantalite- Columbite	Trace	.01- .15	.05	Platy	Black	- - -

1/ The " average" size is the average of the lengths of the grains.

2/ Anorthite content based on Grout, 1932, p. 468, fig. 264.

3/ BeO Content of beryl is from unpublished curve by W. T. Schaller.

Table 6.--Mineralogy of albite-quartz-muscovite pegmatite (Zone 2, wall zone), Peerless pegmatite.

Mineral	Percent	Grain size (inches) Range	Grain size (inches) Average	Shape	Color	Optical data	Remarks
Albite.	58	0.1-1.0 .01-.1 .1 -2.0	0.25 .05 .6	Blocky to subplaty. Sugary-grained. Platy grains.	White to buff.	Blocky to subplaty: N_{α}'= 1.528 to 1.531 (An_4 to An_9). Sugary-grained: N_{α}'= 1.528 to 1.531 (An_4 to An9). Platy: N_{α}'= 1.528 to 1.530 (An_4 to An_8).	Mostly blocky to subplaty. Some sugary-grained in the very fine-grained albite-rich pegmatite that makes up between 10 and 15 percent of the zone. Platy albite occurs in some of the quartz-rich parts of the zone.
Quartz.	28	.05-3.0	.5	Irregular grains.	Colorless to milky white.	- - -	- - -
Muscovite.	8	.1-2.75	.5	Tabular flakes and books.	Silvery to yellowish-white.	- - -	The size increases toward the inner edge of the wall zone.
Perthite.	3	.25-12	2.0	Blocky.	Flesh.	- - -	Grains of perthite are embayed, rounded, and veined by sugary-grained albite and by fine-grained albite, quartz, and muscovite of the matrix.
Tourmaline.	1.5	.02-15.0	.5	Subhedral to euhedral.	Black, bluish-black, blue, and greenish-black.	Black tourmaline: N_{ω} = 1.67. Blue, bluish-black, and greenish-black: N_{ω} = 1.66 - 1.675.	Black grains are chiefly along innermost edge of zone. Blue, bluish-black, and greenish-black grains are distributed throughout the wall zone.
Beryl.	1.08 (outcrop) 0.09 (drill core)	.1-5 (diameter)	0.75 (outer edge of zone) to 3 (inner edge of zone).	Subhedral to euhedral (prismatic).	Colorless, white, pale yellowish-white, pale greenish white.	The maximum index of refraction (N_{ω}) ranges from 1.574 to 1.587 (13.5 to 12.3 percent BeO); in general, the beryl of higher refractive index is from inner part of the zone. Some of the larger crystals have a higher index in the outer part than in the center.	Beryl is most abundant in the inner 3 ft of the wall zone, where it locally is as much as 6 percent of the rock. An unidentified yellow-brown to green-brown, soft, waxy mineral may be an alteration product of beryl.
Apatite.	< 1	.02-.3	- -	Rounded to subhedral.	Bluish-green, green, and gray-blue.	N_{ω} = 1.64. Translucent, grayish-blue, prismatic crystals are abnormally biaxial (-) with 2V=ca. 25°; N_{γ} = 1.63.	Prismatic, grayish-blue apatite 0.1 in. to 0.15 in. in length occurs in vugs.
Varicolored phosphate minerals and alteration products.	< 1	.1-2.0	- -	Irregular to rounded.	Brownish, gray-black, gray-brown, clove-brown, yellow-brown, pinkish-buff, greenish-gray.	- - -	Probably mostly lithiophilite-triphylite. Brownish-gray to black alteration products (probably, in large part, manganese and iron oxides) stain the other minerals of the zone.
Garnet.	Trace.	.02-.6	.1	Rounded to euhedral.	Pink to reddish-brown.	N = 1.82.	- - -
Amblygonite, var. montebrasite.	Trace.	.1-3.0	.75	Rounded.	White to grayish-white.	Biaxial (+), N_{γ}'= 1.615 - 1.625, N_{α}'= 1.600 - 1.610.	Most common in the perthite-rich inner parts of the wall zone along the footwall of the pegmatite. Also found in irregular bodies that may be fracture-fillings in the outer part of the wall zone.
Svanbergite.	Trace.	- -	- -	Microscopic cube-shaped crystals in a pseudomorph of creamy-buff kaolin after beryl.	- - -	Uniaxial (+) N_{ω} = 1.625. N_{ϵ} = 1.639.	Altered beryl containing svanbergite is associated with amblygonite.
Tantalite-columbite.	Trace.	.01-.02 (thickness) .05-.7 (length)	.01 (thickness). .15 (length).	Platy.	Black.	- - -	- - -
Cassiterite.	Trace.	.02-.4	.1	Rounded to euhedral.	Brownish-black.	- - -	- - -
Loellingite(?).	Trace.	.05-.5	.1	Elongate to irregular.	Silvery.	- - -	- - -
Triploidite(?).	Trace.	.6 by 1.5	- -	Irregular.	Dark-yellow to liver-brown.	N > 1.72. Second order interference colors. Pleochroic: Yellow to red-brown.	Contains euhedral inclusions of beryl.
Dahllite (carbonate-apatite).	Trace.	.05 -.25	.1	Rounded.	Buff-white.	Uniaxial (-). N_{ω} = 1.64. Birefringence: .005.	Identified as dahllite by A. J. Gude, 3d, using powder X-ray techniques.
Unidentified mineral.	Trace.	- -	.1	Angular clots graphically included in albite.	Bluish-green to dark-green.	Very fine-grained aggregate with refractive index = 1.58.	- - -

In general, the keelward parts of the wall zone contain less albite and more quartz than exposures of the wall zone in the upper parts of the pegmatite. In 24 segments cut by drill holes, the wall zone contains 50 percent albite and 35 percent quartz. In contrast, an exposure of wall zone near the crest of the northern part of the pegmatite contains 70 percent albite and 20 percent quartz. The measured beryl content is 1.08 percent in surface exposures and only 0.09 percent in drill core. This change can also be correlated with the changes in albite and quartz content; figure 7 shows that beryl tends to be most abundant in albite-rich layers.

The layers of the wall zone (fig. 7 and table 4) can be correlated and a meaningful sequence of units can be constructed for the map area. Contacts between layers are generally gradational. Layers such as "4" and "9" in table 4 have somewhat sharper contacts that in places cut across adjacent layers. These layers may be fracture-fillings, or they may have crystallized from segregation of fluids that were trapped by more rapidly crystallizing adjacent rocks.

The outermost layer of some parts of the wall zone consists of quartz-muscovite pegmatite similar to the border zone except that it is coarser-grained. Ordinarily, however, the outermost layer is quartz-albite-or albite-quartz-muscovite pegmatite.

The next layer in the sequence, is similar to the albite-quartz-muscovite pegmatite, but it also contains distinctive sugary-grained aggregates of albite (85 percent), quartz (10 percent), and accessory minerals. These aggregates form lenses and layers parallel to the larger-scale layers.

This layer is succeeded in many places by an albite-perthite-quartz layer that contains coarse perthite crystals in a groundmass of albite, quartz, and muscovite. It is chiefly fine- to medium-grained but also contains sugary-grained albite-quartz aggregates.

Another non-perthite layer containing sugary albite and quartz follows, and it is succeeded in turn by layers containing fine- to medium-grained albite, quartz, and muscovite (layers 7 and 8 of table 4; layer 9 of fig. 7).

A perthite-bearing layer containing quartz, albite, and muscovite is next in the sequence both in the drill holes (fig. 7) and in the open pit (table 4). It is succeeded by still another layer of fine- to medium-grained albite-quartz-muscovite pegmatite. This innermost layer of the wall zone is quartz-albite pegmatite, recognized only in a few places.

Another type of layer, not shown in either figure 7 or table 4, consists of medium-grained lenses of quartz-rich pegmatite that rarely exceed 1 foot in thickness and 3 feet in length. A lens of this type in the main pit has an average grain size of 1.25 inches and contains quartz (60 percent), muscovite (24 percent), albite (14 percent), beryl (1 percent), and sparse accessory minerals.

It can be expected that further detailed study will lead to the recognition of still more layers in the sequence. Each of the layers from 2 to 10 in table 4, and 4 to 11 in figure 7 may be repeated more times than shown here.

The albite (An_{4-9}) in all parts of the wall zone, except the sugary-grained aggregates, is blocky to subplaty. The average grain size is about 0.25 inch. In a few places, such as layer 7 of table 4, the albite is platy. Platy albite (An_{4-8}) has an average grain size of 0.6 inch. The anorthite content of the albite tends to decrease toward the inner part of the wall zone (fig. 7), but there is overlap and repetition that presumably is related to the repetition of the layers and to crosscutting relations between these units.

Beryl tends to be most abundant in albite-rich layers, especially in the inner part of the wall zone where it locally forms as much as 6 percent of the rock (pl. 2). The average size increases from 0.75 inch in diameter in the outer part of the wall zone to 3 inches in diameter at the inner edge. The BeO content of the beryl tends to decrease toward the inner part of the zone, but as with the albite, there is overlap and repetition. In the drill holes (fig. 7) the BeO content of beryl tends to decrease from layers 2 to 5; it increases in layer 6, which contains sugary albite-quartz aggregates; it decreases again in the perthite-rich pegmatite of layer 7, which probably is a segregation; then it increases in the albite-quartz pegmatite of layer 8. Beryl with the lowest BeO content occurs in quartz-albite pegmatite of layer 12. The index of refraction of beryl from the outer part of some of the larger crystals is higher than for beryl from the center of the crystals.

Crystals of black tourmaline, as much as 10 inches in diameter, are most abundant near the contact with the first intermediate zone. Grains of blue, bluish-black, and greenish-black tourmaline, as much as 1 inch in length, and bluish-green grains of apatite, 0.02 to 0.3 inch in length, are distributed throughout the wall zone.

Varicolored phosphate minerals occur in irregular to rounded masses as much as 2 inches in diameter. Most of these minerals are probably members of the lithiophilite-triphylite group. One dark-yellow to liver-brown mass may be triploidite (?). Small, rare, buff-white grains are dahllite. _/ Brownish-gray

_/ Determined in part by powder X-ray work done by A. J. Gude, 3d.

to black alteration products of the phosphate minerals, probably manganese and iron oxides, stain the other minerals of the zone in irregular streaks and patches.

Reddish-brown grains of garnet, black plates of tantalite-columbite, and brownish-black grains of cassiterite are sparsely distributed in the wall zone. Rounded grains of amblygonite, 0.1 to 3 inches in size, are most common in perthite-rich layers along the footwall parts of the zone but have also been observed in small irregular bodies that are possibly fracture-filling in the outer part of the zone. Optical data indicate that this amblygonite is relatively high in hydroxyl and is probably on the montebrasite side of the amblygonite-montebrasite series. Microscopic cube-shaped crystals of svanbergite occur in a pseudomorph of creamy-buff kaolin after beryl that is associated with a grain of amblygonite at the base of the pinnacle in the main open cut (fig. 2). An unidentified bluish-green to dark-green soft mineral occurs as 0.1-inch angular clots that are graphically included in albite; microscopically the unidentified mineral is very fine-grained and has a refractive index of about 1.578.

Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone).--Zone 3, the first intermediate zone, consists of cleavelandite-quartz-muscovite pegmatite that forms a less complete shell than the wall zone; in plan (fig. 2) and in section (figs. 4 and 5), however, it reflects the overall shape and structure of the pegmatite body almost as well as the wall zone. Where the wall zone is locally absent, Zone 3 is separated from schist only by the border zone. The inner margin of Zone 3 is adjacent to Zone 5 throughout most of the pegmatite body, but in the upper parts of the northeast limbs of the pegmatite, it lies between the wall zone and the downward-tapering Zone 4 (figs. 2, 4, and 5). Zone 3 pinches out upward over most of the crestal parts of the pegmatite. Possibly Zone 3 grades upward into Zone 4 in some of the unexposed parts of the pegmatite.

In most exposures, the contacts of Zone 3 are clearly defined, because the relatively large muscovite content is in sharp contrast with the lower muscovite content of adjacent zones. Locally, where the contact is gradational over a distance of several feet, a cutoff at 10 percent muscovite was used to map the contact with Zones 2 and 5.

The thickness is as much as 15 feet; the average is about 5 feet in the footwall parts of the pegmatite and about 1.5 feet in the hanging-wall parts of the body (fig. 4 and 5).

This zone has a medium-grained pegmatitic texture; the average size of individual grains is about 2.25 inches, but the size ranges widely. Locally, numerous large aggregates of cleavelandite or of large books of muscovite give the zone a coarse pegmatitic texture.

The minerals of Zone 3 are cleavelandite (40 percent), quartz (29 percent), muscovite (28 percent), beryl (1.7 percent), perthite ($<$1 percent), apatite ($<$ 1 percent), tourmaline ($<$ 1 percent), tantalite-columbite ($<$ 1percent), cassiterite ($<$ 1 percent), amblygonite (variety montebrasite) (trace), dark-colored phosphate minerals and their alteration products (trace), garnet (trace), loellingite (?) (trace), vivianite (?) (trace), and dahllite (trace). Locally the proportions of the minerals vary widely. For example, the large exposure between sections A-A' and B-B' (fig. 2), contains areas of about 5 square feet that have 55 percent cleavelandite, 19 percent quartz, 15 percent beryl, and 10 percent muscovite; yet the remaining area contains a relatively high proportion of muscovite - as much as 50 percent- and less than 1 percent beryl. Near the west end of the main pit (fig. 2), Zone 3 contains 60 percent muscovite, 25 percent cleavelandite, 20 percent quartz, and 1 percent beryl. In general, muscovite is most abundant in the thick parts of the zone near the keel of the pegmatite (fig. 4 and 5). Locally, perthite comprises as much as 5 percent of the zone.

Detailed mineralogic data are presented in table 7.

Aggregates of cleavelandite (An_{4-8}) are as much as 18 inches in diameter, but the average size is about 4 inches. Individual plates have an average length of about 1 inch and an average thickness about 0.02 inch.

The largest book of muscovite observed is 3 feet in diameter, but the average size is about 5 inches; aggregates of books are commonly 2 to 3 feet in diameter. Nearly all the muscovite has herringbone and wedge structures, and some is strongly ruled.

Table 7.--Mineralogy of cleavelandite-quartz-muscovite pegmatite (zone 3, first intermediate zone), Peerless pegmatite.

Mineral	Percent	Grain size (inches) Range	Grain size (inches) Average	Shape	Color	Optical data	Remarks
Cleavelandite.	40	0.2 to 3.0	1.0	Platy.	White to grayish-white.	N_{α}' ranges from 1.528 to 1.530 (An_4 to An_8).	Average thickness of platy grains is 0.02 in. but average length is 1.0 in. Aggregates of plates are as much as 18 in. in diameter, but the average size of such aggregates is 4 in.
Quartz.	29	.1 - 4.5	1.5	Irregular.	Colorless to milky.	- - -	- - -
Muscovite.	28	.1 -36.0	5.0	Books and flakes.	Yellowish-silvery.	- - -	Aggregates commonly 2 to 3 ft in diameter. Abundant herringbone and wedge structure, and some ruling. Punch and sheet are rare.
Beryl.	1.46(outcrop) 1.93 (drill core) 1.7 (average)	.5-26.0 (length)	3 (diameter).	Chiefly subhedral to euhedral (prismatic), but less commonly anhedral. Also as tapered, irregularly hexagonal, skeletal crystals containing thin layers of cleavelandite.	White, yellowish-white, and greenish-white.	N_{ω}=1.575 to 1.584 (13.5 to 12.6 percent BeO). Outer parts of crystals have higher indices than the centers.	Beryl forms as much as 15 percent of small cleavelandite-rich parts of the zone.
Perthite.	< 1	.5-12.0 (outer part of zone) 4 -20 (inner part of zone)	3 (outer part of zone) 10 (inner part of zone)	Blocky.	Flesh.	- - -	Perthite is in the outermost part of the zone where it occurs near perthite-rich parts of the wall zone. Larger and more abundant perthite grains occur near the inner contact of the zone where it grades into the perthite-cleavelandite-quartz pegmatite of the second intermediate zone.
Apatite.	< 1	.01- .3	.1	Rounded to elongate.	Bluish-green.	- - -	- - -
Tourmaline.	< 1	.01-2.5	.5	Subhedral to euhedral.	Bluish-black, black, and greenish-black.	Bluish-black: N_{ω} = 1.66.	Commonly occurs along grain boundaries between cleavelandite and muscovite.
Tantalite-columbite.	< 1	.2 -4.0	.25	Platy.	Black.	- - -	Intergrown with cleavelandite.
Cassiterite.	< 1	.05- .65	- - -	Rounded to subhedral.	Brownish-black.	- - -	Occurs along the edges of muscovite books and forms inclusions in beryl and cleavelandite.
Amblygonite, var. montebrasite.	Trace.	.3 - 3.0	1	Rounded to irregular.	Grayish-white.	Biaxial (+) N_{γ}' = 1.62. N_{α}' = 1.61	Sparsely distributed near inner edge of zone. Commonly has a white to buff-white dusty coating. More rarely bordered by fine muscovite grains (0.25 in.).
Varicolored phosphate minerals.	Trace.	.1 - 1.5	- - -	Irregular.	Mostly dark brown.	- - -	Erratically distributed. Probably consists chiefly of lithiophilite-triphylite.
Garnet.	Trace.	- - -	< .25	Rounded.	Reddish-brown to pink.	- - -	Occurs near schist contact.
Loellingite(?).	Trace.	- - -	< .5	Irregular.	Buff to silvery.	- - -	- - -
Vivianite(?).	Trace.	- - -	< .5	Irregular.	Blue.	N_{γ} = 1.65. Pleochroic: deep blue to faint yellow.	Borders loellingite(?).
Dahllite (carbonate-apatite).	Trace.	.05- .5	- - -	Rounded.	White to grayish-white.	N_{ω} = 1.635. Birefringence: .005.	- - -

White, yellowish-white, and greenish-white beryl occurs (1) as prismatic euhedral crystals, (2) as hexagonal, tapered skeletal crystals ("shells") alternating with thin layers of cleavelandite, and (3) as anhedral masses. The average diameter of the beryl crystals is about 3 inches; the maximum length is 26 inches. N_{ω} ranges from 1.575 to 1.584, indicating that the BeO content ranges from 12.6 to 13.5 percent. The outer parts of many crystals and anhedral masses have higher indices and lower BeO content than the centers.

Flesh-colored perthite grains, 0.5 to 12 inches in size, occur sparsely in the outermost part of the zone, especially near perthite-rich parts of the wall zone. Larger perthite crystals, as much as 20 inches in size, occur near the inner contact of the zone where it grades into perthite-cleavelandite-quartz pegmatite of Zone 4.

Bluish-black to black, euhedral to subhedral grains of tourmaline, as much as 2.5 inches in length, commonly occur along the grain boundaries between cleavelandite and muscovite. Black plates of tantalite-columbite, as much as 4 inches in length, are intergrown with cleavelandite. Brownish-black grains of cassiterite, 0.05 to 0.65 inch in diameter, occur along the edges of muscovite books and form inclusions in beryl and cleavelandite. Rounded grains of amblygonite, as much as 3 inches in size, are sparsely distributed near the inner edge of the zone. Dark-brown irregular masses of phosphate minerals (probably largely members of the lithiophilite-triphylite group), reddish-brown to pink grains of garnet, buff to silvery grains of loellingite (?), bluish grains of vivianite (?), and white grains of dahllite are rare constituents of Zone 3.

Perthite-cleavelandite-quartz pegmatite (Zone 4, second intermediate zone).--Zone 4, the second intermediate zone, consists of perthite-cleavelandite-quartz pegmatite that forms a hood in the upper part of the northeastern limbs of the pegmatite (fig. 2). The shape of Zone 4 in cross-section (fig. 4 and 5) is that of an asymmetric crescent, titled to the northeast. It is as much as 35 feet thick near the crest of the pegmatite but pinches out down-dip. The zone is absent both in the footwall parts of the pegmatite and on the hanging-wall side of westward-dipping limbs.

The outer edge of Zone 4 is in contact with the wall zone near the crest of the pegmatite, but at depth the downward-tapering Zone 4 is separated from wall zone by the upward-tapering Zone 3. These two units grade into each other. A cutoff at 5 percent perthite is used to mark the contact.

The average size of individual grains is about 10 inches, but crystals of perthite are as much as 20 feet long. Perthite crystals average about 2 feet in length and aggregates of cleavelandite-quartz matrix are as much as 4 feet in size; thus the overall appearance of most exposures is that of very coarse pegmatite.

The minerals of Zone 4 are perthite (40 percent), cleavelandite (30 percent), quartz (23 percent), muscovite (6 percent), tourmaline ($<$ 1 percent), apatite ($<$ 1 percent), and beryl ($<$ 0.5 percent). In upper and outer parts of the zone, perthite constitutes as much as 65 percent of the unit; perthite decreases in abundance toward the interior of the pegmatite.

Detailed descriptions of the minerals are in table 8.

White to flesh-colored blocky crystals of perthite are in a matrix composed of massive quartz and aggregates of white cleavelandite. The average length of individual plates of cleavelandite is about 1 inch, but aggregates are commonly 4 inches in diameter. Masses of quartz are as much as 18 inches in size, but the average is about 1.75 inches. Books of yellowish-silvery muscovite, as much as 6 inches in diameter, are scattered as much as 30 inches in diameter and 50 inches in length and are distributed erratically in the zone. Bluish-black tourmaline occurs as irregular shells and masses along grain boundaries in the cleavelandite-quartz matrix. Rounded bluish-green grains of apatite (0.05 inch) are present in small quantities.

Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).--Cleavelandite-quartz pegmatite of Zone 5, the third intermediate zone, forms a complete shell that underlies the hood-shaped Zone 4 and completely surrounds Zones 6 and 7. In the keelward parts of the pegmatite Zone 5 is bounded on the outside by Zone 3 (figs. 4 and 5). In a few places, especially at the crest of the northwestern part of the pegmatite (fig. 4), Zone 5 is in contact with the wall zone. Locally, irregular replacement bodies of muscovite-cleavelandite pegmatite and lithia mica-cleavelandite pegmatite cut Zone 5.

Zone 5 has a maximum thickness of at least 35 feet, but in most parts of the pegmatite it is between 15 and 30 feet thick (figs. 4 and 5).

Table 8.--Mineralogy of perthite-cleavelandite-quartz pegmatite (Zone 4, second intermediate zone), Peerless pegmatite.

Mineral	Percent	Grain size (inches) Range	Grain size (inches) Average	Shape	Color	Remarks
Perthite.	40	1-240	24	Blocky.	White to flesh.	- - -
Cleavelandite.	30	- -	1.0	Platy.	White to grayish-white.	Average size of cleavelandite aggregates is about 4 in.
Quartz.	23	.25-18	1.75	Irregular.	Colorless to milky-white.	- - -
Muscovite.	6	.1-6	2.5	Books and flakes	Yellowish-silvery.	- - -
Beryl.	< 0.5	?-50 (length) .5-30 (diameter)	- -	Euhedral.	White.	Erratically distributed.
Tourmaline.	< 1	- -	- -	Irregular shells and masses.	Bluish black	Commonly occurs along grain boundaries in the cleavelandite-quartz matrix.
Apatite	< 1	- -	.05	Rounded.	Bluish-green.	- - -

The average size of individual grains is approximately 1.5 inches. The size of aggregates of minerals ranges widely. Aggregates of cleavelandite are as much as 5 feet in diameter, though the average is about 4 inches.

Zones 5 contains cleavelandite (45 percent), quartz (45 percent), muscovite (6 percent), dark-brown to purple phosphate minerals and their alteration products (1 percent), amblygonite (variety, montebrasite) (0.5 to 1 percent), beryl (0.5 percent), tantalite-columbite ($<$ 1 percent), apatite ($<$ 1 percent), tourmaline ($<$ 1 percent), and cassiterite ($<$ 1 percent). In general the outer one-third of this zone tends to be relatively rich in quartz--as much as 70 percent quartz and 23 percent cleavelandite in some exposures. The inner part tends to be relatively rich in cleavelandite; it has as much as 62 percent cleavelandite and 30 percent quartz in some places.

Table 9 contains detailed mineralogic data.

The cleavelandite (An_4) occurs in white to grayish white, platy grains that average about 1 inch in length and 0.02 inch in thickness. The cleavelandite plates are both flat and curved. They occur as radiating clusters and as aggregates of diversely oriented plates. In the quartz-rich parts of the zone, cleavelandite forms irregular streaks and clots surrounded by massive quartz. The contact with Zone 6 is commonly marked by a cleavelandite-rich layer, 1 to 3 feet thick.

Books and flakes of silvery-yellow muscovite range in size from 0.1 to 20 inches. The distribution of larger books is very irregular. As in Zone 3, the muscovite has abundant herringbone and wedge structures.

Grayish-white rounded grains of amblygonite, as much as 3 feet in diameter, are commonly coated by buff-white alteration products and are veined and embayed by quartz. Optical data indicate that this is montebrasite of approximately the same composition as in outer zones. Irregular aggregates of dark-brown to purplish phosphate minerals--probably lithiophilite-triphylite--are intergrown with variable amounts of strongly stained, intergrown cleavelandite, quartz, and muscovite to form dark-colored pod-shaped to irregular masses that are as much as 3 feet in diameter.

Beryl is most abundant in the outer parts of the zone but the distribution is irregular. White, faintly greenish, and semi-transparent beryl occurs both as prismatic euhedral crystals and as anhedral masses

Table 9.—Mineralogy of cleavelandite-quartz pegmatite (Zone 5, third intermediate zone), Peerless pegmatite.

Mineral	Percent	Grain size (inches) Range	Average	Shape	Color	Optical data.	Remarks
Cleavelandite.	45	- - - 0.2-3.0 (length)	0.02 (thickness). 1.0 (length)	Platy.	White to grayish-white.	N_{α}' is 1.528 (An_4).	Occurs chiefly as aggregates of diversely oriented or radiating cleavelandite plates, many of which a curved. These aggregates are as much 5 ft in diameter; the average is abo 4 in.
Quartz.	45	.25-12	1.75	Irregular.	Colorless to milky-white.	- - -	- - -
Muscovite.	6	.1-20	3.0	Books and flakes.	Silvery-yellow.	- - -	Wedge and herringbone structures are common. Some of the muscovite is strongly ruled.
Varicolored phosphate minerals.	1	.2-6.0	.75	Irregular.	Dark brown to purple.	- - -	Probably consist largely of lithiophilite-triphylite and their alterat products. Irregular aggregates of these minerals associated with stro stained cleavelandite, quartz, and muscovite form dark-colored, pod-sh to irregular masses as much as 3 ft diameter.
Amblygonite, var. montebrasite.	.5-1	.2-36.0	6.0	Rounded to subhedral.	Grayish-white.	Biaxial (+); commonly 2V>75°. N_{γ}' =1.62.	Commonly coated by a buff-white alteration product. Veined and emba by quartz.
Beryl.	.5	.3-15 (diameter)	3 (diameter)	Euhedral (prismatic). Also anhedral masses intergrown with cleavelandite, quartz, and muscovite.	White, pale green; some semi-transparent.	N_{ω} = 1.584 to 1.587 (12.6 to 12.3 percent BeO).	Tends to be most abundant in the out part of the zone, but the distributi is irregular.
Tantalite-columbite.	< 1	.25-4.0 (length) .01- .15 (thickness)	.8 (length) .01 (thickness)	Platy.	Black.	- - -	Commonly between plates of cleavelandite.
Apatite.	< 1	.2-6.0	.6	Anhedral to subhedral.	Pale green to dark bluish-green.	N_{ω} = 1.654. N_{ϵ}'= 1.651 One specimen has 2V>10°.	- - -
Tourmaline.	< 1	- - -	.2	Euhedral.	Pale blue. Bluish-black. Black.	N_{ω} = 1.66. N_{ω} = 1.66 to 1.67. N_{ω} = 1.67.	Aggregates are commonly 0.75 in. in diameter.
Cassiterite.	< 1	.02-.75	.25	Rounded, subhedral, and euhedral.	Brownish-black.	- - -	Most common along grain boundaries between muscovite and cleavelandite; also occurs as inclusions in cleavelandite, amblygonite, muscovite, and quartz.

that are intimately intergrown with cleavelandite. The diameter of grains of beryl ranges from 0.3 to 15 inches N_ω ranges from 1.584 to 1.587 indicating a BeO content of 12.3 to 12.6 percent. Thin black plates of tantalite-columbite are interleaved with cleavelandite. Pale-green to dark-bluish anhedral masses of apatite occur irregularly in this zone. Euhedral grains of bluish-black tourmaline form aggregates that are commonly about 0.75 inch in diameter, but isolated grains of pale-blue and black tourmaline also occur in the zone. Brownish-black grains of cassiterite, having an average grain size of about 0.25 inch, occur most commonly along grain boundaries between muscovite and cleavelandite but are also found as inclusions in cleavelandite, amblygonite, quartz, and muscovite.

Near the bottom of diamond drill hole 3 (fig. 4) vugs as long as 0.75 inch are lined with quartz crystals; other small vugs are filled with limonite. In this drill hole, the bottom 8.7 feet were in an open hole that is probably a vug or a solution cavity in the main fault zone; there is no reason to believe that this part of the pegmatite has abandoned mine workings.

Quartz-microcline pegmatite and quartz pegmatite (Zones 6a and b, fourth intermediate zone; fracture-fillings).--Zone 6 consists of quartz pegmatite and a hood of quartz-microcline pegmatite. This hood overlies both the quartz pegmatite and the lithia mica-bearing core and replacement unit (figs. 2 and 5). Quartz pegmatite is the central unit of some parts of the pegmatite, as in the east part of section EE', figure 5, and in section AA', figure 4.

The thickness of quartz pegmatite may be as much as 40 feet. The quartz-microcline hood also reaches a thickness of about 40 feet.

The quartz-microcline pegmatite has a very coarse pegmatitic texture. The minerals are quartz (59 percent), microcline (40 percent), and lithia mica ($<$ 1 percent). Colorless to milky white quartz occurs in masses as much as 30 feet in diameter, separating large crystals of flesh-colored microcline, as much as 15 by 10 by 6 feet in size. Perthite was not recognized in this zone. Megascopic gridiron twinning was observed in some of the microcline. Very fine-grained (less than 0.05 inch) yellowish-green lithia mica is disseminated along some cleavage surfaces and cracks in the microcline and may be genetically related to lithia mica of the replacement unit.

Quartz pegmatite consists essentially of massive, milky to colorless quartz (99 percent); the minor accessory minerals include spodumene ($<$1 percent), dark-brown phosphate minerals ($<$ 1 percent), and beryl (trace). Remnants of two spodumene crystals, 24 inches and 6 inches in length, occur at the north end of this zone in the northwestern part of the pegmatite. Dark-brown phosphate minerals, probably lithiophilite-triphylite, are exposed as irregular clots, 2 to 8 inches in size, in the southwestern limb of the pegmatite.

Three prominent quartz fracture-filling units, 6 inches to 2 feet thick, are exposed on the western side near the north end of the pegmatite. These units cut Zones 1, 2, 3, and 5, but do not extend across the pegmatite-schist contact. Smaller quartz fracture-filling units are exposed elsewhere in the pegmatite but are not large enough to be mapped. All of these fracture-fillings consist of massive milky quartz; no accessory minerals were observed.

Lithia mica-clevelandite pegmatite (Zone 7, core). --Lithia mica-cleavelandite pegmatite forms the very small core of this pegmatite (figs. 2 and 5). The maximum thickness is probably about 15 feet; the longest dimension is probably down the dip and may be as much as 50 feet. The chief exposures are in the open pit near section EE' (fig. 5).

The core has a very fine-grained pegmatitic texture; the average grain size is about 0.1 inch. Aggregates of lithia mica and cleavelandite are much larger.

The minerals of core include lithia mica (82 percent), cleavelandite, (15 percent), quartz (1 percent), dark-brown phosphate minerals (1 percent), tantalite-columbite ($<$ 1 percent), and cassiterite ($<$ 1 percent). The innermost part of the core is composed almost exclusively of olive-green lithia mica, in grains averaging about 0.05 inch in size; in the outer part of the core lithia mica is associated with cleavelandite, in 1 inch aggregates and thin, vein-like stringers as long as 2 feet. Individual plates of cleavelandite commonly are 0.1 to 0.4 inch in size. Quartz grains are as much as 0.5 inch in diameter. Dark-brown phosphate minerals, probably lithiophilite-triphylite, occur in irregular clots as large as 8 inches. Cassiterite and tantalite-columbite are irregularly distributed in the core as grains generally less than 0.5 inch in size.

"Lithia mica" is a field name that has been used for mica occurring in other Black Hills pegmatites as fine-grained olive-green aggregates differing greatly in appearance and habit from muscovite of outer zones. Presumably it also differs in chemical composition and structure. The lithia mica resembles lepidolite in habit and appearance, but not in color and lithia content. Unfortunately, data on mineralogic variations in Black Hills micas are as yet very incomplete, and an accurate mineralogic name cannot be applied to this co-called lithia mica.

A purified sample of the lithia mica was studied by petrographic, X-ray, and spectrographic methods. The mica has the following optical properties: biaxial (-), 2V - ca. 30° (definitely $<$ 37 1/2°), N_γ = 1.593 ± 0.001, N_β' = 1.588 ± 0.001. The fusibility of the mica is about 2. A semi-quantitative spectrographic analysis by P. J. Dunton and R. G. Havens of the U. S. Geological Survey, gave the results shown in table 10, p.47. An X-ray powder diffraction photograph by A. J. Gude, 3d, (U. S. Geological Survey), showed that mica is muscovite in which the strongest lines are spaced as follows:

Cu K_α; λ = 1.5418 Å.

I	d-spacing
10	9.936
9	3.345
8	2.556
7	2.006

The results are in accord with the work of Levinson (1953, p. 101), who found that micas with less than about 3.3 percent Li_2O have the normal muscovite structure. Mica from the core of the Peerless pegmatite containing 0.2 percent lithium is within the general range of normal muscovite, according to Levinson's graphs (1953, figs. 4 and 5, p. 103).

Lithia mica-cleavelandite-quartz pegmatite (replacement unit).--The lithia mica-cleavelandite-quartz replacement unit extends outward from the core across all of the intermediate zones (figs. 2 and 5). The shape of the unit is very irregular, and the size is not exactly known. The main body of the replacement unit extends at least 30 feet from the core, but small parts of the replacement unit are as much as 100 feet from the core.

The replacement unit is principally in Zones 5 and 6, but masses 1 to 3 feet in diameter occur in Zones 3 and 4. The wall zone contains fracture-fillings, 0.1 to 3 inches thick, filled with fine-grained grayish-yellow material that may be lithia mica, but otherwise there is no evidence that the wall zone contains minerals of the replacement unit.

The composition of the replacement unit varies greatly, depending on the zone replaced and upon the percentage of relict minerals. As much as 20 percent of some mapped exposures of this unit consists of unreplaced, irregular-shaped relicts. In some parts of Zone 5 replacement has produced a mottled rock with irregular embayed clots of cleavelandite-quartz pegmatite surrounded by the very fine-grained lithia mica-cleavelandite pegmatite. Elsewhere replacement of this zone has resulted in a "bladed" texture, with elongate (2 to 24 inches) tabular remnants of cleavelandite-quartz pegmatite separated by the very fine-grained lithia mica-cleavelandite pegmatite. Masses of the replacement unit in quartz-microcline pegmatite have a tabular shape that suggests fracture control.

Outside of the mapped limits of the replacement unit, some lithia mica associated with cleavelandite occurs along minute fractures and as interstitial aggregates in other units. These may be genetically related to the core and replacement unit.

Muscovite-cleavelandite pegmatite (replacement unit).--The muscovite-cleavelandite replacement unit is exposed near the contact between Zones 5 and 6 between sections D-D' and E-E' (fig. 2). The maximum thickness is nearly 40 feet. Pod-shaped to irregular masses of muscovite-cleavelandite pegmatite are exposed in Zone 5 in the underground workings, but these masses are too small to be mapped.

The contacts are very irregular in detail. Muscovite-cleavelandite pegmatite fills fractures in the quartz pegmatite and extends outward from these fractures into massive quartz. Irregular to rounded relicts of quartz pegmatite are cut by muscovite-cleavelandite aggregates along the contact of these two units. The contacts with the cleavelandite-quartz pegmatite of Zone 5 are equally complex and irregular. The form of the boundaries of this replacement unit suggests that it was controlled, in part, by an irregular network of fractures that formed after the consolidation of Zone 6.

The minerals, excluding relict masses of partially replaced pegmatite, consist of muscovite (69 percent), cleavelandite (30 percent), apatite ($<$ 1 percent), tourmaline ($<$ 1 percent), tantalite-columbite ($<$ 1 percent), lithia mica ($<$ 1 percent), cassiterite (trace), and beryl (?) (trace). The average size of individual grains is about 0.2 inch. Buff-white plates of cleavelandite and flakes and books of silver-yellow muscovite average about 0.2 inch in size but are as large as 1 inch. The cleavelandite occurs in irregular streaks along gradational contacts with Zones 5 and 6, and is also disseminated through the replacement unit as irregular aggregates, as much as 1 inch in diameter. Small rounded grains of greenish-blue apatite and black to bluish-black tourmaline are irregularly distributed throughout the unit. Plates of tantalite-columbite are as large as 1 by 3 inches but generally are less than 0.5 inch in size.

Tourmaline-quartz pegmatite (fracture-fillings).--Drusy fracture-fillings of tourmaline-quartz pegmatite occur on the northwestward-trending fault just southwest of the large unmined pinnacle, and also along the main east-west fault northwest of this pinnacle (figs. 2 and 5). These faults must have formed after the consolidation of the core of the Peerless pegmatite because they cut all the zones, replacement bodies, and the core. On the other hand, the faults formed before the consolidation of the tourmaline-quartz pegmatite because these fracture-filling units occur on slickensided surfaces of the faults and the drusy structure is undisturbed. These structural relations indicate that the tourmaline-quartz fracture-filling units are not necessarily directly related in origin to the main mass of the Peerless pegmatite. The thickness of the tourmaline-quartz fracture-fillings ranges from 0.25 to 0.5 inch.

The minerals are tourmaline (90 percent) and quartz (10 percent). The average grain size is about 0.15 inch. The tourmaline is in pale-pink, translucent, prismatic crystals that range from 0.05 to 0.25 inch in length. Optically the tourmaline is colorless, uniaxial (-), N = 1.632. A few grains seem to be abnormally biaxial (+) with 2 V = 10° to 40°. The quartz occurs in tiny colorless crystals similar in size to the tourmaline but is less regularly distributed.

Variation in mica composition

In order to determine the compositional differences in mica from various units of this pegmatite, a series of samples collected from five zones and from the muscovite-cleavelandite replacement unit was analyzed spectrographically (table 10). The results show that the content of calcium, rubidium, boron, and perhaps

Table 10. Spectrographic analyses of mica, Peerless pegmatite 1/.

Pegmatite Unit	Segment of pegmatite	Location	Composition (in percent)															
			Fe	Ti	Mn	Mg	Na	B	Ba	Be	Cs	Ga	Li	Nb	Rb	Sn	Sr	Zr
Zone 1. Quartz-muscovite-plagioclase pegmatite.	Southeast	East side of pegmatite in underground workings.	0.x	0.0x-	0.0x	0.0x+	0.x+	0.0x	0.00x-	0.00x-	0.0x-	0.00x+	0.0x+	0.00x	0.x	0.0x-	0.00x-	0.00x-
Zone 3. Cleavelandite-quartz-muscovite pegmatite.	do.	East side of pegmatite at surface.	.x	.0x-	.0x	.00x-	.x	.x-	0	.00x-	.0x	.00x+	.0x	.00x	.x	.0x	0	Tr.
Do.	do.	East side of pegmatite in underground workings.	.x	.00x+	.0x	.00x	.x	.0x+	0	.00x-	.0x	.00x+	.0x+	.00x	.x	.0x	0	.00x
Do.	do.	Foot wall of pegmatite in underground workings.	.x	.00x+	.0x	.0x	.x+	.0x	0	.000x+	.0x	.00x+	.0x+	.00x	.x	.0x-	0	.00x
Do.	West	Foot wall.	.x	.0x-	.0x	.0x+	.x+	.0x	.00x-	.00x-	.0x	.00x+	.x-	.00x	.x	.0x	.00x-	.00x-
Zone 4. Perthite-cleavelandite-quartz pegmatite.	Southeast	East side of pegmatite at surface.	.x	.00x+	.0x	.00x+	.x	.0x+	0	.00x-	.0x	.00x+	.0x	.00x	.x	.0x	0	.00x-
Do.	do.	do.	.x	.0x-	.0x	.0x-	.x+	.0x+	0	.00x-	.0x	.00x+	.0x	.00x	.x	.0x	0	.00x-
Zone 5. Cleavelandite-quartz pegmatite.	do.	East side of pegmatite at surface.	.x	.0x-	.0x	.00x-	.x	.x-	0	.00x-	.0x	.00x+	.0x	.00x	.x+	.0x	0	Tr.
Do.	do.	Center of pegmatite in underground workings.	.x	.00x+	.0x	.00x	.x+	.0x+	0	.00x-	.0x	.00x+	.0x+	.00x	.x	.0x	0	.00x+
Do.	West	Foot wall.	.x	.0x-	.0x	.00x	.x	.x-	0	.00x-	.0x	.00x+	.0x	.00x-	.x	.0x+	0	.00x-
Muscovite-cleavelandite replacement unit.	---	---	.x	.00x+	.0x+	.00x	.x	.x-	0	.00x-	.x-	.00x+	.0x+	.00x-	.x+	.0x	0	.00x-
Do.	---	---	.x	.00x-	.0x+	.00x	.x	.x-	0	.00x-	.x-	.00x+	.0x	.00x-	.x+	.0x	0	.00x-
Zone 7. Lithia mica-cleavelandite pegmatite.	---	---	.x	---	---	.0x-	.5	---	---	---	.6	---	.2	---	.8	.0x	---	---

1/ Analyses by J. C. Hamilton, U. S. Geological Survey Denver Laboratory. The samples from Zone 7 had been analyzed previously by P. J. Dunton and R. G. Havens, and were reexamined by Hamilton.

tin and manganese increases from the wall of the pegmatite inward. The lithium content of mica from Zone 7 is 0.2 percent, but the lithium content of all but one of the samples from other units is 0.0X or 0.0X+ percent. The magnesium and niobium content of mica show a poorly defined tendency to decrease from the wall inward. Analyses of four samples from Zone 3 suggest that in the lower parts of this zone the muscovite may contain more magnesium and lithium and less boron than muscovite in structurally higher parts of this zone.

Faults

A system of westerly-trending faults cuts all units of the Peerless pegmatite except the tourmaline-quartz fracture-filling units. Most of these are normal faults, but a few are reverse faults. The dip is commonly between vertical and 70° S., the fault that cuts quartz pegmatite and muscovite-cleavelandite pegmatite northwest of the unmined pinnacle dips 70° N. (figs 2 and 5).

The main east-west fault on the north side of the large open pit is vertical near its eastern end but dips 84° S. on the west side of the pegmatite. The apparent displacement has been determined from the position of pegmatite units on either side of the fault. The south side is offset as much as 45 feet to the west; the maximum vertical offset is probably about 25 feet, down to the south. Branch faults have dips as low as 75° S. or 82° N.

The fault that trends northwest on the southwest side of the unmined pinnacle is a normal fault that dips 78° to 88° SW. The vertical offset is about 2 feet. Other faults shown on the maps (figs. 2 and 3) similarly have small displacements.

Chemical composition

The chemical composition of the Peerless pegmatite has been determined by (1) using successive geologic sections to compute the volume of each unit in the pegmatite, (2) converting volume to tonnage, (3) determining the tonnage of each mineral (table 11) by use of the data on mineral distribution in table 3, and (4) converting the minerals into chemical equivalents.

Table 12 contains the data on mineral composition used in making the calculations. These are based on optical studies, typical chemical analyses recorded in the literature from many localities, and a partial spectrographic analysis of lithia mica.

Table 11. --Estimated mineral content of the Peerless pegmatite. 1/

Mineral	Tons
Plagioclase	226,500
Quartz	213,000
Muscovite	50,000
Perthite and microcline	25,000
Lithia mica	5,000
Beryl	3,500
Tourmaline	2,900
Iron-lithium-manganese phosphates	2,400
Amblygonite	1,600
Apatite	1,100
Other minerals	1,500
Totals	**532,500**

1/ Data in this table are not to be interpreted as reserves. Tonnages listed are in non-minable as well as minable rock.

Table 12.--Mineral compositions used in computing chemical composition of the Peerless pegmatite.

Composition (in percent)

Mineral	SiO_2	Al_2O_3	Fe_2O_3, FeO	MgO	CaO	Na_2O	K_2O	Li_2O	H_2O	P_2O_5	BeO	Other Constituents
Quartz	100	-	-	-	-	-	-	-	-	-	-	---
Plagioclase (An_5)	67.1	20.3	-	-	1.0	11.2	0.4	-	-	-	-	---
Perthite and microcline	64.4	19.8	-	-	.4	2.7	12.7	-	-	-	-	---
muscovite	45.2	36.5	1.5	0.5	.2	1.0	9.0	-	5.0	-	-	1.1
Lithia mica	47.0	35.0	.5	-	-	.7	10.5	0.4	4.0	-	-	1.9
Beryl	66.8	18.9	-	-	-	.2	-	.1	-	-	12.8	1.2
Tourmaline	37.0	32.0	14.0	2.0	-	2.0	-	-	3.0	-	-	10.0
Iron-lithium-manganese phosphates	-	-	35.0	-	-	-	-	9.0	-	45.0	-	11.0
Amblygonite	-	34.0	-	-	-	3.0	-	9.5	5.0	47.5	-	1.0
Apatite	-	-	-	-	51.0	-	-	-	2.0	42.0	-	5.0

The only water shown in table 12, and thus of the completed estimates of the chemical composition of the pegmatite (table 13), is in mica, tourmaline, amblygonite, and apatite. Any additional water that may be contained in the pegmatite cannot be estimated. Other errors that may be introduced by inaccuracies in table 12 probably do not change the final results as much as errors in the tonnage estimates of table 11.

The calculated chemical composition of the Peerless pegmatite (table 13) shows that the silica content, at 77.0 percent, is extraordinarily high. The only other constituents that form more than 0.6 percent of the pegmatite are alumina, soda, potash, and probably water. Potash forms only 1.7 percent of the pegmatite, yet soda forms 5.0 percent. Despite the commonness of various rare minerals in this pegmatite, the content of rare elements is very small.

Similar calculations have also been made to determine the content of silica, alumina, soda, and potash in four subdivisions of the pegmatite (table 14). These show that silica increases greatly toward the center of the pegmatite. Alumina decreases as silica increases. Soda is more or less constant in Zones 1 to 5, but decreases to 0.4 percent in the center of the pegmatite. Potash reaches a peak of 4.0 percent in Zones 3 and 4, but is much less in outer and inner units.

The mineral distribution of the various units (tables 3 to 9) indicates that a more detailed breakdown and more complete chemical data would show many additional interesting relationships. Silica, for example, is a rich constituent of the border zone (tables 4 and 5). Probably it alternately decreases and increases in the wall zone (table 4, fig. 7). Then it probably increases through Zones 3, 4, 5, and 6, and decreases again in Zone 7.

Table 13.--Estimated chemical composition of the Peerless pegmatite.

	Percent
SiO_2	77.0
Al_2O_3	13.7
Fe_2O_3 and FeO	.5
MgO	.1
CaO	.6
Na_2O	5.0
K_2O	1.7
Li_2O	.1
H_2O	.6
P_2O_5	.4
BeO	.1
Other constituents	.2
Total	100.0

Table 14.--Distribution of the principal chemical constituents of the Peerless pegmatite.

		Chemical composition (in percent)				
Units	Tons	SiO_2	Al_2O_3	Na_2O	K_2O	Other consitiuents
Zones 1 and 2	143,000	73.7	16.0	6.5	1.3	2.5
Zones 3 and 4	130,000	70.7	17.6	4.7	4.0	3.0
Zone 5	205,000	79.1	11.8	5.3	.7	3.1
Zones 6 and 7 and replacement units	54,500	92.3	4.5	.4	1.3	1.5
Entire pegmatite	532,500	77.0	13.7	5.0	1.7	2.6

Further discussion of this sort must be delayed until more data are available from this and other pegmatites. The predominance of silica, alumina, soda, and potash, and the very small content of other constituents suggests that laboratory studies on relatively simple systems may be applied directly in studies of petrologic relations in this pegmatite.

Origin

The origin of the Peerless pegmatite and other Black Hills pegmatites has been discussed for many years. The pegmatitic fluid generally has been considered a derivative either of the Harney Peak pegmatitic granite or of a deep-seated parent of the Harney Peak granite. The greatest disagreement has been with regard to what happened after the pegmatitic fluid began to crystallize. The earliest authors considered Black Hills pegmatites to be true igneous rocks. Between 1925 and 1939 various authors emphasized the role of replacement processes in an open system. More recent authors have considered systematic fractional crystallization in a restricted system to be the chief factor in the development of the Peerless and other Black Hills pegmatites.

The proximity of the zoned pegmatites like the Peerless to the so-called Harney Peak granite has led all investigators to believe that these rocks are genetically related. Furthermore, the layered pegmatite of the Peerless border and wall zones is similar to the layered pegmatite that is characteristic of the so-called granite of Harney Peak.

The attitudes of the various segments of the Peerless pegmatite and discordance with the schist indicate control of the intrusion by fractures. Dike-like apophyses extending outward from the main body doubtless are also fracture-controlled. In some places a secondary schistosity has been developed parallel to the contact. These relations suggest that the pegmatite fluid was sufficiently viscous to shoulder aside and deform country rock.

The alteration of staurolite to mica and chlorite in schist near the pegmatite may have been caused by introduction of water from the pegmatite. Potash may also have been introduced from the pegmatite. Another possibility, however, is that potash was released by biotite in adjacent rock. The Fe:Mg ratio in the biotite may have increased during the breakdown of staurolite and the formation of chlorite, and as this ratio increases, the potash content decreases.

Higazy (1949) presented the suggestion that pegmatites of this area were formed by metasomatic replacement of schist wall rocks. He based his conclusions on origin almost entirely on the study of thin sections and chemical analyses of perthite, assuming that the pegmatites consist almost solely of perthite. In as much as none of the Black Hills pegmatites known to the authors consist almost entirely of perthite., Higazy's inferences and conclusions cannot be applied to the problem at hand.

The layered structure and repetition of rock types in the border and wall zones suggest a complex origin for these units that can best be understood by comparing the sequence of layers (table 15) with the normal zonal sequence of Black Hills pegmatites described by Page and others (1953, table 3). (See table 15). The outer layers of the border and wall zones evidently crystallized progressively from Assemblage 1a to 3g. The only anomaly in this sequence is the second occurrence of Assemblage 1f. Field relations show that this is younger than the adjacent layers of Assemblage 1h, and thus may be a fracture-filling injected at a later stage in the development of the wall zone. The sharply defined aggregates of sugary albite-quartz in two layers of Assemblage 2a surrounding a layer of Assemblage 3g suggest rapid changes in physical and chemical conditions. Possibly the layer of Assemblage 3g formed from liquid that was trapped during rapid crystallization of the sugary to fine-grained pegmatite of Assemblage 2a. Perthite-bearing segregations in the wall zone resemble pegmatite that crystallized later as Zone 4 of the Peerless and thus represent similar chemical stages in the crystallization history. Similar pegmatite forms intermediate zones and cores of many other Black Hills pegmatites.

The sugary grain-size of the albite-quartz aggregates may have been caused in part by a sharp decrease in pressure and temperature, resulting in rapid development of nuclei and the partial depletion of volatiles and consequent rapid crystallization. In figure 7, it can be seen that sugary pegmatite tends to occur near discordant contacts, where volatiles or heat are likely to escape; so far as known, however, there is no spatial relationship between sugary pegmatite and altered wall rocks, which would be expected if volatiles escaped from the fluid into the wall rocks. On the other hand, the alteration of staurolite to mica and chlorite in the wall rock suggests that water was added from the pegmatite. Possibly volatiles were depleted during crystallization of mica-bearing pegmatite, and convection in the liquid may not have been rapid enough to replenish the supply. The great decrease in mica content from Assemblage 1a to 2a suggests that the volatile content of the fluid decreased during crystallization of these layers.

Table 15.--Sequence of layers in border and wall zones, Peerless pegmatite.

Layer number, fig. 7, diamond drill holes	Layer number, table 4, open pit	Mineralogy	Equivalent mineral assemblage in other Black Hills pegmatites 1/	Remarks
12	11	Quartz-albite	2b	- - -
11	-	Albite-quartz-muscovite	1h	- - -
-	10	Quartz-albite-muscovite	1f	- - -
-	9	Perthite-quartz-albite-muscovite-tourmaline	3p	Segregation or fracture-filling
10	-	Albite-quartz-perthite	3d	- - -
9	8	Albite-quartz-muscovite	1h	- - -
-	7	Quartz-muscovite-albite	1c	2-in. grains of cleavelandite
8	6b	Albite-quartz	2a	Contains sugary albite and quartz
7	-	Albite-perthite-quartz	3g	Contains sugary albite and quartz
6	6a	Albite-quartz	2a	Contains sugary albite and quartz
5b	5	Albite-quartz-muscovite	1h	- - -
-	4	Quartz-albite-muscovite	1f	Fracture-filling or segregation
5a	3	Albite-quartz-muscovite	1h	- - -
4	2	Quartz-albite-muscovite	1f	- - -
3	-	Quartz-muscovite-albite	1c	- - -
2	-	Quartz-muscovite	1a	- - -
1	1	Quartz	Variant of 1a?	- - -

1/ Page, L. R., and others 1953., U. S. Geol. Survey Prof. Paper 247, table 3.

In table 15 the sugary albite-quartz pegmatite is succeeded by Assemblage 1, which is followed again by Assemblage 3, and then again by Assemblages 1 and 2. These repetiteions may have been caused by several mechanisms:

1. The system may have been open, either because new material was introduced from below, or because volatiles and heat escaped into the wall rock. These events would change the chemical equilibrium and could account for the observed repetition of layers.

2. Mixing of liquids from various pegmatitic fluids may have caused changes in chemical composition at the crystallizing face.

3. Poor convection may have caused the liquid to be out of equilibrium at the crystallizing face. Thus layers of Assemblages 2 and 3 may have crystallized earlier than they would otherwise. When good convection was restored, the minerals of Assemblage 1 would again crystallize.

Assemblages 1 and 2 in the innermost part of the wall zone are similar to the outermost zones of many Black Hills pegmatites. The intermediate zones and core similarly are in the sequence of zones described for other pegmatites of the Black Hills (Page and others, 1953, p. 16, table 3). After the wall zone had crystallized, the pegmatitic fluid must have been isolated. Crystallization would then proceed in a restricted system, as described by Page and others (1953, p. 20-23) and by Cameron and others (1949, p. 104-105). As crystals were deposited to form the various zones, the minerals that formed early in the mesh work at the crystallizing front were embayed, corroded, and veined by later minerals. Quartz-fracture filling units cut zones that lie outside of the quartz pegmatite of Zone 6a, and it is logical to suppose that these fracture-filling units formed during the stage when Zone 6a was crystallizing.

The core and the two replacement units have a high mica content that suggests concentration of water and flourine in the rest liquid during the last stage of crystallization. It follows logically that the replacement bodies formed from hydrothermal or pneumatolytic materials that escaped into zones that had already crystallized. Relicts of these zones can be recognized in the replacement units.

The genetic significance of replacement textures in the Peerless pegmatite was overemphasized by earlier authors. These authors lacked the detailed maps and drill hole data now available and, consequently, depended more on detailed mineralogic and textural relations than now seems warranted. F. L. Hess was one of the first to suggest a genetic process involving continuous flow of solutions that replaced pre-existing pegmatites, and part of his data was derived from the Peerless pegmatite (Hess, 1925, p. 289-298). Hess described replacement textures among quartz, feldspar, muscovite, and other minerals that are now most logically explained by reaction between crystals and the rest liquid at the crystallizing front during the development of the zones.

Landes (1928, p. 519-530, 537-558) made a study of the Peerless and other Keystone pegmatites that led him to suggest a three-stage sequence: (1) a magmatic stage, in which microcline and quartz formed together with some tourmaline, muscovite, beryl, triphylite, and apatite; (2) an intermediate stage, in which hydrothermal solutions soaked through the pegmatite and replaced older minerals with spodumene, amblygonite, and beryl; (3) a vein stage, in which hydrothermal solutions replaced earlier minerals and filled fissures with albite, lepidolite, muscovite, tourmaline, quartz, and metallic minerals. He later (Landes, 1933, p. 55) noted the possibility that "hydrothermal solutions" in larger pegmatites such as the Peerless, Etta, Hugo, and Ingersoll, may have been residua of the crystallization of the pegmatite magma itself. The paragenetic sequence of Landes relies heavily on the textural relations of individual minerals, at the expense of the internal structural relations of the pegmatite. Landes, for example, postulated that the albite was formed during a late "vein stage," because in many places albite forms embayments and vein-like masses that cut other minerals. Nevertheless, structural relations indicate that albite of the outer zones must have been formed prior to the crystallization of the inner zones. Furthermore, the anorthite content of albite decreases toward the center of the pegmatite, thus suggesting normal magmatic differentiation. Significantly, detailed mapping has shown no evidence for through-going channels of hydrothermal solutions.

Ziegler (1914b, p. 275) observed amblygonite along slickensided fault surfaces in the Peerless pegmatite and believed that the amblygonite was deposited after the faulting. Amblygonite found along a fault surface in the locality described by Ziegler has textural relations, indicating that it is a normal part of the cleavelandite-quartz assemblage that is cut by the fault, and is not a post-fault mineral.

Weis (1953, p. 681-684) determined the filling temperature of "primary" fluid inclusions in one beryl crystal from Zone 2, four crystals from Zone 3, and two crystals from Zone 4. The temperature ranges are so great that it seems unwise, without further work, to attach significance to these results. In the one crystal from Zone 2 (Zone 1 of Weis), 15 inclusions ranged from 257° to 405° C, with a mean of 317° C; 172 inclusions in 4 crystals from Zone 3 (Zone 1a of Weis) ranged from 232° to 450° C, with a mean of 359° C; 41 inclusions in 2 crystals from Zone 4 (Zone 3 of Weis) ranged from 304° to 447° C, with a mean of 405° C. The determinations are fairly evenly distributed throughout these ranges. Weis himself (1953, p. 692-693) lacked confidence in his data from the Peerless pegmatite. He did suggest, however, that the apparent increase in temperature from the wall inward may be in part explained by evidence obtained "by the U. S. Geological Survey" showing that the Peerless pegmatite "probably formed as a result of two or more separate intrusions" (Weir, 1953, p. 693).

This statement can be explained only as a misunderstanding. The only evidence for multiple intrusion is in the layering of Zones 1 and 2, which suggests the possibility that there were injections of new material after crystallization began. Even if this were the correct interpretation, however, it would have little or no bearing on the data obtained by Weis from Zones 3 and 4.

Additional work bearing on genesis of this pegmatite should be profitable. Fluid-inclusion studies of minerals from all zones and from different structural positions within each zone might yield significant results.

Mineralogic studies and spectrographic and chemical analyses are needed to determine the nature of the change in composition of the pegmatite magma during crystallization and the importance of changing concentrations of the various constituents in the crystallization process. Further detailed studies of the layering in Zones 1 and 2 should be emphasized.

MINERAL DEPOSITS

Scrap mica is the chief product of the Peerless pegmatite. Other minerals that have been produced are beryl, potash and soda feldspar, amblygonite, and tantalite-columbite (table 1). Minerals of potential economic value that have not yet been marketed include lithia mica, cassiterite, and phosphate minerals of the lithiophylite-triphylite group.

Grade figures for all of these minerals in the various units of the pegmatite are contained in table 3. Beryl grade is based chiefly on grain measurements, on typical faces, and on drill core. No assay data are available from the drill cores. All other grade figures are from visual estimates on numerous exposures.

Mica

The main muscovite mica deposit is Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone). Mica also occurs in Zones 2, 4, 5, and 7, and in the replacement bodies.

The muscovite content of the main mica deposit ranges from 10 to 60 percent, but the average grade is about 28 percent. Books of muscovite in this unit are as much as 3 feet in diameter, and the average size is about 5 inches. Because of the coarse grain size, especially when the mica is in aggregates, about two-thirds of the mica is recoverable by hand-cobbing.

Zones 2, 4, and 5 contain 6 to 8 percent mica, and the average grain size ranges from 0.5 inch in Zone 2 to 3 inches in Zone 5. Less than one-third of this mica can be recovered by hand-cobbing. Ordinarily the only mica recovered from these units is a byproduct during mining for other minerals or during development work.

The muscovite is yellowish-silvery, and most of the books contain wedge and herringbone structures; some of the books are ruled. High quality scrap mica is produced everywhere in Zone 3 except in areas cut by faults, where there is some iron staining. A few books contain enough flat mica to warrant preparing sheet and punch mica during periods of favorable market conditions (table 2).

The small muscovite-cleavelandite replacement unit contains aggregates of 0.2 inch muscovite books that can be sold as scrap mica.

Lithia mica

The lithia mica in the core and replacement body of lithia mica-cleavelandite pegmatite may be a potential source of scrap mica for specialized uses. The lithia content of 0.4 percent is much too low for the lithium market, but the content of cesium and rubidium is high.

Beryl

Beryl occurs chiefly in Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone). It is extracted from this unit as a byproduct of scrap-mica mining. Beryl has also been obtained from the inner part of the wall zone and from Zones 4 and 5. Traces of beryl have been observed in Zones 1 and 6a, and in the muscovite-cleavelandite replacement unit.

The beryl content of the various layers of the wall zone varies widely. Figure 7 shows a range from 0 to 0.6 percent beryl in the layers cut by the drill holes. The richest beryl units contain abundant albite. Measurements of beryl crystals in surface exposures show that the inner part of the wall zone contains much more beryl than the outer part of the zone (table 16). The beryl content of the various layers in surface exposures has not been determined.

Grain measurements on surface exposures of the wall zone indicate an average beryl content of 1.08 percent (table 16). Measurements on drill core give 0.09 percent beryl (table 6). These figures suggest that the beryl content decreases in the keelward parts of the wall zone; this decrease may be correlated with a corresponding decrease in the albite content. Possibly, however, the explanation of the low beryl content of the drill core is that the euhedral beryl of the wall zone tends to break out of the core and go into the sludge during drilling. This possibility cannot be evaluated without assays of both core and sludge. In the absence of such data, the grade is best estimated as 0.6 percent beryl--an average of the surface and drill hole figures. The inner part of the wall zone probably has very nearly the same grade as the 1.7 percent beryl content of Zone 3.

Table 16.--Measurements of beryl in seven exposures of Zone 2, albite-quartz-muscovite pegmatite (wall zone), Peerless pegmatite

Part of wall zone measured	Location	Dimensions of smallest crystal (feet)	Dimensions of largest crystal (feet)	Number of beryl crystals measured	Area of beryl (sq. ft)	Area measured (sq. ft)	Beryl (percent)	Weighted average beryl (percent)
Inner part (40 percent of wall zone).	Northwestern part of pegmatite.	.04 by .05	.25 by .35	22	1.2979	21.6	6.01	2.30
	Northwestern part of pegmatite.	.04 by .05	.35 by .6	14	.8478	24.0	3.53	
	Main pit.	.04 by .05	.5 by .8	89	1.5529	120.0	1.29	
	Main pit.	.08 by .08	.7 by .33	22	1.2125	48.0	2.53	
Outer part (60 percent of wall zone).	Main pit.	- - -	- - -	- -	.1675	48.	.35	.35
Wall zone (northeast segment).	Northwestern part of pegmatite.	.08 by .10	1 by .35	20	1.2260	80.	1.53	.98
	Northwestern part of pegmatite.	.08 by .08	.08 by .08	4	.0964	55.	.18	
						Average percent beryl in wall zone - -		1.08

Beryl also is irregularly distributed in Zone 3, mica-rich parts of the zone tend to have less than 1 percent beryl, whereas portions of the zone rich in cleavelandite contain as much as 15 percent beryl. Measurements of beryl on typical surface exposures indicate an average grade of 1.46 percent (table 17). The average grade in the drill holes is 1.93 percent beryl (table 7). Consequently the average grade of the entire zone is about 1.7 percent beryl.

Data on the beryl content of other zones are less accurate and are based chiefly on visual estimates. Zone 4 has less than 0.5 percent beryl. Zone 5 has about 0.5 percent beryl in surface exposures, but measurements in the drill core indicate a content of 0.12 percent beryl.

The mineralogic properties of beryl in the various units are presented in table 18. The beryl ranges from colorless to white and from pale yellowish-white to greenish-white. Subhedral to euhedral crystals are most common, but shell intergrowths of beryl and cleavelandite were noted in Zone 3, and anhedral masses of beryl intergrown with cleavelandite, quartz, and muscovite are common in Zones 3 and 5. The beryl crystals in the border zone and the outer part of the wall zone are too small to be hand-cobbable. The beryl crystals in the inner part of the wall zone and in the first intermediate zone average 3 inches in diameter. Masses of beryl as much as 30 inches in diameter were produced from Zone 4. The proportion of the total beryl that can be hand-cobbed is about one-third in the Zone 2, two-thirds in Zone 3, and one-half in Zone 5.

The BeO content of the beryl ranges from an average of 12.4 percent in Zone 4 to an average of 13.1 percent percent in Zone 1. A few crystals of beryl are as low as 12.3 percent (N_{ω} = 1.587) or as high as 13.5 percent BeO (N_{ω} = 1.574).

Beryl in the layered rocks of the border and wall zones has a range in refractive index and BeO content that is almost as great as the range in all of the units of the pegmatite. The data for the various units have been tabulated in figure 7. These show that the BeO content of beryl tends to decrease from the wall inward in the border and wall zones, but in contrast the BeO content of beryl in the layers containing sugary albite-quartz aggregates tends to be higher than in the adjacent lower albite-quartz-muscovite unit.

Table 17.--Measurements of beryl in five exposures of Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone), Peerless pegmatite.

Location	Dimensions of smallest crystal (feet)	Dimensions of largest crystal (feet)	Number of beryl crystals	Area of beryl (sq. feet)	Area measured (sq. feet)	Beryl (percent)	Weighted average beryl (percent)
Main pit.	.03 by .04	.6 by 1.5	12	2.0332	100.0	2.03	
Main pit.	.05 by .15	.6 by .8	14	2.6675	315.0	.85	
Main pit.	.1 by .2	.35 by 1.2	11	1.8210	42.0	4.34	1.46
Northwestern part of pegmatite.	.02 by .02	.07 by 1.2	36	.8755	39.6	2.21	
Northwestern part of pegmatite	.05 by .05	.30 by .45	13	.3956	38.2	1.04	
Totals			86	7.7928	534.8		

Table 18.—Mineralogy of beryl, Peerless pegmatite.

Unit	Thickness of unit (feet) Maximum	Thickness of unit (feet) Average	Beryl: Grade (percent beryl) 1/	Beryl: Color	Beryl: Shape	Beryl: Size (inches) Range	Beryl: Size (inches) Average	Beryl: (N_ω) Index of refraction Range	Beryl: (N_ω) Index of refraction Average	Beryl: Number of refractive index determinations	Beryl: Average BeO content (percent) 2/
Zone 1. Quartz-muscovite-albite pegmatite (border zone).	0.2	0.04	Trace.	Colorless to white.	Subhedral to euhedral.	0.1-0.5	0.25	1.577-1.581	1.579	6	13.1
Zone 2. Albite-quartz-muscovite pegmatite (wall zone). 3/	20.	5.	0.6 3/	Colorless, pale yellowish-white, white, pale greenish-white.	Euhedral (prismatic).	.1-2, diameter.	.75, diameter (outer part of zone).	1.574-1.587 3/	1.580	57	13.0 3/
						.25-5, diameter.	3, diameter (inner part of zone).				
Zone 3. Cleavelandite-quartz-muscovite pegmatite (first intermediate zone).	15.	1.5 ft on hanging wall. 5 ft on footwall.	1.7	White, yellowish-white, greenish-white.	Euhedral (prismatic); "shell" intergrowths; anhedral.	.5-26	3	1.575-1.584	1.580	18	13.0
Zone 4. Perthite-cleavelandite-quartz pegmatite (second intermediate zone).	35.	20	< .5	White.	Euhedral.	.5-30, diameter.	---	---	---	--	---
						? -50, length.					
Zone 5. Cleavelandite-quartz pegmatite (third intermediate zone).	35.	20	.5	White, greenish-white.	Euhedral (prismatic); anhedral.	.3-15, diameter.	3	1.584-1.587	1.586	6	12.4
Zone 6a. Quartz pegmatite (fourth intermediate zone).	40.	---	Trace.	---	---	---	---	---	---	--	---
Muscovite-cleavelandite pegmatite (replacement unit).	< 40.	---	Trace.	---	---	---	---	---	---	--	---

1/ Based on grain measurements on typical exposures and drill core in Zones 2 and 3. Other figures as visual estimates.

2/ Based on unpublished curve by W. T. Schaller, U. S. Geological Survey.

3/ See figure 7 for data on beryl in the various layers of Zone 2.

Potash feldspar

The chief potash feldspar of the Peerless pegmatite is perthite in zone 4, perthite-cleavelandite-quartz pegmatite (second intermediate Zone). Perthite also is abundant in some layers of the wall zone (table 4 and fig. 7) that resemble Zone 4 in composition. Non-perthitic microcline is a significant constituent of Zone 6a, microcline-quartz pegmatite. The average grade of the second intermediate zone is about 40 percent perthite, but the perthite content ranges from 65 percent in the upper and outer parts of the zone to about 20 percent in the inner part of the zone. The perthite occurs in blocky crystals ranging from 1 inch to 20 feet in maximum dimension; the average length of perthite crystals is about 2 feet. The perthite is clean and nearly free from iron stain except in areas cut by faults.

Non-perthitic microcline crystals that average about 10 feet in diameter form about 40 percent of Zone 6a (quartz-microcline pegmatite). This unit has not been mined for feldspar because it is small and contains large masses of quartz that would cause mining to be difficult and expensive.

Soda feldspar

The large cleavelandite aggregates of the Peerless pegmatite have been mined for soda feldspar, especially in Zones 3, 4, and 5. Cleavelandite and non-platy albite are such abundant consitiuents of the Peerless pegmatite (table 3) that mining depends less on grade than on market conditions and on the feasibility of recovering cleavelandite as a byproduct of mining for other minerals.

The average grade of Zones 3, 4, and 5 is about 40 percent cleavelandite. Aggregates of cleavelandite have an average diameter of 4 inches but some are as large as 5 feet.

Amblygonite

Amblygonite (variety, montebrasite) occurs chiefly in the cleavelandite-quartz pegmatite of Zone 5 (table 3). Some of the layers of the wall zone contain amblygonite. Traces of amblygonite occur in Zone 3.

The average grade of Zone 5 is between 0.5 and 1 percent amblygonite. The mined-out upper portions of this zone in the vicinity of the main pit may have contained more than 1 percent amblygonite. Hess (1925, p. 289) described a mass of amblygonite in the Peerless pegmatite as being "27 feet across," with other dimensions approaching this figure. Such a mass, however, would have contained nearly as much amblygonite as the total recorded production from the Peerless mine. Nevertheless, present exposures in old workings in the upper part of the pegmatite contain about 1 percent amblygonite. The grade is much less in underground exposures.

The amblygonite of Zone 5 occurs in rounded, grayish-white crystals that range in diameter from 0.2 inch to 3 feet; the average size is about 6 inches. The average size of amblygonite grains in the wall zone is about 0.75 inch, and in the first intermediate zone it is about 1 inch. The grains are commonly corroded and rounded by other minerals of the zones and are coated with a white dusty alteration product. Optical properties given in tables 6, 7, and 9 indicate that the amblygonite is nearer the montebrasite or hydroxyl end than the amblygonite or flourine end of the series. _/

_/ Based on Winchell, 1951, p. 223.

Other minerals

The Peerless pegmatite also contains tantalite-columbite, cassiterite, and lithiophilite-tryphilite.

Tantalite-columbite has been observed in Zones 1, 2, 3, 5, and 7, and in the replacement units. The average grade probably does not exceed 1 pound of tantalite-columbite in 10 tons of rock in any of these units, and the grade of Zones 1 and 2 may be much less.

Tantalite-columbite occurs as thin plates that have an average length of 0.2 inch and an average thickness of 0.01 inch. Blades as much as 4 inches in length and 0.15 inch in thickness are intergrown with cleavelandite and muscovite in Zones 3 and 5 and in the muscovite-cleavelandite replacement unit. The intimate association with muscovite and cleavelandite in these units makes hand-cobbing very difficult. However, a single crystal of "columbite," associated with quartz and mica, was reported by Hess (1925, p. 293) to weigh more than 200 pounds.

Cassiterite has been observed in Zones 2, 3, 5, and 7, and in the replacement units. The richest of these units is Zone 3, which probably contains an average of 0.2 pound of tin per ton of rock; a very rich exposure covering 315 square feet in the main pit contains about 5 pounds of tin per ton of rock. Zones 5 and 7 and the replacement units may contain 0.1 pound of tin per ton of rock. The wall zone contains only a trace.

The size of observed grains of cassiterite ranges from less than 0.1 to 2 inches but larger masses have been reported by A. F. Walker, the mine superintendent. The cassiterite is erratically distributed, but it is commonly associated with muscovite.

Approximately 40 tons of dark-colored aggregates of phosphate minerals has been stockpiled east of the main pit, but none of this material has been sold. The minerals in these aggregates are probably largely members of the lithiophilite-triphylite group and their alteration products. These phosphate minerals occur as irregular aggregates and pod-shaped masses in Zones 2, 3, 5, 6, and 7, and in the lithia mica-cleavelandite pegmatite replacement unit. Individual masses of phosphate minerals range in size from less than 0.5 to 12 inches. Irregular aggregates of the phosphate minerals intergrown with varying amounts of other minerals are commonly 3 feet in diameter in Zone 5. They form about 1 percent of Zones 5 and 7 but less than 1 percent of the other units.

RESERVES

The reserves of mica, beryl, potash feldspar, and amblygonite are estimated to range from 1 to 6 times past production of the minerals. Reserves of soda feldspar are many times greater than past production.

The chief minable unit is Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone). This unit contains the principal reserves of muscovite and beryl. The average thickness of Zone 3 is about 5 feet in the footwall parts of the pegmatite and about 1.5 feet in the hanging-wall parts of the pegmatite (figs. 4 and 5). The depth ranges from 32 feet (fig. 5, section F-F') to 215 feet (fig. 4, section A-A'), as measured down the dip. The total length at the surface is about 360 feet.

Adjacent parts of the wall zone also contain beryl and muscovite, as well as small quantities of potash feldspar. The average thickness is about 5 feet but the maximum thickness is 20 feet. Beryl occurs chiefly in the inner 40 percent of the zone.

The main potash feldspar deposit is Zone 4. This unit is crescent-shaped in cross-section (figs. 4 and 5) and occurs mainly along the crest of the pegmatite and along the hanging walls of northeastward-dipping limbs. The deposit is as much as 35 feet thick in the upper part of the pegmatite (fig. 4, section D-D'), but it pinches out down dip. A large outcrop of the second intermediate zone in the northeastern part of the pegmatite is 235 feet long and 95 feet in maximum width (fig. 2); two smaller outcrops in the northwestern part of the pegmatite are 12 feet and 25 feet in length.

Potash feldspar reserves also are present in Zone 6a, quartz-microcline pegmatite. This unit is in the unmined pinnacle in the main pit (fig. 2), where it is 80 feet long and 25 feet in maximum width; a smaller outcrop to the north of the unmined pinnacle is 8 feet in diameter. The maximum thickness is probably about 40 feet.

Zone 5, cleavelandite-quartz pegmatite, is notable chiefly for its amblygonite reserves, but it also is very rich in soda feldspar. Most of this deposit is between 15 and 30 feet thick; the depth, measured down the dip, ranges from 22 feet (fig. 5, section F-F') to 250 feet (fig. 4, section A-A'). The length at the surface is 375 feet.

Zone 7 and the replacement bodies are small. The largest continuous exposure of the lithia mica-bearing core and replacement unit is 48 feet long, and the thickness may be as much as 50 feet. Smaller exposures of these rocks occur in the northern part of the main pit (fig. 2). The muscovite-cleavelandite replacement unit crops out in two exposures, 4 by 7 feet and 30 by 60 feet in size, in the old cut northwest of the unmined pinnacle (fig. 2).

U. S. BUREAU OF MINES DIAMOND DRILLING

Much of the data for this report was obtained from the study of cores from seven diamond drill holes that were drilled by the U. S. Bureau of Mines in the fall of 1949 (tables 19 to 25). The purpose of the drilling was to determine the extent of beryl-bearing units at depth in the Peerless pegmatite. The drilling was under the supervision of Stewart Ferguson and Eugene O. Binyon of the U. S. Bureau of Mines. Geological work during the drilling was done by D. M. Sheridan, R. E. Roadifer, and J. J. Norton of the U. S. Geological Survey. Sheridan logged the drill core.

The U. S. Bureau of Mines is preparing a separate report covering all but the geologic aspects of this work.

Table 19.--Detailed log of U. S. Bureau of Mines diamond drill hole 1, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: 352 ft N. 9° E. from the portal of the adit of the main underground workings of the Peerless mine.

Altitude of collar: 4,617.5 ft.

Inclination : Minus 39°

Bearing : S. 63 1/2° W.

Length : 210.0 ft.

Angles of intersection of drill core with bedding, schistosity, pegmatite contacts, and fractures: -

Depth (in ft)	Angle between core and: Bedding	Schistosity	Pegmatite contacts	Fractures
10-15	20°	Parallel to beds.		
20-35	5°	40° - 50°.		
45-50	45°	55°.		
51	25°	35°.		
55-63	-	50° - 60°.		
63	-	57°.	65°	
100.8	-	- - -	-	50°
101	-	- - -	68°	
101-125	10°-25°	30° - 50°.		
125-155	0°-15°	50° - 70°.		
155-165	15°-25°	30°.		
165-177	25°-50°	Parallel to beds.		
183-188	5°-10°	15°.		
190-200	35°-50°	15° - 60°.		
207-210	10°-20°	Parallel to beds.		

Table 19. --Detailed log of U. S. Bureau of Mines diamond drill hole 1--Continued.

Deascription of rocks: -

Depth (in ft)	
0, - 10.0	Overburden. No core.
10.0-63.0	Quartz-mica-chlorite schists, interbedded with quartz-mica schist. Irregular discontinuous quartz stringers, as much as 6 in. thick, comprise approximately 5 percent of the core. Some of the quartz stringers contain muscovite (< 10 percent) and traces of green apatite in grains as much as 0.1 in. in diameter. Quartz-mica-chlorite schist beds cut at 10 - 40.7 ft. and at 45.9 - 60.8 ft. consist of: quartz (45 percent), muscovite (30 percent), biotite (20 percent), chlorite (4 percent), garnet (< 1 percent), and staurolite(< 1 percent). Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite, 0.05 to 1 in. in diameter, comprise as much as 5 percent of some of this schist. Some of the pseudomorphs contain relicts of brown staurolite. Metacrysts of staurolite form about 2 percent of the core from 10 - 14.7 ft but the pseudomorphism to micaceous minerals increases towards the pegmatite contact. Quartz-mica schist beds cut at 40.7 - 45.9 ft and 60.8 - 63.0 ft consist of: quartz (50 percent), muscovite (30 percent), biotite (20 percent), and garnet (trace). The schist for 3 in. above the pegmatite contact at 63.0 ft has been altered to a muscovite-rich schist containing muscovite (50 percent), quartz (45 percent), and biotite (5 percent).

Table 19.--Detailed log of U. S. Bureau of Mines diamond drill hole 1-- Continued.

63.0-101.0 Pegmatite.

63.0- 63.2 Quartz-muscovite _/ pegmatite (zone 1, border zone).--Very fine-

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_/ Throughout the logs, the sequence of mineral names applies only to the core segment that is being described. It may differ from the name of the entire unit. Zone 1, for example, is ordinarily quartz-plagioclase pegmatite, even though it is quartz-muscovite pegmatite in this core segment.

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grained (0.1 in.). Contains quartz (60 percent), muscovite (35 percent), albite (?), (3 percent), apatite ($<$1 percent), and tourmaline ($<$ 1 percent).

63.2- 73.4 Quartz-albite-muscovite pegmatite (zone 2, wall zone).--Contains quartz (55 percent), albite (30 percent), muscovite (12 percent), tourmaline ($<$1 percent), apatite ($<$ 1 percent), perthite ($<$1 percent), unidentified alteration products of phosphate minerals ($<$1 percent), garnet (trace), tantalite-columbite (trace), cassiterite (?) (trace), beryl (trace), and loellingite (?) (trace). Average grain size is approximately 0.35 in., but the size ranges widely. Albite is white to grayish-white; the minimum index of refraction (N_{α}') ranges from 1.530 at 63.3 ft to 1.528 at 72 ft. Muscovite is yellowish-silvery; the maximum size of books is 2 in. Two pale-white translucent grains of beryl, 0.5 by 0.35 in. and 0.25 by 0.35 in., are at 63.9 ft; the index of refraction (N_{ω}) is 1.581. Black tourmaline at 66.4 ft has $N_{\omega} = \pm 1.67$. One grain of perthite, 1.7 by 1 inch in size, at 71.5 ft is veined and embayed by quartz.

73.4- 76.2 Quartz-cleavelandite-muscovite pegmatite (zone 3, first intermediate zone).--Contains quartz (45 percent), cleavelandite (35 percent), muscovite (20 percent), tourmaline ($<$ 1 percent), and apatite ($<$1 percent). Average

Table 19.--Detailed log of U. S. Bureau of Mines diamond drill hole 1-- Continued.

	grain size is about 1.5 in. Cleavelandite is white to grayish-white; minimum index of refraction (N_{α}') is 1.528. Maximum size of yellowish-silvery muscovite books is 3 in. The index of refraction (N_{ω}) of a bluish-black grain of tourmaline at 75.0 ft is 1.66.
76.2- 84.6	Cleavelandite-quartz-muscovite pegmatite (zone 5, third intermediate zone).--Contains cleavelandite (50 percent), quartz (40 percent), muscovite (6 percent), tourmaline ($<$1 percent), and apatite ($<$1 percent). Average grain size is about 1.5 in. Cleavelandite ($N_{\alpha}' = 1.528$) comprises 97 percent of the core from 76.2 to 78.4 ft, but is distributed evenly in the rest of the unit in aggregates that range in size from 0.5 to 4 in. Yellowish-silvery muscovite books are as long as 2.25 in.
84.6- 87.4	Quartz-cleavelandite-muscovite pegmatite (zone 3, first intermediate zone).--Contains quartz (65 percent), cleavelandite (25 percent), muscovite (10 percent), tourmaline ($<$1 percent), apatite (trace), and tantalite-columbite (trace). Average grain size is about 2 in. Cleavelandite and muscovite are the same as between 73.4 and 76.2 ft. Two plates of tantalite-columbite are 0.2 by 0.01 in. in size.
87.4-100.7	Albite-quartz-perthite pegmatite (zone 2, wall zone).--Contains albite (45 percent), quartz (35 percent), perthite (10 percent), muscovite (6 percent), tourmaline (1 percent), unidentified alteration products of phosphate minerals ($<$1 percent), apatite ($<$1 percent), tantalite-columbite (trace), and garnet (trace). This unit can be subdivided as follows on the basis of mineralogy:

Table 19. --Detailed log of U. S. Bureau of Mines diamond drill hole 1--Continued.

Estimated percentage of principal minerals

Depth (in ft)	Average grain size (in in.)	Blocky to sub-platy albite	Sugary albite	Quartz	Muscovite	Perthite
87.4- 92.1	0.6	50	-	35	12	< 1
92.1- 93.8	.5	45	-	35	3	13
93.8- 95.4	.5	50	-	45	4	-
95.4- 99.0	.7	30	5	25	3	35
99.0-100.7	.3	40	10	40	10	-

Average grain size is 0.5 in., but it decreases to 0.3 in. near the contact with the border zone at 100.7 ft. Perthite crystals, however, are as much as 4.5 in. Perthite is pale flesh-colored; it is embayed and veined by albite, quartz, and muscovite. Albite occurs chiefly as blocky to subplaty grains having an average size of 0.3 in. The minimum refractive index of cleavage fragments (N_{α}') is 1.528-1.529. Albite also occurs as very fine-grained (< 0.05 in.) irregular aggregates that are about 1 in. thick (N_{α}' = 1.528-1.529). Muscovite has an average grain size of 0.15 in. near the contact at 100.7 ft; but books are as large as 2 in. at 87.4 to 92.1 ft. Bluish-black grains of tourmaline (N_{ω} = 1.66) average 0.15 in. in size, but aggregates are as large as 1 in.

100.7-101.0 Quartz-muscovite pegmatite (zone 1, border zone). --Very fine-grained (0.1 in.). Contains quartz (60 percent), muscovite (35 percent), albite (3 percent), apatite (trace(, and tourmaline (?) (trace). White grains of albite, 0.15 in. in size, occur only at 100.7 - 100.75 ft.

Table 19. --Detailed log of U. S. Bureau of Mines diamond drill hole 1-- Continued.

101.0-210.0 <u>Quartz-mica schist</u>, interbedded with quartz-mica chlorite schist. Irregular discontinuous quartz stringers, 0.1 to 1.5 in. thick, comprise about 5 percent of the core. A quartz stringer, 1.5 in. thick, at 197.9 ft contains traces of pyrite.

The quartz-mica schist contains quartz (50 percent), muscovite (30 percent), biotite (20 percent), chlorite (0 - 0.3 percent), and garnet (< 1 percent). Some beds contain as much as 5 percent pseudomorphs of muscovite and biotite after euhedral staurolite, but in general the pseudomorphs are less common than in quartz-mica-chlorite schist.

The quartz-mica-chlorite schist contains quartz (45 percent), muscovite (35 percent), biotite (10 - 15 percent), chlorite (5 - 10 percent), and garnet (1 percent). Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite form about 5 percent of this schist. Quartz-mica-chlorite schist was cut at 130.7 - 143, 148 - 162.4, 162.9 - 164.4, 165.7-169.5, 170.5-175.2, and 175.9 - 178 ft. At 180.7 - 185.7 ft and 190.7 - 197.3 ft, quartz-mica schist and quartz-mica-chlorite schist are finely interbedded in one-inch beds.

Table 20--Detailed log of U. S. Bureau of Mines diamond drill hole 2, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: 3 feet N. 63 1/2° E. from collar of hole 1.

Altitude of collar: 4,616 feet

Inclination : Minus 85°.

Bearing : S. 63 1/2° W.

Length : 137.9 feet

Angles of intersection of drill core with bedding, schistosity, pegmatite contacts, and fractures:-

Angle between core and:

Depth (in ft)	Bedding	Schistosity	Pegmatite contacts	Fractures
16-60	5°-17°	5° - 20°.		
63	10°	35° (perpendicular to beds).		
64- 66.4	10° - 20°	20°.		
66.5	- -	- -	50°?	
92	- -	- -	90°.	
92-100	45°-55°.	40°-55°		
100.7	- -	65°.		
100.8	- -	- -	62°.	
126.8	- -	- -		70°.
127.6	30°	- -	50°.	
128-130	15°-25°.	- -		
130-131	25°-30°.	15° (50° angle with beds).		
131.8	35°	Parallel to beds.		
134-137.9	5° -15°	20°.		

Table 20.--Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

Description of rocks: -

Depth (in ft)	
0. - 16.0	Overburden and schist. No core.
16.0 - 31.0	Quartz-mica-staurolite schist.--Contains quartz (50 percent), muscovite (30 percent), biotite (14 percent), staurolite (5 percent), garnet (< 1 percent), and chlorite (<1 percent). Brown metacrysts of staurolite range in size from 0.15 to 0.75 inches. Pseudomorphs of muscovite and biotite after staurolite occur from 26 to 31 feet. Irregular discontinuous quartz stringers, 0.1 to 3.5 inches thick comprise about 10 percent of the core.
31.0 - 66.0	Quartz-mica-chlorite schist.--Contains quartz (45 percent), muscovite (30 percent), biotite (17 percent), chlorite (6 percent), garnet (1 percent), staurolite (<1 percent), and tourmaline (?) (trace). Staurolite metacrysts form about 2 percent of the core from 31 to 46 feet, but pseudomorphism to muscovite, biotite, and chlorite increases as the pegmatite contact is approached. From 46 to 66 feet, staurolite occurs only as relicts in pseudomorphs that range in size from 0.1 to 1.5 inches. Traces of black tourmaline (?), in grains less than 0.05 inches in size, occur at 63 - 66 feet. Irregular discontinuous quartz stringers 0.1 to 3 inches thick form about 5 percent of the core.
66.0- 66.5	Quartz-muscovite schist, an altered varity of schist lying adjacent to the pegmatite contact. Contains quartz (55 percent), muscovite (45 percent), and tourmaline (?) (< 1 percent). Black grains of tourmaline are less than 0.05 inches in size. Irregular discontinuous stringers of quartz, 0.05 - 0.1 inches thick, form about 15 percent of the core. The core is heavily iron-stained.

Table 20.--Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

66.5- 92.0 Pegmatite.

66.50-66.52 Quartz-muscovite pegmatite (Zone 1, border zone).--Very fine-grained (0.05 inch) pegmatite containing quartz (65 percent), muscovite (35 percent), tourmaline (< 1 percent), and apatite (< 1 percent). The index of refraction (N_{ω}) of bluish-black tourmaline is 1.67.

66.52-70.8 Quartz-albite-muscovite pegmatite (Zone 2, wall zone). --Contains quartz (50 percent), albite (35 percent), muscovite (13 percent), tourmaline (1 percent), apatite (< 1 percent), tantalite-columbite (< 1 percent), and garnet (< 1 percent), and an unknown yellowish-gray mineral that may be lithia mica (trace). The average grain size is about 0.5 inches, but muscovite books are as much as 1.75 inches. This zone can be subdivided as follows on the basis of mineralogy:

Estimated percentage of principal minerals

Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Quartz	Muscovite
66.52-67.0	0.5	< 1	75	20
67.0 -69.8	.5	30	55	14
69.8 -70.8	.35	65	25	8

Albite is grayish white. The minimum index of refraction of cleavage fragments (N_{α}') is 1.528. Tourmaline occurs as black euhedral grains (N_{ω} = 1.67).

Table 20.--Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

70.8- 72.1 <u>Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone).</u>-- Contains quartz (55 percent), cleavelandite (25 percent), muscovite (20 percent), apatite (< 1 percent), tourmaline (< 1 percent), and tantalite-columbite (< 1 percent). Average grain size is about 1 inch. The maximum size of recovered books of muscovite is 4 inches. Three plates of tantalite-columbite are 0.08 by 0.01 inch in size.

72.1- 82.9 <u>Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).</u>-- Contains cleavelandite (82 percent), quartz (14 percent), muscovite (3 percent), apatite (< 1 percent), and tourmaline (trace). The average grain size is about 1 inch. The outer part of the zone, at 72.1 - 73.0 feet, is relatively rich in quartz (65 percent), and has correspondingly less cleavelandite (30 percent). Cleavelandite forms 75 percent of the core at 73.0 - 77.0 feet, and 96 percent of the core at 77.0 - 82.9 feet. The minimum refractive index of cleavage fragments (N_{α}') of the cleavelandite is 1.528. The maximum size of muscovite books is 1.75 inches.

82.9-87.6 <u>Quartz pegmatite (Zone 6b, fourth intermediate zone).</u>--Consists entirely of massive quartz.

87.6-90.3 <u>Cleavelandite pegmatite (Zone 5, third intermediate zone).</u>--Contains cleavelandite (93 percent), quartz (3 percent), muscovite (3 percent), apatite (trace), and tantalite-columbite (trace). The average size of individual grains is about 1 inch.

90.3-91.95 <u>Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone).</u>--Contains cleavelandite (72 percent), quartz (16 percent), muscovite (11 percent), and apatite (< 1 percent). Average grain size is about

Table 20. --Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

1 inch. The maximum size of recovered muscovite books is about 3 inches. The minimum index of refraction (N_{α}') of cleavelandite is 1.528.

91.95-92.0 Quartz-muscovite-albite pegmatite (Zone 1, border zone). --Contains quartz (55 percent), muscovite (25 percent), and albite (20 percent). Very fine-grained (0.02 inch). The maximum size of muscovite books is 0.25 inch. White to creamy-white albite ($N_{\alpha}' = 1.529$, in 0.2-inch grains, occurs only at 91.95 feet.

92.0-100.8 Quartz-muscovite-tourmaline schist. --Contains quartz (40 percent), muscovite (35 percent), tourmaline (25 percent), and apatite (trace). Black euhedral grains of tourmaline ($N_{\omega} = 1.67$) range in size from less than 0.05 to 1.1 inches, but the average tourmaline grain is 0.5 inch long and 0.2 inch in diameter. The tourmaline crystals contain mesgascopically visible quartz grains, which are oriented in layers parallel to the adjacent bedding. The touramline grains tend to lie in the plane of the foliation but are diversely oriented in this plane. Traces of bluish-green apatite in 0.5 inch grain occur at 92.0 - 92.2 feet. The composition of the schist is fairly consistent except for a quartz-rich bed at 95.4 - 95.8 feet which contains quartz (55 percent), muscovite (40 percent), and tourmaline (5 percent). Irregular discontinuous quartz stringers, less than 0.1 inch thick, form 1 percent of the core.

100.8-127.6 Pegmatite.

100.8-110.3 Albite-quartz-muscovite pegmatite (Zone 2, wall zone). --Contains albite (55 percent), quartz (40 percent), muscovite (5 percent), apatite (< 1 percent), tourmaline (< 1 percent), tantalite-columbite (trace), cassiterite (?) (trace), and an unidentified yellow-brown to green-brown mineral (trace). The average grain size is 0.4 inch. About 20 percent

Table 20. --Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

of the albite is very fine-grained (< 0.05 inch) and occurs in irregular aggregates as large as 2 inches. The remainder of the albite is blocky to platy and averages about 0.4 inch in grain size. The minimum index of refraction (N_{α}') of the blocky to platy albite cleavage fragments is 1.529 at 100.9, slightly under 1.529 at 102.1, and is 1.528 at 104.8 and at 109.5 feet. The maximum size of muscovite is 1.25 inches. Black and bluish-black grains of tourmaline range in size from less than 0.05 to 0.15 inch . One bluish-black grain of tourmaline is apparently zoned, with refractive index (N_{ω}) ranging from 1.665 to 1.675. Five plates of tantalite-columbite are 0.01 inch thick and 0.03 to 0.1 inch long. One black grain, 0.08 by 0.02 inch , may be cassiterite (?). An unidentified yellowish-brown to green-brown mineral occurs in irregular rounded masses, 0.2 inch in diameter; the mineral is soft and waxy. One grain of the unidentified mineral has the shape of a rounded hexagon, suggesting that it may be an alteration product of beryl.

110.3-111.4 <u>Cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone)</u>.--Contains cleavelandite (95 percent), muscovite (5 percent), apatite (trace), and tourmaline (trace). The average grain size is 1 inch. The maximum size of recovered muscovite is 1.75 inches.

111.4-119.3 <u>Cleavelandite pegmatite (Zone 5, third intermediate zone)</u>. --Contains cleavelandite (97 percent), muscovite (2 percent), quartz (< 1 percent), tourmaline (< 1 percent), apatite (< 1 percent), tantalite-columbite (trace), and cassiterite(?) (trace). The average grain size is about 1 inch. The minimum index of refraction of cleavelandite (N_{α}') is 1.528. The maximum

Table 20.--Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

size of muscovite is 1 3/4 inches. Tourmaline has the following characteristics:--pale blue tourmaline, 0.05 inch grains, at 112 feet, $N_{\omega} = 1.66$; bluish-black tourmaline, 0.05-inch grains, at 118.7 feet, $N_{\omega} = 1.66$; and black tourmaline, .75-inch grain, at 118.8 feet, $N_{\omega} = 1.67$. Four black plates of columbite-tantalite are 0.01 to 0.02 inch thick and 0.03 to 0.2 inch long. Several rounded to irregular 0.02-inch grains are probably cassiterite (?).

119.3-127.6 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (75 percent), quartz (11 percent), muscovite (10 percent), perthite (2 percent), tourmaline (< 1 percent), apatite (< 1 percent), and tantalite-columbite (< 1 percent). The core is heavily iron-stained. The average grain size decreases from 0.4 inch at 119.5 feet to 0.2 inch at 127 feet. The zone can be subdivided as follows on the basis of mineralogy:

Estimated percentage of principal minerals

Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite
119.3-120.0	0.4	40	-	35	3	20
120.0-120.9	.3	55	-	35	6	-
120.9-217.6	.2	75	10	5	10	-

Albite occurs chiefly as subplaty grains; some is sugary-grained (< 0.05 inch). The minimum refractive index of cleavage fragments of subplaty albite ranges from slightly under 1.529 at 119.4 feet to slightly over 1.529 at 127.6 feet. Perthite between 119.3 and 120.0 feet consists

Table 20.--Detailed log of U. S. Bureau of Mines diamond drill hole 2-- Continued.

of white to creamy-white grains, 1 inch in size, embayed and veined by quartz. Muscovite is as long as 1.3 inches. Tourmaline between 120.0 and 120.9 feet occurs as greenish-black grains 0.06 by 0.5 inch in size, bluish-black grains 0.01 to 0.05 inch in size, and black grains (N_{ω} = 1.67) 0.15 inch in diameter. Greenish-black grains (N_{ω} = 1.66), or 0.02 to 0.5 inch in size occur between 120.9 and 126.6 feet. Tantalite-columbite plates are as long as 0.15 inch.

127.6-130.5 Quartz-mica-tourmaline schist.--Contains quartz (45 percent), muscovite (35 percent), biotite (10 percent), and tourmaline (10 percent). Tourmaline forms 15 percent of the schist at 127.8 feet but decreases in amount to 5 percent at 130.0 feet. The tourmaline (N_{ω} = 1.67) occurs in black euhedral grains which range in size from 0.01 to 0.1 inch. Irregular discontinuous quartz stringers, less than 0.3 inch thick, form less than 5 percent of the core. Lineation of tourmaline needles is 35° to the core at 129 feet.

130.5-137.9 Quartz-mica schist.--Contains quartz (50 percent), muscovite (30 percent), biotite (20 percent), and tourmaline (trace). Traces of tourmaline occur only at 130.5 - 131.5 feet. Irregular discontinuous quartz stringers, as much as 2 inches thick, form less than 5 percent of the core.

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: 151 feet S. 57° E. of hole 1, and 329 feet N. 36 1/2° E. of the portal of the adit of the main underground working of the Peerless mine.

Altitude of collar: 4,628 feet.

Inclination : Minus 20°.

Bearing : S. 63 1/2° W.

Length : 331.8 feet.

Angles of intersection of drill core with bedding , schistosity, pegmatite contacts, and fractures: -

	Angle between core and:			
Depth (in ft)	Bedding	Schistosity	Pegmatite contacts	Fractures
6-39	5°-25°	Approximately parallel to beds.	-	-
39.2	-	- - -	Irregular	-
39.5	-	- - -	60°	-
40-50	10°-30°	Approximately parallel to beds	-	-
55-60	-	25°-30°.	-	-
63	5°	28°.	-	50°
64.5	-	18°.	-	-
70-80	0-15°	Approximately parallel to beds.	-	-
80-87	15°-33°	Approximately parallel to beds.	-	-
88	25°	15°	-	-
89-105	5°-25°	15°-25°.	-	-
106	70°	- - -	-	-
107-112	15°-25°	25°.	-	-
113.5	35°	Parallel to beds.	-	-
114.3	55°	45°	-	-

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

Depth (in ft)	Angle between core and: Bedding	Schistosity	Pegmatite contacts	Fractures
114.4	-	- - -	65°	-
142.7	-	- - -	-	40°
157.4	-	- - -	50°	-
157.8	60°	53°.	-	-
158.5	63°	60°.	-	-
160- 180	55°-65°	55°-65°.	-	-
181- 185	35°-40°	45°.	-	-
186.5	-	55°.	-	-
187.2	-	- - -	50° (?).	-
229- 232	-	- - -	-	35°-40°.
240	--	- - -	-	40°.
308.4- 311.1	-	- - -	-	55°-65°.
318.9	-	- - -	-	30°.
320.9	-	- - -	-	50°.
321.6	-	- - -	-	55°.

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

Description of rocks: -

Depth
(in ft)

0. - 4.5 Overburden. No core.

4.5- 39.2 Quartz-mica-chlorite schist. --Contains quartz (45 percent), muscovite (30 percent), biotite (15 percent), chlorite (8 percent), garnet (1 percent), and staurolite (trace). Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite, o.1 to 1 inch in size, average about 5 percent of the core. Some of the pseudomorphs contain relicts of brown staurolite. Isolated elongate dark-green flakes of chlorite, 0.05 to 0.25 inch in size, also occur in the matrix. Metacrysts of red-brown garnet are 0.05 to 0.1 inch in diameter. Irregular discontinuous quartz stringers, ranging in thickness from 0.01 to 5 inches, form 5 percent of the core.

39.2- 39.5 Quartz-plagioclase pegmatite. --Not shown on the cross-section (fig. 5). The only minerals are quartz (75 percent) and plagioclase (25 percent). The quartz is massive and colorless to slightly milky. White plagioclase grains (average about 0.5 inch in size) occur in aggregates as large as 1.5 inches.

39.5- 50.0 Quartz-mica-chlorite schist, as at 4.5 - 39.2 feet. Quartz stringers, 0.1 to o.75 inch thick, form about 3 percent of the core.

50.0- 55.0 No core. This lack of core and heavy iron staining at 55 - 60 feet suggest a zone of fractures.

55.0- 114.4 Quartz-mica-chlorite schist, as at 4.5 - 3.92 feet. Interbedded with quartz-mica schist. Quartz stringers as at 39.5 - 50.0 feet. The quartz-mica schist contains quartz (50 - 60 percent), muscovite (20 -25 percent), biotite (10 - 20 percent), chlorite (0-3 percent), and garnet (trace). Some beds contain as much as 3 percent pseudomorphs of muscovite and biotite after staurolite, but the pseudomorphs are less common than in the quartz-mica-chlorite schist. Beds of quartz-mica schist were cut at 60 - 64, 68.5 - 70,

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill holes 3-- Continued

Depth
(in ft)

75.5 - 77.0, 88 -88.7, 99.8 - 101.6, and 109 -114.4 feet. At 103.9 -109 feet, quartz - mica schist beds, 1 to 5 inches thick, comprise about 40 percent of the core. Traces of soft yellowish-white lath-shaped grains, 0.05 to 0.1 inch long, occur at 113.5 -114.4 feet, near the pegmatite contact; these grains consist of unidentified clay minerals and may be altered plagioclase metacrysts.

114.4-157.4 Pegmatite.

114.40-114.45 Quartz-muscovite pegmatite (Zone 1, border zone). --Contains quartz (80 percent), muscovite (20 percent), and apatite (trace). A sheet of massive, colorless to slightly smoky quartz, 0.1 to 0.4 inch thick, forms the outer part of the zone adjacent to the schist. The average grain size of the inner part of the zone is 0.05 inch .

114.45-122.3 Albite-quartz-muscovite pegmatite (Zone 3, wall zone). --Contains albite (55 percent), quartz (35 percent), muscovite (8 percent), unknown alteration products of phosphate minerals (1 percent), beryl (0.12 percent of 7.75 feet of recovered core), tourmaline (<1 percent), apatite (trace), tantalite-columbite (trace), loellingite(?) (trace), and garnet (trace). The average size of individual grains is 0.35 inch and of aggregates is about 0.75 inch . The zone can be subdivided as follows on the basis of mineralogy:

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

	Estimated percentage of principal minerals.				
Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite
114.45-114.7	0.4	4	-	75	20
114.7- 120.2	.35	40	5	40	10
120.2 -122.3	.4	80	-	15	3

Depth (in ft)

Albite is white, grayish, and buff or reddish stained. Minimum refractive index of cleavage fragments (N_{α}') is 1.528. Muscovite grains have a maximum dimension of 2.25 inches. Four beryl crystals have the following characteristics:

Depth (in ft)	Size	Shape	Color	Orientation	N_W
114.46	0.01 sq. in.	Rounded, subhedral.	White, iron stained.	---	1.579
114.5	0.15 by 0.4 in.	Elongate, euhedral.	"	Perpendicular to contact	-
114.5	0.15 by 0.5 in.	Elongate.	"	---	1.577
119.0	0.5 by 1.05 in.	Prismatic.	Milky white.	---	1.583

Three grains of columbite-tantalite are 0.01 inches thick and 0.1 to 0.2 inches long. Dark-brown to black unknown alteration products of phosphate minerals stain the core. One buff-silvery penetration twin, 0.3 inches in diameter, is tentatively identified as loellingite (?). A rounded reddish-brown grain of garnet (N_{ω} = 1.82) is 0.25 inches by 0.15 inches in size.

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

Depth (in ft)	
122.3-135.2	Cleavelandite-muscovite-quartz pegmatite (Zone 3, first intermediate zone).--Contains cleavelandite (55 percent), muscovite (35 percent), quartz (8 percent), tourmaline (< 1 percent), apatite (trace), and cassiterite (trace). The average grain size increases from 0.75 inch at 122.5 feet to 2 inches at 133 feet. The maximum size of muscovite books recovered in the core is 8.5 inches, and the average size is about 3 inches. The muscovite is ruled and contains "herringbone" structures. Blue-black and green-black, euhedral to subhedral grains of tourmaline range in size from 0.01 to 0.35 inch . Four irregular grains of cassiterite, ranging in size from 0.05 to 0.65 inch , occur along the edges of muscovite books.
135.2-144.5	Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).--Contains cleavelandite (85 percent), quartz (10 percent), apatite (2 percent), muscovite (1 percent), tourmaline (< 1 percent), and an unidentified altered phosphate mineral (trace). The average size of individual grains is about 1 inch. Quartz occurs as a massive pod at 141.6 - 142.2 feet, but forms less than 1 percent of the rest of the core. Cleavelandite (N_{α}' - 1.528) occurs in aggregates as large as 15 inches in diameter. Eight subhedral to rounded grains of apatite (mangan apatite?), pale green to dark bluish-green, occur at 135.75 - 136.0 feet; these range in size from 0.2 to 1.5 inches - average 0.75 inch ; N_{ω} - 1.654, N_{ϵ} = 1.651. Blue to blue-black euhedral tourmaline grains average 0.05 inch in size. An irregular 0.5- inch aggregate at 144.4 feet consists of a claylike pinkish-buff material, surrounded by a halo of brown stains in the surrounding cleavelandite; the claylike material was not identified; probably it is an altered phosphate mineral.

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole 3--Continued.

Depth (in ft)	
144.5-148.5	Muscovite-cleavelandite pegmatite (Zone 3, first intermediate zone).--Contains muscovite (85 percent), cleavelandite (10 percent), beryl (2.61 percent of 2.9 feet of recovered core), quartz (2 percent), apatite (trace), and tourmaline (trace). The average grain size is about 8 inches. Muscovite books are as large as 18 inches in maximum dimension. One large prismatic grain of beryl, 375 inches long and 1 inch thick, occurs at 144.7 - 145.0 feet. The beryl (N_w = 1.582) is pale milky-white, with a very faint greenish tint.
148.5-157.2	Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (60 percent), quartz (25 percent), muscovite (5 percent), perthite (4 percent), tourmaline (1 percent), unknown alteration products of phosphate minerals (1 percent), beryl (0.33 percent of 7.95 feet of recovered core), apatite ($<$0.5 percent), tantalite-columbite (trace), unidentified bluish-green to dark-green mineral (trace), amblygonite (?) (trace), and loellingite (?) (trace). The overall average grain size of this segment of wall zone is about 0.75 inches. The zone can be subdivided as follows on the basis of mineralogy and texture:

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

		Estimated percentage of principal minerals				
Depth (in feet)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite
148.5-149.9	0.6	70	25	2	1.5	-
149.9-151.2	.5	50	5	30	5	-
151.2-151.9	5-in. perthite crystal in 0.3-in. groundmass.	20	Trace.	30	5	40
151.9-157.2	.4	40	20	30	7	-

Depth
(in ft)

Most of the albite is blocky to platy. Sugary albite (< 0.1 inch) occurs as irregular aggregates and discontinuous layers 0.25 to 4 inches thick. Perthite occurs only as a 5-inch fleshy-white grain at 151.5 feet that is veined and embayed by albite and quartz. Tourmaline is black to blue-black and subhedral to euhedral. Bluish-green subhedral to rounded grains of apatite average 0.05 inch in size. Four plates of tantalite-columbite are all less than 0.1 inch in length.

An unidentified bluish-green to dark-green soft mineral occurs in 0.1-inch angular clots with a graphic texture in albite; microscopically the mineral is a very fine-grained aggregate with a refractive index of 1.58.

Dark-brown and black unknown alteration products of phosphate minerals occur as heavy stains, and several 0.2-inch grains consisting mostly of brown limonitic clay are probably highly altered phosphate minerals. Traces of white amblygonite (?) occur in these heavily stained aggregates; microscopically this mineral is very finely crystalline, and has a maximum refractive index of about 1.62.

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole--Continued.

Eight grains of beryl have the following characteristics:

Depth (in ft)	Size	Shape	Color	N_{ω}
150.1	1 by 2 in.	Rounded prismatic.	White with colorless to faint green portions.	1.5805 in center. 1.5815 at one end.
150.35	0.15 by 1.1 in.	Anhedral.	Iron-stained.	1.582.
150.4	.02 sq. in.	Subhedral.	" "	- - -
150.45	.3 by .75	Rounded prismatic.	Colorless to white, stained along fractures.	1.582.
150.5	.3 by .75 in.	Subhedral.	"	1.582.
152.45	.25 by .3 in.	Rounded prismatic.	Milky to colorless, stained buff to yellow-brown.	1.582.
152.5	.1 by .2 in.	"	"	1.582.
152.5	.2 by .25 in.	"	"	1.582.

157.2-157.4 <u>Quartz-muscovite-albite pegmatite (Zone 1, border zone)</u>.--Contains quartz (60 percent), muscovite (30 percent), albite (10 percent), beryl (0.42 percent of 0.2 foot of recovered core), apatite ($<$ 0.5 percent), and tantalite-columbite (trace). The average grain size is 0.1 inches. The average size of muscovite decreases from 0.15 inches at 157.2 feet to 0.05 inches at 157.4 feet, and the percentage of muscovite increases from 15 percent at 157.2 feet to 40 percent near the schist contact. White blocky to subplaty grains of albite ($N_{\alpha}' = 1.530$), 0.05 to 0.5 inches in size, occur only from 157.2 to 157.3 feet. A cluster of 0.1 inch beryl grains occurs at 157.2; $N_{\omega} = 1.579$. Four colorless to white, buff-stained, subhedral grains of beryl at 157.3 - 157.35 feet range in maximum dimension from less than 0.1 to 0.5 inch. $N_{\omega} = 1.577$. The maximum size of bluish-green apatite is 0.07 inch. One grain of tantalite-columbite, 0.15 by 0.01 inches, was noted.

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

Depth
(in ft)

157.4-187.2 Quartz-mica schist.--Similar to the schist at 55.0 - 114.4 feet except that at 157.6 feet and at 185.9 - 187.2 feet adjacent to pegmatite contacts, the schist contains very little biotite and is relatively rich in muscovite. Quartz stringers, 0.05 to 1 inch thick, form 5 percent of the rock.

187.2-331.8 (?) Pegmatite.

187.20-187.25 Quartz-muscovite pegmatite (Zone 1, border zone).--Very fine-grained (0.1 inch). Contains quartz (75 percnet), muscovite (20 percent), albite (3 percent), and apatite (0.5 percent).

187.25-311.1 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (60 percnet), quartz (30 percent), muscovite (5 percent), perthite (4 percent), tourmaline (1 percent), amblygonite (< 1 percent), unidentified phosphate minerals and their alteration products (< 1 percent), lithia mica (< 1 percent), beryl (0.01 percent of 118 feet of recovered cpre), cassiterite (< 0.5 percent), apatite (< 0.5 percent), tantalite-columbite (< 0.5 percent), dahlite (trace), triploidite (?) (trace), unidentified dark-gray to green mineral (trace), and loellingite (?) (trace). The average grain size is about 0.3 inch , but the grain size ranges widely. Sugary aggregates and discontinuous layers consisting predominantly of albite (70 percent) and quartz (25 percent) have an average grain size of 0.05 inch . The grain size elsewhere is generally less than 1 inch, but perthite-rich pegmatite has an average grain size of as much as 3 inches at 295 feet.

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

This zone can be subdivided as follows on the basis of mineralogy and texture.

		Estimated percentage of principal minerals				
Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite
187.25-219.2	Sugary phase 0.05 Other .35	20	40	30	8	< 1
219.2 -220.5	.4	35	Trace.	45	10	4
220.5-243.7	Sugary phase .05 Other .35	15	50	30	2	-
243.7-292.7	Sugary phase .05 Other .35	20	40	30	5	1
292.7-302.4	1.3	35	Trace.	20	2	40
302.4-311.1	.4	65	-	30	2	< 1

Albite occurs both as blocky to platy grains and as sugary grains. Minimum indices of cleavage fragments (N_α') of blocky to platy albite range from 1.530 at 187 feet to 1.528 at 310 feet. Sugary albite at 244 feet has N_α' = 1.529. Flesh-colored crystals of perthite, 0.3 to 8 inches long are embayed and veined by albite and quartz. Sever iron-stained, pale-white euhedral crystals of beryl (N_ω = 1.579), 0.01 to 0.09 square inches in area, occur at 188 feet. At 306.7 feet two milky-white subhedral grains, 0.15 by 0.25 inches and 0.25 by 0.4 inches, have N_ω = 1.580. At 308.1 feet a similar beryl grain, 0.5 by 0.85 inch, has N_ω = 1.579. Gray-white amblygonite (variety, montebrasite) occurs as grains having a maximum length of 3 inches; N8° = 1.62. Dahlite (carbonate-apatite) occurs as a buff-white mineral, as much as 0.25 inches in diameter, at

Table 21. --Detailed log of U. S. Bureau of Mines diamond drill hole 3--Continued.

194 and 222.5 feet; uniaxial (-); N_{ω} = 1.64; birefringence, ρ.005. _/

_/ Identified by A. J. Gude, 3d, using powder X-ray technique.

Gray-brown, clove-brown, yellowish-brown, and black unidentified phosphate minerals occur as irregular clots and streaks, 0.1 to 1.5 inches in size, and their alteration products stain the other minerals in the core. Triploidite (?) occurs as a yellowish-brown irregular aggregate, 1.5 by 0.6 inch in size, at 187.8 feet.

Tantalite-columbite and cassiterite grains are less than 0.25 inch in maximum dimension. Tourmaline occurring as blue-black to black subhedral to euhedral grains as much as 1 inch long forms a maximum of 15 percent of the core at 263.5 - 264.6 feet. Approximately 1 percent of the core from 292.7 - 302.4 feet consists of irregular fracture fillings, 0.1 to 3 inches thick, composed of very fine yellowish to grayish-yellow mica (probably a lithia mica).

311.1-322.1 <u>Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone)</u>.--Contains quartz (50 percent), cleavelandite (25 percent), muscovite (25 percent), beryl (0.03 percent of 9.2 feet of recovered core), tourmaline (trace), apatite (trace), tantalite-columbite (trace), and dahlite (trace). The average grain size is about 1.5 inches. The maximum size of muscovite is 7 inches, and the average size of recovered books is 3 inches. A yellowish-white prismatic grain of beryl (N_{ω} = 1.582) at 317.3 feet is 0.6 in. by 0.1 inch in size.

Table 21.--Detailed log of U. S. Bureau of Mines diamond drill hole 3-- Continued.

Depth (in ft)	
	The core is considerably fractured and iron-stained from 311.1 to 322.1 feet. Pyrite and chalcopyrite, in grains ranging in size from 0.05 to 0.25 inch, occur along and near some of the fractures, and a powdery-blue mineral is associated with some of the chalcopyrite. Vuggy cavities near some of the fractures are lined with quartz crystals, 0.1 to 0.75 inch in length; other small vugs are filled with limonite.
322.1-323.1	No core recovered.
323.1-331.8	Cavity. In fault zone.
331.8	Hole abandoned.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: 97 feet S. 86° E. from hole 3.

Altitude of ocllar: 4,600 feet

Inclination : 0°.

Bearing : S. 63 1/2° W.

Length : 327.2 feet

Angles of intersection of drill core with bedding, schistosity, and pegmatite contacts: -

Depth (in ft)	Angle between core and: Bedding	Schistosity	Pegmatite contacts
18-25	15°-30°	15°-40°	-
27.5	20°	25°	-
34-55	20°-40°	20°-45°	-
66.5	60°	70°	-
71-73	70°-76°	70°-75°	-
77.2	- -	- -	75°
80	40°	40°	-
84	30°	30°	-
89-139	15°	15°	-
139.5	- -	- -	15°
141.7	- -	- -	20°
149.5	- -	45°	-
149.7	- -	- -	60°
159.6	- -	Parallel to contact	45°
159.8	55°-60°	55°-60°	-

Table 22. --Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)	Bedding	Schistosity	Pegmatite contacts
159.9	30°	30°	-
160-165	30°-40°	Parallel to beds.	-
165-170	50°	50°	-
170-181	60°-70°	60°-70°	-
185-199.8	30°-50°	30°-50°	-
200	65°	65°	-
200.5	45°	- -	-
200.9	- -	- -	35°
201.3	- -	- -	40°
203-205	50°	50°	-
209.5	25°	25°	-
210-233	45°-55°	Parallel to beds.	-
246	70°	60°	-
250-260	45°-50°	45°-55°	-
260.6	- -	- -	75°-80°

Description of rocks:-

Depth
(in ft)

0- 12.6 Overburden and schist. No core.

12.6- 45.8 Quartz-mica-staurolite schist. --Contains quartz (45 percent), muscovite (30 percent), biotite (15 percent), staurolite (6 percent), chlorite (3 percent), garnet (<1 percent), and andalusite (<1 percent). Brown metacrysts of staurolite range in length from 0.1 to 0.75 inch.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)	
	Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite increase in abundance with depth; at 42 - 45.8 feet about 50 percent of the staurolite metacrysts are mica pseudomorphs. Andalusite occurs sparingly as tabular pinkish metacrysts, 0.5 to 1.75 inches in length, and is rimmed by a white fine micaceous material; several irregular 1.5-inch patches of the white fine micaceous material at 25 feet are probably pseudomorphous after andalusite. Irregular discontinuous quartz stringers, ranging in thickness from 0.05 to 0.75 inches, form less than 5 percent of the core.
45.8- 72.0	Quartz-mica-chlorite schist.--Contains quartz (45 percent), muscovite (35 percent), biotite (15 percent), chlorite (5 percent), staurolite (< 1 percent), garnet (< 1 percent), tourmaline (< 1 percent), and andalusite (trace). Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite, comprise 5 to 10 percent of the core; relict staurolite within these pseudomorphs decreases in amount with depth. Several 2-inch aggregates of white very fine micaceous material at 50 - 55 feet contain traces of pink andalusite. Black euhedral tourmaline grains, 0.03 inches in length, form about 3 percent of the core at 70.5 - 72.0 feet. Quartz stringers, 0.1 to 1 inch thick, form less than 5 percent of the core.
72.0-74.7	Quartz-mica-tourmaline schist.--Contains quartz (45 percent), muscovite (40 percent), tourmaline (10 percent), biotite (5 percent), garnet (< 1 percent), and chlorite (< 1 percent). Mica pseudomorphs after staurolite form about 4 percent of the core. Black euhedral grains of tourmaline are 0.01 to 0.04 inches in length. Quartz stringers, 0.1 to 0.5 inches thick, form about 5 percent of the core.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in feet)

74.7- 77.2 Pegmatite.

74.7- 75.0 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (85 percent), muscovite (15 percent), tourmaline (trace), and apatite (trace). The average grain size is about 0.2 inch but some of the quartz is massive.

75.0- 77.1 Quartz-albite-muscovite pegmatite (Zone 2, wall zone).--Contains quartz (60 percent), albite (25 percent), muscovite (14 percent), beryl (0.92 percent of 2.05 feet of recovered core), and apatite (< 0.5 percent). Average grain size is about 0.6 inch. The minimum refractive index (N_{α}') of subplaty albite at 75.8 feet is 1.530. The maximum size of muscovite is 1.75 inches, but the average is 0.4 inch. Pale milky beryl occurs in 14 euhedral grains, which range in length from 0.1 to 1 inch, at 75.6 - 77.0 feet. Two grains at 76.4 feet have $N_{\omega} = 1.578$, but grains at 76.6 to 77.0 feet have N_{ω} ranging from 1.574 to 1.577. Green rounded grains of apatite ($N_{\omega} = 1.64$) range in size from less than 0.05 to 0.25 inch.

77.1- 77.2 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (85 percent), muscovite (14 percent), tourmaline (1 percent), and apatite (trace). A layer of massive quartz at the schist contact is 0.3 inch thick. The rest of the zone has an average grain size of 0.1 inch.

77.2-139.5 Quartz-mica schist.--Contains quartz (45 - 60 -ercent), muscovite (25 - 35), biotite (10 - 20 percent), tourmaline (trace), and chlorite (trace). Rich in muscovite and contains little biotite at 77.2 - 77.4 feet. About 3 percent of the core consists of muscovite and biotite pseudomorphs after euhedral staurolite ranging in length from 0.05 to 1.5 inches. Some of

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)

pseudomorphs have well-defined muscovite centers and biotite rims. Traces of black tourmaline, less than 0.05 inch in length, occur at 77.2 - 79 feet. Quartz stringers as much as 2 inches thick comprise less than 5 percent of the core.

139.5-141.7 Pegmatite.

139.5-139.9 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (85 percent), muscovite (12 percent), albite (2 percent) and apatite (<1 percent). A layer of massive quartz, 0.5 inch thick, is at the schist contact. The rest of the zone averages about 0.15 inch in grain size.

139.9-141.6 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (50 percent), quartz (40 percent), muscovite (10 percent), tourmaline (1 percent), beryl (0.08 percent of 1.7 feet of recovered core), apatite (trace), and cassiterite (?) (trace). The average grain size is about 0.5 inch. The maximum size of muscovite is 0.7 inch. Bluish-black euhedral to subhedral grains of tourmaline range in size from less than 0.05 to 0.25 inch. Two buff-white euhedral grains of beryl (N_ω = 1.580 at 141.2 feet are 0.15 and 0.13 inch in diameter. Several brownish-black rounded grains, 0.1 to 0.2 inch in diameter, may be cassiterite.

141.6-141.7 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (80 percent), muscovite (17 percent), albite (2 percent), and apatite (< 1 percent). A layer of massive quartz, 0.15 inch thick, is adjacent to the schist contact. The average grain size of the rest of the zone is about 0.1 inch.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth
(in ft)

141.7-149.2 Quartz-mica schist, as at 77.2 - 139.5 feet.

149.2-149.7 Quartz-mica-tourmaline schist, as at 72.0 - 74.4 feet. Black euhedral tourmaline (N_w = 1.672) grains range in size from 0.05 to 0.5 inch.

149.7-159.6 Pegmatite.

149.7-.49.8 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (80 percent), muscovite (16 percent), albite (3 percent), and apatite ($<$1 percent). Albite occurs only at 149.8 feet. Very fine-grained (0.1 inch).

149.8-159.3 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (75 percent), quartz (18 percent), muscovite (6 percent), beryl (0.18 percent of 9.5 feet of recovered core), tourmaline ($<$ 1 percent), apatite (trace), tantalite-columbite (trace), and an unidentified blue-gray to green-gray mineral (trace). Average grain size is about 0.5 inch. The maximum size of muscovite is 1 inch. Blue-black and green-black, subhedral to euhedral grains of tourmaline range in length from 0.1 to 0.75 inch. Three plates of tantalite-columbite are 0.01 by 0.05 inch in size. A blue-gray to green-gray soft mineral, probably an altered phosphate occurs in rounded grains, 0.05 to 0.3 inch in diameter. Nine grains of beryl have the following characteristics:

Table 22. --Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)	Size	Shape	Color	N_ω
150.4	0.25 by 1.15 in.	Prismatic.	Milky white to faintly green.	1.580
150.8	.2 by .4 in.	Subhedral.	Buff-stained.	1.579
151.2	.01 sq. in.	"	Buff-white.	-
151.2	.01 sq. in.	"	" "	-
151.2	.10 sq. in.	"	" "	1.582
155.8	.02 sq. in.	Rounded	Buff-stained	1.580
155.8	.04 sq. in.	"	" "	1.580
155.8	.04 sq. in.	"	" "	1.580
157.9	.4 by 1.5 in.	Euhedral.	White.	1.579

Depth
(in ft)

159.3-159.6 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (70 percent), muscovite (25 percent), albite (3 percent), and apatite (2 percent). Very fine-grained (0.1 inch). The minimum refractive index (N_α') of albite at 159.45 feet is 1.530. Bluish-green grains of apatite range in size from 0.01 to 0.1 inch.

159.6-163.3 Quartz-mica-tourmaline schist.--Contains quartz (45 percent), muscovite (35 percent), biotite (15 percent), tourmaline (5 percent), garnet (< 1 percent), and apatite (< 1 percent). At 159.6 - 159.7 feet, muscovite forms 50 percent of the schist, and there is no biotite; biotite increases away from the contact. Black euhedral grains of tourmaline average about 0.05 inch in diameter and 0.25 inch in length. Blue-green grains of apatite (N_ω = 1.63) are 0.05 inches in size. Brown-red grains of garnet, 0.15 inch in diameter, occur at 159.6-160.1 feet.

Table 22. --Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)	
163.3-185.3	Quartz-mica schist, as at 77.2 - 139.5 ft. Quartz stringers are 0.05 to 0.5 inch thick.
185.3-200.9	Quartz-mica-chlorite schist. --Contains quartz (45 percent), muscovite (30 percent), biotite (20 percent), and chlorite (5 percent). Muscovite, biotite, and chlorite pseudomorphs after euhedral staurolite, 0.1 to 0.75 inch in length, form about 5 percent of the core. A quartz stringer, 2.5 inches thick, cuts the schist at 199.9 feet. Irregular discontinuous quartz stringers, 0.05 to 1 inch thick, form less than 5 percent of the core.
200.9-201.3	Quartz-plagioclase pegmatite. --Contains quartz (92 percent), plagioclase (6 percent), muscovite (2 percent), and tourmaline(?) (trace). The plagioclase is oligoclase-andesine (An_{29}, $N_{\alpha}' = 1.543$); it occurs in 0.5 inch grains set in a matrix of massive colorless to milky quartz. Muscovite flakes average about 0.4 inch in size. This pegmatite stringer is too small to be shown in cross-section (fig. 4) and may not be connected to the main body of the Peerless pegmatite.
201.3-260.6	Quartz-mica-chlorite schist, interbedded with quartz-mica schist. Quartz stringers form about 5 percent of the core. The composition of the quartz-mica- chlorite schist is the same as at 185.3 - 200.9 feet. The composition of the quartz-mica schist beds is the same as at 77.2 - 139.5 and 163.3 - 185.3 feet. Quartz-mica-chlorite schist occurs from 201.3 to 220.3 feet. At 220.3 - 240.6 feet, quartz-mica schist, in 1- to 6-inch beds, forms 40 percent of the core and is interbedded repeatedly with beds of quartz-mica-chlorite schist. Quartz-mica schist occurs from 240.6 to 260.6 feet.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)

260.6-327.2 Pegmatite.

260.6-260.8 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (65 percent), muscovite (35 percent), and apatite (1 percent). Very fine-grained (0.1 inch). At 260.7 feet a vuggy layer of 0.05-inch quartz crystals is at 70° to the core.

260.8-272.2 Albite-quartz-perthite pegmatite (Zone 2, wall zone).--Contains albite (50 percent), quartz (25 percent), perthite (10 percent), muscovite (9 percent), tourmaline (4 percent), beryl (0.06 percent of 10.7 feet of recovered core), apatite (< 1 percent), tantalite-columbite (trace), and garnet (trace). The average grain size is about 0.7 inch but the grain size ranges widely. The zone can be subdivided on the basis of mineralogy and texture as follows:

Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite	Tourmaline
		Estimated percentage of principal minerals					
260.8-264.8	0.5	55	5	25	13	-	1
264.8-269.3	3 in. perthite in .4 in. groundmass	40	3	25	6	25	< 1
269.3-270.6	.3	55	15	25	5	-	Trace
270.6-272.2	.6	45	-	25	5	-	25

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4--Continued.

Depth
(in ft)

Albite occurs as blocky to platy grains and also as sugary aggregates up to 2 inches across. The minimum index of cleavage fragments (N_{α}') from a subplaty grain at 260.8 feet is 1.530, and the index from a platy grain at 261.7 feet is 1.529. An elongate euhedral grain of buff-stained pale-white beryl (N_{ω} = 1.579), .25 by 1 inch, is at 260.9 feet. A pale greenish- white subhedral grain of beryl (N_{ω} = 1.580), 0.35 by 0.2 inch, is at 266.6 ft. Flesh-colored perthite grains, 0.5 to 12 inches in maximum dimension, are embayed by albite, quartz, and muscovite. The maximum size of muscovite books is 1.75 inches. Bluish-black to black tourmaline (N_{ω} = 1.68) occurs as euhedral grains as much as 0.5 inch long, and also aggregates as much as 4 inches in maximum dimension. Some of the larger aggregates of tourmaline between 271.5 and 272.2 feet are veined by quartz. A 1.5-inch aggregate of tourmaline at 262.7 feet is associated with red garnet (N = 1.82) in 0.25-inch grains. Six platy grains of tantalite-columbite were recognized; the maximum length is 0.1 inch.

272.2-277.1 — Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone).--Contains quartz (35 percent), cleavelandite (30 percent), muscovite (30 percent), tourmaline (1 percent), and apatite (< 1 percent). Average grain size is about 2 inches. The maximum size of muscovite books is 8 inches; the average size is about 3 inches. Black grains of tourmaline are 0.05 to 1 inch long. The maximum size of bluish-green apatite grains is 0.2 inch.

Table 22.--Detailed log of U. S. Bureau of Mines diamond drill hole 4-- Continued.

Depth (in ft)	
277.1-303.2	Quartz-cleavelandite pegmatite (Zone 5, third intermediate zone).--Contains quartz (55 percent), cleavelandite (40 percent), muscovite (3 percent), tourmaline (< 0.5 percent), cassiterite (trace), and apatite (trace). The average size of individual grains is about 1 inch; the average size of aggregates is about 2.5 inches. The maximum size of cleavelandite aggregates is 8 inches and of muscovite books is 2 inches. Green-black and blue-black tourmaline occurs in euhedral to subhedral grains, 0.05 to 0.75 inch in length. Five grains of cassiterite range in diameter from 0.05 to 0.2 inch. The core from 302.0 to 303.2 feet is iron-stained and broken; probably it is in the main fault zone.
303.2-327.2	Quartz-permatite (Zone 6b, fourth intermediate zone).--Consists wholly of colorless to milky massive quartz. The core is broken and iron-stained, and core recovery was low. Probably the main fault zone is from 302 to 305 feet, and numerous subsidiary fractures cut the rock from 305 to 327 feet.
327.2	Hole terminated in pegmatite.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: 340 feet S. 72° W. of hole 3, and 205 feet N. 39° W. of the portal of the adit of the main underground workings of the Peerless mine.

Altitude of collar: 4,580 feet

Inclination : 0°.

Bearing : N. 63 1/2° E.

Length : 256.6 feet

Angles of intersection of drill core with bedding, schistosity, pegmatite contacts, quartz vein contacts, and fractures: -

Angle between core and:

Depth (in ft)	Bedding	Schistosity	Pegmatite contacts	Quartz vein contacts	Fractures
15 - 50	5° - 20°	Parallel to beds	-	-	-
51.5	10°	10°-15°	-	-	-
54 - 60	5° - 10°	Parallel to beds.	-	-	-
62 - 66	5° - 10°	35°-40°	-	-	-
70.3	- -	50°	65°	-	-
71.4	- -	- -	-	-	20°
72.1	- -	- -	30°	-	-
72.1- 72.8	0° - 15°	0°-20°	-	-	-
72.8	- -	- -	30°	-	-
78	10°	15° (25° angle with beds).	-	-	-
81	- -	- -	40°	-	-
163.4	- -	- -	75°-80°	-	-
163.5	85°	90°	-	-	-

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	Bedding	Schistosity	Pegmatite contacts	Quartz vein contacts	Fractures
164.1	65°	80°	-	-	-
164.6	40°	60°	-	-	-
165.1	- -	55°	-	40°	-
165.5	- -	-	-	-	35°
167.7	- -	70°	-	-	35°
169.8	35°	45°	30°	-	-
169.9	- -	- -	-	-	70°
177.0	- -	- -	30°	-	-
177.2	- -	- -	44° } zonal contacts	-	-
177.7	- -	- -	40° } zonal contacts	-	-
180.0	- -	- -	35° } zonal contacts	-	-
238.2	- -	- -	35°	-	-
238.8-243.3	30°-45°	25°-40° (55°-70° angle with beds).	-	-	-
243.6	45°	Parallel to quartz vein.	-	60°	-
244.6	40°	- -	-	55°	-
246	45°	35°	-	-	-
250-255	20°	Approximately parallel to beds.	-	-	-

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Description of rocks: -

Depth (in ft)	
0 - 15.0	Overburden and schist. No core.
15.0-60.9	Quartz-mica-chlorite schist, interbedded with quartz-mica schist. The estimated composition of the quartz-mica-chlorite schist is quartz (45 percent), muscovite (25-30 percent), biotite (15 - 20 percent), chlorite (4 - 10 percent), and garnet (0.5 percent). Pseudomorphs of muscovite, biotite, and chlorite after euhedral staurolite, ranging from 0.05 to 1 inch and averaging 0.4 inch in diameter, comprise as much as 10 percent of individual beds; the average is about 4 percent. Some pseudomorphs contain relicts of brown staurolite; others have chlorite centers and muscovite or biotite rims; and others are aggregates of muscovite flakes. The mica flakes are about 0.05 inch in diameter in the pseudomorphs, but only 0.02 inch in the matrix. Isolated elongate dark-green flakes of chlorite 0.05 to 0.2 inch in size, also occur in the matrix. Metacrysts of red-brown garnet, 0.05 inch in diameter, are most abundant along contacts of the more micaceous beds. Quartz-mica schist beds were cut at 40.9 - 41.8, 42.0 - 43.2, and 45.9 - 46.5 feet. These beds consist of quartz (50 - 60 percent), muscovite (20 - 39 percent), biotite (10 - 15 percent), and chlorite (trace to 3 percent). Pseudomorphs after staurolite form less than 3 percent of the volume of quartz-mica schist. Irregular discontinuous quartz stringers, as much as 1 inch thick, form approximately 5 percent of the core.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)

60.9- 70.3 Quartz-mica- tourmaline schist. The composition at 62 ft is quartz (55 percent), muscovite (25 percent), biotite (15 percent), and tourmaline (5 percent); at 70 feet it is quartz (45 percent), muscovite (30 percent), and tourmaline (25 percent). Muscovite increases to 45 percent and tourmaline decreases to 10 percent in a one-inch layer at the pegmatite contact. Muscovite aggregates pseudomorphous after staurolite form about 1 percent of the rock. Black euhedral metacrysts of tourmaline are as much as 0.25 inch in size. Quartz stringers up to one-fourth inch thick from about 3 percent of the core.

70.3- 72.1 Pegmatite.

70.3- 70.5 Albite-quartz-muscovite pegmatite (Zone 1, border zone).--Contains albite (50 percent), quartz (35 percent), muscovite (12 percent), tourmaline (2 percent), and apatite (trace). Moderately iron-stained. Very fine-grained (0.15 inch). The grain size of the individual minerals varies widely. White to grayish, buff-stained, blocky to subplaty albite (N_{α} = 1.531) grains are 0.05 to 0.3 inch in size; colorless to milky quartz grains are from less than 0.05 to 0.4 inch; yellowish-silvery muscovite from 0.05 to 0.25 inch; greenish-black to black euhedral tourmaline grains are as much as 0.3 inch; and rounded bluish-green apatite grains are less than 0.05 inch.

70.5- 72.1 Quartz-albite pegmatite (Zone 2, wall zone). Subdivided as follows:

70.5-71.3 Quartz-albite pegmatite.--Contains quartz (85 percent), albite (12 percent), muscovite (2 percent), and beryl (0.12 percent of 0.75 foot of recovered core). Average grain size is 1 inch. One yellowish-white prismatic grain of beryl (N_{ω} = 1.586), 0.5 by 0.1 inch, is at 71.1 feet.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)

71.3-72.1 Albite-quartz-muscovite pegmatite. --Contains albite (60 percent), quartz (30 percent), muscovite (6 percent), apatite (< 0.5 percent), and tourmaline (trace). Average grain size 0.4 inch.

72.1- 72.8 Muscovite-quartz-tourmaline schist. --Contains muscovite (45 percent), quartz (40 percent), tourmaline (15 percent), and apatite (trace). Black tourmaline metacrysts are as much as 0.4 inch in length, but the average is about 0.2 inch. Few quartz veinlets.

72.8- 74.0 Albite-quartz-muscovite pegmatite (Zone 2, wall zone). --Contains albite (60 percent), quartz (30 percent), muscovite (8 percent), unidentified alteration products of phosphate minerals (2 percent), and apatite (trace). The average grain size is about 0.3 inch. Approximately 35 percent of the pegmatite is sugary-grained (0.05 inch), in irregular aggregates as much as 3 inches in size, and the remainder of the pegmatite averages about 0.6 inch in grain size. The alteration products of phosphate minerals occur as grayish-brown to grayish-black stains, in 0.05- to 0.1 inch spots.

74.0- 81.0 Muscovite-quartz-tourmaline schist, as at 72.1 - 72.8 feet, is cut by a few irregular quartz stringers, 0.25 to 1 inch thick. A few beds at 79 - 81 feet contain as much as 40 percent tourmaline.

81.0-163.4 Pegmatite.

81.0-81.05 Quartz-muscovite pegmatite (Zone 1, border zone). --Contains quartz (94 percent), muscovite (5 percent), albite (< 1 percent), and apatite (trace). Very fine-grained (0.05 inch). White to buff-stained albite (N_{α}' = 1.530) occurs only at 81.05 feet.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
81.05-87.5	Albite-quartz-pegmatite (Zone 2, wall zone). --Contains albite (60 percent), quartz (35 percent), muscovite (4 percent), and apatite (trace). The average size of individual grains is 0.4 inch. Albite (N_{α}' = 1.530) occurs in white blocky to subplaty grains. The maximum size of recovered muscovite books is 0.25 inch.
87.5- 89.0	Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone). --Contains cleavelandite (60 percent), quartz (25 percent), muscovite (15 percent), tourmaline (1 percent), amblygonite (< 1 percent), and apatite (trace). Average grain size is about 1.5 inches. The maximum size of recovered muscovite books is 1.75 inches. Black tourmaline grains range in size from 0.05 to 0.75 inch. Grayish-white amblygonite (variety montebrasite) occurs in a single grain, 0.4 by 2 inches at 88.0 feet; N_{γ}' = 1.62. The amblygonite grain has a buff-white dusty coating and is bordered by fine muscovite, 0.25 inch in grain size.
89.0-128.0	Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone). --Contains cleavelandite (55 percent), quartz (40 percent), muscovite (4 percent), amblygonite (0.5 percent), cassiterite (< 0.5 percent), tourmaline (trace), apatite (trace), and tantalite-columbite (trace). Average size of individual grains is about 1.25 inches, but the average size of aggregates is 3 inches. Cleavelandite (N_{α}' = 1.528) occurs in aggregates as large as 3 feet in size. The maximum size of muscovite is 1.5 inches. Ten

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
	irregular to elongate subhedral grayish-white grains of amblygonite (variety montebrasite), 0.5 to 2.5 inches in length, were cut between 101.0 and 106.0 feet; $N_{\gamma}' = 1.62$. Brownish- black irregular to subhedral grains of cassiterite range in diameter from less than 0.05 to 0.25 inches; cassiterite is most abundant at the contact of muscovite and cleavelandite; a few grains of cassiterite are included in cleavelandite, amblygonite, muscovite, and quartz. One grain of tantalite-columbite, 0.05 by 0.01 inch in size, was noted.
128.0-136.0	<u>Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone)</u>. --Contains cleavelandite (60 percent), quartz (30 percent), muscovite (7 percent), beryl (3.17 percent of 4.0 feet of recovered core), amblygonite (1 percent), cassiterite ($<$ 0.5 percent), and apatite (trace). Average grain size is about 1.75 inches. The largest muscovite book recovered is 1.25 inches in size; numerous small flakes of muscovite in the rubble suggest that a considerable amount of muscovite went to sludge. Two white anhedral masses of beryl (N_{ω} = 1.582 to 1.583) are 1.75 and 2 inches in maximum dimension. The beryl has ground edges, indicating loss of beryl in the sludge. Amblygonite (variety, montebrasite) occurs in one grayish-white irregular grain, 1 by 2 inches in size, at 133.2 feet; $N_{\gamma}' = 1.62$. Fine muscovite (0.2 inch) rims the amblygonite grain. Brown-black, rounded to irregular grains of cassiterite are 0.05 to 0.1 inch in diameter.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
136.0-141.0	Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).--Contains cleavelandite (50 percent), quartz (45 percent), muscovite (4 percent), tourmaline (0.5 percent), cassiterite ($<$ 0.5 percent), and apatite (trace). Average grain size is about 1.5 inches. The maximum size of muscovite is 1.75 inches. Brownish-black grains of cassiterite range in size from 0.05 to 0.2 inch. Green-black to blue-black tourmaline grains average about 0.15 inch in length.
141.0-150.9	Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone).--Contains quartz (40 percent), cleavelandite (30 percent), muscovite (25 percent), beryl (5.06 percent of 3.1 feet of recovered core, apatite (trace), and tourmaline (trace). Average size of individual grains is about 1 inch. Cleavelandite (N_{α}' = 1.528) occurs in aggregates as large as 4 inches in size. The maximum size of muscovite is 2.25 inches. A 2.5-inch- long anhedral beryl grain at 144 feet is milky white with a faint greenish tint. The outer edge of the beryl grain (N_{ω} = 1.583) is complexly intergrown with quartz, cleavelandite, and muscovite; the center of the grain has N_{ω} = 1.580. A 0.05-inch fracture cutting across the beryl is filled with fine-grained muscovite.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
150.9-163.2	Albite-quartz-muscovite pegmatite (Zone 2, wall zone).-- Contains albite (50 percent), quartz (35 percent), muscovite (10 percent), perthite (3 percent), tourmaline (3 percent), unidentified alteration products of phosphate minerals (1 percent), beryl (0.12 percent of 11.4 feet of recovered core), apatite (trace), tantalite-columbite (trace), and an unidentified soft green-gray mineral (trace). Average grain size is about 0.8 inch. This unit can be subdivided as follows on the basis of mineralogy and texture:

Estimated percentage of principal minerals

Depth (in ft)	Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite	Tourmaline
150.9-155.7	Sugary grained - 0.05-0.1 Other - 1.	40	15	30	5	-	6
155.7-157.3	1	30	3	30	10	25	-
157.3-163.2	.5	45	5	35	12	-	.5

Albite is blocky, platy, and sugary. The sugary albite occurs with quartz in aggregates up to 3 inches across. Coarse platy albite occurs in aggregates averaging 2 inches in diameter. Flesh-colored blocky perthite, 0.25 to 2.25 inches in diameter, is embayed and veined by albite, quartz, muscovite. The average size of muscovite is 0.6 inch, and the maximum is 2.5 inches. Two white to irregularly translucent, slightly milky elongate grains of beryl (N_{ω} = 1.581) occur at 151.6 - 151.7 feet; the dimensions of

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth
(in ft)

the grains are 1.25 by 0.5 inches and 125 in. by 0.25 inch . Blue-green apatite grains, 0.05 to 0.1 inch in size, occur in aggregates as large as 0.5 inch . A rounded greenish-gray, soft mineral, 0.2 inch in size, occurring in traces may be aggregates of very fine-grained lithia mica. Gray-brown to black unidentified alteration products of phosphate minerals stain the core. Blue-black euhedral grains of tourmaline average about 0.2 inch in length. Three plates of tantalite-columbite are 0.05 inch long and less than 0.01 inch thick.

163.2-163.4 Albite-quartz-muscovite pegmatite (Zone 1, border zone). --Contains albite (45 percent), quartz (40 percent), muscovite (12 percent), garnet (2 percent), apatite (trace), and tourmaline (trace). Average grain size is about 0.2 inch . Albite at 163.3 feet has N_{α}' = 1.530. Red-brown grains of garnet range in size from less than 0.05 to 0.25 inch .

163.4-163.8 Quartz-muscovite-tourmaline schist. --Contains quartz (40 percent), muscovite (40 percent), tourmaline (18 percent), and garnet (2 percent). Black euhedral tourmaline grains range in length from 0.05 to 0.4 inch .

163.8-165.1 Quartz-mica schist. --Contains quartz (50 percent), muscovite (30 percent), and biotite (20 percent). Traces of tourmaline occur at 164 feet. Few quartz lenses, 0.05 to 0.5 inch in thickness.

165.1-166.2 Quartz vein. --Colorless to grayish-milky quartz.

166.2-169.8 Quartz-mica schist, as at 163.8 - 165.1 feet.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)

169.8-238.2 Pegmatite

169.8-170.2 Quartz-muscovite pegmatite (Zone 1, border zone). --Contains quartz (70 percent), muscovite (25 percent), albite (4 percent), and apatite (0.5 percent). Very fine-grained (0.15 in.). A layer of colorless massive quartz, 0.1 inch thick, separates the border zone and the schist. Albite (N_α' = 1.530) occurs only at 170.2 feet.

170.2-177.2 Albite-quartz-perthite pegmatite (Zone 2, wall zone). --Contains albite (50 percent), quartz (25 percent), perthite (15 percent), muscovite (7 percent), beryl (1.55 percent of 6.5 feet of recovered core), unidentified phosphate minerals and their alteration products (1 percent), tourmaline ($<$ 0.5 percent), apatite ($<$ 0.5 percent), and tantalite-columbite (trace). Average grain size is about 0.6 inch. The zone can be subdivided as follows on the basis of mineralogy and texture:

Estimated percentage of principal minerals

Depth (in ft)	Average grain size (in in.)		Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite	Beryl
170.2-173.4	Sugary-grained-	0.05	55	14	25	5	-	-
	Other -	.5						
173.4-176.2	Other -	.7	25	12	20	6	35	0.3
176.2-177.0		.7	45	-	35	4	-	11.6

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth
(in ft)

Albite occurs chiefly as blocky to platy grains. Aggregates of sugary albite containing 10 percent quartz are as much as 3 inches across. Flesh-colored perthite crystals, 1 to 3.5 inches in diameter, are corroded and veined by albite, quartz, and muscovite. Tantalite-columbite occurs as two platy grains, 0.01 by 0.05 inch and 0.01 by 0.25 inch. Five grains of beryl have the following characteristics:

Depth (in ft)	Size	Shape	Color	N_{ω}
175.5	2 grains, each 0.2 by 0.7 in.	Subhedral.	White.	1.585
175.9	.07 sq. in.	Rounded euhedral.	"	1.583
176.0	.14 sq. in.	" "	"	1.584
176.9	1.75 by 2 in.	Subhedral.	"	1.585

177.0-177.2 Quartz-muscovite-albite pegmatite (Zone 1, border zone).--Contains quartz (45 percent), muscovite (33 percent), albite (20 percent), garnet (1.5 percent), unidentified alteration products of phosphate minerals (0.5 percent), tourmaline (trace), and apatite (trace). Average grain size is about 0.1 inch. White to buff-stained subplaty albite has $N_{\alpha}' = 1.531$. Reddish-brown garnet occurs with muscovite and quartz in an irregular aggregate, 1.5 inches in diameter. A blue grain of tourmaline, 0.25 by 0.1 inch, is adjacent to the garnet aggregate.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
177.2-177.7	Quartz-albite pegmatite (Zone 2, wall zone). --Contains quartz (65 percent), albite (30 percent), muscovite (2 percent), beryl (1.80 percent of 0.5 feet of recovered core), unidentified phosphate minerals and their alteration products (1 percent), apatite (trace), and tantalite-columbite (trace). Quartz grains and aggregates of platy albite average 1 inch in size. A white irregularly-stained subhedral grain of beryl (N_{ω}= 1.584) at 177.5 feet is 0.9 by 0.5 inch. Several rounded dark-green to brown grains, (0.05 to 0.5 inch in size), are probably altered phosphate minerals of the lithiophilite-triphylite group.
177.7-180.0	Quartz-muscovite-albite pegmatite (Zone 1, border zone). --Similar to pegmatite at 177.0 - 177.2 feet.
180.0-186.6	Albite-perthite-quartz pegmatite (Zone 2, wall zone). --Contains albite (35 percent), perthite (30 percent), quartz (25 percent), muscovite (6 percent), unidentified alteration products of phosphate minerals (1.5 percent), garnet (0.5 percent), tourmaline (0.5 percent), apatite (trace), tantalite-columbite (trace), and cassiterite (trace). Average grain size is about 0.9 inch. The zone can be subdivided as follows on the basis of mineralogy and texture.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth
(in ft)

Estimated percentage of principal minerals

Depth (in ft)		Average grain size (in in.)	Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite
180.0-180.7	Sugary grained	- 0.03	15	45	30	2	-
	Other	- .4					
180.7-184.5	Sugary-grained	- .05	15	10	25	4	45
	Perthite	- 6					
	Other	- .5					
184.5-186.6	Sugary-grained	- .05	25	20	30	9	15
	Other	- .6					

Blocky to platy albite occurs as grains that average 0.5 inch in size, but are in aggregates as large as 4 inches. Sugary albite (N_{α}' = 1.531) occurs as aggregates, averaging 1.5 inches across, that contain 25 percent quartz. Pink to reddish garnet occurs in aggregates as much as 0.75 inch in diameter (average 0.3 inch) that are most abundant at 180.7 feet. Bluish tourmaline rims some of the garnet. Bluish-black tourmaline (0.25 inch), brownish-black cassiterite (0.2 inch), and greenish apatite (0.05 inch), occur in traces. Much of the rock is stained by grayish-buff to brownish-black alteration products of phosphate minerals.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
186.6-200.1	<u>Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone)</u>. --Contains quartz (40 percent), cleavelandite (36 percent), muscovite (17 percent), beryl (5.60 percent of 11.2 feet of recovered core), tourmaline (0.5 percent), unidentified phosphate minerals and their alteration products (< 0.5 percent), perthite (trace), apatite (trace), cassiterite (trace), and loellingite (?) (trace). Average grain size is about 2 inches. The maximum size of muscovite books is 8 inches.

Three grains of beryl have the following characteristics:

Depth (in ft)	Size	Shape	Color	N_{ω}
189.1	1.75 by 2.5 in.	Subhedral.	Pale yellowish-white to greenish-white	1.581
189.1	.4 by .5 in.			
199.0-199.3	32.37 sq. in. in 7 irregular masses intergrown with cleavelandite.	Anhedral.	White	1.583-1.584
199.3-200.0				1.582

Several 0.5-inch perthite grains occur at 186.7 feet. Eight grains of cassiterite, 0.1 to 0.25 inch in diameter, occur as inclusions in beryl and cleavelandite at 199.0 - 199.5 feet. Phosphate minerals occur as rounded to irregular dark-colored grains, 0.1 to 1 inch in diameter; their alteration products stain other minerals. Bluish-black and black euhedral grains of tourmaline average 0.3 inch in length; they commonly occur as inclusions in muscovite.

Table 23。--Detailed log og U。 S。 Bureau of Mines diamond drill hole 5-- Continued。

Depth
(in ft)

200。1-207。2 Cleavelandite-muscovite pegmatite (Zone 5, third intermediate zone)。-- Contains cleavelandite (85 percent), muscovite (9 percent), quartz (4 percent), beryl (2。58 percent of 7。0 feet of recovered core), cassiterite ($<$0。5 percent), apatite (trace), and tourmaline (trace). Average grain size is about 1 inch。 An aggregate from 200。1 to 206.4 feet consists chiefly of plates of cleavelandite (N_{α}' = 1。528) averaging 1.25 inches long; other minerals are muscovite (5 percent), quartz (3 percent), cassiterite ($<$0.5 percent), apatite (trace), and tourmaline (trace)。 Pegmatite from 206.4 to 207.2 feet consists of muscovite (40 percent), beryl (25.80 percent of 0.7 feet of recovered core), cleavelandite (24 percent), and quartz (10 percent)。 The average size of individual grains is 1 inch。 Muscovite books range in size from 0。05 to 0。5 inches, averaging 0。3 inches。 Three grains of beryl have the following characteristics:

Depth (in ft)	Size	Shape	Color	N_{ω}
206。5-206。8	1 by 3。5 in。	Rounded, irregular。	White	1。584 - 1。587 (4 determinations)。
207。0	。5 by 1。0 in。	Irregular。	"	1。586。
207。1	1.75 by 1.75 in。	Subhedral。	"	1。586。

207.2-217.0 Quartz pegmatite (Zone 6b, fourth intermediate zone)。--Consists entirely of colorless to slightly milky, massive quartz。

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
217.0-231.6	Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).--Contains cleavelandite (50 percent), quartz (45 percent), muscovite (3 percent), apatite (trace), and cassiterite (trace). Average size of individual grains is about 1.25 inches. Cleavelandite aggregates are as large as 15 inches in size. The maximum size of muscovite books is 2.5 inches. One grain of cassiterite, less than 0.1 inch in diameter, is included in cleavelandite.
231.6-235.1	Perthite-cleavelandite-quartz pegmatite (Zone 4, second intermediate zone).--Contains perthite (65 percent), cleavelandite (20 percent), quartz (10 percent), muscovite (4 percent), and apatite (trace). Average grain size is 4 inches. Two flesh-colored grains of perthite are 15 and 3 inches in length; the edges of the grains are embayed by quartz, cleavelandite, and muscovite. The maximum size of muscovite is 1 inch.
235.10-238.15	Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone).--Contains quartz (60 percent), cleavelandite (20 percent), muscovite (20 percent), beryl (0.47 percent of 2.25 feet of recovered core), tourmaline ($<$ 0.5 percent), and apatite (trace). Average grain size decreases from 2 inches at 235.1 feet to about 0.7 inches at 237 feet. Cleavelandite has $N_{\alpha}' = 1.530$. The maximum size of muscovite is 2 inches. Three buff-stained white euhedral grains of beryl ($N_{\omega} = 1.580$) at 237.4 feet are 0.35, 0.7, and 1.25 inches in maximum exposed dimensions. Black euhedral grains of tourmaline, associated with muscovite, average about 0.5 inch in length and 0.1 inch in diameter.

Table 23. --Detailed log of U. S. Bureau of Mines diamond drill hole 5-- Continued.

Depth (in ft)	
238.15-238.20	Quartz-muscovite pegmatite (Zone 1, border zone). --Contains quartz (78 percent), muscovite (20 percent), tourmaline (1 percent), and apatite (trace). Very fine-grained (0.15 inch). A layer of massive quartz, 0.1 to 0.5 inch thick, is immediately adjacent to the schist contact.
238.2-243.6	Quartz-mica schist, as at 163.8 - 165.1 feet. Traces of tourmaline occur at 238.2 - 238.5 feet.
243.6-244.6	Quartz vein. --Colorless to slightly milky massive quartz. Contains irregular fragments of schist. Mica flakes and chlorite flakes are as much as 0.25 inch in size.
244.6-256.6	Quartz-mica-chlorite schist, as at 15.0 - 40.9 feet. Irregular quartz stringers, 0.05 to 0.75 inch in thickness, form 5 percent of the rock.

Table 24.--Detailed log of U. S. Bureau of Mines diamond drill hole 6, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: Same as hole 5.

Altitude of collar: 4,578 feet

Inclination : Minus 30°

Bearing : N. 63 1/2 ° E.

Length : 154.2 feet

Angles of intersection of drill core with bedding, schistosity, and pegmatite contacts: -

	Angle between core and:		
Depth (in ft)	Bedding	Schistosity	Pegmatite contacts
20	10°	5°	-
24-38	5° - 15°	Subparallel to beds.	-
40-52	5°	10°	-
56.5	20°	15°	-
57.5	- -	- -	45° (?)
94-97	30°	Parallel to beds.	-
121.6	- -	Parallel to pegmatite contact.	18°.
125-131	30°	Parallel to beds.	-
132.5	10°	- -	-
133.2	0°	20°	-
134	10° (opposite to beds at 132.5 ft.)	- -	-
135-154	5° - 15°	Parallel to beds.	-

Table 24.--Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Description of rocks: -

Depth (in ft)	
0 - 57.5	Quartz-mica-chlorite schist, brownish gray, interbedded with lighter gray quartz-mica schist and micaceous quartzite. The quartz-mica-chlorite schist contains quartz (45-50 percent), muscovite (25-30 percent), biotite (10-20 percent), chlorite (3-5 percent), and garnet (0.5 percent). Pseudomorphs after staurolite are 0.2 to 1.5 inches long; they form as much as 5 percent of individual beds, but the average is about 3 percent. Isolated elongate dark-green flakes of chlorite, 0.05 to 0.2 inch in size, occur in the schist matrix. Metacrysts of reddish-brown garnet (average 0.05 inch in diameter) are especially numerous along the contacts of quartz-mica-chlorite schist with beds of quartzite and of quartz-mica schist. Interbeds of quartz-mica schist at 6.5 - 17.0, 32.0 - 35.0, and 50.5 - 57.5 feet consist of quartz (55-65 percent), muscovite (10-25 percent), biotite (5-15 percent), and garnet ($<$ 0.5 percent). Quartzite beds at 24.0 - 30.0 and 30.5 - 32.0 feet contain quartz (75-85 percent), muscovite and biotite (15-25 percent). Quartz veinlets, 0.05 to 5 inches thick, comprise about 5 percent of the core.
57.5- 90.5	Pegmatite.
57.5-57.6	Quartz-muscovite-tourmaline pegmatite (Zone 1, border zone).--Contains quartz (75 percent), muscovite (15 percent), tourmaline (5 percent), albite (2 percent), and apatite (0.5 percent). Very fine-grained (average 0.15 inch). Bluish-black grains of tourmaline range in size from 0.05 to 0.3 inch . Iron-stained albite (N_{α}' = 1.531) occurs in 0.2 inch aggregates.

Table 24.--Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth (in ft)

57.6- 61.5 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (55 percent), quartz (30 percent), muscovite (10 percent), tourmaline (4 percent), unidentified alteration products of phosphate minerals (< 0.5 percent), and apatite (< 0.5 percent). The average grain size of most of this unit is about 0.5 inch, but from 58.5 to 61.5 feet about 20 percent is very fine-grained (average 0.05 inch), sugary albite (N_α' = 1.529) and quartz, in irregular aggregates as much as 2 inches in size. White subplaty albite (N_α' slightly more than 1.529) occurs in aggregates as large as 3 inches. The average size of muscovite books increases from 0.25 inch at 58 feet to 0.75 inch at 61.5 feet. Bluish-black euhedral grains of tourmaline, 0.05 to 0.5 inch in size, occur in aggregates as much as 1.5 inches in size; a concentration is at 60.5 to 61.5 feet. Rounded brown clay-like aggregates, 0.05 to 0.25 inch in size, at 58.5 - 61.5 feet, are probably altered phosphate minerals; brownish to gray-brown alteration products of phosphate minerals stain the other minerals in the core.

61.5- 78.6 Cleavelandite-quartz pegmatite (Zone 5, third intermediate zone).--Contains cleavelandite (55 percent), quartz (40 percent), muscovite (2 percent), tourmaline (0.5 percent), apatite (< 0.5 percent), cassiterite (trace), and tantalite-columbite (trace). The average size of individual grains is about 1.25 in., but the average size of aggregates is 6 inches. White cleavelandite (N_α' = 1.528) occurs in aggregates as large as 4 feet. The

Table 24. --Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth (in ft)	
	maximum size of muscovite books is 0.75 inch. Euhedral bluish-black grains of tourmaline (N_{ω} = 1.66) average about 0.25 inch in length. Rounded to elongate bluish-green grains of apatite average about 0.05 inch in diameter. Four euhedral brownish-black grains of cassiterite, 0.05 to 0.2 inch in size, occur from 75.4 to 78.6 feet. Two grains of tantalite-columbite are 0.15 by 0.5 inch and 0.01 by 0.2 inch.
78.6- 86.5	Quartz-cleavelandite-muscovite pegmatite (Zone 3, first intermediate zone). --Contains quartz (75 percent), cleavelandite (13 percent), muscovite (11 percent), tourmaline (trace), and apatite (trace). Average grain size is about 1.5 inches. The maximum size of muscovite books is 2 inches.
86.5- 90.5	Albite-quartz-muscovite pegmatite (Zone 2, wall zone). --Contains albite (65 percent), quartz (30 percent), muscovite (5 percent), tourmaline (1 percent), tantalite-columbite (trace), and apatite (trace). Average grain size is 0.5 inch. White blocky to subplaty albite (N_{α}' = 1.529) occurs in aggregates as much as 3.5 inches in size. The maximum size of muscovite books is 0.75 inch. Euhedral to subhedral bluish-black grains of tourmaline, averaging about 0.15 inch, occur in aggregates as large as 0.5 inch. One blade of tantalite-columbite is 0.65 inch long and 0.01 inch thick.

Table 24. --Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth
(in ft)

90.5-100.0 Quartz-mica schist.-- Consists of quartz (55 percent), muscovite (25-30 percent), biotite (15-20 percent), and accessory garnet. Quartz stringers, as much as 0.2 inch thick form about 2 percent of the core.

100.0-121.6 Pegmatite.

100.0-105.5 Albite-quartz-muscovite pegmatite (Zone 2, wall zone). --Contains albite (50 percent), quartz (40 percent), muscovite (8 percent), tourmaline (1 percent), beryl (0.31 percent of 5.3 feet of recovered core), garnet ($<$ 1 percent), and apatite (trace). The average grain size increases from 0.4 inch at 100.5 feet to 1 inch at 105.0 feet. White subplaty albite (N_{α}' = 1.530) occurs in aggregates as much as 3.5 inches in size. The maximum size of muscovite is 0.9 inch. Bluish-black grains of tourmaline, as much as 0.25 inch long, occur in aggregates as large as 1.5 inches. Reddish rounded grains of garnet are as much as 0.25 inch in diameter. Five beryl grains have the following characteristics:

Depth (in ft)	Size	Shape	Color	N_{ω}
104.9	0.15 in. long	Euhedral.	Pale greenish-white.	1.580
104.9	.3 in. long.	do.	do.	1.580
105.0	.05 sq. in.	do.	do.	1.581
105.0	.04 sq. in.	do.	do.	1.580
105.3	.5 by 2.5 in.	Rounded.	do.	1.580 (center) 1.583 (at one end).

Table 24.--Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth (in ft)	
105.5-115.5	<u>Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone)</u>.--Contains cleavelandite (50 percent), quartz (40 percent), muscovite (10 percent), tourmaline (< 1 percent), amblygonite (< 1 percent), tantalite-columbite (< 0.5 percent), apatite (trace), vivianite (?) (trace), loellingite (?) (trace), and unidentified buff-white to greenish-brown phosphate minerals (trace). The average size of individual grains 0.75 inch; the average size of aggregates is about 1.75 inches. Cleavelandite ($N_{\alpha}' = 1.528$) occurs in aggregates as much as 4 inches in size. Muscovite and quartz grains have maximum dimensions of 2 to 3 inches. Black to greenish-black euhedral grains of tourmaline average about 0.75 inch, but aggregates are as large as 2.25 inches. Amblygonite (variety montebrasite) occurs in one white irregular grain, 2 in. long and 0.8 inch wide, at 115.4 feet; $N_{\gamma}' = 1.62$. Fine-grained muscovite (0.2 inch) occurs along the grain boundaries of the amblygonite crystal. Loellingite (?) occurs as silver-gray irregular grains, 0.05 to 0.3 inch in diameter, at 112.8 - 113.7 feet. Irregular bluish grains of vivianite (?) commonly border the loellingite grains; $N_{\gamma} = 1.65$; $N_{\alpha} = 1.610$; pleochroic from deep blue to faint yellow. Also at 112.8 - 113.7 feet, irregular buff-white to greenish to dark-brown rounded grains, 0.1 to 0.75 inch in size, are probably partially altered phosphate minerals. Eight grains of tantalite-columbite, as much as 0.3 inch long, are associated with muscovite and cleavelandite at 111.1 - 111.4 feet.

Table 24. --Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth
(in ft)

115.5-121.4 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (60 percent), quartz (30 percent), muscovite (7 percent), unidentified altered phosphate minerals and their alteration products (1.5 percent), tourmaline (1 percent), apatite (trace), and tantalite-columbite (trace). Average size is about 0.4 inch, but the grain size ranges widely. Approximately 15 percent of the unit is very fine-grained ($<$ 0.1 inch). Albite decreases and quartz increases in amount from 120.5 feet to the contact with border zone at 121.4 feet. Albite at 121.2 feet has N_{α}' = 1.530. The maximum size of muscovite is 1 inch. Buff-white to brown, rounded irregular grains, 0.05 to 0.3 inch in size, are probably altered phosphate minerals. Euhedral to subhedral, bluish-black grains of tourmaline are 0.05 to 0.4 inch in size. Two grains of tantalite-columbite are 0.05 and 0.15 inch long and 0.01 inch thick.

121.4-121.6 Quartz-muscovite pegmatite (Zone. 1, border zone).--Contains quartz (80 percent), muscovite (20 percent), apatite (1 percent), and tourmaline (trace). Average grain size is 0.1 inch. Green to bluish-green grains of apatite are 0.01 to 0.1 inch in diameter.

121.6-121.7 Muscovite-quartz-tourmaline schist.--Contains muscovite (50 percent), quartz (40 percent), and tourmaline (10 percent). Black to brownish-black tourmaline grains average about 0.02 inch in diameter and 0.15 inch in length.

Table 24.--Detailed log of U. S. Bureau of Mines diamond drill hole 6-- Continued.

Depth (in ft)	
121.7-154.2	Quartz-mica-schist.--Contains quartz (45-65 percent), muscovite (20-35 percent) biotite (10-20), chlorite (trace to 3 percent), garnet (trace to 1 percent), staurolite (trace), and tourmaline (trace). Pseudomorphs of muscovite and biotite after euhedral staurolite, ranging from less than 0.1 to 1.5 inches in length, form as much as 10 percent of individual thin micaceous beds but are completely absent in more quartzose beds; the average content of these pseudomorphs in the schist is 3 percent. Traces of brown staurolite occur in some of the pseudomorphs. Red grains of garnet average 0.05 inch in diameter. Black tourmaline grains, less than 0.05 inch in size, occur at 121.7 to 121.9 feet. Quartz stringers, 0.05 to 0.75 inch thick, form about 3 percent of the core; traces of yellow sulfides (chalcopyrite and pyrite) occur in and adjacent to some of the quartz stringers.

Table 25.--Detailed log of U. S. Bureau of Mines diamond drill hole 7, Peerless pegmatite, Pennington County, South Dakota.

Location of collar: Same as hole 5 and 6.

Altitude of collar: 4,579 feet.

Inclination : Minus 15°.

Bearing : N. 63 1/2° E.

Length : 155.8 feet.

Angles of intersection of drill core with bedding, schistosity, and pegmatite contacts: -

	Angle between core and:		
Depth (in ft)	Bedding	Schistosity	Pegmatite contacts
40 - 55	5°	Parallel to beds.	- -
59	- -	30°	- -
61	- -	10°	- -
120.2	- -	10°	26°.
122-150	10° - 25°	Parallel to beds.	- -
154	50°	35°	- -

Description of rocks:

Depth (in ft)	
0- 38.0	No core.
38.0-45.0	<u>Quartz-mica-chlorite schist</u>.--Contains quartz (45 percent), muscovite (20-30 percent), biotite (20-25 percent), chlorite (5 percent), and garnet (0.5 percent). Pseudomorphs of muscovite and biotite after staurolite, 0.1 to 0.3 inch in diameter, comprise 2 percent of the core. Elongate dark-green flakes of chlorite are 0.05 to 0.15 inch in size. Reddish-brown metacrysts of garnet, 0.05 inches in diameter, are irregularly distributed in the schist. Quartz stringers, 0.05 to 1 inch thick, form approximately 8 percent of the core.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 7--Continued.

Depth
(in ft)

45.0- 62.0 Quartz-mica schist.--Contains quartz (55-60 percent), muscovite (20-25 percent), biotite (15 percent), and chlorite (1-3 percent). Quartz stringers, 0.05 to 0.75 inches thick, form about 5 percent of the core.

62.0-120.2 "Pegmatite.

62.0- 62.4 Quartz-muscovite pegmatite (Zone 1, border zone).--Contains quartz (75 percent), muscovite (20 percent), beryl (0.5 percent)_/, tourmaline

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_/ Beryl percentages for hole 7 are based on visual estimates. The area of beryl on the core was not measured, as for other holes, because the core recovery in pegmatite was only 41 percent and results would not be significant.

(0.5 percent), and apatite (0.5 percent). Very fine-grained (average 0.2 inch). Two subhedral white grains of beryl (N_{ω} = 1.581) are 0.1 by 0.5 inch and 0.1 by 0.25 inch in size.

62.4- 69.2 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (50 percent), quartz (35 percent), muscovite (8 percent), tourmaline (3 percent), unknown alteration products of phosphate minerals (0.5-1 percent), garnet (trace), and apatite (trace). Individual grains average about 0.5 inch , but aggregates of grains are commonly 1 inch in size. Approximately 15 percent of the albite is very fine-grained (0.05 inch), occurring in sugary aggregates, 1/2 in. to 3 inches in size. Aggregates of blocky to subplaty albite are as large as 3 inches in diameter. The maximum size of muscovite books is 1 inch. Bluish-black euhedral tourmaline grains average about 0.4 inch in length.

Table 23.--Detailed log of U. S. Bureau of Mines diamond drill hole 7-- Continued.

Depth (in ft)	
69.2- 70.8	Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone).--Contains cleavelandite, (50 percent), quartz (40 percent), muscovite (10 percent), tantalite-columbite ($<$0.5 percent), tourmaline (trace), and apatite (trace). Average grain size is about 1 inch. The maximum size of recovered muscovite books is 2 inches. One black plate of tantalite-columbite is 0.02 inch thick and 0.75 inches long.
70.8-108.0	Cleavelandite-quartz-muscovite pegmatite (Zone 5, third intermediate zone).--Contains cleavelandite (65 percent), quartz (25 percent), muscovite (7 percent), cassiterite ($<$0.5 percent), apatite ($<$ 0.5 percent), and tourmaline (trace). The average size of individual grains is about 1 inch, but the average size of aggregates is 3 inches. The maximum size of cleavelandite aggregates is 13 inches, and of muscovite books is 3.5 inches. Very fine muscovite (0.2 inch) occurs in several aggregates, 2 to 3.5 inches in size, between 80.8 and 89.5 feet. Brownish-black grains of cassiterite, 0.05 to 0.9 inch in size, occur along the boundaries between cleavelandite and muscovite. Bluish-green grains of apatite are mostly 0.05 inch in diameter, but one elongate prismatic grain is 1.1 by 0.2 inches.
108.0-113.0	Cleavelandite-quartz-muscovite pegmatite (Zone 3, first intermediate zone).--Contains cleavelandite (45 percent), quartz (40 percent), muscovite (14 percent), tourmaline ($<$ 0.5 percent), and apatite (trace). Average grain size is about 1.5 inches. The maximum size of recovered muscovite books is 1.5 inches. Greenish-black to bluish-black grains of tourmaline average 0.25 inch in size.

Table 25.--Detailed log of U. S. Bureau of Mines diamond drill hole 7-- Continued.

Depth
(in ft)

113.0-120.0 Albite-quartz-muscovite pegmatite (Zone 2, wall zone).--Contains albite (50 percent), quartz (35 percent), muscovite (9 percent), perthite (5 percent), tourmaline (0.5 percent), unknown alteration products of phosphate minerals (0.5 percent), garnet (< 0.5 percent), apatite (trace), and tantalite-columbite (trace). The average grain size is about 0.5 inches, but the grain size ranges widely. The zone can be subdivided as follows on the basis of mineralogy and texture:

Depth (in ft)	Average grain size (in in.)	Estimated percentage of principal minerals: Blocky to platy albite	Sugary albite	Quartz	Muscovite	Perthite
113.0-114.4	Perthite - 2 Other - .5	45	-	25	4	25
114.4-120.0	Sugary-grained - .05 Other - .4	45	8	35	10	-

Sugary albite occurs in irregular clots, 0.5 to 3 inches in size; blocky to subplaty albite is in aggregates as much as 2 inches in size. Flesh-colored grains of perthite range in size from 0.5 to 3.5 inches and are embayed and veined by albite, quartz, and muscovite. The maximum size of muscovite is 1.5 inches. Bluish-black subhedral grains of tourmaline are 0.25 to 0.5 inch long. One grain of tantalite-columbite is 0.05 inch long and 0.01 inch thick. Pink rounded grains of garnet, ranging in size from less than 0.05 to 0.2 inch occur from 118.0 to 120.0 feet.

Table 25. --Detailed log of U. S. Bureau of Mines diamond drill hole 7-- Continued.

Depth (in ft)	
120.0-120.2	Quartz-muscovite-albite pegmatite (Zone 1, border zone). --Contains quartz (75 percent), muscovite (15 percent), albite (10 percent), garnet (0.5 percent), and apatite (trace). Very fine-grained (average 0.15 inches). Albite occurs chiefly near 120.0 feet. Reddish rounded grains of garnet are 0.05 inch in size.
120.2-155.8	Quartz-mica schist. --Contains quartz (45-65 percent), muscovite (15-30 percent), biotite (10-25 percent), garnet (0.5 percent), and chlorite (trace). Pseudomorphs of muscovite and biotite after euhedral staurolite, 0.05 to 0.5 inch in size, comprise as much as 5 percent of some of the more micaceous beds, but the average is only about 2 percent. Quartz stringers, 0.05 to 0.25 inch thick, form approximately 5 percent of the unit.

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USGS-TEI-226 Part II

CONTENTS

TABLES

ABSTRACT

The Peerless pegmatite, Pennington County, S. Dak., contains significant reserves of beryl, scrap mica, potash and soda feldspar, and amblygonite. This pegmatite also contains low-grade reserves of tantalite-columbite and cassiterite.

Beryl forms 1.7 percent or 1,360 tons of the 80,000 tons of rock in Zone 3, cleavelandite-quartz-muscovite pegmatite (first intermediate zone). Additional beryl is in Zone 2, albite-quartz-muscovite pegmatite (wall zone); Zone 4, perthite-cleavelandite-quartz pegmatite (second intermediate zone); and Zone 5, cleavelandite-quartz pegmatite (third intermediate zone). Total beryl reserves are about 3,000 tons.

Reserves of scrap mica, like beryl, are principally in Zone 3 but also in Zones 2, 4, and 5. Zone 3 contains 28 percent or 22,000 tons of scrap mica, of which about 65 percent can be recovered by hand-cobbing. The total quantity of scrap mica in Zones 2-5 is 48,000 tons.

The chief potash feldspar reserves consist of 20,000 tons of perthite in Zone 4. Cleavelandite recoverable for use as soda feldspar is a very abundant constituent of Zones 3, 4, and 5. Zone 5 contains 0.5 to 1.0 percent or 1,000 to 2,000 tons of amblygonite.

INTRODUCTION

The Peerless pegmatite, near Keystone in Pennington County, S. Dak., is a large zoned pegmatite that has been a significant source of scrap mica, beryl, potash feldspar, soda feldspar, and amblygonite. The pegmatite contains seven zones, two replacement units, and two fracture-filling units. Part I of this report is a description of the pegmatite that is detailed in every respect except reserves, which are discussed only in a general way. Part II contains specific reserve data.

RESERVE CALCULATIONS

The quantity of unmined pegmatite has been calculated from successive geologic sections (figs. 4 and 5). The area of each section was measured by use of a planimeter. The volume of pegmatite between adjacent sections was then calculated. The factor used to convert volume to tonnage was 11.75 cubic feet per short ton of pegmatite. This figure was obtained by measuring similar pegmatite material from the Helen Beryl pegmatite near Custer, S. Dak. The volume and tonnage of the principal units containing reserves are shown in table 26.

The grade figures used in making reserve estimates are from Part I of this report (tables 3 and 17, and p. 59).

RESERVES OF PRINCIPAL ECONOMIC MINERALS

The principal industrial minerals are beryl, mica, and feldspar. Reserves of these are shown in table 27. This pegmatite also contains amblygonite, tantalite-columbite, cassiterite, and lithiophilite-triphylite and associated phosphate minerals.

Beryl

The Peerless pegmatite contains an estimated 2,820 tons of beryl in Zones 2, 3, and 5 (table 27). In addition there may be as much as 250 tons of beryl in Zone 4, but no accurate grade data are available.

The most significant aspect of the beryl reserve data is that 80,000 tons of rock in Zone 3 probably has the exceedingly high grade of 1.7 percent beryl, and thus contains about 1,360 tons of beryl. This grade figure is based on grain measurements on typical surface exposures and drill core (tables 3, 7, and 17); the surface exposures indicated 1.46 percent beryl, and the drill core indicated 1.93 percent beryl. Approximately 70 percent of this beryl is large enough to be hand-cobbed.

A large share of the beryl in the wall zone is in similarly high-grade rock in the inner and upper parts of the unit, where the grade exceeds 1 percent. As much as 75 percent of the 860 tons of beryl in the wall zone may be in these parts of the zone. Grain measurements on surface exposures indicate an average grade of 1.08 percent beryl over the entire thickness of the zone, and 2.30 percent beryl in the inner 40 percent of the zone (table 16). On the other hand, the grade in the drill core was only 0.09 percent beryl.

Table 26. --Reserves of pegmatite, Peerless mine. 1/.

Block 2/	Zone 2, Wall zone: Volume (cubic ft)	Zone 2, Wall zone: Weight (short tons)	Zone 3, First intermediate zone: Volume (cubic ft)	Zone 3, First intermediate zone: Weight (short tons)	Zone 4, Second intermediate zone: Volume (cubic ft)	Zone 4, Second intermediate zone: Weight (short tons)	Zone 5, Third intermediate zone: Volume (cubic ft)	Zone 5, Third intermediate zone: Weight (short tons)	Zone 6a, Part of Fourth intermediate zone: Volume (cubic ft)	Zone 6a, Part of Fourth intermediate zone: Weight (short tons)
Northwest of section A-A'.	159,400	13,600	34,100	2,900	0	0	94,000	8,000	0	0
Between sections A-A' and B-B'.	327,400	27,900	154,200	13,100	4,800	500	451,400	38,400	0	0
Between sections B-B' and C-C'.	184,000	15,700	123,500	10,500	16,800	1,400	312,000	26,600	0	0
Between sections C-C' and D-D'.	240,500	20,500	142,000	12,100	62,800	5,300	332,800	28,300	0	0
Between sections D-D' and E-E'.	459,500	39,100	282,500	24,000	312,800	26,600	884,200	75,300	5,600	500
Between sections E-E' and F-F'.	289,800	24,700	192,000	16,300	184,800	15,700	303,200	25,800	6,400	500
Southeast of section F-F'.	19,100	1,600	14,600	1,200	6,500	600	27,400	2,300	0	0
Totals - - - - - - - - - - - - -	1,679,700	143,100	942,900	80,100	588,500	50,100	2,405,000	204,700	12,000	1,000

1/ A conversion factor of 11.75 cubic ft per short ton was used to calculate tonnage.

2/ Refer to figures 2, 4, and 5 of Part I.

Table 27.--Reserves of beryl, muscovite, potash feldspar, and soda-feldspar. 1/

		Beryl				Muscovite			Potash feldspar			Cleavelandite (soda-feldspar)		
Zone	Total weight of zone (short tons)	Grade (percent)	Reserves (short tons)	Estimated percent re-coverable by hand-cobbing	Average BeO content of beryl (percent)	Grade (percent)	Reserves (short tons)	Estimated percent re-coverable by hand-cobbing	Grade (percent)	Reserves (short tons)	Estimated percent re-coverable by hand-cobbing	Grade (percent)	Reserves (short tons)	Estimated precent re-coverable by hand-cobbing
2. Wall zone.	143,000	0.6	860	35	13.0	8	11,000	20	3	4,000	20	-	-	-
3. First intermediate zone	80,000	1.7	1,360	70	13.0	28	22,000	65	< 1	-	-	40	32,000	50
4. Second intermediate zone	50,000	< .5	- 2/	60?	-	6	3,000	30	40	20,000	60	30	15,000	50
5. Third intermediate zone	205,000	.3	600	55	12.4	6	12,000	30	0	-	-	45	92,000	50
6a. Quartz-microcline pegmatite of fourth intermediate zone.	1,000	0	-	-	-	0	-	-	40	400	90	-	-	-
Total reserves	479,000	-	2,820	-	-	-	48,000	-	-	24,400	-	-	139,000	-

1/ Grade figures are based on table 3 of Part I.

2/ Reserves not calculated because grade is not known accurately.

Mica

Scrap mica occurs chiefly in Zone 3, the same unit that contains the principal beryl reserves. The 80,000 tons of rock in this zone contain an estimated 28 percent, or 22,000 tons of mica, of which approximately 65 percent can be recovered by hand-cobbing. Only 0.007 percent of all the mica produced in the past has been sold as punch and sheet mica, and most of this was sold under the favorable market conditions of World War II (tables 1 and 2).

Zones 2, 4, and 5 also contain reserves of scrap mica, but the grade is only 6 to 8 percent mica and only 20 to 30 percent can be recovered by hand-cobbing. The muscovite-cleavelandite replacement unit contains about 70 percent mica, but the total reserves are only about 1,150 tons of rock having 800 tons of mica.

Lithia mica of Zone 7 and the associated replacement unit contains only about 0.4 percent Li_2O and thus is not usable as a lithium mineral, but possibly it will be used at some future time as scrap mica or as a source of cesium or rubidium. Zone 7 is estimated to contain 2,000 tons of rock having 82 percent lithia mica, and the replacement unit is estimated to contain 5,500 tons of rock having 60 percent lithia mica. These figures indicate a total of 5,000 tons of lithia mica.

Potash feldspar

Potash feldspar reserves consist chiefly of an estimated 20,000 tons of perthite that forms 40 percent of Zone 4. Approximately 60 percent of 2,400 tons of this perthite can be recovered by hand-cobbing. Zone 2 contains only 3 percent potash feldspar. Zone 6a, on the other hand, contains 40 percent microcline, but this unit contains only about 1,000 tons of pegmatite and thus only 400 tons of microcline.

Soda feldspar

Albite occurs in all units of the pegmatite except Zone 6. Only cleavelandite aggregates that are large enough to be hand-cobbed are sold as soda feldspar. Cleavelandite is mined as a byproduct of mica and beryl in Zone 3, and as a byproduct of potash feldspar in Zone 4. It also is the major constituent of Zone 5. These units contain 30 to 45 percent cleavelandite, and the total quantity of cleavelandite is 139,000 tons. Approximately 50 percent can be recovered by hand.

Amblygonite

Amblygonite is a significant constituent of Zone 5, but only traces occur in other units. Zone 5 is estimated to contain between 0.5 and 1.0 percent amblygonite in 205,000 tons of rock. Thus the total quantity of amblygonite is 1,000 to 2,000 tons.

Other minerals

The content of tantalite-columbite in Zones 3, 5, and 7, and in the two replacement units probably does not exceed 1 pound in 10 tons of rock. The content in other units is much less. The total quantity of tantalite-columbite in the entire pegmatite may be as much as 15 tons. The quantity of cobbable tantalite-columbite may be only about 2 tons, if recovery in the future is about the same as in the past.

The cassiterite content of Zones 3, 5, and 7, and the lithia mica-cleavelandite replacement unit may be between 0.1 and 0.2 pounds per ton of rock. The total quantity would be between 15 and 30 tons of cassiterite. Only about 4 tons can be obtained by hand-cobbing if the recovery is the same in the future as in the past.

Lithiophilite-triphylite and associated phosphate minerals form about 1 percent of Zones 5 and 7 and the lithia mica-cleavelandite replacement unit. These minerals are less abundant in Zones 2, 3, and 6. The total quantity of these phosphate minerals is probably about 4,000 tons.