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COMPOSITION OF A PEGMATITE, KEYSTONE, SOUTH DAKOTA[1]

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ABSTRACT

The composition of a geologically simple pegmatite has been determined by geologic mapping and diamond drilling at a locality near Keystone, South Dakota. The pegmatite contains 33.6 percent albite, 30.4 percent quartz, 21.0 percent perthite, 14.0 percent muscovite, and 1.0 percent accessory minerals. Its bulk chemical composition is 74.2 percent SiO_2, 15.0 percent Al_2O_3, 4.6 percent Na_2O, 4.2 percent K_2O, 0.6 percent H_2O, and 1.4 percent other constituents. This composition is near the thermal minimum at 2.5 kbar in the system $NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O.

Virtually the entire body is albite-quartz-perthite pegmatite. Other rocks include a 1-foot albite-quartz-muscovite border zone and sparse quartz-perthite fracture-fillings. The country rock is quartz-mica schist, which is altered only near the contact.

The perthite content exceeds 30 percent near the hanging wall, and gradually diminishes to less than 10 percent near the footwall. This decrease is offset mainly by an increase in albite; quartz and muscovite are more uniform in abundance. Like similar gradients in many zoned pegmatites, this may reflect transfer of alkalies through gas associated with pegmatitic magma.

INTRODUCTION

Bulk composition and variations in composition within a structurally simple pegmatite in the southern Black Hills, South Dakota, have been determined from analyses of a set of drill core samples collected from the hanging wall to the footwall. Reliable data of this kind are uncommon, for pegmatites have textures and structures that put many difficulties in the way of one who tries to collect representative samples; yet such data are indispensable to a proper understanding of the petrogenesis of pegmatites.

The pegmatite is on the Diamond Mica claim, about 1 mile south of Keystone in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ NE$\frac{1}{4}$ Sec. 17, T. 2S., R. 6E. The center of the pegmatite is 950 S. 70° W. from the portal of the main adit of the Etta mine. The name of the claim seems to have been derived from the diamond shape of muscovite crystals in a smaller pegmatite that lies 500 feet to the south of the one described in this paper.

Nearby are many large well-zoned pegmatites, some of which have long been mined for potash feldspar, spodumene, scrap mica, beryl, and other minerals. These include the Etta, Hugo, and Peerless, which have been described in a series of previous publications (Sheridan and others, 1957; Norton and others, 1962, 1964). The Harney Peak Granite, to which the pegmatites are related, lies to the west and southwest.

[1] Publication authorized by the Director, U. S. Geological Survey.

The original object of the drilling was to test the possibility that this is a zoned pegmatite, rather than the homogeneous body it appears to be in outcrop. It has several affinities with zoned pegmatites: the perthite-bearing rock of the outcrop resembles that in perthite hoods lying above inner zones of many Black Hills pegmatites; muscovite is more abundant than in most homogeneous pegmatites; and the pegmatite has a shape much like that of the nearby zoned pegmatites, rather than the tabular form common among homogeneous pegmatites in the Black Hills (Redden, 1963, p. 237). Nevertheless, two drill holes through the central part of the pegmatite, at the locations shown in Figures 1 and 2, leave no doubt that inner zones either do not exist at all or are of very small size.

Because the drill core was an excellent sample of the pegmatite, an extensive program of analytical work was later undertaken. The core was of BX size, which has a diameter of $1\frac{5}{8}$ inches. Recovery was 97 percent in pegmatite. Pegmatite in the drill core of each hole was divided into five samples, of which one is of the border zone at the footwall and the others represent the main body of the pegmatite. The border zone yielded 1.7 feet of core in hole 1 and 2.6 feet of core in hole 2. The remaining 196.5 feet of pegmatite in hole 1 was divided into four samples of about 49 feet each; the corresponding 141.7 feet in hole 2 was divided into samples of about 35 feet each. Wall rock beneath the footwall was divided into 4 samples from hole 1 and 5 samples from hole 2, of which 3 from each hole were used in the analytical work. Fuller descriptions of the samples are in Table 1.

Description of the Pegmatite

The pegmatite crops out as a nearly circular knob about 300 feet in diameter (Fig. 1) surrounded by quartz-mica schist. The dip is steep to the northeast.

Nearly all of the outcrop and nearly all of the drill core consist of albite-quartz-perthite pegmatite. A few coarse-grained quartz-perthite fracture-filling units and a fine-grained border zone of albite-quartz-muscovite pegmatite are the only other kinds of rock observed.

The thickness of the border zone in surface exposures ranges from about 1 inch to 1 foot. Drill hole 1 passed through 1.7 feet of border zone at the footwall, but because the contact with schist was at an angle of only 15° to the drill core, the calculated true thickness is only 5 inches. In drill hole 2, which had 2.6 feet of border zone at an angle of 35°, the calculated true thickness is 18 inches.

Virtually all the rest of the rock is albite-quartz-perthite pegmatite. The perthite is in megacrysts, as much as 5 feet long, set in a matrix of albite, quartz, and muscovite. The perthite content decreases and the

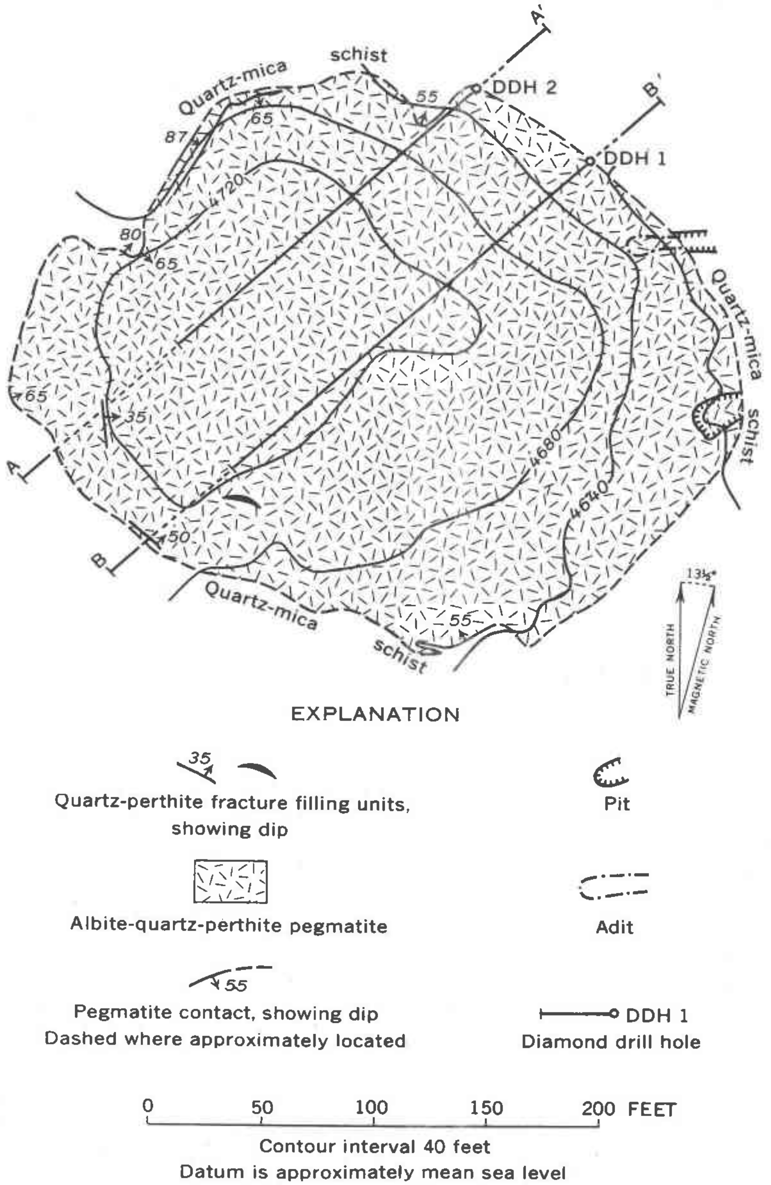

FIG. 1. Geologic map.

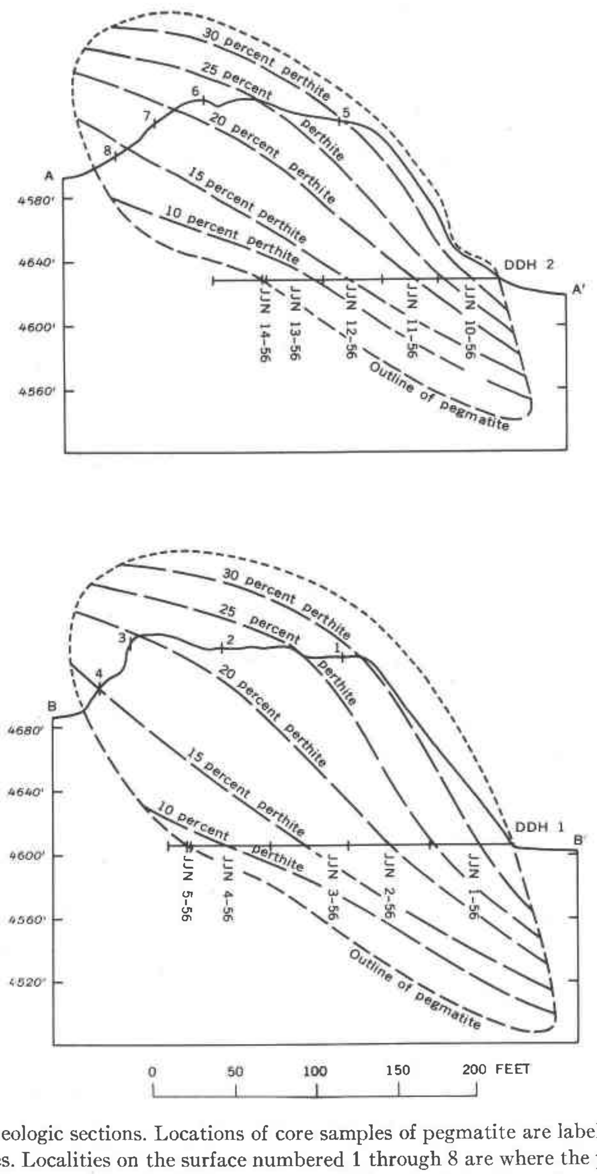

FIG. 2. Geologic sections. Locations of core samples of pegmatite are labeled alongside the drill holes. Localities on the surface numbered 1 through 8 are where the perthite contents of Table 5 were determined. Isograms show inferred distribution of perthite. Short-dashed lines indicate supposed position of the top of the pegmatite prior to erosion.

TABLE 1. DESCRIPTION OF SAMPLES

Field No.	Laboratory No.	Rock	Depth (feet)	Length in drill hole (feet)	Length of core recovered (feet)	Percent recovery
		DRILL CORE, HOLE 1				
JJN 1-56	C716	Pegmatite	0–49.7	49.7	47.6	96
JJN 2-56	C717	Pegmatite	49.7–99.5	49.8	49.3	99
JJN 3-56	C718	Pegmatite	99.5–147.5	48.0	46.3	96
JJN 4-56	C719	Pegmatite	147.5–196.5	49.0	48.3	99
JJN 5-56	C720	Pegmatite (border zone)	196.5–198.2	1.7	1.7	100
JJN 6-56	C721	Altered quartz-mica schist	198.2–198.8	.6	.6	100
JJN 7-56	C722	Quartz-mica schist	198.8–200.8	2.0	2.0	100
JJN 9-56	C724	Quartz-mica schist	208.0–210.0	2.0	1.8	90
		DRILL CORE, HOLE 2				
JJN 10-56	C725	Pegmatite	0–36.6	36.6	33.7	92
JJN 11-56	C726	Pegmatite	36.6–70.9	34.3	33.4	97
JJN 12-56	C727	Pegmatite	70.9–106.6	35.7	35.4	99
JJN 13-56	C728	Pegmatite	106.6–141.7	35.1	35.1	100
JJN 14-56	C729	Pegmatite (border zone)	141.7–144.3	2.6	2.6	100
JJN 15-56	C730	Quartz-mica schist	144.3–146.9	2.6	2.5	96
JJN 17-56	C732	Quartz-mica schist	154.1–156.1	2.0	2.0	100
JJN 19-56	C734	Quartz-mica schist	170.0–175.0	5.0	4.7	94
		CHIP SAMPLES				
JJN 20-56	C793	Quartz-mica schist	From near center of NE1/4 sec. 17, T. 2 S., R. 6 E., about 1/4 mile west of the drill holes. Collected by P. M. Orville.			
JJN 32-63	D100291	Quartz-mica schist	From SW1/4 NE1/4 NE1/4 sec. 7, T. 1 S. R. 6 E., 7 miles N. 9° W. from the drill holes.			

albite content increases from the hanging wall to the footwall; this change is not obvious in outcrop, but very pronounced in the drill core. Albite and quartz have an average grain size of about $\frac{1}{2}$ inch, but the texture is so variable that in one part of the drill core most of the grains may be about $\frac{1}{8}$ inch across and in another only a few feet away 1-inch grains may predominate. A few places, both at the surface and in the drill core, have aplitic albite-rich aggregates several inches or several feet across. Quartz also occurs as graphic intergrowths with perthite, in some of which the quartz rods are as much as 4 inches long. Much of the muscovite is in small particles associated with albite and quartz, but muscovite books are as much as 3 inches across and $1\frac{1}{2}$ inches thick. Occasional thin blades of muscovite several inches long are intergrown with biotite. Aggregates of the variety known as "bull mica", some of them 2 feet across, contain as much as 70 percent muscovite intergrown with quartz or with quartz and albite. Aggregates containing 50 percent tourmaline intergrown with albite, quartz, and muscovite are as much as 1 foot in diameter, but individual tourmaline crystals are not more than 2 inches across. Apatite and garnet are minor accessory minerals, which rarely have a grain size of more than $\frac{1}{2}$ inch.

The few fracture-filling units shown on the geologic map are of quartz-perthite pegmatite containing 40 to 70 percent quartz, 25 to 60 percent perthite, 0 to 10 percent muscovite, and sparse albite. The masses of quartz and perthite in the fracture fillings are commonly several feet in their maximum dimension. Muscovite is most abundant and of largest size near the edge of fracture fillings, where it is in books as much as 8 inches across.

Drill hole 2 cut a body of pure quartz at 27.8 to 28.5 feet that appeared to be a fracture filling, and perthite from 28.5 feet to 29.8 feet may have been a part of this fracture filling. Otherwise the only evidence of fracture fillings in the drill holes is 2-inch bodies of quartz found in two places.

Shape and Size of the Pegmatite

The probable shape and size of the pegmatite prior to erosion are shown by the structure contour map of Figure 3, which is based on the geologic map and on the position of the footwall in the two drill holes. The contours describe a body with a rounded top and a tapering bottom, but with an overall shape not far from that of an ellipsoid in which the long axis is about 430 feet, the intermediate axis 280 feet, and the short axis 170 feet in length.

A cause of uncertainty in the position of contours is that the dip of the hanging wall is not exactly known. In the only good exposure the dip is 55° east, but the dip elsewhere has to be at a steeper angle so that the contact will not intersect the cliff on the east side of the pegmatite. Small exposures near the adit suggest a nearly vertical dip. The restored position of the upper contact used on the structure contour map is shown in the sections of Figure 3, in which the top of the pegmatite has a rounded shape and its uppermost point is at an altitude of about 4,800 feet. The bottom of the pegmatite is drawn with a wedge shape caused by the intersection of the steeply dipping hanging wall with the moderately dipping footwall. Both the rounded top and wedge-shaped bottom are similar to shapes recorded on many published maps and section of Black Hills pegmatites that are thoroughly known from mine openings and drill holes.

The volume of the pegmatite, computed from the structure contour map, is between 8,500,000 and 9,000,000 cubic feet, which at in average specific gravity of 2.65 contains between 700,000 and 750,000 tons of

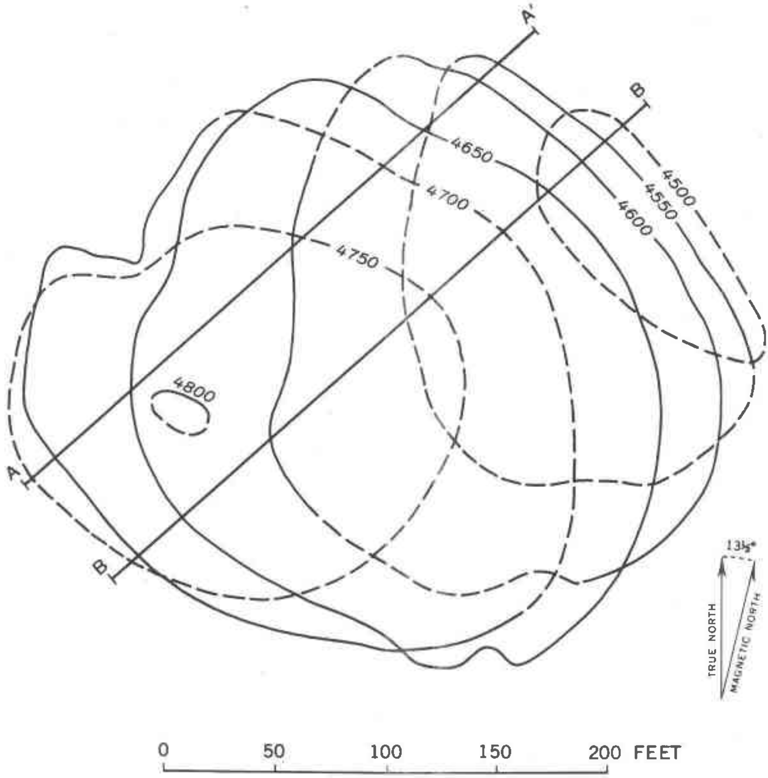

FIG. 3. Structure contour map showing inferred size and shape of the pegmatite prior to erosion. Dashed lines are where location of the contour is not well known.

rock. Nearly half of this quantity of rock lies between altitudes 4,600 and 4,700 feet—that is, in the region from slightly below the drill holes to a level near the top of the outcrop. The rest of the pegmatite is almost evenly divided between that below 4,600 feet and that above 4,700 feet.

Chemical Analyses of Pegmatite

The 10 standard rock analyses of pegmatite are in Table 2 and averages of the analyses are in Table 3. SiO_2, Al_2O_3, Na_2O, and K_2O are so abundant that in all the norms except those of the border zone the total of quartz (Q), albite (Ab), and potassium feldspar (Or) exceeds 94 percent (Table 2). Most of the remainder in the norms is corundum, which ranges from 2.2 to 4.9 percent and is expressed as muscovite in the mode. CaO is so meager that it is all used up in calculating normative apatite; there is no anorthite in the norm of any sample. Iron and magnesium are also

TABLE 2. COMPOSITION OF PEGMATITE IN DRILL CORE

	DRILL HOLE 1						DRILL HOLE 2			
	JJN 1-56	JJN 2-56	JJN 3-56	JJN 4-56	JJN 5-56	JJN 10-56	JJN 11-56	JJN 12-56	JJN 13-56	JJN 14-56
CHEMICAL ANALYSES Analyst: M. Balazs										
SiO_2	73.39	74.84	74.93	74.47	74.23	72.93	74.19	74.06	75.03	73.99
Al_2O_3	15.14	14.63	14.52	14.77	15.76	15.46	14.92	14.96	14.60	15.89
Fe_2O_3	.30	.26	.37	.45	.39	.31	.29	.37	.43	.36
FeO	.27	.31	.45	.31	.20	.27	.36	.38	.45	.40
MgO	.04	.04	.08	.07	.06	.05	.04	.06	.06	.05
CaO	.24	.23	.28	.35	.49	.22	.26	.30	.28	.35
Na_2O	4.52	4.35	4.38	5.62	5.33	3.97	4.83	5.14	5.62	5.24
K_2O	5.08	4.17	3.69	2.79	2.16	5.46	3.95	3.51	2.29	2.18
TiO_2	.01	.01	.02	.01	.01	.01	.01	.02	.02	.01
P_2O_5	.32	.30	.30	.36	.38	.33	.31	.34	.30	.33
MnO	.02	.02	.02	.03	.01	.02	.02	.02	.02	.07
H_2O+	.40	.54	.71	.47	.81	1.06	.85	.45	.46	.78
H_2O-	.04	.01	.06	.02	.01	.02	.03	.03	.04	.06
CO_2	.01	.01	.01	.01	.01	.01	.01	.00	.00	.01
Cl	.00	.01	.00	.01	.01	.00	.00	.01	.01	.01
F	.07	.10	.14	.09	.09	.08	.09	.11	.12	.07
Subtotals	99.85	99.83	99.96	99.83	99.95	100.20	100.16	99.76	99.73	99.80
Less O	.03	.04	.06	.04	.04	.03	.04	.05	.05	.03
Totals	99.82	99.79	99.90	99.79	99.91	100.17	100.12	99.71	99.68	99.77
SPECTROGRAPHIC ANALYSES[a] Analyst: Paul R. Barnett										
B	.03	.015	.015	.015	.007	.03	.015	.015	.015	.007
Be	.0004	.004	.0005	.006	.007	.003	.0004	.0005	.002	.008
Ba	.0007	.0003	.0007	.0007	.003	.0007	.0003	.0003	.00015	.0015
Cr	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015
Cu	.00015	.00007	.00007	.0007	.0015	.00015	.00015	.00015	.0003	.0015
Ga	.003	.003	.003	.003	.0015	.003	.003	.003	.003	.003
Li	.02	.03	.04	.015	.006	.015	.025	.03	.025	.006
Nb	.0015	.0015	.003	.003	.0015	.0015	.003	.003	.0015	.0007
Pb	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015
Sn	.0015	.003	.003	.003	.0015	.0015	.003	.003	.003	.0015
Sr	.0003	.0007	.0015	.0015	.0015	.0007	.0003	.0003	.0003	.0007
Y	0	0	0	0	0	0	0	0	0	.0007
Zr	.0007	.0007	0	.0007	.0007	.0007	0	0	.0007	.003
NORMS[b]										
Q	27.7	33.6	35.3	31.1	35.0	28.9	31.0	30.7	33.6	35.2
Ab	38.2	36.8	37.1	47.6	45.1	33.6	40.9	43.5	47.6	44.3
Or	30.0	24.7	21.8	16.5	12.7	32.3	23.3	20.8	13.5	12.9
C	2.2	3.0	3.3	2.5	4.7	3.0	2.7	2.7	2.9	4.9
Ap	.4	.4	.5	.6	.8	.4	.4	.5	.5	.6
Mt	.4	.4	.5	.7	.6	.4	.4	.5	.6	.5
Totals	98.9	98.9	98.5	99.0	98.9	98.6	98.7	98.7	98.7	98.4

TABLE 2.—(*Continued*)

	DRILL HOLE 1						DRILL HOLE 2			
	JJN 1-56	JJN 2-56	JJN 3-56	JJN 4-56	JJN 5-56	JJN 10-56	JJN 11-56	JJN 12-56	JJN 13-56	JJN 14-56
CALCULATED MODES[c]										
Quartz	26.8	32.4	34.0	30.1	32.0	27.8	29.9	29.7	32.4	32.1
Albite	31.9	32.0	33.0	44.5	43.0	26.9	36.2	39.5	45.4	42.3
Perthite	29.2	20.0	15.2	11.5	1.3	29.1	19.3	16.0	6.6	.6
Muscovite	11.2	14.9	16.7	12.6	22.6	15.3	13.6	13.6	14.4	23.8
Totals	99.1	99.3	98.9	98.7	98.9	99.1	99.0	98.8	98.8	98.8
MODES[d]										
Quartz	24	31	32	31	34	26	30	29	34	30
Albite	33	32	34	40	42	28	37	40	42	45
Perthite	31	20	15	16	2	31	18	15	8	0
Muscovite	11	16	18	12	21	14	14	15	15	24
Totals	99	99	99	99	99	99	99	99	99	99

[a] Be and Li are quantitative. All others are semiquantitative, reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, etc., which represent approximate midpoints of group data on a geometric scale. Results by quantitative methods would be in the same group about 60 percent of the time. Looked for but not detected: Ag, As, Au, Bi, Cd, Ce, Co, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, La, Mo, Nd, Ni, Os, Pd, Pt, Re, Rh, Sb, Sc, Sm, Ta,Te, Th, Tl, U, V, W, Yb, and Zn.

[b] Q—quartz; Ab—albite; Or—orthoclase; C—corundum; Ap—apatite; mt—magnetite.

[c] Quartz $=SiO_2$, albite $=NaAlSi_3O_8$, and perthite $=Or_{80}Ab_{20}$. Muscovite in JJN5 and 14-56 is the average of the analyses of muscovite from JJN 5-56 in table 4. Other muscovite is the average of muscovite analyses from JJN 1, 3, and 4-56, table 4. The procedure is to solve simultaneous equations of the form shown below in an example taken from JJN 1-56. M = muscovite; K = microcline; A = albite; and Q = quartz. The total for equation (1) is percent K_2O multiplied by 100; the total of (2) is the same for Na_2O; (3) for Al_2O_3; and (4) for SiO_2

$$(1)\quad 9.6M+13.7K=508$$
$$(2)\quad .8M+2.3K+11.8A=452$$
$$(3)\quad 31.8M+18.5K+19.4A=1514$$
$$(4)\quad 49.3M+65.5K+68.8A+100Q=7339$$

[d] Determined by Beth M. Madsen by mineral separation and X-ray techniques. Samples of 35 to 100 grams were ground to pass a 30 mesh screen, then separated into −200 mesh and +200 mesh fractions, and the +200 mesh material further separated into fractions of specific gravity >2.85, 2.70 to 2.85, 2.58 to 2.70, and <2.58. For the 2.58–2.70 fraction and the entire −200 mesh fraction, which together are generally about three-fourths of the whole sample, the content of quartz, albite, microcline, and muscovite were determined by X-ray in the manner described by Tatlock (1966). The −2.58 fraction is chiefly perthite, but was examined optically to detect other minerals. The 2.7–2.85 fraction consists virtually entirely of muscovite. Only about 1 percent of each sample is of specific gravity greater than 2.85; it is chiefly tourmaline, but also includes apatite, biotite and garnet. The microcline of the 2.58–270 and the −200 mesh fractions was arbitrarily increased by 10 percent to express it as perthite, and albite was reduced accordingly; calculation by J. J. Norton from Madsen's data.

trifling in quantity; they occur in tourmaline, garnet, biotite, and muscovite. Fluorine is mainly in muscovite (Table 4), but doubtless also in apatite.

The only marked change in chemical composition from one sample to another is in the proportion of K_2O and Na_2O. The greatest abundance of K_2O and of normative potassium feldspar is near the hanging wall.

TABLE 3. AVERAGE COMPOSITION OF PEGMATITE IN DRILL CORE

	Albite-quartz-perthite pegmatite			Albite-quartz-muscovite pegmatite
	Drill hole 1	Drill hole 2	Average of drill holes 1 and 2	
CHEMICAL COMPOSITIONS[a]				
SiO_2	74.40	74.04	74.22	74.11
Al_2O_3	14.77	14.99	14.88	15.82
Fe_2O_3	.34	.35	.35	.38
FeO	.33	.36	.35	.30
MgO	.06	.05	.05	.06
CaO	.27	.26	.27	.42
Na_2O	4.72	4.88	4.80	5.28
K_2O	3.94	3.82	3.88	2.17
TiO_2	.01	.01	.01	.01
P_2O_5	.32	.32	.32	.36
MnO	.02	.02	.02	.04
H_2O+	.53	.71	.62	.80
H_2O-	.03	.03	.03	.04
CO_2	.01	.01	.01	.01
Cl	.01	.01	.01	.01
F	.10	.10	.10	.08
Subtotals	99.86	99.96	99.92	99.89
Less O	.04	.04	.04	.04
Totals	99.82	99.92	99.88	99.85
NORMS[b]				
Q	31.9	31.0	31.5	35.1
Ab	40.0	41.3	40.6	44.7
Or	23.3	22.6	22.9	12.8
C	2.7	2.8	2.8	4.8
Ap	.5	.4	.5	.7
Mt	.5	.5	.5	.6
Totals	98.9	98.6	98.8	98.7
CALCULATED MODES[b]				
Quartz	30.8	29.9	30.4	32.1
Albite	35.3	36.9	36.1	42.6
Perthite	19.0	17.9	18.5	.9
Muscovite	13.9	14.2	14.0	23.3
Totals	99.0	98.9	99.0	98.9
MODES[c]				
Quartz	30	30	30	32
Albite	35	37	36	44
Perthite	20	18	19	1
Muscovite	14	14	14	22
Totals	99	99	99	99

[a] Calculated from chemical analyses in table 2. Compositions of albite-quartz-perthite pegmatite in Holes 1 and 2 are weighted averages based on the length of drill hole represented by each sample—49.7 feet for sample JJN 1-56, 49.8 feet for JJN 2-56, and so on. Composition of albite-quartz-muscovite pegmatite is average of samples JJN 5-56 and JJN 14-56.

[b] Calculated from the average chemical composition shown above.

[c] Weighted average of modes in table 2.

Toward the footwall the K_2O content gradually diminishes and the Na_2O content increases. The narrow border zone, which has abundant muscovite and scarcely any perthite in the mode, is enriched in Al_2O_3 and Na_2O.

The trace element contents are in no way unusual. Although Black Hills pegmatites are noted for having such rare elements as beryllium, lithium, and tantalum, it is the exception rather than the rule to find sizable bodies of rock in which these constituents are abundant. The lithium content ranges from 0.006 percent in the border zone to a high of 0.04 percent near the center of the pegmatite. About three-fourths of the lithium is in muscovite (Table 4), and the rest is probably dispersed in feldspar. The greatest amount of beryllium is the 0.007 and 0.008 percent in the border zone, which is enough to indicate that beryl is present, even though not observed, because 0.008 percent beryllium is equivalent to about 0.2 percent beryl. Tin and niobium are at most 0.003 percent. Probably tantalum is about the same, but it was undetected because the

TABLE 4. ANALYSES OF MUSCOVITE CONCENTRATES FROM DRILL CORE SAMPLES OF HOLE 1[a]

Laboratory no. Field no.	159896 JJN 2–56		159897 JJN 2–56			159898 JJN 3–56			159899 JJN 4–56		159900 JJN 5–56		
	A	B	A	B	C	A	B	C	A	B	A	B	C
SiO_2	50.5	50.3	52.6	55.0	54.5	48.6	48.4	48.2	49.3	49.0	52.4	51.8	51.7
Al_2O_3	31.7	31.6	30.6	28.6	28.0	32.2	32.0	31.7	31.9	31.9	32.1	31.9	31.5
Fe_2O_3	1.1		1.0		2.3[b]	1.0		3.2[b]	1.4		.71		1.2[b]
FeO	1.8		1.5			2.1			1.7		.54		
MgO	.05		.00			.06			.09		.00		
CaO	.11		.07			.20			.26		.20		
Na_2O	.72		.95			.79			.97		1.0		
K_2O	9.6	9.4	9.0	8.3	8.3	9.8	9.6	9.6	9.6	9.5	8.8	8.8	8.7
Li_2O	.26		.24			.30			.19		.04		
TiO_2	.05		.05		.03	.06		.04	.06		.04		.02
P_2O_5	.04		.06			.07			.17		.05		
MnO	.06		.05		.01	.06		.03	.08		.03		.01
H_2O+	3.4		3.5			3.5			3.5		3.9		
H_2O-	.06		.10			.05			.20		.13		
F	.57		.53			.74			.60		.29		
Less O ($=F_2$)	.24		.22			.31			.25		.12		
Totals	99.8		100.0			99.2			99.8		100.1		

A. Analyses by rapid chemical methods by Paul Elmore, Samuel Botts, and Gillson Chloe by methods similar to those described in U. S. Geological Survey Bulletin 1144-A. Li_2O and F done separately by J. J. Warr, Jr., Fred Simon, and Joseph Budinsky.

B. Repeat analyses by rapid chemical methods by Paul Elmore and Leonard Shapiro.

C. Analyses by X-ray fluorescence by Paul Elmore and Leonard Shapiro.

[a] Content of impurities estimated from microscopic examination by J. J. Norton: quartz—2 to 5 percent; feldspar—about 1 percent; other impurities negligible.

[b] Total Fe as Fe_2O_3.

TABLE 5. PERTHITE CONTENT OF SURFACE EXPOSURES

Locality[a]	Perthite content, in volume percent
1	26
2	23
3	18
4	15
5	29
6	20
7	20
8	13

[a] Localities are shown on Figure 2.

threshold value for the analytical method is 0.1 percent. Boron, at 0.007 to 0.03 percent, is in tourmaline.

MODES AND CALCULATED MODES OF PEGMATITE

Table 2 shows calculated modes based on the chemical analyses and also modes determined by B. M. Madsen from mineral separations and X-ray study. The methods used are described in footnotes to the table.

The two sets of modes are remarkably similar, but it should be confessed that this outcome was not easily achieved. At first sight the amount of Al_2O_3 in the analyses seemed too small for the quantity of muscovite in the rock, and the amount of K_2O seemed insufficient for the microcline and muscovite. The discrepancies were resolved by determining the composition of the muscovite and the feldspars.

TABLE 6. BULK COMPOSITION OF THE PEGMATITE (IN PERCENT)

Chemical composition		Norm	
SiO_2	74.2	Q	31.4
Al_2O_3	15.0	Ab	38.9
Fe_2O_3	.3	Or	24.8
FeO	.3	C	2.9
CaO	.3	Ap	.6
Na_2O	4.6	Mt	.4
K_2O	4.2		
P_2O_5	.3		
H_2O+	.6		
F	.1		
Others	.1		
Totals	100.0		99.0

Chemical analyses of muscovite concentrates (Table 4) show a low content of Al_2O_3 but enough iron to take the place of the missing aluminum. The analyses also show a generally high content of SiO_2, which is attributable partly to contaminating quartz. X-ray examination of four mica samples by D. R. Wones indicated they are virtually pure $2M$ muscovite with no unusual traits, though with a few percent quartz in most samples and a detectable amount of feldspar in some of them.

Five perthite concentrates were sanidinized by D. B. Stewart and from their $\bar{2}01$ spacing were found to be $Or_{73-75}Ab_{25-27}$. These samples contained 5 to 10 percent of discrete albite grains and 1 to 4 percent quartz. If these contaminants are eliminated from consideration, the average composition of the perthite is $Or_{80}Ab_{20}$.

Albite seems certain to be nearly pure $NaAlSi_3O_8$. That it lacks CaO is obvious enough from the sparsity of CaO in the rock analyses. The minimum index of refraction of (001) cleavage flakes in most of the drill core is about 1.529, indicating a composition very near An_0 (Emmons and others, 1953, Fig. 6). In the border zone the An content may be slightly greater, but scarcely enough to be noticeable. B. M. Madsen found compositions of An_1 or An_2 in each core sample by X-ray, using values for 2θ $(1\bar{3}1)$—2θ (131) and the graph of Smith and Yoder (1956, p. 641, Fig. 3). The K_2O content of the albite, though not determined, probably is also low. Similar albite from outer zones of the nearby Hugo pegmatite and albite from the Peerless pegmatite have about 0.2 percent K_2O, which indicates about 1 percent Or (Norton and others, 1962, p. 105; Emmons and others, 1953, p. 18).

Bulk Composition of the Pegmatite

A question yet to be answered is what adjustments are needed in using the chemical analyses of the drill core to determine the bulk composition of the pegmatite.

The border zone can be disregarded in estimating bulk composition, for despite its differences from the rest of the pegmatite, it is too small to affect the results. Even if one is generous enough to grant an average thickness of 1 foot for the border zone, the total quantity of rock is only about 2 percent of the pegmatite, which if introduced into a weighted average composition for the entire drill core would cause changes of only 0.01 to 0.03 percent for Na_2O, Al_2O_3, and K_2O, and no change at all for other constituents.

In the rest of the pegmatite, the wide range in abundance of perthite creates the main problem in estimating bulk composition. Isograms drawn on the geologic sections of Figure 2 indicate that the perthite content exceeds 30 percent near the hanging wall and decreases at a uniform

TABLE 7. COMPOSITION OF SCHIST

	DRILL HOLE 1			DRILL HOLE 2			CHIP SAMPLES	
	JJN 6–56	JJN 7–56	JJN 9–56	JJN 15–56	JJN 17–56	JJN 19–56	JJN 20–56	JJN 32–63
CHEMICAL ANALYSES[a]								
SiO_2	71.75	75.42	78.13	69.50	75.16	67.49	73.35	73.38
Al_2O_3	13.89	12.09	10.85	14.28	12.17	14.94	13.20	12.82
Fe_2O_3	1.84	.50	.69	2.22	.51	.44	.62	.88
FeO	1.94	2.75	2.34	2.78	3.12	4.95	3.27	3.29
MgO	1.03	1.09	.97	1.64	1.22	1.94	1.45	1.42
CaO	.86	1.04	.49	.68	.99	.75	.63	.61
Na_2O	.70	3.30	2.02	2.62	2.34	2.28	1.94	1.88
K_2O	4.36	2.03	2.44	3.33	2.58	3.98	3.22	2.88
TiO_2	.46	.49	.44	.58	.52	.63	.54	.58
P_2O_5	.64	.14	.12	.11	.11	.21	.13	.15
MnO	.07	.04	.03	.05	.05	.06	.04	.06
H_2O+	1.63	.80	.95	1.60	1.03	1.64	1.28	1.56
H_2O-	.07	.02	.03	.21	.01	.02	.05	.06
CO_2	.02	.01	.01	.01	.00	.06	.02	.02
Cl	.00	.01	.00	.00	.01	.01	.01	.00
F	.47	.13	.12	.11	.06	.18	.08	.08
Subtotals	99.73	99.86	99.63	99.72	99.88	99.58	99.83	99.67
Less O	.20	.05	.05	.05	.03	.08	.03	.03
Totals	99.53	99.81	99.58	99.67	99.85	99.50	99.80	99.64
SPECTROGRAPHIC ANALYSES[b]								
B	0.15	0	0.015	0	0.015	0.015	0	0.005
Ba	.03	.03	.03	.03	.03	.03	.03	.05
Be	.0009	.0005	.0005	.0004	.0002	.0006	.0002	.0001
Ce	.007	.007	.007	.007	.007	.007	.007	0
Co	.0007	.0015	.003	.0015	.0015	.0015	.0015	.0007
Cr	.007	.003	.003	.007	.007	.007	.007	.007
Cu	.003	.0007	.0015	.003	.003	.0015	.0015	.003
Ga	.0015	.0007	.0007	.0007	.0007	.0007	.0007	.0015
La	.003	.003	.003	.003	.003	.003	.003	.003
Li	.07	.03	.03	.03	.025	.04	.006	.0029
Nb	.0007	.0007	.0007	.0015	.0007	.0007	.0007	0
Nd	.003	.003	.003	.007	.003	.003	.003	0
Ni	.0015	.003	.0015	.003	.003	.003	.003	.002
Pb	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015
Sc	.0015	.0015	.0007	.0015	.0015	.0015	.0015	.001
Sn	.015	<.001	<.001	<.001	.001	.001	0	0
Sr	.003	.015	.007	.015	.015	.015	.007	.015
V	.007	.007	.003	.015	.007	.007	0	.007
Y	.0015	.003	.0015	.003	.0015	.0015	.003	.002
Yb	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
Zr	.015	.015	.015	.015	.015	.015	.03	.03

Sample locations are described in table 1. All samples except JJN 6–56 are schist consisting mainly of quartz, plagioclase, muscovite, and biotite. JJN 6–56 is about 60 percent schist, 30 percent muscovite-tourmaline rock, and 10 percent pegmatite stringers.

[a] Analyst for JJN 20–56 is Lucile N. Tarrant. Analyst for JJN 32–63 is Christel L. Parker. Analyst for all others is M. Balazs.

[b] Be and Li in the drill core samples, and B, Be, and Li in JJN 20–56 are quantitative analyses by Paul R. Barnett. Li in JJN 32-63 is a quantitative analysis by Harriet Neiman. All other determinations are

TABLE 7.—(*Continued*)

		DRILL HOLE 1			DRILL HOLE 2			CHIP SAMPLES	
		JJN 6–56	JJN 7–56	JJN 9–56	JJN 15–56	JJN 17–56	JJN 19–56	JJN 20–56	JJN 32–63
		NORMS In terms of standard molecules[c]							
Q		50.9	46.7	56.3	40.4	49.9	38.0	48.8	50.6
Ab		5.9	27.9	17.1	22.2	19.8	19.3	16.4	15.9
An		.1	4.2	1.7	2.6	4.2	2.3	2.3	2.0
Or		25.8	12.0	14.4	19.7	15.3	23.5	19.0	17.0
C		8.0	2.9	4.3	5.4	4.0	6.0	5.7	5.9
Ap		1.5	.3	.3	.3	.3	.5	.3	.4
Mt		2.7	.7	1.0	3.2	.7	.6	.9	1.3
	Totals	94.9	94.7	95.1	93.8	94.2	90.2	93.4	93.1
		In terms of molecules representing modal constituents[d]							
Apatite		1.5	.3	.3	.3	.3	.5	.3	.4
Hematite		1.8	.5	.7	2.2	.5	.4	.6	.9
Biotite	Phlogopite	3.5	3.8	3.4	5.7	4.2	6.7	5.0	4.9
	Siderophyllite	5.4	7.6	6.5	7.7	8.6	13.7	9.0	9.1
	(Biotite total)	8.9	11.4	9.9	13.4	12.8	20.4	14.0	14.0
Muscovite	Muscovite	29.1	7.4	12.3	16.6	10.9	16.3	15.2	12.3
	Paragonite	0	1.0	1.8	1.3	1.2	1.6	3.2	6.7
	(Muscovite total)	29.1	8.4	14.1	17.9	12.1	17.9	18.4	19.0
Plagioclase	Anorthite	0.1	4.2	1.7	2.6	4.2	2.3	2.3	2.0
	Albite	5.9	27.2	15.9	21.3	19.0	18.2	14.2	11.3
	(Plagioclase total)	6.0	31.4	17.6	23.9	23.2	20.5	16.5	13.3
Quartz		51.3	47.1	56.7	40.8	50.4	38.8	49.3	51.1
	Totals	98.6	99.1	99.3	98.5	99.3	98.5	99.1	98.7

semiquantitative. Analyst is Paul R. Barnett for all samples except JJN 32–63, which is by Joseph Haffty. 0 means looked for but not detected.

All semiquantitative determinations except of JJN 32–63 are reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, etc., which represent approximate midpoints of group data on a geometric scale. Results by quantitative methods would be in the same group about 60 percent of the time. Looked for but not detected: Ag, As, Au, Bi, Cd, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sm, Ta, Te, Th, Tl, U, W, and Zn. For JJN 32–63, the series is 7, 5, 3, 2, 1.5, 1, etc., and the results would agree with those of quantitative methods about 30 percent of the time. Looked for but not detected: Ag, As, Au, Bi, Cd, Eu, Ge, Hf, Hg, In, Mo, Pd, Pr, Pt, Re, Sb, Sm, Ta, Te, Th, Tl, U, W, and Zn.

[c] Q—quartz; Ab—albite; An—anorthite; Or—orthoclase; C—corundum; Ap—apatite; Mt—magnetite.

[d] Procedure: All P_2O_5 is calculated as apatite and remaining CaO is assigned to anorthite. All MgO and FeO are assigned to biotite, the MgO as phlogopite ($K_2O \cdot 6MgO \cdot Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$) and the FeO as siderophyllite ($K_2O \cdot 5FeO \cdot 2Al_2O_3 \cdot 5SiO_2 \cdot 2H_2O$). The remaining K_2O is calculated as muscovite. The Na_2O and the remaining Al_2O_3 are divided between paragonite and albite. Remaining SiO_2 is quartz.

rate to less than 10 percent near the footwall. The isograms are based on the calculated modes of Table 2 and on data in Table 5 for perthite content of surface exposures at eight localities marked on the geologic sections. At each of the surface localities the perthite content was determined by a point count of 500 points spaced 0.1 foot apart along a steel tape laid on the outcrop at several places within a circle of 20-foot radius.

To count more than 500 points would be of little practical value because the surface has many irregularities and many patches covered by lichen or rubble, all of which cause inaccuracies. The pattern of the isograms is much like that of perthite-rich hoods shown in many published maps and sections of Black Hills zoned pegmatites; a similar effect in layered pegmatites has been noted by Orville (1960, p. 1474–1475).

The isograms, when put to use as the basis for calculating a weighted average, indicate that the overall perthite content of the pegmatite is 21 percent. The quartz and muscovite abundances are probably very close to the 30.4 percent and 14.0 percent that Table 3 shows for the average calculated mode of albite-quartz-perthite pegmatite. About 1 percent may be allowed for accessory minerals, of which the only significant ones are tourmaline at about 0.6 percent, apatite at 0.2 percent, and biotite at 0.2 percent. This leaves 33.6 percent for albite.

The major constituents of the bulk chemical composition shown in Table 6 were calculated from this mode. Minor constituents of the same table are from the average chemical composition of albite-quartz-perthite pegmatite in Table 3. The pegmatite contains a total of 95.1 percent normative quartz, albite, and potassium feldspar, and the remainder includes 2.9 percent normative corundum and 0.6 percent H_2O, leaving only 1.4 percent for all other constituents.

Composition of Wall Rock

The analyses of country rock in Table 7 include not only drill core but also chip samples selected to show the nature of the schist at localities remote from the pegmatite. The chief reason for examining wall rock compositions is to ascertain in what way, if any, they were changed during emplacement and crystallization of the pegmatite, for such changes should cause differences among the samples of country rock.

The wall rock is a metasedimentary quartz-mica schist that consists mainly of quartz, sodic plagioclase (about An_{15}), muscovite, and biotite. Accessory minerals include chlorite, garnet, tourmaline, microcline, iron oxides, and staurolite. Modes have not been determined, but Table 7 has a set of norms expressed in terms of modal constituents that is probably close to the actual modes. In this calculation, FeO and MgO are assigned entirely to biotite, but Fe_2O_3, which probably is also chiefly in biotite, is expressed as hematite. Though hematite does exist in the rock, the abundance of ferric iron near the pegmatite contact presumably reflects oxidation of biotite at the time the pegmatite was emplaced. The biotite calculation makes use of siderophyllite, instead of the less aluminous end member, because the rock contains a large amount of Al_2O_3 that can reasonably be placed only in biotite and because biotites from similar

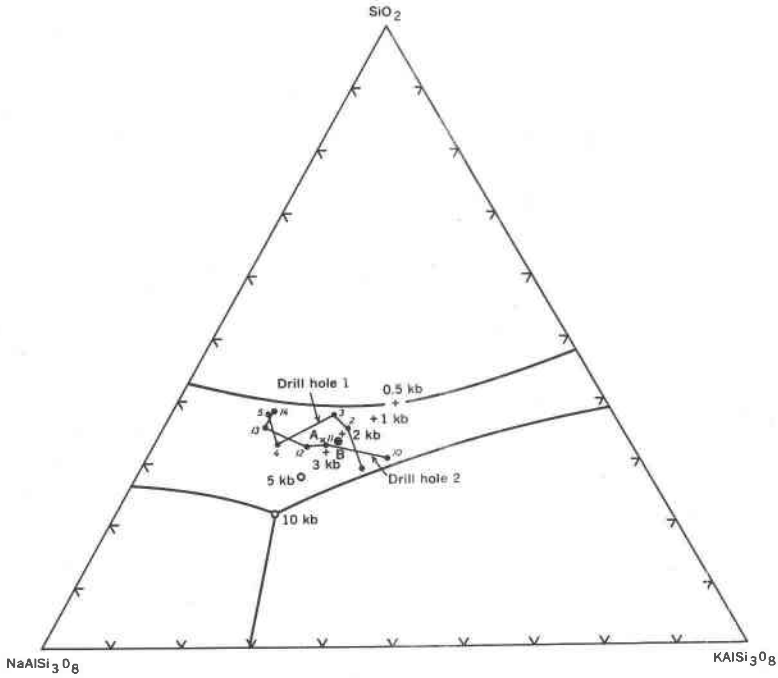

FIG. 4. Ternary diagram showing relation of pegmatite compositions to the system $NAlSi_3O_8$–$KAlSi_3O_8$–Sio_2–H_2O. Dots show the content of normative albite, orthoclase, and quartz in pegmatite from the drill holes; the numerals 1, 2, etc., correspond to samples JJN 1–56, JJN 2–56, etc. Point A, shown by an x, is the average composition of albite-quartz-perthite pegmatite in the drill holes. *B* is the inferred bulk composition of the pegmatite. The isobaric minimum (plus signs) and isobaric eutectic (circles) at 0.5, 1, 2, 3, 5, and 10 k bar P_{H_2O} and the field boundaries at 0.5 and 10 k bar P_{H_2O} are from Luth, Jahns, and Tuttle, 1964, Figure 4.

rocks elsewhere in the world seem generally to have a high content of aluminum (Deer, Howie, and Zussman, 1962, p. 62–64). The Al_2O_3 that remains after calculating muscovite is divided between paragonite and albite. This procedure, which makes paragonite the vehicle for any excess Al_2O_3, causes a few small anomalies: the most obvious is the total absence of paragonite in JJN 6–56, which is partly pegmatite and probably has modal microcline.

Samples JJN 20–56 and JJN 32–63, which are remarkably similar to each other in chemical composition, show the nature of the schist where it cannot have been affected by any pegmatite. JJN 20–56 was $\frac{1}{4}$ mile from the drill holes, in an area that has several pegmatites but none closer than 500 feet away. JJN 32–63 was from a locality quite outside the pegmatite region of the southern Black Hills. It is lithologically similar to the rocks on the Diamond Mica claim, and evidence from regional geologic mapping suggests it may be in the same stratigraphic position, yet it is 4 miles from the nearest pegmatite and in an area of lower grade metamorphism in which staurolite is absent.

Some of the differences between these two samples and the ones from the drill holes probably reflect only differences in the original sediments. For example, JJN 19–56 from the bottom of hole 2 is highly aluminous, and thus micaceous, and JJN 9–56 from the bottom of hole 1 is a highly siliceous and quartzose.

The only conspicuously altered samples are JJN 6 and 7–56, both of which came from within 2.6 feet of the footwall in hole 1. Below these samples is a gap of 7.2 feet in which no analysis was made nor did the schist appear abnormal; the next analyzed sample, JJN 9–56, seems to be unaltered. The most obvious anomaly in samples JJN 6 and 7–56 is that one has the least Na_2O and the most K_2O and the other the most Na_2O and least K_2O among all the wall rock samples. Obviously sodium and potassium were redistributed, but whether a significant amount of either constituent was added to the schist or subtracted from it is dubious. JJN 6–56 exceeds all other samples of schist and pegmatite in content of F and Li, most of which are probably in its abundant muscovite. This sample also has more boron and more P_2O_5 than others, indicating enrichment in tourmaline and apatite.

The samples from hole 2 have no obvious alteration effect except the abundance of ferric iron in JJN 15–56 at the pegmatite contact. All three samples have a sizable content of Na_2O, but not enough to imply that much or any of it was introduced when the pegmatite was emplaced.

Taken all together, the analyses provide no encouragment for views that substantial amounts of any constituent were added to the wall rock or substracted from it. The only obvious changes are immediately adjacent to the pegmatite contact, where alkalies were redistributed, iron was oxidized, and fluorine, lithium, boron, and phosphorus were added to the schist. Hydrous fluids escaping while the pegmatite crystallized can have caused these changes, but such fluids seem not to have had perceptible effect farther away from the pegmatite contact.

Norms of the schist expressed in terms of Q, Ab, Or, and C (Table 7) have generally higher contents of Q and C and a greater ratio of Or to A than the pegmatite samples. Nonetheless, differences in composition between schist and pegmatite are not great. In the deep-seated conditions under which the pegmatite presumably formed, the schist must have been at nearly the same temperature and exactly the same confining pressure

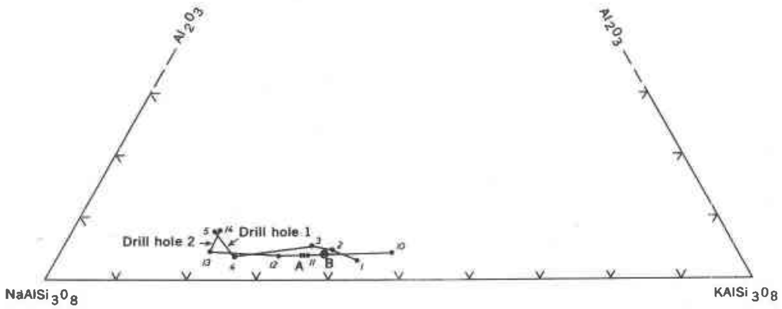

FIG. 5. Ternary diagram showing composition in terms of normative albite, orthoclase, and corundum. Points *A* and *B* and sample numbers are the same as in Figure 4.

as the pegmatite fluid. With little difference from the pegmatite in composition, temperature, or pressure, the wall rock remained almost inert.

PETROGENESIS

The bulk composition, indicated by point B on Figure 4, is very near the minimum melting composition in the system $NAlSi_3O_8$—$KAlSi_3O_8$—Sio_2—H_2O at 2.5 kbar P_{H_2O}. The pegmatite also contains 2.9 percent normative corundum. H. R. Shaw found that Al_2O_3, when added to the minimum melting composition at 2 kbar in the system $KAlSi_3O_8$—SiO_2—H_2O, caused the melting point to be depressed by 20–30°C and shifted slightly toward SiO_2, and about 3 percent muscovite was formed (U. S. Geological Survey 1961, p. 74). The feldspar of this pegmatite crystallized as two separate minerals; thus the liquidus is low enough to intersect the solvus and point B of Figure 4 is a eutectic.

The absence of potassic feldspar in the narrow border zone implies that crystallization at the outset was from a composition on the Q-Ab side of the eutectic. Yet the effect required is so slight that it could have been caused merely by assimilating a trifling quantity of the wall rock. The schist seems the obvious source for the abundant Al_2O_3 of the border zone, and it may also have provided some SiO_2 and Na_2O.

If this pegmatite were of uniform composition, rather than potassic near the hanging wall and sodic near the footwall, and if muscovite were less plentiful, there would be little more to say about the conditions of crystallization. The problems are illustrated in Figure 5, which shows the proportions of normative albite, orthoclase, and corundum. Normative corundum, which is a measure of the amount of muscovite, is both sizable and nearly constant in abundance in the 8 samples from albite-quartz-perthite pegmatite. Yet the ratio $KAlSi_3O_8$:$NaAlSi_3O_8$ ranges from 22:78 to 49:51. Normative quartz (Fig. 4) in hole 2 shows a modest but progressive decrease accompanying the increase in $KAlSi_3O_8$. The same trend may exist in hole 1, but it is disrupted by a small enrichment in quartz at the center of the pegmatite, which suggests the beginnings of the silica-rich conditions of the innermost parts of many pegmatites.

Crystallization from liquid alone seems unable to bring about the wide range in the ratio of Or to Ab in this small pegmatite of otherwise nearly uniform composition. A gas phase co-existing with the liquid is a likely cause. The introduction of H_2O and F in wall rock of drill hole 1 indicates that a gas phase was associated with the magma from which this pegmatite formed, and the redistribution of potassium and sodium in the wall rock further shows that this gas phase had the ability to carry alkalies. Though the gas phase affected only a small part of the wall rock, it can have had broader influence on the distribution of alkalies in the pegmatite. Orville (1963) showed that diffusion through a hydrous gas under a temperature gradient is an effective mechansim for differentiating alkalies, and that feldspar in the cooler environment, which in a pegmatite would ordinarily be its upper part, becomes enriched in Or relative to Ab. Jahns and Burnham (1958, 1962, 1969) suggest diffusion together with actual upward movement of the gas to account for some of the differentiation effects of pegmatites.

The nearly identical compositions in two drill holes, 60 feet apart, leave no doubt that the process had a high degree of regularity and was unimpeded in its operation. In the Hugo pegmatite most of the differentiation of alkalies probably was before the fluid began to crystallize (Norton *et al.*, 1962, p. 119–120). There is no temptation to revise previously expressed views (Norton *et al.*, 1962, p. 100–103) that concentrations of albite-rich rock in the lower part of a pegmatite need not be a product of albitization or of an albite-muscovite replacement stage separate from primary crystallization. Nevertheless, remnants of gas persisting after the rock solidified can have promoted modest rearrangement of material as the feldspars adjusted to lower temperatures, for not only did the original potassic feldspar exsolve to form perthite, but also the plagioclase lost whatever potassium it originally possessed.

The abundance of corundum in the norm and muscovite in the mode suggests a greater kinship with zoned pegmatites than with unzoned pegmatites. In 73 unzoned pegmatites of the Black Hills for which modes are provided by Redden (1963, p. 238–239), the median value is 4 percent muscovite, and only 10 of these pegmatites have more than 5 percent muscovite. Yet many of the modes of zoned pegmatites examined by Redden (1963, p. 225–227) have an abundance of muscovite. Similarly, in the Quartz Creek district, Colorado, all but a few of the homogenous pegmatites contain 3 percent or less muscovite, but larger amounts of muscovite are found in many differentiated pegmatites (Staatz and Trites, 1955, p. 66–107; Norton, 1966, p. 5–9, pl. 1). According to Burnham (1967, p. 42–43), muscovite crystallizes from granitic magmas of high water content and correspondingly high water pressure. Furthermore, the uniformity of the Al_2O_3 content of the main body of this pegmatite, which shows that Al was not transported a noticeable distance, implies that muscovite formed mainly from the liquid. Only the muscovite of the altered wall rock of JJN 6–56 was assuredly produced by pneumatolytic or hydrothermal means.

The quartz-perthite fracture fillings have compositions that are common in late stage products of Black Hills pegmatites. Not only do many such fracture fillings appear in other pegmatites and in Harney Peak Granite, but also inner zones of many zoned pegmatites are of similar composition. Though the drilling has not entirely excluded the possibility that this pegmatite has a small quartz-perthite core or even a quartz core, it leaves little doubt that any trend toward such compositions, which are near the SiO_2-$KAlSi_3O_8$ sideline of Figure 4, was a subordinate element in the petrogenesis.

In short, the analytical data reported here represent circumstances in which differentiation has become noticeable but its effects are almost entirely confined to potassium and sodium. Bulk composition is at the granite minimum, and compositions of individual samples are on one side or the other of the minimum according to their alkali content. The host rock of quartz-mica schist reacted slightly near the pegmatite contact, but otherwise it was a virtually inert container in which magmatic crystallization proceeded.

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