Pegmatite Investigations 1942–1945 Black Hills, South Dakota

By LINCOLN R. PAGE *and* OTHERS

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Descriptions, maps, and diagrams of deposits of mica, beryl, lithium, tantalum, tin, and feldspar

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FOREWORD

This report is based on field work in the Black Hills between 1942 and 1945 by geologists of the U. S. Geological Survey as part of its program of Strategic Mineral Investigations. The work was carried on by the eleven authors working in teams, or individually with close cooperation of other members of the group. Therefore, although the senior author is primarily responsible for the sections of the report that are not ascribed to individual members, the entire report embodies the efforts of the group, which consisted of Lincoln R. Page, James J. Norton, Walter C. Stoll, John B. Hanley, John W. Adams, Lloyd C. Pray, Thomas A. Steven, Max P. Erickson, Peter Joralemon, Robert F. Stopper, and Wayne E. Hall.

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By Lincoln R. Page and Others

ABSTRACT

The pegmatites of the Black Hills, South Dakota, occur in two main areas—one around the Harney Peak uplift in the southern Black Hills, and the other on the Nigger Hill uplift in the northern Black Hills. The Nigger Hill area in Lawrence County, known as the Tinton district, is primarily a source of tin, tantalum, and lithium minerals. The Harney Peak area includes three mining districts. The Keystone district, in Pennington and Custer Counties, extends along the northeast and east flanks of Harney Peak. Since 1898 it has been one of the largest domestic sources of lithium minerals, and also has produced feldspar, beryl, scrap and sheet mica, tin, and tantalum minerals. The Hill City district, in Pennington County, is along the north and northwest flanks of Harney Peak. In the past, tin was the main product from pegmatites of the district, but in 1944 and 1945 it produced sheet and scrap mica, feldspar, and lithium minerals. The Custer district, in Custer County, includes all of the area underlain by pre-Cambrian rocks south of the Hill City and Keystone districts, along the southern flank of Harney Peak. This district is the main source of sheet mica in the Black Hills. In addition, it has been the largest producer of columbite-tantalite in the southern Black Hills and is second to the Keystone district as a source of lithium minerals, feldspar, and beryl. Since 1879 the Harney Peak area has yielded sheet and scrap mica, beryl, columbite-tantalite, microlite, amblygonite, spodumene, lepidolite, pollucite, rose quartz, feldspar, and cassiterite valued at more than $6,000,000.

Between 1939 and 1945 seventeen members of the U. S. Geological Survey, working for various periods of time, made many detailed studies of the Black Hills pegmatites to assist in the production of sheet mica, beryllium, tantalum, and lithium minerals needed for war uses. Part of this work was undertaken in cooperation with the U. S. Bureau of Mines, the Metals Reserve Company, and the Colonial Mica Corporation. This report is concerned primarily with the mica, beryl, tin, and lithium deposits of the Harney Peak area, although the Giant-Volney lithium and tantalum deposit of the Tinton district is also described.

The Black Hills are a range of mountains carved from a domal uplift 60 miles wide and 125 miles long in the direction of the main, north-northwest to south-southeast axis. Pre-Cambrian rocks crop out in the central Black Hills along the axis of the uplift in an area 60 miles long and 25 miles wide; the Keystone, Custer, and Hill City districts are at the southern end of this belt of pre-Cambrian rocks. Paleozoic and younger rocks dip outward from pre-Cambrian terrane. The pre-Cambrian rocks of the Tinton district are exposed on a small domal uplift isolated from the main pre-Cambrian area by sedimentary rocks. Harney Peak, in the southern part of the main area of pre-Cambrian rocks, is composed largely of pegmatitic granite surrounded by metamorphic rocks that in general dip outward from it. The Harney Peak granite crops out in a roughly circular area 10 miles in diameter. Most of the pegmatites examined intrude highly folded and faulted schists, gneisses, and quartzites, although some occur in granites. In the Tinton district, Tertiary monzonite, lamprophyre, and alkalic rocks intrude the pegmatites and metamorphic rocks, but Tertiary intrusions are not exposed in the Harney Peak area. In the Tinton district gold-bearing sulfide veins are clearly younger than the Tertiary intrusive rocks.

The pegmatites of the southern Black Hills occur within an area of about 275 square miles. Reconnaissance suggests that most of them dip outward from the Harney Peak granite. They are sparse in some places and closely spaced in others. About 1,500 are known in an area of 13 sq miles that forms part of the Custer district. In the Tinton district about 200 have been mapped in an area of 6 sq miles.

The pegmatites range from a few inches to more than a mile in length and from a fraction of an inch to more than 500 ft in width, but most pegmatites now mined are less than 1,000 ft long, and many are less than 200 ft. Few are more than 100 ft wide. Most bodies are tabular or thinly lenticular in plan and section, but others are branching, irregular, or teardrop-shaped. A few are pipe-like, arcuate, or sinuous. The shape is influenced by the type of wall rock; the more irregular, branching bodies occur in quartzite, granite, and other massive rocks, and the more tabular, lenticular, pipe-like, teardrop-shaped, and sinuous bodies occur in schistose rocks.

The most abundant minerals of South Dakota pegmatites are the plagioclase feldspars (oligoclase and albite), the potash feldspars (perthite and microcline), and quartz. In a few pegmatites spodumene, lepidolite, muscovite, and tourmaline are major constituents. The common accessory minerals are tourmaline, beryl, garnet, biotite, apatite, lithiophilite-triphylite and associated phosphates, amblygonite, spodumene, lepidolite, zinnwaldite, columbite-tantalite, cassiterite, magnetite, pyrite, uranium minerals, löllingite, and arsenopyrite. Less common are topaz, pollucite, chrysoberyl, tapiolite, microlite, siderite, galena, sphalerite, andalusite, sillimanite, graphite, and others.

The minerals are uniformly distributed in many pegmatites, but in others they tend to be concentrated in specific structural units. South Dakota pegmatites have been classified on the basis of mineral distribution and texture: (1) "Unzoned"—pegmatites that have mineral composition and texture uniform from wall to wall, (2) "Zoned"—pegmatites that have units of contrasting composition and texture, (3) "Homogeneous"—pegmatites that have uniform composition and texture but have a finer-grained layer at the contacts. The Black Hills pegmatites can also be classified on the basis of their structural relationships to the wall rocks: (1) those that follow the structure of enclosing metamorphic rocks, (2) those that cut across the structure of metamorphic and granitic rocks, and (3) those that grade imperceptibly into granite or aplite.

The internal lithologic and structural units of pegmatites are known as (1) "zones"—units that are roughly concentric around a "core" and reflect the shape of the pegmatite body, (2) "fracture-filling units"—pegmatite that fills fractures in pre-existing pegmatite, and (3) "replacement units"—pegmatite that owes its position to replacement of pre-existing pegmatite.

A definite sequence of mineralogic units has been recognized

in South Dakota pegmatites. Normally these occur as zones, but under special conditions they may occur as fracture fillings or replacement bodies without reversal of the sequence. The assemblages of essential minerals in these units, in the probable order of decreasing age, are: (1) muscovite, quartz, plagioclase; (2) quartz, plagioclase; (3) perthite, quartz, plagioclase; (4) perthite, quartz; (5) perthite, quartz, plagioclase, amblygonite, spodumene; (6) plagioclase, quartz; (7) plagioclase, quartz, spodumene; (8) quartz, spodumene; (9) plagioclase, quartz, lepidolite; (10) quartz, microcline; (11) microcline, plagioclase, lithia-mica; and (12) quartz. In some pegmatites two or more of these assemblages may be telescoped or combined. Some assemblages can be subdivided on the basis of accessory minerals.

The constancy of the sequence of mineral assemblages, the deformation features in the wall rocks, the internal and external structural features of the pegmatites, mineral variations, textural characteristics of the pegmatites, and the scarcity of evidence of hydrothermal action, all indicate that most units of the South Dakota pegmatites were formed by crystallization in an essentially closed system. Evidence for migration of materials outward from the pegmatite liquid is found in the development of granulite formed from schist at the contact of the pegmatite and formation of replacement bodies from earlier formed zones in the pegmatites themselves. This, however, is a very minor part of the pegmatite history. Processes other than simple crystallization must be considered in explaining the origin of certain pegmatite units. Liquid immiscibility, crystal settling and rising, convection, gaseous transfer, hydrothermal replacement, and other processes probably are involved in the formation of some units of pegmatites.

Much of the work in 1943 and 1944 pertained to mining of mica of "strategic" quality and was done with the cooperation of the Colonial Mica Corporation and the U. S. Bureau of Mines. The physical and electrical properties of South Dakota sheet mica and the methods of preparation and mining in use during this period are described. Geologic study of mica deposits indicates that they occur in definite positions in pegmatites and that their structure is predictable within limits. Three types were recognized: (1) wall-zone deposits, (2) intermediate-zone deposits, and (3) replacement deposits. Wall-zone deposits yielded the bulk of the mica. This type of deposit contains as much as 50 percent mica, but books containing sheet mica recoverable by hand sorting rarely exceed 5 percent, of which less than one-fifth is recoverable as punch and sheet mica. Reserves of sheet, punch, and scrap mica are estimated to be sufficient for several years, if mined at the same rate as in the period 1943–1945.

Deposits in the Black Hills have been the largest domestic source of beryl. During the period 1943–44 approximately 500 tons were produced from 68 mines and prospects. Beryl deposits are of 6 main types: (1) wall- and border-zone, (2) intermediate-zone, (3) core, (4) fracture-filling, (5) replacement, and (6) vein deposits.

Most of the beryl has come from intermediate-zone deposits n which concentrations are most common in: (1) the inner part of mica-bearing zones, (2) amblygonite-bearing zones, and (3) the outer parts of spodumene-quartz, lepidolite-quartz, perthite-quartz, or quartz pegmatite units. The shape, color, and composition of beryl varies with position in the pegmatite and with the associated minerals. Small concentrations of beryl are not uncommon within zones, but deposits of minable size average only 0.5 to 1.0 percent and rarely contain as much as 2 percent beryl. Most of the South Dakota beryl ore sold in the past contained more than 10 percent BeO. Reserves of similar BeO content probably equal or exceed the past production.

The lithium deposits of the Black Hills have produced spodumene, amblygonite, and lepidolite. They are classified as (1) intermediate-zone, (2) core, (3) fracture-filling, and (4) replacement deposits. Spodumene has been produced from all types of deposits, but amblygonite is recovered only from intermediate zones, and lepidolite only from core deposits. Few deposits contain as much as 50 percent spodumene; the average is between 10 and 25 percent. Amblygonite deposits rarely have an average grade in excess of 15 percent, but masses up to several hundred tons have been mined. Appreciable quantities of lepidolite have been mined only at the Bob Ingersoll Dike No. 1, where part of the core was entirely lepidolite and part was mixed lepidolite, cleavelandite, and quartz.

Tantalum minerals are recovered as byproducts of pegmatite mining. They are most abundant in lithia-bearing pegmatites. The proportion of Ta_2O_5 in columbite-tantalite increases toward the center of the pegmatite. Microlite occurs only with lepidolite.

Tin occurs as cassiterite in the pegmatites and in associated "pegmatitic" quartz veins as: (1) wall-zone, (2) intermediate-zone, (3) core, (4) replacement, and (5) vein deposits.

Some feldspar-bearing pegmatites were studied in the course of other investigations, but no detailed examinations of these deposits were made. It is apparent, however, that the feldspar-rich units are similar in structure to deposits of other pegmatite minerals.

About 125 pegmatite mines and prospects are described in detail, and these descriptions serve as a basis for the broader generalizations of structure and origin.

INTRODUCTION

The Black Hills area of South Dakota has been a source of pegmatite minerals since the McMackin mica mine (now known as the Crown mine) was opened by H. E. McMackin in 1879 (O'Harra, 1902, pp. 75–77). Between 1879 and 1945, two pegmatite areas—one around the Harney Peak uplift in the southern Black Hills, and the other on the Nigger Hill uplift in the northern Black Hills—have produced mica, beryl, columbite-tantalite, microlite, amblygonite, spodumene, lepidolite, pollucite, rose quartz, feldspar, and cassiterite, valued at more than $6,000,000 (table 1).

The Nigger Hill area in Lawrence County, commonly known as the Tinton district (pl. 1), is primarily a source of tin, tantalum, and lithium minerals. The Harney Peak area includes three mining districts, each an important source of a different major pegmatite mineral. The Keystone district, in Pennington and Custer Counties, extends along the northeast and east flanks of Harney Peak. Since 1898 it has been one of the largest domestic sources of lithium minerals, and also has produced feldspar, beryl, scrap and sheet mica, tin, and tantalum minerals. Tin has been the main product from the pegmatites in the Hill City district, Pennington County, along the north and northwest flanks of Harney Peak, but in 1944 and 1945 this district was a source of sheet and scrap mica, feldspar, and lithium minerals. The Custer district, in Custer County, includes the area of pre-Cambrian rocks south of the Hill City and Keystone districts, along the southern flank of Harney Peak. This district is the main source of sheet mica in the Black Hills. In addition it has had the largest production of columbite-tantalite minerals in the southern Black Hills, and is second to

TABLE 1.—*Pegmatite minerals (except tin) produced in the Black Hills, South Dakota, 1879–1944*

Year	Feldspar [1]		Beryl [1]		Mica [1, 2]			Spodumene [3]		Amblygonite [3]		Lepidolite [3, 4]		Columbite-tantalite [1]		Rose quartz [1]
	Tons	Value	Tons	Value	Scrap (tons)	Sheet and punch (pounds)	Total value	Tons	Value	Tons	Value	Tons	Value	Pounds	Value	Value
1879-July 1, 1884						[5] 80, 135	$342, 539									
1884						[5] 18, 150	[5] 63, 525									
1884–1897																
1898								30	$750							$3, 150
1899							[2] 193, 936	500	12, 500							
1900																
1901								870	21, 750							
1902								200	5, 000							
1903								600	12, 000							
1904								250	5, 000							
1905										80	$3, 200					
1906								200	4, 000							
1907							567, 000	200	4, 000	980	39, 200					20, 611
1908								200	4, 000							
1909								90	1, 800	1,020	40, 800					
1910																
1911								?	?	300	12, 000					
1912								?	?	120	4, 800					
1913							12, 609	?	?	780	19, 500					162
1914			6	$538			7, 504			46	1, 150					404
1915							10, 914			256	5, 120					350
1916							59, 770			537	10, 740					467
1917							11, 008	1, 200	24, 000	81	1, 620					
1918			3	270			10, 464	1, 320	72, 600	180	9, 900			4, 500	$2, 250	700
1919			3	180			5, 245	1, 000	60, 000	203	9, 390			300	90	
1920							3, 875	625	30, 625					4, 000	1, 450	
1921			2	105			2, 290	595	25, 825					3, 400	1, 150	
1922			3	157			4, 980	570	19, 950	16	640	2	$50. 00	600	240	
1923	150	$600	6. 5	330			6, 480	1, 000	35, 000	37	?			1, 350	540	
1924	1, 800	7, 200					9, 267	1, 208	48, 200	151	?	24	600. 00	1, 197	598	
1925	2, 000	8, 000					19, 427	1, 000	40, 000	14	840	3	60. 00			
1926	4, 500	27, 000	25. 5	1, 271			21, 500	800	32, 000	243	10, 520			2, 100	650	
1927	4, 400		30	1, 500			26, 000			80	3, 520			1, 096	378	7, 800
1928	5, 240	125, 000								100	4, 400			34, 899	26, 332	
1929	3, 800		222. 5	12, 238			9, 513	40	?					22, 117	17, 261	
1930	7, 500		7	350										4, 100	2, 870	
1931	11, 062	39, 013					2, 400							300	210	
1932	6, 067	22, 256					1, 949									
1933	3, 220	12, 058	83. 5	2, 914			2, 400			55. 6	2, 224					
1934	9, 190	30, 892	25	875			6, 650	26	?	[6] 519. 7	22, 788	15	300. 00	425	168	750
1935	22, 473	78, 656	60	1, 800			3, 440			134	4, 520			7, 900	5, 530	850
1936	32, 144	103, 671						640	?	500	20, 560	2	40. 00			
1937	41, 392	158, 976						778. 7	?	131	4, 240	162. 3	3, 164. 36			
1938	42, 297	122, 467						18	?	[7] 377	15, 960	556. 73	11, 051. 23	33, 922	?	
1939	48, 328	133, 893	84	?	[8] 1, 200		[8] 14, 400	[8] 680	[8] 17, 000	160	6, 400	897. 82	17, 507. 49	35	?	[8] 2, 000
1940	54, 692	157, 323	74	2, 276	[8] 1, 722	[8] 40, 567	[8] 33, 401	[8] 635	[8] 19, 050	80	3, 200	1, 127. 00	21, 966. 50	[8] 2, 000	[8] 3, 000	[8] 3, 200
1941	59, 015	170, 723	151	8, 976	[8] 2, 124	[8] 307, 323	[8] 71, 987	2, 191. 6	[8] 76, 245	132	4, 752	1, 374. 24	30, 920. 30			
1942	64, 842	225, 410	205	18, 433	2, 545	399, 224	120, 266	[9] 3, 162. 2	[8] 98, 130	336	?	1, 292. 42	29, 079. 45	200	?	
1943	70, 913	342, 643	238	29, 688	2, 234	[10] 274, 515	[10] 457, 849	4, 303	?	814	?	1, 579. 65	71, 084. 25	837	?	
1944	64, 806	288, 188	306	44, 565	2, 558	[10, 11] 72, 164	[10] 455, 612	?	?	?	?	809. 9	40, 495. 00	?	?	?
Total	564, 831	2, 053, 969	1, 535	126, 466	12, 383	1, 192, 078	2, 558, 200	24, 932. 5	669, 425	8, 463. 3	261, 984	7, 856. 06	226, 318. 58	125, 278	62, 717	40, 444

[1] The production figures for 1923-36, except where noted, are from Cummings, J. B., Harris, Wilbur, and Lincoln, F. C.: Pegmatite mining in South Dakota, p. 9, Brookings, South Dakota State Planning Board, 1937. Figures for 1936–43 are from the U. S. Bureau of Mines, Minerals Yearbook, except where indicated.

[2] Production records for scrap, sheet, and punch mica are incomplete. Cummings, J. B., Harris, Wilbur, and Lincoln, F. C., give total value for 1879–1901 as $600,000. Sheet and punch mica include all types of preparation from untrimmed to full trimmed.

[3] After F. C. Lincoln, U. S. Bureau of Mines unpublished report, 1943. Revised in part by L. R. Page from owner's figures.

[4] Triphylite production in 1907–08 was 100 tons valued at $3,000.

[5] After O'Harra, C. C., The mineral wealth of the Black Hills: South Dakota School of Mines Bull. 6, pp. 75–76, 1902. Possibly there is duplication. The Custer Chronicle, Custer, S. D., records a production of 8,000 lb in 1880 and 4,842 lb in 1881 from the McMackin (Crown) mica mine.

[6] Includes production of Beecher Lode for 1933.

[7] Included production of High Climb for 1934–38.

[8] From reports of the South Dakota State Mine Inspector.

[9] Includes production of Dyke Lode for 1936–1942.

[10] From records of the Colonial Mica Corporation.

[11] Includes only trimmed sheet.

the Keystone district as a source of lithium, feldspar, and beryl.

Between 1939 and 1945 the U. S. Geological Survey, as part of its program of Strategic Minerals Investigations, made many detailed studies of the Black Hills pegmatites in an attempt to find, and to assist in the production of mica, beryl, tantalum, and lithium minerals needed for war uses. This work, in part, was carried on in conjunction with the program of sampling, underground and surface exploration, and diamond drilling conducted by the U. S. Bureau of Mines. Detailed mapping of many individual properties was done at the request of Metals Reserve Company, its subsidiary Colonial Mica Corporation, and other Federal agencies charged with increasing domestic mineral production during the war.

Seventeen members of the U. S. Geological Survey worked for various lengths of time on pegmatites of the Black Hills. The first work was done by Ward C. Smith, Lincoln R. Page, and others in connection with investigations of tin reserves of the Tinton district (Smith and Page, 1941). The present report is concerned primarily with the mica, beryl, tin, and lithium deposits of the Custer, Hill City, and Keystone districts of the southern Black Hills, but detailed maps of the Giant-Volney columbite-tantalite and spodumene deposit in the Tinton district, made in 1943 and 1944, are included. Most of the mapping was done with plane table and alidade, transit and tape, or compass and tape, on scales that range from 1 in. to 10 ft to 1 in. to 50 ft. In mapping, the chief purpose was to define parts of pegmatites that might be sources of minerals of strategic or commercial value. Operating mines were inspected and mapped at different stages of development to obtain a maximum of information, but lack of time prohibited detailed mineralogic studies, and it was not possible to revise some maps that were made early in the program. Consequently, some of the early maps lack the detail and refinements of those made when workers had gained experience from continued work on the project.

The first work in the Custer, Hill City, and Keystone districts was done from June to December 1942, by Walter C. Stoll, assisted by Wayne E. Hall. Reconnaissance and detailed mapping were done, and detailed estimates of available reserves of sheet mica, beryl, and lithium minerals were prepared. Lincoln R. Page and John B. Hanley spent the month of July investigating tin-, tantalum-, lithium-, beryllium-, and mica-bearing pegmatites. From May 1943 to July 1945, a field party under the direction of Lincoln R. Page was engaged in detailed mapping of mica, beryl, columbite-tantalite, and spodumene deposits. James J. Norton, Lloyd C. Pray, Peter Joralemon, John W. Adams, Thomas A. Steven, Robert F. Stopper, Max P. Erickson, Albert F. Trites, Jr., and John B. Hanley assisted in this work for various periods of time. Many of the maps and mine descriptions in this report are the combined results of work by several men, and specific credit for individual descriptions is given where possible.

The pegmatite program was carried out under the general supervision of D. F. Hewett and Ward C. Smith during the years 1939–42, G. R. Mansfield and H. M. Bannerman during 1942–44, and E. N. Cameron during 1944–45. R. H. Jahns, E. N. Cameron, and S. E. Clabaugh critically reviewed this manuscript and made many helpful suggestions.

Throughout the Geological Survey's investigations in the Black Hills the owners of the mining properties, without exception, cooperated willingly in making available to us production figures, maps, reports of private engineers, and other related information. Because it is impossible to mention all the operators by name, acknowledgment of their assistance is given as a group. The cooperation of the U. S. Bureau of Mines, through district engineer E. Y. Dougherty and project engineers Fremont F. Clarke, Gerald A. Munson, and Clair Smith, is appreciated. Hubert O. DeBeck and Stewart Ferguson, district managers, and George Purcell, vice-president, of Colonial Mica Corporation made available the data on mica production, qualification, and purchases from 1942 through 1945. Special acknowledgment is due the Custer Mining Account for valuable information relating to the methods of preparing sheet mica and for the use of their electrical testing machine.

HISTORY

Sheet mica was the first pegmatite mineral mined in the Black Hills. It was first produced from the McMackin (Crown) mica mine at Custer in 1879. The opening of this mine was rapidly followed by the discovery and operation of other mines, and in 1880 the district produced more than 8,000 lb of sheet mica, primarily from the McMackin and Lost Bonanza mines (Custer Chronicle, June 18, 1881). In June 1881 there were more than 100 mica prospects in the district, of which 25 were partly developed and 4 were being worked for market. Mica mining continued until 1884 and a total of about 98,285 lb of rough sheet, valued at about $406,064, was produced (O'Harra, 1902, pp. 75–77). According to Sterrett (1923, p. 289) there was little production from 1884 to 1899. Between 1906 and 1911 the Westinghouse Electric and Manufacturing Co. reopened the New York, White Spar, and other mines, and the yearly mica production increased to as much as 1,500,000 lb of rough sheet and 1,000 tons of scrap. After operation of these mines was suspended in 1911, little sheet mica was produced until 1942, when more than 300,000 lb of sheet and untrimmed punch was sold. Some scrap mica, however, has been produced continuously as a byproduct of other pegmatite mining.

In December 1942 Colonial Mica Corporation started purchasing mica of "strategic" quality at a subsidy price, and the yearly production rose to a value of nearly $500,000 by the time the Colonial Mica Corporation's buying program was terminated on April 1, 1945. Mica from more than 275 mines and prospects was sold during this period.

After the first period of mica mining, which lasted from 1879 to 1884, active explorations for tin began in the Black Hills. Cassiterite was identified as early as 1876 (Headden, 1890, pp. 347–350) in gold dust from Bear Gulch in the northern Black Hills, and placer mining was undertaken in 1884. In 1883 cassiterite was recognized in the Etta pegmatite at Keystone (Blake, 1885, p. 602) and between 1884 and 1893 the Harney Peak Tin Mining, Milling, and Manufacturing Co. extensively prospected the southern Black Hills. During this period more than 205,000 lb of metallic tin, valued at $43,000 was produced (Cummings and others, 1936, pp. 1–4). From 1901 to 1910 more than 108,000 lb of metallic tin, valued at $32,000 was recovered, mainly by the Tinton Reduction Co. in the Tinton district, though minor quantities came from the southern Black Hills. Between 1911 and 1920 the main production was from the Hill City district; minor quantities were produced from the Tinton district. About 38,000 lb of metallic tin, valued at about $16,000, was produced during this period. After seven years of idleness, mining in the Tinton district was resumed and 8,602 lb of metallic tin, valued at $3,412, was produced during the years 1927–36. In 1939 the U. S. Bureau of Mines extensively explored the most promising tin pegmatites of the Tinton district and found no deposits of economic importance. Wartime demands for tin caused Barium Stainless Steel Co. to reopen some of the old mines in the Hill City district in 1942, but no substantial production was attained before the close of operations in 1944. The total production of metallic tin for the Black Hills from 1884 to 1936 was about 180 tons, valued at about $95,000.

Spodumene was the third pegmatite mineral exploited in the southern Black Hills and amblygonite was the fourth. Production of lithium minerals started in 1898, when Reinbold and Co. shipped 30 tons of spodumene from the Etta mine (Connolly and O'Harra, 1929, p. 240). This company continued to produce spodumene from the Etta mine until 1905, when Maywood Chemical Co. leased the property. In 1908 Maywood purchased the Etta mine and since then has operated it intermittently. The Etta mine has been the largest single source of spodumene in the Black Hills. Prior to 1937 the only other spodumene producers were the Wood Tin, Boomerang, Sunday Fraction, and Palmer Gulch mines, which produced 800 tons from 1899 to 1901 (O'Harra, 1902, p. 79); the Bob Ingersoll mine, which produced 8 tons in 1924 and 26 tons in 1934; and the Dewey mine, which produced 40 tons in 1929. From 1937 to 1945 there was intermittent but appreciable production from other properties in the Custer, Hill City, Keystone, and Tinton districts.

The first recorded amblygonite production came from the Tin Queen mine about 1905 (Hess, 1911, p. 652). At this time Reinbold and Co. changed from spodumene to amblygonite as a source of lithia, with the result that amblygonite production in the Keystone district increased until 1916. From 1905 to 1916 almost no spodumene was produced in the Black Hills, but in 1916 amblygonite was not in demand, and spodumene again became the dominant source of lithium. Between 1916 and 1945 amblygonite was produced intermittently from several mines in the Keystone, Custer, Hill City, and Tinton districts.

The first shipment of lepidolite was made in 1922 from the Bob Ingersoll mine, but intensive mining for this mineral did not start until 1937; it reached its peak in 1943. Lepidolite operations ceased at the Bob Ingersoll at the end of 1944. The only other lithium-bearing mineral sold from the Black Hills is triphylite. Two shipments totaling 100 tons were made in 1907 and 1908 (Ziegler, 1914, p. 656).

The presence of beryl in pegmatites of the Black Hills was known as early as 1883 (Cummings, Harris, and Lincoln, 1937, p. 4), but production was first recorded in 1914 when 6 tons was sold. The 25.5 tons obtained in 1926 exceeded the amount produced prior to that year, and since then the southern Black Hills has been the largest domestic source of beryl. Discovery of large crystals in the Bob Ingersoll mine in 1926 focused attention on beryl. Peak production was attained under the stimulus of subsidy prices in 1943 and 1944.

The tantalum-bearing minerals, although among the first to be discovered, were of value only as specimens until 1918, when A. T. Roos of Deadwood sold 4,500 lb of columbite-tantalite for $2,250 (Hess, 1919, pp. 807–808; Cummings, Harris, and Lincoln, 1937, p. 53). Since then there has been intermittent production from all of the pegmatite districts. Until 1928 this mineral was produced as a by-product of other mining, but in that year the Fansteel Corporation worked the Giant-Volney pegmatite in the Tinton district solely for columbite-tantalite. In 1943, microlite, a calcium tantalate, was discovered by the U. S. Geological Survey geologists in heavy concentrates from the Bob Ingersoll mill. About a ton of this mineral was recovered before operations ceased in 1944. The largest sources of tantalum-bearing ores have been the Giant-Volney pegmatite in the Tinton district, the Etta, Bob Ingersoll, Hugo, and Peerless mines in the Keystone district, and the Beecher, Tin Mountain, and Dakota Feldspar mines in the Custer district.

Feldspar, one of the most important pegmatite minerals, was first produced by the Keystone Feldspar and Chemical Co. in 1923 (Cummings, Harris, and Lincoln, 1937, p. 20). In 1925 the Dakota Feldspar Co. started production at the Dakota Feldspar mine and in 1928 the Abington Sanitary Manufacturing Co. began shipping from the White Elephant mine in the Custer district. Grinding mills at Keystone and Custer, started in 1929 and 1936 respectively, treat a large part of the crude feldspar before it is shipped to eastern markets.

GENERAL GEOLOGY

The Black Hills of South Dakota are a range of mountains carved from a domal uplift. They are oval in plan, 60 miles wide, and 125 miles long in the direction of the main, north-northwest to south-southeast, axis. The mountains rise as much as 4,000 ft above the surrounding plains. The highest summit is Harney Peak, 7,240 ft above sea level; mountains in the Tinton district, at the north end of the Black Hills rise to altitudes greater than 6,000 ft. Pre-Cambrian rocks crop out in the central Black Hills along the axis of the uplift in an area 60 miles in length and 25 miles in maximum width. Paleozoic and younger sedimentary rocks dip outward from this pre-Cambrian terrane. The pre-Cambrian rocks of the Tinton district are exposed on a domal uplift isolated from the main pre-Cambrian area by sedimentary rocks. Harney Peak, in the southern part of the main area of pre-Cambrian rocks, is composed largely of pegmatitic granite surrounded by metamorphic rocks that in general dip outward from it. The pegmatite districts of the southern Black Hills are along the flanks of this granite mass and to the south of it.

The general geology of the southern Black Hills has been described by Newton and Jenny (1880), Darton (1909), Darton and Paige (1925), Crosby (1888), Carpenter and Hoffman (1888), and Van Hise (1890, pp. 203–204). During the present work no attempt was made to restudy the regional, structural, or petrographic features of the pre-Cambrian rocks, because the main problem was to make economic studies of individual pegmatite mining properties. Most of the pegmatites examined intrude highly folded and faulted schists, gneisses, and quartzites, although some occur in granites. At the edges of the area of pre-Cambrian rocks the pegmatites and metamorphic rocks are directly overlain by Cambrian quartzite. In the Tinton district, Tertiary monzonite, lamprophyre, and alkalic rocks intrude both the metamorphic rocks and the pegmatites, but Tertiary intrusions are not exposed in the pegmatite-bearing areas of the southern Black Hills. Gold-bearing sulfide veins cut the pegmatites in both areas. In the Tinton district these sulfide veins are clearly younger than the Tertiary intrusive rocks.

METAMORPHIC ROCKS

The pegmatites of the Custer and Hill City districts are intruded into various folded, dark-gray, fine- to coarse-grained, quartz-mica schists and quartzites. South and east of the town of Custer the schists contain more or less sillimanite and garnet, and in places are mottled with patches of coarse-grained muscovite derived from sillimanite. Southwest of Custer there are small areas of sillimanite-bearing schist, but in general the varieties of mica schist observed show a lower grade of metamorphism. Quartzite is abundant southeast of Custer and northeast of Hill City.

In the Keystone district hornblende schists and gneisses occur interbedded with quartz-mica schists, quartzites, and graphitic schists. The metamorphic rocks of the Tinton district are similar to those in the Keystone district.

IGNEOUS ROCKS

HARNEY PEAK GRANITE

In the southern Black Hills the Harney Peak granite of pre-Cambrian age, a roughly circular body 10 miles in diameter, intrudes the metamorphic rocks. Many granite sills and dikes occur around, and particularly to the south of, the main body. The Harney Peak granite and the mechanics of its intrusion have been discussed by Paige (Darton and Paige, 1925, pp. 4–5), Balk (1931, pp. 736–748), Runner (1928, p. 186 and 1943, pp. 431–458), Taylor (1935, pp. 278–292), and others. Runner believes that the Harney Peak dome was formed by the multiple injection of sills of pegmatitic granite at the margins of a laccolith-like structure. The other investigators considered the main body to be stocklike in shape.

The Harney Peak granite is light gray to pink and of varied texture. Most of the rock has a grain size between half and one inch, but locally microcline-perthite crystals as much as a foot in diameter are scattered through the finer-grained matrix. In places coarse-grained pegmatite is abundant as irregular streaks, pods, and lenses that grade imperceptibly into the granite, and the pegmatites of the region are believed to be closely related to the granite in age and origin. Reconnaissance examinations suggest to the writers that much of the Harney Peak granite mapped by Paige is similar in texture to the fine-grained, outer zones of some pegmatites in the southern Black Hills. Although in many places the granite grades imperceptibly into coarser-grained granite pegmatite, in other places dikes of coarse-grained pegmatite, obviously emplaced along fractures, cross the granite. Some of the pegmatites that grade into granite show zonal distribution of minerals similar to that of pegmatites in schistose country rock. Within the granite bodies there are also numerous tabular zoned pegmatites that have sharply defined walls. The Gap, Lake, and November mines are in pegmatites of this type.

PEGMATITES

DISTRIBUTION

The pegmatites of the southern Black Hills occur in an area of about 275 sq miles (pl. 1). Available information indicates that most of them dip outward from the Harney Peak granite. In some parts of the area they are scattered widely and in others they are closely spaced. Pegmatites are most abundant south of the Harney Peak granite in the Custer district, where Gwynne (1944, p. 23) mapped about 1,500 pegmatites in about 13 sq miles. This is the only detailed mapping of its kind, and there is no information as to the total number of pegmatites in the southern Black Hills area. In the Tinton district about 200 pegmatites have been mapped (Smith and Page, 1941) in an area of about 6 sq miles.

CLASSIFICATION

The pegmatites of the Black Hills are light-colored rocks of varied texture that are composed essentially of quartz and feldspar with smaller quantities of other minerals. They approach granite in composition and therefore have been classed as granite pegmatites.

Pegmatites, as a group, show extreme variation in mineralogy, texture, and structure, and for this reason it is difficult to classify them into types without having numerous exceptions. Engineers and miners have classified South Dakota pegmatites on the basis of the main commercial product recovered, calling them sheet-mica, scrap-mica, beryl, spodumene, lepidolite, amblygonite, feldspar, or tin pegmatites. This classification ignores the greater number of pegmatites that have no economic importance and also the fact that a feldspar or scrap-mica pegmatite often becomes a lepidolite or spodumene pegmatite under changed economic conditions. Furthermore, many pegmatites yield more than one product at a time. Consequently, geologists and mineralogists have proposed classifications based on mineralogy, texture, structure, chemical composition, or a combination of these features. Schaller (1933, pp. 144–145) classified the pegmatites on the basis of mineralogy as follows:

> Simple granitic pegmatites consist essentially of microcline or of microcline and quartz and do not contain any quantity of other minerals. Complex pegmatites are those which in addition to microcline and quartz contain an abundance of one or more of such minerals as albite, beryl, topaz, cassiterite, micas, tourmaline, garnets, lithium minerals, rare earth minerals, the columbates and tantalates, the phosphates, and others, many of which contain rarer elements.

Johnston (1945, pp. 1024–1025) divided the microcline-muscovite-quartz pegmatites of northeastern Brazil on the basis of the degree of internal differentiation. He applied the term "homogeneous" to "tabular dikes" that, in general, "have a fairly uniform texture from wall to center and do not contain crystals of remarkable size," and "heterogeneous" to "lens-shaped dikes" showing "a high degree of differentiation with walls of muscovite, gigantic crystals of microcline in the interior of the dike, and a central core or nucleus of quartz." Cameron and others (1945, pp. 372–373) use the terms "unzoned" and "zoned" pegmatites to distinguish the two major types in New England. As these authors use the term "unzoned" for "any pegmatite which appears essentially homogeneous apart from the presence of a border zone" (a finer-grained layer at the contact), the pegmatites included would be similar to the "homogeneous" pegmatites described by Johnston, who illustrates (1945, pl. 1, fig. 1) a homogeneous dike with finer textured rock at the contact. The "zoned" pegmatites include those bodies in which the minerals are distinctly grouped into structural units of contrasting composition or texture that have a systematic arrangement with respect to the walls of a given body.

During the field work in South Dakota the writers also subdivided the pegmatites into "zoned" and "unzoned" types. It now seems desirable, however, to reserve the term "unzoned pegmatite" for the small irregular pegmatites that occur in granite or lit-par-lit gneisses, and show in the strictest sense no layering or systematic arrangement of minerals or textures. Therefore, Johnston's term "homogeneous pegmatite" will be used in this report, as he apparently used it, to include all of the pegmatites that show a uniformity of texture from the wall to the center with the exception of a border zone. In South Dakota the homogeneous type includes pegmatite bodies of a number of mineral compositions, just as the zoned and unzoned pegmatites do. The Black Hills pegmatites may be divided also into three groups on the basis of their relation to the structure of the wallrocks: (1) those that are concordant with the structure of the enclosing metamorphic wallrock, (2) those that cut across the structure of the older metamorphic and granitic rocks, and (3) those that grade imperceptibly into the enclosing granite or aplite. Homogeneous and zoned types occur in each of these groups, but the unzoned type is most common in groups 2 and 3.

SIZE AND SHAPE

The individual pegmatites of each district differ greatly in size and shape. They range from a few inches to more than a mile in length and from a fraction of an inch to more than 500 ft in width. Most of the pegmatites that are being mined are less than 1,000 ft long, and many are less than 200 ft. They are rarely more than 100 ft wide. The greater number are tabular or thinly lenticular in plan and section, but bodies that are branching, irregular, and shaped like tear-drops are common. Pipelike, arcuate, and sinuous shapes are observed occasionally. Some pegmatites, particularly those of the homogeneous type, are very uniform in thickness but others pinch and swell along both strike and dip. In plan and in section thick lenticular bodies characteristically show one blunt end, usually the crest in plunging pegmatites, and one that is either less blunt or very thinly tapered. The more nearly tabular bodies have two tapered ends. As shown in figure 1 many of the bodies mined to date narrow with depth, although some, such as the White Bear pegmatite,[1] seem to thicken below the surface.

The shape of the pegmatite is somewhat related to the type of wallrock. In the more strongly foliated schists, the pegmatites tend to be lenticular or teardrop shaped like the White Star, Dyke Lode, and Bob Ingersoll pegmatites (fig. 1). Where the country rock is highly folded, the pegmatite may conform to the folds, as at the Crown, Antler, and Red Deer mica mines (fig. 1). Crosscutting pegmatites, particularly those that transect brittle rocks such as quartzite, are generally very irregular and commonly have a branching outcrop pattern. The Elkhorn pegmatite (fig. 1) is a good example of this branching type. A pegmatite may also cross pre-existing pegmatites to form a branching pattern. Some irregular pegmatites, such as the Beecher No. 2-Longview and Edison (fig. 1), are composed of two or more lenticular pegmatites that have coalesced. The pegmatites in the Harney Peak granite, such as the Gap, Lake, and November (fig. 1), are commonly tabular to flatly lenticular bodies of fairly uniform thickness.

Minor irregularities of contacts are typical of South Dakota pegmatites. They may be systematic minor undulations or "rolls" that parallel folds in the foliation or bedding of the country rock, as in the White Spar, Crown, and MacArthur, or they may be less systematic and may parallel joint surfaces, as in the Ann pegmatite. Many pegmatites that grade into the Harney Peak granite have exceedingly irregular outlines comparable to those where the wallrock is a lit-par-lit gneiss at the Mountain Beryl claim.

MINERALOGY

The most abundant minerals of South Dakota pegmatites are quartz and feldspar. In a few pegmatites spodumene, lepidolite, muscovite, and tourmaline are major constituents. The common accessory minerals include tourmaline, beryl, garnet, biotite, apatite, lithiophilite-triphylite and associated phosphates, amblygonite, spodumene, lepidolite, zinnwaldite, columbite-tantalite, cassiterite, magnetite, pyrite, uranium minerals, löllingite, and arsenopyrite. The distribution of these more common accessory minerals is shown in table 2. Less common are topaz (Dyke Lode), pollucite (Tin Mountain), chrysoberyl (Rose Quartz, Elk No. 1, and Peerless), tapiolite (Old Mike and Hardestey Homestead), microlite (Bob Ingersoll and Tin Mountain), siderite (Crown), galena (Bob Ingersoll), sphalerite (Dan Patch and Bob Ingersoll), andalusite (Etta), sillimanite (Victory No. 1), graphite (Hardestey Homestead), and others.

The homogeneous pegmatites are generally of simple mineralogy. Potash feldspar, sodic plagioclase, or both, occur intergrown with quartz, muscovite, biotite, apatite, tourmaline, or garnet. More rarely, beryl, cassiterite, lithiophilite-triphylite, magnetite, and sulfides have been observed. It is possible that many other accessory minerals will be found as the result of more detailed work.

The zoned pegmatites contain all of the accessory minerals in greater or lesser abundance and commonly these minerals are either sufficiently concentrated or of large enough size for ready recognition.

The potash feldspar of the Black Hills pegmatites is dominantly a coarsely perthitic microcline. The perthite in some Black Hills pegmatites has been described by Fisher (1945, pp. 18–20). Commonly the albite in the perthite is visible to the naked eye as irregular laminae or "veins," as in vein perthite. Where these laminae have grown together to form an irregular area, it is called "patch" perthite. Potash feldspar with visible perthitic intergrowths is referred to in this report as perthite, and nonperthitic or microscopically perthitic feldspar is designated as microcline. Microcline containing scattered inclusions of albite crystals is not classed as perthite. The perthite occurs as crystals as much as 35 ft long, with interstitial quartz or a finer-grained aggregate of quartz, albite, and more or less muscovite, garnet, beryl, tourmaline, and other accessory minerals. Perthite is most abundant in the intermediate zones of lithium-bearing pegmatites and in the intermediate zones or cores of other bodies. Microcline is most commonly observed in lithium-bearing zones or in quartz cores. In the Giant-Volney pegmatite in the Tinton district and in other pegmatites, microcline is crossed by a network of later albite veinlets that are distinct from those in perthite.

Plagioclase feldspar occurs in almost every pegmatite. Oligoclase has been identified in 7 pegmatites—the Giant-Volney in the Tinton district, the Ann, Silver Dollar, Ruby Reef, Ruby Reef No. 1, and Victory No. 1 in the Custer district, and the Hugo in the Keystone district. Undoubtedly further study would reveal other occurrences. The Victory No. 1 and Silver Dollar pegmatites contain oligoclase determined as An_{23}, but that from the Ann, Ruby Reef, and Ruby Reef No. 1 pegmatites is An_{12-20}. In the Tinton district zoned plagioclase crystals were found in which the cores were oligoclase, An_{12-15}, and the outer shells albite, An_{5-10}. The plagioclase feldspar in the other pegmatites studied is albite, An_{0-10}. In some pegmatites, particularly those that are indistinctly

[1] The names of pegmatites are economic terms and should not be considered formal stratigraphic names.

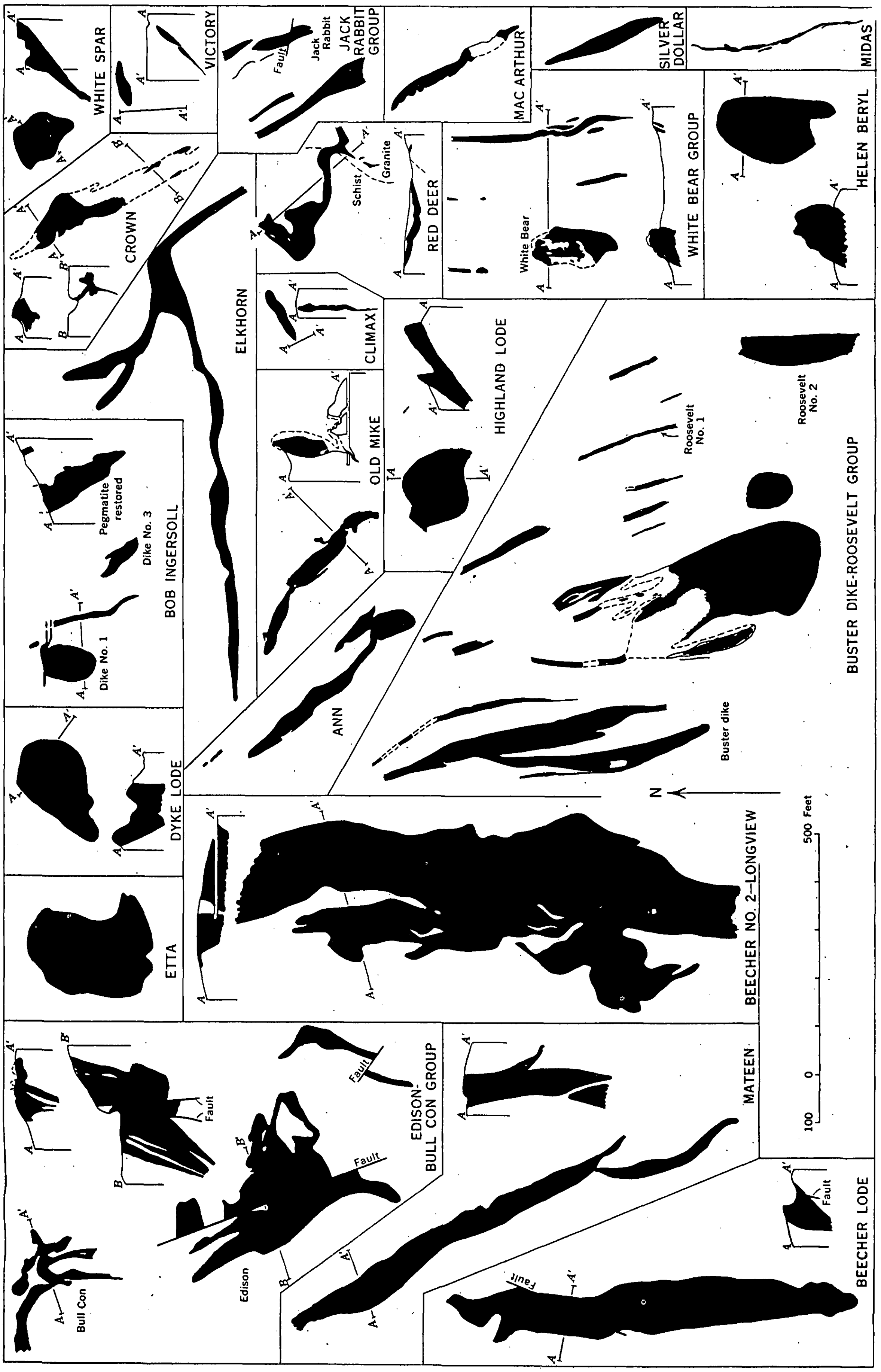

FIGURE 1.—Size and shape of typical South Dakota pegmatites.

TABLE 2.—*Mineral distribution in selected pegmatites, southern Black Hills, South Dakota*

[Compiled by John W. Adams]

	Quartz			Albite			Albite (var. cleavelandite)			Oligoclase			Perthite or microcline			Muscovite			Biotite			Lepidolite			Amblygonite			Apatite			Beryl		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Mica- and feldspar-bearing pegmatites:																																	
Ann	[1] A	--	A	--	--	--	--	--	--	A	--	C	A	--	A	C	--	M	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buster Dike	A	--	A	A	--	A	--	--	C	--	--	--	--	--	A	C	--	M	--	--	--	--	--	--	--	--	--	--	--	--	M	--	M
Crown	C	A	A	A	--	--	M	A	M	--	--	--	--	--	A	C	C	M	--	--	--	--	--	--	--	X	M	M	M	--	M	M	M
Climax	A	--	A	A	--	A	--	--	--	--	--	--	--	--	A	C	--	M	--	--	--	--	--	--	--	--	R	M	--	M	M	--	R
Elkhorn	A	A	A	A	A	M	--	--	--	--	--	--	M	A	A	M	M	M	M	M	--	--	--	--	--	--	--	--	--	--	M	M	R
Florence (Harbach)	A	--	A	A	--	--	--	--	C	--	--	--	--	--	M	C	--	M	--	--	--	--	--	--	--	--	--	--	--	--	M	--	--
Helen Beryl	A	--	A	A	--	M	M	--	--	--	--	--	M	--	A	C	--	M	M	--	M	--	--	--	--	--	--	M	--	--	M	--	M
Highland Lode (Ross)	A	A	A	A	A	--	--	--	M	--	--	--	M	A	A	M	C	--	--	--	--	--	--	--	--	--	--	--	M	--	M	M	M
Jack Rabbit	A	--	A	A	--	--	--	--	--	--	--	--	C	--	C	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	M	--	--
Josie Lode	A	--	A	C	--	--	--	--	--	--	--	--	A	--	A	C	--	M	--	--	--	--	--	--	--	--	--	M	--	--	R	--	--
MacArthur	A	--	A	A	--	--	M	--	--	--	--	--	C	--	A	C	--	M	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--
Marydale	A	--	A	C	--	--	--	--	--	--	--	--	A	--	A	M	--	M	M	--	--	--	--	--	--	--	--	M	--	M	R	--	--
Midas	C	--	A	A	--	C	--	--	--	--	--	--	C	--	A	C	--	M	--	--	--	--	--	--	--	--	--	--	--	--	M	--	--
New York	A	A	A	A	A	--	--	A	M	--	--	--	--	A	M	C	M	M	--	--	--	--	R	--	--	R	--	--	--	--	M	M	R
Old Mike	A	A	A	A	A	C	--	A	C	--	--	--	M	C	A	C	M	M	C	M	--	--	--	--	--	--	--	M	--	--	M	M	M
Punch	C	A	A	C	C	--	--	--	--	--	--	--	A	--	--	M	A	--	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rainbow Mica	A	--	A	A	--	--	--	--	M	--	--	--	--	--	A	C	--	R	--	--	--	--	--	--	--	--	--	M	--	--	--	--	R
Ray	A	--	A	A	--	--	--	--	--	--	--	--	--	--	A	C	--	C	M	--	M	--	--	--	--	--	--	--	--	--	--	--	--
Red Deer	A	--	A	A	--	M	--	--	--	--	--	--	--	--	A	C	--	M	--	--	--	--	--	--	--	--	--	--	--	--	M	--	--
Ruby Reef	A	--	A	--	--	--	--	--	--	A	--	A	C	--	A	M	--	M	M	--	M	--	--	--	--	--	--	--	--	M	--	--	--
Silver Dollar	C	C	A	--	--	--	--	--	--	A	A	--	--	A	A	M	C	--	C	M	--	--	--	--	--	--	--	M	--	M	--	--	--
Sunshine	A	--	A	A	--	C	--	--	--	--	--	--	--	--	A	C	--	M	M	--	--	--	--	--	--	--	--	--	--	--	--	--	R
Victory	A	--	A	A	--	C	--	--	--	--	--	--	--	--	C	A	--	M	--	--	--	--	--	--	--	--	--	--	--	--	R	--	R
White Bear	A	--	A	A	--	C	--	--	--	--	--	--	C	--	A	C	--	M	M	--	M	--	--	--	--	--	--	--	--	--	M	--	R
White Dog	A	--	A	A	--	A	--	--	--	--	--	--	--	--	--	C	--	M	--	--	--	--	--	--	--	--	--	M	--	M	--	--	--
White Spar	A	A	A	A	A	--	--	--	--	--	--	--	M	A	C	C	M	--	--	--	--	--	--	--	--	--	--	M	M	--	M	M	--
Lithium-bearing pegmatites:																																	
Beecher Lode	A	A	A	A	A	C	--	--	C	--	--	--	--	A	--	C	A	--	--	--	--	--	--	M	--	C	--	M	--	--	--	M	--
Beecher No. 2—Longview	A	A	A	A	A	--	--	M	M	--	--	--	--	--	A	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--
Edison	A	--	A	A	--	C	M	--	M	--	--	--	--	--	M	C	--	M	--	--	--	--	--	--	--	--	--	M	--	M	R	--	--
Etta [4]	A	A	A	A	--	--	--	M	--	--	--	--	--	A	--	C	--	--	M	--	--	--	--	--	--	--	--	--	--	--	R	M	--
Hardestey Homestead	A	A	A	A	A	--	--	C	--	--	--	--	--	A	--	C	M	--	--	--	--	--	--	--	--	M	--	--	--	--	M	M	--
Hugo [5]	A	A	A	A	M	--	--	A	C	--	--	--	--	A	M	A	M	--	--	--	--	--	X	--	--	C	--	M	M	M	M	M	--
Ingersoll Dike No. 1	A	A	A	--	--	--	A	A	A	--	--	--	--	A	C	A	C	--	--	--	--	--	--	A	--	C	--	M	M	--	M	M	M
Ingersoll Dike No. 2	C	A	A	A	--	--	--	A	M	--	--	--	--	A	--	A	A	--	--	--	--	--	--	--	--	C	--	M	M	--	M	M	--
Tin Queen [6]	A	A	A	A	A	M	--	--	--	--	--	--	C	A	A	M	C	M	M	--	--	--	--	--	--	M	--	M	M	--	--	M	--
Wood Tin	A	A	A	A	A	--	--	--	C	--	--	--	--	C	M	A	M	--	--	--	--	--	--	--	--	--	--	--	--	--	M	M	--
Dyke	A	A	A	A	A	--	--	C	C	--	--	--	M	A	--	C	C	--	--	--	--	--	--	--	--	M	--	--	--	--	M	M	--
Mateen	A	A	A	A	A	A	--	--	--	--	--	--	--	C	A	C	M	M	--	--	--	--	--	--	--	R	--	M	--	--	R	R	--
Peerless [7]	A	A	A	A	A	--	--	C	C	--	--	--	--	A	A	C	A	M	--	--	--	--	--	--	--	C	--	--	--	--	M	M	--
Custer Mountain	C	A	A	A	A	--	--	C	M	--	--	--	C	A	C	M	C	--	M	--	--	--	--	A	--	--	M	--	M	--	--	M	--

See footnotes at end of table.

TABLE 2.—*Mineral distribution in selected pegmatites, southern Black Hills, South Dakota*—Continued

	Cassiterite			Chrysoberyl [2]			Columbite-tantalite and tapiolite			Garnet			Lithiophilite-triphylite and alteration products			Löllingite and arsenopyrite			Microlite			Spodumene			Topaz			Tourmaline			Uraninite and secondary uranium minerals		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Mica- and feldspar-bearing pegmatites:																																	
Ann																												C		C			
Buster Dike									M																			M		M			
Crown								R						M														M	M				
Climax			R						R				M		M			R										M					
Elkhorn											M			M		M	M											M	M	M			
Florence (Harbach)																												M		M			
Helen Beryl													M		M													M		M			
Highland Lode (Ross)								M									M											M	C				
Jack Rabbit																												M					
Josie Lode										M																		M		M			
MacArthur										M																		M		M			
Marydale																												M		C			
Midas																												M		M			
New York		M						R															M					C	M				
Old Mike		R	R					M	M				M	M									[3] R					M	M				
Punch										M																		M					
Rainbow Mica																												M		M			
Ray										M		M																M		M			
Red Deer										M																		M		M			
Ruby Reef																												M		M			
Silver Dollar																												C	C	M			
Sunshine										M																		M					
Victory													M															M		M			
White Bear																												M		M			
White Dog													R			R												M		M			
White Spar										M				M														M	M				
Lithium-bearing pegmatites:																																	
Beecher Lode		M						M	M														C	C				M					
Beecher No. 2—Longview																							C					M					
Edison							R						M											A				M					
Etta [4]	X	X						X									X						A					M				X	
Hardesty Homestead		M						M															[3] C					M	M				
Hugo [5]		M	M					M	M								X						C					M	M	M			
Ingersoll Dike No. 1			M					M	M												M							M	M	M			
Ingersoll Dike No. 2		M	M					M	M				M	M										C				M	M			R	
Tin Queen [6]								M		M				M														M	M				
Wood Tin								M	M															M				M	M				
Dyke		M						M						M			M							C			R	M	M				
Mateen	M																							C				M					
Peerless [7]		M			R?												X											M	M			X	
Custer Mountain		R						M						M			M						C	C				M	M	M			R

[1] The vertical columns headed by the name of the mineral species are divided into three parts (1) the border and wall zones, (2) intermediate zones, and (3) core. The approximate quantity of constituent minerals in these zones are shown by letters.

A Dominant mineral in the zone.
A Abundant (15 percent or more).
C Common (5 to 15 percent).
M Minor (less than 5 percent).
R Rare.
X Reported in the literature, but the zone in which it occurs is assumed.

Many occurrences of minor minerals that are not of economic importance (such as apatite, garnet, and biotite) have been omitted or are incompletely recorded.

In the intermediate zones, which have been grouped together, a mineral observed to be dominant in any intermediate zone is shown as dominant in the group.

[2] This mineral also occurs at the Scott Rose Quartz mine and the Elk No. 1 mine.

[3] Completely altered to pseudomorphs.

[4] A few other minerals have been reported from the Etta pegmatite. Landes, K. K. (Sequence of mineralization of the Keystone, S. Dak. pegmatites: Am. Mineralogist, vol. 13, pp. 519–530, 537–558, 1928) reports stannite, chalcopyrite, and geyerite. Ziegler, Victor (The minerals of the Black Hills: South Dakota School of Mines, Bull. 10, pp. 101–108, 1914) noted struverite, galena, molybdenite, petalite, olivenite, and cacoxenite.

[5] Other minerals reported are fluorite (Ziegler, op. cit.) and montmorillonite (Landes, op. cit.)

[6] Dufrenite and vivianite have been reported by Ziegler (op. cit.). Pollucite has also been reported.

[7] Minerals reported from the Peerless include stannite (Headden, W. P., Stannite and some of the alteration products, from the Black Hills, South Dakota: Am. Jour. Sci., 3rd. ser., vol. 45, pp. 105–110, 1893) and struverite (Ziegler, op. cit.).

zoned, only one compositional type of plagioclase is present. In others there are several types. If albite is the only plagioclase present, its anorthite content commonly decreases from the wall zone to the center of the pegmatite. A change in physical character of the plagioclase accompanies this decrease in anorthite content. The oligoclase and the more calcic albite grains are always more or less equidimensional or blocky, whereas the more sodic albite grains have a platy form (cleavelandite). The platy form is less perfectly developed in the albite of intermediate composition.

Black tourmaline is the most common accessory mineral and makes up as much as 50 percent of some pegmatite units. It occurs throughout both homogeneous and zoned pegmatites, and in the adjacent wallrock. It is most abundant in the outer part of wall zones, as in the Bob Ingersoll Dike No. 2, New York, and other pegmatities. The wall zone in the southern 30 ft of the White Spar pegmatite, below the 100-ft level, is more than 50 percent black tourmaline in aggregates several feet across. Black tourmaline occurs in individual crystals, radial aggregates, and graphic intergrowths with quartz. Individual crystals more than 6 in. in diameter and 2 to 3 ft long are not uncommon at the Highland Lode, Smith, and White Elephant mines. Many of the larger masses that appear to be one crystal are actually many small crystals in parallel growth. This is also true of the large individuals that form radial aggregates such as occur at the White Elephant mine. All the black tourmaline is too highly fractured or contains too many inclusions to be suitable for optical purposes. Blue, blue-green, green, and pink tourmaline occur in the Bob Ingersoll Dike No. 1. The pink tourmaline is associated with lepidolite and albite (cleavelandite) in the central part of the pegmatite. The blue and the green tourmaline occur as flattened crystals in the muscovite of the wall zone and the inner edge of this zone is marked by a concentration of green tourmaline crystals in a distinct 2-in. layer. Some of them are of gem quality. Blue-green tourmaline with muscovite occurs also in the Beecher Lode pegmatite.

Biotite is a common constituent of the homogeneous pegmatites, but not of the zoned type. It occurs as small flakes, books, or long blades in the outer parts of the bodies. Blades, as much as 10 ft in length, cut across earlier minerals along cracks that are commonly perpendicular to the contacts. Biotite blades have not been observed in spodumene-, amblygonite-, or lepidolite-bearing zones, but they commonly occur in muscovite-, beryl-, and perthite-rich zones.

Small quantities of apatite occur in all of the pegmatites and in the altered wallrocks at their contacts. Normally it is in irregular grains, less than a quarter of an inch across; a few crystals or masses are larger. One mass of blue apatite at the Hugo pegmatite is about 3 ft long. Apatite occurs in various colors; most commonly it is a shade of blue or green. It is very abundant in the granulite at the contacts of the Old Mike and Bob Ingersoll Dike No. 2.

Other phosphate minerals, including the lithiophilite-triphylite group and their alteration products, are important accessory minerals in the mica- and perthite-bearing parts of the pegmatites. Most of the unaltered varieties are dark-green to blue, but commonly black, brown, olive-green, or purple alteration products coat the surface of these minerals. A blue-green mineral of this group occurs in bodies as much as 8 by 3 ft in size at the Dan Patch pegmatite, but in most pegmatites few aggregates of these minerals are more than a foot long. Fisher (1945, pp. 43–45) described the alteration products of lithiophilite from the Custer Mountain pegmatite and gave the following sequence for their development: (1) brown sicklerite, a lithium, manganous, ferric iron phosphate; (2) a greenish mineral—possibly manganese dufrenite; (3) manganese heterosite (purpurite), a manganic, ferric iron phosphate; (4) a black opaque mineral, perhaps a hydrated manganous, ferric iron phosphate; and (5) possible iron and manganese hydroxides. In addition to these alteration products that form shells around the edges of the lithiophilite, he also noted irregular patches of unidentified yellow, white, and greenish minerals in films and powders; possibly lazulite; and manganese dufrenite. Similar sequences and types of alteration are common throughout the area, but no detailed mineralogic study of them was made. Purpurite was noted as particularly abundant at the Dyke Lode and Rainbow No. 4 pegmatites. A deep-blue mineral, identified as vivianite, is common in the Old Mike pegmatite.

Garnet is a conspicuous accessory mineral in a few pegmatites. Both red and brown garnet have been noted, but the brown manganese variety is generally coated with a dark-colored manganese alteration product. These garnets are highly altered, friable, and occur in euhedral or subhedral crystals. Red garnet seems to be most common in the homogeneous pegmatites and brown garnet in the zoned bodies. Red garnet, of nearly gem quality, is associated with potash feldspar and pyrite at the Greene mine. In the Highland Lode, small red-brown garnet crystals occur with black tourmaline in albite that forms rims around perthite crystals.

Sulfides and arsenides, including pyrite, galena, sphalerite, chalcopyrite, pyrrhotite, arsenopyrite, and löllingite, occur sparingly in a few pegmatites. Probably the most generally distributed of these minerals is löllingite, which was observed in the Elkhorn, White Cap, Dyke Lode, Hot Shot, and other pegmatites as rounded masses, as much as 12 inches in diameter. It is generally found in an intermediate zone around a perthite or perthite-quartz core and is associated with the muscovite, quartz, beryl, and albite that occur interstitial to perthite. At the Dan Patch, Victory, and White Dog mines specimens were obtained in which this mineral fills irregular cracks in plagioclase that is intergrown with quartz and muscovite. Löllingite alters to iron oxides and a greenish mineral, probably scorodite.

Pyrite, pyrrhotite, chalcopyrite, and arsenopyrite are occasionally found in the pegmatites as minute grains and small aggregates. At the Edison pegmatite these minerals occur in fractures that obviously cut the pegmatite; in other bodies this relationship is not so clear.

Galena associated with sphalerite has been reported from the Bob Ingersoll mine (E. L. Tullis, oral communication). Dark red-brown to black sphalerite is abundant at the Dan Patch mine, where it occurs in aggregates of fine-grained muscovite ("bull mica") and albite.

One specimen of topaz associated with quartz and albite was found at the Dyke Lode by John Fisher, the operator. The topaz was an anhedral gray grain, 1½ in. long and ½ in. thick. A single irregular patch of brownish siderite, 2 in. long and 1½ in. wide, was found in gray albite at the Crown mine. Calcite and other carbonates are found along some fractures in the pegmatites but they are clearly secondary. Graphite occurs with amblygonite and feldspar at the Hardestey Homestead pegmatite, generally as minute flakes associated with black manganese oxides in the outer part of the amblygonite nodules.

The minerals of economic importance are discussed later in the sections that describe the deposits of mica (muscovite), lithium (spodumene, amblygonite, lepidolite, zinnwaldite), tantalum (columbite-tantalite, tapiolite, microlite), beryllium (beryl), and tin (cassiterite).

TEXTURE

The size of the mineral grains and the quantity of any mineral vary widely within any one pegmatite. In general, the average grain size increases from the outer to the inner part of a pegmatite, but this order may be reversed for a mineral that is most abundant in the outer zones. The grain size of pegmatite minerals is rarely uniform within any given unit and in many the normal pegmatite texture is more nearly that of a porphyritic than an equigranular rock. In this report, for economic reasons and for convenience, pegmatites and pegmatite units are described according to their general appearance, as fine-, medium-, or coarse-grained. A fine-grained pegmatite is one in which most of the grains and aggregates are less than 2 in. in maximum dimension. A medium-grained pegmatite is one in which most of the grains or aggregates are more than 2 in. and less than 12 in. in maximum dimensions. A coarse-grained pegmatite is one in which most of the grains or aggregates of minerals are larger than 12 in. Much has been written about the large or "giant" crystals of spodumene in the Etta pegmatite, one of which was 47 ft long. Individual crystals of beryl as much as 18 ft in length have been mined at the Bob Ingersoll mine. Crystals of such sizes are rare although crystals of beryl, spodumene, feldspar, tourmaline, or other minerals 3 to 5 ft in length are common.

INTERNAL STRUCTURE

Lithologic units of contrasting mineralogy and texture were recognized in the Black Hills pegmatites as early as 1875 when Newton and Jenny (1880, p. 11) observed the "roughly concentric arrangement" of tourmaline, mica, and quartz inward from the walls in what they called "granite deposits in Custer Park." Later workers in this area have described a variety of lithologic units within some of the pegmatites, and persons engaged in pegmatite mining have recognized that the economic minerals have a systematic distribution within the pegmatites. Structural analysis of many zoned pegmatites in the United States during the years 1939–45 has shown clearly that many of these lithologic units are also structural units. Three major types of units within pegmatite bodies were recognized, namely, (1) zones, (2) fracture-filling bodies, and (3) replacement bodies. In the Black Hills pegmatites, zones and fracture-filling bodies are the most abundant and also the most important as sources of industrial pegmatite minerals.

ZONES

Zones are the most numerous and economically the most important structural units in the Black Hills pegmatites. A zoned body is a lithologic and structural unit within a pegmatite that differs from the rest of the pegmatite in mineral composition, texture, or both, and is roughly concentric around a central nucleus or core. Four types of structural zones have been recognized in pegmatites, namely, (1) border zone, (2) wall zone, (3) intermediate zones, and (4) core.

These four types of zones have been found in the pegmatites of the Black Hills, and elsewhere in the United States. Not all zones are present in every pegmatite, although the presence of at least two can be expected, except in some pegmatites that formed as segregations in granite. In the ideal case, the border, wall, and intermediate zones form concentric shells that reflect to a greater or lesser degree the shape of the pegmatite body. However, these shells may be incomplete or discontinuous, and may occur as a series of disconnected lenses or pods. Such lenses or pods nevertheless show a distinct structural relation to the walls of the pegmatite and occur at a definite place in the zonal sequence. They should not be confused with similarly shaped masses of individual minerals that occur haphazardly within a zone. As a rule the proportions of the constituent minerals of a zone vary from place to place and the contacts between zones are generally gradational.

The outer structural unit or border zone is invariably present at the contact of pegmatite and schist, but it is rarely wide enough to map. On the maps of this report, except as noted, it is included with the wall zone. Border zones are very fine-grained selvages, commonly as much as several inches thick, but only rarely as thick as 12 or 18 in. In the thinner parts of a pegmatite only the border zone will be present if the total thickness of the pegmatite at this point is less than twice the thickness of the border zone. The texture of the border zone adjacent to the contact is that of a fine-grained aplite, but within an inch the average size of the grains may approximate that of an extremely coarse-grained granite. There is a gradation from this texture to the fine- or medium-grained pegmatite texture of the wall zone. Where schist wallrocks have been altered to granulite the border zone pegmatite is coarser-grained than elsewhere on the same contact, but finer than that of the wall zone.

The border zone has a mineral assemblage similar to that of the adjacent wall zone, although the proportion of minerals may be slightly different. However, a mineral may be concentrated locally in one of these zones and be rare in the adjacent one. In some of the pegmatites that cut the Harney Peak granite a true border zone is absent but the pegmatite adjacent to the granite is everywhere finer-grained than that a few inches from the margin. In the Black Hills many wide exposures of fine-grained pegmatite, apparently barren of mineral deposits, are actually dip-slope exposures of the border zone. Unless this fact is recognized the prospector may overlook valuable deposits that are beneath this thin layer of barren rock.

The wall zone, like the border zone, is a lithologic unit paralleling the contact of pegmatite and country rock. In many pegmatites this is one of the most productive zones. Its contacts with the border zone and with the intermediate zone or the core are generally gradational in composition and texture. The thickness of the wall zone differs even within a single pegmatite body. The wall zone ranges from a few inches to many feet in thickness and the thickness at the footwall of a pegmatite may be different from that at the hanging wall. Wherever the pegmatite is narrower than the combined average thickness of the hanging and footwall parts of this zone, the full width of the pegmatite inside the border zone will have the composition of the wall zone. The entire wall zone of some pegmatites can be mined with profit, but in other pegmatites only local concentrations or shoots of minerals can be worked profitably.

The intermediate zone or zones represent transitions from the wall zone to the core. They are more complex in structure because the variation in thickness of outer zones in different parts of a pegmatite cause irregularities in the shape of the intermediate zones. With each successive intermediate zone, this irregularity in shape becomes progressively more evident. The shape of the core has less similarity to the shape of the walls of the pegmatites than do either the wall or intermediate zones.

In practice it is often necessary to map individual units within the intermediate zones or to combine two or more discontinuous intermediate zones to reveal the economic possibilities of the deposit. This combination of units has the same structural behavior as the individual units. Because the intermediate zones are successive transitions between wall zones and cores, the outer intermediate zone resembles the wall zone most closely in structure, and the innermost intermediate zone has a structure similar to that of the core. Core-margin mica, beryl, and amblygonite deposits are innermost intermediate zones.

The core or central zone of a pegmatite reflects the shape of the entire pegmatite, modified by the combined irregularities in thickness of the outer zones. In a uniform lenticular pegmatite the core is a continuous body. In an irregular pegmatite the core may consist of several isolated segments, and each segment may be enclosed in concentric intermediate zones. In an incompletely explored pegmatite, a supposed core may be found by additional work to be a wall or intermediate zone.

The extensions of zones in depth depend on the configuration of the pegmatite itself. The zones tend to parallel the nearest wallrock contact and they plunge parallel to the plunge of the pegmatite body. The lenticular parts of discontinuous zones commonly have their two longest axes parallel to the nearest contact and plunge parallel to the nearest keel, crest, or roll. Commercial concentrations of mica, beryl, feldspar, etc., which occur as shoots within zones, commonly appear to be structurally parallel to rolls and also to the keel and crest of the pegmatite. For example, the mica shoot at the White Bear pegmatite is parallel to the hanging wall of the pegmatite and plunges parallel to the crest of the body. The richer parts of the wall zone in the MacArthur, Crown, White Spar, and New York mica mines were parallel to rolls in the pegmatite contact. Many of the potash feldspar bodies are hood-shaped and cap intermediate zones and cores. The longest dimension of these bodies commonly parallels the crest of the pegmatite.

FRACTURE-FILLING BODIES

Fracture-filling bodies are structural units that were formed in fractures in previously existing pegmatite. Their contacts may be sharp or gradational. The sharp contacts are commonly the result of simple fracture filling and the gradational contacts may be either the result of fracture-filling before the adjacent pegmatite was completely solid or they may be the result of minor selective replacement. If, however, replacement is the dominant process involved in the formation of the unit it is classed as a replacement body. Many of the larger fracture-filling bodies are themselves made up of units of contrasting mineralogy and texture that have the characteristics of zones. This is true in the Helen Beryl, Pleasant Valley, New York, and Soda Spar pegmatites. More commonly quartz, feldspar, or both are the only minerals in these bodies.

Fracture-filling bodies are not uncommon in otherwise homogeneous pegmatites. The coarse-grained units in the northeast pegmatite on the Harbach claim, the Helen Beryl, Soda Spar, Pleasant Valley, and other pegmatites are examples. If large enough they constitute minable bodies and contain not only the minerals of the enclosing pegmatite, but also those characteristic of zones that form later in the general sequence. In some apparently homogeneous pegmatites the fracture-filling bodies may connect at depth with more highly differentiated and zoned parts of the same pegmatite. The fracture-filling bodies rarely extend beyond the pegmatite contacts into the schist. Usually, if they extend to the contact, they follow it for a short distance.

In the zoned pegmatites, fracture-filling bodies of appreciable size are rare, but, where present, they may have considerable influence on the value of the pegmatite in which they occur. At the White Elephant, Agnew, and Elkhorn pegmatites, small closely spaced fracture-filling bodies of muscovite and associated minerals cut across the perthite and decrease its value as a commercial feldspar. At the White Elephant, the replacement of potash feldspar by muscovite outward from similar fracture fillings has formed muscovite aggregates suitable for scrap mica. In the New York, Hardestey Homestead, and other pegmatites, quartz bodies have formed along fractures that may or may not extend outward from a central core of quartz. In the Hardestey Homestead pegmatite several of these quartz units extend from the core to the pegmatite contact and in one place as much as 20 ft into the schist. In the New York pegmatite some of the quartz units are enclosed by a rim of albite (cleavelandite) containing cassiterite.

Extensions of fracture-filling bodies in depth can be predicted from their strike, dip, thickness, and plunge. The attitude of fracture fillings is independent of the shape of the pegmatite bodies in which they occur, but some, as at the New York mine, appear to be structurally related to the walls and plunge of the main body.

REPLACEMENT BODIES

Replacement bodies include those units which may or may not be obviously controlled by pre-existing structures, and which apparently formed by replacement of pre-existing pegmatite. They are commonly very irregular, precluding accurate prediction of their extensions in depth unless they obviously formed at the expense of specific mineralogical or textural units. Some replacement bodies definitely follow fractures and are therefore similar in structure to fracture-filling bodies

The spodumene-quartz rock of the Giant Volney pegmatite in the Tinton district is the largest unit of replacement origin known in the Black Hills area. The deposition of spodumene was apparently controlled by the gneissic structure of the earlier pegmatite units, but in detail the deposit is highly irregular. On the basis of relict gneissic structure the approximate shape and extent of the spodumene-bearing unit can be determined. Ellipsoidal bodies of microcline cut across the structure of the spodumene-quartz rock, and their size, shape, and distribution cannot be predicted in advance of mining.

Irregular units of muscovite-rich pegmatite occur in the core of the Beecher Lode pegmatite and between zones in the Bob Ingersoll Dike No. 2 deposit. These units are composed primarily of muscovite flakes in random orientation (known to the miners as "bull mica" or "mica schist") and appear to have formed partly at the expense of pre-existing pegmatite. Some bodies have no obvious structural control; others formed outward from fractures.

Almost every zoned pegmatite contains small patches or groups of minerals that were formed by replacement of adjacent minerals, but there is little proof that they formed after the main pegmatite was completely solid.

ZONAL SEQUENCE

The minerals of the Black Hills pegmatites appear to occur in a definite sequence from the border zone inward to the core. Table 3 summarizes the available information concerning the zonal position and order of relative abundance of the more common essential minerals in 80 pegmatites. More than 55 mappable lithologic units that have the structural characteristics of zones have been observed, and others may be found. In table 3, the observed units in the 80 pegmatites listed have been divided into 12 major lithologic types or zones on the basis of the essential minerals—muscovite, plagioclase, perthite, microcline, amblygonite, spodumene, lepidolite, lithia mica, and quartz. These major zones are numbered (1) to (12) from the wall inward to the core. Zones (1) to (10) are subdivided into two or more units on the basis of the proportions of the essential minerals. Further subdivisions on the same basis are possible. Zones indicated by question marks in table 3 are either poorly exposed or too small to allow determination of their exact position.

The examples given in table 3 are believed to represent all types of zoned pegmatites found in the Black Hills. Some of the zones could be subdivided on the basis of the abundance of an accessory mineral. In addition, some of these zones could be combined if the distribution of a single mineral, such as spodumene, were mapped separately. Not all the zones occur in all the pegmatites, probably because of original differences in the composition of the solutions from which they formed, because they occurred in incomplete zones (parts of which were removed by erosion or are not yet exposed), or because of differences in the conditions under which various pegmatites formed. For the same reasons, the thickness of the zone and the proportions of constituent minerals may differ in similar zones of different pegmatites. Nevertheless, it is apparent in all of the zoned pegmatites examined that muscovite is most abundant in the zones outside of those containing the greatest quantity of perthite, and that the lithium minerals occur inside the zone richest in perthite. The plagioclase in the outer zones (1) to (3) is usually in more or less equidimensional or blocky grains that commonly are more calcic in composition than the platy plagioclase that characterizes the inner zones. Quartz is generally most abundant in the cores of the pegmatites, either as interstitial fillings between other minerals or as a monomineralic unit.

The distribution of minerals of economic importance within the Black Hills pegmatites is listed below in relation to the type of zone and the zone sequence of table 3.

Mineral of economic importance	*Zone sequence (Table 3)*	*Zone*
1. a. None	2, 3	Border.
b. Fine-grained scrap mica, perthite, and beryl.	1	
2. a. None	2, 3	Wall.
b. Sheet mica and beryl	1	
c. Scrap mica, beryl, and columbite.	1	
d. Cassiterite	1, 2	
e. Perthite, scrap mica, sheet mica, and beryl.	3	
3. a. None	2, 6	Intermediate.
b. Sheet and scrap mica, perthite, and beryl.	3	
c. Perthite and columbite-tantalite.	3, 4	
d. Beryl, amblygonite, tantalite, cassiterite, spodumene, and perthite.	5	
e. Spodumene and tantalite	7, 8	
f. Cassiterite	6	
4. a. None	2, 6, 12	Core.
b. Lepidolite and microlite	9	
c. Microcline	5, 10, 11	
d. Spodumene	5, 7, 8	
e. Perthite	3–5	
f. Cassiterite	5, 7, 9, 11	

RELATION OF PEGMATITES TO THE STRUCTURE OF THE WALL ROCKS

The Black Hills pegmatites that intrude metamorphic rocks can be separated into two groups, namely, those that conform to regional foliation or bedding and those that transect these structures. The wall rocks of both groups show structural features that apparently were formed during emplacement of the pegmatite. For example, the foliation of the mica schist wall rocks at the Old Mike pegmatite is crumpled into folds which indicate that both walls of the pegmatite have been dragged upward. Similar drag structures can be observed in the granulite exposed at the pegmatite contact in the upper adit at the Etta mine. The schistose layers of wall rock at the south end of the White Spar pegmatite are highly folded. The axes of these folds plunge parallel to the end of the pegmatite and at an angle to drag folds in undisturbed schist. A similarly crumpled and folded schist is found at the north end of the Helen Beryl pegmatite.

A secondary or induced schistosity has been observed at and near the contact of some pegmatites in easily deformed schists. This induced foliation may extend several feet out from the contact, and it may completely encircle the pegmatite. It follows in minute detail all irregularities of the pegmatite contact. Folds in this schistosity plunge parallel to the rolls on the contact and also to the keel and crest of the pegmatite. An excellent example of this induced foliation occurs at the Victory pegmatite, which is generally concordant with the regional foliation. The Old Mike and Helen Beryl pegmatites show an induced foliation along some of their contacts although they are not concordant with the regional structure.

Pegmatites that are essentially conformable to the regional structure plunge parallel to the linear structure of the schist. The New York pegmatite, for example, plunges parallel to the long axis of stretched quartz pebbles, and the pegmatites north of the Silver Dollar mine plunge parallel to hornblende needles in the schist. The Victory and many other pegmatites show similar structural relationships.

The Mateen pegmatite, which crosscuts the schist structure, contains spodumene crystals that lie at right angles to the pegmatite contacts. These crystals plunge in the same direction, but not at the same angle, as the linear structure in the wall rocks.

Undoubtedly many of the pegmatites in the Black Hills region owe their shape and localization to preexisting folds. The Crown, Antler, and Red Deer pegmatites are good examples. However, emplacement of the Crown pegmatite and perhaps of others may have caused the formation of new folds.

The relation of schist structure to pegmatites is incompletely known, but available evidence shows that linear structure in the schist may indicate the average plunge of adjacent pegmatites. Folds of the schistosity near the contacts can be used similarly, but the plunge of these minor folds parallels the plunge of the nearest crest, keel, or roll, which may be different from the average plunge of the body.

TABLE 3.—*Zone sequences in pegmatite bodies, Black Hills, South Dakota*

Group	Essential minerals (Minerals of zones)	Common accessory minerals	Type	Dominant (Essential minerals in order of decreasing abundance)	Minor	Number of pegmatites	Border [2]	Wall	Intermediate	Core
1	Muscovite (M). Quartz (Q). Plagioclase (Pg). a. Albite. b. Oligoclase.	Tourmaline. Beryl. Biotite. Perthite. Apatite. Cassiterite. Columbite.	a	Q, M	Pg	5	5			
			b	M, Q	Pg	1	(?) 1	1		
			c	Q, M, Pg						
			d	Pg, Q	M	8	5	7		1
			e	Q, Pg	M	4	3	3		
			f	Q, Pg, M		20	15	16		3
			g	Pg, M, Q		3	2	2	1	
			h	Pg, Q, M		17	14	16	1	
2	Quartz (Q). Plagioclase (Pg) a. Albite. b. Oligoclase.	Tourmaline. Beryl. Perthite. Apatite. Muscovite. Cassiterite. Columbite-tantalite.	a	Pg, Q		3	1	1	2	
			b	Q, Pg		6			6	
3	Perthite (P). Quartz (Q). Muscovite (M). Plagioclase (Pg). a. Albite. b. Oligoclase.	Tourmaline. Beryl. Li, Mn, Fe phosphates. Columbite-tantalite. Apatite. Löllingite. Biotite.	a	Pg, M, Q, P						
			b	Pg, Q, M, P		2	2	2		
			c	Pg, Q, P, M		1	1			1
			d	Pg, Q, P	M	5	1		1	4
			e	Pg, P, Q, M		1		1		
			f	Pg, P, M, Q		2	2	2		
			g	Pg, P, Q	M	2	1	1	1	
			h	P, Pg, Q, M		1	1			1
			i	P, Pg, Q	M	3	1	1	2	
			j	Q, Pg, M, P		1	1	1		
			k	Q, Pg, P, M		3	3	2		1
			l	Q, Pg, P	M	6	3	2	2	2
			m	Q, P, Pg, M		5	5	5		
			n	Q, P, Pg	M	7			3	4
			o	Q, P, M	Pg	1	1			1
			p	P, Q, Pg	M	8	2	2	5	2
			q	P, Q, M	Pg	8	5	3	2	3
			r	Q, Pg, P	M	1			1	
			s	Q, Pg, M	P	2			2	
4	Perthite (P). Quartz (Q).	Tourmaline. Beryl. Plagioclase. Li, Mn, Fe phosphates. Muscovite. Columbite-tantalite. Apatite. Löllingite.	a	Q, P		12			4	8
			b	P, Q		24			4	20
			c	P	Q	4			3	1
5	Perthite (P). (or microcline). Quartz (Q). Plagioclase (Pg). (usually cleavelandite). Amblygonite (A). Spodumene (S).	Tourmaline. Beryl. Cassiterite. Tantalite-columbite. Muscovite. Apatite.	a	A		1			1	
			b	Q, P, A	Pg					
			c	Q, P, Pg, A						
			d	Q, Pg, A, P		3			3	
			e	Pg, Q, A	P	1			1	
			f	Pg, Q, A, S	P	1			1	
			g	P, Pg, Q, A, S		2			1	1
			h	Q, P, S, A	Pg	1			1	
			i	P, Q, S		2			1	1
			j	Q, Pg, P, S		1				1
6	Plagioclase (Pg). a. Cleavelandite. Quartz (Q).	Tourmaline Beryl Cassiterite. Tantalite. Muscovite. Apatite. Amblygonite.	a	Q, Pg		3			2	1
			b	Pg, Q		4			4	
			c	Pg	Q	1			1	
7	Plagioclase (Pg). a. Cleavelandite. Quartz (Q). Spodumene (S).	Beryl. Tourmaline. Muscovite. Cassiterite. Tantalite. Apatite.	a	Q, Pg, S		2			1	1
			b	Pg, Q, S		2			2	
8	Quartz (Q). Spodumene (S).	Microcline. Plagioclase. Lepidolite. Beryl.	a	Q, S		8			1	7
9	Plagioclase (Pg). a. Cleavelandite. Quartz (Q). Lepidolite (L).	Microlite. Spodumene. Beryl. Amblygonite Tantalite-columbite. Cassiterite. Microcline. Tourmaline. Apatite.	a	Q, Pg, L		1				1
			b	Pg, Q, L						
			c	Pg, L	Q					
			d	L	Pg, Q					
10	Quartz (Q). Microcline (P).	Spodumene. Muscovite. Plagioclase. Apatite.	a	Q, P		1			1	
			b	P, Q		1				1
11	Microcline (P). Plagioclase (Pg). Lithia Mica (LiM). Quartz (Q).	Cassiterite. Apatite.	a	P, Pg, LiM, Q		1				1
12	Quartz (Q).	Plagioclase. Beryl. Microcline. Muscovite.	a	Q		14				14

Pegmatites:

Type	Addie	Aladin	Ann	Arcade No. 1 and 2	Beecher Lode	Beecher No. 2	Bellmare No. 1	Big Spar No. 1	Blue Bonnet-Star	Bonnie Lode	Bob Ingersoll No. 1	Bob Ingersoll No. 2	Bob Ingersoll No. 3	Bob Ingersoll No. 4	Burgess	Burt	Buster Dike claim	Climax	Crown	Custer Mountain
1a													[3]X							
1b	X																			
1c																				
1d																				
1e						[3]X														
1f					X	X			X	X	[3]X	X	X				X			
1g																				
1h											X							X	X	
2a																				
2b					X							X					X			
3a																				
3b																				
3c																				
3d	X																			
3e																				
3f																				
3g																				X
3h																				
3i																				
3j																				
3k										?					[5]X					
3l																	X		X	
3m			X											X						
3n													X					X		
3o							[5]X													
3p						X										X				
3q		X		[5]X				X								X				
3r																				
3s																				
4a			X																	
4b		X						X	X			X				X				X
4c					X						X									
5a																				
5b					?															
5c																				
5d											X	X								
5e														X						
5f																				
5g					?															?
5h																				
5i																				
5j																				
6a											X									
6b																				X
6c																				
7a						X														
7b																				
8a					X							X								X
9a											X									
9b																				
9c											?									
9d					?						?									?
10a																				
10b																				
11a																				
12a			?		?									X				?	X	

Type	Dan Patch	Dyke Lode	Earl Lode	Edison	Elkhorn	Etta	Florence	Gap	Glenwood	Giant-Volney	Harbach (Middle)	Harbach (Northwest)	Harbach (Northeast)	Hardesty Homestead	Helen Beryl	Highland Lode	Homestead No. 2	Homestead No. 3	Hub	Hugo
1a	[3]X																			
1b																				
1c				?																
1d																X	X			[3]X
1e					X	X														
1f	X						X		X		[5]X	X								X
1g																			X	
1h		X	X	X	?					X				X	X					
2a										X				X						
2b																				[6]X
3a						?														
3b																				
3c																				
3d																	X			
3e								[4]X												
3f																				
3g			X																	
3h																				
3i																				
3j																				
3k																				
3l	X																	[5]X		
3m																				
3n					?											X				
3o																				
3p	X					[7]?							X							[6]X
3q															X					
3r																				X
3s	X																			X
4a		X	X																	
4b	X				X			X				X	X		X	X			X	
4c														X						
5a										X										
5b			?																	
5c																				
5d																				X
5e																				
5f														X						
5g		X																		
5h																				X
5i						X									X					
5j																				
6a							X													[8]X
6b																				
6c									X											
7a						X														
7b		X		X																
8a		X		X		X				[10]X										
9a																				
9b																				
9c																				
9d																				
10a																				X
10b										X										
11a																				X
12a	?				?	X	?		X					X						

Type	Hunter-Louise	Jack Rabbit (Main)	Jack Rabbit (Southwest)	Josie	Lake	Lost Bonanza	Lost Indian	Lucky Star	MacArthur	Marydale	Mateen	Mica King No. 1	Mica Queen	Midas	Monkey Lode	New York	November	Old Mike	Old Missouri	Pine Top
1a											[3]X	?								
1b																				
1c																				
1d	X				[4]X	[5]X											[4]X			
1e											X									
1f								X					[5]X		X	X				
1g																		X		
1h									X									X		X
2a																		?		
2b																X				
3a																				
3b												X								
3c							[5]X													
3d					X															
3e																				
3f														X						
3g																				
3h																				
3i																				
3j																				
3k																				
3l		X	X																	
3m																				
3n											X					?				
3o																				
3p																		X		X
3q				[4]X						[5]X									[5]X	
3r																				
3s																				
4a			X					X							X					
4b				X					X					X		X	X			
4c																				
5a																				
5b																				
5c															?					
5d																				
5e																				
5f																				
5g																				
5h																				
5i																				
5j											X									
6a																				
6b																X		X		
6c																?				
7a																				
7b																?				
8a	X																			
9a																				
9b																?				
9c																				
9d																				
10a																?				
10b																				
11a																				
12a		X										X				X		X		X

Type	Pleasant Valley	Punch	Rainbow Mica	Rainbow No. 4	Red Deer	Ruby Reef	Ruby Reef No. 1	Ruby Reef claims (other pegmatites)	Seal	Silver Dollar	Sitting Bull	Soda Spar	Surprise	Sunshine	Tip Top	Victory	White Bear	White Cap	White Spar	Wonder Lode
1a											[3]X							[3]X		
1b																				
1c																				
1d																		X		
1e																				
1f														[4]X	X					
1g			X																	
1h									X		X					X		X	X	
2a												X								
2b											X									
3a									?											
3b				X																
3c																				
3d	[6]X											X								
3e																				
3f										X										
3g																				
3h													[5]X							
3i		X		X											X					
3j																				X
3k					X												X			
3l																				
3m						X	X	X												
3n							X				?					X			X	
3o																				
3p																	X			X
3q																				
3r																				
3s																				
4a			X		X	X			?		X				X			X		?
4b				X					X	X		X		X				X		
4c																		X		
5a																				
5b																				
5c																				
5d																				
5e																				
5f																				
5g												X								
5h																				
5i																				
5j																				
6a																				
6b		[9]X																		
6c																				
7a																				
7b																				
8a																				
9a																				
9b																				
9c																				
9d																				
10a																				
10b																				
11a																				
12a		X						X							X			X		

[1] Table 3 is a compilation of observations made by several geologists engaged in various types of examinations; lithologic units mapped by one person may include one or more units that were separated by another observer. Where possible these units are shown separately in the table though they may not appear on the accompanying maps of the pegmatite. A few pegmatites such as the Hugo, Helen Beryl, White Cap, Sitting Bull, Etta, and Dan Patch were reexamined to determine the zonal sequence in detail. Groups of essential minerals are numbered 1 to 12 from the walls inward to the center of the pegmatite. The position of some of the lithologic units listed is unknown and the relative abundance of the contained minerals is in some cases only approximate. The presence of lithologic units in each pegmatite is shown by an "X". Units that are poorly exposed and of small size are indicated by question marks and are not included in the tabulation of "Occurrences in structural zones".

[2] The outermost unit, except where noted, is tabulated both as a border and wall zone.

[3] These outer units are present only as border zones.

[4] Border zones cannot be accurately delimited because of the textural gradation between pegmatite and the granite wallrocks and therefore have not been counted as border zones.

[5] These pegmatites are of uniform mineralogic composition, but are fine-grained at the edges and therefore are composed of only border zones and cores.

[6] These units occupy the same zonal position, but occur in different parts of the Hugo pegmatite.

[7] This is the outermost unit, but probably formed by replacement of schist.

[8] This is a core in one segment of the pegmatite and is probably comparable to zone (5) in the main segment.

[9] This unit contains as much as 80 percent muscovite. Perhaps should be included at the inner edge of zone 3, but perthite is lacking.

[10] This is a replacement body in the same sequence as zones of the same composition.

WALL-ROCK ALTERATION

The formation of many pegmatites is accompanied by alteration of adjacent wall rocks. The degree of alteration ranges widely and is most intense along those pegmatites that cross the structure of well-foliated schist. The changes include both recrystallization of wall-rock minerals and introduction of new minerals from the pegmatite. In many pegmatites it is difficult to determine which process is more important.

The most common results of the alteration of wall rocks are (1) the formation, by recrystallization, of a foliation parallel to the pegmatite contact, (2) the introduction of tourmaline, and (3) the formation of feldspar granulite. Less common is the development of beryl, feldspar, biotite, and apatite metacrysts in schist and the alteration of sillimanite to muscovite, biotite to chlorite, and hornblende to biotite. During the formation of foliation parallel to the pegmatite contact the micas and other minerals undergo a rearrangement, with or without an increase in grain size, and other minerals such as tourmaline are introduced into the wall rock.

Tourmaline in schistose country rocks is very common, and in some places it is the dominant mineral for as much as three or four feet from the pegmatite contact. Although widespread, it is developed most abundantly in quartz-mica schists. At one pegmatite in the Tinton district, tourmaline occurs in schist along one contact, but is lacking in a biotite-rich rock along the other contact. The tourmaline appears to have grown selectively in quartz-mica schist in preference to the hornblende schist from which the biotite rock developed.

A light-colored, fine- to medium-grained feldspar granulite is common along the contacts of pegmatites that cross the structure of the enclosing schists. The original schistose structure is completely destroyed where the alteration is most intense. The granulites commonly have sharply defined outer limits, but they may grade imperceptibly into schist. They are predominantly plagioclase feldspar and quartz, with accessory tourmaline, apatite, beryl, biotite, and muscovite. The Old Mike, Bob Ingersoll Dike No. 2, and the Etta pegmatites are partly enclosed by this rock.

Metacrysts of gray microcline, irregular in shape and filled with relict grains of schist, occur near the White Bear, Surprise, Buster Dike, and Etta pegmatites. At the Etta property the microcline is associated with blades and flakes of biotite as much as 3 in. in length. Beryl crystals, 2 in. or less in length, together with pink microcline metacrysts, occur in the biotite schist wallrocks of the Mountain Beryl pegmatite. The beryl is pale-green to colorless and resembles beryl in the outer part of the pegmatite.

ORIGIN

The present study of South Dakota pegmatites has been concerned primarily with economic factors rather than petrologic or other scientific problems, but a large part of the information collected will aid in determining the genesis of these deposits. Before a theory of origin can be offered with confidence, more attention should be given to the relation of different types of pegmatite to regional structure and lithology of host rocks, and additional petrographic and chemical data should be obtained. In spite of the shortcomings of the present study, certain facts and conclusions relating to origin can be presented here. In general, the discussion that follows is concerned more with the origin of structural units within pegmatites than with the origin of pegmatites themselves.

It is generally assumed that the source of the solutions from which pegmatites form is a deeply buried, differentiating magma. During crystallization of the magma, fluids escape and work outward and upward, finally crystallizing in the form of pegmatites. The exact nature of the solutions, especially whether they resemble magmas or aqueous solutions, is an unsolved and widely debated problem. Certainly the solutions are highly mobile and contain relatively large quantities of sodium, potassium, silicon, beryllium, fluorine, boron, phosphorus, lithium, and many less common metallic and rare-earth elements, with relatively small quantities of magnesium, calcium, and iron. We may postulate that the formation of a pegmatite is a continuous process beginning with a silicate-rich solution similar to a granite magma but richer in water and other volatiles. During crystallization, the solution changes progressively so that the late residual fluids are more nearly like concentrated aqueous solutions.

Kemp (1924, pp. 697–723) and Johannsen) 1932, vol. 2, pp. 77–84) have summarized the theories on the origin of pegmatites. Most of the theories assume that the pegmatites have been derived as a byproduct of the differentiation of granite. Prior to Schaller's paper of 1925 (pp. 269–279), most geologists considered pegmatites to be true igneous rocks representing the last intrusions from a solidifying magma source. Schaller proposed that the initial "simple" pegmatite was of igneous origin, but that all minerals of the "complex" pegmatites except early potash feldspar, quartz, and perhaps a little plagioclase were introduced by a series of hydrothermal replacements. In the same year Landes (1925, pp. 353–411) suggested that the primary minerals formed by crystallization from a liquid included potash feldspar (mainly microcline), quartz, muscovite, biotite, black tourmaline, beryl, garnet, arsenopyrite, and manganoapatite. He considered that a later group of minerals formed under hydrothermal conditions and that these were followed by secondary minerals derived from earlier ones by ground-water alteration. Hess, also in 1925 (pp. 289–298), noted the many replacement phenomena in pegmatites and attributed them to fluids that accompanied and followed the formation of the pegmatite, reacting with earlier-formed minerals in the cooler and outer parts of the body. The importance of hydrothermal replacement is difficult to evaluate. In some pegmatites, particularly those at Pala, Calif. (Schaller, oral communication, 1945), it is undoubtedly a major factor in producing the structures, textures, and mineral associations of the pegmatite bodies.

Many of the mineralogical and structural features related to the pegmatites of South Dakota cannot be explained on the basis of previously proposed theories of pegmatite genesis. Structures such as induced foliation in wallrocks adjacent to pegmatites as well as primary gneissic and zonal structures in the pegmatites themselves indicate that the processes governing a large part of pegmatite development are more closely analogous to those governing the formation of granitic igneous rocks than to the formation of hydrothermal rocks. Pegmatite units, formed primarily by hydrothermal replacement of pre-existing pegmatites, though small and few, indicate that aqueous solutions were responsible in part for the development of some South Dakota pegmatites. The main difference between the theories of previous workers and that proposed here is not the presence or absence of magmatic and hydrothermal stages, but the relative importance and length of each stage. Schaller (1925) and Landes (1925), for example, place most of the plagioclase and the lithium minerals of pegmatites in a hydrothermal stage and the potash feldspar in a magmatic stage. The distribution and structural position of plagioclase and lithium minerals in South Dakota pegmatites requires that most units containing them be included as part of the magmatic stage, though like other pegmatite minerals they may also occur in units formed primarily by hydrothermal solutions. The potash feldspar in the Black Hills pegmatites is in part earlier and in part later than lithium minerals and is both preceded and followed by plagioclase (see table 3).

Any comprehensive theory of origin of the pegmatites must be based on a consideration of (1) the source of the solutions from which pegmatites form, (2) the physical and chemical nature of these solutions, (3) the effect of the wallrocks on these solutions as well as the effect of these solutions on the wallrocks, and (4) the history of crystallization of these solutions. In addition, it is essential that the theory explain all of the mineralogic and structural phenomena of the pegmatites by processes that are compatible with those by which the pegmatite solution originated and crystallized. Some of the more important of these phenomena include:

1. The zonal structure.
2. The constancy of the zonal sequence of essential minerals.
3. The repeated occurrence of concentrations of minor minerals such as beryl, in specific parts of the zonal sequence.
4. The systematic variation in the composition of minerals, such as beryl, plagioclase, and columbite-tantalite with respect to zonal position.
5. The systematic variation in the composition of mineral groups, such as the lithium minerals, with respect to zonal position.
6. The occurrence of concentrations of perthite in the upper parts of some pegmatites as hoods above quartz or albite-quartz pegmatite.
7. The general increase in grain size of the minerals from the outer to the inner zones.
8. The general increase in abundance of replacement textures at the contacts between minerals from the outer to the inner zones.
9. The occurrence of fracture fillings lithologically similar to interior zones but crosscutting outer zones.
10. Zonal structure in fracture fillings.
11. The occurrence of units formed essentially by hydrothermal (or pneumatolytic) replacement, that transect zonal structures.
12. The presence of primary gneissic structure within pegmatite.
13. The presence of zoned crystals of plagioclase.

Furthermore, the theory must explain the presence of many structural and mineralogical phenomena in the wallrocks adjacent to the pegmatites, including:

1. Foliation parallel to the pegmatite contact and to gneissic and zonal structures within the pegmatite.
2. Linear structures parallel to linear structures of the pegmatite.
3. Crumpling, dragfolding, and fracturing at the contacts of pegmatite bodies.
4. Feldspar granulite, tourmaline and biotite rocks, and other contact-metamorphic rocks at the pegmatite contacts.
5. Tourmaline, beryl, microcline, muscovite, and biotite metacrysts.

There is considerable speculation involved in the assignment of a source for pegmatite solutions. Most geologists consider the close areal association of pegmatites with igneous rocks to be ample evidence that pegmatites are derived by differentiation from deeply buried magmas. Nevertheless, it is possible that all or part of the pegmatite solutions have been derived from metamorphic rocks by some process of ultrametamorphism. The pegmatites of the southern Black Hills presumably have been derived by differentiation from the Harney Peak granite, and detailed areal mapping may some day provide evidence on whether the pegmatite solutions came from the main body or from smaller satellitic bodies such as occur on Buckhorn Mountain in the Custer district and Mount Rushmore in the Keystone district. In either case the chemical nature of the solutions probably was highly variable, and the pegmatites, even within the same district, differ greatly in bulk composition. Such differences may be accounted for either by assuming (1) a number of sources, (2) the fractionation of a single solution, (3) a number of different solutions from the same source, or (4) any combination of these factors.

The physical and chemical nature of the pegmatite solutions as they escaped from the differentiating Harney Peak granite magma is unknown, but undoubtedly changed to a greater or lesser degree as the solutions rose in the earth's crust by (1) assimilation of wallrocks, (2) escape of materials into the wallrocks, and (3) changes in temperature and pressure. Probably the process of differentiation did not stop when these solutions escaped from the magma, and further changes in their chemical and physical nature may have been caused by fractional crystallization and subsequent filter-pressing.

In any event, by the time they reached their present positions in the earth's crust, many of these solutions were sufficiently viscous to deform the enclosing rocks. The wallrock deformation produced by these pegmatite solutions include the formation of (1) drag folds, (2) flowage folds, (3) fractures, and (4) foliation. These structural features indicate not only a viscous liquid but also a liquid that was moving upward, either by its own pressure or by the confining pressure of its wallrocks. Linear structures within some pegmatites, such as the Mateen spodumene-bearing body, appear to be evidence that pegmatite solutions also may have enlarged the channelways along which they are emplaced by expanding laterally. Tear-drop shaped and other "streamlined" bodies that were introduced along regional foliation strongly suggest that they also were formed by a rising, viscous liquid. Linear structures in wallrocks that closely parallel either the linear structures on the contact of a pegmatite, or the average plunge of the body itself, support the suggestion that the same forces that controlled the shape of the pegmatite also deformed the adjacent wallrock.

Gneissic structure and flow banding within some pegmatite units indicate that the pegmatite solution was not only viscous but was also in motion during the early stages of crystallization. In many other pegmatites, muscovite, spodumene, beryl, tourmaline, cassiterite, columbite-tantalite, and other minerals are bent, broken, and cemented by later pegmatite minerals in a way suggesting movements within the pegmatite during consolidation. For example, at the Crown pegmatite bent and cup-shaped muscovite books at the nose of the smaller rolls are so arranged as to suggest distention of the pegmatite after their formation, but before the pegmatite became rigid. Muscovite books in the Pitt pegmatite also are warped or bent. Spodumene crystals in the Edison pegmatite are both bent and fractured. Cassiterite, tourmaline, and columbite-tantalite crystals in the Giant-Volney and other pegmatites are commonly fractured and cemented by groundmass minerals. Most of the mica books in the Climax, New York, and other pegmatites are ruled, but this feature may be the result of movement during, or shortly after, the consolidation of the pegmatite.

Many of the fracture-filling bodies in the New York, Helen Beryl, Pleasant Valley, and other pegmatites follow longitudinal, diagonal, or cross fractures that are structurally related to the contacts and plunges of the enclosing bodies. These fracture fillings are analogous to the pegmatites, aplites, and veins in granite that are in fracture systems related to the contacts, linear structures, and plunge of the granite body. This suggests that pegmatites containing fracture-filling bodies formed from crystallizing solutions whose physical characteristics resembled those of granite magmas. In addition, all of the features mentioned above that indicate the pegmatites formed from a viscous, moving liquid are evidence that in the early stages of crystallization the pegmatite solutions were more nearly magmatic than hydrothermal in character. Bent and broken spodumene crystals in the Edison pegmatite suggest that this essentially magmatic character was maintained at least to the beginning of spodumene crystallization.

The chemical characteristics of the pegmatitic solutions just prior to and during crystallization are indicated both by the mineralogic composition of the units formed and the texture of these units. The abundance of feldspars, quartz, and muscovite in all pegmatites is evidence that the original solutions were essentially sodium, potassium, aluminum silicates with appreciable quantities of calcium and water. The rarer minerals present indicate that in addition there was more or less iron, manganese, beryllium, phosphorous, lithium, boron, fluorine, arsenic, sulfur, and many other metallic and rare-earth elements. The presence of many of these elements plus the generally very coarse texture of the rocks suggests that the pegmatite solution contained appreciable quantities of dissolved gases and mineralizers. A few minerals, such as sillimanite, andalusite, biotite, garnet, and perhaps part of the muscovite, tourmaline, and other minerals that occur near schist walls or inclusions in some South Dakota pegmatites suggest that assimilation of wallrock material altered the composition of the solution just prior to the beginning of crystallization. Probably the same process took place earlier when the assimilated material could be uniformly distributed throughout the solution, but it is impossible to determine the proportion of elements introduced into pegmatite solutions by such processes. All of the Black Hills pegmatites contain small quantities of the rarer elements, and a few have these elements in abundance. This fact indicates that some process segregated them prior to the emplacement of the pegmatite, and their occurrence in definite units within the pegmatites suggests that the same process continued after emplacement.

The zonal structure, the constancy of the zonal sequence of essential minerals of pegmatites (table 3), and the systematic variation in the composition of some minerals or groups of minerals with respect to the zonal structure imply a process of fractional crystallization of a liquid in situ, rather than crystallization of liquids in an open system as suggested by Schaller (1927, pp. 59–63). The increasing abundance of some of the rarer minerals in the inner zones of pegmatites completely surrounded by zones essentially barren of them likewise substantiates this theory, as it avoids the difficult mechanical problem of introducing these minerals by hydrothermal solutions into the interior of pegmatite bodies without leaving traces of their having passed through the outer parts. Furthermore, their arrangement in the order of the zonal sequence is best explained by fractional crystallization. Zoned fracture-filling bodies that are continuous with inner zones show that the material from which they formed came from within the pegmatite and not from external sources. In these structural units there are many replacements of one mineral by another. The early minerals of each unit are corroded, and new minerals are deposited against the corroded edges. Although a definite sequence can be worked out, there are usually places in the same unit where contradictions are found. For this reason the minerals of a unit are considered to be essentially contemporaneous and the corrosion of early crystals is attributed to rest liquids.

The coarse textures of pegmatites are usually assumed to be the result of the presence of mineralizers, slow cooling, unusual concentrations of crystallizing elements, or a combination of these factors. In general the grain size of pegmatite units shows an increase from the contacts inward. Pegmatites and pegmatite units formed early in the sequence, composed essentially of plagioclase and quartz, commonly are finer grained than units of similar composition late in the zonal sequence. As there is no evidence that the rate of cooling decreased markedly during the formation of these inner zones, the large size of the crystals must be attributed to the influence of mineralizers or to unusual concentrations of the crystallizing elements. The repetition of concentrations of minerals such as beryl, muscovite, and potash and soda feldspars in several zones and the systematic variations in the compositions of these minerals indicates that the concentration of the component elements of the pegmatite solution varies widely throughout pegmatite development. In some units there appears to be a correlation between the abundance of a mineral and the size of the crystals, and large size may be caused by unusual concentrations of the crystallizing elements. In other units large crystals appear to have been formed under the influence of mineralizers. The presence of minerals such as lepidolite only in inner zones or cores suggests that the mineralizers become an increasingly important factor in the later stages of pegmatite formation. If the proportion of mineralizers increases during crystallization the pegmatite solution may be expected to change progressively from a silicate-rich to a more aqueous solution.

Wallrock alterations indicate that changes in temperature, pressure, or other physical conditions may cause the pegmatite solution to give up its contained mineralizers during crystallization, just as granitic magmas do in producing contact-metamorphic rocks. In the Black Hills the most intense alteration is adjacent to pegmatites or parts of pegmatites that cross cut the country rock and consequently are in the most favorable position for the escape of pegmatite liquids. Pegmatites such as the Old Mike, Etta, and Bob Ingersoll Dike No. 2 are partly enclosed by feldspar granulite, as much as 8 feet thick, where the contact is discordant with the wallrock schist. The presence of apatite, tourmaline, beryl, and other minerals indicates that the granulite was developed by solutions from the pegmatite. It is evident that the pegmatite formed after the granulite because the contacts between pegmatite and granulite are sharp, pegmatite stringers cut the granulite, and the border zones, though somewhat coarser textured against granulite than against schist, are nevertheless finer grained than the wall zones. Therefore, it appears reasonable to suppose that the materials necessary to form the granulite escaped from the pegmatite solution before crystallization of the border zone. As the structure of the schist is for the most part pseudomorphically preserved, it is probable that the replacement of the schist was caused by hydrothermal or perhaps by pneumatolytic solutions. The same type of solutions probably caused the introduction of other minerals, such as tourmaline, into the schist far from the contacts of pegmatites. These solutions may form different types of rocks where different types of schist were replaced. Biotite was formed from hornblende schist at the hanging-wall contact of one of the Rough and Ready pegmatites in the Tinton district, and at the other contact tourmaline-quartz rock was developed from quartz-mica schist. The absence of biotite in the pegmatite itself strongly suggests that there was little assimilation of the wallrock; there was, however, the addition of considerable material to the country rock by escaping solutions. In general, it appears that under certain conditions of structure, temperature, and pressure, the more volatile constituents of a pegmatitic solution may escape prior to the beginning of crystallization.

The presence in the pegmatites themselves of a few replacement units that must have formed prior to the complete consolidation of the pegmatite also indicates that under certain conditions the pegmatite liquids may allow the escape of hydrothermal (or pneumatolytic) solutions at any time during crystallization. Replacement bodies are most common in the later stages of pegmatite development and in many pegmatites represent the last stage. The occurrence of his type of pegmatite unit in the late stages of pegmatite formation may be correlated with the increase in proportion of mineralizers during crystallization and a corresponding change in the solution toward one more nearly hydrothermal in character.

The history of crystallization of Black Hills pegmatites also substantiates the theory that pegmatite solutions are essentially magmatic in character throughout a large part of their history and that they change progressively into solutions that are more nearly hydrothermal in character. In South Dakota there are two main mineralogic groups of pegmatites. A large group consists of poorly or well zoned pegmatites that are composed essentially of feldspar, quartz, and muscovite. Some of them contain appreciable quantities of tourmaline, beryl, apatite, garnet, and biotite. A much smaller group has outer zones essentially like those of the first, but the inner zones contain considerable quantities of cleavelandite, quartz, and lithium minerals with smaller quantities of tourmaline, apatite, garnet, biotite, cassiterite, columbite-tantalite, beryl, uranium minerals, microlite, pollucite, phosphates, etc. These pegmatites are characteristically well zoned and the lithium and rarer metallic and rare-earth minerals are confined largely to inner zones. The generalized zone sequence for 80 South Dakota pegmatite (table 3) includes examples of both types and the zonal sequence for both is the same in all districts. Not all pegmatites contain all of the units in the generalized sequence of table 3, but all units that do occur are in the same order from the pegmatite contact to the core. Furthermore, some replacement units have a structural position that is in accord with their position in the general mineralogical sequence. For example, the quartz-spodumene replacement body in the Giant-Volney pegmatite was formed at the same position in the sequence as the quartz-spodumene zones of the Etta, Hugo, and other pegmatites. The formation of replacement bodies instead of zones indicates that under favorable conditions hydrothermal (or pneumatolytic) solutions may escape from the crystallizing pegmatite at several stages in pegmatite development. These bodies may or may not be followed by the formation of additional zones. If the feldspar-rich pegmatites are of magmatic origin and the lithium-rich and rare-mineral-bearing pegmatites were developed by subsequent replacement by solutions introduced from outside sources, it is difficult to understand why both the zonal sequence and the sequence of replacement bodies are the same in all the pegmatites of the various districts.

Replacement textures, structures, and minerals are common in zones as well as in replacement bodies, but they have apparently been formed by different processes in each type of unit. Clear evidence that these units were formed by through-going hydrothermal (or possibly pneumatolytic) solutions from outside sources during or after crystallization of the pegmatite is lacking, but there is evidence that some of the replacement units and wall rock alterations were formed by the action of hydrothermal (or possibly pneumatolytic) solutions derived from the crystallizing pegmatite.

The most abundant replacement phenomena in the pegmatites are the corrosion and embayment of one mineral by another; the "veining" along cleavages, partings, and similar structures; the corroded remnants of one mineral in another; and pseudomorphs of individual crystals. Pseudomorphs of textures and of structures, such as fractures, gneissic structure, and zonal boundaries, are less abundant. Pseudomorphs of textures and structures that are characteristic of completely consolidated rock are considered the best evidence of hydrothermal replacement. Other replacement textures and pseudomorphs of individual crystals can and probably did develop through reaction between crystals and rest liquids (reaction replacement) before consolidation was complete. Corroded beryl, spodumene, amblygonite, perthite, microcline, and tourmaline crystals commonly occur in relationships that preclude corrosion by hydrothermal solutions. Many of these corroded minerals are fractured and veined by groundmass minerals that show no sign of having been formed by hydrothermal replacement. Pseudomorphs of muscovite and other minerals after beryl, tourmaline, and spodumene likewise are found in structural positions that would be less favorable for hydrothermal replacement than for reaction replacement. For example, in the Etta, Beecher Lode, and other pegmatites isolated crystals of spodumene (the earliest mineral to form in the zone) have been pseudomorphically replaced by hydrous micas and clay minerals without any alteration of the younger surrounding minerals that enclose, corrode, and vein the spodumene crystals. Furthermore, these pseudomorphs show a direct relation to the zonal structure in that they are most abundant in the feldspar-rich outer parts of the spodumene deposit and less abundant in the quartz-rich inner part. Corrosion and embayment, veining, corroded remnants, and pseudomorphs of crystals conclusively prove replacement, but not which process was involved. Therefore, although these phenomena are of use principally in determining the paragenesis of the minerals within individual units, they must be used with other evidence to indicate whether hydrothermal, pneumatolytic, or reaction replacement is the dominant process in the development of specific pegmatite units.

Few South Dakota pegmatites contain units that apparently have formed by hydrothermal processes. These units have mineralogical compositions similar to zones and fracture-filling units that probably formed by other processes. Most of the units considered to be of hydrothermal replacement origin are too small to show on the maps or to mine, although there are such exceptions as the large quartz-spodumene replacement body in the Giant-Volney pegmatite in the Tinton district. This quartz-spodumene unit pseudomorphically replaced gneissic, fine-grained albite-quartz pegmatite and coarser-grained oligoclase-quartz-muscovite pegmatite. Fractures in the quartz lenses of the albite-quartz rock were preserved and accentuated by the introduction of spodumene in the form of veinlets. Replacement was less complete and relict minerals are more common in the oligoclase-rich rock. After the introduction of spodumene and quartz, lenticular bodies of microcline and quartz that are devoid of the gneissic structure and fractures which characterize the earlier units developed in the spodumene body, but truncate the pseudomorphic textures and structures. These microcline bodies are satellitic to a microcline-quartz core that shows no sign of having been introduced by replacement. Many of the smaller replacement bodies in the pegmatites of the southern Black Hills do not have a mineralogic composition comparable to that of any zone of the containing pegmatite. The muscovite bodies that were formed along fractures in the perthite-quartz units of the White Elephant pegmatite are typical examples. In many bodies, however, the introduced minerals are those which normally would have been present if additional zones had formed. For example, small replacement bodies of cleavelandite are not uncommon in pegmatites that have perthite-quartz cores, and if an additional zone had formed in such a pegmatite it would normally have been rich in cleavelandite. Consequently, it seems reasonable to assume that the solutions that produce replacement bodies after forming the zones contain the silicates necessary to form additional zones, but have accumulated such a large quantity of water and other mineralizers that they are essentially hydrothermal solutions.

Many of the minerals in the pegmatites show changes in composition correlated with the zonal sequence and structure. The plagioclase in many Black Hills pegmatites is albite, but a few pegmatites also contain oligoclase. The Rough and Ready and the Giant-Volney pegmatites are known to contain zoned plagioclase crystals with cores of oligoclase surrounded by albite. The indices of refraction of plagioclase feldspars in numerous pegmatites show that the contained plagioclase is either uniform in composition or its anorthite content decreases from the walls to the core. In none of the pegmatites did the plagioclase have a higher anorthite content in the inner zones. Where zoned plagioclase crystals have been observed, the plagioclase of younger pegmatite units is of the same anorthite content as the outer part of the zoned crystals, or lower. These changes in the anorthite content of plagioclase in the pegmatites are analogous to the normal variation in plagioclase composition in igneous rocks and would not be expected as the result of hydrothermal replacement.

The composition of beryl also shows a systematic variation paralleling the decrease in anorthite content of plagioclase. In some South Dakota pegmatites, beryl of progressively higher index of refraction is found from the contact toward the core. This increase in the index of refraction indicates a progressive increase in the alkali content of the beryl and probably also an increase in the alkali content of the solution from which it formed. Beryl in the outer zones of the pegmatites characteristically consists of shells that enclose and replace minerals of the adjacent groundmass, but the edges of the crystals are usually slightly corroded and replaced by groundmass minerals, indicating essentially contemporaneous deposition. Crystals of groundmass minerals are fewer and are more corroded in the inner zones, suggesting that the solutions from which beryl was deposited became increasingly corrosive in the later stages of pegmatite formation. These progressive changes with respect to zonal structure are explainable not by crystallization from a series of hydrothermal solutions, but by fractional crystallization from a single liquid.

The lithium minerals as a group show a similar variation in composition that can be correlated with their position in the pegmatite. Iron-manganese-lithium phosphates occur most abundantly in zones outside of those containing amblygonite. The lithium phosphate, amblygonite, occurs primarily in the outer part of spodumene-bearing zones or outside of lepidolite-rich zones. Lepidolite is formed later in the sequence than spodumene. This sequence of minerals and its relation to zonal structure is more readily explained on the basis of successive crops of crystals from a single solution than by crystallization from a series of liquids introduced at different times. The changes in composition of the lithium minerals also support the theory that the proportion of mineralizers, such as flourine and water, increases toward the end of pegmatite development. This increase also may be correlated with evidence of increasing amount of replacement. The iron-manganese-lithium phosphates have not received detailed laboratory study, but field evidence suggests that they have suffered less corrosion than amblygonite. Amblygonite generally occurs as rounded and corroded crystals that are in part interstitial to spodumene. Most of the spodumene crystals in zones rich in feldspar are corroded, and are pseudomorphically replaced in whole or in part by micaceous and clay minerals. This pseudomorphic replacement is less common in zones rich in quartz. In general, the spodumene crystals are much less corroded in quartz-rich than in the feldspar-rich zones. Some replacement bodies contain spodumene but no amblygonite. The lepidolite zones show much more replacement textures than the spodumene zones. The sequence of lithium minerals and the increased abundance of replacement textures indicates that there has been a systematic and progressive change in the composition of the pegmatite solution to approach that of an aqueous liquid of hydrothermal character.

The perthitic character of potash feldspar within the Black Hills pegmatites is directly related to its zonal position. Potash feldspar formed earlier in the zonal sequence than the lithium minerals is megascopically perthitic, and only rarely have crystals devoid of this intergrowth been observed in these zones. Few corroded crystals of albite occur in the perthite, but such crystals are common in potash feldspar that was formed at the same time or later than lithium minerals. These corroded, lathlike crystals of albite show no systematic orientation within the potash feldspar crystals and are apparently true inclusions, though additional albite may replace the edges of the potash feldspar crystals. Potash feldspar in zones containing amblygonite and spodumene is perthite in some pegmatites, microcline in others, and in still others both occur in separate crystals. Microcline found in the spodumene or later zones is generally characterized by megascopic gridiron twinning, which is very rare in the perthite. This gradation in the perthite content of potash feldspar and its relation to the zonal sequence is not directly related to the abundance of plagioclase in the zones, because perthite is commonly most abundant in units where there is more quartz than plagioclase. Microcline also occurs in quartz-rich units that are enclosed by zones rich in albite. Some relict microcline crystals in replacement units at the Hugo pegmatite have been hydrothermally replaced and corroded by cleavelandite, but do not show perthitic structure. The potash feldspar in the outer zones of the Hugo pegmatite is perthitic. This type of relationship, plus the inclusion of corroded crystals of albite in the microcline, strongly suggest that the development of perthite in pegmatites may be caused by processes other than hydrothermal replacement. The perthite in many pegmatites is corroded by an intergrowth of quartz and albite, and the field evidence indicates that this perthite formed before the groundmass. The occurrence of perthite early in the zonal sequence and in units where there is little evidence of replacement strongly suggests that the corrosion was produced by reaction with rest liquids.

The occurrence of concentrations of perthite as hoods within zones that also contain quartz, plagioclase, and muscovite (zone 3, table 3) is plausibly explained only on the basis of fractional crystallization, because hydrothermal solutions cannot logically be expected to produce concentrations of perthite that are always in hoods. Concentrations of perthite characteristically occur in the upper part of the pegmatite body, and the perthite content decreases from the outer to the inner contact, and also down the dip. This gradation may be from nearly 100 percent perthite in the upper and outer parts to mere traces in the inner and lower parts of the zone. Textures indicate that the uniform intergrowth of albite, quartz, and muscovite which forms the groundmass throughout the zone formed later than the perthite. The large size and the concentration of perthite crystals in the upper part of the pegmatite body strongly suggests that they may have accumulated either by floating in a liquid or by crystallizing from an immiscible liquid floating on another liquid. Little is known of the composition, pressure, and temperature of the pegmatitic liquid, or of its behavior and characteristics during crystallization. The large perthite crystals in a groundmass of wall-zone minerals at the top of pegmatites, such as in the Bob Ingersoll Dike No. 2, suggest that these crystals may have started to grow and accumulate very early. It is very unlikely that hydrothermal solutions either always selected this part of the pegmatite for the deposition of perthite concentrations or always selected the inside of the zone as a place to start replacement of perthite by quartz, muscovite, and albite, and very probably such replacement would destroy the crystal form of the unreplaced perthite. Consequently, the possibility that hydrothermal solutions formed either perthite or microcline zones in the South Dakota pegmatites is considered remote, and the origins of perthite and microcline are considered to be similar in that they were formed by orderly crystallization of a single pegmatite solution. The recurrence of these minerals in different zones is probably the result of changes in the composition of the crystallizing solution which caused it to be saturated with respect to the components of potash feldspar at more than one period in pegmatite formation.

In summary, the evidence indicates that the Black Hills pegmatites were formed from solutions derived from the differentiation of the Harney Peak granite. These solutions were composed of relatively large quantities of sodium, potassium, aluminum, silcon, beryllium, fluorine, boron, phosphorus, lithium, and many less common metallic and rare-earth elements, with relatively small quantities of magnesium, calcium, iron, and manganese. Water and other mineralizers were dissolved in this solution. The pegmatite solution, as intruded, was a viscous liquid moving upward under pressure sufficient to deform and push aside the wall rocks and to develop gneissic and flow structures within some pegmatite units. Crystallization of the pegmatite solution was an orderly process that was interrupted at intervals by the escape of mineralizers and dissolved silicates which altered wall rocks or earlier pegmatite units. Fractional crystallization of the pegmatite solution produced zones characterized by distinctive minerals or mineral assemblages arranged in a consistent zonal sequence.

The zonal sequence of the essential minerals from the walls inward is: (1) plagioclase, quartz, and muscovite; (2) plagioclase and quartz; (3) perthite, quartz, muscovite, and plagioclase; (4) perthite and quartz; (5) perthite (or microcline), quartz, plagioclase, amblygonite, and spodumene; (6) plagioclase and quartz; (7) plagioclase, quartz, and spodumene; (8) quartz and spodumene; (9) plagioclase, quartz, and lepidolite; (10) quartz and microcline; (11) microcline, plagioclase, lithia micas, and quartz; and (12) quartz. The composition of the essential and accessory minerals in these units shows systematic variations that can be correlated with this zonal sequence and indicates that during crystallization the pegmatite solution became richer in mineralizers. The increase in the abundance of replacement textures from the outer to the inner zones and the increase in grain size from the walls to the center of the pegmatite substantiate the theory that the proportion of mineralizers in the solution increased with continued crystallization and that the solution changed from one that was essentially magmatic to one that was essentially hydrothermal in character. During crystallization, fracturing of earlier-formed zones allowed the escape of part of the pegmatite liquid along fractures to form fracture-filling bodies. This part of the pegmatite solution crystallized in the same orderly fashion as the main body, and in some instances conditions were also favorable for the release of mineralizers and dissolved silicates as hydrothermal solutions. These hydrothermal solutions caused replacement of the fracture walls and produced fracture-controlled replacement units. At intervals during crystallization of some pegmatites conditions were favorable for the escape of mineralizers and dissolved silicates from the rest-liquid. These produced replacement bodies similar in composition to that of the zone that would have formed at that time. There is no evidence that any replacement bodies in the Black Hills pegmatites were formed in channelways by solutions from outside the pegmatite body nor is there any evidence that hydrothermal solutions from outside sources were responsible for development of other pegmatite units.

TERTIARY DIKE ROCKS

In the Tinton district no pre-Cambrian igneous rocks other than the pegmatites are exposed but granite fragments have been noted in intrusive breccias that cut the pegmatites. Tertiary monzonite and syenite porphyries are cut both by pseudoleucite- and nepheline-bearing rocks and also by lamprophyre dikes. These dike rocks in turn cut the pegmatites.

MICA DEPOSITS

DISTRIBUTION

Muscovite mica occurs in nearly all South Dakota pegmatites, but only a few of them contain sufficient concentrations or large enough books to allow profitable mining of sheet and punch mica, scrap mica, or both. Other pegmatites, worked primarily for minerals such as feldspar or spodumene, yield mica as a byproduct. The largest production of sheet mica in the Black Hills is from the Custer district. The Keystone and Hill City districts rank second and third respectively. Sheet mica has never been produced in the Tinton district. Scrap mica is produced or has been produced in all districts. A list of mines and prospects from which sheet and punch mica were recovered in 1943, 1944, and 1945 is given below. The location of the larger mines is shown on plate 1.

South Dakota mica prospects that produced a total of less than 100 pounds of trimmed sheet and punch mica during 1943, 1944, and 1945

Custer District:
- Amber.
- Ajax.
- Alvira.
- Ambrose.
- Apex.
- Banty.*
- Beecher Lode.
- Bedrock.
- Big Timber.
- Big Tiny.*
- Black Gold.
- Blue Bell.
- Bonnie Lode.
- Bowman.*
- Bullhead.*
- Bumper.*
- Bunyar.
- Burgess.*
- Burley.*
- Chipmunk.*
- Clare Green.
- Cloverleaf.*
- Covered Wagon.*
- Coyote.*
- Dakota Girl.
- Dakota Standard.
- Dale.*
- De Sota.
- Dorothy V.
- Duke.*
- Duncan (Andrews).*
- Eddie Joyce.
- Eureka.
- Fitzgerald.
- Francis.
- Gold Nugget.*
- Gray Rocks.
- Green Burleson.
- Hampton.
- Grice Wayside.
- Hardrock.
- Helen Beryl.
- High Hat.*
- Highland Lode.*
- Homestead No. 1.*
- Homestead No. 2.
- Hope.*

See footnote at end of table.

Custer District—Continued
- Hot Shot.
- Independence.
- Jack of Diamonds.*
- Jack Pot.
- Joan Lode.*
- Judd.*
- Klondike.
- Lame Deer.*
- Last Hope.
- Last of the Thousand.
- Last Penny.*
- Lauretta
- Leon Lode.*
- Lerrue.
- Lion's Den.
- Little Fortune.
- Little Mica Lode.
- Little Sioux.
- Lois Lode.
- Lone Ridge.*
- Lookout No. 1.
- Lost Indian.*
- Lost Queen.*
- Lucky Boy.*
- Lucky Mine.
- Lucky Star.
- Lucky Strike.
- Lucky Strike No. 1.
- Lucky Strike No. 2.
- Make or Break.*
- Marie.*
- McKirahan.*
- Mica Queen No. 2.
- Mica Queen Proper.*
- Minneapolis Mica Lode.
- Mitchell.*
- Mohawk Mica.*
- New Deal.*
- O. K. Lode.*
- Oriental.*
- Pitt.*
- Promintory Lode.
- Promise.
- Rattlesnake.
- Raver Roosevelt.*
- Raver (Cannon).
- Ray.

South Dakota mica prospects that produced a total of less than 100 pounds of trimmed sheet and punch mica during 1943, 1944, and 1945—Continued

Custer District—Continued
- R. K. Mica.
- Robin.
- Rock Crusher.
- Ronald Spar.
- Ross Dike.*
- Side Hill.
- Silver Penny.
- Smokey.
- Sole.
- Sunshine.*
- Specimen.
- Spring.
- Star.
- Stinkeroo.
- Sunnyside.*
- Tiger Lily.
- Top Hat.*
- Top Mine.*
- Town Fraction.
- Triangle.*
- Tubbs No. 2.*
- Wallpole.*
- Walsh.
- White Cloud.
- White Diamond.
- Wilhelm.
- Willie.
- Woodfred.
- Wonder Lode.*

Prospects:[1]
- Andrews, A. J.
- Barnett.
- Bay, Ralph.
- Beck.
- Beck, T.
- Benji.
- Bourassa, C.
- Bower—Combs.*
- Bracha.*
- Caster, M. J.
- Dakken, John.
- Dickson, Lloyd.
- Donaldson, I. M.
- Dowdy, Bonnie.
- Eliott.
- Eliott, Wintah.
- Evans.*
- Fay.
- Fisher.*
- Gabel, L.
- Gates, A.
- Gideon, C. C.
- Graham.
- Graham, B. H.
- Gundlach, A. H.
- Gundlach, J.
- Hammer, Iva.
- Hardestey, Bert.
- Harris.

Prospects—Continued
- Heidepriem, Eric.
- Herman, J.
- Jackson, J. E.
- Jeffries.
- Kouba.
- Knabe.*
- Knight.
- Landis.*
- La Rue.
- Le Roy.
- Long, J. D.
- Long, J. D. and Edwards, Fred.
- Martin.
- Matthews, C.
- Miller, F.*
- Mogck, Tina.
- Nystrom, N. E.
- Oens, Sam.
- Peterson, P. D.
- Phelps, John.
- Polreisz, Fay.
- Reuwsatt.
- Roseberry, Carl.
- Roseberry, John.
- Rouillier, N. E.
- Schultz.
- Schultz, Louie.*
- Sheeley, Ray.
- Sheets, Wayne.
- Slater, T. C.*
- Solomon, Ray.
- Thompson.
- Thompson, Mabel.
- Tubbs, Page.
- Ventling, Helen.
- Walton, A.
- Young, F. L.
- Zwiefel, A.

Keystone District:
- Bob Ingersoll.
- Election.*
- Etta.
- Eureka (Madill).*
- Goat Lode.
- Jumbo.
- King Mine.
- Maryland.*
- Niel Homestead.*
- Nile Homestead.
- Ponca.*
- Prospect.
- Sagdalin.*
- Silver Streak.*
- Specimen.
- Wood Tin.

Hill City District:
- Eureka (Mills).*

*Production exceeded 10 lb.

[1] Names of prospects unknown or in question. Sales of mica made under owner's name only.

South Dakota mica mines that produced a total of more than 100 pounds of trimmed sheet and punch mica in 1943, 1944, and 1945

Custer District:
- Ann.*
- Aladin.
- Antler.
- Arcade (Victory No. 1—Hoefert).
- Ballard.
- Big Spar No. 1.
- Blue Bonnet.*
- Burt.*
- Buster Dike.*
- Climax.*
- Coolidge.
- Crown.*
- Dakota Feldspar.
- Dalmon.
- Earl Lode.*
- Gap Lode.*
- Harbach.
- Homestead No. 2.
- Hub.
- Glenwood.
- Jack Rabbit.*
- Josie Lode.
- L5 No. 4.
- Lakeside.
- Lost Bonanza.*
- Lucky Star.
- Lucky Star No. 1.
- MacArthur.*
- Marydale.
- Maybe.
- Mica Queen.
- Midas.
- New York.*
- November.*
- Old Mike.*
- Old Missouri.
- Oreville Spar.

Custer District—Continued
- Pigtail.
- Punch.*
- Rainbow.
- Red Deer.*
- Roosevelt.
- Ruby Reef and Ruby Reef No. 1.
- Seal.
- Sheeley Prospect.
- Silver Dollar.*
- Sunday Dog.
- Surprise.
- Terry Lode.
- Tip Top.
- Victory .*
- White Bear.*
- White Dog.
- White Spar.*
- Wiehe.

Keystone District:
- Anna Lode.
- Dan Patch.
- Davis.
- Dyke Lode.
- Hugo.*
- King.
- Mica Lode.
- Peerless.
- White Cap.
- Mica Hill.

Hill City District:
- Dewey Lode.*
- Monkey Lode.*
- Pearl.
- Tin Queen.*

*Production exceeded 1,000 lb.

COMPOSITION AND PHYSICAL PROPERTIES OF MICA

COMPOSITION

Mineralogically the term mica covers a large group of aluminum silicate minerals with similar physical characteristics, but it is applied in commerce only to those that are valuable because of certain special properties (Sterrett, 1923, Chowdhury, 1941, Olson, 1942, and Wierum and others, 1938). Minerals of the mica group include muscovite, phlogopite, lepidomelane, biotite, zinnwaldite, lepidolite, paragonite, and roscoelite. Muscovite is an orthosilicate of aluminum and potassium; phlogopite contains magnesium and fluorine; lepidomelane contains ferric iron and a little magnesium; biotite contains iron and magnesium; zinnwaldite is an iron- and lithium-bearing mica; lepidolite contains lithium and fluorine; paragonite is a sodium-bearing mica corresponding to the potassium variety, muscovite; and roscoelite is a vanadium-bearing mica. The clintonite, vermiculite, and chlorite groups are micaceous minerals that are similar to the true micas except that cleavage plates split from them are not flexible and elastic.

Most of the mica of commerce is muscovite, but appreciable quantities of phlogopite are also used in the electrical industry. Only muscovite is produced in South Dakota, and in this report the term mica, unless qualified, refers to that variety.

PHYSICAL PROPERTIES

Muscovite crystallizes in the monoclinic system with an approximately hexagonal form. It has a perfect basal cleavage, along which it can be split into thin sheets. The cleavage plates are elastic, flexible, and tough. In addition, mica has other cleavages or partings along which percussion and pressure figures are formed. The percussion figure is obtained by striking a sheet of mica a sharp blow with a blunt punch. It is a six-rayed star formed by three cracks or cleavages intersecting at angles of about 60°. The pressure figure is obtained by pressing the cleavage surface with a dull point. It is formed by less perfectly developed cleavages that bisect the angles between the rays of the percussion figure.

Muscovite has a high luster, comparative softness, and great resistance to the conduction of heat and electricity. It is generally transparent and colorless to light-colored in thin sheets, but sheets 1/16 in. thick may be colorless or a shade of red, amber, yellow, brown, or green. The commercial uses of muscovite are particularly dependent on its flexibility, elasticity, toughness, nonconductivity, and color.

Mica has several physical characteristics related to crystal structure, color, and inclusions that determine its value, and therefore these characteristics have been given special names by the miners. Muscovite referred to as "A," "fishtail," "fishbone," "herringbone," or "horsetail" mica has cleavage imperfections called "ridges" or "reeves." "A" mica has two sets of reeves that intersect at an angle of about 60°, forming a "V." The reeves have the same orientation as the rays of the pressure figure. A crystal of mica in which the reeves extend in only one direction is called "hairlined" mica. The terms fishtail, fishbone, herringbone, or horsetail refer to mica in which two sets of reeves are at angles of 120° and a third set bisects the others at their intersection to form a center line or spine, so that the entire structure resembles a feather or a fish skeleton. Commonly crystals or books of "A" or herringbone mica are thicker on one side than on the other and are called "wedge" mica. Wedge structures also occur in otherwise perfect crystals. The laminae in some mica books are interlocked so that the mica splits readily in some places and not in others. Mica with this characteristic is referred to as "crossgrained," "tied," or "tangle sheet" mica. In South Dakota the terms "fish," "fishy," "A," and "tied" mica are often used by miners to include mica that has any or all of these structural defects that lower the percentage of recoverable flat sheets.

In some mica books successive laminae do not extend completely across the crystal, but uniform sheets of greater thickness may be obtained. The edges of these laminae are marked by a faint line and may be followed by very narrow, irregular cracks known as "hair cracks." These incomplete laminae are called "partial films" and their presence lowers the recovery of usable films when this type of sheet mica is filmed in fabrication.

Waviness and rippling of cleavage sheets together with "ruling" (cracks parallel to the rays of the pressure figure) in mica are commonly the result of deformation near faults. Where deformation is severe the ruling cracks are so closely spaced that the mica breaks into narrow strips called "ribbons." These defects may also occur in pegmatites that are not faulted, and are probably the result of readjustment within the pegmatite during formation.

Muscovite, in 1/16 in. sheets, is classified on the basis of color, as ruby, rum, white, or green mica. Some micas show a noticeable color banding parallel to the reeves of the "A" and herringbone structure. The banding forms either a series of parallel streaks or a cross-hatched pattern. Some books of dark ruby mica have a darker-colored, distorted hour-glass figure within a parallelogram of lighter-colored mica, which however is darker colored than the main crystal. The top and bottom of the hour-glass are not symmetrical and the sides of each part intersect at an angle of about 53°. On one side of the hour-glass figure the change in color makes an angle of about 27° with the long side of the parallelogram and on the other side about 12°. A densely air-stained spot, known as a "silver spot," occurs at the narrow part of the hour-glass.

A great variety of minerals occurs included between, or penetrating, the mica laminae and constitute one of the major defects in mica. If these inclusions are black the mica is referred to as "specked," "stained," "black-stained," or "black" depending on the abundance of inclusions. Magnetite, tourmaline, biotite, pyrite, and manganese or iron oxides are the most common black-mineral inclusions in mica. Quartz, chalcedony, feldspar, zircon, beryl, apatite, and other light-colored minerals may be associated with the black inclusions or they may occur separately. Scattered small grains of colorless minerals are referred to as "sand." The inclusions may be oriented in definite lines or patterns along crystallographic directions or they may be scattered irregularly through the mica. Red inclusions of limonite and hematite are called "red spots" or "red specks," depending on size, and the mica containing them is said to be "red-stained." Some mineral inclusions change the electrical properties of mica. Magnetite, biotite, and both the red and black iron oxides are particularly detrimental because they change the power factor appreciably. Tourmaline, pyrite, and the light-colored minerals have little or no effect on the electrical properties, but they may pierce the laminae and form pin holes that make the mica useless for electrical purposes. Gas bubbles in mica produce what is known as air-staining, although the exact nature of the gas is unknown. If the bubbles are uniformly distributed and closely spaced the mica will have a silvery appearance and will be called silver-stained or densely air-stained mica. Where these gaseous inclusions occur in streaks the mica is said to contain silver streaks. These streaks are often confused with cracks. Silver spotted mica contains densely air-stained spots, usually less than ⅛ in. in diameter. Microscopic examination of these spots show that they have formed around inclusions of minerals such as zircon, and that the mica itself is altered to a greenish color. The laminae have been perforated and broken so that this is a much more serious defect than the normal heavy air-stain.

The use of mica in the electrical industry is governed not only by the absence of physical defects but also by the dielectric constant and power factor of the mica. The dielectric constant of mica is the ratio of stored energy in a dielectric field occupied by the mineral to the stored energy that would exist in the same space if air were used in place of mica. The dielectric constant of most mica ranges from 6.5 to 8.5; the average is about 7.2. The power factor of mica, expressed in percentage, is a measure of the loss of electrical energy in a condenser in which mica forms the dielectric medium. Mica of low power-factor, less than 0.04 percent, is essential for condensers. The power factor as determined by use of the Bell Laboratories Q machine designed for electrical testing of mica is also expressed in power factor groups as E1, E2, and E3. The relationship between power-factor groups and Q value are given below.

The physical properties of mica are the basis for elaborate classifications by which sheet mica is classified for use in the electrical industry.

MINING, PREPARATION, AND USES OF MICA

MINING

Mining in most of the mica mines of the United States is done by open-pit and quarrying operations, although mica zones have been followed underground in some of the larger mines. In South Dakota all of the larger mica mines and many of the smaller ones are worked from shafts or adits with connecting drifts, crosscuts, stopes, raises, or winzes. Most of the mines were started as open pits and later extended underground, but most pits were made in the search for feldspar, and mica was obtained as a byproduct. During the period

Q and power factor values for electrical quality groups E1, E2, and E3.[1]

Q or power factor group	Form	Q value μ	Power factor	Rapid method meter readings of mica tested at thicknesses indicated: 0.010 in. (0.007 to 0.015 in.)	0.020 in. (0.015 to 0.025 in.)	0.030 in. (0.025 to 0.035 in.)
E1	Block mica.	2,500 min.	0.0004 max.	95 to 100	95 to 100	95 to 100
	Films	2,500 min.[2]	0.0004 max.	----	----	----
E2	Block mica.	350 to 2,500	0.00285 to 0.0004	87 to 95	77 to 95	71 to 95
	Films	1,500 min.[2]	0.00067 max.	----	----	----
E3	Block mica.	50 to 350	0.02 to 0.00285	50 to 87	32 to 77	24 to 71
	Films	200 to 1,500[2]	0.005 to 0.00067	----	----	----

[1] Furnished by Mr. George A. Purcell, Colonial Mica Corporation.

[2] Extensive commercial tests have satisfactorily verified the validity of the Q values of capacitors made with group E1 block mica. However, the ranges for groups E2 and E3 are tentative and subject to further verification.

1943–45 mica was sorted from the rock either at the face or at chutes at most mines. A picking belt was used at the Burt mine in conjunction with a power shovel, and at the Old Mike mine (at that time a glory hole operation) in conjunction with a mucking machine. In a few mines rock broken in stopes was sorted at chutes underground and again at the surface. This second sorting operation was made feasible by the subsidy on the smaller sizes of mica. In most underground operations only the overbreak was hoisted to the surface; in others all broken rock was hoisted and sent either to the dump or used to backfill stopes.

Accurate determination of the cost of mining mica in the Black Hills from 1943 to 1945 was not possible because data are incomplete. The cost varied widely from mine to mine depending on (1) the richness of the deposit, (2) the value of the byproducts, (3) whether mining was open-pit or underground, (4) the type of equipment used, (5) the efficiency of the management, (6) the cost of labor and materials, (7) the amount of development work necessary, and (8) the length of time in operation. Other factors being equal, the cost of open-pit mining was a half to one-third that of underground mining.

Before December 1943 the cost of producing a ton of sheet-bearing crude mica from 14 selected properties ranged from $100 to more than $900. In the period 1943–45 most of the mica was produced by underground operations, and the cost was probably between $150 and $400 per ton. The best records available show that at one of the larger properties the average total cost per ton of crude mica was about $200. At another property for which records of total expenditures are available, the figure is about $400. The direct mining costs, excluding the price of the property, machinery, buildings, and other items that had value when operation was suspended were about $150 and $350 respectively at the two mines.

No pegmatites were worked primarily for scrap mica because the price ($20 per ton) was insufficient to allow profitable mining except where the pegmatite contained at least 15 percent recoverable mica. All pegmatites mined for sheet mica yielded less than 10 percent crude mica by methods in use during 1942–45.

PREPARATION

Crude mica, as recovered from the mine, is in crystals or "books" as much as a foot or more in length and several inches in thickness. Commonly the outer part of the book is coated with crushed and broken mica, and some rock, that must be removed before the solid mica in the center can be rifted and trimmed. The process of removing this useless mica and rock is called "cobbing" and may be done either at the mine or at the rifting shop. In South Dakota during the years 1942–45 all but a few operators sent mica to the rifting shops without cobbing. After cobbing is completed the books are split into plates less than an eighth of an inch in thickness. This process, known as "rifting," is followed by "trimming," an operation in which the rough edges and the loose scales on the cleavage surfaces are removed. If only the ragged edges of the rifted mica are removed with the fingers or a knife the product is called "thumb-trim mica;" if all ragged edges and cracks on two adjacent sides of the plate are trimmed off it is said to be "half-trim mica;" if all edges are trimmed with a knife so that the cracks extend in from only two sides of the sheet it is called "three-quarter-trim mica;" and if the plate is trimmed on all sides so that all cracks, reeves, and cross-grains are removed it is "full-trim mica." All edges trimmed with the knife are beveled and the finished product is known as "block mica."

The trimmed block mica is graded according to the size of the largest usable rectangle that can be cut from the block. The usable rectangle must be free of cracks, pin holes, reeves, and cross-grain. In domestic grading a block that will yield a circular pattern 1, 1½, or 1¼ in. in diameter is called "punch." If it will yield a circular pattern 2 in. or more in diameter it is designated as "circle." Rectangular sizes 1½ by 2 in. and larger are known as sheet mica. In 1943–45 the mica purchased was commonly graded on the basis of specifications of the American Society for Testing Materials.

The Society states that natural mica shall be graded according to the area of the usable rectangle which can be cut from the specimen and the minimum dimension of one side. The mica in the usable rectangle shall meet the quality requirements specified by the purchaser.

The standard A. S. T. M. chart to be "used for grading natural block mica and mica splittings according to size" agrees closely with the following "India grading scale", which has been in general use for many years:

Grade	*Area of rectangle (in square inches)*	*Minimum dimension of one side (in inches)*
Extra special	60 to 80	----------
Special	48 to 60	----------
A1	36 to 48	4
1	24 to 36	3
2	15 to 24	2
3	10 to 15	2
4	6 to 10	1½
5	3 to 6	1
5½	2½ to 3	1
6	1 to 2½	¾

Mica is divided also, either before or after grading, into specific classes based on imperfections inside the usable rectangle of each block. Domestic classifications used until 1943 separated the block mica into clear and stained mica on the basis of inclusions.

The classification of prepared sheet mica in 1943–45 usually was based on standards adopted in 1938 by the American Society for Testing Materials (A. S. T. M. Designation: D 351–38). The A. S. T. M. quality designations are:

Classification	*Description*
Clear	Free of all mineral and vegetable inclusions, stains, air inclusions, waves, or buckles. Hard transparent sheets.
Clear and slightly stained.	Free of all mineral and vegetable inclusions, cracks, waves, and buckles, but may contain slight stains and air inclusions.
Fair stained	Free of mineral and vegetable inclusions and cracks. Hard. Contains slight air inclusions and is slightly wavy.
Good stained	Free of mineral inclusions and cracks but contains air inclusions and some vegetable inclusions and may be somewhat wavy.
Stained	Free of mineral inclusions and cracks but may contain considerable clay and vegetable stains and may be more wavy and softer than the better qualities.
Heavy-stained	Free of mineral inclusions but contains more clay and vegetable stains than stained quality. Distinctly inferior as regards rigidity and toughness.
Black-stained and spotted.	May contain some mineral inclusions consisting of magnetic (black), specularite (red), and hydrous iron oxide (yellow).

The Colonial Mica Corporation procured mica under government subsidy from 1942 to 1945. The grades and qualities purchased were defined in terms of the standards of the American Society for Testing Materials given above and in figure 2. From December 1942 to April 1945, qualities designated as no. 1, no. 2, and no. 2 inferior, were purchased at subsidy prices. Until May 1943 sheet mica with half-trim preparation was purchased on the basis of individual prices for

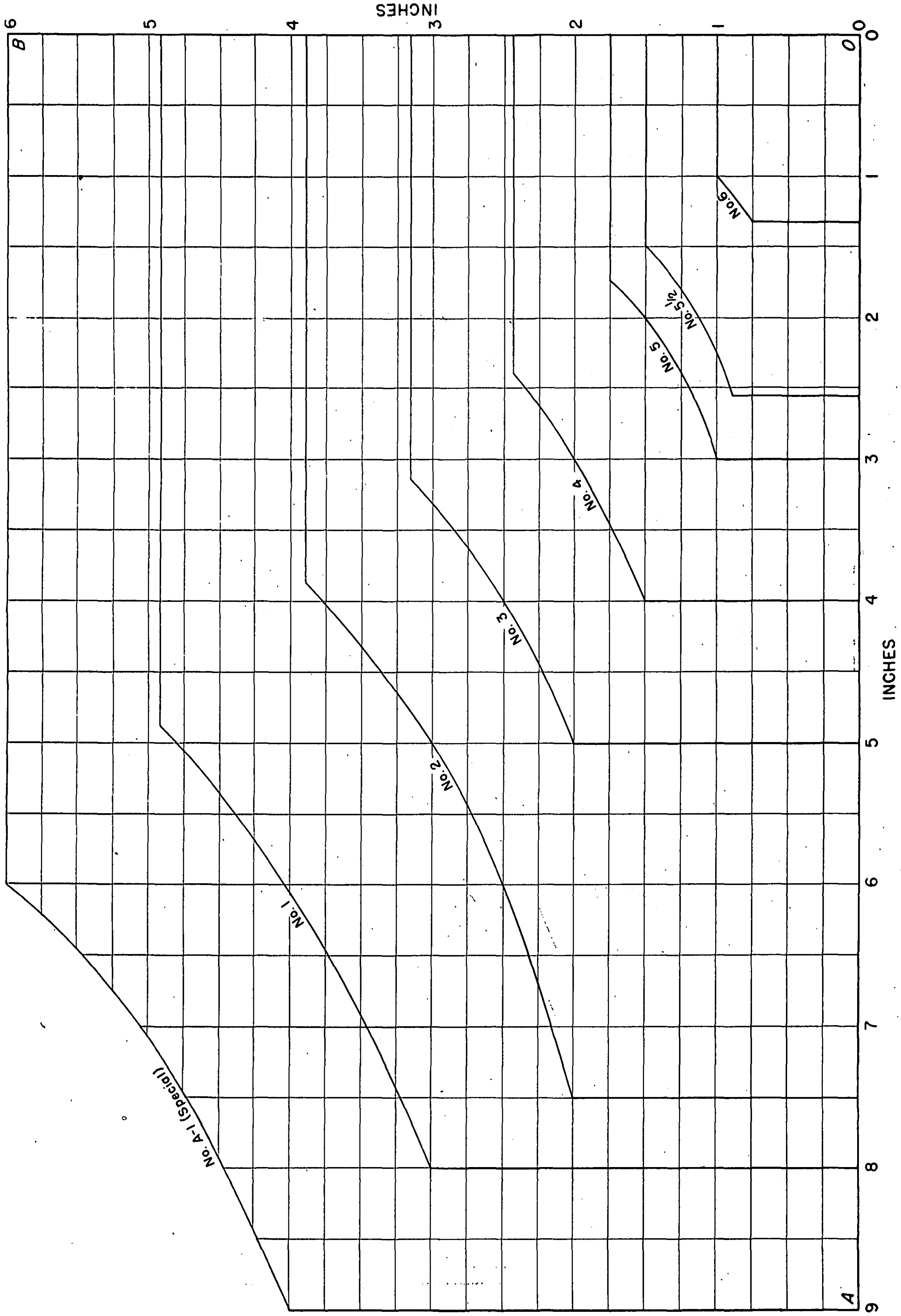

FIGURE 2.—A. S. T. M. chart for grading natural block mica and mica splittings.

individual grades. Mica smaller than 1½ in. by 2 in. was purchased as untrimmed (actually thumb-trim) punch. From May 1943 to February 1944, full-trimmed small sheet (1 by 1 in. to 1½ by 2 in.) and three-quarter trimmed large sheet was purchased at $5.00 per lb. Then a price of $6.00 per lb was offered until August 7, 1944. At this time a bonus of $2.00 per lb was given for full-trimmed sheet (2 sq in. and up). On January 1, 1945, the specifications on small sheet were revised and only punch sizes of more than 2 sq in. in area were bought as full-trimmed sheet mica. The remainder, capable of forming a 1-in. circle, was purchased as untrimmed punch at 30 cents per lb. In April 1945 prices were changed and mica was purchased on the basis of grade and quality. These qualities and grades conformed to A. S. T. M. standards. The quality equivalents for domestic and A. S. T. M. standards are given below (after Colonial Mica Corporation).

Domestic	*A. S. T. M.*
No. 1	Clear and slightly stained. Fair stained.
No. 2	Good stained.
No. 2 inferior	Stained. Heavy stained.
No. 3	Black spotted. Black stained.

The quality of mica produced from individual mines is determined by two factors, (1) the character of the crude mica, and (2) the kind of preparation given the mica. Poor preparation can cause mica otherwise of good quality to be classed as of lower quality.

During the period of Colonial Mica Corporation purchases, a number of rifting and trimming shops were started in and around Custer. In general the preparation consisted of four steps (1) cobbing rock from mica, (2) rifting books into sheets, (3) trimming and scaling sheets, and (4) checking the final product before sale. The costs of these operations varied considerably with the experience of the workers, the type of sheet mica desired, and the type of mica worked.

The records of some of these shops are available and show interesting data on the human element in the preparation of mica. Figure 3 shows the value of having mica workers experienced in one particular

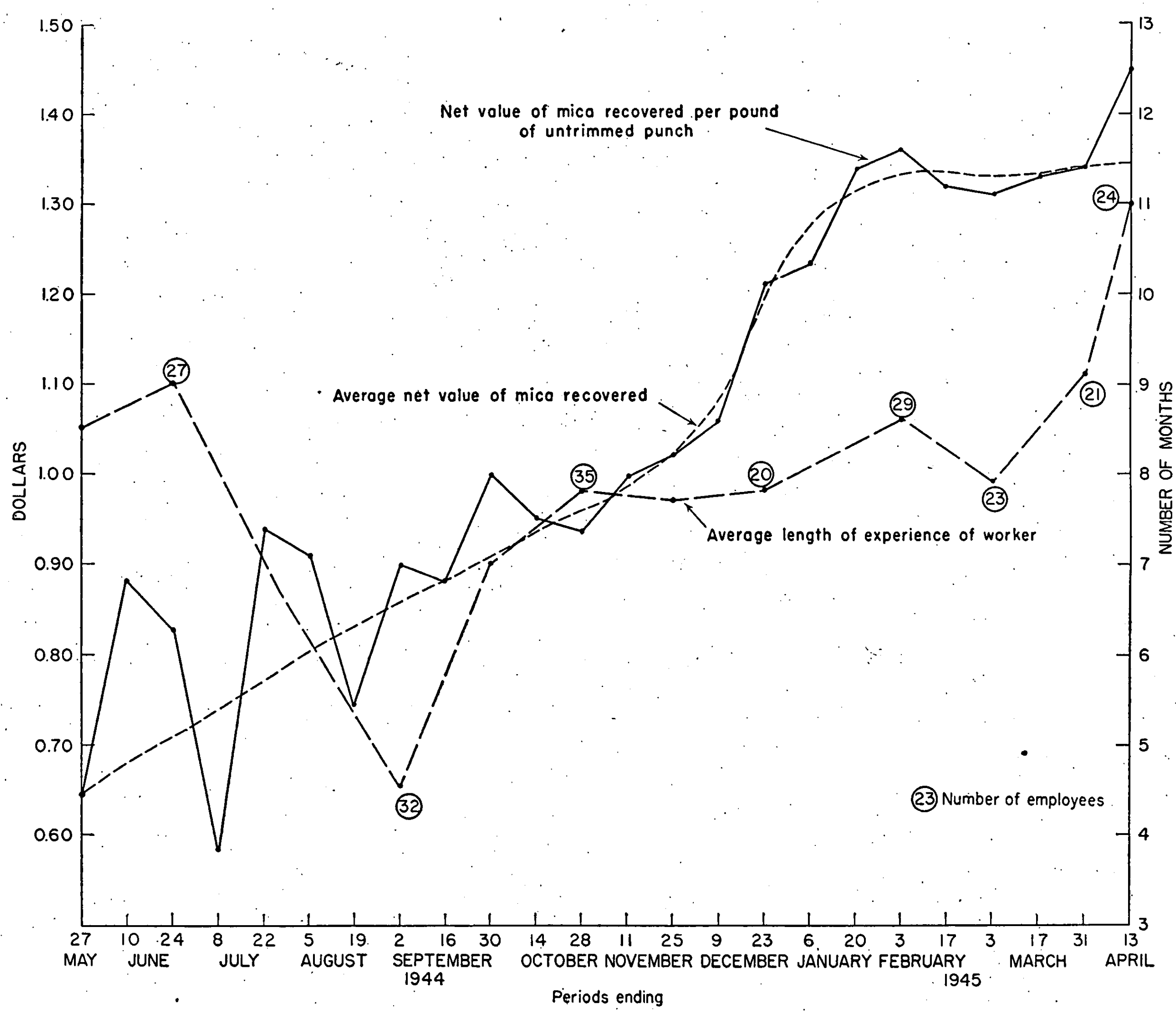

FIGURE 3.—Increase in efficiency with experience of punch trimmers.

operation. The average number of months experience in working with mica per worker and the average net value of mica recovered (at $6.00 per lb, less labor costs) per pound of untrimmed punch have been plotted against time. The wide variations in the curve for net value of mica recovered are attributed, in a large part, to variation in crude mica worked. A curve showing the average net value of mica is given. The high part of the curve for "experience per worker" prior to September 2 is caused by the fact that although many of these persons had trimmed punch mica previously, they had little experience in trimming punch under the methods employed during the later period. The low point is at the time when a number of new people were hired and trained.

The graphs in figure 4 show the marked change in efficiency of workers with experience and the resulting increase in net value of the prepared mica from a single mine. The data are for five shops, A–E. Employees of shops C, D, and E had been working on mica for about 2 months before the time shown. Shops A and B began operation at the time indicated and used workers entirely new to the work.

Figure 4A shows the total and trimming cost of preparing a pound of full trimmed punch and sheet mica (grade 6 and up) by two methods. Curves no. 1 and no. 2 are for mica rifted in shop D and trimmed in shop A—method (1). Curve no. 3 is for mica completely prepared by shop A where the same worker both rifted and trimmed—method (2).

The net value per ton of crude mica after deducting the rifting costs is given in figure 4B. The untrimmed punch and sheet was valued at 40 cents per pound.

Figure 4C shows (1) the net value per ton of crude mica after deducting the preparation costs and (2) the preparation cost per pound of full trimmed punch and sheet mica (grade 6 and up) in shops A and B. The methods used in shops A and B were essentially the same. At the points on the curves for September and October, the preparation costs were greater than the value of the product recovered. For comparison, a similar set of curves (fig. 4D) is given for shops C, D, and E.

The table below shows the net recovery, cost per pound, and net value per ton of all the mica produced from one mine. This mica was processed in several shops. Shop (z) processed 184 tons of crude at a higher cost per pound, but at a greater average net value per ton of crude mica than other shops. The workers of shops (v) and (w) had previous experience in preparing mica whereas shops (x) and (z) started with only a few experienced employees. The abrupt improvement in recovery in shop (v) in the last period of record was the result of intensive training of workers

Variation in recovery, costs, and net value per ton of mica from a South Dakota mine

Prepared by shop	Period	Crude mica processed, pounds	Average percentage of sheet mica [1] recovered	Average cost of preparation per pound of sheet mica	Average net profit above preparation costs per ton of crude mica
v	Nov. 8, 1943–Feb. 1, 1944	40, 750	5. 17	$1. 69	$369. 00
v	Feb. 1, 1944–Mar. 8, 1944	122, 130	3. 43	1. 79	260. 77
v	Feb. 12, 1944–Mar. 21, 1944	20, 280	2. 85	2. 48	182. 63
v	June 2, 1944–April 14, 1945	68, 091	12. 06	2. 27	1, 062. 02
	Total	251, 231			
	Average		5. 88	2. 06	468. 61
w	June 15, 1943–Sept. 1, 1943	12, 151	5. 00	1. 33	382. 51
w	Sept. 1, 1943–Nov. 9, 1943	28, 590	2. 48	2. 06	160. 84
w	Feb. 1, 1944–Mar. 8, 1944	20, 260	3. 54	1. 96	250. 36
w	Feb. 12, 1944–March 21, 1944	12, 330	4. 08	1. 47	322. 97
	Total	73, 331			
	Average		3. 78	1. 70	279. 17
[2] x	Oct. 26, 1943–Feb. 8, 1944	3, 818	6. 65	1. 25	518. 28
[3] y	Feb. 12, 1944–Mar. 21, 1944	14, 440	5. 45	2. 01	353. 17
z	April 24, 1944–April 12, 1945	368, 401	12. 12	[4] 3. 00	914. 02
	Total	386, 659			

[1] Sheet includes trimmed mica purchased by Colonial Mica Corporation, 1 x 1 in. and larger, as full or as ¾ trim.
[2] Includes a number of individuals working without supervision.
[3] New shop starting up. Figures include reworking scrap and washer punch of other shops.
[4] Cost of recovering 257,098 lb of byproduct mica and the training of 500 rifters and trimmers are included in the $3.00 per lb cost. The costs of Shop V, $2.27 per lb, did not include training help or working byproducts. The best recovery of full trimmed sheet by Shop z was 17.59 percent from 5,277 lb of crude mica.

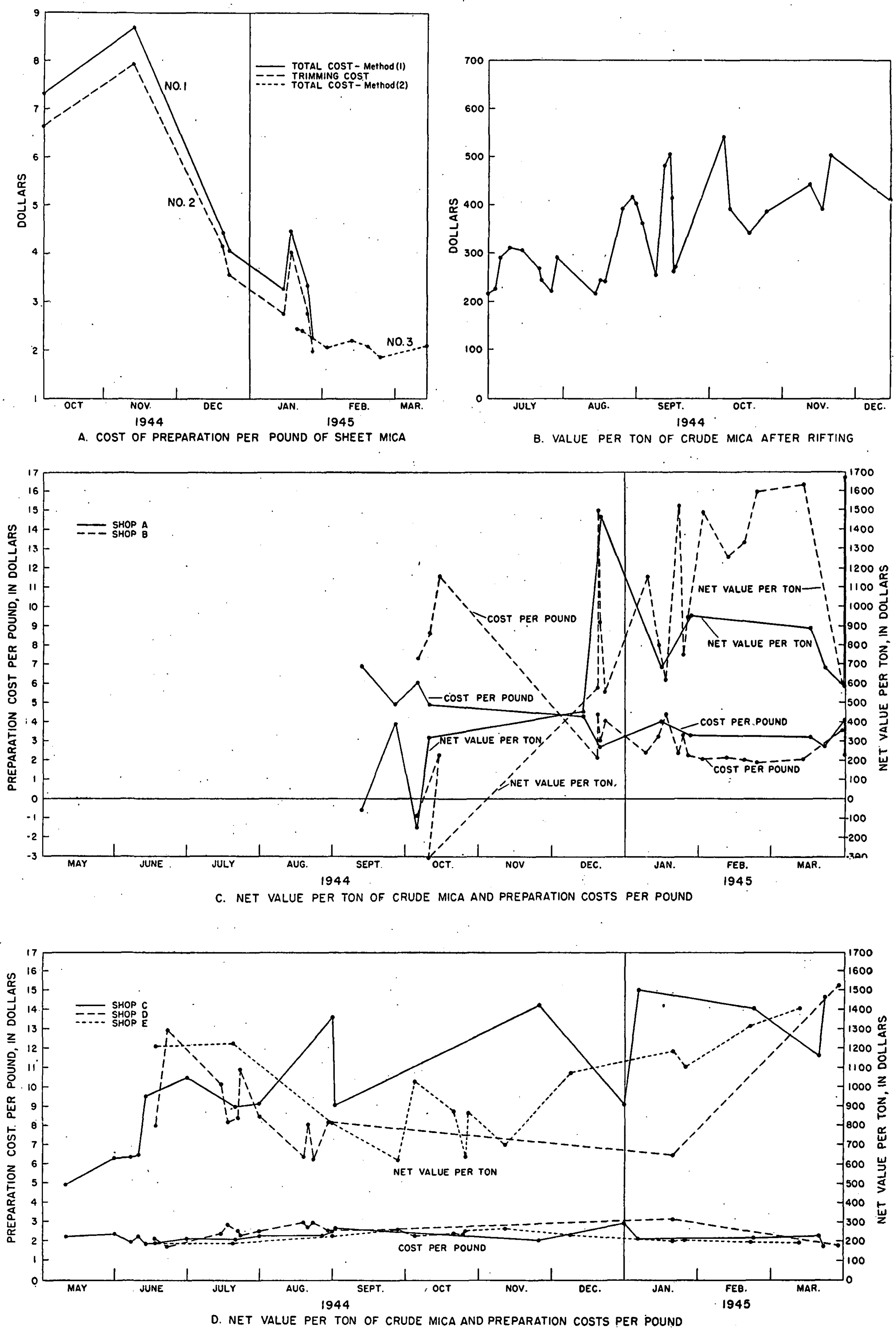

FIGURE 4.—Graphs showing variation in costs of preparation and net values of crude mica from mine A, prepared in five separate shops, A–E.

by an expert. The average recorded quality of mica from shops with 12 percent recoveries was greater than for shops with lower percentages of recovery. The type of crude mica did not change markedly during the period of operation.

The recovery of sheet from crude mica can be increased by slow and careful operation to the point at which the cost is prohibitive. Where royalties are on the gross value, it may be economical for the operator to get less than the maximum recovery. In addition, the type of crude mica governs the recovery of sheet, but in general, intelligent preparation determines whether or not the handling of crude mica is profitable.

USES

The electrical and glazing industries use most of the sheet and punch mica produced. The better qualities are used in the manufacture of magnetos, spark plugs, radios, condensers, and sound-detecting equipment. The lower qualities are used in electric installations of all kinds, in stove windows and doors, and gas-lamp chimneys and shades. Large quantities of thin sheets or splittings are cemented together in the manufacture of micanite, a built-up mica. Built-up mica is useful where natural sheets are too small for the required purpose and where molding under heat is necessary to prepare the desired product.

Scrap mica is ground by a dry or wet process. Dry-ground mica is used by the building industry to coat tar and other roofing paper, to furnish fire-proof and heat-retaining coverings when mixed with other materials, and in concrete to simulate natural rock. Wet-ground mica is used by the wall-paper and decorative products industries, as a filler in paint, rubber, and plastics, as protective coatings for tents and tarpaulins, as coatings on welding rods, and is mixed with oil as a lubricant. Ground phlogopite is used as an ingredient in certain molded electrical insulation where it is bonded with natural or synthetic resins, gums, asphalt, rubber, silicate cement, or lead borate.

TYPES OF MICA DEPOSITS

Mica deposits of the Black Hills can be divided on the basis of structure into two main types: the wall-zone type and the intermediate-zone type. Wall-zone mica deposits are more common and more likely to contain minable concentrations of sheet-bearing mica, but many wall zones contain little or none. In the wall-zone type of mica deposit the mica books tend to occur perpendicular to, and within a few feet of, the hanging-wall or footwall contacts of the pegmatite. Narrow parts of pegmatites containing wall-zone deposits may be entirely mica-bearing pegmatite from one border zone to the other. This type of deposit should not be confused with poorly zoned pegmatites through which a few muscovite books are scattered.

The intermediate-zone type of mica deposit includes the special kind known as the "core-margin" type. Few such deposits produce much sheet mica, but they are likely to contain minable concentrations of scrap mica.

The intermediate-zone mica deposits containing sheet mica in the Black Hills are of four classes:

1. Deposits between a wall zone barren of sheet mica and an amblygonite-bearing intermediate zone, as at the Tin Queen and Dyke Lode mines.
2. Deposits (core-margin type) between a wall zone barren of sheet mica and a central core of quartz, as at the Punch mine.
3. Deposits between a wall zone barren of mica and an intermediate zone of perthite-quartz-beryl pegmatite, as at the White Cap mine.
4. Deposits between a sheet-mica-bearing wall zone and an intermediate zone barren of sheet mica, as at the Old Mike mine.

Within the structural zones the concentration of muscovite books may vary widely. In some pegmatites only the hanging-wall side of the pegmatite contains sufficient mica to pay for mining; in others both footwall and hanging-wall mica deposits can be mined profitably. In still other pegmatites, especially in the wall-zone type of deposit, only the keel or crest of the pegmatite contains minable concentrations. In general, the more profitable part of a mine in the wall-zone type of deposit occurs where the footwall and hanging wall merge at the keel of the pegmatite. At the crest there appears to be a tendency for the wall zone to be narrower, less continuous, or absent.

Books of "A" or wedge mica of light-ruby color are generally more abundant adjacent to the intermediate zones or core. The Old Mike mine is a good example of deposits in which flat mica books occur in the wall zone and also in the outer part of the intermediate mica zone, but the books at the inner edge are "A" or wedge type. In the Bob Ingersoll and some of the other lithia pegmatites the muscovite is in "A" books that rarely contain sheet. The mica characteristic of the outer part of the wall zone in pegmatites that cut the Harney Peak granite is commonly wedged and tangled like that in the intermediate zones, and sheet is recovered only from the larger books at the inner edge of the wall zone.

Mica from the intermediate-zone type of deposits yields a smaller proportion of sheet than does that from the wall-zone type, and it is generally pale brownish-ruby, yellow, or white. Pegmatites with central zones of cleavelandite or lithium minerals contain colorless, yellow, or white mica that rarely yields sheets. The mica that occurs at the margin of a quartz or perthite-quartz core is commonly a darker-colored, flat ruby mica.

In some pegmatites aggregates of small interlocking muscovite crystals, called "bull mica" or "mica schist" by the miners, form more or less tabular bodies parallel to zone boundaries (as at the Bob Ingersoll Dike No. 2), or irregular bodies within a zone (as at the Beecher Lode), or replacement bodies along fractures (as at the White Elephant). These units are important sources of scrap mica in the Black Hills.

STRUCTURE OF MICA DEPOSITS

The wall-zone mica deposits of the Black Hills occur in shapes including tabular, lenticular, pipelike, cylindrical, circular, and horse shoe. Structurally they are similar in that they parallel the nearest wall in strike and dip, and generally they plunge parallel to the nearest end (crest or keel) of the pegmatite. The mica deposits also tend to plunge parallel to minor undulations or rolls of the pegmatite contacts. The richer parts or "shoots" are usually related to the rolls, crests, or keels, and therefore are easily followed after the structure of the pegmatite body is determined. In the intermediate-zone deposits, the shoots parallel the pegmatite contact less closely and, if the zone is the core-margin type, its shape is determined by the shape of the core. These deposits are generally less regular and the mica is less unformly distributed than in the wall-zone type.

MINERALOGY

The mineralogy of the mica-bearing wall zones is ordinarily simple. The dominant minerals are albite, quartz, and muscovite, associated with perthite, tourmaline, biotite, beryl, apatite, garnet, and lithiophilite-triphylite. At least five pegmatites—the Ruby Reef No. 1, Ruby Reef, Ann, Victory No. 1, and Silver Dollar—contain oligoclase instead of albite in the wall zones. In the intermediate-zone type of mica deposit the albite may or may not be cleavelandite; where it is not cleavelandite the sheet-mica content of the mica is commonly higher.

Microcline and perthite are rarely major constituents of a minable wall-zone sheet-mica deposit in South Dakota. If perthite is abundant in the wall zone, muscovite books are generally not abundant enough to justify mining operations for sheet mica alone. The sheet mica recovered from such a deposit, however, is of good quality and may contain less air-stain than that from deposits in which the dominant feldspar is plagioclase. The richest ruby sheet-mica pegmatites of the Custer district (such as the White Spar, Climax, Buster Dike, Crown, Victory, and to a lesser degree the New York) have very little if any microcline or perthite in the wall zones, but contain large perthite crystals in the core surrounded by an intergrowth of quartz and albite. The Buster Dike pegmatite contains semi-platy cleavelandite in parts of the wall zone, and the mica is of the "A" or "fishtail" variety.

Black tourmaline is generally scattered through the wall zone, but tends to be concentrated near the outer edge of the sheet-mica zones. In general, where tourmaline is very abundant there is less mica than in other parts of the wall zone. In the White Spar mine, however, tourmaline abundance was used as a guide to good mica, although at the south end of the pegmatite tourmaline occurred without mica.

The beryl in wall-zone mica deposits commonly occurs as skeletal crystals or "shells" around albite, quartz, tourmaline, muscovite, and the other minerals of the wall zone (figs. 5 and 6). Where the mica is of the "A" or "fishtail" variety and is associated with cleavelandite, the beryl more commonly occurs as corroded euhedral or subhedral crystals and occasionally as skeletal crystals.

The muscovite mica of the Black Hills is mostly of the ruby variety, but a few mines produce pale-rum to colorless mica. The muscovite of the wall-zone deposits occurs in books as much as 12 in. or more in length and several inches thick. A few books 2 to 3 ft across have been found. The books generally are arranged so that their long axes are nearly perpendicular to the walls of the pegmatite. At the Red Deer mica mine, blades of muscovite, as much as 6 ft long, 15 in. wide, and 4 inches thick, are oriented at right angles to the contact and extend out from the hanging wall of the pegmatite across the wall zone. These blades appear to have been formed along fractures that cut across the normal type of muscovite books in the wall zone. The late muscovite in the blades has poor splitting qualities and consequently less is recoverable as sheet mica than from the earlier-formed mica books.

In the intermediate-zone mica deposits the muscovite books have less tendency to grow perpendicular to the walls of the pegmatite. The books may be arranged in radial aggregates, but commonly they have a haphazard orientation. There is a distinct tendency for this mica to show "A" structure, reeves, wedge shape, partial films, and waviness.

SIZE, MICA CONTENT, AND QUALITY OF DEPOSITS

SIZE

Mica deposits in the Black Hills range in size from small ones that have produced a few pounds of mica to others that have produced hundreds of tons. The size of a deposit depends on the size of the pegmatite and of the lithologic unit in which the deposit occurs. The wall-zone and intermediate-zone types of deposits are commonly less than 6 ft thick, except in the narrow parts of the pegmatite where they may be twice that thick. Rarely, as at the Old Mike mine, the wall-mica zone is as much as 20 ft thick, and at the Tin Queen mine, the intermediate zone has a similar thickness. In the Custer district, the New York pegmatite is the most extensively explored sheet-mica-bearing pegmatite. Mica has been mined on the hanging wall of the pegmatite for about 450 ft along the strike, and more than 450 ft down the dip. Along the footwall of this pegmatite, mica was mined to a depth of about 250 ft below the outcrop. The mica zones ranged from 2 to 6 ft in thickness. This is probably the largest sheet-mica mine of the district. The total amount of crude mica produced is unknown, but must have been 1500 to 2000 tons. Probably the next most productive sheet-mica mine was the Buster Dike, which is said to have produced more than 638 tons of crude mica from a hanging-wall mica shoot 160 ft long down the dip and as much as 90 ft along the strike; the average thickness was 9 ft. The largest production of prepared sheet mica in the period 1942–45 came from the Victory mine, which yielded about 360 tons of crude mica. This mica deposit averaged about 5 ft in thickness, had strike length of 100 ft, and extended 180 ft down the dip. Because of the high percentage of recovery of sheet mica from the crude, the production of sheet mica from this mine exceeded that of the Buster Dike and Old Mike properties, which produced more crude mica.

In the Keystone district the Bob Ingersoll, Hugo, Dan Patch, Peerless, and Wood Tin mines have furnished much of the scrap mica produced. The Hugo, a sheet-bearing deposit, is probably the largest pegmatite of this type in the district. From 1942 to 1945 the largest production of sheet mica came from wall zones at the Hugo and Dan Patch mines. Part of the scrap-mica deposits in the Bob Ingersoll mine are wall zones that average about 5 ft in thickness in Dikes No. 1 and No. 2. They are essentially cylindrical and at the surface are about 130 ft by 70 ft in plan. These bodies, together with mica-rich intermediate zones and smaller replacement bodies, have produced to date more than 1700 tons of scrap mica.

MICA CONTENT

The average muscovite content in the South Dakota mica deposits varies widely. Wall zones rarely contain more than 25 percent muscovite and the intermediate zones and replacement bodies rarely more than 60 percent. Local concentrations in the wall zones may contain as much as 50 percent mica, as in some parts of the Crown, Buster Dike, Bob Ingersoll, and other pegmatites. Some intermediate-zone and replacement deposits of mica may be as much as 90 percent muscovite, but such concentrations are small and rare.

The only available quantitative figures on total mica content in Black Hills mica deposits were obtained by the U. S. Bureau of Mines during their work on scrap mica in 1945. Grab samples weighing 1500 to 5000 lb, were obtained from 19 pegmatites, and included samples from wall zones, intermediate zones, and replacement bodies. Each sample was milled in an experimental crushing and screening plant. The muscovite in samples from each mill fraction was picked out by hand and weighed, and the original content of the rock was determined by calculation. Results of these tests given in the table below show that the mica-bearing wall and intermediate zones contained 14 to 26 percent muscovite and that the replacement bodies contained 62 to 65 percent. Samples of waste material from sheet-mica mining at the Buster Dike, Climax, Crown, New York, Victory, and White Spar pegmatites contained 6 to 16 percent muscovite. Waste from scrap-mica mining at the Bob Ingersoll, Peerless, and Wood Tin properties contained from 7 to 15 percent muscovite.

Mica content of some South Dakota deposits, in percentage

	Mica content [1]	Type of deposit	Remarks
Samples from pegmatite:			
Beecher Lode	65.2	Replacement unit (?).	Aggregates of fine-grained muscovite (bull mica).
Helen Beryl (A).	14.0	Wall zone	From east side of pegmatite.
Helen Beryl (B).	14.4	Wall zone	From adit.
Highland Lode	15.4	Intermediate and wall zones.	North end of open-pit.
November	62.2	Replacement unit (?).	Aggregate of fine-grained muscovite (bull mica).
Old Mike (A)	21.2	Wall zone	North end of pegmatite.
Old Mike (B)	20.6	Wall zone	North end of pegmatite.
Tin Queen	18.8	Intermediate and wall zones.	Southern open-cut.
Wood Tin	26.1	Wall zone	Open-cut.
Samples from dumps: [2]			
Buster Dike	13.3	Wall zone	Waste from sheet-mica mining.
Bob Ingersoll (A).	10.8	Wall zone (?)	Waste from scrap-mica mining.
Bob Ingersoll (B).	7.6	Wall zone to core	Waste from all mining.
Climax (A)	14.5	Wall zone and core	Waste from early sheet-mica mining.
Climax (B)	16.5	Wall zone	Waste from sheet-mica mining, 1943–44.
Crown	15.5	Intermediate and wall zones.	Waste from sheet-mica mining.
Edison (A)	10.5	Wall zone and core	Picking-belt waste (plus 1 inch) from spodumene mining.
Edison (B)	6.8	Wall zone and core	Minus 1 inch part of spodumene ore.
Etta	17.5	Intermediate and wall zones.	Mica-rich waste from spodumene mining.
Hugo	24.7	Wall zone (?)	Mica-rich waste from feldspar mining.
New York	13.3	Wall zone	Waste from sheet-mica mining.
Peerless	9.8	Wall zone (?)	Waste from scrap-mica and other mining.
Victory	17.1	Wall zone	Waste from sheet-mica mining.
White Spar	6.6	Wall zone	Waste from sheet-mica mining.
Wood Tin	15.1	Wall zone	Waste from scrap-mica and beryl mining.

[1] Data from: Clarke, F. F., Scrap mica project, Custer and Pennington Counties, South Dakota. U. S. Bureau of Mines War Minerals Report (unpublished) June 1945. Munson, G. A. Free-impact crushing and selective screening as a means of recovering scrap mica: U. S. Bureau of Mines Report of Investigations (unpublished) July 1945.

[2] Source of the major part of the waste in the dump is indicated under the column headed "Type of deposit."

During the years 1942-45 the mica recovered by hand sorting was commonly 1.5 to 5 percent of the rock. The average at the Buster Dike was 10 percent, at the Victory 5 to 6 percent, at the White Spar 3 to 4 percent, at the New York 1.5 to 2 percent, and at the Tin Queen 1.6 percent. Sterrett (1923) states that during early operations of the New York mine 5 to 6 percent book mica was recovered. No figures are available for the content of recoverable mica in the scrap-mica-bearing pegmatites, but the Bureau of Mines samples at the Wood Tin property indicate that about 10 percent of the total mica was recovered by hand sorting.

Comparison of percentage of book mica recovered with that left in the waste shows that on the average about 25 percent of the total mica is recovered by hand sorting. Where the mica books are unusually large, as at the Buster Dike, as much as 40 percent may be recovered.

QUALITY

The sheet mica from different mines in each South Dakota district, like that from districts in other parts of the country, is of various qualities and grades (sizes). The mica sold to, and qualified by, Colonial Mica Corporation at Custer during 1944 contained about 25 percent of no. 1 and no. 2 qualities and, except for a very small quantity of no. 3, the remainder was classed as no. 2 inferior. No records are available as to the grades (sizes) of sheet mica purchased after May 1943, and quality figures are incomplete for the period before May 1944.

Most of the mines in the South Dakota districts that were operated in 1942–43, do not yield much no. 3 mica if the crude mica is carefully prepared. Some mines, such as the Hot Shot, Mica King, and St. Louis mines, which have been worked in the past, do yield no. 3 quality mica. A few properties contain mica of no. 2 inferior quality only. During 1943–44 individual lots of mica qualified at Custer contained from zero to 98 percent no. 1 and no. 2 qualities. Many operators in the Custer district found it profitable to sacrifice a higher average quality for more pounds of acceptable material of lower quality. It is believed that some of the mines from which Colonial Mica Corporation refused to accept mica after December 7, 1943, could have produced mica of acceptable quality by more careful preparation.

South Dakota mica is similar to most India ruby mica in that air-staining is a major defect, and in addition, it has mineral inclusions, reeves, ribs, waves, ripples, curves, ruling, and clay stains. Air-staining is the most serious defect, and in mica from such mines as the Gap, Hugo, and Crown, it may be so intense and uniform that some of the mica must be classed as no. 3 quality. By careful rifting, however, much mica of higher quality can be recovered from books that appear to be densely air-stained. In the mica from the Gap, St. Louis, and Triangle A mines, minute mineral specks cloud the mica and combined with the air-staining, reduce part of the mica to no. 3 quality. Some of the less densely air-stained mica shows silver streaks. These streaks are commonly called "shadow cracks." They are not cracks, however, and have no effect on the splitting quality of the mica, but cause an otherwise no. 1 and no. 2 quality piece to be classed as no. 2 inferior. Certain micas, particularly the very hard, flat, deep-ruby micas from the Silver Dollar, Ruby Reef and other mines, contain silver spots.

All minerals of the mica zones are found as inclusions in South Dakota mica. Of these, black tourmaline is the most abundant. In general, the tourmaline crystals parallel rather than cross the mica laminae. Three other black minerals have been noted in minor quantities in the mica, but two of them, magnetite and biotite, are rare. More common is a mineral with dendritic to mammillary structure, which under the microscope appears to consist of gray-white, semi-transparent minute specks that resemble a clay mineral. Where several of these mineral grains are superimposed they are opaque and black. They were formed, however, with the mica and are not related to surface alteration. The Triangle A and Hot Shot mica is thus black-spotted or stained, but this type of staining is found at only a few mines.

Feldspar, quartz, beryl, apatite and other light-colored minerals occur in mica books, generally as thin plates between laminae, but in some cases, they penetrate them. These inclusions are often referred to as "sand" and generally only large ones are noticeable. Hematite and limonite stains are common in mica obtained within about 20 ft of the surface or along fault zones, but like clay and vegetable stains, disappear at depth.

Most of the mica mines produce almost perfectly flat mica. Rippled, curved, and crumpled sheets are not common except from parts of pegmatites that have been faulted or deformed. Mica found near the fault in the Jack Rabbit mine was highly rippled, that from the ends of the sharp rolls in the Crown mine is curved and probably was deformed while the pegmatite was still crystallizing, and mica from the extreme ends of rolls or the keels and crests of a few other pegmatites shows a tendency for the mica to be curved.

Reeves and ribs are most common in sheet mica from the intermediate-zone type of deposit, as these defects are related closely to the "A" structure and wedge type of mica. Wedged and "A" structure books are also formed at the inner edge of some wall-zone deposits where the mica is in contact with core minerals. The presence of these defects in trimmed-sheet mica is the result of poor preparation.

Stoll had 100 samples of South Dakota mica tested by the National Bureau of Standards for power factor during 1942, and the results are tabulated below. The power factors have a range in percent of 0.00 to 0.28 at 100 Kc/s and 0.00 to 0.10 at 1000 Kc/s. (See table below.) The density of air-staining does not appreciably change the value of the power factor. In 1945 it was possible for Hanley and Page, through the courtesy of the Custer Mining Account, to test a group of mica specimens on the Bell Telephone Laboratories' Q machine. The tests were made without first giving the mica a spark test. The specimens tested were in large part collected to show specific defects, although some were collected to show the different qualities of mica obtainable at the properties.

The mica from 23 of the mines and prospects rated E1. Specimens from 27 others contained mica rated as both E1 and E2, but 13 of them fall so close to the E1 group that the error in testing (±1 of the rapid meter reading) may be significant. Mica from 8 deposits was consistently rated E2 and from 2 others E3. Three mines and prospects contained mica of both E2 and E3 ratings and mica from 2 mines showed a range from E1 to E3. Mica from some of the mines would undoubtedly show a wider range if more specimens were tested.

Results of power factor tests on South Dakota mica by the National Bureau of Standards

Mine	Specimen No.	Description of mica in area under electrodes	Thickness (inches)	Power factor in percent at: 100 kc/s	1000 kc/s
Ballard	1A	Clear	0.07	0.01	0.01
Do	1B	do	.04	.03	.02
Do	2A	do	.03	.08	.04
Do	2B	Bubbles	.07	.02	.02
Do	3A	Many bubbles	.06	.04	.03
Do		do	.06	.09	.04
Bellmare No. 1	24A	Few bubbles	.04	.03	.02
Do	24B	do	.05	.05	.03
Bellmare No. 2	23A	Full of bubbles	.07	.02	.02
Do	23B	do	.06	.03	.02
Do	1A		.04		.06
Do	1B		.05		.07
Do	2A		.06		.03
Do	2B		.06		.04
Climax	1A	Clear	.03	.04	.04
Do	1B	do	.03	.05	.05
Do	1C	do	.05	.02	.02
Do	2A	do	.07	.01	.01
Do	2B	do	.03	.02	.02
Do	2C	do	.06	.01	.01
Crown	5A	Many tiny bubbles	.04	.08	.04
Do	5B	do	.03	.05	.04
Do	5C	do	.04	.06	.03
Do	6A	Some bubbles	.07	.02	.01
Do	6B	do	.08	.01	.01
Do	6C	do	.04	.02	.02
Dan Patch	18A	Some large bubbles	.05	.02	.01
Do	18B	A few bubbles	.04	.02	.02
Do	19A	Many bubbles	.06	.02	.01
Do	19B	Bubbles	.04	.01	.02
Do	20A	A few bubbles	.04	.01	.01
Do	20B	Many bubbles	.08	.01	.01
Dewey Claim	9	Clear	.07	.01	.01
Do	10A	Many bubbles	.05	.28	.10
Do	10B		.04	.19	.09

Results of power factor tests on South Dakota mica by the National Bureau of Standards—Continued

Mine	Specimen No.	Description of mica in area under electrodes	Thickness (inches)	Power factor in percent at: 100 kc/s	1000 kc/s
Dorothy	31A	A few bubbles	.06	.01	.01
Do	31B	do	.08	.01	.01
Do	32A		.05	.01	.01
Do	32B		.05	.01	.01
Hugo	4A		.05	.03	.02
Do	4B		.03	.03	.03
Do	4A-1	Many bubbles	.07	.14	.06
Do	4A-2	do	.05	.04	.04
Do	5A	do	.08	.03	.02
Do	5B	do	.05	.04	.04
Lofton	25A	A few tiny bubbles	.08	.01	.01
Do	25B	do	.05	.02	.02
Do	26A	do	.04	.02	.02
Do	26B	do	.04	.01	.01
McKirahan	27A	Many tiny bubbles	.04	.01	.01
Do	27B	do	.04	.07	.03
Do	28A	do	.03	.02	.01
Do	28B	do	.06	.01	.01
Do	29A	do	.05	.02	.02
Do	29B	Some tiny bubbles	.05	.01	.01
Do	30	Some bubbles	.08	.01	.01
New York	6A	Many bubbles	.07	.06	.08
Do	6B	do	.10	.04	.02
Do	7A	do	.07	.02	.02
Do	7B	do	.08	.07	.03
Do	8A	do	.04	.07	.04
Do	8B	do	.08	.07	.02
Noble	21A	A few bubbles	.04	.03	.03
Do	21B	Bubbles	.06	.02	.02
Do	22A	Some bubbles	.05	.02	.02
Do	22B	do	.06	.01	.01
Pinetop	3A		.06	.03	.02
Do	3B		.06	.03	.02
Punch Mica Lode	1		.11	.01	.01
Foot of shaft C	2		.04	.03	.03
Foot of shaft A	3		.03	.04	.03
Pit No. 2	4		.08	.10	.04
Foot of shaft B	5		.05	.04	.03
Red Deer	33	Tiny bubbles	.06	.01	.01
Silver Dollar	3A	A few bubbles	.06	.02	.02
Do	3B	Clear	.08	.01	.01
Do	3C	do	.03	.02	.02
Do	4A	One bubble	.08	.01	.01
Do	4B	Small bubbles	.06	.02	.02
Do	4C	Many tiny bubbles	.07	.01	.01
St. Louis	34A	Tiny bubbles	.03	.04	.03
Do	34B	do	.03	.05	.06
Do	35A	do	.04	.05	.05
Do	35B	do	.04	.06	.05
Star claim	7A	Some bubbles	.04	.03	.02
Do	7B	A few bubbles	.05	.02	.02
Do	7C	Very few bubbles	.03	.04	.03
Do	8A	A few bubbles	.05	.03	.03
Do	8B	Some bubbles	.05	.02	.02
Triangle A	9A	Silvery appearance	.03	.04	.04
Do	9B	do	.07	.02	.01
Do	9C	do	.08	.02	.02
Do	10A	Many tiny black specks and bubbles.	.04	.05	.04
Do	10B	Bubbles	.06	.03	.02
Do	10C	do	.06	.03	.02
Do	11A	Silvery appearance, yellow stain, some tiny black spots.	.07	.10	.05
Do	11A-1	Bubbles, part of 11A, free of stain and spots.	.06	.02	.01
Do	11B	Bubbles	.06	.04	.02
Victory	11A	Clear	.07	.01	.01
Do	11B	do	.06	.02	.01

Results of power factor tests on South Dakota mica by the National Bureau of Standards—Continued

Mine	Specimen No.	Description of mica in area under electrodes	Thickness (inches)	Power factor in percent at: 100 kc/s	Power factor in percent at: 1000 kc/s
Wildwood	12A		.08	.01	.01
Do	12B	A few bubbles	.08	.01	.01
Do	13A	Some tiny bubbles	.04	.03	.02
Do	13B	do	.11	.00	.00
Do	14A	do	.07	.01	.01
Do	14B	A few bubbles	.07	.01	.01
Do	15A		.05	.02	.01
Do	15B		.05	.01	.01
Do	16A	Bubbles	.06	.01	.01
Do	16B	do	.06	.05	.02
Do	17A		.04	.02	.02
Do	17B		.05	.02	.01

Electrical tests on South Dakota mica with the Bell Telephone Q Machine

Mine	Specimen No.	Thickness (inches)	Rapid meter reading	Rating	Remarks
Aladin	1	0.013	98	E1	
Ann	1a	.022	96	E1	Red spots.
Do	1b	.022	96	E1	No spots.
Do	2a	.023	94	E2	Yellow clay.[1]
Do	2b	.023	94	E2	Mineral inclusions.
Do	3	.010	95	E1/E2	Air and clay stains.
Antler	1	.016	94	E2	Heavily air- and clay-stained.
Do	2	.014	98	E1	Clear.
Do	3	.024	93	E2	Heavily air-, clay-, and iron-stained.
Beecher Lode drift.	1a	.024	96	E1	Albite inclusions.
Do	1b	.024	94	E2	Tourmaline inclusions.
Blue Bonnett	1	.013	97	E1	Clay-stained.
Do	2 split a	.019	98	E1	Air-stained.[2]
Do	Split b	.023	97	E1	Air-stained.
Do	3a	.023	97	E1	Tourmaline inclusion.
Do	3b	.023	95	E1/E2	Air-stained.
Bob Ingersoll	1	.012	89	E2	Slightly air-stained.
Do	2	.013	94	E2	Slightly air -stained.
Bonnie Lode	1	.014	97	E1	Slightly air-stained.
Do	2	.010	99	E1	Relatively clear.
Do	3	.025	97	E1	Air-stained.
Burgess	1	.036	87	E2	Relatively clear.
Do	1 split a	.016	91	E2	Relatively clear.
Do	Split b	.020	88	E2	Slightly air-stained.
Do	2a	.018	96	E1	Air-stained.
Do	2b	.018	93	E2	Cracks.
Do	2c	.018	94	E2	Air-stained.
Do	3a	.018	92	E2	Reeved.
Do	3b	.018	93	E2	Crack.
Do	3c	.018	96	E1	Air-stained.
Burt	1a	.012	99	E1	Air-stained.
Do	1b	.016	99	E1	Air-stained.
Do	2a	.030	97	E1	Black-stained.
Do	2b	.030	97	E1	Air-stained.
Do	2c	.030	96	E1	Crack.
Do	4	.025	95	E1/E2	Air-stained.
Do	5a	.014	94	E2	Hole.
Do	5b	.014	96	E1	Clear.
Do	5c	.014	95	E1/E2	Air-stained and crack.

[1] Some pieces of mica were tested on different areas that had different defects. These are numbered 2a, 2b, etc.

[2] Some pieces of mica were split and each piece tested separately. These are designated split a, split b, etc.

Electrical tests on South Dakota mica with the Bell Telephone Q Machine—Continued

Mine	Specimen No.	Thickness (inches)	Rapid meter reading	Rating	Remarks
Buster Dike, 156-foot level.	1	.018	93	E2	Heavily air-stained.
Do	2	.017	97	E1	Air- and clay-stained.
Do	3	.024	97	E1	Heavily air-stained.
Do	4	.012	99	E1	Heavily air-stained.
Do	5	.030	95	E1/E2	Heavily air-stained.
Do	Split a	.012	98	E1	
Do	Split b	.023	95	E1/E2	
Do	Split b–1	.015	97	E1	
Do	Split b–2	.013	97	E1	
South Stope No. 2 level.	6a	.024	91	E2	Lightly air-stained.
Do	6b	.024	94	E2	
Do	6c	.024	96	E1	Relatively clear.
Do	7 split a	.019	91	E2	Lightly air-stained.
Do	Split b	.019	93	E2	Lightly air-stained.
Do	Split c	.017	93	E2	Reeve.
Top of south stope.	10	.022	97	E1	Heavily air-stained.
Do	11	.028	96	E1	Heavily air-stained.
"Checker board mica," mine unknown.	1 split a	.017	94	E2	Silvery.
Do	Split b	.020	92	E2	Silvery.
Do	Split c	.023	92	E2	Silvery.
Climax	1 split a	.021	96	E1	Very light air-stain.
Do	Split b	.020	95	E1	Silver spots.
Do	Split b	.020	97	E1	Silver streaks.
Do	2	.029	94	E2	Silver streaks.
Do	3	.020	96	E1	Waved. Tourmaline inclusions.
Do	4	.018	97	E1	Air-stained. Waves.
Crown South drift, 100-foot level.	1	.028	90	E2	Cracks.
Do	2	.027	89	E2	Cracks. Mineral inclusions.
Do	3	.020	89	E2	Mineral inclusions. Reeves.
Do	4a	.030	82	E2	Dark spots. Air-stained.
Do	4b	.033	88	E2	Mineral inclusions.
Do	4c	.030	86	E2	Same piece (4b) split down, same area.
Custer Mica Lode No. 2.	1	.023	100	E1	Silver streak.
Dalmon	1	.020	97	E1	Clay-stained.
DeSoto	1	.018	97	E1	Lightly air-stained.
Do	2	.018	94	E2	Biotite inclusions.
Dewey	1	.016	69	E3	Silvery.
Do	2	.023	76	E3	Silvery.
Diamond Mica	1	.029	97	E1	Relatively clear.
Do	2	.013	99	E1	Clear.
Do	3	.025	97	E1	Air-stained.
Do	4	.019	90	E2	Clear. Crack.
Do	5	.025	94	E2	Slightly air-stained. Crack.
Dyke Lode	1 split a	.025	94	E2	Clear. Mineral inclusions. Cracks.
Do	Split b	.015	95	E1	Black-stain. Crack.
Earl Lode	1	.024	89	E2	Red spots. Air-stained. Cracks.
Gap Lode	1	.018	96	E1	Silvery.
Do	2	.017	96	E1	Silvery.
Glenwood	1	.016	93	E2	Cracks. Clay streaks.
Do	2	.022	92	E2	Crack. Air- and clay stained.
Do	3	.016	93	E2	Slightly air, and clay-stained.
Do	4	.012	93	E2	Slightly air- and clay-stained.
Do	5	.015	91	E2	Air-stained. Waves.
Do	6	.019	93	E2	Air-stained. Waves.
Do	7	.016	91	E2	Air-stained and clay stained.

Electrical tests on South Dakota mica with the Bell Telephone Q Machine—Continued

Mine	Specimen No.	Thickness (inches)	Rapid meter reading	Rating	Remarks
Glenwood	8	.010	91	E2	Slightly air-stained.
Do	9	.025	90	E2	Cracks. Tourmaline inclusions.
Do	10	.022	89	E2	Cracks, and air-stained.
Do	11	.017	92	E2	Cracks. Air- and clay-stained.
Do	12	.020	92	E2	Silver streak.
Do	13	.018	91	E2	Air- and clay-stained.
Do	14	.018	92	E2	Extensive silver streaks.
Do	15a	.017	91	E2	Black mineral inclusions.
Do	15b	.017	90	E2	No inclusions.
Do	Split a	.010	92	E2	No inclusions. Two films, one from each side of specimen. 15a.
Do	Split b	.011	93	E2	Inclusions.
Do	16	.024	86	E2	Heavily stained.
Green Beryl	1 a	.014	99	E1	Slightly air-stained.
Do	1 b	.014	98	E1	Reeved.
Do	2 a	.016	97	E1	Reeved. Air-stained.
Do	2 b	.016	98	E1	Slightly air-stained.
Harbach. 50-foot level of shaft.	1 a	.022	95	E1	Silver-stain. Holes.
Do	1 b	.022	93	E2	Holes. Reeved.
Do	1 c	.022	95	E1/E2	Air-stained.
Do	2	.022	98	E1	Silvery. Air-stained. Tourmaline inclusions.
Helen Beryl. Footwall of pegmatite.	1	.020	82	E2	Silvery. Air-stained. Red spots.
Do	2 split a	.018	92	E2	Heavily air-stained.
Do	Split b	.019	90	E2	Heavily air-stained. Many red spots.
Do	4 a	.014	83	E3	Red spots.
Do	4 b	.014	85	E2	Red spots. Lightly air-stained.
Do	5	.019	69	E3	Red spots. Heavily air-stained.
Do	6	.015	67	E3	Red spots. Heavily air-stained. Silver streaks.
High Climb	1	.012	97	E1	Cracks.
Do	2	.025	96	E1	Air-stained. Cracks.
Do	3	.022	96	E1	Air-stained. Silver streaks. Spots.
Do	4	.020	97	E1	Fairly clear.
Do	5	.012	96	E1	Slightly air-stained.
Do	6	.019	96	E1	Slightly air-stained.
Do	7	.022	95	E1/E2	Silver streaks. Reeved.
Do	8 split a	.012	96	E1	Slightly air-stained.
Do	Split b	.019	96	E1	Slightly air-stained.
Highland Lode. Pit above drift.	1	.013	100	E1	Very lightly air-stained.
Do	2	.016	93	E2	Checkerboard color bands. Air-stained. Reeved.
Main open pit.	3 split a	.026	89	E2	Very slightly air-stained.
Do	Split b	.020	87	E2	Very slightly air-stained.
Hot Shot	1 a	.020	45	E3	Heavily black-stained.
Do	1 b	.020	43	E3	Slightly heavier stain than 1 a.
Do	2 a	.022	74	E3	Slightly black-stained.
Do	2 b	.022	31	E3	Heavily black-stained. Mineral inclusions.
Hugo	1	.010	99	E1	Air-stained.
Do	2	.013	98	E1	Air-stained. Tourmaline inclusions.
Do	3	.015	99	E1	Air-stained. Tourmaline inclusions.
Do	4	.019	95	E1/E2	Air-stained.
Do	5	.021	94	E2	Air-stained.

Electrical tests on South Dakota mica with the Bell Telephone Q Machine—Continued

Mine	Specimen No.	Thickness (inches)	Rapid meter reading	Rating	Remarks
Jack Rabbit. Southwest pegmatite.	1	.022	94	E2	Cracks. Inclusions.
Do	2	.014	94	E2	Slightly air-stained. Crack.
North drift, lower level.	1	.029	94	E2	Slightly air-stained. Inclusions.
Do	2	.026	92	E2	Air-stained. Few albite inclusions.
Josie Lode	1	.010	96	E1	Red spots. Air-stained.
Do	2	.020	92	E2	Heavily black-stained.
Lake	1	.020	94	E2	Heavily air-stained. Associated with biotite.
Do	2 a	.013	96	E1	Heavily air-stained. Associated with biotite.
Do	2 b	.013	85	E3	Biotite and muscovite. Cracks.
Lost Bonanza. Near raise, in adit.	1	.023	96	E1	Cracks. Inclusions and brown spots.
Do	2	.016	98	E1	Stained. Spots and cracks.
Do	3	.020	97	E1	Stained. Spots and cracks.
Shaft dump	4	.016	99	E1	Slightly air-stained.
Do	5	.017	99	E1	Air-stained.
Do	6	.012	99	E1	Slightly air-stained.
Open pit	7	.016	99	E1	Green spots. Metallic inclusions. Air-stained.
Face of adit	8	.018	99	E1	Air-stained. Red spots.
Do	9	.013	98	E1	Air-stained. Red spots.
Lost Indian	1	.017	98	E1	Lightly stained.
Do	2	.017	99	E1	Silver streak. Relatively clear.
Do	3	.029	97	E1	Clear.
Do	4	.016	97	E1	Clear.
MacArthur. Base of shaft.	1	.014	99	E1	White mica. Brown spots.
Do	2 split a	.015	87	E2	Air-stained.
Do	Split b	.015	97	E1	Less air-stain than split a.
Do	3 split a	.019	94	E2	Air-stained.
Do	Split b	.015	95	E1	Air-stained.
Do	4	.018	97	E1	Air-stained. Tourmaline inclusions.
Mica Hill Lode.	1	.018	97	E1	Air-stained. Tourmaline inclusions.
Mica King	1 a	.016	86	E2	Very heavily air-stained, and cloudy with black specks. (1 a and 2 b)
Do	2 b	.021	70	E3	
Do	3	.019	99	E1	Air-stained.
Do	4	.014	99	E1	Air- and dark-stain.
Midas. Open pit.	1 split a	.011	98	E1	Silver spot.
Do	Split b	.020	98	E1	Silver spot.
Do	2	.023	97	E1	Slightly air-stained.
Do	3	.014	98	E1	Slightly air-stained.
Shaft	4	.025	96	E1	Silver streaks.
Midas Dike No. 2.	1	.104	99	E1	Air-streaked.
Do	2	.017	99	E1	Air-streaked.
Mohawk (Langford) ruby mica pegmatite.	1	.014	96	E1	Air-stained. Dark inclusions.
Do	2	.030	94	E2	Air-stained. Dark inclusions and spots.
Do	3	.019	96	E1	Air-stained. Dark inclusions and spots. Silver streaks.
Do	4	.020	95	E1	Air-stained. Dark inclusions and spots. Holes.
Do	5	.022	97	E1	Air-stained. Dark inclusions and spots. Cracks.

Electrical tests on South Dakota mica with the Bell Telephone Q Machine—Continued

Mine	Specimen No.	Thickness (inches)	Rapid meter reading	Rating	Remarks
Mohawk	6	.015	96	E1	Dark streaks. Cracks. Reeved.
Do	7	.020	97	E1	Mineral inclusions. Brown spots.
Do	8	.025	95	E1/E2	Reeved. Dark and brown spots. Air-stained.
Mohawk (Langford) white mica pegmatite.	1	.022	89	E2	Brown spots. Dark stains.
Do	2	.021	96	E1	Dark spots and stains.
New York. Raises on 300-foot level.	1	.021	68	E3	Air-stained. Minute black and red spots.
Do	2	.016	95	E1/E2	Air-stained. Red spots.
Do	3	.015	74	E3	Very heavily air-stained. Minute black spots.
Do	4	.030	94	E2	Air-stained.
Do	5	.020	76	E2	Red spots. slightly air-stained.
Do	6	.015	91	E2	Very slightly air-stained.
Old Mike. West drift.	1	.016	99	E1	Ruby. Black spots and air-stained.
Do	2	.025	98	E1	Colorless. Slightly air-stained.
Oreville spar	1	.020	99	E1	Heavily air-stained.
Do	2	.011	97	E1	Heavily air-stained. Reeves.
Do	3	.021	97	E1	Silvery. Clay-stained.
Do	4	.026	99	E1	Heavily air-stained.
Do	5	.016	96	E1	Heavily air- and lightly clay-stained.
Pine Top. Hanging wall.	1	.025	99	E1	Color banding. Slightly air-stained. Red spot.
Pit	1	.024	93	E2	Curved. Slightly air-stained.
Rachael D	1	.011	96	E1	Very heavily air-stained.
Do	2	.012	94	E2	Very heavily air-stained. Black spots.
Do	3	.022	93	E2	Very heavily air-stained.
Do	4	.012	97	E1	Silver streaks.
Do	5	.011	97	E1	Very slightly air-stained.
Do	6	.022	96	E1	Slightly air-stained. Clay stains.
Rainbow	1	.014	99	E1	Clear.
Do	2	.012	99	E1	Clear. Colorless with ruby outer zone.
Do	3	.026	99	E1	Clear. Silver streak.
Rainbow No. 4	1	.012	95	E1/E2	Clear.
Do	2	.030	96	E1	Clear. Hair cracks.
Do	3	.016	98	E1	Clear. Partial films.
Do	4	.018	97	E1	Clear.
Red Deer	1 split a	.012	75	E3	Very heavily air-stained. Red spots. Clouds of small black inclusions.
Do	Split b	.012	78	E3	
Do	2	.014	97	E1	Moderately air-stained. Few red spots.
Do	3	.018	96	E1	Moderately air-stained. Few red spots.
Do	4	.015	96	E1	Slightly air-stained. Large feldspar inclusions.
Do	5	.010	72	E3	Very heavily air-stained. Red spots. Magnetite inclusions.
Footwall	1	.018	94	E2	Moderately air-stained. Many black spots.
Do	2	.018	97	E1	Slightly air-stained. Silver streaks.
Do	3 split a	.011	96	E1	Slightly air-stained.
Do	Split b	.018	90	E2	Black and red spots.
Do	4 split a	.012	97	E1	Slightly air-stained. Silver streaks.
Do	Split b	.026	95	E1/E2	Slightly air-stained.
Do	Split c	.018	95	E1/E2	Slightly air-stained. Magnetite inclusions.
Do	5a	.010	98	E1	Clear.
Red Deer—Con. Footwall	5b	.010	97	E1	Air-stained.
Roosevelt No. 1	1	.018	97	E1	Clear. Silver spot.
Do	2 split a	.016	90	E2	Moderate air-staining. Red spots.
Do	Split b	.013	94	E2	Moderate air-staining.
Do	3	.015	97	E1	Clear.
Ruby Reef	1a	.030	91	E2	Clear. Silver spot. Clay-stain.
Do	1b	.030	94	E2	Clear. Silver spot.
Do	2	.025	96	E1	Clear.
Seal	1	.017	96	E1	Clear.
Do	2	.024	97	E1	Clear.
Silver Dollar	1	.018	97	E1	Very slightly air-stained.
Do	2	.011	98	E1	Clear.
Do	3	.019	99	E1	Clear. Silver spot.
Stinkeroo No. 13	1	.013	98	E1	Checkerboard color bands.
Do	2	.019	98	E1	Checkerboard color bands. Magnetite stains.
Sunshine	1	.010	94	E2	Moderately air-stained. Red spots. Reeves.
Do	2	.012	92	E2	Moderately air-stained.
Do	3	.011	80	E3	Moderately air-stained. Many red spots. Reeves.
Surprise. East drift.	1	.026	98	E1	Slightly air-stained.
Shaft	2	.025	98	E1	Slightly air-stained. Clay stain.
Do	3	.014	98	E1	Very slightly air-stained.
Do	4	.016	92	E2	Moderately air-stained. Few black spots.
Do	5	.012	95	E1/E2	Slightly air-stained.
Terry Shaft at 62 feet.	1	.023	94	E2	Moderately air-stained. Silver spots and streaks.
Do	2	.030	96	E1	Moderately air-stained. Silver spot. Clay-stained.
North stope	1a	.013	98	E1	Very slightly air-stained. Few small black spots.
Do	1b	.013	99	E1	Clear.
Do	2	.011	98	E1	Slightly air-stained. Silver streaks.
Tin Key	1	.010	99	E1	Silver streak.
Tin Queen	1	.014	98	E1	Clear.
Do	2	.013	99	E1	Clear.
Tip Top	1	.010	98	E1	Clear.
Top Hat	1	.013	97	E1	Very slightly air-stained. Silver streak.
Do	2	.012	98	E1	Clear.
Victory	1	.010	97	E1	Moderately air-stained. Black specks.
Do	2	.030	98	E1	Silver spot.
Do	3	.020	90	E2	Very slightly air-stained.
Do	4	.016	99	E1	Clear.
Do	5a	.022	96	E1	Silver spot.
Do	5b	.022	95	E1/E2	Clay-stain.
Do	6	.013	93	E2	Perfectly clear.
Do	7	.015	96	E1	Very heavily air-stained. Silver spots.
Walsh Mica	1	.015	99	E1	Clear.
White Bear	1	.011	99	E1	Clear.
Do	2	.032	96	E1	Slightly air-stained.
White Dog	1	.020	97	E1	Slightly air-stained.
Do	2	.022	97	E1	Clear.
White Mica	1	.022	85	E2	Very heavily air-stained.
Do	2	.016	90	E2	Very heavily air-stained.
Do	3	.019	85	E2	Very heavily air-stained.
White Spar. Footwall, 75-foot level.	1	.018	98	E1	Very slightly air-stained. Silver streaks.
Hanging-wall pillar, 100-foot level.	1	.026	95	E1/E2	Very slightly air-stained.
Do	2	.025	99	E1	Slightly air-stained. Silver streaks.
Do	3	.019	99	E1	Slightly air-stained.

Careful analysis of the results indicates no consistent relationship between air-staining and E rating. Mica of E1 rating from the Oreville Spar, Gap, Buster Dike, Lake, Hugo, and Victory mines is heavily air-stained or silvery. Heavily air-stained mica from the Dewey is E3. Perfectly clear mica is likely to be E1, but the Glenwood, Burgess, and Victory mines contain some clear mica that is E2. The Glenwood mica consistently tests E2 no matter what defects are present, and the Victory mica generally tests E1. Slightly air-stained mica, such as that from the Bob Ingersoll mine, may test either E1 or E2.

The abundance of red (iron oxide) or black (magnetite) inclusions appears to be the most significant defect controlling the E rating. Small quantities of these inclusions may occur in mica of E1 rating, but larger quantities appear to lower the power factor appreciably. These inclusions are most abundant in mica from the Hot Shot (E3), Mica King (E2, E3), Helen Beryl (E2, E3), Sunshine (E2, E3), Glenwood (E2), White Mica (E2), and the white mica-bearing Mohawk pegmatite (E2). Black tourmaline and feldspar inclusions apparently have little effect. Silver streaks and silver spots are most common in the mica with E1 and E2 ratings. Spark tests on specimens show that the silver spots are serious defects, although they do not lower the E rating, and mica that contains silver spots cannot be used for some electrical purposes that require E1 or E2 mica.

Facilities were not available for making additional electrical tests of mica on large samples of each quality of mica from each of the mines and prospects in South Dakota. Such a program would permit definite statements as to types of mica expectable from each mine. The data of the tables on pages 37–40 indicate only that mica of the determined E rating occurs at the properties from which the samples tested were collected.

PRODUCTION

The total production of mica from the Black Hills is valued at more than $2,500,000 (table 1). During the years 1943–45 at least 24 mines yielded more than 1,000 lb of prepared large and small sheet mica (three-quarter trim and full trim). Of these mines one produced more than 40,000 lb and three about 20,000 lb each. Forty-five mines produced 100 to 1,000 lb, 66 prospects produced 10 to 100 lb, and about 200 prospects less than 10 lb each. The total production of sheet mica in 1943 was 85,143 lb, and in 1944 it was 72,164 lb. In 1943 the production of untrimmed punch was 189,372 lb. Practically no mica of no. 3 quality was produced in the Black Hills between December 1942 and April 1945, although some was produced after that date.

The scrap-mica production in 1943 was 2,234 tons, with an average value of about $18 per ton. It is estimated that 2,558 tons of scrap mica was produced in 1944.

The outlook for future production of mica in the Black Hills is favorable. If subsidy prices had continued the 1944 level of production of full-trim sheet probably would have been maintained for several years. Some mines of good productivity should be able to operate profitably even at greatly reduced prices for mica.

RESERVES

The total reserves of scrap and sheet mica in the Black Hills pegmatites are not known but are believed to be many times greater than the past production. Accurate calculation of crude-mica reserves is impossible because of the nature of the deposits, the range of mica content within a deposit, the lack of development work, the lack of information on mica content in rock previously mined, and the wide range in the percentage of mica recovered by different operators. In addition, the reserves of sheet mica depend on the percentage of sheet recovered from crude mica, which in turn depends on the methods and efficiency of preparation. The reserves of particular qualities and grades (sizes) of mica likewise are dependent both on the above factors and also upon the size and physical characteristics of the individual mica books.

At the end of 1945 there were no measured or blocked out reserves of crude mica in the Black Hills, and the indicated reserves were less than 100 tons. The lack of measured and indicated reserves does not mean that the mines were worked out. This situation existed because the development work in the mines was rarely ahead of actual mining, and records of the mica content of rock mined were too incomplete to allow calculations of reserves in specific blocks of mica-bearing rock that were only partly outlined by mine workings. In addition, the few mines in which development work was done in advance of mining during the years 1942–45 were operated in such a way as to complete mining of blocked-out reserves at the end of the purchasing program of Colonial Mica Corporation.

The inferred reserves of mica in the Black Hills are large, but actual estimates can be made for only a few deposits because detailed geologic or production data are lacking. No attempt was made by the Geological Survey geologists to map or study the scrap-mica mines except as they were included in other parts of the program. Therefore, data on reserves of this type of mica are incomplete. The best quantitative information on inferred reserves of scrap mica was obtained by the Bureau of Mines during the investigation of scrap-mica in 1945. Results of the Bureau of Mines sampling suggest that scrap mica recoverable by milling from 17 pegmatites and waste

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dumps, excluding the Beecher and November (see table on p. 35), may be about 45,000 tons, contained in about 355,000 tons of rock. The latter figure does not include mica-bearing rock from some of the larger scrap-mica-producing properties such as the Peerless, Bob Ingersoll, Wood Tin, Hugo, Beecher, and others. The largest single reserve in mines sampled by the Bureau of Mines was at the Old Mike property, where mica-rich rock in place was estimated to contain about 13,000 tons of recoverable scrap mica. Geological information suggests that the total reserves of scrap mica in deposits containing 12 percent or more recoverable mica are several times the 45,000-ton figure given above.

Estimates of inferred reserves of sheet-bearing mica also are incomplete. Calculations based on data obtained from the larger mines operating in 1942–45 (see list on p. 25) indicate that 1500 to 3000 tons of sheet-bearing mica could be recovered by extending the present workings through a radius of 50 ft in the plane of the mica deposits. Recoverable book mica in the deposits listed on page 25 ranges from 0.5 to 6 percent, and 1.5 to 12 percent of the book mica is recoverable as full-trimmed sheet of grade 6 and larger. The total possible reserves in these deposits may be several times greater than the figure given. Five pegmatites—the Climax, White Spar, White Dog, Jack Rabbit, and Punch—were essentially worked out during the years 1942–45, and probably insufficient mica remains in them to warrant future operation. Six pegmatites operated in the same period—the Star-Blue Bonnet, Ballard-Crown, Old Mike, Hugo, New York, and Red Deer—are believed to have reserves in excess of 100 tons each of sheet-bearing mica that could be mined without extensive development work. It is estimated that the 12 other deposits listed below contain 25 to 100 tons of sheet-bearing mica and on further development might yield more.

Ann.	Dewey Lode.	MacArthur.
Antler.	Earl Lode.	November.
Burt.	Gap.	White Bear.
Buster Dike.	Glenwood.	White Cap.

The St. Louis, Triangle A, Hot Shot, and Mica King mines were not operated between 1942 and 1945, but together they probably contain several hundred tons of sheet-bearing mica.

The largest potential reserve of sheet-bearing mica is probably in pegmatites that have been prospected only slightly or that are as yet undiscovered. There has been little prospecting for new deposits in recent years, but during the war years (1942 to 1945) efforts were made to develop many already known deposits. Development of these deposits offset the loss of production from worked-out mines. For example, new production from the Victory and Glenwood mines, in 1944–45, balanced the loss of production sustained when the White Spar, Climax and other mines were exhausted. Structural and mineralogical studies suggest that with guided, systematic prospecting and exploration, some of pegmatites not now considered potential sources of mica can become important producers.

Reserves of sheet mica of a particular quality and grade are more difficult to estimate than are the crude-mica reserves, because the quality and size of a sheet is dependent not only upon the size and type of book mica recovered but also upon the method of preparing the sheet for market. From 1942 to 1945 the quality of mica produced was controlled by the specifications of Colonial Mica Corporation and only qualities meeting these specifications were prepared. The average South Dakota mica purchased by Colonial Mica Corporation was 25 percent of qualities no. 1 and no. 2, and 75 percent no. 2 inferior. A higher quality could have been produced by more careful preparation.

Probably a third of the sheet mica recovered from the inferred reserves of crude mica will contain 15 percent or more of no. 1 and no. 2 quality mica. Perhaps an equal amount will be of no. 3 quality. The remainder of the reserves will contain mica of no. 2 inferior quality. No close estimates can be made as to the grade (size) of sheet mica of these qualities, but probably full-trimmed sheet mica, 3 sq in. in area or larger, will make up less than 30 percent of all grades larger than no. 6.

From 1942 to 1945, only certain small mines produced sheet mica averaging 50 percent or more of qualities no. 1 and no. 2, and the recoverable mica content was less than 1.5 percent of the pegmatites mined. Only one, the Tin Queen, produced more than 1,000 lb of mica of this quality, and it was the only mine that produced such mica at a profit. At the other properties in this class, such as the Roosevelt, Rainbow, and Ruby Reef, the operations were small and unprofitable.

The large mines, such as the Buster Dike, White Spar, Climax, Victory, Old Mike, White Bear, Silver Dollar, Jack Rabbit, and MacArthur, produced sheet mica with a smaller percentage of no. 1 and no. 2 qualities (15 to 40 percent), but because the total quantity of mica was large, this group produced the greater part of no. 1 and no. 2 quality mica purchased in this period.

Another group of pegmatites that produced sheet mica before January 1944 includes the Blue Bonnet, November, Lost Bonanza, Antler, Ballard, Crown, New York, Dakota Feldspar, Burt, Monkey Lode, Dan Patch, Hugo, White Cap, Red Deer, and Dewey Lode. These pegmatites contain a large reserve of mica that is dominantly of no. 2 inferior quality. Some of the deposits contain from 5 to 15 percent of no. 1 and no. 2 qualities and appreciable quantities of no. 3 quality. The no. 3 quality mica from these mines was not prepared in 1942–45. In general the concentration of mica was sufficient for economic operation at 1943 costs and prices, and many mines probably could be operated under less favorable price conditions. The St. Louis, Mica King, Triangle A, and Hot Shot pegmatites have potentially large reserves of no. 3 quality mica associated with some mica of no. 2 inferior quality.

PROSPECTING FOR MICA

The problem of finding new deposits of mica in the Black Hills is one that is becoming increasingly serious, because many of the large mica-bearing pegmatites are fast approaching exhaustion. This is true both of pegmatites that have been mined only for mica and of pegmatites that have yielded mica as a byproduct of feldspar, spodumene, ambylgonite, or lepidolite production. Geologic studies in the years 1942–45 indicate that the Black Hills is a favorable area for locating new deposits by careful and intelligent prospecting. Pegmatites are very abundant, well exposed, and many have been prospected only superficially. Reexamination of known deposits and prospecting of adjacent areas, in the light of recently acquired knowledge of the structural and mineralogical characteristics of mica deposits, should lead to the development of new mines.

Problems involved in prospecting for mica deposits in South Dakota are numerous. The prospector should consider (1) the areal distribution of known deposits, (2) the type of host rock in which the pegmatites occur, (3) the shape, degree of exposure, and the internal structure of the pegmatite, (4) the mineralogy of the zones, and (5) the quantity, quality, and size of the mica books.

The areal distribution of known mica deposits, together with figures on their productivity, is a useful guide to the areas most suitable for prospecting. The Tinton district has never produced sheet mica, but has known reserves of scrap mica, and further prospecting can be expected to reveal similar deposits. Both sheet and scrap mica have been produced from the Keystone, Hill City, and Custer districts, and it is obvious from production figures that scrap-mica-bearing deposits are more likely to be found in the Keystone district and sheet-mica-bearing deposits in the Custer district. In the Custer district the more productive mines have been within six miles of Custer; consequently, this area should receive first attention in any search for sheet-mica deposits.

In the Black Hills the largest and richest mica deposits are in pegmatites with quartz-mica schist wallrocks, which may or may not have been altered to feldspar granulite. Consequently, prospecting in areas of quartz-mica schist should be more fruitful than in areas underlain by quarztite, hornblende schist, and granite. The presence of feldspar granulite, as at the Old Mike and other places, is a favorable indication that the pegmatite may have mica-rich wall zones. Relatively few pegmatites with granite wallrocks have mica zones that contain large and abundant mica books and this type of pegmatite rarely can be mined for mica alone.

The shape, degree of exposure, and internal structure of a pegmatite are very important in determining whether or not it may contain a good mica deposit. Bluntly lenticular and tear-drop-shaped pegmatites are much more likely to contain large mica deposits than pegmatites that are more nearly tabular. The presence of numerous rolls on the pegmatite contacts also are considered favorable, as these rolls may contain the richest or the only minable parts of the deposit.

Many wall-zone mica deposits occur either at the keel or the crest of plunging pegmatites and are crescent-shaped in plan. Others occur along the hanging-wall and footwall parts of the pegmatite but are absent along the crest or top. Still others completely enclose the inner part of the body. Consequently, in prospecting it is essential to recognize just what part of the pegmatite is exposed and to be sure that the critical parts have been observed. Figure 1 shows a number of cross-sections through mica-bearing pegmatites and illustrates the change in shape of pegmatites with depth. Only the upper part of the White Bear, for example, is exposed, whereas the White Spar and the Highland Lode have been exposed more deeply. With deeper erosion the remnants of these pegmatites would appear as thin, more or less tabular bodies. Greater reserves of mica remain in those pegmatites that have been the least eroded, but the presence of the mica deposits is less obvious. The richer parts may be hidden beneath barren border zones, or the wall zones may be less well developed in the wider top parts of the pegmatite. It is possible to tell whether the top or bottom part of a lenticular pegmatite is exposed, because the contacts on the top diverge with depth and near the bottom converge or are parallel. Commonly a small mica shoot recognized in a poorly exposed pegmatite can be followed down to more extensive bodies. Most of the sheet and scrap mica produced in the Black Hills has come from wall zones or intermediate zones adjacent to wall zones. Very little sheet mica, but considerable scrap mica, has been produced from other zones, fracture-filling bodies, and replacement bodies. The prospector should look for the well-zoned pegmatites because homogeneous pegmatites rarely contain mica in minable quantity. Zoned pegmatites that have fine-grained border zones rich in plagioclase, muscovite, or both, generally contain wall zones composed of the same minerals but coarser grained. Border zones commonly form dip slopes that should be examined carefully by prospectors, because they may hide valuable minerals in the underlying adjacent wall zones. Pegmatites that have border and wall zones of fine-grained feldspar and quartz with little or no muscovite commonly contain sheet-bearing mica zones adjacent to the border and wall zones as at the Dyke Lode and White Cap mines.

The absence of muscovite books in the zones does not necessarily mean an absence of deposits in the remainder of the pegmatite, because replacement and fracture-filling bodies of bull mica may occur in the intermediate zones or core.

The scrap- or sheet-mica possibilities of a well-zoned pegmatite containing muscovite may be judged by considering the presence or absence of the minerals listed below.

1. Abundant cleavelandite, especially in the wall zones, indicates that the muscovite books in general will contain little sheet mica. Blocky plagioclase, especially in wall zones, is indicative of sheet-bearing mica books.
2. The presence of potash feldspar in wall zones or mica-rich intermediate zones suggests that the muscovite books will not be sufficiently abundant or contain enough sheet mica to warrant mining for mica alone.
3. The presence of lithium minerals in the inner zones generally indicates that a large proportion of the mica books will contain only scrap mica.
4. The presence of unusually large quantities of black tourmaline commonly indicates a wall zone poor in mica.
5. The presence of large euhedral crystals of potash feldspar with interstitial quartz and albite in a core, sharply separated from a plagioclase-rich wall zone, is indicative of abundant sheet mica in the wall zone. Pegmatites of this type include the White Spar, Climax, and Victory.
6. Pegmatites with oligoclase rather than albite in the plagioclase-rich wall zones contain high-quality mica, but the mica content is commonly very low.
7. Wall zones with "shell" beryl are commonly muscovite-bearing zones.

The size and quality of mica books as well as the quantity determine to a large extent whether or not a mica deposit can be worked by hand methods. Mica books that contain a large proportion of the larger sizes of sheet mica of high quality can be mined from deposits of lower mica content than those that produce similar sheets of lower quality. There is no way to predict the sizes and qualities of mica books in advance of mining. A reasonable quantity of crude mica from each prospect must be mined and prepared before the possibilities of the deposit are known. There is little reason to expect that the books in a deposit will increase in average size or quality with depth. Definite differences in the size and quality of mica exist between different mica shoots or zones in the same pegmatite, and each must be sampled separately. Faulting may influence the size pattern or quality of book mica by deformation, and this type of defect will disappear beyond the limits of the fault zone.

In summary, if a mica-rich pegmatite is coarse-grained; well zoned; has cleavelandite in the wallzone; and is associated with intermediate zones or a core of feldspar, quartz, or lithium minerals, it is likely to be a favorable prospect for scrap mica. If it has a blocky albite in the wall zone, and intermediate zones or cores of potash feldspar and quartz or of potash feldspar alone in a matrix of intergrown quartz and albite, it is a favorable prospect for sheet mica.

In exploration the mica deposits should be followed in order to outline the shape and size of the zone. In addition, where narrow shoots occur in a zone, the entire zone should be explored, because several individual mica shoots may occur, separated by barren rock. In exploring a deposit by sinking a shaft or by diamond drilling, care should be taken to consider not only the strike and dip but also the plunge of the deposit.

BERYL DEPOSITS

DISTRIBUTION

The beryl deposits of South Dakota are on the flanks of Harney Peak in the southern Black Hills. The largest production has come from the Keystone district, which in 1944 produced at least 207 tons of beryl. About half of this production was from the Bob Ingersoll mine. The Custer district produced about 58 tons of beryl in 1944 and the Hill City district produced a little in 1943 and 1944. Colonial Mica Corporation and Metals Reserve Company bought beryl at subsidy prices from more than 13 properties in the Keystone, 47 properties in the Custer, and 3 properties in the Hill City district during 1943 and 1944. These mines and prospects are listed below and some of them are shown on plate 1. The production by districts during these years is given below.

South Dakota mines producing beryl in 1943 and 1944

Custer District:
- Amber.
- Ballard.
- Beecher.
- Blue Bird.
- Bull Moose.
- Buster.
- Climax.
- Coyote.
- Dakota Feldspar.
- Dot.
- Earl Lode.
- Elkhorn.
- Frozen Foot.
- Green Mine.
- Harbach.
- Hawk.
- Helen Beryl.
- Hub.
- J. 7.
- Jack Rabbit.
- Joan Lode.
- Knowles.
- Lucky Twist.
- Maby.
- MacArthur.
- Michaud.
- New Deal.
- Old Mike.
- Pitt.
- Pleasant Valley.
- Pringle.

Custer District—Continued
- Pringle mines, various.
- Rare Minerals.
- Rasmussen.
- Red Rose.
- Roosevelt.
- Ross.
- Ross (F. B. McLaughlin).
- Silver Dollar.
- Spencer Cheadle.
- Tin Key.
- Tip Top.
- Top Hat.
- Victory.
- White Elephant.
- Wildwood.
- Wonder Lode.

Hill City District:
- Monkey Lode.
- Pearl.
- Tin Queen.

Keystone District:
- Anna.
- Bob Ingersoll.
- Dan Patch.
- Dyke Lode.
- Etta.
- Eureka (Madill).
- Hardestey.
- Hugo.

South Dakota mines producing beryl in 1943 and 1944—Con.

Keystone District—Continued	District Unknown:
Peerless.	Ackerman.
Plate Lode.	Mary Marie.
Soda Spar.	Pine Creek.
White Cap Lode.	Prospect (Root).
Wood Tin.	Ruth Van Overscheld.

South Dakota beryl production (in pounds), by districts, 1943 [1] *and 1944*

Year	Keystone district	Custer district	Hill City district
1943	302, 362	105, 407	2, 317
1944	414, 526	115, 791	1, 360
Total	716, 888	221, 198	3, 677

[1] Figures are incomplete. Minerals Yearbook gives a total of 238 tons for 1943 and 306 tons for 1944. The difference probably should be attributed to the Keystone district.

TYPES OF BERYL DEPOSITS

Beryl, a beryllium aluminum silicate, occurs in nearly all zoned pegmatites in the Black Hills. Although concentrations of this mineral may be found in any structural position within the pegmatite body, by far the greatest production has come from deposits in the intermediate zones. Because beryl is in many cases difficult to recognize and there is generally less of it than of other valuable minerals in the intermediate zone, the limits of beryl concentrations were mapped only where beryl was the chief mineral of interest.

Beryl occurrences of the Black Hills are divided into six main types of deposits on the basis of structure and mineralogy. They are as follows:

1. Wall- and border-zone deposits.
2. Intermediate-zone deposits.
   a. Inner part of a mica-bearing zone.
   b. Amblygonite-bearing zone.
   c. Outer part of a spodumene-bearing zone.
   d. Outer part of a lepidolite-bearing zone.
   e. Outer part of a perthite-quartz-bearing zone.
   f. Outer part of a quartz-bearing zone.
3. Core deposits.
4. Fracture-filling deposits.
5. Replacement deposits.
6. Vein deposits.

Types of occurrences 1–4 are found only within pegmatite bodies. A replacement type (5) of deposit may occur within the pegmatite, but it is recognized most easily where it is in schist. Type (6) is grouped with the pegmatites, although these deposits are primarily quartz veins. They appear to have a close genetic relation to pegmatites, but are not directly connected with them.

The wall- and border-zone type of beryl deposit is common in the Black Hills, but little beryl has been produced from this type. Beryl, as euhedral to subhedral crystals, too small for hand cobbing, occurs with scrap and sheet muscovite, albite, quartz, and tourmaline. Where sheet mica is present the beryl is dominantly of the skeletal crystal or "shell' type (fig. 5).

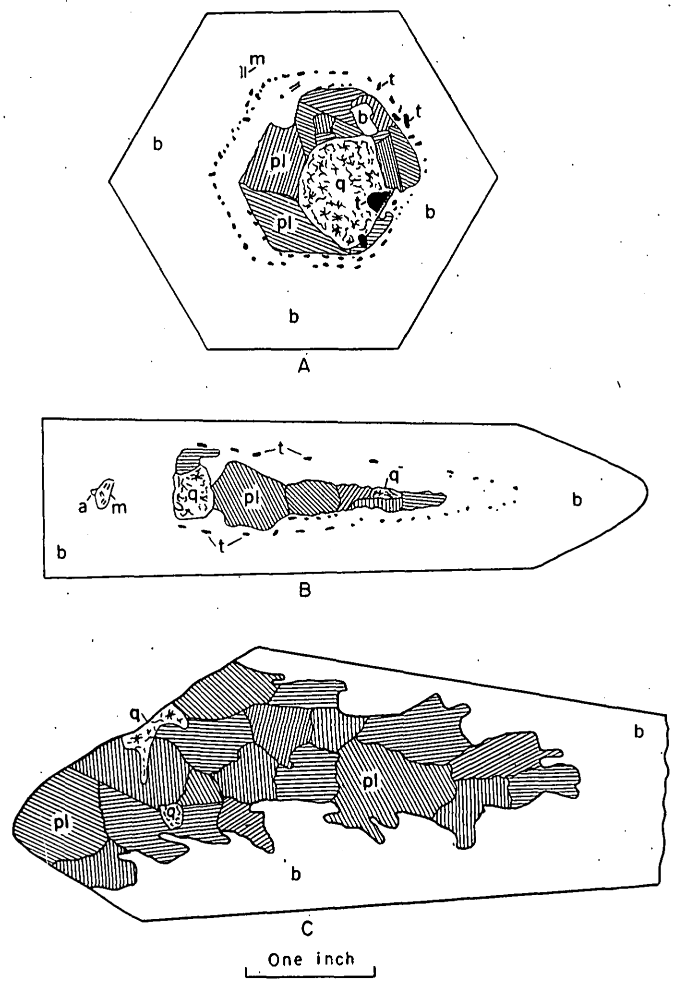


FIGURE 5.—Sections through "shell" beryl crystals. (A) and (B), cross-section and longitudinal section respectively of two crystals from the Helen Beryl pegmatite. (C), longitudinal section of tapered crystal from the Florence pegmatite. Shape of feldspar grains diagrammatic. Plagioclase, *pl*; tourmaline, *t*; quartz, *q*; muscovite, *m*; apatite, *a*; and beryl, *b*.

At the inner edge of this zone the individual beryl crystals are larger than at the outer edge. Crystals that start their growth near the schist contact may increase in diameter toward the center of the pegmatite and may extend across the inner edge of the wall zone. Extremely large crystals that start near the inner edge of the wall zone may extend into or across the adjacent intermediate zone, and generally they increase in diameter as they approach the core of the dike. Figure 6 shows such a crystal, 18 ft long, in Dike No. 2 of the Bob Ingersoll mine. The apparent thinning of the crystal at its lower end is due to the fact that the axis of the crystal was not parallel to the exposure. Beryl may be disseminated evenly throughout those pegmatites, or parts of pegmatites, in which only the border and wall zones are present, or through poorly zoned pegmatites. This type of deposit would require milling for beryl recovery.

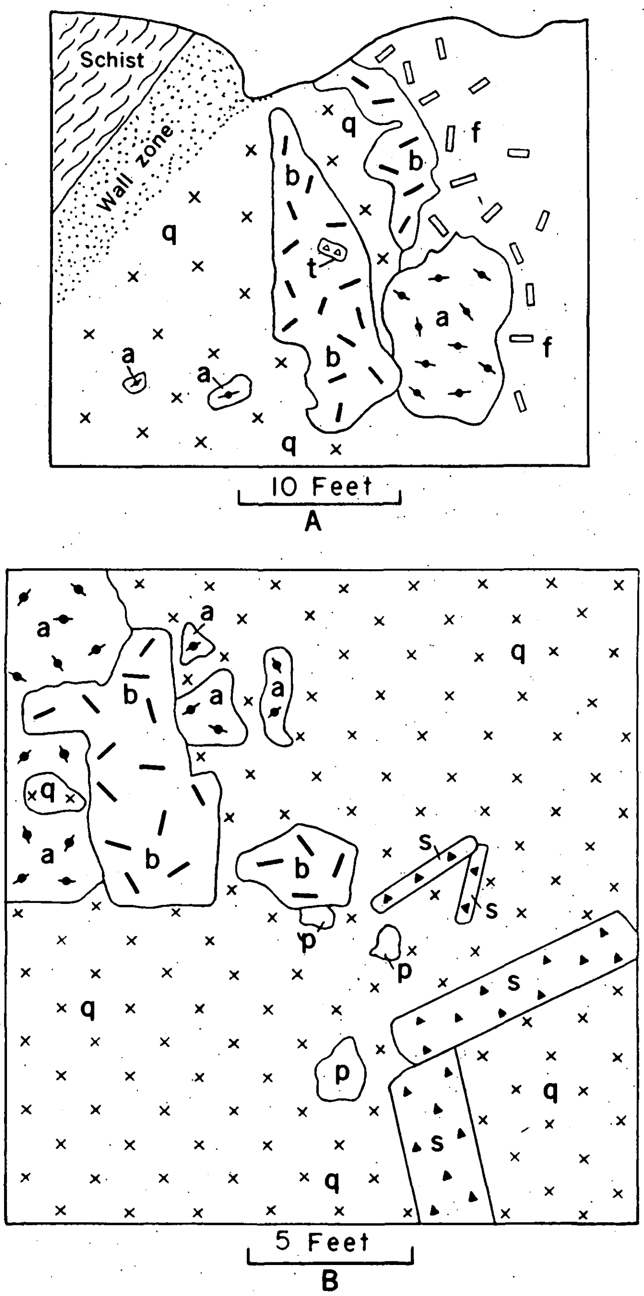


FIGURE 6.—Sketch showing outlines of large beryl crystals and associated minerals. (A), Bob Ingersoll mine, Dike No. 2. (B), Dyke Lode. Beryl, *b*; quartz, *q*; perthite, *f*; amblygonite, *a*; spodumene, *s*; tourmaline, *t*; and lithiophilite-triphylite, *p*.

Most of the beryl produced in South Dakota has come from the intermediate-zone type of deposit. Beryl deposits at the inner edge of the mica-bearing wall zones, subtype (a), are very productive. The Peerless, Wood Tin, and Bob Ingersoll pegmatites are good examples of this type, but the mica is almost entirely of scrap quality. The beryl in most sheet-bearing mica deposits is too small to recover by hand cobbing. The Old Mike mine is the only large beryl deposit that has also produced appreciable quantities of sheet mica from the same zone. At the Peerless, Bob Ingersoll, Dyke Lode, and Beecher Lode pegmatites, subtypes (b-f) merge with subtype (a), and as the two zones are usually mined together it is difficult to determine whether the wall zone or intermediate zone is the more important source of beryl.

The core type of beryl deposit is relatively rare and generally of small size. Beryl with quartz or perthite and quartz in small lenticular bodies or pods appears to have been the last group of minerals to crystallize in many pegmatites. These masses are essentially pegmatite cores, but they may be found either singly or as a number of lenses or pods, haphazardly arranged in any one pegmatite. These beryl-rich pods should not be confused with beryl-rich lenses of discontinuous intermediate zones that occur in definite structural positions within a pegmatite. In narrow dikes beryl may occur throughout a continuous, narrow core of quartz or quartz-perthite pegmatite between well-developed wall zones. Deeper exposures may prove that such apparent cores are actually intermediate zones.

Fracture-filling beryl deposits, type 4, are closely related to types 1, 2, and 3. They are late pegmatite units formed along fractures within a pegmatite. Some are zoned with respect to the walls of the fracture, and their composition is determined by the stage of crystallization of the main body at the time of their formation. The Helen Beryl deposit, although essentially of type 1, is cut by numerous fracture-filling deposits. The Pleasant Valley, Sunshine, and other beryl deposits of this type have not been particularly large producers. Other small, beryl-rich units are unzoned and were formed along fractures as in the quartz core of the Crown pegmatite.

The replacement beryl deposits, type 5, are primarily those in which beryl has been introduced into the schist wallrocks, as at the Mountain Beryl and Old Mike mines. They are very rare in the Black Hills and have never produced beryl. Some beryl occurs with cleavelandite and other minerals as irregular replacement bodies in earlier formed zones of the pegmatite.

The vein type of beryl deposit, type 6, is represented by quartz veins in schist. They are conspicuous in the Hill City district and are pegmatitic veins of quartz, muscovite, beryl, and cassiterite. They have no visible connection with pegmatites, but their distribution and mineralogy suggest that they were formed at a later stage by the processes that produced the pegmatites. They are associated with similar veins that contain less muscovite, no beryl, and wolframite or hubnerite rather than cassiterite.

STRUCTURAL FEATURES OF BERYL DEPOSITS

In internal structure, beryl-rich pegmatites resemble mica pegmatites. The beryl-bearing zones reflect the structure of the pegmatite contact to a greater or lesser degree and beryl-rich shoots tend to follow the structure of the rolls, keel, or crest of the pegmatite.

The downward and lateral extensions of beryl-rich shoots are most easily predicted in the deposits that occur in zones close to the pegmatite contacts. Because beryl crystals grow to large sizes, they may extend beyond the zone in which they normally occur.

MINERALOGY

Beryl is a widely distributed pegmatite mineral, but minable concentrations are not common. In the richer deposits beryl is closely associated with albite, perthite, quartz, and muscovite. Where albite is the dominant mineral in the mica zones, beryl is commonly more abundant in these mica zones than elsewhere in the dike. Where perthite is predominant in a zone, beryl is lacking or is more closely associated with the quartz, albite, and muscovite interstitial to the perthite. Consequently, the promising beryl deposits are found in pegmatites containing appreciable quantites of albite.

In the wall-zone beryl deposits, the beryl is associated with muscovite and more or less equant or blocky albite. It commonly has low indices of refraction, hence the alkali content is also probably low. Table 4, pp. 49–50, summarizes the optical data available. The beryl crystals are generally euhedral to subhedral where associated with scrap mica. Skeletal crystals or "shells" of beryl (fig. 5) around albite, quartz, mica, tourmaline, and other minerals occur associated with sheet mica. Outwardly, this "shell" has a good hexagonal form, but the inside is irregular and the detailed contact relations (fig. 7) suggest that the

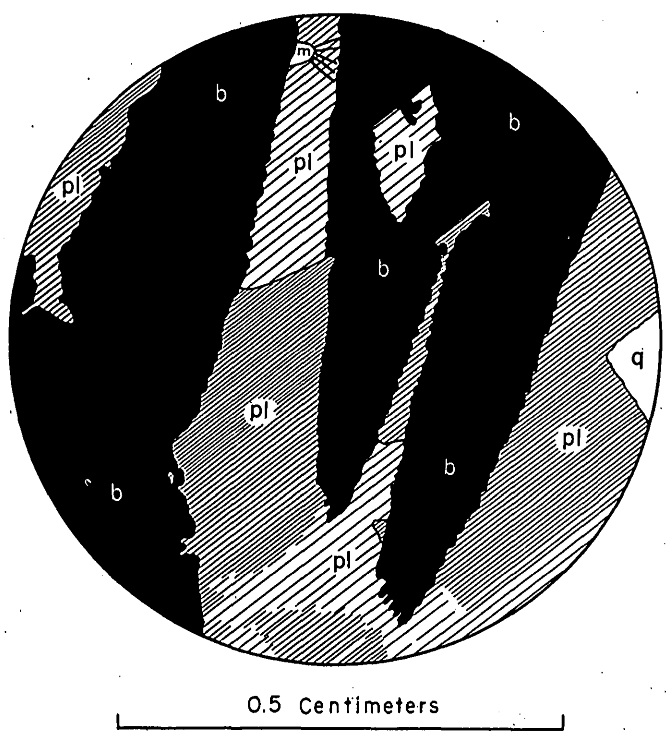


FIGURE 7.—Contact relationships in "shell" beryl crystal, Harbach mine. Beryl, *b*; plagioclase, *pl*; quartz, *q*; muscovite, *m*.

beryl partly replaced other minerals in the center of the crystal, although the smooth outer contact, the distribution of tourmaline inclusions, and the field relations indicate that these minerals are essentially contemporaneous. Many of these "shell" beryl crystals are tapered, and the small end of the crystal, commonly closest to the schist wall, is composed entirely of beryl (fig. 5). In some crystals both the large and small end are entirely beryl. Beryl in the wall-zone deposits is light yellowish-green or pale-green.

Beryl of the intermediate zones shows large differences in composition, color, and form. The crystals at the inner edge of mica-bearing zones, subtype (a), are similar to those in the wall zone, except that "shells" are less common. Where the inner edge of the mica-bearing zone contains appreciable cleavelandite, many beryl crystals are corroded at the corners and are cut by irregular veinlets of cleavelandite. Similar corroded crystals are common where the inner zones or core of the pegmatite contains lithium minerals. Where the mica-bearing zone is adjacent to a core of quartz or perthite-quartz, the beryl crystals are generally euhedral, green, and as low in alkalies as beryl of the wall zone. In lithium- or cleavelandite-bearing pegmatites the beryl commonly is white, pink, or blue.

Beryl occurring with amblygonite, subtype (b), is white and is associated with cleavelandite as an interstitial filling between amblygonite, quartz, microcline, or spodumene crystals. The Bob Ingersoll, Dyke, Peerless, and Beecher pegmatites contain deposits of this type. The beryl at the outer edge of spodumene zones, subtype (c), commonly occurs either at the inner edge of a potash feldspar zone, in which it may be euhedral, or in the outer part of the spodumene zone, as interstitial fillings between spodumene crystals. At the Beecher Lode the beryl is interstitial to spodumene and can be recognized only with difficulty because of heavy iron-stain. At this mine beryl also occurs interstitial to muscovite crystals in an intermediate zone or replacement unit of scrap mica.

The beryl in the outer edges of lepidolite-bearing zones, subtype (d), is in corroded crystals, white, pink, or blue, associated with cleavelandite, lepidolite, quartz, and microcline. The largest mass of beryl, 61 tons in weight, mined at Dike No. 1 of the Bob Ingersoll mine was taken from the wall zone at the edge of the lepidolite core. Beryl deposits in other parts of this dike were in the intermediate zone adjacent to the lepidolite core.

The beryl at the outer edge of perthite-quartz pegmatite, subtype (e), generally occurs as green to pale-yellow, euhedral crystals that are low in alkali content. It is commonly associated with albite and quartz interstitial to perthitic feldspar crystals. Where appreciable muscovite is associated with the albite, as at the Wonder Lode, Tip Top, and Tin Queen pegmatites, some of the beryl forms "shell" crystals.

Beryl at the outer edge of quartz pegmatite, subtype (f), is in green to yellowish euhedral crystals. It is commonly associated with small quantites of scrap muscovite, albite, perthite, quartz, and some phosphate minerals.

Core deposits of beryl, type 3, are rare. Those cores in which beryl is concentrated probably represent what in a more completely exposed dike could be recognized as a wall or intermediate zone. Beryl occurs in the cores of numerous small dikes, 1 to 2 ft thick, between mica wall zones, and at the Crown pegmatite some beryl occurs along late fractures in the quartz core. These occurrences are not economically important.

Fracture-filling deposits, type 4, and replacement deposits, type 5, have the same mineralogy as the zones from which they were derived. Where a fracture-filling or replacement deposit was formed at the same time as an intermediate zone, the minerals of the beryl deposit and of the zone are the same. The vein type of deposit, type 6, as exemplified by the Cowboy, Cassiterite, Last Chance, and Mohawk tin veins, contains milky white vein quartz, with clots and streaks of fine-grained muscovite and clots or masses of white beryl. The beryl from these veins has a refractive index, N_o=1.568–1.570, as low as any beryl from the pegmatite deposits. (See table 4, pp. 49–50.)

COMPOSITION OF BERYL

by J. W. Adams

Beryl generally occurs only in relatively small quantities as compared to the total bulk of minerals mined in pegmatites. To obtain a marketable product, the beryl is generally hand picked or "cobbed." The cobbed beryl, with some of adhering and admixed rock, constitutes beryl "ore." One lot of 130 tons shipped from the Black Hills in November 1943 averaged 11.85 percent of BeO. As this lot includes material from many pegmatites in the Keystone, Custer, and Hill City districts, the analysis for BeO gives a fair average of the quality of the ore produced. Below are listed the available analyses for BeO of ore from individual mines.

Mine	*Percent BeO*
Beecher Lode	9.86
Bob Ingersoll	11.18
Dan Patch	10.84
Etta	10.65
Greene	12.25
Greene	12.70
Various Mines	11.50
White Elephant	12.04
Wood Tin	9.72
Wood Tin	9.81
Wood Tin	10.10

Theoretically, beryl contains 14.0 percent of BeO, this percentage is seldom reached in the mineral itself, and never in the hand-cobbed beryl ore because of the quartz, feldspar, and other minerals that are accidentally included. These gangue minerals are attached to the beryl or enclosed within it, as is common in shell beryl (fig. 5). Careful sorting will raise the BeO content of individual shipments of beryl ore.

Microscopic mineral inclusions and the substitution of alkalies (Na_2O, K_2O, Li_2O, CsO) in the crystal structure for an equal amount of BeO also reduce the percentage of BeO. The substitution may reduce the theoretical 14 percent BeO content to about 10 percent. On the basis of refractive indices, beryl from the Black Hills appears to contain from 10.5 to 14 percent BeO. The quantity of alkalies in beryl varies in different pegmatites, in different zones in a single pegmatite, and, in some deposits, in parts of a single crystal.

It has been demonstrated that the optical and physical properties of beryl vary with the quantity of alkalies (Na_2O, Li_2O, CsO) present. Winchell's graph of these variations (1933, p. 272) shows an increase in the indices of refraction, birefringence, and specific gravity with increase in alkali content.

In 1943–44 more than 131 individual beryl specimens from 59 mines or prospects were studied microscopically. The index of refraction of the slow ray (ω) was determined in white light by oil immersion methods, and other pertinent data such as form, color, inclusions and associated minerals were noted. These studies were begun at the request of the Custer office of the Colonial Mica Corporation for information that would serve as a guide to the approximate BeO content of beryl offered for sale in small lots. Later, similar investigations were made in an attempt to determine why beryl from some mines, and even from some parts of a single mine, could not be floated successfully by the Bureau of Mines. A summary of the data showed that the index of refraction and the physical appearance of beryl differed between units in the same pegmatite and that beryl in similar lithologic units had similar properties. Time did not permit detailed mineralogical studies at all mines to determine the variations between zones, within zones, or within single crystals. The data available are summarized in table 4 (pp. 49–50), but only two deposits, the New York and Crown, were studied in detail. Data for other deposits must be considered incomplete. No complete study was made of the variation within zones or within crystals. Some specimens were not obtained in place, and information regarding their position within the pegmatite is lacking. Unfortunately the BeO content of only two of the beryl specimens has been determined. These two analyses for BeO were made by the U. S. Bureau of Mines and are included in table 4. No determinations have been made of the specific gravity of any of the specimens.

In table 4 the pegmatites are grouped into the mica-bearing and potash feldspar-bearing pegmatites (in which lithium minerals are rare), and the lithium-bearing pegmatites.

TABLE 4.—*Characteristics of beryl, southern Black Hills, South Dakota*

	Specimen number	Index of refraction (N_o)	Form	Color	Inclusions	Zonal position in pegmatite	Remarks
Mica- and feldspar-bearing pegmatites:							
Ann	131	1.574	Euhedral	Pale green-brown	Few	Core	Outer edge of core.
Apex Lode	1	1.570	Euhedral	Green	Scattered	Wall	Lower dike near hanging wall.
Big Spar No. 1	2	1.575	Euhedral	Green	Few	Wall	With perthite, quartz, and muscovite.
Bull Head	3	1.570	Euhedral	Light green		?	
Bull Moose	122	1.574	Euhedral	Pale green	Numerous	Wall	
Burt	4	1.570	Euhedral	Yellow-green		Margin of core	
Climax	5	1.573	"Shell"	Brown-white	Scattered	Wall	Core of albite-quartz, tourmaline, and muscovite.
Crown and Ballard	6	1.591	Anhedral	White	Scattered	Core	Fracture filling in quartz core.
Do	7	1.589	Euhedral	Pale green	Scattered	Intermediate	Tabular crystal. One foot from core.
Do	8	1.585	Euhedral	White	Scattered	Intermediate	Five feet from core.
Do	9	1.580	"Shell"	Light brown	Numerous	Wall	One foot from schist, 50-foot level.
Do	10	1.576	Euhedral	Light brown	Numerous	Wall	4½ feet from schist. Tapered.
Do	11	1.581	Euhedral	Light brown	Numerous	Wall	One foot from schist.
Do	12	1.574	Euhedral	Light green	Few	Wall (?)	From dump. Associated with muscovite.
Dan Patch	13	1.579	Euhedral	Yellow-green	Numerous	Intermediate	Fragment of large crystal.
Dewey Lode	119	1.575	Euhedral	Light golden	Very few	Wall (?)	Glassy. Associated with biotite.
Dorothy	14	1.572	Euhedral	Yellow-green	Very few	Wall	
Earl	111	1.576	Euhedral	Yellow-green	Few	Intermediate	Adjacent to wall zone.
Do	112	1.580	?	White	Few	Intermediate	Adjacent to core.
Elkhorn	15	1.572	?	Yellow-green	Numerous	Intermediate	Perthite-quartz pegmatite.
Do	16	1.577	?	Yellow-green	Numerous	Intermediate	In quartz-albite pegmatite.
Do	17	1.575	Euhedral	Light brown	Numerous	Intermediate	Largely altered to kaolinite.
Elk No. 1	18	1.581	Euhedral	Brown-white	Scattered	?	
Eureka	19	1.570	Euhedral	Light-green	Numerous	Wall	
Florence (Harbach)	20	1.584	"Shell"	Pale yellow-green	Very cloudy	Wall	Cored, tapered crystal. Edge, large end.
	20	1.580	do	do	Very cloudy	Wall	Edge small end (fig. 5).
Do	21	1.582	Euhedral	Brown-white	Few	Wall	Tapered. Beryl throughout.
Helen Beryl	22	1.592	Euhedral	Yellow		Wall	Outer edge, zoned crystal.
Do	22	1.578	Euhedral	Yellow		Wall	Interior of above crystal.
Do	23	1.575	?	Colorless		Wall	Gem quality.
Do	24	1.586	"Shell"	Light green	Very few	Wall	Quartz, albite, tourmaline inside shell.
Do	25	1.584	Euhedral	Yellow-green	Few	?	Embedded in pink perthite.
Do	26	1.591	"Shell"	Yellow-green	Few	Wall (?)	Terminated. Index for edge of pinacoid face.
Do	26	1.580	"Shell"	Yellow-green	Few	Wall (?)	2½ inches from termination; intergrowth surface.
Do	27	1.590	Euhedral	White	Numerous	Fracture filling	Fragment of 2-inch crystal.
Do	121	1.591	Euhedral	Smoky grey	Few	Wall (?)	Glassy. Index at center of crystal slightly lower.
Highland Lode (Ross)	28	1.575	Euhedral (?)	Golden-yellow	Very few	Intermediate (?)	Fragment; U. S. B. M. analysis 12.55 percent BeO.
Do	29	1.574	Euhedral (?)	Green	Very few	Intermediate (?)	Fragment; U. S. B. M. analysis 12.45 percent BeO.
Do	30	1.574	Euhedral	Light blue-green	Cavities often with bubbles.	Intermediate (?)	Fragments from 5-ton crystal.
Homestead No. 3	124	1.580	Euhedral	Yellow-green	Very few	Wall	One inch from schist.
Hub	125	1.580	Euhedral	Yellow-green	Few	Wall	Glassy.
Jack Rabbit	31	1.571	Euhedral	Green	Elongated cavities	Intermediate	In part glassy.
Do	32	1.572	Euhedral	Light green	Elongated cavities	Intermediate	Glassy. Sericitic alteration.
Do	33	1.568	Euhedral	Light green	Numerous	Intermediate	Glassy. Sericite on edges.
Knowles	117	1.571	Euhedral	Light brown		?	Half-inch crystal.
Do	118a	1.569	Euhedral	Light brown	Elongate inclusions parallel to the c-axis.	?	Center of 1-inch crystal.
Do	118b	1.570	Euhedral	White		?	Half-inch crystal adjacent to 118b.
L5 No. 3	34	1.580	?	White		Core	Fragment.
MacArthur	35	1.570	Euhedral	Light yellow-green		Wall	
Do	36	1.572	Euhedral	Light yellow-green		Wall	North end of drift.
Mica King No. 1	37	1.572	Euhedral	Light blue-green	Numerous	?	Dump.
Midas	38	1.571	Euhedral	Yellow-green	Few	Core	
New York	39	1.590	Anhedral	White	Numerous	Intermediate (?)	With lepidolite.
Do	40	1.587	Subhedral to anhedral.	Yellowish to white		Intermediate	Mixed with small muscovite flakes.
Do	41	1.585	Anhedral	White		Intermediate	Interstitial.
Do	42	1.586	Subhedral to anhedral "shell."	Yellowish		Intermediate	
Do	43	1.585	Subhedral to anhedral "shell."	Yellowish			
Do	44	1.583	Subhedral	Greenish-grey to white.		Wall	
Do	45	1.578	Euhedral "shell."	Pale green		Wall	Center of crystal is pink albite and quartz.
Do	46	1.577	Euhedral "shell."	Pale green		Wall	Center of crystal is pink albite and quartz.
Do	47	1.577	Euhedral "shell."	Pale green		Wall	Included in muscovite book.
Do	48	1.575	Euhedral "shell."	Pale green		Wall	Center of crystal is pink albite and quartz.
Old Mike	49	1.588	Euhedral	White	Very abundant	Core (?)	3-inch terminated crystal with cleavelandite.
Do	50	1.581	Euhedral	Yellow-white	Few	Core (?)	1-inch terminated crystal with cleave landite.
Do	51	1.577	Anhedral (?)	Pale green	Few	?	With albite.
Oreville Spar	128	1.591	?	Pale pink	Numerous	?	Dump.
Do	129	1.582	Euhedral	White	Numerous	?	Dump.
Do	130	1.591	?	Pale pink	Few	?	Dump.

See footnote at end of table.

TABLE 4.—*Characteristics of beryl, southern Black Hills, South Dakota*—Continued

	Specimen number	Index of [1] refraction (N_o)	Form	Color	Inclusions	Zonal position in pegmatite	Remarks
Mica- and feldspar-bearing pegmatites—Continued							
Pleasant Valley	52	1.580	Euhedral	Pale yellow-green	Abundant	Fracture filling	
Do	126	1.580	Subhedral	Light green	Very few	Wall	Glassy.
Do	127	1.584	Euhedral	White	Abundant	Outer edge of core	
Rainbow Mica	53	1.568	Euhedral	Light green-brown	Abundant	Core	
Do	54	1.570	Euhedral	Light green-brown		Core	
Do	55	1.570	Euhedral	White-stained	Numerous	Core	
Rainbow No. 4	56	1.588	Euhedral	Light brown to white	Numerous	Wall	⅝-inch crystal, largely sericitized.
Do	56	1.583	Subhedral	Pale yellow	Numerous	Wall	Adjacent to above, may be same crystal.
Do	57	1.584	Euhedral	White		Core	From crystal 18 inches in diameter.
Do	58	1.580	?	Pale yellow	Few	Core	Fragment from South pit.
Do	59	1.580	Euhedral	Pale yellow	Very few	Core	North pit, 1-inch crystal.
Roosevelt Feldspar	113	1.569	Euhedral	Light green	Elongate inclusions, parallel to the C-axis.	?	Dump.
Saint Louis	60	1.575	?	Light green	Abundant	Interstitial to perthite.	Fragment.
Star	61	1.570	Euhedral	Pale yellow-green	Very few	Inner edge wall zone.	Crystal 3 inches in diameter.
Do	62	1.568	Euhedral	Pale green-white	?	Wall (?)	From dump.
Stinkeroo No. 13	116	1.576	Euhedral	Light brown	Few	Wall	In muscovite.
Sunshine (Upper pit)	63	1.570	Euhedral	White	Abundant	Fracture filling	Crystal 1 inch in diameter.
Sunshine (Upper pit?)	64	1.576	Euhedral	Light brown	Abundant	Core?	Crystal 2 inches in diameter.
Triangle "A"	115	1.578	Euhedral	Light green	Very cloudy	?	Radial aggregate.
Victory	65	1.573	"Shell"	Heavily stained	Abundant	?	
Do	66	1.573	"Shell"	Heavily stained	Abundant	Inner edge of wall zone.	Crystal 4 inches in diameter with center of tourmaline, albite, and quartz.
Do	67	1.572	?	Green-white	Few	?	
Do	68	1.571	?	Blue-green	Elongated cavities	?	Glassy.
Do	69	1.574	Euhedral	White	Many	?	
White Bear	70	1.575	"Shell"	Yellow	Very few	Wall	Quartz, albite, and muscovite in center of crystal.
Do	71	1.575	Euhedral	Sea-green	Many inclusions and elongated cavities.	?	Part of large crystal. Glassy.
White Cap	72	1.574	Euhedral	Light brown	Scattered	Intermediate	
Do	73	1.585	?	Pale green-white	Scattered	Intermediate	
White Spar	74	1.573	"Shell"	Pale yellow	?	?	Crystal 1½ inches in diameter with albite, muscovite, and quartz center.
Do	75	1.574	Euhedral	Yellow-green	?	Core	Open-pit. Near phosphates.
Do	76	1.575	?	Light green	?	Core	Open-pit. Glassy.
Do	77	1.574	Euhedral	Light green	?	Core	43-foot level.
Do	78	1.571	Euhedral	Yellow	Very few	?	Glassy crystal, ¾ inch in diameter.
Do	79	1.575	Euhedral	Light green	None	Core	Glassy, fragment of crystal.
Wilhelm	80	1.583	Anhedral	White	?	?	Dump. Intergrowth with columbite-tantalite.
Wonder Lode	81	1.572	Euhedral	Pale green	?	?	Part of large glassy crystal.
Lithium-bearing pegmatites:							
Beecher	82	1.591	Euhedral	White	Numerous	Intermediate	Crystal 4 inches in diameter.
Do	83	1.592	Anhedral	White	Numerous	Intermediate	
Bob Ingersoll Dike No. 1	84	1.586	Anhedral	Pale pink		Core	Upper dike, with lepidolite.
Do	85	1.585	Anhedral	White		Core	Upper dike, with lepidolite.
Do	123	1.592	Euhedral	Pale blue	Few	Core	
Do	88	1.583	?	White	Numerous	Wall (?)	From upper pit. ±100-ton mass. Adjacent to lepidolite.
Do	91	1.585	?	White	Numerous	Wall (?)	Upper dike, 3½ feet from schist.
Do	92	1.585	?	White	Numerous	Wall	Same mass as above, 6 inches from schist
Do	93	1.580	?	Pale green	Numerous	Wall (?)	Dump, upper dike.
Bob Ingersoll Dike No. 2	86	1.578	Euhedral	Pale green-white	Numerous	Wall	Lower dike.
Do	87	1.584	Euhedral	Pale blue-white	Numerous	Intermediate	Lower dike. With amblygonite.
Do	89	1.582	"Shell"	White	Numerous	Wall	Lower dike. One foot from schist hanging wall.
Do	90	1.581	?	Pale-green	Numerous	Wall	Lower dike.
Custer Mountain	94	1.575	Euhedral	White	Numerous	?	Dump.
Do	95	1.580	Anhedral	White	Numerous	Intermediate	
Dyke Lode	96	1.575	Euhedral	Colorless	None	?	Reported to be from vug, half-inch crystal fragment.
Do	109	1.580	Euhedral	White		Intermediate	Fracture filling.
Edison	97	1.588	Anhedral	White	Numerous	Wall zone	
Etta	98	1.589	?	White	Few, small	?	
Do	99	1.589	?	White	Few, small	?	
Peerless	100	1.581	?	White		?	
Soda Spar	101	1.579	Euhedral (?)	Pale rose	Numerous	Fracture filling	
Tin Mountain	102	1.585	?	White	?	?	
Tin Queen	103	1.574	Euhedral	White	Few		Perthite-quartz-muscovite pegmatite.
Do	104	1.581	Euhedral	White	Few	?	3-inch crystal.
Do	105	1.571	Euhedral	Light green	Numerous	Wall	North face, old open-cut.
Do	106	1.570	?	White	Numerous	Wall	North face, old open-cut.
Do	110	1.575	Euhedral	Stained	Chlorite	Wall (?)	North wall, old open-cut.
Wood Tin	107	1.584	Anhedral	White	Numerous	Intermediate	
Do	108	1.586	Anhedral	White	Numerous	?	With spodumene.
Tin veins:							
Cowboy	114	1.569	Euhedral	Light green	Elongate inclusions parallel to the c-axis.	Throughout vein	Associated with quartz and muscovite.
Mohawk	120a	1.568	Euhedral	White	Numerous	Throughout vein	Associated with quartz and muscovite.
Do	120b	1.570	Anhedral	White	Numerous	Throughout vein	Associated with quartz and muscovite.

[1] Values of index of refraction for ordinary ray determined by immersion method in white light. Error ±0.003 for true value of index, but differences shown between specimens from same property are correct relatively.

The index of refraction (slow ray, ω) of 30 beryl specimens from the 11 lithium-bearing pegmatites shows an arithmetical average of 1.582 and a range from 1.570 to 1.592. Eleven of these specimens, known to be from wall zones, averaged 1.579; six specimens from intermediate zones averaged 1.585; and three from cores averaged 1.588. The 104 samples of beryl from 45 mica- and feldspar-bearing pegmatites averaged 1.577 and ranged from 1.568 to 1.592.

The difference between the average indices for the two classes of pegmatites is less than the variation found in individual pegmatites because the indices of beryl from all zones are included in the averages. The data available, although incomplete, indicate that in well-zoned pegmatites the index of refraction of beryl found in the various zones may be expected to increase from the wall zone to the core. This variation is well shown by specimens collected from the New York and the Crown pegmatites (table 4). At the New York pegmatite the beryl from the wall zone has indices ranging from 1.575 to 1.583 and in the intermediate zones from 1.585 to 1.590. The highest of these indices (1.590) was that observed in a specimen associated with lepidolite and amblygonite. At the Crown pegmatite a complete suite of beryl specimens from all zones showed indices of 1.574 to 1.580 for the wall zone beryl, 1.585 to 1.589 for the intermediate zone beryl, and 1.591 for beryl from the quartz core. When referred to Winchell's graph these values for the Crown pegmatite indicate that the BeO content of the beryl ranges from about 13.5 percent in the wall zone to about 10.5 percent in the core. This decrease in contained BeO and accompanying increase in index of refraction as the core of the pegmatite is approached appears to be true for many well-zoned pegmatites although the variation may be small. In poorly zoned pegmatites, and in very thick zones such as the wall zone at the Helen Beryl pegmatite, beryl crystals within a single zone may have a great range in index.

One apparently anomalous group of beryl crystals was obtained from the Rainbow No. 4 property. A small sericitized crystal from the inner edge of the wall zone showed an index of refraction of 1.588 and specimens from the core were considerably lower, none exceeding 1.584.

At the Bob Ingersoll mine, white beryl of relatively high index of refraction was found within a few inches of the schist wall in Dike No. 1. This beryl (specimens 88, 91, and 92) constituted part of a 61-ton crystal aggregate extending from the core almost to the schist wall. A specimen of pale-green beryl (93) from the dump of the upper dike probably represents the normal wall-zone material.

Differences of composition within individual crystals are indicated by appreciable differences in the value of the index of refraction as measured in various parts of the same crystal. A zoned beryl crystal less than 2 in. in diameter from the Helen Beryl pegmatite (specimen 56) showed an index of 1.592 for the yellow outer edge and 1.578 for the yellow-green interior. A tapered "shell" crystal with a quartz-albite-tourmaline center from the Florence pegmatite (fig. 5) ranged from 1.584 in the large end to 1.580 in the small end. Both examples indicate an increase in the alkali content in the beryl that crystallized last.

The color of beryl is also affected by the quantity of alkalies, and may be used as a rough guide in estimating the composition. White, very pale blue, blue-green, or pink beryl may be expected to have a high index of refraction and to contain less than 12 percent BeO. Green, yellow-green, golden-yellow, or pale brown beryl generally has a low index of refraction and contains more BeO. Only two specimens of completely colorless beryl were noted: a small crystal fragment from the Dyke Lode, and a crystal from the Helen Beryl property. Both had an index of refraction of 1.575. Unfortunately the zonal position of these crystals is unknown, but one reportedly was found in a vug.

The abundance and nature of inclusions in the beryl have not been studied in sufficient detail to determine the relation, if any, between inclusions and alkali content. The quantity of inclusions may affect the grade of the beryl ore, particularly if the inclusions are minerals. The commonest inclusions observed are minute cavities and "clouds" of very small grains of undetermined minerals. Some cavities of larger size contain fluid. More rarely the cavities are prismatic, forming negative crystals, or are tubes parallel to the c-axis of the crystal. Beryl that is glassy in appearance or approaches gem quality commonly contains very few inclusions.

SIZE AND GRADE

The size of beryl deposits in the Black Hills ranges from those that have produced a few pounds to those that have produced many tons. The length of a deposit depends on the length of the pegmatite, and on the length of the zone in which it occurs. The width of beryl-bearing zones is rarely more than 5 to 6 ft and their extension in depth is varied. Few beryl deposits in South Dakota contain as much as 2 percent of beryl. The larger and richer deposits appear to contain 0.5 to 1 percent of beryl, but many pegmatites contain less than 0.5 percent. Within any one zone, however, the proportion of beryl varies radically and local areas may be rather rich. In Dike No. 1 at the Bob Ingersoll mine a mass of beryl weighing 61 tons extended across nearly the entire thickness of the beryl zone.

In 1943 the Bureau of Mines sampled the dumps of 77 pegmatite mines for beryl (see list below) and also sampled the Helen Beryl and Elkhorn pegmatites. Metals Reserve Company in the same year sampled the Helen Beryl, Old Mike, and Highland Lode (Ross) properties. In addition, beryl was mined at the Bob Ingersoll and Wood Tin properties under contract to Metals Reserve Company.

PRODUCTION

Beryl produced from the Black Hills pegmatite is reported to total 1,535 tons valued at $126,466. The production in 1943 and 1944, by districts, is given on p. 45. The average beryl ore shipped from mica and feldspar mines contains about 12 percent of BeO and that from the lithium mines ranges from 9 to 12 percent.

RESERVES

The beryl reserves of the Black Hills are estimated to be sufficient to maintain for several years the rate of past production under economic conditions comparable to those of 1944. There are no measured or indicated reserves because of the nature of the deposits and the lack of specific figures on the beryl content of beryl-rich zones or pegmatites. In the past beryl has been recovered as a byproduct of mica, feldspar, or lithium mineral mining, as none of the deposits are sufficiently rich to be mined for beryl alone.

Mine dumps sampled for BeO *by the U. S. Bureau of Mines 1943, Black Hills, South Dakota*

Custer District:
- Aman.
- Ballard.
- Beecher Lode.
- Big Time (Big Tine).
- Big Tom No. 1.
- Blue Bird.
- Bull Head.
- Buster Dike.
- Charles Pringle.
- Crown.
- Custer Mountain.
- Custer Peak (Bowden).
- Dakota Feldspar.
- Dorothy V.
- Earl Lode.
- Elkhorn.
- Elk No. 1.
- Forty-five.
- Glen Carroll.
- Greene (Pink Monster).
- Helen Beryl.
- Highland Lode (Ross).
- Highview.
- Knowles.
- La Rue.
- Lucky Strike (Woods).
- Lucky Twist.
- Michaud.
- Minnie V.
- Mountain Queen.
- Myrtle Ann.
- New York.
- Old Mike.
- Payday (Lofton).
- Phenacite.
- Rainbow No. 1.

Custer District—Continued
- Red Bird (Cons. Feld. Co.).
- Red Bird (McClaren).
- Red Spar.
- Rives No. 1.
- Royal Flush.
- Smith.
- Tin Mountain.
- Tip Top.
- Victory.
- Warren Draw.
- White Cloud.
- White Spar.
- Wilhelm.
- Wonder Lode.
- Wright Mica.

Keystone District:
- Big Chief.
- Bob Ingersoll.
- Dan Patch.
- Dike.
- Etta.
- Eureka.
- Ferguson.
- Glendale.
- Hardestey.
- Hugo
- King.
- Peerless.
- Put.
- Queen.
- Sitting Bull (Wallace).
- Soda Spar.
- White Cap.
- Wood Tin.

Mine dumps sampled for BeO *by the U. S. Bureau of Mines 1943, Black Hills, South Dakota*—Continued

Hill City District:
- Campaign.
- Campaign No. 4.
- Cowboy.
- Eureka (Hultz).

Hill City District—Continued
- Gertie.
- Mohawk.
- Monkey Lode.
- Staline.

Beryl deposits are divided into two classes—those from which beryl can be recovered by hand sorting and cobbing, and those from which beryl can be recovered only by milling. The inferred reserves of beryl in each class are estimated to be several thousand tons, but deposits that are known and blocked out probably contain less than 1,000 tons. The largest inferred reserves are in the Keystone district, which in the past has been the most productive district in the United States. The reserves in each of the seven largest deposits—the Bob Ingersoll, Peerless, Wood Tin, Hugo, Dan Patch, Dyke Lode, and White Cap—are believed to be in the order of 50 short tons or more of beryl that contains 10 to 12 percent of BeO. The grade of the deposits, on the basis of mineral counts, is estimated to be from 0.5 to 1.5 percent beryl, of which slightly more than half can be recovered by hand-sorting. In addition to reserves in place in the pegmatites, the waste dumps of the district contain appreciable quantities of beryl that could be recovered partly by hand sorting and partly by milling. The dump sampling by the U. S. Bureau of Mines in 1943 revealed that the 13 richest waste dumps contained a total of about 305,000 tons of beryl-bearing rock. The beryl content was not accurately determined, but visual inspection, past production, and available assays indicate that these waste dumps probably contain 0.5 percent or more beryl. The largest waste dumps are at the Etta, about 81,000 tons; the Peerless, about 30,000 tons; and the Hugo, about 30,000 tons. The dumps at the Bob Ingersoll, Dyke Lode, and Big Chief are smaller but exceed 5,000 tons each. Smaller dumps at the Wood Tin, White Cap, Hardesty Homestead, Sitting Bull (Wallace), Soda Spar, Put, and King contain a total of about 10,000 tons of beryl-rich rock. It is probable that the beryl reserves in unprospected pegmatites of the Keystone district are at least as large as the reserves in developed deposits.

In the Custer district inferred reserves at eight mines are believed to be on the order of 50 to 100 tons each of beryl that could be recovered by hand sorting. These mines are the Beecher Lode, Highland Lode, Tin Mountain, High Climb, Old Mike, Greene, Elkhorn, and Dakota Feldspar. The beryl content of these deposits is similar to that of deposits in the Keystone district. In 1943 the U. S. Bureau of Mines sampled waste dumps at 51 mines in the district (see list, at left). Eleven of them contained a total of about 165,000 tons of rock with a beryl content similar to that in beryl-rich dumps in the Keystone district. One dump in this group, at the New York, contained about 22,000 tons of rock, and six others—Tin Mountain, Earl Lode, Old Mike, Beecher Lode, Crown, and High Climb—each contained from 2,000 to 6,000 tons. The Custer Mountain, Rainbow No. 4, Warren Draw, and Wright Mica properties have dumps totaling about 1,300 tons.

The largest potential reserve of beryl in the Custer district is in the Helen Beryl pegmatite. It is estimated from mineral counts and available assays that the deposit contains 0.5 to 1 percent beryl. At least 100,000 tons of beryl-rich rock is available. The beryl in this deposit can be recovered only by milling.

Additional prospecting and exploration undoubtedly will increase the known beryl reserves in the Custer district just as it will in the Keystone area, and perhaps double the known reserves.

The beryl reserves of the Hill City district are believed to be small, but careful prospecting might disclose minable deposits.

PROSPECTING FOR BERYL

Prospecting for beryl in the Black Hills undoubtedly would be rewarded by the location of new deposits, although they probably could not be worked for beryl alone, unless economic conditions became more favorable than they were in 1943–44.

Beryl is a difficult mineral to recognize in the field unless it is in fairly large euhedral crystals of a distinctive color. Many deposits in the Black Hills contain anhedral and irregular pieces of yellowish, white, pale pink, or pale blue beryl that is identified erroneously as quartz, feldspar, or amblygonite, even by miners who have mined beryl for years. Consequently, a knowledge of the physical character and the normal structural and mineralogical environments of beryl is essential for intelligent prospecting. Uniform distribution of beryl within a pegmatite or a zone is rare, and commonly the larger crystals are separated by larger barren areas than are the smaller crystals. In some zones beryl is concentrated in shoots that parallel the structure of the pegmatite. The irregular distribution and the small proportion (generally less than 2 percent) of beryl in the rock make it difficult to appraise a new deposit except by comparison with other mines. Past experience in the Black Hills indicates that highly productive beryl deposits occur in pegmatites that contain appreciable quantities of albite and muscovite. The best deposits of coarse-grained beryl are in the coarse-grained zones of zoned pegmatites. Therefore, if beryl is found in a well-zoned, coarse-grained pegmatite rich in albite or muscovite, exploration of the deposit is probably justified. Exploration for coarse-grained beryl should be confined to the zones or parts of pegmatite similar to those that have been productive at other mines, namely, (1) the inner part of scrap-mica zones, (2) the outer part of perthite and perthite-quartz cores, (3) the amblygonite-bearing zones at the outer part of lepidolite-cleavelandite or spodumene-quartz zones, and (4) the outer part of quartz cores. The most productive deposits have well-defined wall zones that are rich in albite. Pegmatites with perthite-rich wall zones are commonly less productive. Green and yellowish-green, subhedral to euhedral beryl is generally associated with zones rich in blocky plagioclase and perthite. White, pale pink, or blue euhedral beryl occurs in zones rich in lithia minerals.

Fine-grained beryl generally is most abundant in homogeneous pegmatites or zones that are rich in plagioclase and muscovite. In some muscovite zones, particularly those that contain sheet mica, the beryl is usually in "shells", although euhedral and tapered crystals are more common in some deposits. Corroded crystals are characteristic of zones rich in scrap mica and cleavelandite. Scattered crystals may occur in pegmatite cores, as at the Tip Top and White Spar where the quartz-albite rock interstitial to large perthite crystals contains beryl. In addition, beryl may occur in quartz cores, as at the Crown pegmatite. Fracture-filling units connected with any of these zones may also contain beryl.

The replacement deposits of bull mica, as for example, those in the Beecher Lode, may contain appreciable quantities of beryl either in grains or as interstitial fillings around the muscovite. It is generally white, yellow, or golden.

Pegmatites that in texture resemble the normal Harney Peak granite but contain a larger proportion of plagioclase, merit prospecting as possible sources of beryl. They contain disseminated, fine-grained beryl that has escaped notice in the past. Because of their large size these deposits may be mined if milling of pegmatite minerals becomes economically feasible.

LITHIUM DEPOSITS

DISTRIBUTION

Lithium-bearing pegmatites occur in all of the Black Hills pegmatite districts. Most of the known spodumene-, amblygonite-, and lepidolite-bearing pegmatites are listed below. The locations are shown on plate 1. Most of the other economically valuable pegmatites contain various quantities of lithiophilite-triphylite minerals.

TYPES OF LITHIUM DEPOSITS

Lithium pegmatites are divisible into three types on the basis of the chief lithium mineral present (spodumene, amblygonite, or lepidolite), but from an

Lithium-bearing pegmatites of the Black Hills

Custer District	Keystone District	Hill City District	Tinton District
Spodumene-bearing pegmatites			
Beecher Lode. Beecher No. 2. Custer Mountain. Dike No. 2. Dike No. 9. Helen Beryl. L5 No. 3. Longview. New Age. New York. Rose Quartz. Tin Mountain.	Bob Ingersoll Dike No. 2. Bull Con. Dyke Lode. Edison (Bull Con). Etta. Glendale. Hardestey. Hugo. King. Nickel. Queen. Soda Spar. Wood Tin.	Dewey. High Climb. Hunter and Louise. Ida. Mateen. Western Feldspar.	Giant-Volney. Unnamed pegmatite, east of the Tinton school house.
Amblygonite-bearing pegmatites			
Beecher Lode. Big Tom No. 1. Climax. Custer Mountain. Eruption. Rare Minerals. New York. Rose Quartz. Tin Mountain. Tip Top. Volcano.	Bob Ingersoll Dikes No. 1 and No. 2. Dyke Lode. Hardestey. Hugo. Peerless. Soda Spar.	Dewey. High Climb. Oreville Spar. Mateen. Tin Queen.	Giant-Volney.
Lepidolite-bearing pegmatites			
Beecher Lode. Custer Mountain. New York. Tin Mountain.	Bob Ingersoll Dike No. 1.		

economic viewpoint the following mineralogical and structural classification seems to be more desirable:

1. Intermediate-zone deposits.
   a. Quartz-spodumene, perthite-spodumene, or quartz-albite-spodumene pegmatite intermediate zone below or surrounded by a perthite-quartz pegmatite.
   b. Amblygonite-perthite-quartz pegmatite intermediate zone at the inner edge of perthite-quartz pegmatite.
   c. Amblygonite-spodumene-perthite-quartz pegmatite intermediate zone at the inner edge of a perthite-quartz pegmatite.
2. Core deposits.
   a. Spodumene-quartz pegmatite core inside zones of subtype 1a, 1b, or 1c.
   b. Lepidolite-cleavelandite pegmatite core inside of cleavelandite-quartz or cleavelandite-quartz-muscovite pegmatite.
3. Fracture-filling deposits.
4. Replacement deposits.

STRUCTURE

Most lithium deposits of the Black Hills occur in the intermediate zone or core, some surrounded by considerable thicknesses of wall- and intermediate-zone material, and others by only a few inches of unproductive rock. All exposures indicate that these deposits are completely enclosed by outer zones and pinch out before the pegmatite itself pinches out. If the pegmatite contains perthite, as at the Bob Ingersoll and Beecher Lode pegmatites, the deposits appear to terminate upward against a "hood" or incomplete zone of perthite-quartz pegmatite that is thicker above than on the sides of the lithium deposits. Lithium deposits also always occupy the thicker part of the pegmatite body and tend to be near the crest of, and slightly off center in, the pegmatite. The size, shape, and location can be predicted, in part, on the basis of structure of the wallrock contacts and of the wall zones.

Many lithium-bearing pegmatites are complex in shape and internal structure. This complexity is generally the result of coalescence of a number of bodies. (See maps of Edison, Mateen, and Tinton pegmatites, pls. 14, 15, 26, 27, 40.) Where such coalescence has occurred, the barren outer zones may extend into the center of the lithium-bearing body.

The fracture-filling type of lithium deposits is not common in the Black Hills and few are of commercial importance. They are essentially tabular deposits that have the attitude of the fractures along which they were formed. The Soda Spar pegmatite in the Keystone district contains small lithia-bearing fracture-filling units that have a zonal structure.

The spodumene-quartz unit of the Giant-Volney pegmatite of the Tinton district is a replacement deposit in which spodumene-quartz pegmatite includes relict albite, quartz, cassiterite, and muscovite of the original zones. The gneissoid structure of these earlier zones has been preserved and can be used to predict the attitude and extensions of the later-formed spodumene deposit.

MINERALOGY

The economically important lithium minerals—spodumene ($LiAl(SiO_3)_2$), amblygonite ($Li(Al, F)PO_4$), and lepidolite ($KLiAl(OH, F)_2Al(SiO_3)_3$)—are formed late in the paragenetic sequence of pegmatite minerals and occur in the inner parts of pegmatite bodies, completely surrounded by barren zones. Lithiophilite-triphylite ($LiMnPO_4$–$LiFePO_4$) and its alteration products is the only other common lithium-rich mineral in the South Dakota pegmatites. Small quantities of lithium may be present in tourmaline, beryl, muscovite, and other minerals associated with spodumene, amblygonite, and lepidolite.

SPODUMENE

Spodumene, the principal lithium ore mineral in the Black Hills, theoretically contains 8.4 percent of Li_2O, but commonly sodium is substituted for part of the lithium in the spodumene molecule. For this reason the fresh spodumene rarely contains more than 7.5 percent of Li_2O. In addition, spodumene may have been altered after crystallization by potash-rich solutions that leached out the lithia (Schwartz and Leonard, 1926, pp. 257–264). Hand-sorted fresh spodumene rarely contains more than 6.5 percent of Li_2O, and completely altered spodumene may contain only a fraction of a percent of Li_2O. Spodumene occurs as grains or crystals in perthite, albite (cleavelandite), and quartz. The spodumene crystals range from grains of microscopic size, as in the Giant-Volney deposits, to lath-like crystals as much as 47 ft in length, as at the Etta (Hess, 1910, pp. 649–653, Ziegler, 1914, p. 654, and Schaller, 1916, p. 138). Spodumene crystals in the Dyke Lode, Beecher Lode, Tin Mountain, Custer Mountain, Edison, Etta, Hugo, and Bob Ingersoll Dike No. 2 pegmatites are 1 to 10 ft in length, but larger crystals are common only at the Etta and Beecher Lode pegmatites. Few crystals in the Hunter-Louise and Beecher Lode No. 2-Longview deposits are more than 1 ft in length. The spodumene of the Mateen pegmatite is in crystals of very uniform size, and average 6 in. in length, 1 in. in width, and a fraction of an inch in thickness. At the Giant-Volney pegmatite, in the Tinton district, most of the spodumene is in grains less than 1/16 in. in diameter, but a small part of the deposit contains grains 1/4 in. or more across. Only one large crystal, 15 in. long, was found. Fresh, hard spodumene crystals are commonly white or gray in color, but some colorless spodumene is found at the Dyke Lode, green spodumene (hiddenite) at the Etta, and pink spodumene (kunzite) at the Beecher Lode. Altered, soft spodumene crystals are black, dark- to light-green, gray, white, or red-brown. Spodumene crystals are not altered uniformly, and the green, white, or red alteration product may occur as thin seams along cleavages, fractures, and crystal boundaries. Spodumene is associated with perthite, quartz, beryl, albite (cleavelandite), amblygonite, lepidolite, microcline, and numerous accessory minerals such as muscovite, tourmaline, tantalite-columbite, and cassiterite. Spodumene apparently crystallized as euhedral crystals but smooth crystal faces are not common. Many large crystals at the Etta mine are elliptical in cross-section and the surfaces appear to have been corroded. At the Etta and Hugo mines many crystals are rimmed by fine muscovite, with or without tourmaline, which in turn are encased in cleavelandite crystals oriented at right angles to the spodumene. Some cleavelandite crystals are as much as 6 in. long. The muscovite and cleavelandite rims obviously owe their position to the spodumene crystals and appear to have been formed by a reaction between spodumene and a liquid. Some cleavelandite is not so obviously related to spodumene and occurs with quartz or muscovite as interstitial fillings between spodumene crystals. At the Etta mine such cleavelandite, quartz, and muscovite aggregates commonly contain accessory beryl, tantalite-columbite, and cassiterite. Perthite, amblygonite, quartz, and beryl occur between spodumene crystals at the Bob Ingersoll Dike No. 2, Dyke Lode, Beecher Lode, and other deposits. Where perthite is the dominant interstitial mineral the spodumene is commonly soft, altered, and easily weathered. There is less alteration where albite, quartz, beryl, and amblygonite surround the spodumene crystals.

Most of the spodumene mines in the Black Hills contain altered or "rotten" spodumene in which the lithia content is low. The alteration of spodumene has been attributed both to surface leaching and to hydrothermal action, but recent exploration seems to indicate that most of it is the result of reaction with, or leaching by, solutions unrelated to surface water. During alteration the spodumene is pseudomorphously replaced by very fine-grained, white, green, or brownish micaceous minerals, probably of the muscovite, clay, and lepidolite groups.

Information at hand does not warrant prediction of the location and extent of altered spodumene in pegmatites. It has been found (1) along late fractures that appear to have been channelways for sulfide solutions; (2) in the narrower, lower parts of spodumene zones and pegmatites; (3) in rock rich in albite, perthite, or microline; (4) at the ends of spodumene crystals that extend into quartz cores; and (5) in spodumene crystals in the perthite-quartz pegmatite zones. In the Mateen, Old Mike, and Hardestey pegmatites pseudomorphs of spodumene found in intermediate and wall zones contain little if any lithia. Spodumene in the upper parts of pegmatites apparently has little chance of being intensely altered. The field relations suggest that alteration is primarily the result of reaction between spodumene crystals and interstitial liquids, and secondarily of leaching by later sulfide-bearing solutions.

AMBLYGONITE

Amblygonite, the second most abundant lithium mineral, contains the theoretical maximum of 10.1 percent of Li_2O. Partial analyses of Black Hills amblygonite show a range in lithia content of 9.87 to 3.87 percent. Shipments of amblygonite have rarely contained more than 9 percent Li_2O.

The amblygonite is commonly white or gray; colorless amblygonite occurs in the Dyke Lode, and lemon-yellow to greenish-yellow amblygonite has been found at the Glenwood and High Climb mines. Most of the amblygonite occurs in rounded or ellipsoidal bodies that range from less than 1 in. to more than 10 ft in maximum dimension. These bodies are coated with a thin layer of sericite and muscovite, as in the Giant-Volney pegmatite—or with a dull chalky or buff-colored mineral, as in the Tin Queen, High Climb, and Bob Ingersoll pegmatites. The coatings and a greater specific gravity of amblygonite allow it to be readily distinguished from potash feldspar. Crystal faces are rarely observed in amblygonite, although some of the ellipsoidal masses appear to have been formed by the corrosion of euhedral crystals. Part of the amblygonite in deposits of type 1 (c) occurs as anhedral masses that are interstitial to spodumene crystals.

Beryl, albite (cleavelandite), perthite, quartz, and spodumene are the most common minerals associated with amblygonite. Small masses of cassiterite, tantalite, muscovite, and tourmaline may occur in the same zones. Except for a few crystals of amblygonite in the wall zone of some pegmatites in the Tinton district, the mineral occurs only between perthite-quartz and spodumene-quartz, or lepidolite-bearing zones. All of these minerals are very coarse and easily hand-sorted. Consequently, the number of byproducts is greater from amblygonite mining than from any other pegmatite operation.

LEPIDOLITE

Lepidolite is a potash- and lithium-bearing mica of varied composition that has extensive use in the glass industry. Commonly the name lepidolite is applied to any lithium-bearing mica, including zinnwaldite, the iron-bearing variety. Shipments of lepidolite have contained from less than 3 percent to more than 4.5 percent of Li_2O. The mineral is lilac, pink, or violet-gray, and occurs either in massive aggregates of crystals less than ½ in. across or as individual scattered flakes.

Dark-gray, green, or yellowish lithium-bearing mica is also included in the lepidolite group by the miners. These minerals commonly contain less than 3 percent of Li_2O.

Lepidolite generally is associated with albite, of the cleavelandite variety, and quartz. In some pegmatites, such as the Custer Mountain, it is interstitial to spodumene and amblygonite. Pink, green, and blue tourmaline; white, pink, or blue beryl; and microlite are commonly associated with lepidolite at the Bob Ingersoll Dike No. 1.

The lithium minerals in zoned pegmatites occur in a definite sequence from the pegmatite walls to the core. Lithiophilite-triphylite and associated iron and manganese phosphates commonly occur with muscovite and perthite in zones outside of those that contain amblygonite. Amblygonite occurs in an intermediate zone either alone or with spodumene, but outside of the main lepidolite or spodumene-bearing zone. Lepidolite occurs either interstitial to crystals of spodumene or is surrounded by a spodumene-bearing zone.

The positions of lithium minerals in the zonal sequence suggest that the available lithia combines first with iron, manganese, and phosphate until they are no longer available. If there is an excess of phosphate and lithia, amblygonite forms; if only lithia is in excess, spodumene crystallizes. The formation of lepidolite apparently depends on the availability of potash, water, and fluorine. If they are available in sufficient quantities lepidolite will form without spodumene.

SIZE AND GRADE

Lithium-bearing pegmatites in the Black Hills generally are large pegmatite bodies. Spodumene and lepidolite pegmatites—the Mateen, Beecher, Beecher No. 2, Etta, Edison, and Bob Ingersoll Dike No. 1—shown in figure 1 represent the variation in size and shape of the lithium-bearing pegmatites. Most lithium pegmatites are irregular bodies; irregularity of form appears to be characteristic. Few deposits contain more than 200,000 tons of lithium-bearing rock.

In discussion of grade of lithium deposits it should be remembered that the Li_2O content of lepidolite, spodumene, and amblygonite varies widely even within the same deposit. Consequently, it is necessary to refer to the percent of each mineral, disregarding its Li_2O content, or to give the Li_2O content of both the rock and the average mineral. Because of variations in composition and distribution of these minerals the net result is only an approximate grade. The best grade-figures are usually obtained from mining operations, not from sampling. Two spodumene properties, the Edison and Mateen, were sampled on the surface and by diamond drilling during exploration by the U. S. Bureau of Mines in 1943 to 1945. At this time (1945) it appears doubtful that assays of diamond-drill cores will give the true value of a spodumene property, and large samples are probably necessary for fair results.

Areas containing lithium-bearing minerals can be shown on maps, but predictions of grade are hazardous.

The Bob Ingersoll mine has been the major source of lepidolite in the Black Hills. Its production has come from a vertical, cone-shaped deposit about 125 ft long and about 25 ft in average diameter.

The size of amblygonite deposits has not been studied in detail during recent field work.

Spodumene-bearing pegmatites of the Black Hills rarely average more than 20 percent of recoverable spodumene except in small areas. The richest deposit, the Etta, has, over a period of years, averaged about 10 percent of recoverable spodumene. The shipped product averaged about 6 percent of Li_2O. The Giant-Volney pegmatite at Tinton contains about 25 percent of spodumene, and concentrates recovered by milling contained about 5.5 percent of Li_2O.

PRODUCTION

Production of lithium minerals from Black Hills pegmatite districts is given in table 1. The tonnages of these minerals produced at any one time are entirely dependent on demand. Operators of many of the lithium pegmatites mine selectively, so that when the demand for these minerals is poor they mine mica, feldspar, or beryl, depending on market conditions. Any lithium minerals produced at these times are stock-piled until an acceptable price can be obtained.

RESERVES

It appears impossible to block out measured reserves of lithium minerals accurately in advance of mining. Diamond drilling can indicate the size of spodumene-bearing pegmatite, but sampling may not give an accurate measure of the grade.

Reserves of spodumene appear to be at least as large as the total past production. As most of the coarse spodumene that can be hand cobbed has been mined, milling will be necessary to recover much of the remaining material. The chances of finding new bodies of milling grade appear favorable. There are more than 25 known spodumene-bearing pegmatites in the Black Hills, but only three or four have been developed sufficiently to allow evaluation of their possibilities.

The lepidolite deposit at the Bob Ingersoll mine is nearly exhausted. Only three other pegmatites—the Tin Mountain, Custer Mountain, and Beecher Lode—appear to be possible sources of lepidolite. New lepidolite pegmatites may be found by exploration, but no predictions of reserves can be made.

Amblygonite pegmatites are numerous and if there were an active market for amblygonite many poorly developed prospects might yield considerable quantities of this mineral. Most mines that produced amblygonite in the past could probably increase their yield. Reserves are relatively large.

PROSPECTING FOR SPODUMENE, AMBLYGONITE, AND LEPIDOLITE

The recognition of pegmatites that may contain spodumene, amblygonite, and lepidolite deposits is difficult because these deposits occur only in the innermost zones and may be capped by a considerable thickness of barren pegmatite. In Black Hills pegmatites, the minerals that may be favorable indications of spodumene, amblygonite, or lepidolite are: (1) pink, green, or blue tourmaline; (2) white, pink, or blue beryl; (3) cleavelandite, or saccharoidal albite; (4) cassiterite, microlite, and tantalite; (5) a distinctly yellow muscovite; (6) yellow muscovite pseudomorphs of tabular crystals (spodumene) in plagioclase-rich wall zones; (7) quartz with a dull, greasy, and cherty appearance; (8) abundant lithiophilite-triphylite; and (9) blue apatite. Pink tourmaline, blue beryl, and microlite have been observed only in association with lepidolite. Sugary albite and yellow muscovite pseudomorphs of tabular crystals in wall zones are good indications that spodumene occurs in the pegmatite.

Pegmatites that contain these mineral indicators and also contain exposed spodumene, amblygonite, and lepidolite, should be evaluated on the basis of the normal zonal sequence (table 3) and the probable thickness of any outer zones present, in relation to the size of the body. For example, a pegmatite 20 ft thick probably would not contain a minable zone of lithium minerals if the wall zone consisted of plagioclase, quartz, and muscovite, because probably it would also have intermediate zones of plagioclase and quartz; quartz, perthite, and plagioclase; and perthite and quartz. The total thickness of these four zones is normally greater than the thickness of the pegmatite in question. If the same pegmatite had a wall zone of quartz and cleavelandite, a lithium-bearing zone about 10 ft thick would be possible. The more valuable lithium deposits tend to occur in large zoned pegmatites and in the widest parts of the body.

Pegmatites that contain visible spodumene, amblygonite, or lepidolite are more easily evaluated than those which show only indications of the presence of these minerals. The thickness of the non-lithium-bearing zones can be measured and the possible size of the lithium-bearing body can be determined from the size and structural features of the pegmatite. The probable grade of the spodumene, amblygonite, or lepidolite zone and the lithia content of the minerals can also be determined.

The prospector should keep in mind that the lower and narrower parts of a spodumene-bearing pegmatite commonly contain a larger proportion of altered or "rotten" spodumene. Coarse grained spodumene may be expected to occur in the inner part of the spodumene-bearing zones, particularly where it is in a matrix of quartz.

The size of spodumene and amblygonite crystals has a direct relationship to the size of the body and the perfection of the zonal structure. The larger the deposit and the more perfect the zoning, the larger will be the crystals of these two minerals.

Fracture-filling bodies of lithium minerals are rarely big enough to mine, but their presence may indicate lithium-rich zones in the interior of the body. Replacement bodies of lithium minerals may be large, but unless the structure controlling the shape of the deposit is known, it is impossible to predict its extensions.

The Black Hills area appears to be favorable for finding additional deposits of lithium minerals. The Keystone district is perhaps the most favorable part of the area, but less well-known parts of the Custer, Hill City and Tinton districts offer definite possibilities of new deposits. Many of the deposits previously worked for feldspar have produced small quantities of lithia minerals and should be explored in depth.

TANTALUM DEPOSITS

No pegmatites in the Black Hills were mined for tantalum minerals alone from 1942 to 1945; however, 125,278 lb, valued at $62,717, has been produced. In 1928–29 the Fansteel Metallurgical Co. worked the Giant-Volney pegmatite at Tinton for columbite-tantalite. The company is reported to have recovered 4 lb of this mineral per ton of rock removed.

The tantalum minerals recovered from Black Hills pegmatites are columbite ($FeMnCb_2O_6$)-tantalite ($FeMnTa_2O_6$), tapiolite ($Fe(Ta, Cb)_2O_6$), and microlite ($Ca_2Ta_2O_7$). Columbite and tantalite are isomorphous and natural columbite-tantalite consequently shows a wide range in composition from almost pure columbite to nearly pure tantalite. Tapiolite has been recognized only at the Old Mike mine in the Custer district, and microlite has been recognized at the Bob Ingersoll mine in the Keystone district and at the Tin Mountain mine in the Custer district (Hess, 1933, p. 535). The mines in which tantalum minerals have been recognized are listed below. Assaying for Ta_2O_5 is expensive, but the specific gravity of these minerals has been used to determine their tantalum content. Colonial Mica Corporation purchased columbite-tantalite ores in Custer, basing its price on the tantalum content as indicated by the relationship of specific gravity to tantalum content is as follows:

Tantalum-bearing pegmatites of the Black Hills

Custer District:
- Beecher Lode.
- Climax.
- Crown.
- Custer Mountain.
- Dakota Feldspar.
- Highland Lode (Ross).
- New York.
- Old Mike.
- Tin Mountain.
- Wilhelm.

Keystone District:
- Bob Ingersoll.
- Dyke Lode.

Keystone District—Continued
- Dan Patch.
- Edison (Bull Con).
- Etta.
- Hardestey.
- Hugo.
- Peerless.

Hill City District:
- High Climb.
- Tin Queen.

Tinton District:
- Giant-Volney.

Specific gravity	*Percent* Ta_2O_5	*Specific gravity*	*Percent* Ta_2O_5
6.0	30	6.7	55
6.1	35	6.8	60
6.3	40	7.0	65
6.4	45	7.2	70
6.5	50		

Specific gravity determinations of columbite-tantalite minerals suggest that the tantalum content increases from the walls toward the cores, but more information is needed. In the wall zones and in intermediate zones containing only perthite, quartz, and muscovite, columbite is the common tantalum-bearing mineral, and it rarely contains more than 30 percent of Ta_2O_5. In wall or intermediate zones rich in cleavelandite, quartz, and beryl, tantalic oxide in the columbite-tantalite rarely exceeds 50 percent. In spodumene and amblygonite intermediate zones or cores, columbite-tantalite may be expected to yield at least 40 percent of Ta_2O_5. Quartz cores inside of intermediate zones of cleavelandite contain tantalite high in tantalic oxide that may be associated with tapiolite, as at the Old Mike mine. Microlite apparently is found only in association with lepidolite, as at the Bob Ingersoll and Tin Mountain mines.

This wide variation in composition of ore from different parts of a deposit results in confusion in selling ore by specific gravity. Where the ore is in coarse pieces, a number must be tested, and wide variation is usually noted. This is not as marked in concentrates from milling, although the Ta_2O_5 content depends on which pegmatite zone has been mined.

Except in the Tinton district, the production of tantalum minerals has been incidental to other mining, and production increases only as pegmatite mining increases.

TIN DEPOSITS

The tin mineral cassiterite occurs in a few pegmatites in each district of the Black Hills. In some properties tin can be recovered as a byproduct of other mining, but none of them has the combination of high grade and large quantity of ore necessary for commercial operation. The occurrences and deposits of cassiterite are listed below, and data of past production are given in the table below. The tin deposits are divided into two types, pegmatites and "veins". The vein type is so closely related in geographic distribution, mineralogy, and (presumably) origin to the pegmatites that deposits of this type have been included in this report.

The pegmatite tin deposits are further divided on the basis of structure into (1) wall-zone type, (2) intermediate-zone type, (3) core type, and (4) replacement type.

In the wall-zone type of tin deposit cassiterite occurs with quartz, calcic-albite or oligoclase, and muscovite, with more or less microcline, tourmaline, apatite, and beryl. Except locally, these deposits all contain less than 10 lb of tin per ton of rock and its distribution is erratic. The wall-zone type of deposit may be in a quartz-

Tin-bearing pegmatite deposits of the Black Hills

Custer District:
- Beecher.
- O. K. Lode.
- New York.
- Tenderfoot.
- Tin Mountain.

Keystone District:
- Bob Ingersoll.
- Etta.
- Hugo.
- Peerless.

Hill City District:
- Addie.
- High Climb.
- Hunter-Louise.
- General Harney.
- Gerty.
- Tin Queen.
- Mateen.

Tinton District:
- Giant-Volney.
- Rough and Ready.
- Unnamed pegmatites (see Smith and Page, 1941).

Veins

Hill City District:
- Campaign.
- Campaign No. 4.
- Cassiterite.
- Cowboy.
- Good Hope (Salinas Group).
- Last Chance.
- Mohawk.
- Tin Spike.
- Tin Chance.
- Tin Chance No. 1.

Tin produced from the Black Hills [1]

Year	Source	Short tons	Character	Percent tin	Pounds tin	Value [2]
1884	Bear Creek and Sand Creek [3]	5–6	Stream tin	[4] *50. 0*	*5, 500*	*$1, 210*
1884	Etta Mine	Several cwt	Metallic			
1886	Etta Mine	400. 0	Ore	. 5	14, 000	*3, 059*
1886	Bear Creek	6. 5	Ore	4. 6	598	*129*
1887	Am. and Clev. Tin Mining Company	3. 0 Several cwt	Stream tin Ore	*50. 0*	*3, 000*	*887*
1887	H. W. Fowler		Metallic		250	*74*
1887	Tin Mt. Mine		Concentrate			
1888	Harney Peak Tin Min., Milling & Mfg. Co	50. 0	Ore	*2. 5*	*2, 500*	500
1892	Harney Peak Tin Min., Milling & Mfg. Co	150. 0	Concentrate	*60. 0*	*180, 000*	*37, 800*
1893	Harney Peak Tin Min., Milling & Mfg. Co	Small amount	Concentrate			
1901	Oreville	. 6	Concentrate	*60. 0*	*817*	*212*
1903	Tinton Tin Mining Co	40. 0	Concentrate	62. 5	*50, 000*	*14, 000*
1904	Tinton Tin Mining Co	Small amount	Concentrate			
1906	Gertie Tin Mine	1. 8	Concentrate	66. 5	2, 500	*1, 050*
1907	Gertie Tin Mine	Several cwt	Metal			
1907	Frank Hebert, Oreville		Concentrate			
1907	Bear Gulch and Gold Hill Mining Company		Concentrate			
1907	Wes. Chem. Red. Company		Concentrate			
1909	Tinton Red. Co	24. 0	Concentrate	*34. 0*	*16, 714*	*4, 832*
1910	Tinton Red. Co	38. 0	Concentrate	50. 0	38, 000	12, 600
1911	Bear Creek, Tinton	Small amount	Stream tin			
1913	J. L. White, Tinton	1. 0	Stream tin	*75. 0*	*1, 500*	660
1914	Bear Creek, Tinton	Few cwt	Stream tin			
1915	Hill City Tungsten Producers Company	43. 0	Ore	1. 5–2	*1, 505*	*602*
1915	J. L. White	. 25	Stream tin	60. 0	*300*	*120*
1916	Hill City Tungsten Producers Company	?				
1916	J. L. White	. 2	Stream tin	*60. 0*	*240*	[5] 108
1917	Am. Tin & Tungsten Company	22. 0	Concentrate	26–65	*22, 000*	8, 200
1917	J. L. White	. 1	Stream tin	*60. 0*	*196*	75
1918	Tin Boom Mine	. 2	Concentrate	60. 0	*240*	200
1920	Nat. Tin Corp	12. 0	Concentrate	50. 0	12, 000	6, 000
1927	Black Hills Tin Co., Tinton	1. 0	Concentrate	65. 0	325	200
1928	Tinton and Harney Peak areas		Stream tin		4, 000	2, 000
1929	Tinton and Harney Peak areas		Stream tin		500	200
1930	Tinton and Harney Peak areas	. 5	Concentrate	31. 5	315	100
1931	Tinton and Harney Peak areas		Stream tin		189	50
1932	Tinton and Harney Peak areas		Stream tin		1, 000	220
1933	Tinton and Harney Peak areas		Stream tin		225	88
1934	Tinton area		Stream tin		448	234
1935	A. J. Johnston, Tinton		Stream tin	65–72	1, 300	260
1936	A. J. Johnston, Tinton		Stream tin	65	300	60

[1] Cummings, J. B., Basham, Lester, and Lincoln F. C., 1936.
[2] Based on market prices of metallic tin for year.
[3] Bear Creek is in the Tinton district, and Sand Creek is just across the State line in Wyoming.
[4] Italic figures are estimates.
[5] The recorded production of tin concentrates, worth $14,000, proved to be tantalum concentrates.

muscovite or in a plagioclase-quartz pegmatite. At the Mateen pegmatite the greatest concentration of cassiterite is in quartz-muscovite pegmatite of the border and wall zones, and at the Hunter-Louise it is in plagioclase-quartz pegmatite wall zone. The Rough and Ready and Giant-Volney pegmatites of the Tinton district have wide tin-bearing zones of the wall-zone type (Smith and Page, 1941). The wall-zone type of tin deposit seems to offer the best possibilities of appreciable tin concentration, as the other types are characterized by sporadic masses rather than uniform dissemination. Like other mineral deposits of the wall type, the narrower parts of the pegmatites are homogeneous in mineral composition.

At the Bob Ingersoll, Dyke Lode, and other complexly zoned pegmatites cassiterite occurs in the intermediate zones or cores as isolated masses or "nuggets" some of which weigh several pounds. It is commonly associated with tantalum minerals and cleavelandite. At the Peerless mine abundant cassiterite occurs with cleavelandite in an intermediate zone. At the New York mine there is a similar occurrence in cleavelandite at the edge of the quartz-pegmatite core and also in cleavelandite at the edges of quartz along fracture-filling bodies that cut all earlier zones. Cleavelandite has partly replaced other minerals at the edges of these bodies. Thin irregular veinlets of cleavelandite with cassiterite cut the spodumene zone of the Etta and other pegmatites in such a way as to suggest that they have replaced part of the pegmatite.

The vein type of cassiterite deposit has been described under beryl pegmatites. Such small veins as the Mohawk, Cowboy, Tin Spike, Cassiterite, Campaign, and Last Chance may have small shoots of relatively rich ore, containing perhaps 2 or 3 percent of tin, but the small size of the bodies precludes profitable mining.

The Mohawk, Cowboy, Cassiterite, Tin Chance, and similar deposits at Hill City contain black, deep-brown to ruby, or gray cassiterite in crystals as much as 1 in. wide embedded in flaky muscovite and beryl. Some cassiterite occurs in quartz gangue, but variations in the richness of veins appears to be related directly to variations in the abundance of mica and beryl.

FELDSPAR DEPOSITS

Since 1923 about half a million tons of crude feldspar, valued at more than $2,053,969, have been produced from the feldspar deposits of the Black Hills. Feldspar has come from the Keystone, Hill City, and Custer districts and reserves are available also in the Tinton district.

During 1942–45 the U. S. Geological Survey made detailed studies only of the feldspar-bearing pegmatites that produced appreciable quantites of mica, spodumene, or beryl. None of the large feldspar properties has been mapped in detail, and information as to internal structure of these pegmatites is incomplete. Preliminary observation not supported by detailed mapping indicates that these deposits fit into the structural pattern given for other South Dakota pegmatite deposits.

DESCRIPTIONS OF MINES AND PROSPECTS

ADDIE TIN MINE (HILL CITY DISTRICT)

The Addie tin mine is in sec. 28, T. 1 S., R. 5 E., about 3 miles east of Hill City, Pennington County, South Dakota. Gardner described the property in 1939 (pp. 29–30).

When L. R. Page visited the mine in July 1942 the extensive underground workings were inaccessible. The Barium Stainless Steel Company is reported to have rehabilitated the property in 1944.

In July 1942 pegmatite was exposed only at the collar of a caved, inclined shaft, 800 ft deep, and at the raise to surface 170 ft to the southwest. The pegmatite at the raise is 7 to 8 ft wide, strikes N. 40° E., and dips 60°–70° NW. At the shaft collar the pegmatite is 15 ft wide.

The tin deposit is of the wall-zone type. Muscovite-quartz, pegmatite, containing cassiterite, is 1 ft thick on the footwall and as much as 5 ft thick on the hanging wall. The core is composed of plagioclase and quartz grains less than 1 in. in diameter with scattered crystals of potash feldspar as much as 2 in. in diameter.

AJAX CLAIM (CUSTER DISTRICT)

The Ajax Claim, in the NE ¼ sec. 22, T. 5 S., R. 5 E., was located October 18, 1943, by Frank L. Young of Hot Springs, South Dakota. It includes a granitic pegmatite, about 30 ft wide that strikes N. 50° E., along the east side of Beaver Creek. No mica of sheet quality was observed by L. R. Page (May 1944) in the small open-cuts that prospect the pegmatite. Less than 10 lb of sheet mica, reported to have come from this claim, was sold in 1943 to the Colonial Mica Corporation.

ALADIN MICA MINE (CUSTER DISTRICT)

by J. W. Adams

The Aladin mica mine is in the SE¼ sec. 26, T. 3 S., R. 4 E., about ¾ of a mile south of the town of Custer, Custer County. It was operated from October 1943 to January 1944 by G. W. Beach of Custer, and produced more than 300 lb of trimmed sheet and punch mica. The property is now held by the G. W. Beach Estate.

The Aladin mine appears to have been opened many years ago but details are not known. In June 1945, the main workings were a pit and a small cut 100 ft to the south. The pit is roughly triangular in shape, 50 ft long, 25 ft wide, and 30 ft deep. A shaft, partly filled with water and of unknown depth, is located near the west end of the pit. An adit, 22 ft long, breaks into the north wall of the pit above the present floor level.

The mine workings are located along the hanging wall of one of a group of large pegmatite bodies which form a northwest-trending ridge. The pegmatite probably was intruded conformably into pre-Cambrian mica schist because, although the actual wall rock is not exposed, several parallel mica schist partings are present along the western margin of the pegmatite. The partings strike N. 10° W. and dip 65° SW. In addition to a thin border zone developed along the partings, the pegmatite shows two well-developed zones: a wall zone of perthite-quartz-muscovite pegmatite and a core of perthite-quartz pegmatite.

The perthite-quartz-muscovite pegmatite is 8 to 10 ft thick and is the source of sheet mica. It is a fine- to medium-grained rock consisting chiefly of pink perthite (60 percent) and quartz (30 percent). The remaining 10 percent is made up largely of an intergrowth of muscovite and biotite in various proportions. Apatite and black tourmaline are accessory minerals. The footwall zone of this unit is not exposed.

Perthite-quartz pegmatite of undetermined thickness makes up the core and is the source of any feldspar that may have been sold from the property. It consists of pink to gray perthite and colorless to pale-rose quartz that occurs both in large masses and in graphic intergrowth. Minor accessories are albite, apatite, biotite, muscovite, and an iron sulfide.

Pale to dark ruby muscovite occurs in the pegmatite in crystals 6 to 8 in. in diameter. Approximately one-third of the sheet mica produced has been of size 1½ by 2 in. or larger. The mica is hard and flat, but much of it shows dense mineral and air-stains. It is predominantly of no. 2 inferior quality, though a small percentage is of no. 1 and no. 2 qualities.

This property could probably produce a considerable quantity of mica at a comparatively low mining cost.

ANN MICA MINE (CUSTER DISTRICT)

by T. A. Steven

The Ann mica mine is about 8 miles south of the town of Custer in the SW¼SW¼ sec. 32, T. 4 S., R. 5 E., Custer County. The southwest corner of section 32 marks the approximate west center post of the claim which extends into adjacent sections to the west and to the south. The claim is unpatented and belongs to Mrs. Gladys Wells and associates, of Custer. Mr. Wiley Reed had charge of the operation of the mine after September 1940.

The claim was first located about 1885 by Isaac Tanner, who did little work and the claim reverted to public domain. A Mr. Green relocated the property about 1924. He sold it to a Chicago company, which developed an open-cut along the southerly end of the pegmatite. The claim then lapsed and was located by Mr. Mel Tanner, son of the original locator, in 1927 or 1928 and Mr. Scovel Johnson in 1937. Mr. Johnson sold the property to the present owners in December 1939.

In July 1944, R. F. Stopper made a transit survey of the underground workings and started a plane-table map of the surface workings. Both were completed in August and September 1944 by T. A. Steven. J. W. Adams assisted both Stopper and Steven. Maps of the surface workings were made with telescopic alidade and plane table on scales of 1 in. to 40 ft (pl. 2) and 1 in. to 20 ft (pl. 3). The underground workings were mapped on a scale of 1 in. to 20 ft (pl. 3). Mr. Wiley Reed, operator of the Ann mine, provided much useful information concerning the property, and his willing cooperation throughout the work is greatly appreciated.

Surface workings at the Ann mica mine consist of two open-cuts, one along the west side and south end of the pegmatite, and the other along the hanging wall of the smaller of the two coalescent dikes. The underground workings consist of a 300-ft adit, a 60-ft crosscut, and two raises from the adit level to the southwestern open-cut. A raise was started from the crosscut and considerable work was done on it subsequent to the mapping.

METAMORPHIC ROCKS

The metamorphic rocks in the vicinity of the Ann mica mine are interbedded quartz-mica schist, quartzite, and quartz-biotite-sillimanite schist. In general the bedding of the metamorphic rocks strikes N. 30° W. and dips 35°–70° SW., and the foliation strikes N. 70°–75° E. and dips 30°–40° SE. Locally, a second foliation has been developed adjacent and parallel to the walls of the pegmatite. The undulations in the contacts of the pegmatite with quartz-biotite-sillimanite schist as shown on the surface map (pl. 2) are surface traces of gentle folds.

Many folds with an amplitude of but a few feet, whose axes plunge south to about S. 10° E., have been observed. The distance between anticlinal crests is commonly less than 10 ft. The largest fold of this type noted is shown on the adit level map (pl. 3). It may have been accentuated by the injection of the pegmatite. The intersections of foliation and bedding surfaces in the schist are parallel to the direction of plunge of the minor flexures and also to the plunge of the south end of the Ann pegmatite. Where concordant walls were observed in the natural outcrops or in the mine workings, they follow these minor flexures closely.

The lowest stratigraphic unit distinguished in mapping (pl. 2) consists of a quartz-mica schist with a few thin beds of quartzite. The quartz-mica schist, exposed only in mine workings, is composed of quartz, biotite, and muscovite in various proportions. The quartzite is a granular, friable rock composed of quartz and biotite. It is exposed in the adit for slightly more than 100 ft.

Above the quartz-mica schist is a poorly exposed series of interbedded quartz-mica schists and quartzites. The quartzite ranges from a granular quartz-biotite rock similar to that described above to a dense, hard quartzite with little or no biotite. Although exposures are too poor to permit accurate estimates, the unit is about 75 to 90 ft thick. Quartzite appears to be the predominant rock and exercises the greatest control on the structure of the pegmatite.

The quartz-biotite-sillimanite schist, which overlies the interbedded quartzite and schist, is the only unit mappable at the surface. It is a dark-gray, well-foliated rock, and is readily distinguished in outcrop by the resistant sillimanite, which stands in relief on the weathered surface. It is approximately 75 to 80 ft thick and can be traced for a considerable distance across the area mapped. A hard, dense quartzite overlies the quartz-biotite-sillimanite schist.

Along the pegmatite contact there is locally considerable tourmaline and biotite in the metamorphic rocks, and mica schist wall rocks are altered to a dense, granular rock.

PEGMATITE

The Ann pegmatite, apparently formed by the coalescence of two dikes, strikes N. 40°–50° W. and dips 30°–60° SW. The smaller dike and two small pegmatites near the northerly limit of the mapped area appear to be concordant with the structures of the metamorphic rocks. The larger pegmatite transects both the strike and dip of the regional structures at a slight angle. It has an outcrop length of 450 ft, and (exclusive of the area of coalescence) has a maximum width of 45 ft. The smaller dike has an outcrop length of 130 ft.

The bulbous south end of the pegmatite body plunges S. 10°–15° E. parallel to the axes of the minor folds in the metamorphic rocks. The angles of plunge change from nearly horizontal in the area between the two open-pits to about 55° between the adit and 5247–ft level. Probably north of the horizontal section the plunge increases, as the core is exposed along the westernmost limb of the body. Both ends of the pegmatite that forms the eastern limb appear to pitch gently northwest.

Exposures are small, but suggest that the discordant parts of the pegmatite are, with two exceptions, limited to the interbedded quartzite and quartz-mica schist unit in the metamorphic rock sequence. At its northerly end the pegmatite is in contact with the quartz-biotite-sillimanite schist, and the hanging-wall contact of the pegmatite appears to dip a little less steeply than the bedding in the schist. As shown on the 5247-ft level map (pl. 3), the southerly end of the pegmatite has cut across the interbedded quartzite and quartz-mica schist unit into the quartz-mica schist unit.

The pegmatite transects the metamorphic strata in a series of irregular steps with successive concordant and discordant segments. As this takes place both along the strike and down the dip, the shape of the walls is virtually unpredictable. Cross-sections are at best diagrammatic where inferred without immediate control.

The discordant segments are extremely irregular, but the directions of plunge of the segments fall roughly into two sets; one plunges 45°–70° to the S. 5°–25° W., and the other plunges as much as 30° to the west. The variation within each set is caused in part by changes in the shape of the discordant segments, as is well illustrated by comparing the crosscutting part of the dike as shown on the adit level and on the 5247-ft level maps (pl. 3). The transection of the quartzite bed by the pegmatite between sections A–A′ and B–B′ on both levels represents the same segment of the pegmatite, yet on the 5247-ft level it is almost perpendicular to the strike of the quartzite bed, whereas on the adit level it cuts the quartzite at an angle of about 45°.

Pegmatite cuts across quartz-mica schist in only one place on the 5247-ft level (pl. 3). The induced foliation in the schist adjacent to the contact obscures the original structural features.

At the junction of the two coalescent parts, the pegmatite cuts across the schist-quartzite wall between them. Probably, the two parts of the pegmatite were emplaced about the same time, and the only evidence of a border and wall zone is a tourmaline-rich streak within the pegmatite where the core extends from one part to the other. The ends of the schist partings, as exposed in the northeasterly open-cut, are apparently offset about 8 ft but, considering the effect of drag, the actual offset is probably 14 to 16 ft.

The small rolls on the dike walls seem to follow the southward plunging minor folds in the metamorphic rocks and the larger irregularities to follow the fracture systems in the quartzite. The structure of the pegmatite in the mine workings suggests that where the wall-rock is quartzite fracture systems control the shape of the pegmatite.

The extent and attitude of the metamorphic rock parting between the two pegmatites in depth is uncertain. The crosscut from the main adit encountered the end of a quartzite parting within the pegmatite approximately S. 30° W. of the south end of the schist-quartzite parting exposed in the west wall of the northeasterly open-cut. However, in the raise driven from this crosscut the parting may not be continuous.

Quartz-perthite-oligoclase-muscovite pegmatite.—Although the Ann pegmatite is poorly zoned, two structural and mineralogic zones have been distinguished. Muscovite and oligoclase form a poorly defined zone where they are more abundant adjacent to the walls, associated with some quartz and various amounts of perthitic microcline. A narrow border zone is present, but is not shown on the map. The core of the pegmatite is chiefly quartz and perthitic microcline. Local concentrations of book muscovite in the wall zone have been mined.

In the Ann mica mine, quartz-perthite-oligoclase-muscovite pegmatite forms a 2- to 5-ft wall zone on the hanging wall of the dike and a 1- to 2-ft zone on the footwall, but where thin schist partings are present within the pegmatite, the zones are much thicker.

The quartz and oligoclase grains are generally less than 2 in. in diameter and together with muscovite books of various sizes they surround perthite crystals which are as much as 1½ ft in diameter. In general the larger perthite crystals occur where this mineral is abundant. Most of the muscovite is in small books, but some are more than 1 ft in diameter.

In some of the richer mica shoots, the dominant minerals are quartz and muscovite, with subordinate oligoclase and perthite. Elsewhere the perthite is considerably more abundant and in places is the chief constituent of the zone.

The oligoclase is pearly white to flesh-colored. Polysynthetic twinning is poorly developed or absent. The plagioclase is a sodic oligoclase with minimum indices of refraction on cleavage fragments ranging from about 1.534 to 1.537 (An_{14}–An_{18}). Accurate estimates of the relative abundance of the feldspars cannot be made because of the difficulty in distinguishing between oligoclase and the perthite with which it is associated. Black tourmaline is generally present as an accessory mineral, and locally biotite is a minor constituent.

Quartz-perthite pegmatite.—The core of the Ann pegmatite is essentially an intergrowth of coarse-grained quartz and perthite. The perthite is pink to flesh-colored, and individual masses are as much as several feet in diameter. The quartz is interstitial to the perthite and also forms graphic intergrowths with it. Muscovite is erratically distributed. Local concentrations of soft scrap muscovite with a pronounced herringbone structure are found around some of the larger quartz masses. Black tourmaline is a conspicuous accessory.

Quartz pegmatite.—One of the small pegmatites near the northern edge of the mapped area has a narrow, veinlike mass of quartz cutting it for most of its length. The quartz pegmatite is 6 in. to 1 ft in thickness and cuts not only the quartz-perthite core, but also the quartz-perthite-oligoclase-muscovite wall zone. It does not extend beyond the limits of the pegmatite.

MICA DEPOSITS

Mica was the only mineral produced from the Ann mine in 1942–45. Perthitic microcline could be produced from the central zone of the pegmatite, but the widespread distribution of black tourmaline and the abundant quartz makes it a low-grade deposit.

The mica content of the quartz-perthite-oligoclase-muscovite pegmatite wall zone is extremely variable. Commercial deposits or shoots occur along the hanging walls of both pegmatites, but the discontinuity of these concentrations makes profitable mining difficult. Within the mica shoots, the larger books of muscovite occur near the inner limit of the mica-bearing zone and are less abundant than the smaller books.

Production figures for the Ann mica mine prior to purchases of the Colonial Mica Corporation are not complete. From October 1940 to October 1942, about 16,700 lb of mine-run mica was produced from the southwestern open cut, but the sheet-mica content is not known. The table below summarizes the known production of the mine.

The sheet mica produced during 1942–45 was a hard ruby muscovite of fair quality. Air-stain and mineral-stain are the most common defects. The individual lots of mica sold to Colonial Mica Corporation in 1944 contained as much as 7 percent quality no. 1, 8 to 45 percent quality no. 2, and 61 to 100 percent quality no. 2 inferior; the average of combined no. 1 and no. 2 qualities was about 20 percent.

Mica produced from Ann mica mine, October 1940–April 1945

Year	Crude (pounds)	Large sheet				Small sheet, full trim		Untrimmed punch	
		¾ trim		Full trim		Weight, lb	Value	Weight, lb	Value
		Weight, lb	Value	Weight, lb	Value				
Oct. 1940–Oct. 1942	16,700								
1943:									
Mine	?	65.44	$327.20			580.61	$2,903.05		
Dump	?					104.80	524.00		
1944:									
Mine	?	37.99	227.99	58.31	$466.48	1,209.27	7,255.62		
Dump	?					63.01	399.06		
1945:									
Mine	?			38.31	306.48			869.75	$260.94
Total		103.43	555.19	96.62	772.96	1,957.69	11,080.73	869.75	260.94

Colonial Mica Corporation, during 1943–45, purchased from the mine 200.05 lb of large sheet, 1,957.69 lb of small sheet, and 869.75 lb of untrimmed punch mica; the total value was $12,669.82. Mr. Mel Tanner, during the same period sold an additional 155.50 lb of small sheet reclaimed from the dump. About 10 percent of all mica sold was large sheet.

The sporadic occurrence and the variability of the mica shoots within the Ann mica mine make it very difficult to estimate the reserves. Within the mine workings, book muscovite is exposed in quantity only in the northeastern open-cut, along the hanging wall of the smaller of the coalescent dikes. Further development work may disclose a downward extension of this shoot. No comparable concentration of mica has been found in the underground workings. Local concentrations of muscovite occur in the wall zone of the pegmatite away from the mine workings.

ANTLER MICA MINE (CUSTER DISTRICT)

The Antler mica mine, in the NW¼ sec. 27, T. 4 S., R. 5 E., is on a lode claim located August 19, 1941, by Louis Graham of Custer. The mine can be reached by 1.9 miles of poor mine road from the Flynn Creek Camp Ground according to the following mileage schedule.

Miles	
0.0	Flynn Creek Camp Ground.
0.2	Turn right.
1.2	Turn right.
1.4	Turn left.
1.7	Turn right.
1.8	Old feldspar mine on left.
1.9	Antler mine.

The Antler mine comprises an irregular open-cut and stripped area along a pegmatite having a sharp anticlinal and synclinal structure that is parallel to the folds in the quartz-mica schist wall rocks. The axes of the folds in the schist and in the pegmatite plunge 20 degrees S. 20° W. The west, or anticlinal, part of the pegmatite has been mined about 60 ft down the nose of the fold. This part of the pit averages 25 ft in width and the face shows about 6 ft of soft weathered schist above the pegmatite. The west edge of the anticlinal part of the pegmatite has been explored by a 25-ft drift that trends N. 80° W. from the center of the west side of the main pit. A small open-cut extends 15 ft northward along the pegmatite from the northwest corner of the main pit, and another on the east limb of this structure extends northeastward. About 75 ft east of the drift an open-cut extends 40 feet, N. 20° W., along the east limb of the synclinal fold.

The pegmatite is 1 to 4 ft thick. Its average thickness is probably nearly 3.5 ft on the anticlinal structure and it appears to be thickening down the plunge and on the northwest limb of the fold. A small cut, about 100 ft to the north, revealed about 10 ft of perthite-quartz pegmatite as a core, containing muscovite, between wall zones 1 to 2 ft thick. On the east limb of the syncline the pegmatite is 1.5 ft thick. The strike and dip of the pegmatite varies widely. The west limb of the anticlinal structure, in general, trends north and dips 20°–40° W.; the east limb trends about N. 25° E. and dips 20°–45° SE.; and the east limb of the synclinal structure trends N. 20° W. and dips 40° SW. At the portal of the drift the pegmatite strikes N. 70° W. and dips 20° SW., but at the face it strikes N. 35° W. and dips 35° SW.

The pegmatite in the main pit is composed of plagioclase, quartz, and muscovite, with accessory perthite and a little tourmaline. In the exposures north of the main pit and also in the drift, these same minerals occur in different proportions in the wall zones around perthite-quartz pegmatite core. In the drift the core is 1 to 2 ft thick.

The wall zones in the drift and main pit contain as much as 20 percent muscovite, in books as much as 15 in. in length. Intensive ruling and fracturing, however, cause the mica to break easily and sheets larger than 2 by 2 in. are rare. The mica is soft, more wavy than is usual in most mica of the Custer district, and densely air-stained. Mineral inclusions parallel to the laminae are common. A small part of the mica observed in April 1945 is hard and free of defects and could be classed as no. 1 and no. 2 qualities, but most of it is of no. 2 inferior or no. 3 qualities. During 1943 the Antler mine was operated by Floyd Frye and produced 481.61 lb of trimmed sheet and 694.50 lb of untrimmed punch mica, valued at $2,248.75.

APEX CLAIM (CUSTER DISTRICT)

The Apex claim, in the NW¼ sec. 22, T. 5 S., R. 5 E., is held by Lon Pitts of Pringle, South Dakota. It is on the north side of U. S. Highway 85, 4.5 miles east of Pringle. The claim was worked for scrap mica, beryl, and feldspar prior to 1943. Less than 10 lb of trimmed sheet and punch were sold in 1943 to Colonial Mica Corporation.

The main open-pit, on the northeast side of a ridge of quartzite, is on a branching pegmatite that transects schist and quartzite. The L-shaped open-cut extends 75 feet S. 45° W., along a branch of the pegmatite that dips 75° NW., and then S. 45° E. for another 75 ft along the main part of the pegmatite. The open-cut, which is 15 to 20 ft wide, contains aggregates and masses of muscovite of scrap quality associated with coarse white to buff perthite and rose quartz. A small pit southeast of the main cut is said to have produced 1,000 lb of beryl.

About 300 ft southwest of the main pit, near the base of the southwest side of the ridge, a second dike was prospected for sheet mica by means of a small pit. A few small books of hard, flat air-stained ruby mica were seen in August 1943.

ARCADE NO. 1 AND NO. 2 CLAIMS (CUSTER DISTRICT)

The Arcade No. 1 and No. 2 claims held by H. L. Hoefert are in the NW¼ sec. 22, T. 3 S., R. 5 E., 4.3 miles by road from Custer, South Dakota. It is ½ mile south of the Iron Creek road, 1 mile east of the intersection with U. S. Highway 16.

The claims are on an unusually large granitic pegmatite that forms a ridge on the west side of Bismark Lake. Most of the exposures are in granitic pegmatite, but some are mainly graphic granite and rose quartz, with interstitial plagioclase, quartz, muscovite, and tourmaline. The property has been prospected by means of several small pits, and by an open-cut 50 ft long in a N. 70° W. direction, 20 ft wide, and 10 ft deep at the face. Books and blades of muscovite intergrown with biotite cut the graphic granite. None of the muscovite was of sheet size. According to Mr. Hoefert about 100 tons of feldspar and 10 lb of sheet and punch mica were recovered from this property.

BALLARD MICA MINE (CUSTER DISTRICT)

The Ballard mica mine, in the NE¼ sec. 16, T. 3 S., R. 4 E., 2½ miles northwest of Custer, is owned by Mr. F. Ballard of Custer. The mine is on the northern end of the Crown pegmatite and was worked in 1942–44 and in 1945 by William Quinn.

The mine workings include two open-cuts on the north and west sides of the main pegmatite. One pit follows the mica-bearing wall zone of the pegmatite for 60 ft. It is 25 ft wide and 15 ft deep at the face. A more northerly cut is 90 ft long, 25 ft wide, and 30 ft deep at the face. A 60-ft shaft, inclined at 19°, extends southward from this cut and a drift from the base of the shaft prospects the pegmatite for 60 ft to the south.

The geology of the Ballard mine is given in the description of the Crown mica mine.

The total recorded mica production of this mine is given below. The mica sold in 1944 contained about 8 percent of no. 2 quality and approximately 1 percent of no. 3 quality; the rest was no. 2 inferior quality.

BEECHER LODE (CUSTER DISTRICT)

by Peter Joralemon

The Beecher Lode claim is 4.9 miles southeast of Custer in the NW¼ sec. 18, T. 4 S., R. 5 E. It may be reached by following the old Pringle road 4.2 miles south of Custer and then the Flynn Creek road 0.6 of a mile to a mine road that leads to the Beecher pegmatite. The Beecher Lode lies southeast of the Beecher No. 2 or Longview claim, and north of the Black Diamond spodumene claim.

The Beecher Lode has been described by Fisher (1942), Munson (1943), Clarke (1944), and Smith (1942), and mentioned by Lincoln (1937, 1943). The property was examined by W. C. Stoll in 1942, and by Page and Joralemon in 1944.

In November 1943, the U. S. Bureau of Mines bulldozed part of the Beecher Lode pegmatite, but exposed bedrock in only a few places. In March 1944, a report and a large scale map of the north drift and the northwestern part of the north pit were made by L. R. Page and Peter Joralemon. In May 1944, a topographic map on a scale of 1 in. to 40 ft was prepared by Francis Freeland of the U. S. Bureau of Mines and on this base Peter Joralemon of the U. S. Geological Survey, assisted by Freeland, mapped the geology.

HISTORY

The first work at the Beecher Lode was carried out by Bond and Sutherland in 1900. A shaft near the north end of the pegmatite was sunk in search of mica. The claim was patented in May 1912. From 1910 to 1915, the property was leased to Dennis Hennault of Deadwood, South Dakota, and in 1924 or 1925, it was sold to Collingwood and Green of Custer, South Dakota, who are reported to have done most of the excavation of the three large open-pits. Apparently, this work was done from 1925 to 1934 in the mining of spodumene, columbite, and beryl. In 1934, the Beecher Lode was leased to Lon Pitts, and in 1935 to George Bland of Hill City, South Dakota. Mr. Bland subleased the property to Fansteel Metallurgical

Mica produced from Ballard mica mine (in pounds) [1]

Year	Pounds of large sheet produced, of sizes indicated (in.)							Pounds of small sheet produced		
	2 by 2	2 by 3	3 by 3	3 by 4	3 by 5	4 by 6	Total	Full trim	Untrimmed punch	Scrap
1942: Mar. 6–Oct. 22	271.00	105.00	18.00	13.50	7.50	2.00	417.00		[2] 13,784.50	95,801
1942: Dec. 18–31	57.19	28.88	12.38	6.38	3.38		108.21	66.56	899.00	
1943	269.41	141.11	34.63	12.41	7.13	1.32	466.01	373.64	11,595.75	
1943							[3] 24.68			
1944							[3] 16.62	39.24		
Total	597.60	274.99	65.01	32.29	18.01	3.32	1,032.52	479.44	26,279.25	95,801

[1] During the 1943 operations 6,985 lb of beryl, estimated to contain 10 percent BeO, was sold to Colonial Mica Corporation and Metals Reserve Company (Deadwood).
[2] Includes 267.50 pounds 1½ by 1½ in. untrimmed punch.
[3] Not graded as to size.

Corporation which continued work on the south end of the property. In 1937, George Bland, Judge Bland, J. W. McGrew, and A. Forrester, of Kansas City, bought the property. Since that time, Bland has operated the Beecher Lode intermittently under lease from the other owners, and has carried out small-scale operations for spodumene and beryl. Many of the smaller pits and trenches on the property were excavated to remove large individual spodumene crystals. Four diamond-drill holes were made in 1941, and two the following spring. In 1943 and 1944, Bland mined spodumene at the northeast side of the pegmatite and mica from the drift at the base of the 60-ft vertical shaft.

Production figures from the Beecher Lode are incomplete, but the available production data are given below:

Year	Tons
Amblygonite [1]	
1909–10	820
1926	200
1927	80
1928	180
1933–34	500
1935	40
1936	140
1937	90
Total	1, 970

[1] Lincoln, F. C., 1943.

Columbite	
1927–35	[2] 18
1928	6
1935–41	1
Total	25

[2] Excluding production of 1928. From Lincoln, Miser, and Cummings, 1937.

Beryl	
1927–35	60
1942	30
1943	10
Total	100
Spodumene	
1937	5
1943	45
Total	50
Scrap mica	
1927–35	150

Sheet mica	Pounds
1943	[3] 3. 00
1944	[4] 14. 18
Total	17. 18

[3] Includes 5 percent of no. 1, 14 percent of no. 2, and 81 percent of no. 3 inferior.
[4] Includes 6 percent of no. 1, 26 percent of no. 2, and 68 percent of no. 2 inferior.

D. J. Fisher (1942) reports that a total of 33 tons of tantalite has been produced from the Beecher Lode pegmatite.

DEVELOPMENT WORK

The Beecher Lode has been explored by three large open-pits, a 60-ft and 25-ft vertical shafts at the north and south ends of the pegmatite respectively, two short inclined shafts in the southern part of the north pit, a drift from the 60-ft shaft, 7 adits and tunnels, 27 small trenches, and 6 diamond-drill holes.

Logs of the first four drill holes are not available, but some information regarding these holes has been obtained (Fisher 1942, p. 29, and oral report by Mr. George Bland).

Diamond-drill hole no. 1 (pl. 4) cut pegmatite from the surface to 51 ft, and schist from 51 to 60 ft; hole no. 2 intersected pegmatite from the surface to 50 ft, and garnet-bearing amphibole schist from 50 to 56 ft; hole no. 3 entered the east, or foot, wall at 23 ft (see section C-C′); hole no. 4 was in schist for its entire length; hole no. 4A was in schist for 110 ft and in schist that was about 40 percent pyrite for the last 20 ft, of which 1 ft at the end yielded pyrrhotite that contained silver; hole no. 5 intersected mica-rich pegmatite from 66 to 81 ft and quartz and spodumene from 81 to 100 ft; and hole no. 6 cut spodumene pegmatite from 75 to 95 ft, and entered the schist at 98 ft.

GEOLOGY

WALL ROCKS

The Beecher Lode claim is underlain by interbedded pre-Cambrian quartz-mica schist, quartzite, and amphibolite. The foliation, approximately parallel to the bedding, strikes irregularly from N. 30° W. to N. 45° E. and dips from 30° to 75° to the west (pl. 4). The schist contains beds rich in pyrite, pyrrhotite, and a pale-red garnet. It is tourmalinized near the pegmatite contact.

PEGMATITE

The Beecher Lode pegmatite conformably intrudes the schist and at the surface strikes north and dips west. It is lenticular in shape and is about 870 ft in length and as much as 80 ft in thickness. The Beecher No. 2 pegmatite lies 50 to 80 ft west of the Beecher Lode. Apparently, the two pegmatites are not connected.

Five lithologic units, all heavily iron-stained, were mapped at the Beecher Lode. They are (1) a quartz-albite-muscovite pegmatite border and wall zone; (2) a quartz-albite pegmatite unit that is probably an intermediate zone; (3) a perthite pegmatite intermediate zone; (4) a quartz-spodumene unit that may be either an intermediate zone or the core; and (5) a muscovite pegmatite unit, probably an intermediate zone or a replacement body. Intermediate zones of perthite-amblygonite-spodumene and quartz-spodumene-beryl pegmatite at the edges of the quartz-spodumene pegmatite were not mapped. On the map, units of quartz and spodumene-lepidolite pegmatite are included with quartz-spodumene pegmatite because exposures are too small to distinguish.

Quartz-albite-muscovite pegmatite.—The quartz-albite-muscovite pegmatite is composed of muscovite, albite (An_6–An_8, the minimum index of cleavage fragments is 1.529–1.530), quartz, tourmaline, and apatite. Apparently it forms a thin border zone and wall zone around the entire pegmatite and also occurs in lenticular masses near the contact, as in the drift at the bottom of the 60-ft shaft (fig. 8). This zone has an average thickness

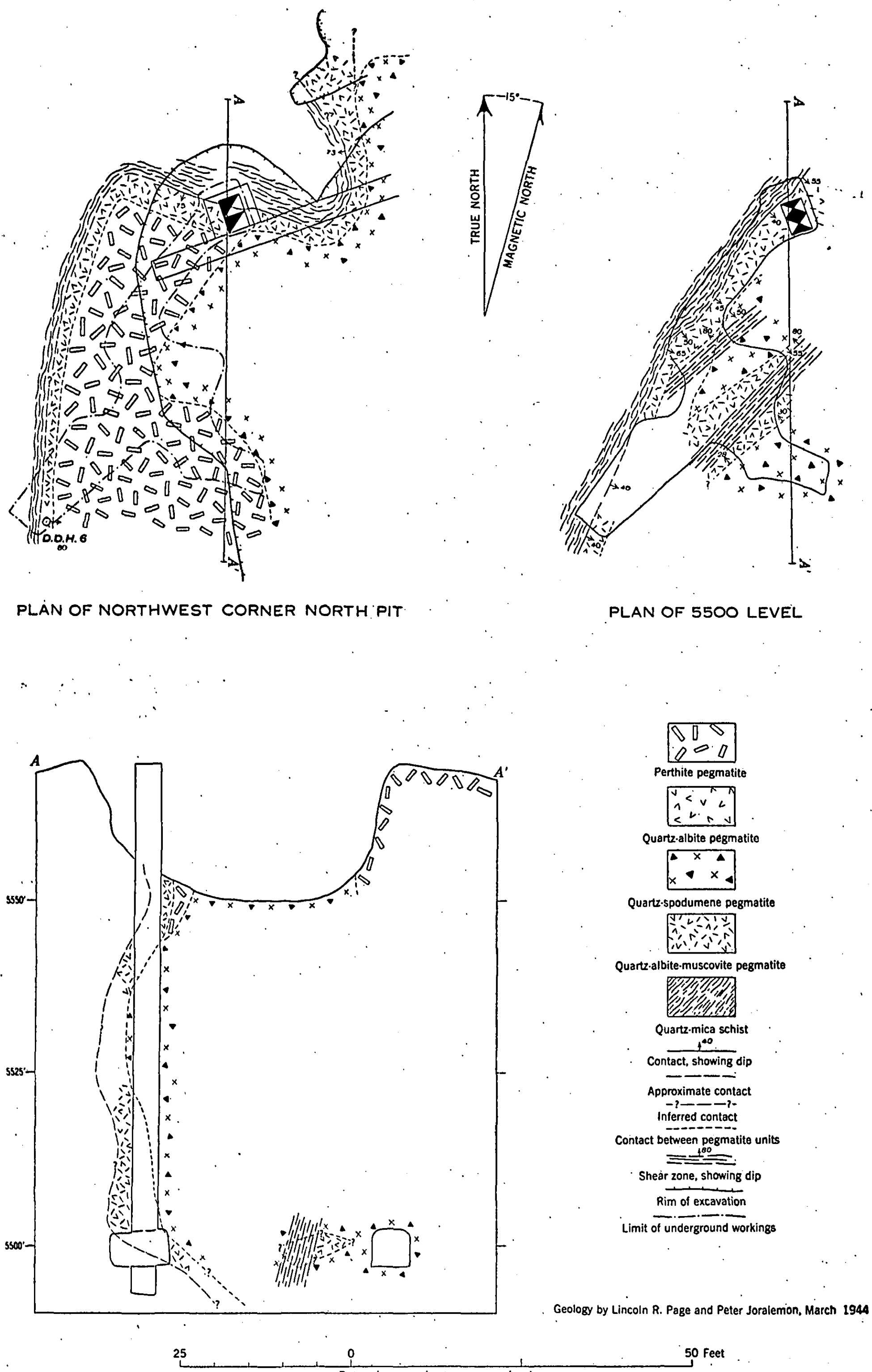


FIGURE 8.—Geologic maps and sections, northwest part of the Beecher Lode pegmatite, Custer County, South Dakota.

of 5 ft on the west wall and perhaps 1 to 2 ft on the east wall of the pegmatite. Diamond-drill holes no. 5 and no. 6 transected considerable thicknesses of quartz-albite-muscovite pegmatite. The muscovite books are as much as 8 in. in diameter and 8 in. thick. The books in the isolated lenticular masses are generally thicker than those in the well-defined parts of the wall zone.

Quartz-albite pegmatite.—A quartz-albite pegmatite unit occurs near the south end of the pegmatite between the wall zone and core. It is composed of quartz and albite with various quantities of muscovite. It is crumbly, and granitic in texture in the southern 100 ft of the pegmatite. In this unit, fine-grained muscovite constitutes 20–30 percent of the rock. Toward the center of the pegmatite muscovite becomes more abundant and occurs in larger flakes. The quartz-albite pegmatite in the southern part of the dike may be closely related genetically with the muscovite pegmatite.

Quartz-albite pegmatite exposed in the small pit northeast of the shaft is considerably coarser grained. It is composed predominantly of quartz and albite in masses 1 to 2 in. long. Thin books and flakes of muscovite are sparsely scattered through the rock. This quartz-albite pegmatite has a texture similar to that of the groundmass of the quartz-albite-muscovite pegmatite, with which it is seems to be genetically related. Abundant small crystals of cassiterite are disseminated through this part of the pegmatite.

Perthite pegmatite.—The perthite pegmatite consists of perthite and a little quartz. In cross-section this zone is crescent-shaped and concave downward, and extends for at least 375 ft along the strike. It has a maximum thickness of about 50 ft, and a horizontal width of about 50 ft remains to be mined. Originally this zone capped the entire north pit. The perthite is in heavily iron-stained crystals as much as 6 or 8 ft long. It is exposed along the west wall of the north pit near the west contact of the dike, and also in part of the middle pit. It lies above the spodumene zone and below the mica zone. Perthite pegmatite occurs as a capping over quartz-spodumene pegmatite between the middle and south pits, and in an isolated lens near the south end of the body. The perthite pegamtite apparently dips west and may plunge moderately to the north, in a direction opposite to the plunge of the pegmatite. The perthite pegmatite apparently does not extend more than 40 ft beneath the floor of the pits. The zone contains widely scattered spodumene and beryl crystals.

Quartz-spodumene pegmatite.—The quartz-spodumene pegmatite is composed of widely spaced spodumene crystals as much as 20 ft long and 5 ft thick, in a matrix of quartz, beryl, amblygonite, and albite, with smaller quantities of columbite-tantalite and lepidolite. At the surface much of the quartz and spodumene is iron-stained, though the spodumene is generally lighter-colored than the quartz. The quartz-spodumene pegmatite is exposed discontinuously for 850 ft along the strike and 100 ft across the strike. It is exposed along the entire length of the 60-ft shaft at the north end and of the 25-ft shaft at the south end of the pegmatite.

The quartz-spodumene pegmatite constitutes the main rock type of the Beecher pegmatite. It is separated from the west wall by 2 to 40 ft of quartz-albite-muscovite pegmatite and perthite pegmatite. The east wall of the pegmatite is poorly exposed, but apparently quartz-spodumene pegmatite extends to within one or two feet of the contact.

Beryl occurs near the outer edges of this zone as aggregates, more than 1 ft in diameter and as much as 10 ft in length. It is commonly interstitial to the spodumene crystals. The beryl from the Beecher Lode is almost invariably anhedral. It is for the most part very heavily iron-stained, and escapes notice unless one is familiar with the deposit.

Ambylgonite almost invariably occurs at or near the contact of the quartz-spodumene pegmatite and the perthite pegmatite as white masses many feet long. The amblygonite mined in the centers of the north, middle and south pits occured just below flat-lying perthite pegmatite that has been stripped off.

Columbite-tantalite is scattered throughout the quartz-spodumene pegmatite, associated with cleavelandite, lepidolite and quartz. The main deposit of columbite-tantalite was in the south pit, where one lens is reported by George Bland to have contained 18 tons of tantalite.

Lepidolite occurs in fine-grained masses in the quartz-spodumene pegmatite; it is associated with quartz and albite (cleavelandite). It seems to be concentrated near the footwall and hanging wall parts of the spodumene zone, but some lenses occur in the center.

Quartz pegmatite, composed almost entirely of milky quartz, in masses several feet in diameter, occurs to the south and east of the open-pits. It is probably part of the quartz-spodumene pegmatite; spodumene is poorly exposed outside of the cuts, but quartz crops out prominently. Quartz is the dominant mineral in the eastern half of the dike and it is possible that this part is the true core of the pegmatite.

Muscovite pegmatite.—The muscovite pegmatite, locally known as "bull mica," consists of about 60 percent muscovite, 20 percent quartz and 20 percent albite, but locally there is as much as 30 percent of beryl, in small yellowish anhedral masses. The muscovite is in flakes and thin curved books less than 1 in. across, oriented at all angles in the quartz, beryl, and albite of the groundmass. The muscovite pegmatite is in isolated pods and lenses at or near the center of the dike. Only scrap mica is found in this type of rock.

STRUCTURE

PEGMATITE

The Beecher Lode pegmatite strikes approximately N. 5° W. and dips 45°–70° W. at the surface. The plunge of the body is obscure. Projection of known contact suggests that the pegmatite at the north end has an average plunge of about 30° to the south. The keel of the dike apparently is considerably flatter, for the average plunge from the 60-ft shaft to the point where the dike is cut by diamond-drill hole no. 5 is about 5° to the south. From the south end of the dike to diamond-drill hole no. 5, the average plunge of the keel of the pegmatite is approximately 25° to the north.

The east side of the dike apparently maintains a dip to the west with depth. The west wall apparently steepens and in places reverses in dip. The reversal is indicated by cores of diamond-drill holes 1, 2, 4, 4A, and 5 (pl. 4). The adit at the south end of the property exposes the west contact of the pegmatite which dips 26° to the east. The L-shaped adit in the middle pit exposes a mica zone which seems to be near the west contact. The drift at the bottom of the 60-ft shaft cuts the pegmatite-schist contact that dips 65° to the southeast (fig. 8).

A large roll exposed in the northwest corner of the north pit plunges almost vertically from the surface to the bottom of the 60-ft shaft. A few minor rolls were seen at the Beecher Lode pegmatite, plunging 50° S. 40° W.

The results of diamond drilling strongly suggest that the dip of the west wall of the Beecher Lode pegmatite steepens with depth, and in some places passes beyond the vertical. The perthite pegmatite exposed at the surface may wedge out westward not far below. The drilling also suggests that the spodumene-bearing pegmatite occurs at depth for almost the entire thickness of the dike. More and better-recorded diamond drilling would indicate more exactly the vertical extent of the pegmatite.

FAULTS

The Beecher Lode pegmatite has been severely fractured, faulted, and oxidized. Much of the rock is so iron-stained that its identity cannot easily be determined. Two main series of faults cut the dike, offsetting it from 1 to more than 10 ft. One series strikes about N. 70° E. and dips from 70°–80° to the north or south. The offsets along the faults appear to be 2 ft or less. Gouge is 1 to 3 in. thick on the fault surfaces. The largest faults strike about N. 20° E. and dip from 50°–70° NW. Several parallel faults occur within a 15-ft zone in the north and middle pits. The pegmatite lying within this zone is badly sheared. Slickensides on the fault surfaces plunge from 30° to 40° to the north. In general the west block of the faults moved down and to the north with respect to the east block, but an opposite movement may have occurred along some of the minor faults.

MINERAL DEPOSITS

The Beecher Lode has produced spodumene, beryl, columbite-tantalite, feldspar, amblygonite, scrap mica, and sheet mica. Small stockpiles of lepidolite and cassiterite-bearing rock were on the property in 1945.

SPODUMENE

Spodumene occurs along almost the full length, and at least two-thirds of the thickness, of the pegmatite. The spodumene crystals, in random orientation, are from 1 to more than 20 ft long and are ½ to 5 ft thick. The spodumene is white and only moderately iron-stained. The quartz-spodumene pegmatite contains 10 to 15 percent of spodumene, although locally there are richer concentrations. Both at the surface and underground, some of the spodumene is soft, soapy, and low in lithia, and some is hard, and high in lithia content. Some single crystals contain both types of spodumene. In such cases, the soft variety cuts the hard mineral in seams. On the surface east of the pits, decomposed spodumene crystals are composed of small pieces of hard spodumene, as much as 1 in. in length, cemented by clay. In 1943–44, Bland mined a disintegrated but continuous spodumene crystal more than 20 ft long from a cut east of the north pit. This crystal was almost horizontal and lay above schist. The east wall of the pegmatite slumped gradually onto the schist without disturbing the spodumene crystal or this part of the pegmatite was horizontal.

The U. S. Bureau of Mines took three samples of spodumene exposed in the pits (Munson, 1943, p. 5). One sample of hard, unaltered spodumene taken from various crystals in the south pit showed 6.76 percent of Li_2O. A sample of highly decomposed spodumene from various crystals in the north pit contained 2.16 percent of Li_2O, and partly altered spodumene crystals from the middle pit contained 5.32 percent of Li_2O. Unaltered spodumene from the drift at the base of the 60-ft shaft is reported by Bland to contain about 6 percent of Li_2O. During mining, Bland sorted the spodumene, by visual estimates, into lots of 4 and 6 percent of Li_2O and combined these to get a 5 percent lithia product. The decomposed appearance of the spodumene has led many investigators to the erroneous belief that the spodumene from the Beecher Lode is not of commercial grade.

Records of spodumene production from the Beecher Lode are incomplete. Apparently all the spodumene has been produced since Bland began operations. In 1937, 5 tons of spodumene was produced (Lincoln, 1943, p. 5), in 1943, 45 tons was shipped; the first five months of 1944 Bland mined 35 tons.

AMBLYGONITE

Amblygonite occurs in the quartz-spodumene pegmatite at or near the contacts with perthite pegmatite. It is generally associated with albite. It is white, only moderately iron-stained, and has a comparatively high lithia content. Only small masses of amblygonite are now visible in the pegmatite, although large masses have been removed from the north, south, and middle pits. A 100-ton mass of amblygonite is reported to have been removed from the center of the middle pit, above the present level. This amblygonite lay close to perthite pegmatite that originally capped the quartz-spodumene pegmatite. A 200-ton mass is said to have been removed from the north pit, also above the present pit bottom. This mass lay near the perthite pegmatite capping. Similarly, the amblygonite in the south pit was above the level of the bottom of the pit, presumably near a perthite capping.

A Bureau of Mines sample of amblygonite from the Beecher Lode showed a Li_2O content of 8.5 percent (Munson, 1943, p. 5).

In 1909, 820 tons of amblygonite was produced. From 1910 to 1926, no production was reported (Lincoln, 1943, p. 5). A small amount was produced each year from 1926 to 1937, and none has been reported since that time. A total of about 1,970 tons of amblygonite has been shipped, and several tons was stockpiled at the property in 1945.

BERYL

Beryl occurs at the Beecher Lode in heavily iron-stained anhedral masses interstitial to spodumene crystals in the outer part of the quartz-spodumene pegmatite, and as anhedral grains in muscovite pegmatite. Masses of beryl weighing several tons are surrounded by large spodumene crystals. The greatest concentrations of beryl are on the eastern and western sides of the north pit. These units of beryl-rich rock are about 70 and 55 ft long respectively and 20 to 30 ft thick. Some beryl was produced from the south end of the center pit, under and near the perthite cap, and small isolated masses of beryl were mined from the south pit.

Many beryllium assays have been made of beryl from the Beecher Lode. In 1943 the Bureau of Mines analyzed samples of minus 2-in. waste material from various dumps on the Beecher property, with the results indicated below.

Beryllium content of dump samples

Source	BeO (percent)
Upper dumps, north pit	0.28
Lower dumps, north pit	.26
Shaft dumps, north pit	.06
Lower dumps, middle pit	.11
Upper dumps, middle pit	.22
Dumps, south pit	.09

Bureau of Mines analyses of the beryl itself indicates that the BeO content ranges from 8.0 to 10.14 percent (Munson, 1943, p. 5). Colonial Mica Corporation sampled beryl produced from the Beecher Lode in 1944 and one analysis revealed 10.94 percent BeO and 4.40 percent Fe_2O_3.

Before the Beecher beryl was identified, many tons were discarded in mining for other minerals. About 60 tons of beryl was shipped from 1927 to 1935 (Lincoln, Miser, and Cummings, 1937, p. 5), 30 tons in 1942, and 10 tons in 1943. Mr. Bland sold about 3 tons in 1944.

COLUMBITE-TANTALITE

Columbite-tantalite generally occurs in crystals near the walls of the spodumene zone, and is associated with albite and quartz. The main concentration of columbite-tantalite is in the southern part of the south pit. Bland reports that 18 tons of columbite-tantalite was produced from one mass and that a 2½-ton mass of columbite-tantalite was removed from the southeast corner of the middle pit.

Most of the columbite-tantalite from the Beecher Lode was sold before Bland began operations. According to Fisher (1942, p. 26), a total of about 33 tons has been produced since 1900. Bland has stockpiled perhaps a ton of rock containing an estimated 7 to 10 percent of fine-grained columbite-tantalite.

A Bureau of Mines analysis of a composite columbite-tantalite sample from the Beecher Lode showed 39.1 percent Cb_2O_5 and 36.8 percent Ta_2O_5 (Munson, 1943, p. 5).

MICA

Most of the scrap mica from the Beecher Lode was produced between 1927 and 1935, from muscovite pegmatite. William Quinn is reported to have ground and screened some muscovite pegmatite more recently. The production was probably about 150 tons (Lincoln, Miser, and Cummings, 1937, p. 5). Several tons of this "bull mica" is stockpiled on the property.

The wall zone of the Beecher Lode contains book mica throughout the length of both the west and east sides of the pegmatite. In general, this zone has a thickness of 2½ to 3 ft along the west wall and 1 to 2 ft along the east wall. Book mica occurs also in one, and possibly more, irregular lenses near the west contact of the pegmatite that are probably connected with the wall zone.

In unfractured and unstained books, the sheet mica is white, hard, and relatively free from air-stain. In the oxidized pegmatite, the mica is soft, curved, and heavily clay-stained. The books are small, averaging 4 to 5 in. in diameter, but they are uncommonly thick. The mica books in the rich mica shoots often have a thickness as great as their longest dimension. The production and quality of sheet mica produced in 1943–44 are given on page 66.

In 1944, Bland explored a mica lens and a few feet of the wall zone in the drift at the base of the 60-ft shaft in the north pit. The wall zone exposed in the drift is about 4 ft thick. About 2,100 lb of mine-run mica was produced in April–May 1944. This was about 2 to 3 percent of the pegmatite mined. Much of the mica must have been lost in mining, as the rock was estimated to contain 10 to 15 percent crude mica. Less than 1 percent of sheet was obtained from crude mica mined.

Bland also explored the eastern wall zone, east of the north pit. This zone is estimated to contain 30 to 50 percent crude mica for a thickness of 1 to 2 ft. The mica has been crushed and curved by the slumping of the pegmatite, and probably also by the faulting. At depth, the mica may be flatter, harder, and less clay-stained.

LEPIDOLITE

Lepidolite occurs with albite, quartz, and commonly with amblygonite, in small masses, generally near the walls of the quartz-spodumene pegmatite. The lepidolite near the south end of the property is gray to purple and very fine-grained. Much of the lepidolite from this part of the pegmatite contains small crystals of spodumene in the groundmass. Lepidolite from the middle and north pit is more lilac in color and coarser grained.

The lepidolite is reported by the U. S. Bureau of Mines to contain 5.16 percent of Li_2O (Munson, 1943, p. 5). Two other samples, taken in 1944, were analyzed by their laboratories at Rolla, Missouri, with the following results:

Analyses of lepidolite by the U. S. Bureau of Mines

	[1] 1	[2] 2
SiO_2	49.18	51.38
Al_2O_3	29.14	37.50
Li_2O	3.76	.37
F	[3] 2.30	.20
K_2O	[3] 2.44	7.00
Na_2O	[3] 1.24	1.26
Fe_2O_3	.37	1.61
H_2O at 100° C	.16	1.61
200° C	.36	.15
700° C	1.35	1.55

[1] Purple lepidolite, north pit.
[2] Greenish lepidolite (?), south pit. No lepidolite observed microscopically.
[3] Probably low.

No lepidolite has been sold from the Beecher Lode, although several tons was stockpiled.

TIN

Cassiterite occurs in the quartz-albite pegmatite exposed in the small pit at the north end of the pegmatite. The cassiterite is in grains less than ½ in. in diameter disseminated through the pegmatite. No horizontal extension of the cassiterite-bearing pegmatite is visible but the zone may extend downward. No cassiterite has been produced; a single ton of cassiterite-bearing rock estimated to contain 2 to 4 percent of cassiterite, has been mined and stockpiled.

RESERVES

Estimates of the reserves of individual minerals in the Beecher Lode can be approximated on the basis of production records and measurements of the excavations. The accuracy of these estimates depends on the validity of the assumption that the relative proportions of each zone are the same at depth.

It is estimated that about 25,000 tons of pegmatite has been excavated at the Beecher Lode. Assuming 1,970 tons to be the total production of amblygonite, the pegmatite mined contained 7.8 percent amblygonite. Probably at least half of the beryl contained in the workings was discarded as waste. This assumption suggests that the pegmatite removed from the pits contained at least 200 tons, or 0.8 percent, of beryl. The columbite-tantalite production of 33 tons indicates a content of 0.13 percent of this mineral in the pegmatite. The production figures for spodumene are incomplete, but visual examination indicates that the spodumene content of the rock is at least 10 to 15 percent. The mica deposit in the wall zone is estimated to contain about 2 percent crude mica for the length of the dike.

If the pegmatite retains its surface size and structure in depth, it would contain 5,000 tons of pegmatite per foot of depth. For each foot of depth, it would contain 500 to 750 tons of spodumene, 390 tons of amblygonite, 40 tons of beryl, and 6½ tons of columbite-tantalite. However, because the dike apparently narrows considerably with depth, the quantity of minerals per foot of depth decreases. The mica zones on either side of the pegmatite have a total length of about 1,600 ft and are 2½ to 3 ft thick. Assuming 2 percent of crude mica, this zone would contain 6 to 8 tons of book mica per foot of depth. The reserves of scrap mica in the muscovite pegmatite cannot be estimated.

The economic minerals in the Beecher Lode pegmatite occur in fairly definite zones and are suitable for selective mining. Mining of the southern half of the dike would produce large quantites of columbite-tantalite and spodumene with some lepidolite. The northern half of the dike could produce large quantites of spodumene, amblygonite, and beryl, with smaller quantites of the other minerals.

BEECHER NO. 2 AND LONGVIEW SPODUMENE CLAIMS (CUSTER DISTRICT)

by Peter Joralemon

The Beecher No. 2 and Longview spodumene claims are in secs. 7 and 18, T. 4. S., R. 5 E., 4.8 miles from Custer. They can be reached by following the old Pringle road 4.2 miles south of Custer and then the Flynn Creek road for 0.6 of a mile. The two claims overlap and ownership is in dispute. The Beecher

No. 2 is claimed by Mr. George Bland of Hill City and his brother Judge Bland. The Longview is claimed by Mr. L. Collingwood and Mr. A. V. Burnside of Custer.

In November and December 1943, and January 1944, during exploration of the property by the U. S. Bureau of Mines, a preliminary geologic map was prepared on a scale of 1:600 or 1 in. to 50 ft. This map, made by tape and compass, was later transferred to a topographic map (pl. 5) made in cooperation with engineers of the U. S. Bureau of Mines.

The U. S. Bureau of Mines project included exploration of the surface by 14 bulldozer trenches, ranging in length from 100 to 370 ft, and totaling 3,619 ft. These trenches trend approximately eastward and prospected the pegmatite for about 900 ft along the strike. In addition, an area of approximately 16,000 sq ft was stripped on the southern part of the pegmatite. Three small areas on the adjoining Beecher claim were also stripped at this time. About 18 samples, each about 5 ft in length were cut across spodumene-bearing pegmatite exposed by trenches.

DEVELOPMENT WORK

The Beecher No. 2 pegmatite was originally prospected for amblygonite and spodumene, but with little success. A 170-ft adit, connected by an 80-ft crosscut to a glory hole 20 ft deep, was driven from the northeast side of the pegmatite (pl. 5). A 20-ft shaft, a 15-ft shaft, and a 20-ft adit were made about 100 ft south of the glory hole. Several small prospect pits are on the property.

GEOLOGY

The Beecher No. 2-Longview pegmatite (pl. 5) conformably intrudes pre-Cambrian quartz-mica schist. It strikes approximately north and dips to the west. Pegmatite is exposed over a length of about 1,150 ft and a width of 210 ft. About 50 ft of schist separates it from the Beecher Lode pegmatite, and a third pegmatite lies 100 ft west of the Beecher No. 2 pegmatite. The three pegmatites are approximately parallel.

WALL ROCK

Quartz-mica schist forms the wall rock of the pegmatite. At a distance from the contacts, bedding and foliation of the quartz-mica schist strike about N. 15° W., but near the contact they appear nearly parallel to the pegmatite. In the southern part of the property the pegmatite dips gently to the west; the average dip is 30°. The dip becomes progressively steeper toward the north and in the northernmost bulldozer trench it is 86° W. There are local reversals in dip in the northern part of the claim, and in places the pegmatite dips 60° E. Isolated bodies of schist, apparently shallow roof pendants, lie within the pegmatite. The smaller schist pendants are isoclinally folded and many small folds occur in the lower 10 ft of the schist pendants. Above these folds the foliation and bedding are more nearly parallel to the walls of the pendants. The ratio of depth to exposed width of a given pendant is approximately 2:1.

Several lenses of amphibolite and many iron-rich beds occur within the quartz-mica schist. One narrow zone within the schist is reported to be composed almost entirely of pyrite. The iron-rich beds are heavily oxidized to a depth of at least 20 ft. Several beds of coarse-grained feldspathic schist and many layers of quartzite occur in the schist.

PEGMATITE

The Beecher No. 2 pegmatite is very irregular. Its average width is about 200 ft; it narrows considerably at the north and south ends. It appears to be a composite of three smaller pegmatites. The main pegmatite is exposed in the eastern half of each bulldozer trench. The southwestern pegmatite, 380 ft in length, is exposed in the southernmost trenches and coalesces with the main body. The northwestern pegmatite joins the main one south of the glory hole and is isolated northward, ending 20 ft beyond the northernmost bulldozer trench.

Four types of pegmatite have been mapped: (1) Aplitic quartz-albite pegmatite forms a border or wall zone that ranges in thickness from a few inches to 8 ft. Even the smallest of the schist pendants are surrounded by a thin shell of this rock. (2) Quartz-albite-muscovite pegmatite is the dominant rock type of the main body, and forms an irregular wall zone around the southwestern pegmatite. Smaller isolated masses occur throughout this pegmatite. (3) The spodumene-bearing pegmatite appears to be the core of the three coalescent pegmatites. Spodumene-bearing rock, in small isolated masses, is only a minor constituent in the northern half of the eastern (main) pegmatite. (4) Microcline-quartz-albite pegmatite occurs as isolated bodies of various sizes, unevenly distributed through the spodumene-bearing pegmatite.

The zones intergrade in highly irregular fashion, and appear to be elongate in the direction of the general westward dip of the pegmatite.

Quartz-albite pegmatite.—The aplitic border zone of the pegmatite is a fine-grained rock composed of quartz and albite. A few small flakes of muscovite occur at right angles to the contact. The first few inches of the border zone are obscurely banded. The schist at the contact is highly quartzose.

Quartz-albite-muscovite pegmatite.—The quartz-albite-muscovite pegmatite ranges in texture from sugary to coarsely granitic. Quartz and albite are the dominant minerals; muscovite occurs in various quantities and ranges from an ⅛ in. to 2 in. in diameter. Tourmaline occurs in the rock. Near the contacts with schist in the centers of the two northern bulldozer trenches, the pegmatite is greatly altered, sheared, and iron-stained.

Quartz-spodumene-albite pegmatite.—The spodumene-bearing zone is quartz-albite-muscovite rock in which spodumene takes the place of some of the albite. In the finer-grained pegmatite, spodumene in crystals not more than 1 in. in length constitutes as much as 35 percent of the rock.

Some spodumene is associated with microcline-quartz-albite pegmatite and occurs as thin "logs" as much as 6 ft in length in 18 in. in width. Commonly these "logs" plunge at very low angles, but they may plunge at any angle or in any direction. The spodumene in the Beecher No. 2 pegmatite is strongly iron-stained and "rotten" near the surface.

Microline-quartz-albite pegmatite.—Microcline-quartz-albite pegmatite grades from masses of microcline several feet in length to medium- to coarse-grained rock consisting mainly of microcline, with a fine-grained groundmass of quartz and albite. In some places the rock is almost entirely quartz.

FAULTS

The Beecher No. 2 pegmatite is cut by a fault that strikes north to N. 20° W. and dips steeply to the west. The offset along this fault is not apparent at the surface, but was recognized in the trenches by 1 to 2 ft of gouge and badly sheared rock. Southward the fault seems to branch into small shears; northward it extends beyond the northernmost trench.

Another fault, striking S. 75° W. and dipping 80°–85° SE., extends westward from the main fault. There is a zone of iron-stained gouge several inches wide and considerable shearing along this fault, but there is no noticeable offset.

RESERVES

There are six spodumene bodies on the Beecher No. 2 and Longview claims that may have economic significance, but little of the spodumene can be economically recovered by hand-cobbing methods and milling is essential to its production. Geologic mapping indicates that the spodumene-bearing pegmatite has an area of 78,350 sq ft; this is equivalent to about 6,200 tons of rock per foot of depth. Visual estimates suggest that the spodumene content is between 10 and 15 percent. Absence of underground exploration precludes estimates as to the over-all shape or size of these deposits.

Analyses of U. S. Bureau of Mines samples indicate that the spodumene contains 5.23 to 6.75 percent of Li_2O; the arithmetical average is 6.04 percent. Eight channel samples taken and analyzed at the Rolla laboratories of the U. S. Bureau of Mines contained 0.03 to 2.18 percent of Li_2O. Grain counts, made on 92 channel samples and groups of samples, showed a range from 1 to 36 percent of spodumene. On the basis of the analyses and grain counts, the U. S. Bureau of Mines engineers estimated that two blocks of spodumene-bearing rock contained a total of 5,611 tons per foot of vertical depth with a lithia content of 0.68 to 0.83 percent (Clarke, unpub. rept., 1944).

BELLMARE CLAIMS (CUSTER DISTRICT)

by W. C. Stoll and W. E. Hall

The Bellmare No. 1 to No. 4 claims are 7 miles southeast of Custer, Custer County, in the NE¼ sec. 22, T. 4 S., T. 5 E., ¼ mile south of Custer State Park. The claims are owned by G. M. Parker, caretaker of Blue Bell Lodge, Custer State Park, who located them in 1939. These claims were examined by Hall and Stoll in October and November 1942, and by J. J. Norton and L. R. Page in May 1943.

BELLMARE NO. 1

The Bellmare No. 1 claim lies adjacent to the western boundary of Custer State Park. Two small cuts have been made on a pegmatite dike about 12 ft wide which strikes due west. The pegmatite is exposed for 60 ft east of the State Park fence. In the remainder of the claim quartzite and a small outcrop of fine-grained pegmatite are exposed. The exposed pegmatite consists of quartz and perthite with a few small mica books. The minable pegmatite body is small, but a little mica and feldspar could be produced. A small pile of mica books that were as much as 3 by 4 in. in diameter was seen by Stoll.

BELLMARE NO. 2

The Bellmare No. 2 claim is east of the Wildwood No. 3 claim. Pegmatite and quartzite crop out along the crest of a ridge. In 50 ft of pegmatite exposed at the southwest end of the claim less than 1 percent of muscovite in small books occurs in massive quartz, perthite, and fine-grained pegmatite. To the northeast the pegmatite is composed chiefly of fine-grained pegmatite, small perthite masses, and a very little muscovite.

BELLMARE NO. 3

The Bellmare No. 3 claim is on the southwest slope of a ridge just north of the Bellmare No. 4 claim. About 1,000 ft from the southeast end of the claim there are a few small cuts in fine-grained pegmatite, perthite, and quartz. The dike, as much as 15 ft in width, strikes northeast for about 400 ft. A small quantity of ruby mica, in books as much as 3 by 5 in., has been removed from these cuts.

BELLMARE NO. 4

The pegmatite on the Bellmare No. 4 claim strikes N. 20° E. for 1,500 ft. At the north and south ends it is scantily exposed by a series of shallow pits in weathered debris, but where the central part of the pegmatite is prominently exposed for 1,000 ft shows a little mica in place. The width and dip of the pegmatite are not known, for no contacts are exposed.

The pegmatite consists mainly of coarse-grained white perthite and massive rose and milky quartz. About 20 percent muscovite is present in the weathered outcrop. The mica is hard, clear, ruby muscovite. Some of it shows air- and red-stains. The books range in size from 1 by 1 to 3 by 5 in. Below the weathered surface a large proportion of the mica should be of punch and small sheet sizes.

BIG SPAR NO. 1 MINE (CUSTER DISTRICT)

by J. W. Adams

The Big Spar No. 1 mine of the Consolidated Feldspar Company is in the SW¼ sec. 21, T. 3 S., R. 4 E., about 2¼ miles west of the town of Custer, Custer County.

The mine is in a pegmatite body several hundred feet long and of unknown depth that strikes about northeast and dips northwestward at a high angle. Pre-Cambrian mica schist forms the footwall. The workings on the property consist of an open-cut 75 ft long, 20 to 30 ft wide, and as much as 50 ft deep.

Two poorly defined zones were observed in the open-cut; a wall zone of perthite-quartz-muscovite pegmatite grades into a central zone of perthite-quartz pegmatite. The wall zone consists chiefly of perthite with lesser amounts of quartz and some muscovite in scattered crystals. Accessory minerals are black tourmaline, iron garnet, and beryl. The core consists chiefly of gray perthite in large masses and in graphic intergrowth with quartz, masses of pale-rose quartz, patches of flaky muscovite, and isolated clusters of black tourmaline. Albite is present locally as small vuggy aggregates.

The economically valuable minerals of the pegmatite are feldspar, mica, and beryl. Probably only a few tons of the beryl has been recovered. In 1943, 148.85 lb of prepared sheet and punch mica were sold to Colonial Mica Corporation.

BLUE BONNET, STAR, AND MICA KING NO. 3 CLAIMS (CUSTER DISTRICT)

by J. W. Adams

The Blue Bonnet, Star, and Mica King No. 3 claims are adjoining properties located in sec. 33, T. 3 S., R. 5 E., about 4 miles southeast of the town of Custer, Custer County. The mining operations on all three claims appear to be in the same pegmatite. The Star claim is owned by Norman C. Spilde and William Quinn of Custer, the Blue Bonnet by Spilde, Quinn, and P. J. O'Connell, and the Mica King No. 3 by Consolidated Feldspar Company of Trenton, New Jersey. The Star and Blue Bonnet claims have been visited several times by geologists of the U. S. Geological Survey. In October 1942, Walter C. Stoll visited the property and the results of his examination are included in this description. The present writer examined both of these properties and the adjoining Mica King No. 3 claims.

DEVELOPMENT

The Star and Blue Bonnet claims were worked from May 1943 to January 1944 by William Quinn, who excavated one large open-cut and several small pits. Most of Quinn's work appears to have been done on the Star claim although probably both properties were worked. All production (except a few pounds) was attributed to the Blue Bonnet. The work done on the property prior to Quinn's operations was probably small. The date of operations at the Mica King No. 3 is not known, but all the properties were idle in 1944.

GEOLOGY

The Star and Blue Bonnet workings extend discontinuously for several hundred feet along the western end of a gently dipping pegmatite 6 to 10 ft thick and over 1,500 ft long. This pegmatite is generally conformable to pre-Cambrian schist and quartzite. It has an average strike of N. 65° W. and dip of 15° to 35° NE. Quartzite forms the hanging wall and schist the footwall of the pegmatite. The pegmatite caps a low ridge with a gentle north slope that is essentially a dip slope. The presence of the border zone over this surface (except where the pegmatite is covered by alluvium) indicates that very little of the upper part of the pegmatite has been eroded.

The pegmatite comprises two rock units in addition to the border zone. These units are a wall zone of quartz-albite-muscovite pegmatite, and a core of perthite-quartz pegmatite. In most places along the footwall, the quartz-albite-muscovite pegmatite zone is well defined and 2 to 4 ft thick, whereas along the hanging wall this unit is generally thin or present only as patches surrounded by perthite-quartz pegmatite. The unsymmetrical character of this pegmatite may be due to partial assimilation of the hanging wall zone by the pegmatite of the core, possibly as a result of the low dip of the pegmatite. Accessory minerals of the pegmatite include a manganese-iron garnet in crystals as much as 6 in. in diameter, biotite, apatite, and beryl.

The Mica King no. 3 claim adjoins the Star and Blue Bonnet claims on the northeast. Workings on this claim are at a lower altitude than those already described, but appear to be in the same pegmatite. The two cuts on the west end of the Mica King No. 3 reveal zoned pegmatite similar to that at the Star and Blue Bonnet. Another pit, 300 ft to the east, was evidently developed for feldspar. The pegmatite exposed in it is composed chiefly of perthite and quartz with occasional patches of scrap mica. Schist forms both the footwall and hanging wall, and the pegmatite appears to transect it.

MINERAL DEPOSITS

MICA

In 1943, 2,051.37 lb of sheet and 53.75 lb of untrimmed punch mica were sold to Colonial Mica Corporation from the Blue Bonnet and Star property. About

16 percent of this amount was large sheet, 1½ by 2 in. and larger. The mica occurs in pale- to dark-ruby, moderately to densely air-stained crystals as much as 8 in. in diameter. Most of the mica sold was of no. 2 inferior quality but some was of no. 1 and no. 2 qualities. The mica from the Star and Blue Bonnet did not have the proportion of no. 1 and no. 2 qualities required by Colonial Mica Corporation in 1944. Determinations of the power factor of specimens of this mica are given in the table below. Estimates of tonnages of rock moved during operations by Quinn show that approximately 1 lb of sheet mica was obtained per ton of rock. Some untrimmed punch mica and an unknown amount of scrap have been sold. No sales of mica from the Mica King No. 3 have been made to Colonial Mica Corporation.

BERYL

Small quantities of beryl have been recovered from the pegmatite, but the precise amount is unknown. Most of the beryl seen was in crystals less than 1 in. in diameter. A pale yellow-green crystal, collected from the edge of perthite-quartz pegmatite zone on the Star claim, showed an index of refraction (ω) of 1.568.

FELDSPAR

No record of feldspar produced is available. Perthite occurs in the entire pegmatite but is most abundant on the Mica King no. 3 claim.

RESERVES

Only a small part of the pegmatite has been mined but if a demand arose for the type of mica available at the Star and Blue Bonnet claims, a large quantity could readily be obtained by extension of the workings.

BONNIE LODE MICA PROSPECT (CUSTER DISTRICT)

by J. J. Norton

The Bonnie Lode claim was located in August 1943 by Francis J. Walsh and David W. Hunter, and was prospected for mica by Joseph Buckley in December of that year. The property was visited on December 16, 1943. The claim is in the NW¼ sec. 11, T. 5 S., R. 4 E., Custer County. It can be reached by road according to the following mileage schedule.

Miles	
0.0	Custer Post Office; south on U. S. Highway 85A.
10.1	Turn right.
11.4	Bonnie Lode claim.

The mica-bearing pegmatite on this claim is apparently the south end of one of the pegmatites, on the Mountain Beryl claim, described by W. C. Stoll (pp. 162–163). It strikes N. 15° W., and dips vertically or very steeply westward. The pegmatite is exposed along the strike for at least 425 ft. Its average thickness is about 4 ft on the Bonnie Lode claim but on the Mountain Beryl claim to the north it is as much as 10 ft thick. A vertical shaft near the south end of the dike had been sunk in pegmatite about 12 ft before the prospect was abandoned. The pegmatite in the shaft consists of quartz-albite-muscovite pegmatite, but perthite occurs in the rock to the north.

The mica is white to pale ruby, moderately air-stained, and of fairly good quality. The mica is tied and wavy, however, and the recovery of sheet from the crude mica is very low. Although 2 percent or more of the rock may be recoverable mica, the sheet mica recovered probably would not cover rifting and trimming costs comparable to those of 1942–45.

BOB INGERSOLL MINE (KEYSTONE DISTRICT)

by J. B. Hanley

The Bob Ingersoll mine, 2 miles northwest of the town of Keystone, is in the NE¼NW¼ sec. 6, T. 2 S., R. 6 E., Pennington County. It can be reached from Keystone by a mine road, 1.5 miles long, that leaves U. S. Highway 16 at a point 1.35 miles north of Keystone, or by an improved mine road, 0.8 of a mile long that turns north from the Keystone-Hill City county road at a point 1.65 miles west of Keystone.

The mine is on the Bob Ingersoll claim, one of three adjoining patented claims. The other claims are the Ben Butler and the Horace Greeley. This group has been owned since 1933 by the Black Hills Keystone Corporation, of which Mr. William K. Wallace, 530 Fifth Avenue, New York, is president, and Mr. A. I. Johnson of Keystone is resident manager. The claims were owned by the Harney Peak Tin Company until about 1895, and then by the Pa-Ha-Sa-Pa Mining Company. From 1917 to 1933 Mr. W. S. Dewing and Mr. Dennis Henault were the owners. The mine was operated by the Black Hills Keystone Corporation intermittently from 1933 to January 6, 1945.

The first published reference to the Bob Ingersoll mine is in a paper on columbite by Blake (1884, pp. 340–341). The mineral paragenesis of the pegmatites was discussed by Landes (1928, pp. 519–558), and the mining and economic factors of the mine have been described by Lincoln (1934, pp. 202–203), and by Cummings, Harris, and Lincoln (1937, pp. 40–43).

Five pegmatites (pl. 6) crop out on the Bob Ingersoll claim. Two of them, called Dike No. 1 and Dike No. 2, have been extensively mined. The other three, of which one is not numbered, have not been developed, although the exploration work in 1945 and 1946 was directed at these pegmatites. Dike No. 1 is about 415 ft S. 70° E. from Dike No. 2, and the surface exposure is 135 ft higher. Dike No. 3 is 130 ft east of Dike No. 1, and Dike No. 4 is 100 ft N. 70° E. from Dike No. 2.

The Bob Ingersoll mine has been the largest producer of lepidolite in the Black Hills, and one of the largest producers of beryl and amblygonite. The total mineral production of the mine since 1922, including both Dike No. 1 and Dike No. 2, is given in the table below.

A preliminary investigation of the Bob Ingersoll mine was made by W. C. Stoll and W. E. Hall in November 1942, and a geological map was prepared. A detailed investigation was started in November 1944 and carried on through July 1945 by Hanley assisted at various times by M. P. Erickson, J. W. Adams, T. A. Steven, and A. F. Trites, Jr. Maps of the surface and underground workings of the pegmatites on a scale of 1 in. to 20 ft were prepared.

Valuable assistance was given by the officials of the Black Hills Keystone Corporation, particularly Mr. A. I. Johnson, during the U. S. Geological Survey investigations.

DIKE NO. 1

Dike No. 1 has been mined by a glory hole, 120 ft long and 80 ft wide, that extends in depth to the main adit level at 5,039 ft altitude (pls. 6, 7). This level is connected with the surface by a 194-ft adit. A 50-ft vertical winze extends from the main level to the 4,990-ft level, and also connects with a sublevel at 5,020 ft altitude.

GEOLOGY

Dike No. 1, a steeply plunging, pipelike body, is exposed in the glory hole for a length of about 90 ft, and a width of about 70 ft. Because of the extensive mining operations the exact length and width cannot be determined. Prior to mining, however, it was exposed as a cliff at least 50 ft high. The long axis of the body trends N. 5° W., and the general dip is steep and to the northeast. The hanging-wall contact dips 70°–85° NE., and at the surface the footwall contact dips 80°–85° NE. The dip of the footwall contact is 50°–60° at the 5,039-ft level, and is less at the 4,990-ft level. Local variations in dip are common, and are caused by rolls in the contacts. The dike probably plunges 65°–70° SSE.

The contacts with the biotite-garnet-staurolite schist are sharp but irregular, with many major and minor rolls. One sharp schist prong in the hanging wall is exposed in the glory hole, and a broad roll is exposed in this contact at the adit level. Several sharp minor rolls are exposed in the footwall in the underground workings. These rolls commonly project about 4 ft into the pegmatite, and have a relatively broad, circular inner end, about 1 ft in diameter, which is connected with the main schist mass by a layer of schist only 3 to 6 in. thick. In general, the contact of the pegmatite with the schist is parallel to the schistosity.

A fault zone, 1 to 15 ft wide, is exposed at the north end of the glory hole and at the north end of each of the three underground levels. This fault zone strikes about N. 70° W., and dips 80° SW., but the individual faults in the zone range in strike from N. 67° W. to N. 83° W., and in dip from 57° SW. to 88° SW. The cross-faults within the zone strike from N. 15°–60° W., and dip from 80° SE. to vertical. The maximum width of this zone is exposed at the 4,990-ft level, and the minimum width is in the glory hole. The horizontal displacement ranges from 1 to at least 2.5 ft. The exact vertical displacement is not known.

Dike No. 1 contains the following zones: (1) a border zone of quartz-cleavelandite-muscovite pegmatite, (2) a wall zone of cleavelandite-quartz-muscovite pegmatite,

Mineral production of the Bob Ingersoll mine, 1922–44 inclusive, in tons[1]

Year	Amblygonite	Lepidolite	Beryl	Potash feldspar (perthite)	Soda feldspar (cleavelandite)	Spodumene	Scrap mica
1922	15.0						
1923	37.6						
1924	151.2						
1925	14.3	14.5					
1933	55.6		53.6				
1934		15.0	11.1	43.1		26.0	24.6
1935							
1936		2.0					
1937–1938 [2]		162.3	3.3	540.6		13.8	
1938–1939 [2]		960.6			66.4		122.9
1939–1940 [2]		852.0	33.4				239.3
1940–1941 [2]	19.2	1,325.3	46.7	104.5	38.5	3.3	400.6
1941–1942 [2]	84.5	1,522.0	52.9	1,594.0		8.6	329.7
1942–1943 [2]	184.3	[3] 1,269.5	59.1	784.9		19.2	421.2
1943–1944 [2]	38.0	[4] 1,584.3	49.3	176.0		1.1	80.1
1944–1945 [5]	[6] 7.0	383.9	99.5	1,227.0		5.0	140.7
Total	606.7	8,091.4	408.9	4,470.1	104.9	77.0	1,759.1

Additional production includes:
Pegmatite rich in gem tourmaline:
1937–38, 2.0 tons.
1938–39, 5.0 tons.
1939–40, 1.8 tons.
Cassiterite production prior to 1943 totaled about 1 ton. In 1945 Metals Reserve Company bought 1,063.1 lb of tin concentrates.
Tantalite produced prior to 1943 by the Black Hills Keystone Corporation totaled about 1,500 lb (46 percent Ta_2O_5). On hand December 31, 1944 were 2,165 lb of microlite concentrates, 1,004 lb columbite-tin concentrates, and 556 lb of columbite.

[1] Based on the production figures supplied by A. I. Johnson, resident manager.
[2] For fiscal year April 30 to April 30.
[3] 4,515 tons of crude lepidolite milled 1942–1943 to produce 1,269.5 tons of lepidolite.
[4] 7,281 tons of crude lepidolite milled 1943–1944 to produce 1,584.3 tons of lepidolite.
[5] May 1 to December 31, 1944.
[6] 334.5 tons of amblygonite was stockpiled at the mine on December 31, 1944.

(3) a discontinuous intermediate zone of perthite pegmatite, (4) a second, discontinuous intermediate zone of quartz-cleavelandite-amblygonite pegmatite, (5) a third, discontinuous intermediate zone of quartz-cleavelandite pegmatite, and (6) a core of quartz-cleavelandite-lepidolite pegmatite. All three intermediate zones and the core have been nearly mined out, and the structure and relationship of these zones are consequently not well shown. The wall zone is thinner in the upper part of the dike.

Quartz-cleavelandite-muscovite pegmatite.—The quartz-cleavelandite-muscovite pegmatite of the border zone has a different mineralogic composition at different levels in the dike. The common facies are quartz-cleavelandite rock with accessory muscovite, and cleavelandite-muscovite rock with accessory quartz. This zone has not been mapped except where for structural reasons its apparent thickness is great enough so that it can be shown clearly. The rock in the zone has an average grain size of less than ¼ in., and ranges in thickness from less than 1 in. to 4 in.

Cleavelandite-quartz-muscovite pegmatite.—The cleavelandite-quartz-muscovite pegmatite of the wall zone is composed of white cleavelandite (75 percent), quartz (10 percent), and clear to light-green muscovite (5 to 10 percent) with accessory columbite, cassiterite, green tourmaline, and other minerals. Parts of this zone are composed entirely of cleavelandite, but muscovite is abundant in other parts. The grain size is large and muscovite books as much as 1 ft in length are not uncommon. The books are wedged, tied, and have "A" structure. Only a very small quantity of relatively clear, flat sheets has been produced. Quartz is mixed with muscovite, and with abundant cleavelandite masses several feet across. Columbite, commonly in thin plates as much as 2.5 ft long and 2 ft wide, and green tourmaline, in crystal aggregates as much as 4 ft long and 1.5 ft wide, occur near the crest of the dike. The muscovite from this zone contains many green tourmaline crystals, a few of them of gem quality.

The wall zone is at least 2 ft thick along the hanging wall in the upper part of the dike, and as much as 8 ft thick along the footwall in the lower part of the dike. The thickness on the footwall in the glory hole is reported to have been 4 to 5 ft. The structure of this zone is shown in the sections in plate 7.

Perthite pegmatite.—The perthite pegmatite of the first intermediate zone is composed predominantly of perthite (90 percent) with some quartz (5 percent) and cleavelandite (4 to 5 percent). This type of pegmatite is exposed only in the pinnacle in the glory hole, and in a small area on the southeast side of the lower level of the glory hole, and is found only in the upper part of the dike. Section G–G′ in plate 7 shows the probable shape and structure of the zone. The pegmatite of the zone probably grades into the quartz-cleavelandite-amblygonite pegmatite and the quartz-cleavelandite pegmatite in depth, but the part of the dike in which this gradation might occur has been mined out.

Quartz-cleavelandite-amblygonite pegmatite.—The quartz-cleavelandite-amblygonite pegmatite of the second intermediate zone is composed of quartz, white cleavelandite, and gray amblygonite with accessory perthite, beryl, and cassiterite. The zone is exposed only in the pinnacle in the glory hole. Some of the amblygonite masses are as much as 6 ft in diameter, and even larger masses are reported to have been found. The zone represents a transition between the perthite pegmatite and the quartz-cleavelandite-lepidolite core, and may grade into the quartz-cleavelandite pegmatite in depth. Section G–G′ in plate 7 shows the possible shape and relationship of this zone.

Quartz-cleavelandite pegmatite.—The quartz-cleavelandite pegmatite of the third intermediate zone is composed of quartz (80 percent) and white cleavelandite (15 percent) with accessory white beryl, green and pink tourmaline, lepidolite, and a minor quantity of muscovite. Cleavelandite commonly occurs in flattened pods in which the individual plates have grown at right angles to a central parting. Beryl occurs in subhedral to euhedral crystals about 1 ft in diameter at the lower level of the glory hole. The index of refraction of the ordinary ray of this beryl ranges from 1.583 to 1.585 ±0.003. One mass of crystals containing about 100 tons of beryl was found in the glory hole in 1944. The mass extended through this zone, the wall zone, and the border zone to within 1 in. of the hanging-wall contact. Lepidolite occurs in small flakes erratically distributed throughout the part of this zone that is adjacent to the core. Green tourmaline and muscovite occur in small quantities adjacent to the wall zone.

The zone is most extensive on the hanging-wall side of the pegmatite, but near the northern end it occurs on both the footwall and hanging-wall sides and nearly encloses the core. It does not occur on the footwall side of the pegmatite in the underground workings. It is well exposed at the adit and 5,020-ft levels. Sections K–K′ and G–G′ in plate 7 show its shape and structure.

Quartz-cleavelandite-lepidolite pegmatite.—The quartz-cleavelandite-lepidolite pegmatite of the core is composed mainly of quartz (40–50 percent), cleavelandite (40–45 percent), and lepidolite (5–20 percent) with accessory green and red tourmaline, microcline, beryl, microlite, and other minerals. The core has been mined out except for a few pillars in the underground workings and a thin veneer on the pinnacle in the glory hole. The middle of the core had a higher lepidolite content than the edges, and large masses of nearly pure lepidolite have been found. The lepidolite is in small purple flakes about ⅛ in. across and occurs chiefly in felted aggregates. The outer parts of the core contain brown microlite as small, rounded masses associated with quartz, cleavelandite, and lepidolite. White microcline occurs in anhedral crystals as much as 2 ft in length. Anhedral or subhedral crystals of bright blue or pale pink beryl commonly occur with the lepidolite. The index of refraction of the ordinary ray of the blue beryl is 1.592±0.003, of the pink beryl 1.586 ±0.003, and of the white beryl 1.585±0.003. Light bluish-white beryl also has been found. Green or pink tourmaline occurs near the outer edges of the core, and where the core is in contact with the wall zone a sharp line of demarcation between the two zones is formed by a ½-to 2-in. band of green tourmaline crystals. This band occurs at the contact of the core with the other zones, but is not as conspicuous as at the contact with the wall zone.

The shape of the core and its relation to the other zones is shown in the sections in plate 7. Probably the bottom of the core is near the 4,990-ft level as only a few small pods are exposed at the back of this level. The maximum thickness of the core below the glory hole probably was slightly less than 30 ft.

MINERAL DEPOSITS

Nine minerals of economic value have been produced from Dike No. 1. They are perthite, cleavelandite, muscovite, amblygonite, lepidolite, beryl, microlite, columbite-tantalite, and cassiterite. These minerals are found in several deposits in the dike. Some of the deposits contain only one economically valuable mineral, such as perthite (potash feldspar), but others contain several, such as lepidolite, beryl, and microlite, or muscovite, columbite-tantalite, and cassiterite.

FELDSPAR

The main feldspar deposit is in perthite pegmatite of the first intermediate zone. The perthite is a white feldspar that has very few mineral impurities and is reported to contain a high percentage of alumina. This deposit has been mined out except for the small part exposed in the pinnacle in the glory hole. The unmined part has a length of about 35 ft, an average width of about 14 ft, and a probable depth of 15 ft. The perthite content is visually estimated to be 90 percent.

MICA, COLUMBITE, AND CASSITERITE

Muscovite occurs in the wall zone as colorless to light-green books more than a foot long. They are generally are wedged or tied, and have conspicuous "A" structure. Some books contain a few, slightly air-stained flat sheets, but are largely of scrap quality. This mica deposit ranges in thickness from 2 ft along the upper part of the hanging wall to 8 ft along the footwall in the lower part of the pegmatite. The wall zone is richest in mica in the northern end of the dike, and in the narrower parts of the deposit. The muscovite mica content of the wall zone is visually estimated as 5 to 10 percent but locally as much as 75 percent of mica.

Small quantities of columbite and cassiterite are found in the wall zone. The two minerals can be separated from the waste material and recovered as byproducts by milling. The content of columbite and cassiterite in the zone is very low, and is estimated to be less than 1 pound per ton. Small quantities of these minerals may have been recovered from other zones of the pegmatite.

AMBLYGONITE

The amblygonite deposit is in the second intermediate zone. The amblygonite is light gray and is in roughly spherical masses. Those observed in the glory hole were as much as 6 ft in diameter. According to Mr. Johnson, one amblygonite mass had a surface length of about 30 ft, an average width of about 4 ft, and extended from the surface nearly to the adit level. The unmined part of the deposit contains only a very small quantity of rock and no estimate of the amblygonite content is possible. Perthite and beryl are associated with the amblygonite. Perthite is most abundant in the upper part of the deposit and is estimated to constitute 5 to 10 percent of the rock.

LEPIDOLITE AND MICROLITE

Lepidolite occurs in the core as aggregates of small lilac or pale purple flakes in random orientation, mixed intimately with cleavelandite and quartz. Near the center of the deposit masses of nearly pure lepidolite were mined, and sold without milling. The lower-grade material in the outer part of the deposit has been recovered by flotation.

This deposit apparently pinches out near the 4,990-ft level, as only a few pods are exposed in the back of the level. The lepidolite content of the deposit is visually estimated at 5 to 20 percent, and production figures indicate that the grade of the richer part of the deposit was about 25 percent. The unmined part of the deposit is predominantly lower-grade ore at the outer edges of the deposit.

Microlite occurs with the lepidolite as rounded, brown grains, which are about 0.025 in. across. This mineral was discovered here by L. R. Page in 1943, in the lower-grade part of the deposit. It can be recovered as a byproduct in the milling of the lepidolite.

BERYL

Beryl is concentrated in the quartz-cleavelandite pegmatite, the quartz-cleavelandite-amblygonite pegmatite, and the quartz-cleavelandite-lepidolite pegmatite. The quartz-cleavelandite pegmatite is probably richer in beryl than the other zones, but as most of the pegmatite has been mined the beryl content cannot be established definitely. Production figures and mineral counts of the walls of some of the workings, made in 1943 by Page, both indicate that the beryl content of the quartz-cleavelandite pegmatite ranges from 0.5 to 1 percent.

DIKE NO. 2

Dike No. 2 has been mined by two glory holes, one 40 ft long and 30 ft wide, and the other 40 ft long and 18 ft wide (pls. 6, 7). The larger glory hole has a sublevel at 5,030 ft altitude. Both glory holes connect with the main level at 4,990 ft altitude. The main level is formed by an open-cut and a series of drifts in addition to the lower parts of the glory holes. A 50-ft shaft, inclined at 57°, connects the lowest level at 4,950 ft altitude with the main level.

GEOLOGY

Dike No. 2, a blunt-nosed, pipe-shaped body with a narrow southwestern extension, is exposed at the surface for 110 ft in length and as much as 80 ft in width. Prior to mining it was exposed throughout a vertical height of 96 ft. The pegmatite outcrop trends N. 20° E., and the general dip is moderately steep to the southeast. The dip of the footwall contact is 50°–60° SE. The dip of the well-exposed, hanging-wall contact is about 50° SE. at the surface and 80° SE. at the 4,990-ft level. Local variations in dip, caused by minor rolls in the contact, are not uncommon. At the northeast end of the pegmatite the apparent dip is 30°–40° SW. The pegmatite probably plunges 53° in a S. 65° E. direction.

Contacts with the enclosing biotite-garnet-staurolite schist generally are sharp, and the schistosity appears to parallel the contact. Locally the hanging-wall contact cuts across the schistosity as in the north end of the hanging-wall drift on the 4,990-ft level, and in the back at the 4,950-ft level. The pegmatite cuts across the schist structure also at the narrow southwestern end.

A fine-grained feldspar-rich rock is exposed in contact with the pegmatite along parts of the footwall. This rock has almost the same mineral composition as the border zone of the pegmatite, but contains bands of biotite-rich material which may represent original schist structures. The contact of the pegmatite with this rock is obscure. This type of rock occurs only beneath the footwall contact where the pegmatite cuts across the schist structure (see pl. 7, sections B–B′, C–C′, and D–D′). The schist beneath this rock commonly is highly jointed, and in places is sheared.

Dike No. 2 contains the following zones: (1) a border zone of fine-grained quartz-albite-muscovite pegmatite, (2) a wall zone of medium- to coarse-grained quartz-albite- muscovite pegmatite, (3) a discontinuous intermediate zone of quartz-albite pegmatite, (4) a second intermediate zone of muscovite-cleavelandite-quartz pegmatite, (5) a third intermediate zone of perthite-quartz pegmatite, (6) a fourth intermediate zone of quartz-cleavelandite-amblygonite-perthite pegmatite, and (7) a core of quartz-spodumene pegmatite. All zones except the border zone are discontinuous and intergrade in depth. The first intermediate zone forms a nearly complete shell around the pegmatite. The perthite-quartz pegmatite, and the quartz-cleavelandite-amblygonite-perthite pegmatite are lenticular masses above and outside the quartz-spodumene pegmatite core. The perthite-quartz pegmatite, and to a lesser degree the quartz-cleavelandite-amblygonite-perthite pegmatite, appear to have taken the place of parts of the outer zones.

Quartz-albite-muscovite pegmatite.—The quartz-albite-muscovite pegmatite of the border and wall zones is composed mainly of grayish quartz (60 percent), white albite (30 percent), and white to light-green muscovite (5 percent). Some of the albite is cleavelandite. Black tourmaline, white beryl, and columbite occur in minor quantities. The outcrops at the northeast end of this pegmatite contain large quantites of perthite, in crystals as much as 2 ft across, but the interstitial material is quartz, albite, and muscovite. The proportion of cleavelandite increases with depth, and in the walls of the 4,950-ft level the albite is predominantly cleavelandite. The average grain size of the cleavelandite is about 2 in., but muscovite, beryl, and black tourmaline commonly occur in crystals 6 in. or more in diameter. With depth, the grains increase in size, and the muscovite books from near the surface are smaller than those from the 4,950-ft level.

The border zone ranges from a knife edge to 2 in. in thickness. The wall zone in general is 4 to 4½ ft thick, but locally the wall zone may be thinner because of corrosion by other pegmatite zones or it may be thicker because of structural changes.

Quartz-albite pegmatite.—The quartz-albite pegmatite in the first intermediate zone is composed mainly of grayish quartz (75 percent), and white albite (20 percent), some of which is cleavelandite. Columbite, lithiophilite-triphylite, and muscovite occur in minor quantites. This zone is almost completely absent in the upper part of the dike, and its probable position is indicated only by the occurrence of lithiophilite-triphylite patches in the outer part of the perthite-quartz pegmatite. In depth the albite is mostly cleavelandite, and at the 4,950-ft level cleavelandite is the only feldspar. The average grain size is about 3 in. at the surface, and increases in depth. The accessory minerals at the 4,950-ft level are much coarser than at the surface, and columbite plates are as much as 2.5 ft long and 1.3 ft wide at this level. The lithiophilite-triphylite patches in the upper part of the dike are about 4 ft long and 1 ft wide. These patches are smaller in depth, and occur only sparsely in the lower levels.

The average thickness of this pegmatite is 5 ft, but locally the zone is absent.

Muscovite-cleavelandite-quartz pegmatite.—The muscovite-cleavelandite-quartz pegmatite of the second intermediate zone is composed chiefly of muscovite (60 percent), cleavelandite (20 percent), and quartz

(15 percent). The accessory minerals are columbite, lithiophilite-triphylite, and uranium minerals. The diagnostic feature of this pegmatite is the occurrence of muscovite as felted aggregates of yellowish-green flakes that range in diameter from ⅛ to 1 in. The cleavelandite, quartz, and the accessory minerals (except columbite) fill the spaces between the mica flakes. Columbite in thin plates a few inches in length is scattered through the zone.

This zone occurs only on the footwall side of the dike between the quartz-albite pegmatite and both the perthite-quartz pegmatite and the quartz-cleavelandite-amblygonite-perthite pegmatite. It is exposed at the surface and in the workings from the east side of the northwest drift on the 4,990-ft level to the middle of the small glory hole, and from the surface to the 5,002-ft level at the west corner of the larger glory hole.

The thickness of this zone ranges from 2 to 5 ft.

Perthite-quartz pegmatite.—The perthite-quartz pegmatite in the third intermediate zone is mainly perthite (85 percent) with quartz (10 percent). Cleavelandite, muscovite, lithiophilite-triphylite, and apatite are the accessory minerals.

Large masses of anhedral to subhedral perthite crystals are cut by numerous thin quartz stringers. The perthite masses also contain many patches of quartz, cleavelandite, and muscovite, and of muscovite and cleavelandite aggregates. Near the outer edges in the upper part of the dike, there are also patches of lithiophilite-triphylite and muscovite. They are especially common in the northeastern end of the dike and occur in the probable position of the quartz-albite pegmatite.

This pegmatite is exposed as a "hood" or capping above the quartz-cleavelandite-amblygonite-perthite pegmatite and the quartz-spodumene pegmatite, and in the upper part of the dike it cuts across all the other zones except the border zone. The shape of this zone is therefore extremely irregular. Sections A–A′ and B–B′ on plate 7 show the probable shape and the relationship of this zone to the other zones. In general it encloses the upper part of the quartz-cleavelandite-amblygonite-perthite pegmatite zone and the quartz-spodumene pegmatite core.

Quartz-cleavelandite-amblygonite-perthite pegmatite.—The quartz-cleavelandite-amblygonite-perthite pegmatite of the fourth intermediate zone is composed chiefly of quartz (30 percent), cleavelandite (30 percent), amblygonite (10 percent), and perthite (10 percent), with spodumene and beryl as major accessory minerals. Lepidolite, tourmaline, cassiterite, and many other minerals occur as minor accessories. The grain size is extremely varied; the typical size is about 2 in. One beryl crystal at least 18 ft in length and 6 ft in diameter lay partly in this zone (fig. 5). Amblygonite crystals a few feet long have been found in the upper part of this zone. Spodumene crystals 1 ft or more in length are distributed uniformly throughout this pegmatite.

This zone forms a lenticular mass near the center of the dike, and wraps around the quartz-spodumene core both in plan and in section. Sections A–A′, B–B′, C–C′, and D–D′ on plate 7 show the probable shape of this zone, and the relationship to the other zones. The maximum thickness is about 25 ft.

Quartz-spodumene pegmatite.—The quartz-spodumene pegmatite in the core is composed chiefly of quartz (80 percent) and spodumene (10 percent) with accessory cleavelandite. The spodumene crystals are as much as 10 ft long, 2 ft wide, and 4 in. thick. Many of them are altered green or pink, and very friable. Cleavelandite occurs in small masses adjacent to the spodumene crystals, and typically forms a rim, 1 to 2 in. thick, around the crystals.

MINERAL DEPOSITS

Seven minerals of economic importance have been produced from Dike No. 2—perthite, cleavelandite, muscovite, amblygonite, spodumene, beryl, and columbite-tantalite. Perthite is found in the third intermediate zone, and amblygonite in the fourth. Muscovite occurs in the wall zone and in the second intermediate zone. Spodumene is in the fourth intermediate zone and the core. Beryl has been mined from the wall zone and the fourth intermediate zone. Columbite occurs in small quantities in the wall zone with the mica deposit, and tantalite in the fourth intermediate zone.

FELDSPAR

The main feldspar deposit is in the third intermediate zone. The feldspar is a whitish perthite that is reported to have a high alumina content. It is cut by many thin quartz stringers about ½ in. thick. The perthite occurs in large masses of anhedral to subhedral crystals that can be recovered easily by hand-cobbing. Patches of quartz, cleavelandite, and muscovite; muscovite and cleavelandite aggregates; and lithiophilite-triphylite and muscovite are scattered through the perthite. These patches typically are about 4 ft long and less than 1 ft thick. Near the nose of the dike this zone contains an appreciable quantity of muscovite, quartz, and cleavelandite.

The zone is extremely irregular in shape, and occurs as a capping above the fourth intermediate zone and the core. It also cuts across all the other zones except the border zone in the upper part of the dike. It is exposed for a length of about 60 ft and a width of about 35 ft at the surface. Along the northern part of the hanging wall it extends at least 80 ft in depth to the main level, but along the footwall it extends only 40 ft in depth. About half has been mined. The perthite content of the deposit is visually estimated to be 85 percent.

In addition to the feldspar in the perthite-quartz pegmatite a smaller quantity of recoverable perthite occurs in the wall zone near the nose of the dike and in the fourth intermediate zone. The perthite content in this fourth intermediate zone is visually estimated to be about 10 percent.

MUSCOVITE

Muscovite occurs in the wall zone and in the second intermediate zone. The muscovite of the wall zone deposit is in larger books at depth than at the surface, with books as much as 1 ft long at the 4,950-ft level. Most of it is wedged, tied, reeved, has "A" structure, and is only of scrap quality. Muscovite occurs throughout the wall zone, but is concentrated a short distance in from the outer edge of the zone. The average thickness of the wall zone is about 4 ft, and the average mica content is visually estimated to be 5 percent. White beryl is associated with the muscovite, concentrated near the contact with the border zone and also along the inner edge of the zone.

The muscovite of the intermediate zone deposit occurs in felted, interlocked aggregates of yellowish-green flakes ⅛ to 1 in. across. The deposit has a surface length of about 45 ft, an average thickness of 3 ft, and is exposed from an altitude of 5,030 ft at the surface down to 5,002 ft in the larger glory hole. About half of the deposit has been mined out. The muscovite content is visually estimated to be 60 percent. Columbite and uranium minerals constitute less than one pound per ton but can be recovered as byproducts.

AMBLYGONITE

The amblygonite deposit is in the fourth intermediate zone where amblygonite occurs as rounded masses or nodules a few feet across, and as smaller masses intergrown with quartz and cleavelandite. Locally, the second type is called "amblygonite conglomerate." The amblygonite can be recovered only by milling. The intergrowth has a typical grain size of about 1 in. Associated with the amblygonite are spodumene, beryl, perthite, cassiterite, and columbite-tantalite.

In size and shape this deposit resembles the quartz-cleavelandite-amblygonite-perthite pegmatite. It is exposed for a length of 100 ft and a maximum width of 23 ft at the 4,990-ft level, and extends at least down to the 4,950-ft level. It has been mined out almost completely above the 4,990-ft level. The amblygonite content is visually estimated to be about 10 percent, and about half of this mineral is in the intergrowths.

In addition to amblygonite this deposit contains spodumene, perthite, and beryl in minable quantities, and small quantities of columbite-tantalite and cassiterite that can be recovered as byproducts in milling of the amblygonite.

SPODUMENE

The spodumene occurs in the fourth intermediate zone and the core, in crystals that are as much as 10 ft long, 2 ft wide, and 4 in. thick. In the intermediate zone the average size of the spodumene crystals is 1 ft or more in length and 4 to 8 in. in width. Many of the crystals in the core are altered and "rotten." The unaltered spodumene is grayish-white, but highly altered crystals have been replaced by a light-green clay mineral or by a pink mica that probably belongs to the lepidolite-muscovite series.

The spodumene deposit is coextensive with the fourth intermediate zone and the core. It is exposed at the 4,990-ft level for a length of 100 ft and a maximum width of 30 ft. Above this level it has been practically mined out. The quartz-spodumene pegmatite of the core is visually estimated to contain 10 percent spodumene, and the quartz-cleavelandite-amblygonite-perthite pegmatite of the intermediate zone to contain 5 to 10 percent spodumene.

BERYL

Beryl occurs in two deposits—one in the wall zone and the other in the fourth intermediate zone. The beryl of the wall-zone deposit is white to cream-colored, and occurs in subhedral to euhedral crystals. The index of refraction of the ordinary ray ranges from 1.578 to 1.582 ± 0.003. The beryl is concentrated between the border zone and the mica concentration, and between the mica concentration and the intermediate zones. The average content of the deposit is estimated roughly as 0.5 percent beryl.

The beryl in the intermediate-zone deposit is white to pale blue, and occurs in anhedral crystals. The index of refraction of the ordinary ray is 1.584 ± 0.003. The beryl appears to be distributed uniformly throughout the deposit, although a few large crystals do occur. The largest crystal, 18 ft long and 6 ft in diameter, extended from the inner edge of the wall zone into the fourth intermediate zone at a place where the quartz-albite pegmatite zone was not present (fig. 6). The average content is estimated to be about 1 percent beryl.

Production records indicate that the beryl content of the two deposits in this dike is about 0.5 to 1 percent.

DIKE NO. 3

Dike No. 3, about 130 ft east of Dike No. 1, has been explored by one small open-cut, 11 ft long, 7 ft wide, and 3 to 4 ft deep, on the southwest side near its southeast end, and by several small prospect holes.

GEOLOGY

Dike No. 3, as shown on plate 6, is exposed as a knob that projects above the surrounding land surface as much as 30 ft. The pegmatite is lenticular with a prong about 25 ft long and 5 ft wide near the middle of its northeast side. The pegmatite is 114 ft long and as much as 30 ft wide. It trends N. 43° W., and in general dips 85°–88° SW. The southeast end plunges 63° S. 8° E.

Contacts with the enclosing quartz-rich biotite schist are sharp and tight. The outcrop has a 1- to 3-ft veneer of schist along the hanging-wall contact and a thinner veneer along the footwall contact. At the northwest end the schist is well exposed adjacent to the pegmatite.

Dike No. 3 has a border zone of quartz-muscovite pegmatite less than 1 to 2 in. thick; a wall zone of quartz-cleavelandite-muscovite pegmatite, and a core of quartz-perthite-cleavelandite pegmatite. These zones appear to be parallel to the walls of the pegmatite (section L–L′ on plate 7).

Quartz-muscovite pegmatite.—The quartz-muscovite pegmatite of the border zone is composed chiefly of quartz (70 percent) and muscovite (20 percent) with accessory cleavelandite. It is very fine grained.

Quartz-cleavelandite-muscovite pegmatite.—The quartz-cleavelandite-muscovite pegmatite of the wall zone is composed mainly of grayish quartz (50 percent), white cleavelandite (30 percent), and muscovite (15 percent), with minor quantities of perthite in subhedral to euhedral crystals. The zone has an average grain size of 2 to 3 in., but the perthite crystals are as much as 1.5 by 2 ft. The grain size increases toward the center of the dike. Throughout the pegmatite the zone has an average thickness of 5.5 ft.

Quartz-perthite-cleavelandite pegmatite.—The quartz-perthite-cleavelandite pegmatite of the core is composed of quartz (30 percent), white to pale-pink perthite (40 percent), and white cleavelandite (25 percent), with accessory muscovite. Muscovite occurs in books 1 ft in diameter, around quartz patches. This pegmatite differs from the wall zone in being coarser grained, and in having a higher proportion of perthite.

MINERAL DEPOSITS

Dike No. 3 contains two economic minerals—feldspar and muscovite. The feldspar, perthite, occurs in the core, and the muscovite in the wall zone.

PERTHITE

The perthite of the feldspar deposit occurs as white to pale-pink masses as large as 9 ft long and 4 ft wide. The deposit has a strike length of 100 ft and an average width of about 10 ft. It may extend more than 20 ft in depth. The feldspar content is visually estimated to be 40 percent.

Some of the perthite crystals in the wall zone could be recovered by hand cobbing. The feldspar content of the wall zone is visually estimated to be about 5 percent.

MUSCOVITE

Muscovite occurs throughout the wall zone as books that range in size from a few inches to about 1 ft. It is generally wedged, reeved, has "A" structure, and therefore probably would yield only scrap mica. This deposit may extend to a depth of at least 50 ft below the present surface. Its muscovite content is visually estimated to be about 15 percent.

Dike No. 3 probably contains only a small quantity of perthite and muscovite, although in mineralogy and structure it strongly resembles Dikes No. 1 and No. 2 at the surface. Further development work might lead to the discovery of lithia-bearing minerals in Dike No. 3.

DIKE NO. 4

Dike No. 4, about 100 ft N. 70° E. of Dike No. 2, has been explored by an open-pit 32 ft long, 10 ft wide, and 8 ft deep.

GEOLOGY

Dike No. 4, as shown on plate 6, is a lenticular body about 120 ft long that has a bulbous northwestern end and a narrower southeastern part. Its width is 52 ft near the northwestern end and 25 ft in the southeastern half. The northwestern part of this pegmatite is exposed as a steep-sided knob, but the southeastern part crops out at the same level as the surrounding schist. The knob has a maximum relief of 38 ft on the northwest side, and a minimum relief of 7 ft on the southeast side.

Contacts with the enclosing biotite-garnet-staurolite schist are well exposed along the hanging wall and along part of the footwall, but the ends of the pegmatite are not exposed. In general the pegmatite strikes N. 17° W. and dips to the southwest at a steep angle. Throughout the wider part both the footwall and the hanging-wall contacts dip 70°–85° SW., but in the narrower part the hanging-wall contact dips 70°–85° SW., and the footwall contact dips 50°–60° NE. The footwall contact reverses in dip on the side of the knob, and the dip to the northeast is progressively more gentle nearer the top of the knob. The internal structure dips steeply to the southwest throughout the pegmatite, as shown in section F–F′, plate 7. The pegmatite probably plunges gently southeast, and the narrower part probably is very close to the top of the pegmatite.

Dike No. 4 contains a border zone of quartz-perthite-muscovite-plagioclase pegmatite, a wall zone of similar rock, a continuous intermediate zone of similar pegmatite in which the perthite is coarse-grained, a discontinuous intermediate zone of cleavelandite-quartz-muscovite pegmatite, and a core of quartz pegmatite that is exposed as two separate pods.

Quartz-perthite-muscovite-plagioclase pegmatite.—Quartz-perthite-muscovite-plagioclase pegmatite forms the three outer zones. The zones differ chiefly in texture. The border zone is ½ to 1 in. thick and very fine-grained, with an average grain size of less than ¼ in. The wall zone averages about 4 ft in thickness, about 1 in. in grain size. In the outer intermediate zone, subhedral perthite crystals as much as 3 ft long occur in a matrix that has the same average grain size as the wall zone and is composed of the same minerals as the other two zones.

The pegmatite in the zones is composed chiefly of grayish quartz, pale-pink perthite, light-green muscovite, and white to very pale-pink cleavelandite with accessory black tourmaline. The muscovite books in the wall and intermediate zones are usually less than 2 in. across. Perthite is visually estimated to make up about 40 percent of the rock in each zone.

Cleavelandite-quartz-muscovite pegmatite.—The cleavelandite-quartz-muscovite pegmatite of the discontinuous intermediate zone occurs only around the two quartz pegmatite pods described below. It has an average thickness of 1 ft, and a uniform thickness and composition through the 38-ft height exposed in the northwest face of the knob. This pegmatite is composed chiefly of white cleavelandite, grayish quartz, and light-greenish muscovite with accessory beryl and amblygonite. Cleavelandite occurs in plates as long as 4 in., and muscovite occurs in wedged-shaped books as long as 6 in. White beryl occurs in euhedral crystals, which have an average diameter of 3 in. The largest crystal exposed measured 5 in. across. Amblygonite, in euhedral crystals as much as 3 in. in diameter, occurs only at the inner edge of the zone.

Quartz pegmatite.—The quartz pegmatite of the core is exposed in two separate pods, one in the knob at the wider part of the pegmatite, and the other adjacent to the open-cut. The larger pod is exposed in the faces of the knob over a maximum width of 12 ft and a maximum depth of 38 ft. The maximum exposed width of the smaller pod is 5 ft and the maximum exposed depth is 8 ft. The pods consist mainly of milky white quartz with accessory cleavelandite, amblygonite, and muscovite. The muscovite occurs in felted aggregates of flakes less than ½ in. across. Euhedral crystals of amblygonite occur only near the outer edges of this pegmatite.

MINERAL DEPOSITS

Three minerals of economic importance—perthite, beryl, and amblygonite—occur in Dike No. 4. The feldspar, perthite, occurs in a deposit in the continuous intermediate zone, and the beryl and amblygonite occur in two deposits in the discontinuous intermediate zone and the outer edges of the core.

FELDSPAR

Feldspar sortable by hand is restricted to the continuous intermediate zone containing the coarse-grained perthite. This zone has an average thickness of 9 ft and a strike length of about 120 ft. It is exposed for 38 ft in depth in the face of the knob, and probably extends for at least an additional 35 ft below the lowest exposure. The perthite content of the deposit is visually estimated to be about 40 percent.

BERYL AND AMBLYGONITE

The beryl and amblygonite deposits each have a thickness of 1 to 2 ft, and occur around both of the quartz pegmatite pods. The larger deposit is exposed in the knob for a strike length of 35 ft, and for 38 ft in depth. Probably, it extends only about 10 ft below the lowest exposure. The smaller deposit prior to mining had a strike length of 38 ft, but at least 60 percent of the deposit has been removed. Beryl is visually estimated to make up less than 0.5 percent of the deposit, and amblygonite probably is slightly less abundant than beryl.

BURGESS MICA PROSPECT (CUSTER DISTRICT)

by J. J. Norton

The Burgess mica prospect, Custer County, in the SE¼ corner of sec. 35, T. 3 S., R. 4 E., was explored by the Minndak Mines Inc. during 1943. Operations ceased shortly after the end of the year because of insufficient mica. The prospect can be reached by road according to the following mileage schedule.

Miles	
0.0	Custer Post Office; go south on U. S. Highway 85A.
2.9	Turn left.
3.1	Turn left.
3.2	Turn left.
3.4	Turn left.
4.1	Turn left.
4.3	Burgess prospect.

The writer and Mr. Stuart Ferguson of the Colonial Mica Corporation visited the prospect December 9, 1943, and later the writer returned with L. R. Page for a brief visit.

The Burgess pegmatite was apparently worked by a small open-pit many years ago. J. C. Koch relocated the claim in 1943 and with C. K. Koch did a small amount of prospect work in June of that year. The Minndak Mines Inc. worked the property from September 14, 1943 until January 1944. Their work consisted principally of sinking a 40-ft inclined shaft about 20 ft from the south end of the pegmatite, and a small amount of drifting from the bottom of the shaft.

The Burgess prospect is on a very small pegmatite that strikes north and dips 52° W. It is about 80 ft long and averages 2 ft in thickness, although it is 5 ft thick at one place in the shaft. The pegmatite consists principally of quartz and albite, with numerous scattered perthite crystals. Accessory minerals include muscovite, biotite, tourmaline, and apatite. A larger pegmatite crops out a few feet northwest of the Burgess, but it is practically barren of mica.

The Burgess mica prospect produced less than 100 lb of trimmed sheet and punch mica, although perhaps 100 tons of pegmatite was mined, showing that the proportion of recoverable mica in the rock is small. The mica is ruby-colored, slightly air-stained, and of good quality, although some of the books are reeved. Samples of the small sheet in two shipments to the Colonial Mica Corporation contained more than 15 percent of quality no. 1, about 30 percent of quality no. 2, and more than 50 percent quality no. 2 inferior.

BURT MICA MINE (CUSTER DISTRICT)

by J. W. Adams

The Burt mica mine in the NW¼ sec. 33, T. 3 S., R. 5 E., Custer County, about 4 miles southeast of the town of Custer, is owned by Kem Koch and Edward Gray of that town. The Burt mine is said to have been worked 50 or 60 years ago by a Mr. Tinsley, who sank a shaft on the dike. Traces of this shaft were probably destroyed by later work. The claim was also held by John Wells prior to the present owners.

A compass and tape map of the property (fig. 9) was made in May, 1945.

The Burt pegmatite has been developed by an open-pit 150 ft long, 50 ft in widest dimension, and as much as 15 ft deep. In addition, several small prospect pits and cuts have been made along the westward extension of the dike. The open-pit is largely the result of operations by Koch and Gray between June 7, 1943 and early 1944. During this work, after the mica was picked at the face, the rock broken by blasting was loaded into a bin by power shovel. Material from the bin was fed to a picking belt where the smaller mica books were recovered. This method of mining proved to be profitable during the period of operation, although some of the excavation of the west half of the pit was dead work. The property became idle in January 1944 because the mica produced was no longer purchased by the Colonial Mica Corporation.

GEOLOGY

WALL ROCK

The pegmatite conformably intrudes pre-Cambrian quartz-mica schist and quartzite that strike approximately N. 70° E. and dip 23°–35° NW. The schist exposed in the open-cut is very soft and friable. A lens of schist, 2 to 3 ft thick in the central part of the open-cut, lies directly below the hanging-wall perthite-quartz-albite zone and is enclosed by mica-rich pegmatite. It is reported to have extended out into the part of the dike now mined out and to have been completely enclosed by pegmatite. The most productive part of the pegmatite was adjacent to this schist inclusion.

PEGMATITE

The pegmatite forms a ridge trending east-west with a north slope that closely follows the hanging-wall surface of the pegmatite. Prospect pits and outcrops show a southwestward extension of the dike four hundred feet beyond the limits of the Burt workings, and it probably extends more than two hundred feet to the northeast. It is 20 to 30 ft thick. In the area of the mine workings, the pegmatite shows conspicuous joints, most of which trend S. 20° E. or S. 47° W. A fault of about 5-ft displacement that cuts the pegmatite near the west limit of the open-cut appears to lie along the axis of an anticlinal structure in the hanging-wall schist.

Only part of the pegmatite exposed in the open-cut shows zoning (fig. 9). The rest consists of graphic granite, finer-grained perthite-quartz pegmatite and isolated patches of perthite-quartz-albite pegmatite. The zoned pegmatite consists of a wall zone of perthite-quartz-albite pegmatite, an intermediate zone of perthite-quartz-muscovite pegmatite, and a central zone of perthite-quartz pegmatite.

Perthite-quartz-albite pegmatite.—Perthite-quartz-albite pegmatite occurs on the hanging wall and footwall in parts of the body; exposures show thicknesses of 4 to 8 ft. The pegmatite consists chiefly of perthite (50 percent), quartz (20 percent), albite (15 percent). Black tourmaline and iron garnet (10 percent) in small rounded aggregates are distributed quite uniformly through the rock giving it a characteristic appearance. Flaky yellow-green muscovite and blue-green apatite are minor accessories.

Perthite-quartz-muscovite pegmatite.—Perthite-quartz-muscovite pegmatite forms an intermediate zone and is the source of commercial sheet-mica in the dike. Where distinguishable it has a thickness of 1 to 2 ft. The pegmatite consists of coarse perthite, quartz, and muscovite, with minor albite, tourmaline, and apatite. As shown in cross-section B–B′ (fig. 9), this zone is present both above and below the central core, and converges to form a single zone where the core is absent. This zone also forms a wall zone around the schist inclusion in the center of the pegmatite (Section B–B′).

Perthite-quartz pegmatite.—Perthite-quartz pegmatite is the dominant rock type of the dike, and locally forms a central core. It consists of large masses and crystals of perthite, and massive, pale rose to white quartz. Much of the perthite and quartz are in graphic intergrowth. Black tourmaline is an abundant accessory, occurring locally in crude, tapered crystals as much as two feet in length. Muscovite, most of it suitable only for scrap, is present in isolated clusters. In the west half of the Burt open-cut, perthite-quartz pegmatite makes up practically the entire exposed portion

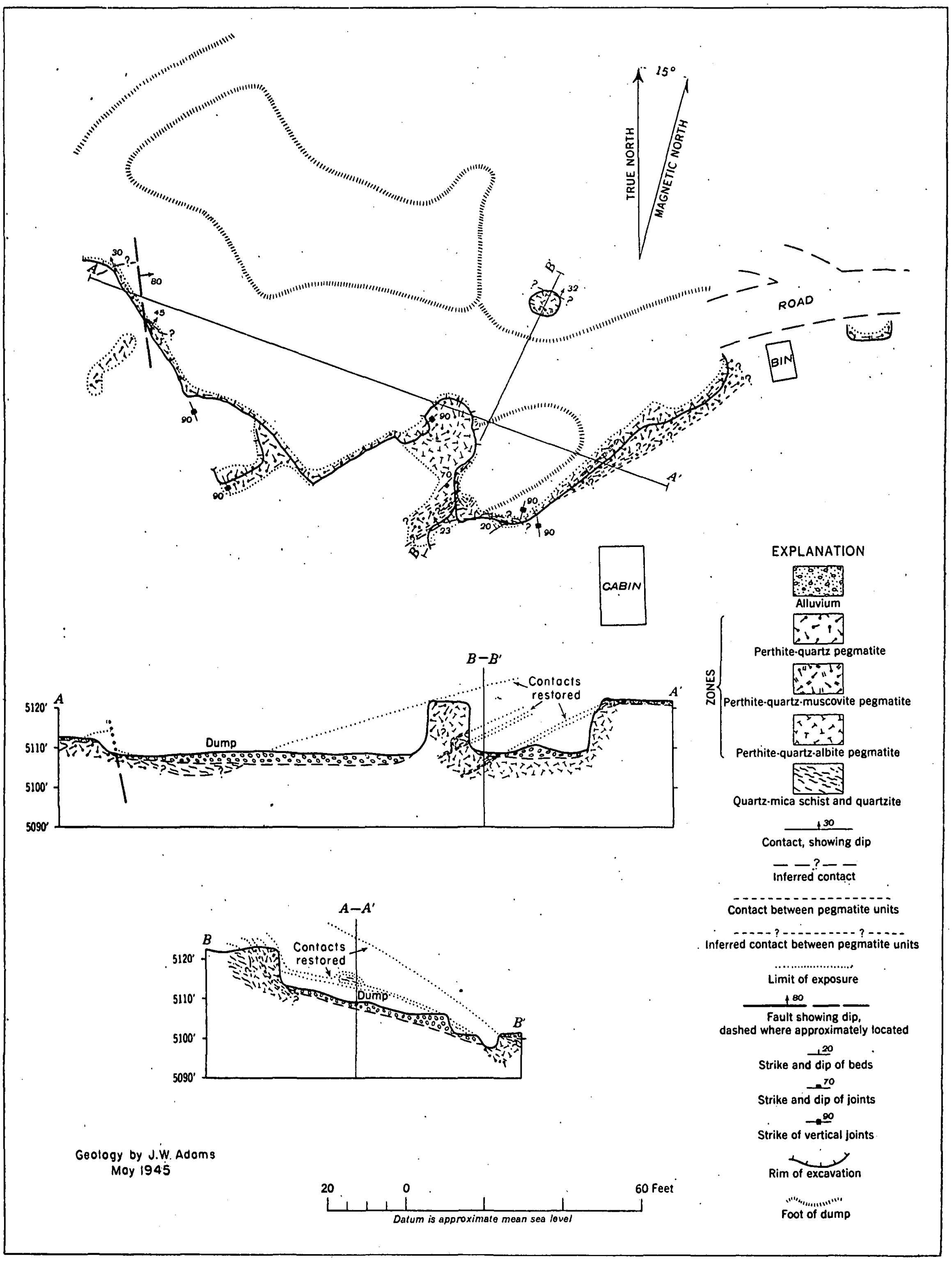


FIGURE 9.—Geologic map and sections, Burt mica mine, Custer County, South Dakota.

of the dike and appears to have encroached upon, or prevented the formation of, the perthite-quartz-albite hanging-wall zone except in a few small areas.

MINERAL DEPOSITS

MICA

Pale-ruby muscovite occurs in books, some of them 7 to 8 in. across. About 20 percent of the mica sold from the property has been of the larger sizes (plus 1½ by 2 in.). The mica is most abundant in the perthite-quartz-muscovite zones although small local concentrations of "tied" mica suitable only for scrap appear in the other parts of the pegmatite. Cracks and mineral inclusions are present in some of the mica, but air-staining is the worst defect.

Qualification of the mica from the Burt mine has been the occasion for considerable disagreement in the past. The Koch-Gray operation was closed down because mica produced and qualified prior to January 1945 averaged less than 10 percent of these qualities. After this date one lot of mica, prepared with particular attention to recovering the better qualities, contained 12.44 lb of small sheet of which 14 percent was no. 1 quality and 17 percent of which was no. 2 quality, and 5.25 lb of large sheet of which 28 percent was no. 2; the remainder was no. 2 inferior. A few pounds of no. 3 quality mica has been sold from the property.

Operations between July 23 and November 15, 1943 were restricted almost completely to the east end of the pit. In this period an estimated 1,200 tons of rock was moved to produce 21 tons of crude mica, from which 812.5 lb of sheet mica was obtained. The sheet-mica content per ton of rock mined was about 0.68 lb, and the sheet mica recovered from crude was 1.9 percent. Figures for the crude mica obtained for the later months of operation are lacking, but 1,545.29 lb of sheet mica was produced from the property between June 1943 and July 1944, from 2,500 to 3,000 tons of rock.

BERYL

A very small quantity of beryl has been found in the pegmatite. One small crystal ($N_0 = 1.570$) was collected from the perthite-quartz pegmatite zone. No sales from the property are recorded.

RESERVES

Reserves of mica at the Burt mine are unknown. Whether mica exists on both the hanging wall and footwall of the pegmatite below the floor of the west half of the pit is not known because the pit floor is now completely covered by debris. The lack of a wall zone of perthite-quartz-albite pegmatite in most of the exposed face in the west half of the pit may indicate a thickening of the central core that eliminated the other zones, or the merging of two pegmatites. In either case the existence of an upper mica zone is unlikely. Examination of the westward extension of the pegmatite (not shown on fig. 9) suggested that mica zones comparable to those already worked occur locally along the pegmatite. At least 100 lb of sheet mica might be obtained readily by mining the block of pegmatite between the east and west portions of the open-cut.

BUSTER DIKE MICA MINE (CUSTER DISTRICT)

by J. J. Norton

The Buster Dike mica mine, Custer County, was one of the principal producers of sheet mica from May 1942 to 1944. The mine is in sec. 2, T. 4 S., R. 4 E., about 3 miles south-southwest of Custer. The Buster Dike property consists of two unpatented claims listed in government records as the Buster Dake (sic) and the Buster Dake (sic) No. 2. The main workings are on the Buster Dike claim proper, which is in the SW¼ NW¼ sec. 2, T. 4 S., R. 4 E. The Buster Dike No. 2 claim is to the northwest, and extends into section 3.

The mine was briefly described in 1942 by W. C. Stoll (unpublished report).

Surface and underground maps of the Buster Dike mine were made by the writer, assisted at various times by L. R. Page, D. M. Kinney, L. C. Pray, and Peter Joralemon. A surface map (pl. 8) was made by plane-table and telescopic alidade on a scale of 1 in. to 40 ft, and five sections (pl. 8) were prepared on the same scale. An underground map and three sections (pl. 9) were made on a scale of 1 in. to 20 ft, by a tape and Brunton compass survey based on a transit line down the shaft. A structure contour map (pl. 9) was made of the hanging wall in the underground workings on a scale of 1 in. to 20 ft and a stope map (pl. 9) on the same scale was made by projecting the underground workings to a plane trending N. 22° W. and dipping 60 degrees SW. The field work was done between August 1943 and January 1944, most of it in November and December 1943.

HISTORY

The Buster Dike property was first prospected many years ago, but no early production has been recorded. S. T. Gamber of Custer relocated the claims in 1939, and worked the two principal open-pits for potash feldspar. Early in 1942 the top of a rich mica zone was discovered at a depth of about 20 feet in the pit near the present shaft house. Gamber continued to work the pegmatite until May 1942, when the property was purchased by the Black Hills Mining Company. The Black Hills Mining Company operated the mine from an inclined shaft and adjacent stopes. Near the close of their operation in 1944, the shaft and levels were backfilled. The large production of mica for which the mine is noted was made during the period of operation by this company.

MINE WORKINGS

The Buster Dike was worked from a 180-ft shaft inclined at 63° to the west and extending from an altitude of 5,555 ft at the collar to 5,395 ft at the bottom. Forty feet northwest of the collar, a 25-ft vertical shaft was connected at its base by an inclined drift to the main shaft. The older work on this pegmatite was done in an open-pit about 20 ft deep. The bottom of this pit was stoped out during the final operations.

The principal drift levels were at 103 ft and 142 ft vertically below the collar of the shaft. On the 103-ft level the drifts extended 37 ft north and 12 ft south of the shaft. The end of the south drift was timbered off at the time of mapping, but at one time the drift extended about 20 ft farther, to the end of the dike. On the 142-ft level the drifts extended 28 ft south and 60 ft north of the shaft. Most of the mica-bearing pegmatite from this level to the surface has been stoped out.

Prospect pits and one moderately large open-cut have been opened on a number of other pegmatites on the property, principally for feldspar.

GEOLOGY

The Buster Dike property contains many west-dipping pegmatites intruding pre-Cambrian metamorphosed sedimentary rocks that consist principally of quartz-mica schist. Pegmatite outcrops are numerous, but very little of the country rock is exposed.

QUARTZ-MICA SCHIST AND ASSOCIATED ROCKS

Most of the country rock is a moderately well foliated schist consisting principally of quartz, muscovite, and biotite. Sillimanite commonly occurs in significant quantities. Small pods of microcline (in grains ¼ to ¾ in. across, and with numerous inclusions of the schist minerals) occur, especially in an exposure 240 ft east-southeast of the main Buster Dike shaft.

PEGMATITE

The pegmatites mapped (pl. 8) include two large groups of irregular pegmatites and a number of small independent tabular bodies. They are subparallel, averaging N. 15° W. in strike and 65° SW. in dip, but at the surface they strike from N. 50° W. to N. 5° E. and dip from 40 to 87 degrees to the west. In the underground workings of the Buster Dike mine, where rolls are strongly developed, the ranges of strike and dip are greater. The average strike in the Buster Dike mine is N. 22° W. and the average dip is 60° SW.

The most unusual feature of the Buster Dike pegmatites is the complex interfingering of many of the intrusions. The Buster Dike mine is in the south end of a pegmatite that to the north joins with other pegmatites to form a single large mass. The group of pegmatites east of the shaft house forms an even more intricate pattern of interfingering pegmatites. If the rocks were more completely exposed they would probably reveal an even more complex structural pattern.

At the time of mapping, the end of the Buster Dike pegmatite was exposed only on the 142-ft level, but its approximate position was known from earlier reports. The plunge of the end of the pegmatite is about 60° to the S. 80° W. North of the shaft there is a conspicuous synclinal roll and a conspicuous anticlinal roll of the pegmatite contact that plunges 55 degrees S. 40° W., and converges with the end of the dike. Just above the 142-ft level the dip flattens markedly, and the synclinal roll disappears. The anticlinal roll remains as a very broad fold in the hanging wall. South of the shaft, according to reports, there are no conspicuous rolls. The workings south of the shaft, above the 142-ft level, were for the most part backfilled and inaccessible. The richest concentrations of mica are structurally limited by the south end of the pegmatite and by the north limit of the large anticlinal roll. The roll plunges toward the south end of the pegmatite, causing a shortening of the mica shoot with depth. It is doubtful whether the mica concentration is more closely related to the rolls or to the south end of the pegmatite.

The surface exposures of the pegmatites are similar in composition and consist essentially of quartz-albite-perthite pegmatite. Zoning is very poorly defined, but in most pegmatites there is a general increase in the percentage of albite toward the walls and of perthite toward the interior of the intrusion. Border zones (pl. 8), 1 in. or more in thickness, grade into wall zones of quartz-albite pegmatite which are generally too narrow to map. Underground the Buster Dike pegmatite has a conspicuous zone of quartz-albite-muscovite pegmatite along the hanging wall and quartz-albite pegmatite on the footwall.

Quartz-albite-perthite pegmatite.—On the surface map (pl. 8) all of the pegmatites have been shown as quartz-albite-perthite pegmatite. In general, these pegmatites consist of quartz-albite aggregates in which the grains are 1 to 2 in. in diameter, accompanied by scattered perthite crystals and quartz masses which are generally less than 2 ft across, although some are larger. In places, well-segregated quartz and perthite occur with little albite in the interior of a dike, as exposed in the two main open pits where potash feldspar was mined. The quartz-albite pegmatite is most conspicuous along the walls, where there is commonly a zone a few inches to 3 or 4 ft thick, almost or entirely devoid of perthite. Determinations of the minimum refractive indices of cleavage fragments from 9 specimens of albite taken from surface exposures ranged from 1.528 to 1.532 (An_4-An_{11}). Muscovite occurs in most of the pegmatite outcrops, commonly near a wall of the dike, but it is present only as flakes and widely scattered small books. Other accessory minerals include tourmaline, biotite, and a little beryl.

Quartz-albite-muscovite pegmatite.—Underground, the Buster Dike pegmatite is quartz-albite-muscovite pegmatite on the hanging wall and quartz-albite pegmatite on the footwall, although from the surface to a depth of about 20 ft it consists principally of quartz and perthite. Near the south end of the dike in the underground workings quartz-albite-muscovite pegmatite is said to have extended from wall to wall. A few muscovite books can generally be found near the footwall, but there is no well-defined mica zone consisting of quartz-albite-muscovite pegmatite on the footwall comparable to that on the hanging wall. The quartz-albite-muscovite pegmatite on the hanging wall is as much as 12 ft in thickness, and an average thickness of 10 ft has been worked in the stopes. Quartz and albite are in grains generally 1 to 2 in. across. The minimum refractive indices of cleavage fragments of two albite specimens from this zone are 1.528 and 1.531 (An_5–An_{10}). Muscovite books are commonly 8 to 12 in. in diameter, and books as much as 4 ft across have been reported. Meager quantities of tourmaline and beryl occur as accessory minerals.

Quartz-albite pegmatite.—The quartz-albite-muscovite pegmatite along the hanging wall of the Buster Dike grades into quartz-albite pegmatite toward the footwall. The thickness of the quartz-albite pegmatite is as much as 15 ft, but the average is probably about 5 ft. This zone is essentially similar to the quartz-albite-muscovite zone except that it generally lacks appreciable quantities of muscovite, although muscovite does occur near the footwall in a number of places. The essential minerals are quartz and albite in grains averaging 1 to 2 in. across. The minimum refractive indices of cleavage flakes from each of two albite specimens were found to be approximately 1.529 (An_6). A small amount of cleavelandite (minimum index approximately 1.528 (An_5) was observed. Tourmaline occurs as an accessory mineral, and in some places a rather rich tourmaline-bearing zone occurs along the footwall, extending as much as 4 ft into the pegmatite.

MINERAL DEPOSITS

MICA

The Buster Dike mine produced mica from a very rich concentration along the hanging wall at the south end of the pegmatite. A total of 602 tons of crude mica was produced from May 1942 through December 1943. Production figures on processed mica previous to the first sale to the Colonial Mica Corporation on December 15, 1942, are not available, but from that date to the end of 1943 the Buster mine produced 17,446 lb of large sheet mica (1½ by 2 in. and larger, three-quarter trim), 2,275 lb of small sheet (1 by 1 in. and 1¼ by 1¼ in., full trim), and 97,197 lb of untrimmed punch from a total of about 384 tons of mine-run mica.

The exact structural relationships of the mica-rich rock are not known beyond the fact that the mica is concentrated in the end of the pegmatite. The northern limit of the mica-bearing pegmatite was not determined but the limit of most of the mining has been the north edge of the strong anticlinal roll, where, apparently, there was a sharp drop in mica content. Possibly rolls with rich mica shoots lie to the north, but no exploration has been carried out in search of them. The drift on the 142-ft level was carried northward, 45 ft beyond the roll, but unfortunately it does not follow the hanging wall. It was driven into the center of the dike and then to the footwall. A crosscut to the hanging wall is reported to have been driven after our mapping was completed.

The Buster Dike mine produced a whitish or very pale ruby mica generally of good quality except for a heavy air-stain. Most of the few black inclusions that occur are tourmaline crystals. Herringbone structure is developed in much of the mica, and causes a low recovery of sheet from the crude mica. Books of mica as much as 4 ft in diameter reportedly have been recovered and books 8 to 12 in. across are abundant.

It is estimated that between July 1, 1942, which is approximately the date of Stoll's examination, and the end of December 1943, about 5,700 tons of pegmatite was mined, and from this amount a total of 558 tons of crude mica, or 9.8 percent, was recovered.

BERYL

At least 10 tons of beryl was produced from the Buster Dike from 1939 to 1942, but only a few hundred pounds between July 1942 and 1943. A few tons of beryl was recovered from later work near the surface. Nearly all of the beryl occurs near the surface in or near the perthite-rich pegmatite, where crystals 1 ft or more across are not uncommon. The refractive indices (N_0) of two specimens of green beryl from near the top of the mica zone were found to be approximately 1.578 and 1.582.

FELDSPAR

Considerable quantites of perthite feldspar were mined in the two principal open-pits on the Buster Dike property prior to the discovery of the mica shoot. The perthite is white, and commonly in crystals several feet long. Possibly other pegmatites on the property could be worked profitably for feldspar.

RESERVES

It is difficult to estimate the mica reserves available in the Buster Dike mine. The known mica-bearing rock above the 142-ft level has been mined out, but it is possible that additional mica shoots could be found by drifting northward along the hanging wall. Below the 142-ft level mica-rich rock can reasonably be expected to extend more than 50 ft down the dip. If the south end of the pegmatite and the north edge of the mica-rich pegmatite continue to converge as shown on the underground map (pl. 9), and if the average thickness of mica pegmatite is 9 ft, then approximately 17,000 cu ft weighing about 1,400 tons, on the basis of 12.5 cu ft to the ton, are available within 50 ft down the dip. If 9.8 percent of this amount is recoverable mica, approximately 138 tons of crude mica is available. Further reserves are expectable at greater depths. If the northern limit of the mica-rich pegmatite, which above the 142-ft level closely coincides with the northern border of a strong roll, maintains its plunge to the south end of the pegmatite, the mica shoot may disappear within 100 ft vertically below the 142-ft level. If, on the contrary, the principal feature controlling the mica shoot is the south end of the pegmatite, and if the rolls are of relatively minor influence, it would be impossible from present evidence to predict the depth to which mica-rich rock may extend.

Most of the pegmatites elsewhere on the Buster Dike property do not appear promising for mica but prospecting the south end of the dike that crops out 200 ft east-southeast of the Buster shaft may be worthwhile.

CARROLL CLAIMS (CUSTER DISTRICT)

by W. C. Stoll

The Carroll claims, known as the Lookout, Rosebud, and Park claims, are in secs. 3 and 10, T. 5 S., R. 4 E., about 2.7 miles northwest of Pringle, Custer County. The claims, which comprise about 20 acres each, are unpatented. They are held by Glenn Carroll of Pringle, Don Carroll of Grand Island, Nebraska, and Bill Moberly of Omaha, Nebraska.

The claims were idle at the time of examination, October 1942, and past production has been small. Only the Lookout claim has been productive. The Park claim, which adjoins the Lookout on the south, is undeveloped, and the Rosebud claim, adjoining the Lookout claim on the southeast, is prospected by only a few small pits. In 1938–39 the Lookout claim produced a small quantity of feldspar, a few hundred pounds of beryl and scrap mica, and a few pounds of columbite-tantalite.

The coarse-grained pegmatite in which the two cuts of the Lookout claim have been made is apparently enclosed in a large mass of fine-grained pegmatite or coarse-grained granite composed of pinkish feldspar, fine-grained muscovite, and a little quartz. This rock forms the large ridge upon which the workings are situated.

The two openings on the Lookout claim are on the southwest slope of a broad and steep ridge which trends N. 65° W. Cut no. 1 is about 25 by 10 ft in plan and about 15 ft deep. The main cut, 75 ft to the east of cut no. 1, is about 40 ft long, 15 ft wide, and 10 to 20 ft deep. Both cuts expose coarse-grained pegmatite composed of pink perthite, white massive quartz, scrap mica, and considerable scattered black tourmaline. Several crystals and small masses of pale greenish-yellow beryl are visible on the walls of the main pit. The largest crystal seen, exposed in basal section, has a diameter of 10 in. and lies at a contact of coarse perthite and massive gray quartz. At one place on the wall, columbite-tantalite blades are intergrown with beryl. Columbite-tantalite, which according to Glenn Carroll is high in Ta_2O_5, and a little beryl have been taken from cut no. 1 as well as from the main cut. West of the openings the coarse pegmatite, visible as a series of massive quartz-and-feldspar outcrops, can be traced about 200 ft along the top of the ridge.

CASSITERITE LODE (HILL CITY DISTRICT)

The Cassiterite Lode claim, a beryl-tin prospect, adjoins the Mohawk tin claim on the north. It is in the NE¼ sec. 25, T. 1 S., R. 4 E., about ½ mile west of Hill City, Pennington County. The claim, held by Mr. George W. Coats, Mr. H. G. Mills, and Mr. F. W. Mills of Hill City, was leased to Mines Minerals Metals, Inc., in December 1941. The property was examined and mapped on July 28, 1942 by Hanley and Page.

In 1942 the workings, which are on a vein, included two shafts 12 and 25 ft deep, a 10- to 15-ft drift from the base of the deepest shaft, and trenches that exposed the vein for about 75 ft along the strike. Another shaft, reported to be 30 to 40 ft deep, was sunk in schist 70 ft southeast of the vein.

The vein on the Cassiterite claim strikes N. 20° W. and dips 45°–70° NE. (fig. 10) and cuts across mica-quartz-garnet schist that strikes N. 20° E. and dips 50° NW. Its thickness ranges from 8 to 30 in., and averages about 24 in. The vein is exposed over a total vertical distance of 50 ft and a total horizontal distance of 75 ft. It consists mainly of quartz. Cassiterite occurs as dark-brown to black crystals and masses as much as 2 in. across associated with clots, masses, and streaks of muscovite and beryl. The muscovite, in small flakes suitable only for scrap, occurs chiefly in the walls of the vein. The beryl is white, pale-yellow, or gray. Few individual crystals of beryl are visible, but in thin-sections the aggregates, which have the appearance of granular feldspar, are seen to be made up of very fine grained, interlocking euhedral crystals. Cassiterite and beryl are commonly observed in the exposures, but although locally each makes as much as 5 percent of the vein, it is estimated that the average cassiterite content is less than 2 percent and the beryl content is probably less than 1 percent. The lenticular nature and small size of the vein preclude an economic operation.

CLIMAX MICA MINE (CUSTER DISTRICT)

The Climax mica mine, near the northwest corner of sec. 29, T.3 S., R.5 E., B. H. M., Custer County, can be reached from Custer by driving 2 miles east on U. S. Highway 16 and then ½ mile south on a dirt road.

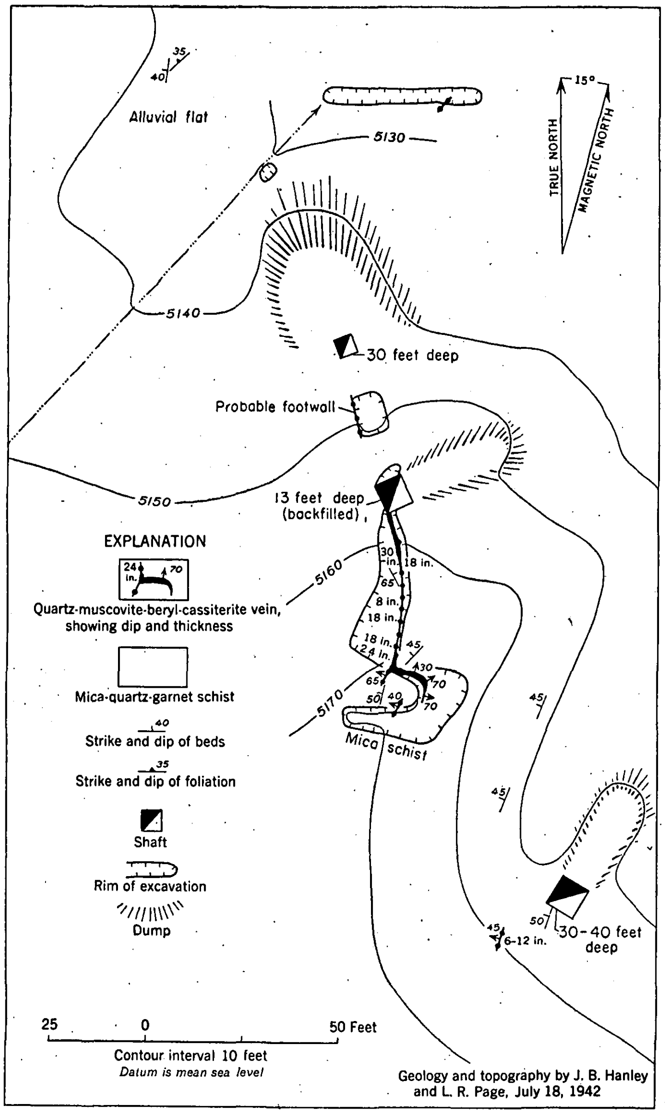


FIGURE 10.—Geologic map, Cassiterite Lode, Pennington County, South Dakota.

It was one of the largest producers in the Custer district in 1943–44 and has produced mica at intervals since about 1880 (Connolly and O'Harra, 1929, p. 251). The available production records are summarized in the table below.

The Climax mica mine, formerly owned by B. B. Albright of Seattle, Wash., was leased to the Climax Mining Company, a subsidiary of Asheville Mica Company, on November 26, 1943. It was purchased by the J. K. Mining Company late in 1944.

A surface map was made in November 1943 by L. C. Pray, assisted by J. J. Norton, on a scale of 1 in. to 20 ft. The underground workings as of November 9, 1943 were mapped by L. R. Page and J. J. Norton (pl. 10). All the maps were revised April 1944 and again in January 1945. In April 1945, Max P. Erickson revised all maps to include the work of the J. K. Mining Company.

MINE WORKINGS

The Climax mica mine was first worked in the 1880's from a 4 by 6 ft vertical shaft 80 ft deep. Apparently the entire pegmatite was stoped to within 15 or 20 ft of the surface for 40 to 50 ft west of the shaft, and to the keel of the pegmatite on the east. A short shaft at the east end of the pegmatites connected these workings with the surface.

The present vertical shaft, on the west end of the exposure of the pegmatite, was dug to a depth of 80 ft by John Wells in the early 1930's. The Climax Mica Company rehabilitated this shaft and extended it from the 80-ft level to its present depth of 178 ft. New levels were driven at 110 and 160 ft. The pegmatite was stoped above the 110-ft level, below and to the west of the earliest workings. The J. K. Mining Company extended the 160-ft level and stoped to the 110-ft level. During the last part of their operation they removed the shaft pillars practically to the surface. In April 1945 the mica-bearing pegmatite was completely mined out above the 160-ft level.

GEOLOGY

PEGMATITE

The Climax mine is in an irregular, lenticular, distinctly zoned pegmatite which conformably intrudes pre-Cambrian mica schists. Four other pegmatites have been mapped as "pegmatite—undivided". Numerous sillimanite- and andalusite-bearing quartz veins occur in the mapped area. The Climax pegmatite strikes approximately N. 55° E., and is vertical, although there are numerous local variations in both strike and dip. The west end of the pegmatite plunges

Mica produced from Climax mica mine

Year	Sheet		Untrimmed punch		Scrap		Washer punch	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1880?–1884	7, 940	$34, 539. 00			?			
1943	4, 750. 39	23, 650. 05	13, 765. 31	$4, 875. 25	124, 664	$1, 401. 43	None	
1944 (to May)	[1] 3, 315. 80	[1] 19, 523. 05	16, 277. 54	4, 833. 26	81, 274	914. 40	12, 400	$496. 00
1945 (to April)	2, 881. 30	23, 050. 40			70, 720	772, 53	None	
Total	18, 887. 49	100, 762. 50	30, 042. 85	9, 708. 51	276, 658	3, 088. 36	12, 400	496. 00

[1] Includes only part of sheet mica sold in Asheville, North Carolina.

40° to 90° S. 55° W. and the east end has an average plunge of 77° to the southwest. The walls of the pegmatite are very irregular and have small rolls plunging both northwest and southwest. The dominant rolls plunge southwest at 55° to 85°; the average is about 70°. The foliation of the schists is crinkled parallel to this set of rolls. Irregular rolls and bulges of the contact pitch 10° to 30° southwest and 10° to 20° southeast, across the steeper structure.

Two zones have been mapped within the Climax pegmatite, an albite-quartz-muscovite pegmatite wall zone, and a quartz-perthite-albite-pegmatite core. To the northeast, and with the same trend as the Climax pegmatite, are five narrow bodies and to the southeast of the workings a large irregular mass of pegmatite. Zones of these bodies have not been mapped separately, therefore they are shown in plate 10 as "pegmatite—undivided".

Albite-quartz-muscovite pegmatite.—Albite-quartz-muscovite pegmatite, the commercial mica zone, is 1 to 4 ft thick along the walls at the thicker parts of the pegmatite and is the only rock in the narrower parts. The albite is white to bluish-gray and occurs as grains as much as several inches in diameter. It is intergrown with subordinate quantities of quartz and muscovite. Tourmaline, beryl, apatite, and lithiophilite-triphylite are accessory minerals.

Quartz-perthite-albite pegmatite.—Quartz-perthite-albite pegmatite comprises the core of the Climax dike. The perthite occurs in crystals as much as several feet in length, together with irregular masses of quartz of similar size in a finer-grained matrix of albite and quartz. At the outer edges of this zone muscovite occurs as white to greenish wedge-shaped "A" books several inches across. Albite occurs intergrown with the quartz and is most abundant near the muscovite. Small quantities of beryl, apatite, tourmaline, cassiterite, löllingite, amblygonite, and lithiophilite-triphylite, have been identified from this part of the pegmatite.

MICA DEPOSITS

The mica occurs in albite-quartz-muscovite pegmatite between the schist walls and the core of quartz-perthite-albite pegmatite, though in the narrower parts of the pegmatite it is found from wall to wall. In general the narrower parts of the mica zones are near the keel and crest of the pegmatite and adjacent to the central core. Mica is found throughout the wall zone of the Climax pegmatite, though not everywhere in commercial quantity.

The muscovite is in strongly ruled, flat, pale ruby books as much as 2 or 3 ft in maximum dimension. Inclusions of tourmaline, quartz, feldspar and other minerals are common. The mica in part is air-stained. During 1943–44 as much as 5 percent of the sheet mica sold was of no. 1 quality, about 20 percent of no. 2 quality, about 1 percent of no. 3 quality, and the remainder of no. 2 inferior quality.

The total known production of mica from the Climax mine is given in the table below. It is estimated that about 5 percent of the rock mined was crude mica. Prior to the J. K. Mining Company's operation the recovery of trimmed sheet from crude mica was about 4 percent. About 30 percent of the sheet was three-quarter trimmed sheet, 1½ by 2 in. and larger. There is no complete record of the individual sizes of the sheet sold but (as the table below shows) the mica sold in January and February 1943 contained approximately 72 percent of sheets 1½ by 2, 2 by 2, and 2 by 3 in., and 28 percent of sheets 3 by 3 to 4 by 6 in.

During operations by the J. K. Mining Company between January and April 1945, a total of 89,878 lb of crude mica was mined. From this amount, 2,881.30 lb, or 3.2 percent was recovered as full-trimmed sheet (2 sq in. or larger), and 16,277.54 lb or 18.2 percent, was recovered as untrimmed punch. Between 30 and 35 percent of this sheet was of no. 1 and no. 2 qualities.

RESERVES

The reserves of mica in the Climax pegmatite are limited to mica left in pillars. The last operations mined most of the shaft and stope pillars above the 160-ft level. Drifts on that level showed the pegmatite to be too narrow and too low grade for profitable operation.

COWBOY TIN MINE (HILL CITY DISTRICT)

The Cowboy tin mine, in the NE¼ sec. 35, T. 1 S., R. 4 E., is owned by Dr. and Mrs. E. B. Hultz of Hill City and Mr. Sherman of Pactola, South Dakota. When the mine was examined on May 10, 1943, the New Cowboy Mining Co. of Rockford, Illinois, was

Sheet and punch mica produced from Climax mica mine, in pounds, showing size distribution, in inches

Date, 1943	Mine run	Untrimmed punch	Sheet (¾ trim)							Total (sheet)
			1½ by 2	2 by 2	2 by 3	3 by 3	3 by 4	3 by 5	4 by 6	
January 9–15	5, 830	427	11. 5	20. 75	33. 44	11. 56	3. 25	3. 81	1. 00	85. 31
January 21–27	4, 350	370	13. 56	28. 88	37. 37	15. 06	6. 69	5. 19	1. 62	108. 37
February 2–6	6, 350	465. 5	20. 31	47. 50	74. 75	34. 75	23. 50	22. 12	14. 00	236. 93
February 11–27	28, 790	475. 7	117. 12	151. 25	93. 62	76. 12	20. 00	15. 00	1. 00	474. 11
Total	45, 320	[1] 1, 738. 2	162. 49	248. 38	239. 18	137. 49	53. 44	46. 12	17. 62	904. 72

[1] Some punch not included.

unwatering the mine. This operation was financed by a Reconstruction Finance Corporation loan.

The Cowboy deposit was discovered by George W. Coats in 1884 and was first worked by the Harney Peak Tin Mining, Milling, and Manufacturing Company which sank the main shaft and did most of the underground work. Later it was operated by the Hill City Tungsten Producers (1916), the American Tin and Tungsten Company (1917) and the National Tin Corporation (1920).

The deposit has been described by Cummings, Basham and Lincoln (1936, p. 15), Gardner (1939, pp. 16–22), and Dougherty, Munson, and Cummings (1945). The present report is based on a brief examination made by L. R. Page, assisted by G. A. Munson of the U. S. Bureau of Mines. At the time of the examination the 300-ft level was flooded and only the 100- and 200-ft levels were accessible for mapping. The mapping of these levels was by tape and compass and the geology was superimposed on a transit and tape map made by D. E. Moulds, who supervised the unwatering of the mine (fig. 11).

MINE WORKINGS

The Cowboy tin mine has been developed by two inclined shafts and an adit. The main shaft, inclined at 68°, was sunk 300 ft on the vein. Drifts at 40, 100, 200, and 300 ft explore the vein and connect with workings from the old shaft. The old shaft connects the 100- and 40-ft levels with the old adit, which was the 35-ft level from the old shaft (about the 10-ft level from the main shaft). On the 300-ft level there are 250 ft of drifts and crosscuts to the southeast of the shaft, and 630 ft to the northwest. On the 200-ft level there are 90 ft of drifts and crosscuts southeast of the shaft and 115 ft of drifts northwest of it. At the 100-ft level a drift explores the vein 40 ft southeast, and 365 ft northwest, of the main shaft. The 40-ft level has been stoped out between the shafts, but extends about 125 ft northwest of the stope. The adit level extends 80 ft northwest of the stope.

GEOLOGY

The Cowboy tin deposit is on a well defined pegmatite quartz-muscovite-beryl-cassiterite vein. The vein on the 100-ft level is composed of three main lenses that strike N. 50° W., N. 70° W., and N. 75° E. They dip, on the average, 65° NE., 80° NE., and 55° NW. respectively (fig. 11). The main tin ore shoot lies in the N. 50° W. lens and appears to plunge steeply east to the 200-ft level and then nearly straight down the dip to the 300-ft level. The vein has a maximum thickness of 6 ft, but its average thickness is less than 1 ft. Along the ore shoot the vein is 2 to 3.5 ft thick at most places.

The vein is predominantly white to gray quartz with disseminated clots, patches, and streaks of muscovite that seem to be most abundant near the walls of the vein, especially in the ore shoot. In places the muscovite is in fractures that cut the vein parallel to the strike and dip. The muscovite flakes are rarely more than ½ in. in diameter and show no sign of orientation. Beryl and cassiterite are closely associated with the muscovite, but are also associated with the quartz. The beryl is pale-yellow to white and nearly all occurs as anhedral masses interstitial to muscovite. It is readily mistaken for feldspar. The largest aggregates are about 2 in. across. Beryl locally makes up 50 percent of the muscovite aggregates but only a fraction of one percent of the vein. Cassiterite occurs with the muscovite and beryl, or in the adjacent quartz as deep ruby, brown, black, or gray grains as much as 2 in. across.

MINERAL DEPOSITS

The vein includes three minerals that are of economic interest—cassiterite, beryl, and scrap mica—but under present conditions these minerals either individually or combined are not sufficiently abundant to be mined profitably. They are most concentrated in one shoot which was sampled by the New Cowboy Mining Company and the U. S. Bureau of Mines. The result of this sampling is shown in figure 12.

The ore shoot crops out only at the old shaft, where it is exposed for a length of 40 ft and a width of as much as 3 ft. On the 40-ft level it is reported to have an average width of about 3.5 ft for a length of approximately 110 ft (Dougherty, Munson, and Cummings, 1945, p. 6). On the 100-ft level it has an average width of 3 ft over a length of 65 ft. On the 200-ft level it has an average width of 3.4 ft over a length of 50 ft. On the 300-ft level it is reported to narrow to an average width of 2.3 ft for a length of 80 ft. The Bureau of Mines calculates the average grade of this ore shoot to be 0.46 percent tin. Outside of this one ore shoot the only wide part of the vein was on the 100-ft level southeast of the shaft. This part was not accessible at the time the mine was examined.

RESERVES

The reserves of unbroken, measured tin ore in the Cowboy mine have been calculated by the Bureau of Mines as "1,000 tons containing 0.46 percent tin." In addition, 640 tons of broken ore in stopes is assumed to have the same grade. Assuming that the ore shoot extends 50 ft below the 300-ft level with a width of 2 ft, the inferred ore is 660 tons.

CROWN MICA MINE (CUSTER DISTRICT)

by L. R. Page and W. C. Stoll

The Crown mica mine, formerly the McMackin mine, is in the NE¼ sec. 16, T. 3 S., R. 4 E., Custer County. It is about 2½ miles northwest of the city of Custer. The property is owned by the New York Holding Company of Custer, and adjoins the Ballard mica claim. The properties are on one pegmatite.

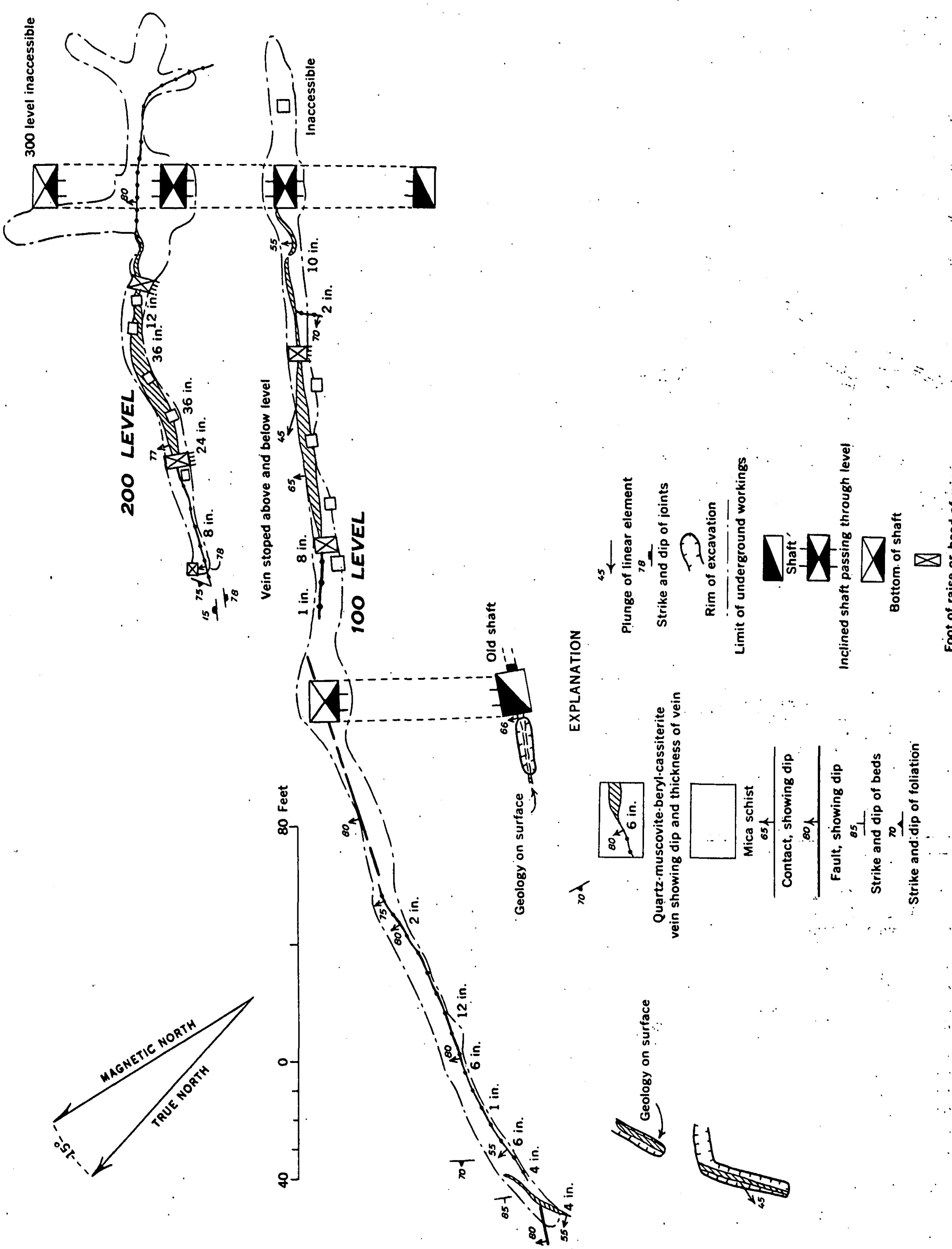
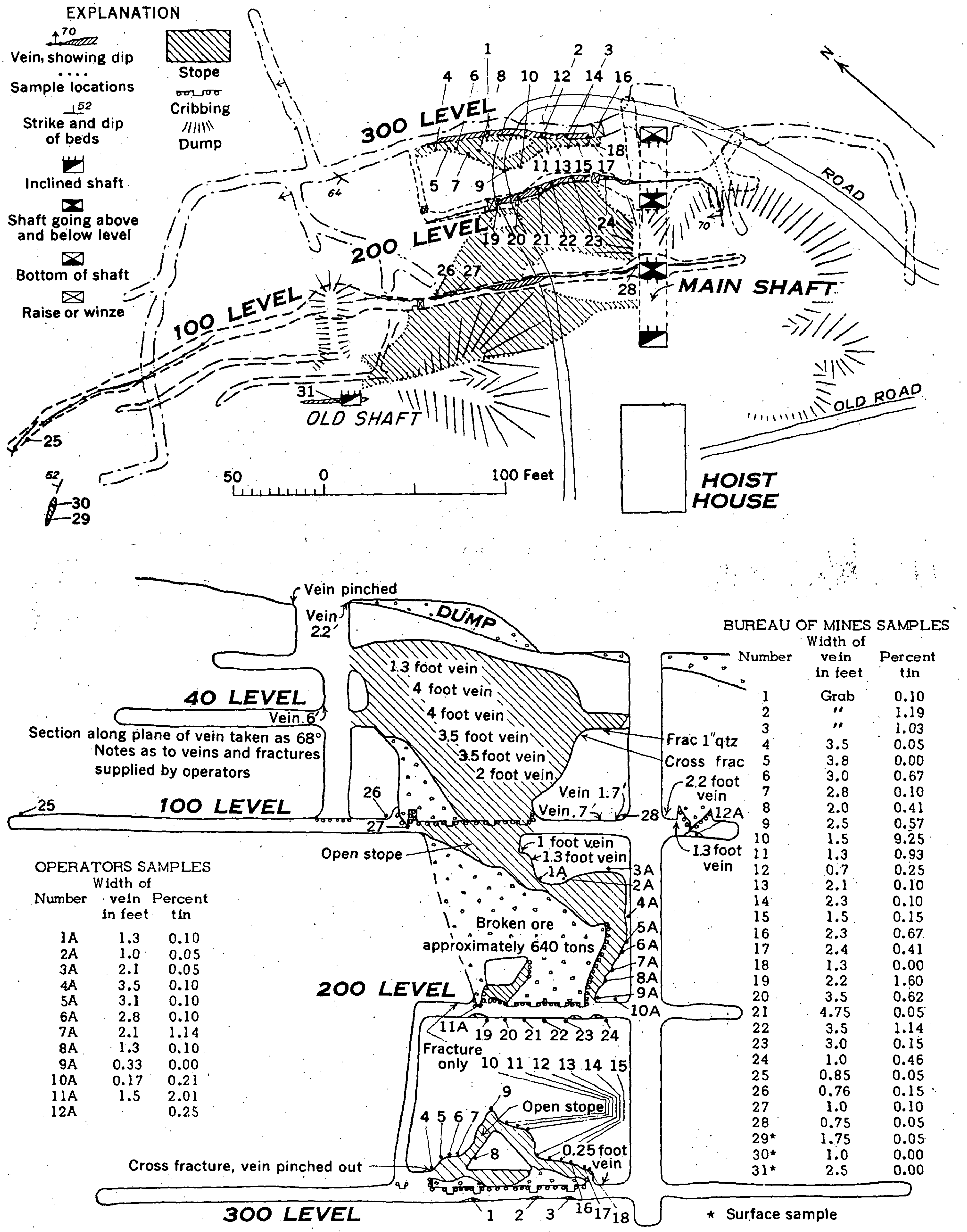


FIGURE 11.—Maps of 100- and 200-ft levels of the Cowboy tin mine, Pennington County, South Dakota.



OPERATORS SAMPLES

Number	Width of vein in feet	Percent tin
1A	1.3	0.10
2A	1.0	0.05
3A	2.1	0.05
4A	3.5	0.10
5A	3.1	0.10
6A	2.8	0.10
7A	2.1	1.14
8A	1.3	0.10
9A	0.33	0.00
10A	0.17	0.21
11A	1.5	2.01
12A		0.25

BUREAU OF MINES SAMPLES

Number	Width of vein in feet	Percent tin
1	Grab	0.10
2	"	1.19
3	"	1.03
4	3.5	0.05
5	3.8	0.00
6	3.0	0.67
7	2.8	0.10
8	2.0	0.41
9	2.5	0.57
10	1.5	9.25
11	1.3	0.93
12	0.7	0.25
13	2.1	0.10
14	2.3	0.10
15	1.5	0.15
16	2.3	0.67
17	2.4	0.41
18	1.3	0.00
19	2.2	1.60
20	3.5	0.62
21	4.75	0.05
22	3.5	1.14
23	3.0	0.15
24	1.0	0.46
25	0.85	0.05
26	0.76	0.15
27	1.0	0.10
28	0.75	0.05
29*	1.75	0.05
30*	1.0	0.00
31*	2.5	0.00

* Surface sample

FIGURE 12.—Assay plans and section, Cowboy tin mine (after U. S. Bureau of Mines).

The Crown was the first mica mine to be operated in the Custer district. It was opened in 1879 and was operated continuously until 1884 by H. E. McMackin. In 1907–11 it was operated by the Westinghouse Electric and Manufacturing Company, who leased the property to the Chicago Mica Company about 1923. The present owners acquired the property from the Westinghouse Electric and Manufacturing Company about 1930. During 1940–43 it was operated under lease by Henry J. Haugen. Mr. Haugen's lease was turned over to the New York Mining Company in April 1943 and operations continued during that summer. In June 1945 a scrap-mica recovery plant was erected on the property by William Quinn of Custer, who intends to rework the old dumps. The total known production from this mine is given in the table below.

The Crown mine has been described by Sterrett (1923, pp. 297–299), Connolly and O'Harra (1929, pp. 251–252), Lincoln (1937, pp. 31, 32) and Cummings, Basham, and Lincoln (1936, p. 13).

In July 1942, L. R. Page, J. B. Hanley, and W. C. Stoll mapped the Crown mine. In 1943 the mine was visited many times by J. J. Norton, L. C. Pray, and L. R. Page. Norton prepared a map of the south drift on the lower level the day before the mine closed. In 1945 M. P. Erickson revised existing maps and sections.

DEVELOPMENT

The mine workings on the Crown property (pl. 11) consist of a large open-pit, an 87-ft vertical shaft with drifts at the 5732-ft and 5686-ft levels, an inclined shaft from the base of the open-cut to the 50-ft level, an inaccessible timbered vertical shaft with crosscuts and drifts of unknown length and direction, and two caved raises to the surface from the 50-ft level.

The 5732-ft level of the Crown mine (pl. 11) consists of a 50-ft crosscut west from the vertical shaft with drifts 170 ft to the north and 50 ft to the south. Stopes from this level extend nearly to the surface. At the base of the inclined shaft underhand stopes extend to a depth of 20 ft, to the base of the large rolls in the pegmatite walls. At the 5686-ft level a 40-ft crosscut was driven to the pegmatite and an additional 30 ft beyond it. The north drift is at least 110 ft long and the south drift is about 120 ft long. One hundred feet south of the shaft, two short crosscuts were driven to the east and west. At the north end of the pegmatite, on the Ballard property, there are two open-pits, a shaft inclined at 19°, and a 60-ft drift (5751-ft level) and two shallow prospect shafts.

GEOLOGY

The Crown pegmatite is a very irregular body that is conformable to the highly folded quartz-mica schist wall rocks. The fold in the schist and the rolls in the pegmatite plunge 13 to 22 degrees S. 20°–30° E. Similar folds and rolls occur along a parallel pegmatite about 250 ft east of the Crown mine.

The main roll in the Crown mine is a very irregular eastward projection from the main pegmatite body. It has been stoped from the surface to a raise from the 5686-ft level. This roll is also exposed at the end of the south drift on this level. Plate 11 shows the very complex structure.

The Crown-Ballard pegmatite, as mapped, shows a border and wall zone of albite-quartz-muscovite pegmatite, an intermediate zone of cleavelandite-quartz-muscovite pegmatite and a core composed of two units—microcline-quartz pegmatite and quartz pegmatite.

The albite-quartz-muscovite pegmatite of the border and wall zones is predominantly a mixture of gray equant grains of albite and quartz. Muscovite flakes, and books as much as 18 in. across, locally comprise as much as 50 percent of the zone; the average is probably about 25 percent. Yellow, pale-greenish, or buff beryl occurs as "shells" around the groundmass minerals or as anhedral grains and aggregates interstitial to muscovite. At the outer edge of "shell" beryl crystals muscovite is intergrown with beryl so that the crystal shape is partly destroyed. The beryl crystals or aggregates rarely exceed 6 inches in diameter. At the contact with quartz-mica schist the pegmatite minerals are less than one inch across. In places a ½-in. layer of muscovite flakes, parallels the contact; inside this layer the flakes and books tend to be perpendicular to the contact. At the ends of some of the smaller rolls the books appear to have been deformed before the pegmatite was completely crystalized. As a result many of them are concavely curved parallel to the contacts.

The cleavelandite-quartz-muscovite pegmatite of the

Mica produced from Crown mine, 1879–1943

Year	Sheet mica		Punch mica		Scrap mica		Total value
	Pounds	Value	Pounds	Value	Pounds	Value	
1879–84	45, 000	$135, 000. 00	?		?		$135, 000. 00
1941	10, 334	3, 903. 58	246, 235	$12, 311. 75	331, 623	$1, 658. 12	17, 873. 35
1942 (to October)	4, 319. 75	?	114, 951. 5	?	177, 801	?	?
1943	8, 553. 49	37, 318. 62	27, 077. 25	6, 666. 12	?	?	56, 119. 57
Total	68, 207. 24	176, 222. 20	388, 263. 75	18, 977. 87	509, 424	1, 658. 12	208, 992. 92

intermediate zone shows a gradational contact with the wall zone but a fairly sharp contact with the units of the core. This zone is characterized by rounded masses of white to gray cleavelandite in radial growth, which are coated with layers of muscovite flakes and books as much as a few inches in thickness. These masses are as much as 3 ft in diameter, but the average diameter is about 18 in. Muscovite books, as much as 3 ft or more across, occur in this zone. The books decrease gradually in abundance from the outer part of this zone to the core. The outer 10- to 15-ft part of this zone has produced appreciable quantities of sheet mica. Beryl crystals as much as 10 or 12 in. across have been found. Many of these crystals are a series of beryl shells around a core of other minerals. Tourmaline, apatite, and columbite-tantalite are accessory minerals.

The two units of the core, microcline-quartz pegmatite and quartz pegmatite, occur as separate bodies. The microcline-quartz pegmatite contains crystals of microcline and perthite as much as 3 ft in length in a matrix of finer-grained minerals. The quartz pegmatite is primarily white massive quartz. Muscovite, beryl, and cleavelandite occur along a few fractures in the quartz. The beryl crystals tend to be tabular and very short in the direction of the *c*-axis.

Two other pegmatites on the Crown property have been mapped but they have not been divided into zones. They are composed of perthite, albite, quartz, muscovite, tourmaline, and biotite.

MINERAL DEPOSITS

MICA

The Crown and Ballard properties together constituted one of the richest deposits of sheet mica in the Black Hills. The known total of sheet mica produced is about 70,000 lb, and probably an equal quantity was not recorded. In addition, more than 390,000 lb of punch mica has been produced.

Crude mica has been recovered both from the wall zone and the intermediate zone. The thickness of the mica-bearing pegmatite perpendicular to the schist walls is as much as 15 ft, and near rolls in the walls of the pegmatite even wider deposits were formed in parts of the mine. It is not possible to determine the mica content of the rock accurately, but samples from the dump, taken by the U. S. Bureau of Mines in 1944, contained about 25 percent muscovite. According to Mr. Haugen, at many places in the mine a car of mica was recovered for every car of waste rock moved. It is estimated that during the 1943 operations of the New York Mining Company 10 to 15 percent of the rock moved was recovered as punch and sheet mica.

The mica is pale to deep ruby. In part it is heavily air-stained, and in part it contains numerous black mineral inclusions. These black mineral inclusions are mostly tourmaline; feldspar, beryl, and quartz also occur as inclusions. In the wall zone the books are in general smaller, flatter, and have less "A"-structure than those in the intermediate zone. Consequently, the proportion of sheet in the mica decreases from the contact toward the core. Ruling is a common defect in mica from both zones.

The quality and grade of the sheet mica from the Crown-Ballard are incompletely known. Most of the mica mined in 1943 contained less than 10 percent no. 1 and no. 2 qualities, and probably contained some no. 3 quality. With better preparation the quality of the mica produced might have been better, and more selective mining might yield better qualities. However, electrical testing of the mica shows that the power factors of samples tested are quite variable, and relatively low.

The mica sold from the Crown mine in 1941 and 1942 (through October 24) was graded by Mrs. Gladys Wells. The percentages of the average sizes of the sheet mica are approximately as given below:

Size (inches)	Percent
2 by 2	57
2 by 3	28
3 by 3	5. 5
3 by 4	5. 6
3 by 5	2. 9
4 by 6	1. 0
6 by 8	. 03

During this period, 1.5 to 2 percent of the mica was recovered as half-trimmed sheet and 39 to 45 percent as untrimmed punch mica. In 1943, the large sheet mica was three-quarter trimmed and the punch sizes full trimmed. In August to November of that year, 76,965 lb of Crown mica yielded 4,873 lb, or 6.3 percent, of trimmed large and small sheet. The recovery of large and small sheet from individual lots ranged from 3 to 14 percent of the crude mica.

BERYL

Most of the beryl in the Crown-Ballard pegmatite is in the wall zone and intermediate zone, but small quantities occur in the quartz unit of the core. Because most of the beryl crystals contain cores of other minerals the beryl is difficult to separate cleanly by hand-cobbing. Milling would be necessary to recover more than a small part of the beryl.

RESERVES

The mica and beryl reserves of the Crown-Ballard pegmatite cannot be estimated with accuracy. Probably the mica reserves of the Crown and Ballard mines are about equal to the recorded production. The quantity of beryl that could be recovered from the remaining pegmatite would depend on the methods used. Samples from the old dumps taken by the U. S. Bureau of Mines show a beryl content of about 1 percent. This indicates that perhaps 75 tons of beryl may remain in the pegmatite.

CUSTER MICA LODE NO. 1 (CUSTER DISTRICT)

The Custer Mica Lode No. 1 claim, a mica prospect in the SW¼ sec. 18, T. 3 S., R. 5 E., was located by G. W. Siewert in 1943. The claim was prospected in the spring of 1944 by the J. K. Mining Company.

The workings consist of two open-pits. One extends 15 ft N. 60° W. along the pegmatite and is 12 ft wide and 6 ft deep. The other shallow pit, 10 ft long and 8 ft wide, is 10 ft southeast of the first.

The pegmatite is about 80 ft long and 1 to 2 ft thick. It dips 37° SW. parallel to the enclosing quartz-mica-sillimanite schist. The pegmatite has a border zone at the contact composed of muscovite-quartz-albite pegmatite, 1 in. thick, with 4 to 6 in. of albite-quartz pegmatite at the inner edge. The apparent core is albite-muscovite pegmatite. The muscovite (30 percent) is in books at the edge of the border zone and along fractures perpendicular to the walls of the pegmatite. The mica books along the fractures are cracked and filled with tourmaline inclusions that cross the laminae of the books. The sheet mica recoverable is moderately air-stained and deep ruby. Minute mineral inclusions occur in a large proportion of the mica, although some of the mica is of no. 1 and no. 2 quality.

CUSTER MICA LODE NO. 2 (CUSTER DISTRICT)

The Custer Mica Lode No. 2, in the SW¼ sec. 18, T. 3 S., R. 5 E., is held by G. W. Siewert of Custer and was prospected by the J. K. Mining Company in the spring of 1944.

The J. K. Mining Company started a shaft on the south end of one of a series of parallel pegmatites on the claim. This shaft was abandoned at a depth of about 10 ft. The pegmatite at the shaft strikes N. 45° W. and dips 45° SW. It is 3 ft thick and about 100 ft long. The border zone, about 1 in. thick, is fine-grained albite (75 percent) and quartz (25 percent). The apparent core of the pegmatite consists of perthite (45 percent), quartz (30 percent), albite (20 percent), muscovite (5 percent), and biotite. The quartz is associated with perthite and muscovite in graphic intergrowths. Books of muscovite are sparsely distributed through the pegmatite. The largest seen was 6 in. long. Possibly some sheets, 2 by 2 in., could be recovered. The mica is dark ruby, very hard, flat, and lightly air-stained. Most of the mica seen was no. 2 quality or better.

CUSTER MOUNTAIN (SKOOKUM) FELDSPAR MINE (CUSTER DISTRICT)

The Custer Mountain (Skookum) feldspar mine, in the SE¼ sec. 30, T. 3 S., R. 5 E., 1½ miles east-southeast of Custer, is held by the George Beach Estate. This mine has often been visited briefly by geologists of the U. S. Geological Survey, but has not been mapped in detail. Fisher (1945, pp. 35–57) mapped and studied it for the South Dakota Geological Survey in 1942, and Paul Pesonen of the U. S. Bureau of Mines made a map of the property in May 1945.

The mine workings include the main open-cut, 125 ft long, as much as 45 ft wide, and 35 ft deep, and two smaller open-cuts. The main open-cut was made during feldspar mining prior to 1942. In 1944 it was deepened at its north end by L. A. Wagonner and John Fisher. They removed lepidolite and spodumene from a hole about 5 ft deep and 10 ft in diameter. Although the main product of this mine has been feldspar, some beryl, spodumene, amblygonite, lepidolite, and scrap mica were recovered.

The pegmatite is exposed discontinuously over an area at least 1,100 ft long and 275 ft wide. Only two types of pegmatite were exposed on the surface—a fine-grained plagioclase-perthite-quartz pegmatite and perthite-quartz pegmatite. However, under the perthite-quartz pegmatite, in the main open-cut other mineralogical and textural zones are exposed. They are, in order down from the surface, 1) plagioclase-quartz-muscovite pegmatite, 2) quartz-spodumene pegmatite, and 3) lepidolite-spodumene pegmatite.

The plagioclase-perthite quartz pegmatite forms the border and wall zones. The average grain size is less than 1 in. and decreases near the contact. The perthite (10 percent) occurs in scattered crystals as much as 1 ft long in a matrix of plagioclase (75 percent), quartz (20 percent), muscovite (5 percent), and tourmaline. The thickness of this zone probably exceeds 30 ft.

The perthite-quartz pegmatite is the source of feldspar. The perthite crystals and white quartz masses are as much as 8 ft in length. A finer-grained intergrowth of plagioclase, quartz, and muscovite is in part interstitial to these large mineral masses. Muscovite occurs as clusters of books and flakes as much as 2 ft across, and some is associated with white beryl.

Underlying this zone is a discontinuous zone, as much as 15 ft in thickness, of plagioclase-quartz-muscovite pegmatite that contains beryl. This rock is dominantly plagioclase with very little mica, but locally white muscovite forms as much as 25 percent of the rock. The mica occurs as "tied" books as much as 8 in. across but suitable only for scrap. A few white, greasy anhedral beryl crystals were observed; the largest one 14 by 12 in. in cross section. The zone is as much as 15 ft thick.

Quartz-spodumene pegmatite occurs below the plagioclase-quartz-muscovite pegmatite except near the top of the spodumene-bearing unit where it is in contact with the perthite-quartz pegmatite. Spodumene crystals, more than 5 ft long, 18 in. wide, and 6 in. thick, form less than 10 percent of the zone. Near the outer part they are "rotten" and altered to a white or greenish-yellow micaceous mineral. Near the inner part of the zone, adjacent to lepidolite, they are hard and fresh. Cleavelandite, with scattered crystals of columbite-tantalite are interstitial to the spodumene crystals. The upper 10 ft of the spodumene zone is exposed in an area 30 by 25 ft in the northern and lower part of the main open-cut.

Lepidolite-spodumene pegmatite occurs under the quartz-spodumene zone and appears to transect it. The lepidolite is dark-gray to purple and is interstitial to spodumene. It is associated with a little quartz, amblygonite, cleavelandite, and traces of autunite. The exposure is about 8 ft high and perhaps 10 ft wide at the bottom of the pit. It may be the top of a lepidolite core.

The reserves of feldspar, spodumene, beryl, and lepidolite are unknown, but structural evidence indicates that all these minerals can be obtained in commercial amounts by further development.

DAKOTA FELDSPAR MINE (CUSTER DISTRICT)

The Dakota Feldspar mine, near the northeast corner of sec. 8, T. 5 S., R. 5 E., is owned by the Dakota Feldspar Company of Rapid City. This mine, formerly the Beryl Mica Lode, was one of the first producers of feldspar, columbite, tantalite, and beryl in the Black Hills. In 1943 the property was operated for mica by John Fisher and L. A. Waggoner of Custer. L. R. Page visited the mine twice during this operation but did not map it in detail. The mine has been described by Connolly and O'Harra (1929, p. 254) and by Lincoln (1937, p. 70).

The mine consists of an adit, and an open-cut 180 ft long, 10 to 25 ft wide, and as much as 90 ft deep at the draw chutes. The adit extends N. 25° E., 180 ft to the draw chutes from the open-cut, and is said to extend an additional 40 ft.

The main pegmatite strikes N. 50°–65° W. and dips 75° NE. parallel to the quartzite in the footwall and to the quartz-mica schist on the hanging wall. The pegmatite is well zoned, having a muscovite-rich wall zone and a potash feldspar-rich core. The open-pit was originally made to remove feldspar from the core, consequently the muscovite-rich parts of the pegmatite were left in the walls of the cut. These walls, near the draw chutes, were mined for mica in 1943. Muscovite books containing sheet mica occur from 4 to 6 ft inside of the hanging-wall contact with schist. The muscovite in the outer part of the wall zone is suitable only for scrap. A total of 615 lb of sheet and 3,026 lb of untrimmed punch was produced in 1943. This mica was air-stained, fairly hard, ruby colored, and probably mainly of no. 2 inferior quality. About 600 lb of beryl was recovered as a byproduct of mica mining.

DALMON MICA MINE (CUSTER DISTRICT)

The Dalmon mica mine, in the NW¼ sec. 24, T. 3 S., R. 4 E., was operated by Robert McRobbie in the fall of 1943.

Five open-cuts prospect an elliptical pegmatite that is exposed as a low knoll. Thin layers of quartz-mica schist that cap the northern and western parts of the outcrop suggest that little of the body has been eroded. The pegmatite, 100 ft long and as much as 75 ft wide, trends N. 40° W. The southwest contact dips 45° to 60° SW. at the base of the knob, and 10° SW. near the top of the exposure. The eastern contact, where exposed, dips 75° NE. The north end appears to plunge 45 degrees N. 56° W. The crest of the pegmatite probably plunges 20° SW. between the northern and southernmost cuts and then steepens near the southeast end of the exposure. The pegmatite is composed of two mineralogic units—perthite-quartz-plagioclase pegmatite and plagioclase-quartz-muscovite-biotite pegmatite.

In June 1945, the pegmatite was exposed by a cut, 15 to 20 ft wide and 15 ft deep at the face, across the northern end of the body from the northeast contact that extended 35 ft S. 55° W. The border of the pegmatite is a 1-in. zone of very fine-grained perthite-quartz-plagioclase pegmatite. This pegmatite grades into the main coarse-grained unit composed of white perthite crystals (30 percent), as much as 2 ft long, in a finer-grained matrix of quartz, plagioclase, and muscovite. There appears to be less perthite near the northeast edge of the pegmatite. Books of muscovite, not more than 6 in. across, are scattered in this rock within a few feet of the contact.

About 50 ft southwest of this cut is a glory hole that is reached by a combination open-cut and adit that trends N. 85° W. The open-cut is 25 ft long and the adit about 10 ft. At the end of the adit the glory hole extends N. 30° E. for about 20 ft and is 5 ft wide at the base. The open-cut crosses perthite-quartz-plagioclase pegmatite. The adit and base of the glory hole are in fine-grained plagioclase-quartz-muscovite-biotite pegmatite. The top of this unit appears to strike N. 50° W., and dips 30° NE. It is about 15 ft thick and is exposed for 5 ft up the northeast face of the glory hole. Perthite-quartz-plagioclase pegmatite lies above the finer-grained unit. Books of muscovite as much as 6 in. across occur at the contact of the two types of pegmatite and thin books as much as 2 in. across occur in the lower unit.

A third open-cut, at the south end of the pegmatite, is 35 ft long in a N. 35° W. direction, 8 to 15 ft wide, and 20 ft deep at the face. The upper 10 ft of the face is perthite-quartz-plagioclase pegmatite and the lower part is plagioclase-quartz-muscovite-biotite pegmatite. The base of the latter unit is exposed 10 ft from the northern end of the cut. It strikes N. 80° E. and appears to dip 30° SE. under 5 to 10 ft of perthite-quartz-plagioclase pegmatite. The contact of perthite-quartz-plagioclase pegmatite and quartz-mica schist strikes east and dips 50° S. on the east side of the cut, and strikes N. 60° W. and dips 60° SW. on the west side of the cut.

Two shallow cuts explore the eastern and western edges of the outcrop.

In the northern open-cut, muscovite occurs in scattered books as much as 6 in. across and 3 in. thick, interstitial to the perthite crystals. In the glory hole a few books of mica were observed at the contact of the pegmatite units in a zone about 12 in. wide. The mica is pale to deep ruby color. It is air stained, but relatively free of mineral inclusions. More than 600 pounds of large and small sheet mica was sold to the Colonial Mica Corporation in 1943. Less than 15 percent was of no. 1 and no. 2 qualities; the remainder was of no. 2 inferior quality.

DAN PATCH FELDSPAR MINE (KEYSTONE DISTRICT)

by W. C. Stoll

The Dan Patch feldspar mine, owned by Consolidated Feldspar Corporation since June, 1940, is 1.5 miles west-southwest of Keystone, Pennington County, in sec. 7, T. 2 S., R. 6 E. In November 1942, the mine was operated for feldspar, and produced mica and beryl as byproducts. In 1945 it was one of the largest producers of feldspar, beryl, and scrap mica in the Keystone district (Anon., 1945, p. 163).

The pegmatite is developed by a single large pit, 100 ft long and 80 ft wide at the bottom, and about 65 ft in maximum depth below the top of the outcrop. The Dan Patch pegmatite appears to be a pipelike body plunging south or southeast. In plan the pegmatite has an oval shape and is about 160 ft in maximum diameter, in N. 75° W. direction, and about 120 ft in minor diameter. The hanging wall dips 50° SE. This is probably the approximate plunge of the pegmatite. The enclosing country rock is a fine-grained quartz-biotite schist which in most places is concordant with the visible pegmatite walls. A few small wedges of schist project from the walls into the pegmatite.

The principal mineral in the pegmatite is coarse perthite, associated with massive quartz, albite, and muscovite. The muscovite, in books of various sizes, forms irregular "nests" in the pegmatite. Deep ruby-red sphalerite and black columbite-tantalite were observed by L. R. Page in association with muscovite "nests". Some of the muscovite is localized at the walls of the deposit and is associated in part with albite and in part with quartz. Beryl crystals occur in scattered local concentrations, associated with massive quartz and muscovite for the most part. There are irregular masses of dark-colored phosphates and black tourmaline.

Most of the mica removed was of scrap quality, but some was large and flat enough to be rated sheet and punch mica. The flat mica is pale brownish to greenish, air-stained, soft, and flexible. More than 200 lb of large and small sheet mica were sold in 1943.

The beryl is white and mostly free of foreign minerals. Crystals are commonly of moderate size, but one 26-ton crystal is reported to have been mined in 1945 (Anon., 1945, p. 163). This mine was one of the principal sources of beryl in the Black Hills during 1943–45.

DEWEY MICA MINE (HILL CITY DISTRICT)

by J. J. Norton

The Dewey mica mine is in the NE¼ sec. 17, T. 2 S., R. 5 E., Pennington County. It was one of the principal sources of sheet mica in the southern Black Hills during 1943. The mine ceased operation in the latter part of the year because the mica was no longer acceptable to the Colonial Mica Corporation. The operators were Harold Duncan and A. V. Burnside. The writer and Stuart Ferguson of the Colonial Mica Corporation visited the mine September 20, 1943.

The Dewey pegmatite, which strikes N. 60° E. and dips 45° NW., is exposed over a length of approximately 300 ft, and has an average thickness of 20 ft. The interior of the pegmatite is composed principally of quartz-perthite pegmatite, but spodumene occurs in the eastern part of the surface exposures. A wall zone of quartz-albite-muscovite pegmatite as much as 5 ft thick lies along the hanging wall.

The west end of the pegmatite has been worked for mica by a narrow open-cut along the hanging wall. A larger open-cut in the eastern part of the outcrop was worked for potash feldspar and also produced some spodumene. A 15-ft inclined shaft along the hanging wall was sunk in 1943 near the center of the surface exposure and just west of an old vertical shaft, now caved.

The available figures on the mica production of this mine during 1943 are tabulated below. The total production was 861.50 lb of untrimmed punch and 1,732.74 lb of small and large sheet mica. The average size of the sheet mica produced was small and only 12 percent was large sheet.

Sheet and punch mica produced during 1943, Dewey mica mine

Total production:		
Small sheet	pounds	1,475.82
Large sheet	do	329.42
Total sheet	do	1,805.24
Untrimmed punch mica	do	861.50
Ratio of large sheet to untrimmed punch:[1]		
Untrimmed punch	do	861.50
Large sheet (1½ by 2 in. and larger, ¾ trim).	do	134.56
Total processed mica	do	996.06
Percentage punch	percent	86.5
Percentage large sheet	do	13.5

[1] 13.87 lb graded as small sheet was sold with this mica.

Sheet and punch mica produced during 1943, Dewey mica mine—Continued

Ratio of large sheet to small sheet:	
Small sheet (1 by 1 in. and 1¼ by 1¼ in. full trim)-----pounds--	1, 461. 95
Large sheet (1½ by 2 in. and larger, ¾ trim)-----pounds--	194. 86
Total sheet-----do----	1, 656. 81
Percentage small sheet-----percent--	82
Percentage large sheet-----do----	18

During the period when untrimmed punch mica was being produced, 13.5 percent of the total mica sold was sheet and 86.5 percent was untrimmed punch. The mica is light ruby and heavily air-stained. The small sheet in four shipments of mica, totaling 88.49 lb, was sampled for quality between October 30 and December 14, 1943. The weighted averages indicate that the mica comprised 2 percent of quality no. 2, 97 percent of quality no. 2 inferior, and 1 percent of quality no. 3. Considerable reserves of this type of mica are still available.

The recorded spodumene production of the Dewey mine is 40 tons in 1927 and 40 tons in 1937 (Lincoln, 1944). Potash feldspar and beryl also have been produced, and small reserves of each are available.

DOROTHY LODE PROSPECT (CUSTER DISTRICT)

by W. E. Hall

The Dorothy Lode is 2 miles southwest of Custer, Custer County, in SW¼ sec. 27, T. 3 S., R. 4 E. The Consolidated Feldspar Corporation of Trenton, New Jersey is the owner of the claim and operated the property for feldspar between August 25, and November 1942. The property was examined October 21, 1942.

The Dorothy Lode pegmatite is about 150 ft long in a N. 30° E. direction and 50 to 100 ft wide. A pit 75 ft wide and 25 ft deep extends from the south end of the outcrop along the strike for a length of 75 ft. Several small cuts expose the contacts of the pegmatite.

The pegmatite consists mainly of coarse-grained cream-colored perthite and massive gray quartz in a matrix of medium-grained quartz, albite, and muscovite. The albite is unevenly distributed throughout the dike.

Muscovite occurs near the south end of the dike along the east wall of the pegmatite. The wall of the pit contains about three percent muscovite, in clusters and books associated with albite. The average size of the books is 3 by 4 in., and the largest one seen was 6 by 9 in. Most of the mica is white, soft, occurs in large clusters, and appears to be mostly of scrap quality; the rest is hard, clear, good quality light-ruby mica.

Muscovite can be traced also along the west wall of the dike, but the zone does not appear to be as definite as the one on the east wall. This mica zone has not been mined.

Some beryl and tantalite are also present in the pegmatite, but the quantity of each is small.

DOROTHY V MICA-BERYL PROSPECT (CUSTER DISTRICT)

by W. E. Hall

The Dorothy V mica-beryl prospect is 1.7 miles west of Custer, in sec. 28, T. 3 S., R. 4 E., Custer County. The present owner (1945) is Max Husaboe of Custer, who purchased the property from Dorothy Van Osdel in 1933. The claim, with an area of 16 acres, is unpatented. It has produced about 500 lb of beryl, and 3 tons of mica, of which 40 percent is said to have been punch size.

The Dorothy V pegmatite crops out as a ridge about 600 ft long and 75 to 100 ft wide. A cut 18 ft long, 6 ft wide, and 6 to 10 ft deep has been excavated into the side of the outcrop.

The main mass of the pegmatite consists of medium-grained potash and plagioclase feldspar, quartz, black tourmaline, and an intergrowth of muscovite and biotite. This part of the pegmatite has no economic value. Several inclusions of schist, adjacent to quartz masses, lie diagonally across the pegmatite. Coarse-grained white perthite, muscovite, and beryl occur in these quartz-rich areas within 3 ft of the contact with the schist. The largest coarse-grained pegmatite mass is 40 ft long and 3 to 6 ft wide, and has been opened for 18 ft. In this length it contains about 30 percent of perthite, 6 percent of muscovite, and 0.5 percent of beryl. No biotite is present. Several other good showings of muscovite can be seen in the outcrop adjacent to schist inclusions.

Light-green beryl, free of inclusions, is found throughout the massive quartz. The average diameter of the crystals is 1½ in.

The ruby-colored muscovite is of small punch size; the largest book seen was 2 by 2 in. Most of the mica is air-stained, and some is red-stained.

DUBUQUE AND ROYAL FLUSH CLAIMS (CUSTER DISTRICT)

by W. E. Hall

The Dubuque and Royal Flush claims are 5.9 miles southwest of Custer, in sec. 31, T. 3 S., R. 4 E., Custer County. These claims were examined in October 1942.

The Dubuque property, formerly owned by S. R. Williams of Redfield, South Dakota, was purchased by G. Behrens of Custer in 1937. It is an unpatented claim that was not in operation in 1942 and with no record of production.

The Royal Flush claim is a 20-acre property owned by Mr. William Nevin and Mrs. Otto Newberry of Custer who received patent on it February 23, 1938. Since then intermittent operations have been carried on by lessees.

Past production of the Royal Flush claim, supplied by Mr. Nevin, is as follows:

Mineral production in tons, Royal Flush claim, 1938–40

Year	Feldspar	Beryl	Scrap mica
1938	81.4	0.5	3.5
1940	67.9	0	7.14
Total	149.3	.5	10.64

The workings on the Dubuque claim consist of five shallow cuts near the northwest end of the Dubuque-Royal Flush pegmatite. On the Royal Flush claim the southeast end of the pegmatite is prospected by two open-cuts. A cut 50 ft long, 25 ft wide, and 8 ft deep has produced most of the minerals, as all the other cuts on the pegmatite are small and only 1 to 4 ft deep.

The Dubuque-Royal Flush pegmatite crops out on the south slope of an east-west ridge. The pegmatite is crossed by a gulch, at an altitude of 5,760 ft, on the Royal Flush property and is exposed diagonally up the slope of the ridge to an altitude of 5,880 ft on the Dubuque property. The pegmatite strikes N. 35° W. and is exposed discontinuously for 1,025 ft. Its average thickness is about 8 ft. The pegmatite strikes parallel to the schistosity of the country rock, but whereas the dip of the pegmatite is 50° to 65° NE., the dip of the foliation of the schist is 40° to 65° SW. Another pegmatite, barren of mica and beryl, crops out on the Dubuque property 30 ft northeast of the main pegmatite. It is 200 ft long and strikes parallel with the main dike.

The Dubuque-Royal Flush pegmatite is composed of a coarse-grained core of perthite and massive quartz surrounded by a discontinuous wall zone of medium-grained albite, quartz, muscovite, beryl, and black tourmaline. The core contains no beryl and but little muscovite. The perthite contains 5 to 10 percent of medium-grained quartz.

The albite-rich wall zone has a maximum width of 6 ft on the hanging wall (northeast) side of the pegmatite and a maximum width of 3 ft on the footwall side. Near the northwest end of the pegmatite a mica-rich band in the wall zone is visible along the hanging wall for 125 ft along the strike. This band ranges from 1 to 6 ft in width and contains as much as 10 percent muscovite. Along the footwall, the wall mica zone is discontinuous, and narrower than on the hanging wall. Its average content of muscovite is 3 percent.

The muscovite is a colorless variety, soft, and suitable only for scrap. Most of it is badly flawed by "A"-structure and fishtailing.

Yellowish-green beryl free of inclusions was seen in place at the open-cut on the northwest end of the dike. It occurs in the pegmatite for 150 ft southeast from the open-cut in the hanging wall albite zone, associated with medium-grained quartz, muscovite, and albite. The crystals seen in the rock have an average diameter of 1½ in., but crystals seen in a small stockpile were as much as 6 in. in diameter.

At the southeastern end of the dike on the Royal Flush claim, beryl of similar color and quality is present in the albite zone along both the footwall and the hanging wall.

DYKE LODE (KEYSTONE DISTRICT)

The Dyke Lode, in the NE¼ sec. 21, T. 2 S., R. 6 E., Pennington County, was one of the large producers of beryl in the Black Hills in 1943. It is about 0.6 of a mile north of the Iron Mountain road, from a point that is 17 miles by road east of Custer and 8 miles south of Keystone.

The property, originally owned by the Reinbold Metallurgical Company, was purchased by Ralph A. Smith of Custer in 1935. It was operated under a lease by Lawrence Judson of Keystone until 1942 when it was acquired by A. V. Burnside and John Newburg of Custer. Burnside operated the property until late in 1944, when it was sold to John Fisher of Custer. The mine was first operated for feldspar, but small amounts spodumene, amblygonite, and beryl were produced. In 1943–45 the mine was operated mainly for spodumene, amblygonite, and sheet mica. The table below gives the known production.

The property was visited by various geologists of the U. S. Geological Survey between 1942 and 1945. Stoll's 1942 report on the property is incorporated in this report with data obtained in 1943–45. In 1943 E. L. Tullis of the U. S. Bureau of Mines mapped the property and in July 1945, Page sketched in the zonal distribution of minerals (pl. 12).

Mineral production, Dyke Lode

Year	Mica (pounds)			Spodumene (tons)	Amblygonite (tons)	Beryl (tons)	Feldspar (tons)
	Sheet	Untrimmed punch	Scrap				
1936–42	None	None	20,000	86	80	40	6,000
1943	101.07	786	20–40,000	50.46	60	28.8	125
1944	108.74						
1945 [1]	63.36	1,566.18					
Total	272.80	2,352.18	40–60,000	136.46	140	68.8	6,125

[1] Production to June. Full-trim large sheet sold January 1 to April 1; 20 to 32 percent no. 1 quality, 35 percent no. 2 quality, the remainder was no. 2 inferior quality.

The Dyke Lode property has been worked from an open-cut 120 ft long, 90 ft wide, and as much as 65 ft deep; and from a 40-ft inclined shaft which is connected with a glory hole in the bottom of the open-cut. The glory hole is about 50 by 30 ft at the top. At the 40-ft level a drift, 38 ft long, connects the glory hole and shaft (pl. 12).

The Dyke Lode pegmatite is pear-shaped with the big end to the northeast. It trends about N. 55° E. and dips steeply southeast. The northeast end is vertical and in places the southwest end dips about 75° SW. Rolls on the contact plunge 70° to the S. 50° E. In general the pegmatite appears to be concordant with the quartz-mica schist wall rocks, but in detail it is crosscutting.

The Dyke Lode pegmatite is complexly zoned, but only four divisions are indicated on the map, and these in a general way. An outer border of fine-grained pegmatite, 1 to 2 in. thick grades into a slightly coarser plagioclase-quartz-muscovite pegmatite wall zone. The wall zone grades into intermediate zones, of which two (the quartz-perthite and the plagioclase-perthite-quartz-spodumene pegmatite) are shown on the map. The plagioclase-perthite-quartz-spodumene pegmatite grades into a quartz-spodumene pegmatite core at its inner edge.

The plagioclase-quartz-muscovite pegmatite of the wall zone is 15 to 30 ft thick. It consists of plagioclase (55 percent), quartz (40 percent), and muscovite (5 percent), and a few crystals of black tourmaline. The plagioclase is white to gray and contains both albite and oligoclase. Muscovite aggregates and books as much as 2 in. across are common, but the average grain size of the rock is less than 1 in.

Quartz-perthite pegmatite forms an intermediate zone outside the spodumene-bearing rock. Perthite crystals several feet across are enclosed in white to rose quartz. The inner part of this zone contains plagioclase (probably albite), muscovite, and dark-colored phosphate minerals. This part of the zone, which is 10 ft thick in places, appears to grade into a mica-rich zone, 2 to 10 ft thick, that contains spodumene. Detailed mapping, using muscovite as a diagnostic mineral, is necessary before the relationships of these mica-rich units can be definitely determined.

The plagioclase-perthite-quartz-spodumene pegmatite is an intermediate zone that represents the gradation from quartz-perthite to quartz-spodumene pegmatite. Spodumene was used as the diagnostic mineral in mapping. This zone produces most of the sheet and punch mica, beryl, amblygonite, and columbite-tantalite, and appreciable quantities of spodumene and feldspar. This zone from the outer to the inner edge is composed of the following units: (1) muscovite-rich pegmatite, 2 to 10 ft thick, the source of sheet, punch, and scrap mica, (2) beryl and amblygonite-rich pegmatite, the source of much of the beryl and most of the amblygonite, and (3) plagioclase-spodumene pegmatite. These units intergrade with adjoining zones and the core. In the entry cut to the open-pit a fracture-filling body of this intermediate zone extends across part of the wall zone. (See pl. 12.)

The spodumene crystals in the intermediate zone are as much as 10 ft long, 2 ft wide, and 1 ft thick. Spodumene produced from this part of the mine contains 5 to 6 percent Li_2O. Crystals of white beryl occur with amblygonite. The two largest observed were 3 ft in diameter and 6 to 8 ft long (fig. 6). One crystal from the fracture-filling body had a refractive index (N_0) of 1.580. The amblygonite masses are of similar sizes and muscovite occurs in books or aggregates of books as much as 2 ft across. The large aggregates contain little sheet mica, but smaller books, rarely more than 10 in. across and 8 in. thick, contain flat, hard, pale-yellow or brownish to colorless mica. There is relatively little air-stain, though mineral-staining is quite common. Most of the mica is of punch sizes and comparatively little is in large sheets. In 1945 the large sheet sold to the Colonial Mica Corporation contained 20 to 30 percent no. 1 quality, and 35 percent no. 2 quality; the remainder was no. 2 inferior quality.

The quartz-spodumene pegmatit e which forms the core of this body in the bottom of the open-cut has been mined from the shaft and glory hole. The spodumene crystals are less altered than those in the intermediate zone. They are as much as 2 ft across and several feet long. Albite, beryl, colorless amblygonite, and one specimen of gray topaz were recovered from the glory hole, but the zones from which these minerals were mined is unknown. One analysis of the colorless amblygonite, made for the U. S. Geological Survey by Charles Bentley of the South Dakota School of Mines, Mining Experiment Station, Rapid City, shows 9.18 percent Li_2O. The spodumene produced in 1945 contained over 6 percent Li_2O.

The reserves of spodumene and amblygonite in the Dyke Lode appear to be moderately large. In the intermediate zone probably 10 to 15 percent of the rock is spodumene and the core may contain as much as 25 percent, of which about half is recoverable by hand-sorting at the face. Structural considerations indicate that the spodumene-bearing rock on the 40-ft level may be as much as 100 ft long and 60 ft wide. The zone probably extends 100 ft below this level, but the content of spodumene or the content of lithia in the spodumene may change radically.

Appreciable reserves of spodumene, beryl, and sheet mica remain in the pegmatite and can easily be recovered either by selective mining or as a byproduct of spodumene mining.

EARL LODE (CUSTER DISTRICT)

The Earl Lode claim, in NE¼ sec. 33, T. 3 S., R. 5 E., Custer County, was located by Langford Landis in June 1937. It is now owned by Landis and Delbert

McKenna of Custer. In 1943 it was a big producer of sheet mica, though it was originally mined for feldspar. Its production is given in the table below.

The property was first examined and mapped by W. C. Stoll in 1942. It was visited by L. R. Page in 1943 while underground operations were in progress. In July 1945 the property was remapped by L. R. Page and A. F. Trites, Jr., using as a base a topographic map made by the U. S. Bureau of Mines (pl. 13).

DEVELOPMENT

The workings on the Earl Lode consist of an open-pit, an adit, a drift, and raises. The open-pit is 170 ft long, 50 ft wide, and as much as 50 ft deep. The adit, 44 ft below the floor of the open-cut, is 105 ft long and connects by a raise to the open-cut. At 90 ft from the portal a drift extends 45 ft southwestward along the hanging wall and 50 ft northeastward. A short raise prospects the hanging wall 15 ft from the northeast end of this drift (pl. 13).

GEOLOGY

The Earl pegmatite strikes about N. 75° E. and dips from 45° to 65° NW.; the average dip is about 55°. It is conformably intruded into interbedded quartz-mica schist and gray quartzite. The pegmatite is about 25 ft thick in the open-cut and narrows to about 10 ft at the adit level.

Mineral production, Earl Lode

	Mica (pounds)				Beryl (tons)	Feldspar (tons)
	Sheet	Untrimmed punch	Scrap	Cobbed		
1937–42				22,398	15	5,000
1943	1,749.79	5,264.5	62,000		.45	200
1944	52.92		?		.29	
Total	1,802.71	5,264.5	62,000	22,398	15.74	5,200

Three zones in the pegmatite have been mapped, a wall zone (including a border zone) of albite-quartz muscovite pegmatite, an intermediate zone of albite-perthite-quartz pegmatite, and a core of quartz-perthite pegmatite. With more detailed mapping these zones could be split into smaller units.

The wall zone is composed of albite (about 80 percent), quartz (15 percent), and muscovite (5 percent). Black tourmaline and beryl are accessory minerals. The albite is in white, buff, or gray anhedral crystals as much as 12 in. across. Muscovite books as much as 32 in. in diameter and 9 in. thick have been found, but most of them are 8 to 12 in. long. Locally, tourmaline is very abundant. In the pit, the hanging wall part of this zone is 1 to 4 ft thick and contains appreciable quantities of perthite. Along the footwall the zone is 3 to 6 ft thick and perthite is rare. Underground along the drift the hanging-wall part of the zone is 2.5 to 4.5 ft thick and the footwall part is 1.5 to 3 ft thick. No perthite was observed in this zone in the underground workings.

The intermediate zone of albite-perthite-quartz pegmatite has different mineral compositions in the open-cut and on the adit level, though structurally it is continuous. In the open-cut this zone consists of perthite crystals several feet long enclosed in a matrix of quartz, albite, and muscovite. These minerals rarely exceed 2 in. in diameter. Beryl, amblygonite, and some black tourmaline are present. This zone may be as much as 10 or 15 ft thick. On the hanging-wall side of the core at the adit level perthite is rare and the zone is dominantly quartz, with albite (cleavelandite), muscovite, and beryl. On the footwall side albite is dominant. Small flakes of muscovite (in aggregates as much as 6 in. across), tourmaline and quartz, are associated with the albite.

Quartz-perthite pegmatite forms the core of the body. In the open-cut it is 20 to 40 percent cream to pink perthite in a matrix of gray to white quartz. On the adit level only a few crystals of perthite occur in the quartz.

MINERAL DEPOSITS

The Earl Lode has produced feldspar, sheet, punch, and scrap mica, beryl, and amblygonite. In the early history of the mine, feldspar was the chief product and during 1943–44 sheet mica was the main mineral produced.

MICA

The muscovite mica in the wall zones is a dark-ruby, flat mica. It is moderately to heavily air-stained and rather soft. The books are large, widely spaced in the zone, and readily loosened from the rock. As a result very few books remain in a face after blasting, although the recovery of crude mica may be 3 to 5 percent. The books, although large, are ruled and cracked so that 6- by 8-in. trimmed sheets are rare. The available information on the size distribution of the mica is tabulated below. Mica from this mine was not acceptable to the Colonial Mica Corporation after January 1944, though a few small lots were sold. These lots contained 15 percent no. 2 quality and 85 percent of no. 2 inferior quality. Additional sheet and punch mica may be obtained if the rest of the wall zone were mined.

The mica in the intermediate zone is mostly of scrap quality. It is greenish and occurs in wedge and "A" books as much as 12 in. long and 8 in. thick. Muscovite is most abundant in this zone at the adit level. In the open-cut it is much finer grained.

Size distribution (in inches) of mica, Earl Lode

Size (inches)	1½ by 2	2 by 2	2 by 3	3 by 3	3 by 4	3 by 5	4 by 6
Pounds	112.48	115.48	71.39	21.20	13.64	13.70	2.77
Percent	32.0	33.0	20.2	6.2	3.9	3.9	.8

Data obtained from 350-pound sample of half-trim sheet; ratio of ½-trim sheet to untrimmed punch about 1:7.9; ratio of ¾-trim sheet to full trim punch, about 1:1.5.

BERYL

About 15 tons of beryl has been produced at the Earl mine, mostly from the intermediate zone around the core, in crystals as much as 5 in. across. Beryl occurs also in the wall zone as crystals less than 1 in. across, but the crystals are not recoverable by hand-sorting. Beryl from the intermediate zone has a refractive indices (N_o) of 1.576 to 1.580. The beryl-bearing zones appear to contain no more than 0.5 percent of beryl.

FELDSPAR

The feldspar deposits are in the intermediate zone and the core of the pegmatite. Records of past production indicate that the perthite recovered was 20 to 30 percent of the material mined from the open-cut. The unmined pegmatite on the property probably contains about the same percentage of this material. All of the potash feldspar-bearing rock appears to lie above the adit level, and to contain an amount of feldspar equal to that already produced.

AMBLYGONITE

There is no record of the sale of amblygonite, and none was seen in place, but half a ton or so is in a stockpile, and reports suggest that it was derived from the intermediate zone.

RESERVES

The reserves of all economic minerals produced from the Earl Lode are at least equal to past production. With the exception of scrap and sheet mica they all occur above the adit level. Because little of the mica-bearing rock was stoped from the adit level, and yet 70 percent of the sheet mica was produced from these workings, the reserves of sheet mica might be expected to be several times the past production.

EDISON SPODUMENE MINE (KEYSTONE DISTRICT)

The Edison spodumene mine, in sec. 9, T. 2 S., R. 6 E., Pennington County, has been owned by Thomas A. Edison, and his estate, since 1923. In 1942 the property was leased to Mr. K. K. Leute, of the Metalloy Corporation of Minneapolis, Minnesota. In July 1943 he assigned the lease to the Lor Mining Company (K. K. Leute, W. W. Osborne, and H. W. Rogers, principals). This company owns the Sitting Bull and Edison No. 1 claims and controls the Bull Con, the north 400 ft of the Sitting Bull No. 1, and the south 2 acres of the Gold Star claims, all original locations by David I. Swanzy, who opened the two spodumene deposits on the Sitting Bull and Bull Con claims in 1917–18. The main portal of the Edison mine adit is on the Gold Star claim, though most of the underground workings and the glory hole are on the Sitting Bull No. 1 claim. The smaller spodumene deposit, developed by adit no. 2 and open-pits, is on the Bull Con claim.

The Edison property can be reached from Keystone, the nearest railroad shipping point, by U. S. Highway 16 to the junction of the Etta mine road, a dirt road south to the Etta mine dumps, and then east 1.2 miles to the Edison spodumene mine.

TABLE 32.—*Production of spodumene, Edison mine*

	Short tons	Grade
1943	714.81	4.59 (percent) Li_2O.
1944	1,442.13	5.38 (percent) Li_2O.

In June 1944 L. R. Page, assisted by J. W. Adams and Peter Joralemon, mapped the surface geology of the Edison mine on a scale of 1 in. to 40 ft and the underground geology on a scale of 1 in. to 20 ft (pl. 14). The surface and underground maps, made by plane table and telescopic alidade, were used by the U. S. Bureau of Mines in planning their exploration program. Adams located the diamond-drill holes by transit and tape. The drill cores were logged by Page, who is also responsible for the projections necessary in preparing the cross sections (pl. 15) and the plans (pl. 16) of the 50- and 100-ft levels. The property had been previously examined for the U. S. Geological Survey by Stoll and Hall in November 1942.

Throughout the work of the U. S. Geological Survey and U. S. Bureau of Mines, the operators of the Edison mine assisted by making available existing maps and production records. In addition, at the request of the Survey, they made six 8-ft drill holes to assist in determining geologic structure. The writer is especially indebted to Mr. James Savage, resident engineer and manager for the Lor Mining Company.

MINE WORKINGS

The Edison mine was originally worked by a series of open-cuts, one of which was in the area occupied by the glory hole (pl. 14). Later two adits were driven eastward from the lower open-cut and were connected by a drift along the eastern side of the pegmatite. These underground workings were later enlarged to the limits of the richer spodumene bodies. Two stopes were worked during the winter of 1943–44. (See pl. 14.) Later, raises were driven from these stopes to one of the open-pits and the rock was mined by glory-hole methods. In September 1944 a 131-ft shaft was sunk in the floor of the pit on the adit level.

The Bull Con spodumene pegmatite, about 450 ft north of the shaft, has been prospected by a short adit and five open-cuts, but no spodumene has been produced from this pegmatite by the present operators.

U. S. BUREAU OF MINES EXPLORATION AND SAMPLING

In late June 1944 the U. S. Bureau of Mines started a diamond-drilling program at the Edison mine. Thirteen holes, with a total length of 2,114.5 ft, were drilled. One of these holes prospected the Bull Con spodumene pegmatite 450 ft north of the mine; the other twelve explored the main Edison pegmatite. Logs of these drill holes are given below. All pegmatite recovered in cores or sludges, except from hole no. 10, was assayed for Li_2O at the Rolla Laboratories of the U. S. Bureau of Mines. The only systematic sampling of spodumene exposures was in the shaft, where 5-ft channels were cut along the west side from the surface to the 131-ft level. However, large samples that represent reject material from the sorting plant were taken, one from the minus 1-in. stockpile and one from the plus 1-in. stockpile. One 4-ton sample was taken from the ore chute as representative of material already broken in the glory hole. In 1943 a series of samples was taken by the Bureau of Mines which included channels of high-, average-, and low-grade ore exposed in the walls of the adit level at that time. Grab samples were also taken of products from the sorting plant.

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine

Hole no. 1

Bearing: N. 68° 17′ E. Altitude: 4,678 ft.
Inclination: Minus 30°. Length: 181.5 ft.

Feet		Description
0–19		Overburden. No core 0–6 and 10–15 ft. Pegmatite fragments.
19–27.5		Hornblende gneiss and schist. Iron-stained and weathered.
27.5–28.5		Muscovite schist, iron-stained and weathered. Foliation 30° to the drill core.
28.5–46.6		Pegmatite.
	28.5–29	Tourmaline-quartz pegmatite. About 75 percent black tourmaline.
	29–34	No core. Sludge contains weathered albite, quartz, muscovite, and spodumene.
	34–42	Quartz-spodumene pegmatite. Iron-stained, soft, brown to olive-green, soapy spodumene (70 percent).
	42–46.5	Albite-quartz pegmatite. Gray quartz (50 percent), fine-grained albite (48 percent), and flakes of muscovite (2 percent). One-inch tourmaline-quartz pegmatite selvage at contact.
46.5–50		Quartz-mica schist. Fine-grained at 47 ft; coarse-grained at 49–50 ft with tourmaline (15 percent). Foliation 55° to the drill core.
50–76.8		Hornblende gneiss and schist. Dark greenish, massive to schistose, medium-grained. Biotite increasingly abundant from 72 to 76.8 ft. Foliation 70–75° to the drill core. Fractured at 52, 55, 70, and 72 ft.
76.8–100		Pegmatite. Possible fault at 75.8 ft.
	76.8–93.5	Quartz-spodumene-albite pegmatite. Composed of (in order of decreasing importance) quartz, spodumene (15–20 percent), albite, muscovite, apatite, columbite-tantalite. Spodumene unaltered and hard. Iron-stained fractures at 77, 81, 88, and 90 ft.
	93.5–100	Albite-quartz-muscovite pegmatite. Quartz (45 percent), muscovite (30 percent), and albite (25 percent). Iron-stained fracture zone.
100–101		Quartz-mica schist. Medium- to coarse-grained. Poorly foliated. Foliation 70° to core.
101–120.9		Pegmatite. Footwall contact 45° to drill core.
	101–101.5	Albite-quartz-muscovite pegmatite.
	101.5–116	Quartz-spodumene-albite pegmatite. From 101.5 to 105 ft gray-green altered spodumene (27 percent) with white muscovite (3 percent), pink or gray albite (20 percent), and gray quartz (50 percent). From 105 to 116 ft, white, hard, unaltered spodumene (15 percent) with quartz, albite, and muscovite. Approximately one-quarter of core recovered was albite-quartz pegmatite barren of spodumene. The largest section of this rock between spodumene crystals was 0.8 ft.
	116–120.9	Albite-quartz-muscovite pegmatite. Fine-grained pink to gray albite is the dominant mineral. Muscovite in books makes up as much as 20 percent of parts of the core. Fractured at 119 ft.
120.9–126		Hornblende gneiss and schist. Medium- to coarse-grained. Foliation 70° to the drill core. Fractured at 121, 124, and 125.
126–135		Quartz-mica schist and quartzite. Medium- to fine-grained biotite schist and quartzite. Probable faults at 130–132 ft and at 134.5 ft.
135–146.2		Hornblende schist and quartzite. Fine-grained hornblende schist, biotite-quartz schist or quartzite, chloritic schists with quartz-sulfide veins. Closely fractured.
146.2–148.7		Albite-quartz-muscovite pegmatite. Narrow selvage zones rich in muscovite and triphylite. Upper contact 55°, lower contact 70° to the drill core. Fractured.
148.7–154		Quartz-mica schist and quartzite. Interbedded muscovite-rich and biotite-rich schists and gray quartzite. Foliation and bedding 40° to 50° to the drill core. Fracture zone at 152 ft.
154–181.5		Hornblende gneiss and schist with quartz-sulfide veinlets (up to 40 percent) parallel foliation. Rock appears to have been crumpled and folded prior to introduction of quartz and pyrite. Hornblende is in part chloritized.

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 2.

Bearing: N. 69° 36′ E. Altitude: 4,685 ft.
Inclination: minus 30°. Length: 188 ft.

Feet		*Description*
0–25		Probably overburden. Pegmatite blocks 0–19 ft. No core 19–25 ft.
25–39.5		Graphitic mica schist. Mineralized with carbonate, arsenopyrite (?), and pyrite. Weathered and iron-stained. Foliation 50° to the drill core. Bedding 35° to core at 32 ft and 40° to core at 39 ft.
39.5–50		Pegmatite.
	39.5–39.6	Muscovite flakes recovered.
	39.6–45.0	Chalky spodumene and quartz (2 percent).
	45.0–50	No core.
50–50.5		Quartz-mica schist. Feldspar (20 percent).
50.5–116		Pegmatite. Hanging-wall contact 70° to core.
	50.5–51	Quartz-muscovite pegmatite. Fine-grained selvage.
	51–55	Sheared and altered pegmatite, with some schist fragments and green soapy spodumene.
	55–65	No core. Pegmatite sludge.
	65–74	Quartz-spodumene pegmatite. Quartz (80 percent), muscovite (5 percent), albite (5 percent), and fresh spodumene (10 percent). Fractured at 70 ft.
	74–75.5	Albite-quartz pegmatite. Quartz (20 percent). Scattered small spodumene and columbite crystals.
	75.5–77	Quartz-spodumene pegmatite. Spodumene (25 percent).
	77–84.5	Albite-quartz pegmatite. Albite (85–90 percent). Fractured at 77.5, 78 to 79.5, and at 82 ft.
	84.5–92.5	Quartz-spodumene pegmatite. Spodumene (20 percent). Strongly fractured 84.5 to 86, 88 to 90, and at 92 ft.
	92.5–94	Albite-quartz pegmatite. Fractures at 94 ft.
	94–102.5	Quartz-spodumene pegmatite. Fresh, hard spodumene (20–25 percent), albite (5 percent), and muscovite (1 percent).
	102.5–116	Albite-quartz-muscovite pegmatite. Albite (80 percent), muscovite (5 percent), and quartz (15 percent). Probable fault zone 106 to 107 ft.
116–182		Hornblende gneiss and schist with disseminated pyrite. Water, 10 gallons per minute, at 148 to 149 ft.
182–188		Quartz-mica schist and quartzite. Fine-grained biotite schists with hornblende, and sulfides for the most part.

Hole no. 3

Bearing: N. 69° 36′ E. Altitude: 4,686 ft.
Inclination: Minus 60°. Length: 150 ft.

Feet		*Description*
0–22		Overburden.
22–26		Schist. Strongly weathered. Probably graphitic mica schist.
26–31		Muscovite-quartz pegmatite. Hanging-wall contact 10° to 20° to the drill core. Footwall contact 25° to the drill core. Completely weathered to mass of iron-stained muscovite (50 percent) and quartz grains.
31–33		Mica schist. Weathered biotite and sulfides.
33–34		Muscovite-quartz pegmatite. Iron-stained and brecciated. Hanging wall contact 35° to the drill core, parallel foliation.
34–52		Graphitic mica schist. Gray, brecciated, gougy schist with pegmatite fragments from 34 to 40 ft. From 40 to 52 ft rock is hard, and impregnated with sulfides and carbonate.
52–53		Albite-quartz-muscovite pegmatite. Hanging-wall contact 45° to the drill core; footwall contact 10° to the drill core. Pegmatite sheared parallel to footwall contact. Muscovite (40 percent), greenish kaolinized feldspar (40 percent), and quartz (20 percent).
53–54.5		Mica schist.
54.5–63		Pegmatite. Hanging-wall contact 50° to the drill core; footwall contact 70° to core.
	54.5–55.3	Quartz-muscovite pegmatite. Fine-grained muscovite (30 percent).
	55.3–62.5	Quartz-spodumene pegmatite. Soft, white, chalky spodumene (40 percent), and feldspar (5 percent).
	62.5–63	Quartz-muscovite pegmatite. Muscovite (40 percent).
63–70.5		Quartz-mica schist and quartzite. Light gray, fine-grained, thinly bedded rock. Foliation 75° to 80° to the drill core. Bedding 60° to 70° to the drill core. Carbonate seams parallel bedding.
70.5–125.2		Pegmatite. Hanging-wall contact, probably 70° to the drill core.
	70.5–73	Quartz-muscovite pegmatite. Muscovite (20 percent), and quartz (80 percent).
	73–83.5	Quartz-spodumene pegmatite. Greenish altered spodumene (30 percent).
	83.5–84	Albite-quartz pegmatite. Albite (80 percent), quartz (20 percent).
	84–84.5	Greenish altered spodumene.
	84.5–86	Albite-quartz pegmatite.
	86–88.5	Spodumene-quartz pegmatite. Greenish altered spodumene.
	88.5–89	Albite-quartz pegmatite with muscovite (30 percent).
	89–93.5	Spodumene-quartz pegmatite. Soft chalky spodumene.
	93.5–94	Albite-quartz pegmatite with muscovite (5 percent).

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 3—Continued

Feet		*Description*
70.5–125.2	Pegmatite.	Hanging-wall contact, probably 70° to the drill core—Continued
	94–97.5	Spodumene-quartz pegmatite. Greenish altered spodumene (20 percent) with some albite and muscovite.
	97.5–98	Albite-quartz pegmatite. Albite shows chalky alteration.
	98–105	Spodumene-quartz pegmatite. Spodumene (10 percent), soft and chalky to 104 ft where it is hard.
	105–107	Albite-quartz pegmatite. Fractured 50° to the drill core. Strong iron oxide stains.
	107–109.5	Spodumene-quartz pegmatite. Spodumene hard but iron-stained.
	109.5–110	Albite-quartz pegmatite.
	110–113	Spodumene-quartz pegmatite. Greenish altered spodumene (10 percent). Possible fault zone 110–112 ft.
	113–125.2	Albite-quartz pegmatite.
125. 2–150	Hornblende gneiss and schist. Foliation 40 to 50° to the drill core. Altered to biotite schist in 0.6 ft zone at contact.	

Hole no. 4

Bearing: N. 70° 25′ E. Altitude: 4,688 ft.
Inclination: Minus 60°. Length: 155 ft.

Feet		*Description*
0–25	Overburden. No core.	
25–41	Quartz-spodumene pegmatite. Soft, white to buff, chalky spodumene.	
41–44	Muscovite-rich pegmatite. Weathered (?). Possibly gouge zone.	
44–56	Hornblende gneiss and schist grading to hydrothermally altered, light-gray, fine- to medium-grained carbonate schist from 44 to 45.5 ft. Fractured.	
56–62.6	Albite-quartz-muscovite pegmatite. Footwall contact 50° to the drill core. Fine-grained buff to gray albite (80 percent) with quartz (17 percent) and flakes of muscovite (3 percent).	
62.6–71	Hornblende gneiss and schist. Medium- to coarse-grained. Altered to biotite schist at 62.6 to 63.6 ft and to carbonate schist at 69.5 to 71 ft. Brecciated and veined at 70 to 71 ft.	
71–136	Pegmatite.	
	71–75	Albite-quartz-muscovite pegmatite. Rock between 71 and 72 ft is quartz (60 percent), albite (35 percent), and muscovite (5 percent). Remainder largely "sugary" albite.
	75–95	Quartz-spodumene pegmatite. Spodumene (30 to 50 percent) hard and fresh except near 6-in. band of muscovite-quartz pegmatite at 77 ft and near albite-quartz pegmatite between 83 and 84 ft. Also altered from 93 to 95 ft.
	95–105	Albite-quartz pegmatite. Cleavelandite (60 percent), quartz (39 percent), and muscovite (1 percent).
	105–120	Quartz-spodumene pegmatite. Spodumene (35 percent) hard and fresh except from 115 to 120 ft.
	120–136	Albite-quartz pegmatite. Albite (75 percent), quartz (20 percent), and muscovite (5 percent). From 122 to 125 ft rock is quartz (60 percent), albite (30 percent), and muscovite (10 percent).
136–155	Hornblende gneiss and schist. Hornblende altered to biotite at contact with pegmatite. Possible fault zone from 145 to 155 ft.	

Hole no. 5

Bearing: N. 72° 24′ E. Altitude: 4,667 ft.
Inclination: Minus 50°. Length: 203 ft.

Feet		*Description*
0–20	Overburden. No core.	
20–55.7	Graphitic mica schist. Dark gray to black; heavily impregnated with pyrite and some arsenopyrite. Fold axis at 35 ft. Crumpled and brecciated from 45 to 55 ft. Quartz-sulfide veins at 40 to 41 ft. Carbonate-sulfide vein at 38.5 ft.	
55.7–63	Pegmatite. Hanging-wall contact 50° to the drill core. Soft, greenish, soapy, muscovite-rich rock. Probably albite-quartz-muscovite pegmatite; brecciated and hydrothermally altered.	
63–86	Hornblende schist. Fine-grained. Strong hydrothermal alteration forming a dull, green or black, carbonate schist with texture of hornblende schist. Alteration decreases from 85 to 86 ft.	
86–99	Hornblende gneiss and schist. Medium- to coarse-grained. Probably a fault at 90 ft.	
99–107	Quartz-mica schist. Fracture zones 106 to 107 and 109 to 110 ft.	
107–121	Hornblende schist. Fine-grained. Altered to carbonate schist 118 to 121 ft. Fracture zone between 114 and 115 ft.	
121–183	Pegmatite. Hanging-wall contact 50° to the drill core.	
	121–151.8	Albite-quartz-muscovite pegmatite. Hydrothermally altered at contact and from 129 to 140 ft.
	151.8–156.6	Quartz-spodumene-albite pegmatite. Spodumene (20 percent). Some fresh, but mostly dark-green altered crystals.
	156.6–175	Albite-quartz-muscovite pegmatite. Variable composition. Brecciated and altered to buff soft mass at 167.3 to 171.7 ft.
	175–176.5	Quartz-spodumene-albite pegmatite. Spodumene (50 percent) green and altered.
	176.5–183	Albite-quartz pegmatite. Green spodumene crystals at 179 ft.
183–203	Hornblende gneiss and schist. Medium-grained. Hornblende altered to biotite at contact. Foliation 50° to the drill core.	

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 6

Bearing: N. 71° 13′ E. Altitude: 4,679 ft.
Inclination: Minus 45½°. Length: 201 ft.

Feet	*Description*
0–20	Overburden. No schist fragments observed.
20–34.5	Pegmatite.
	20–28 Quartz-spodumene-albite pegmatite. Spodumene (10 percent) iron-stained, hard and disintegrated.
	28–34.5 Albite-quartz-muscovite pegmatite.
34.5–67.5	Hornblende gneiss and schist. Medium- to coarse-grained. Highly fractured. Altered along fractures from 62 to 67.5 ft.
67.5–95.5	Pegmatite.
	67.5–80 Albite-quartz pegmatite. Scattered scales of muscovite (1–2 percent). Strong fracture zone 71 to 75 ft.
	80–90 Quartz-spodumene-albite pegmatite. Spodumene (15 percent) hard, brownish green.
	90–95.5 Albite-quartz-muscovite pegmatite. Quartz (50 percent), albite (45 percent), and muscovite (5 percent).
95.5–104	Quartz-mica schist and quartzite. Fine-grained schist grades into quartzite. Bedding 40° to the drill core. Foliation 30° to the drill core.
104–125.5	Hornblende schist and quartzite. Fine-grained, dense rocks. In part chloritic near quartz-pyrite veinlets.
125.6–177	Graphitic mica schists with quartz-pyrite veins. Folded and crumpled 136 to 140 ft. Probable faults 141 to 148 ft and 160 to 170 ft.
177–201	Hornblende gneiss and schist.

Hole no. 7

Bearing: N. 69° 47′ E. Altitude: 4,649 ft.
Inclination: Minus 29½°. Length: 241 ft.

Feet	*Description*
0–34	Hornblende gneiss and schist. In part chloritized, fine- to coarse-grained. Foliation 70° to the drill core. Bedding 35° to the drill core.
34–68	Quartz-mica schist and quartzite. Bedding 35° to 60° to the drill core. Minor folds and numerous fractures.
68–70.8	Quartz-muscovite-albite pegmatite. Footwall contact 60° to the drill core. Quartz (50 percent), muscovite (30 percent), albite (15 percent), accessory graphite and apatite. Rock looks sheared and hydrothermally altered.
70.8–134	Quartz-mica schist and quartzite. Fine- to medium-grained. Scattered thin graphitic beds. Quartz-pyrite, and carbonate-pyrite veinlets. Probable fault zones 101 to 113 ft and 120 to 130 ft. Foliation 65° to the drill core. Bedding 75° to core.
134–138.7	Quartz-albite-muscovite pegmatite. Footwall 85° to the drill core. Quartz (50 percent), albite (30 percent), muscovite (20 percent), and apatite. Hydrothermally altered. Feldspar white to buff chalky mass.
138.7–149	Quartz-mica schist and quartzite. Thinly laminated. Foliation 70° to the drill core. Bedding 65° to the drill core.
149–151.5	Quartz-albite-muscovite pegmatite. Footwall contact 65° to the drill core. Quartz (40 percent), albite (30 percent), muscovite (30 percent), and apatite. Lower 6 inches in a muscovite-quartz selvage zone.
151.5–157.8	Fine-grained, dense, highly folded, black rock. Impregnated with quartz-pyrite- arsenopyrite veinlets. Probably altered hornblende schist.
157.8–167.3	Pegmatite. Hanging-wall contact 70° to the drill core; footwall contact 80° to the drill core. Foliation in schist parallel to contacts.
	157.8–160.3 Quartz-muscovite pegmatite. Fine-grained, schistose selvage. Impregnated with pyrite.
	160.3–167.3 Albite-quartz-muscovite pegmatite. Quartz (35 percent), albite (60 percent), muscovite (5 percent) columbite, and apatite. Tourmaline abundant on lower contact.
167.3–241	Hornblende gneiss and schist. Medium- to coarse-grained hornblende altered to biotite near contact and at intervals in core. Carbonate-sulfide and quartz-sulfide veinlets along fractures.

Hole no. 8

Bearing: N. 69° 31′ E. Altitude: 4,685 feet.
Inclination: Minus 60°. Length: 157 feet.

Feet	*Description*
0–18	Overburden.
18–34	Probably hornblende gneiss and schist. Weathered. Impregnated with pyrite and cut by carbonate-sulfide veinlets. Bedding 20° to the drill core.
34–65	Graphitic mica schist. Impregnated with pyrite and cut by carbonate-sulfide veinlets.
65–67	Muscovite pegmatite. Hanging-wall contact 25° to the drill core. Footwall contact 40° to the drill core. Brecciated altered pegmatite with some graphitic material.
67–67.5	Mixed pegmatite and graphitic schist.

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 8—Continued

Feet		*Description*
67.5–85	Pegmatite.	
	67.5–73	Muscovite pegmatite. Muscovite (80 percent), albite (10 percent), and quartz (10 percent). Feldspar partly altered.
	73–85	Albite-quartz-muscovite pegmatite. Albite (60 percent), quartz (20 percent), muscovite (20 percent), columbite, and graphite. Maybe altered spodumene at 80 ft. Brecciated and altered. Cut by pink calcite veinlets.
85–123.4	Quartz mica schist and quartzite. Thinly bedded, fissile muscovite schists with staurolite and garnet. A few thin, gray quartzite beds. Foliation parallel to bedding and 20° to 70° to the drill core.	
123.4–146	Pegmatite. Footwall contact 60° to the drill core.	
	123.4–125	Albite-quartz-muscovite pegmatite. Albite (50 percent), quartz (40 percent), muscovite (10 percent), and apatite. Fractured and altered, especially near contact.
	125–131.7	Quartz-spodumene pegmatite. Soft to hard, greenish altered spodumene (25 to 30 percent).
	131.7–146	Albite-quartz-muscovite pegmatite. Albite (60 percent), quartz (30 percent), and muscovite (10 percent). At 134 ft pegmatite, especially rich in muscovite and lean in albite.
146–157	Hornblende gneiss and schist. Hornblende altered to biotite at contact. Foliation 45° to core.	

Hole no. 9

Bearing: N. 70° E. Altitude: 4,781 ft.
Inclination: Minus 30°. Length: 200 ft.

Feet		*Description*
0–9	Overburden. No core.	
9–59	Hornblende gneiss and schist. Medium- to coarse-grained. Interbedded with thin layers of fine-grained hornblende-biotite and biotite-quartz schist. Numerous quartz-pyrite-arsenopyrite veinlets parallel foliation. Foliation 65° to the drill core. Bedding 45° to 50° to the drill core.	
59–79.5	Quartz-mica schist. Quartz-biotite schist interlayered with graphitic beds and quartz-sulfide veinlets. Bedding and foliation 60° to the drill core.	
79.5–82	Albite-quartz-muscovite pegmatite. Hanging-wall contact 65° to the drill core.	
82–91	Quartz-mica schist. Fissile, muscovite-rich schist. Possible fault at 91 ft.	
91–91.8	Albite-quartz-muscovite pegmatite. Hanging-wall contact 20° to the drill core.	
91.8–101	Quartz-mica schist. Minor fold axis at 92 ft.	
101–111	Pegmatite. Footwall contact 75° to the drill core.	
	101–108.5	Albite-quartz-muscovite pegmatite. Pink albite (70 percent), quartz (25 percent), and muscovite (5 percent). Chloritic streaks from 101 to 102 ft.
	108.5–111	Quartz-muscovite-albite pegmatite. Gray quartz (70 percent), albite (10 percent), muscovite (10 percent), blue triphylite (?), chlorite, and pyrite (10 percent). Pyrite veins as much as 2 in. thick.
111–186	Hornblende gneiss and schist. Interbedded with hornblende-biotite and quartz-biotite schists. Fine- to medium-grained. Abundant quartz-sulfide veinlets.	
186–200	Quartz-biotite-garnet schist. Abundant quartz-sulfide veinlets.	

Hole no. 10

Bearing: N. 70° 31′ E. Altitude: 4,653 ft.
Inclination: Minus 45°. Length: 230 ft.

Feet		*Description*
0–25	Overburden. No core 0–20 ft.	
25–94	Graphitic mica schist. Impregnated with pyrite. Crumpled and folded 84 to 94 ft. Foliation and bedding 40° to 45° to the drill core.	
94–110.5	Hornblende schist. Fine-grained, black, quartzitic rock. Impregnated with pyrite and quartz.	
110.5–123	Graphitic mica schist. Possibly faults at 115 and 121 ft. Impregnated with pyrite. Bedding 40° to the drill core.	
123–143.5	Hornblende gneiss and schist. Chloritized, sheared, and brecciated. Possible faults at 124, 127, and 132 to 134 ft.	
143.5–154	Graphitic mica schist. Impregnated with sulfides.	
154–159.5	Biotite schist, possibly an alteration of hornblende schist.	
159.5–166.5	Pegmatite.	
	159.5–161.5	Quartz-albite-muscovite pegmatite. Quartz (75 percent), albite (20 percent), and muscovite (5 percent).
	161.5–164.5	Albite-quartz pegmatite. Albite (50 percent).
	164.5–166.5	Quartz-albite-muscovite pegmatite as at 160 ft.
166.5–171.7	Graphitic mica schist. Crushed and crumbled.	

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 10—Continued

Feet		*Description*
171.7–190.3	Pegmatite.	
	171.7–172	Mixed schist and quartz-albite pegmatite. Contact at 171.7 ft is 90° to the drill core and at 172 ft 65° to the drill core.
	172–173	Quartz-muscovite-albite pegmatite. Muscovite (10 percent), albite (10 percent), and quartz (80 percent).
	173–175	Albite (cleavelandite)-quartz-muscovite pegmatite. Muscovite and quartz each 10 percent.
	175–180	Quartz-albite-muscovite pegmatite. Muscovite (10 percent), and albite (20 percent). Muscovite book at 178.2–178.9 ft.
	180–182	Albite-quartz pegmatite. One green to brown altered spodumene crystal. Albite (78 percent), quartz (20 percent), and muscovite (2 percent).
	182–185	Quartz-muscovite pegmatite. Muscovite (15 percent).
	185–189	Albite-quartz pegmatite as at 181 ft.
	189–190.3	Quartz-albite-muscovite pegmatite as at 172 ft.
190.3–192	Carbonate schist, buff-colored, soft rock probably derived by alteration of hornblende schist.	
192–203.5	Hornblende schist. Foliation 45° to the drill core. Three inches of carbonate schist along fracture at 202 ft.	
203.5–208.7	Quartz-albite-muscovite pegmatite. Muscovite 5 percent of rock.	
208.7–210.7	Carbonate schist. Grades into hornblende schist.	
210.7–230	Hornblende schist. Foliation 55° to the drill core.	

Hole no. 11

Bearing: N. 67° 31′ E. Altitude: 4,689 ft.
Inclination: Minus 59°. Length: 68 ft.

Feet		*Description*
0–63	Pegmatite.	Footwall contact parallel foliation, 60° to the drill core.
	0–4	Quartz-spodumene-albite pegmatite. Quartz (55 percent), albite (20 percent), muscovite (10 percent), and spodumene (15 percent).
	4–9	Albite-quartz-muscovite pegmatite. Albite (60 percent), quartz (20 percent), and muscovite (20 percent).
	9–11	Quartz-spodumene-albite pegmatite. Quartz (35 percent), albite (45 percent), and muscovite (10 percent). Spodumene (10 percent) hard and fresh.
	11–15.5	Albite-quartz-muscovite pegmatite. Gray albite (75 percent), quartz (5 percent), and muscovite (20 percent).
	15.5–25	Quartz-spodumene pegmatite. Quartz (50 percent), albite (25 percent), and muscovite (3 percent). Spodumene (22 percent) hard and fresh.
	25–30	Albite-quartz pegmatite. Pink albite (70 percent) and quartz (30 percent).
	30–40	Quartz-spodumene-albite pegmatite. Quartz (40 percent), albite (40 percent), and fresh spodumene (20 percent).
	40–41	Albite-quartz pegmatite as at 25 ft.
	41–44	Quartz-spodumene pegmatite. Fracture zone. Spodumene brown to green.
	44–45.5	Albite-quartz pegmatite as at 40 ft.
	45.5–54	Quartz-spodumene-albite pegmatite. Fresh spodumene (25 percent) from 45.5 to 50 ft. Altered from 50 to 54 ft.
	54–63	Albite-quartz-muscovite pegmatite. Muscovite and quartz increase from zero to 50 percent at contact.
63–68	Hornblende gneiss and schist.	

Hole no. 12

Bearing: S. 67° 54′ W. Altitude: 4,689 ft.
Inclination: Minus 45°. Length: 85 ft.

Feet	*Description*
0–15.5	Quartz-spodumene-albite pegmatite. Quartz (50 percent), albite (35 percent), spodumene (14 percent), muscovite (1 percent), columbite-tantalite, and apatite. Spodumene hard and fresh except from 5 to 9 ft where it is slightly altered.
15.5–39	Albite-quartz-muscovite pegmatite. Quartz predominant from 15.5 to 19 ft; muscovite from 24 to 29 ft. Average composition of entire zone, albite (50 percent), quartz (35 percent), muscovite (15 percent), and columbite-tantalite.
39–40.5	Quartz-spodumene-albite pegmatite.
40.5–47	Albite-quartz-muscovite pegmatite.
47–54	Quartz-spodumene pegmatite. Spodumene fresh. From 47 to 52 ft, no core, probably fault zone.
54–57	Albite-quartz pegmatite.
57–67	Quartz-spodumene pegmatite. Probable fault zone from 59.5 to 67 ft. Spodumene (40 percent) green and altered.
67–68.5	Albite-quartz pegmatite.
68.5–77	Quartz-spodumene-albite pegmatite. Probable fault zone 70 to 80 ft.
77–85	Albite-quartz-muscovite pegmatite. Rich in muscovite.

Logs of U. S. Bureau of Mines diamond-drill holes, Edison mine—Continued

Hole no. 13.

Bearing: S. 68° 44′ W. Altitude: 4,695 ft.
Inclination: Plus 2°. Length: 55 ft.

Feet	Description
0–6	Albite-quartz pegmatite. Fractured and iron-stained.
6–15	Quartz-spodumene-albite pegmatite. Spodumene (10 percent), highly altered. Probable fault zone 9.5 to 15 ft.
15–22.5	Albite-quartz-muscovite pegmatite. Fractured and iron-stained.
22.5–25	Quartz-spodumene pegmatite. Spodumene (10 percent) altered. Probable fault zone 20 to 30 ft.
25–30	Albite-quartz-muscovite pegmatite.
30–35	Quartz-spodumene-albite pegmatite. Spodumene less than 5 percent.
35–40	Albite-quartz pegmatite.
40–50	Quartz-spodumene-albite pegmatite. Spodumene less than 5 percent.
50–55	Albite-quartz-muscovite pegmatite.

GEOLOGY

The Edison and Bull Con pegmatites are complex, irregular bodies that have been intruded along and across the contacts of highly folded hornblende gneiss and schist interbedded with quartz-mica schist, graphitic schists, and quartzite. The long axis of the Edison pegmatite trends N. 25° W., though there are large, complex, troughlike extensions to the east (pl. 14). The western part of the body is made up of three coalescing pegmatites that dip steeply westward and the troughlike eastern part includes at least three coalescing bodies which pitch steeply northwest and also coalesce with the pegmatites that trend N. 25° W.

The Bull Con pegmatite has three northwest-trending arcuate pegmatites which coalesce with a fourth one trending about N. 70° E. In structure it is similar to the Edison pegmatite.

METAMORPHIC ROCKS

Hornblende gneiss and schist.—Medium- to coarse-grained hornblende gneiss and schist crop out on the west side of the Edison and Bull Con pegmatites, as far south as the Edison adit, and along the east side of the pegmatite southeast of the glory hole. At the northern end of the mapped area the pegmatite cuts across the hornblende gneiss. Northeast of the main pegmatite similar gneiss crops out as a mass isolated from the other hornblende rocks.

The hornblende gneiss is composed of greenish amphibole (assumed to be hornblende), biotite, quartz, and plagioclase. It is interbedded with biotite-rich beds that suggest a sedimentary origin, though possibly some of the gneisses may have been igneous rocks. In places, near quartz-sulfide-arsenide-carbonate veins this rock has been altered to a greenish chloritic schist or a brown biotite-rich schist. In other places this altered rock is a yellow to brown mass of fine-grained carbonate and quartz. At the pegmatite contacts hornblende has been converted to biotite for distances as much as 3 ft.

Hornblende schist and quartzite.—The footwall contact of the Edison pegmatite, at its north end and along the north side of the glory hole, is in quartzite. A few yards east of the quartzite outcrops, northeast of the glory hole, is a 15-ft band thin-bedded fine-grained black hornblende schist and quartzite. Similar rocks were cut in the diamond-drill holes.

Graphitic mica schists.—Graphitic mica schists are not exposed at the surface but the diamond drill cores indicate that they underlie the lower part of the valley west of the Edison mine. The schists are thin, laminated, fine-grained, dark-gray to black rocks which contain muscovite, graphite, and quartz in widely differing proportions. Many parts of these schists are highly folded and contorted. Carbonate-sulfide veinlets are conspicuous in some core sections and most of the schist is heavily impregnated with pyrite.

Quartz-mica schists and quartzite.—The oldest rocks in the metamorphic sequence probably are quartz-mica schists that are interbedded with gray quartzite that occurs in more or less massive beds. These schists are partly fissile muscovite-rich rocks and partly massive quartz-rich rocks containing scattered staurolite or garnet crystals. Individual beds differ in texture and in mineralogic composition. The more quartzose beds crop out only on the east side of the pegmatite and in one or two places in the southwest part of the mapped area.

PEGMATITE

The Edison and the Bull Con pegmatites are similar in mineral composition, in external structure, and in internal structure. Two structural zones have been mapped in each: a wall zone of albite-quartz and albite-quartz-muscovite pegmatite (which includes the very thin border zone), and a core of quartz-spodumene and quartz-spodumene-albite pegmatite. Each of the two pegmatites is a composite of at least four bodies which apparently coalesced before complete consolidation with the result that the wall-zone pegmatite may separate areas of spodumene-bearing rock in the interior of the pegmatite body.

Albite-quartz pegmatite and albite-quartz-muscovite pegmatite.—The wall zones of the pegmatites are composed of albite-quartz pegmatite, which in places contains an appreciable quantity of muscovite. More detailed mapping would perhaps lead to the separation of this type of rock into two definite units or zones.

At the contact with schist there is a very fine grained "chilled" selvage, rarely more than an inch thick, which has the same composition as the adjacent wall zone.

The rock is a fine- to medium-grained pegmatite with grains that average less than 1 in. across. Muscovite books in parts of the wall zones are as much as 10 in. across; the average is about 4 in. Much of the albite is in equidimensional grains, but the platy variety, cleavelandite, is more common near the inner edges of the wall zone and where spodumene-bearing pegmatite forms both walls. Some of the albite has a sugary texture. Blades of columbite-tantalite are associated with albite. The crystals are as much as ½ in. in length, but the average is ¹⁄₁₆ in. Apatite, microcline, tourmaline, lithiophilite-triphylite, and black to green "altered spodumene" occur sparsely in this rock. A few crystals of yellowish to brown beryl (N_o=1.592) were observed. The feldspars are commonly white or dark-gray, although some cleavelandite is pink.

Quartz-spodumene pegmatite and quartz-spodumene-albite pegmatite.—Inside the wall zone, quartz, spodumene, and albite occur in widely differing proportions. No attempt was made to distinguish on the map the zones that are primarily quartz and spodumene and those that contain appreciable amounts of albite. If this were done, some relation might be found between the albite-rich spodumene-bearing pegmatite and the low grade ore or "altered spodumene." In general, the more feldspathic spodumene ores come from the narrower spodumene bodies or from the outer edges of the wider ones.

The quartz-spodumene-albite pegmatite is much coarser than the enclosing albite-quartz or albite-quartz-muscovite pegmatite of the wall zones. The average length of the spodumene crystals is less than 4 in., some are 1 ft or more in length. They rarely form more than 25 percent of the rock. They are generally associated with a few small books or scales of muscovite and pink, white, or gray cleavelandite with an indistinct platy habit. In many places the spodumene is altered to a green or brown, soft, soapy or greasy mass, known to the miners as "rotten" spodumene. Many crystals show only incipient alteration along cleavages or cracks and are commonly green when wet. This altered spodumene is probably a hydrous mica or clay mineral.

The quartz-spodumene pegmatite which constitutes the main bulk of the core contains spodumene crystals as much as 8 ft long. The average length is perhaps about 12 in. Locally, spodumene forms more than 50 percent of the rock but the average is 25 percent. The crystals are generally hard, glassy, and white, but along fractures they show various degrees of alteration. Along these fractures the accompanying quartz is heavily iron-stained.

STRUCTURE

The structure of the Edison and Bull Con spodumene deposit is controlled by (1) bedding and foliation of the metamorphic rocks; (2) major and minor folds; (3) prepegmatite fracturing; (4) internal structure and coalescence of the pegmatite bodies; and (5) faulting and fracturing.

Foliation is poorly developed in the hornblende gneiss and apparently has no uniform strike, though it strikes within about 45° of north. It dips 55°–80° NE., where measured near the Bull Con pegmatite, but to the south and east the dip is within 15° of vertical. The other metamorphic rocks, for the most part, have a foliation about parallel to bedding, though local divergences are large. No systematic relationship was observed between foliation and the minor fold axes in this area of intense folding.

In some places the pegmatites followed bedding or foliation planes within the mica schists or the contact between quartzite and hornblende schist and gneiss, but in other places they followed fractures across the more massive hornblende rocks. The structural features of the schists are obscure and additional regional work would be necessary to understand them completely. However, diamond-drill data suggest that the pegmatites lie on the limb of a large isoclinal fold on which are numerous minor folds. These minor folds control the shape of the eastern pegmatite contact at the Edison mine and with fracturing resulted in the development of the northwestward pitching pegmatite structures. The influence of the minor folds on this contact can be seen on the adit level (pl. 14). Prepegmatite fracturing are believed to have caused the crosscutting synclinal structure noted in the area southeast of the glory hole. The three bodies, trending N. 25° W., that have been most thoroughly prospected by the drilling are essentially concordant with the foliation and bedding of the mica schists. They coalesce upward and pinch out both in depth and along the strike. This pinching out is believed to be related to their position near the noses of the folds, and to the fact that the graphitic and mica schists are less competent than the quartzite and hornblende schists and gneiss. Locally they undoubtedly cut across the country rock.

The internal structure of the pegmatite is very complex. Each of the individual pegmatites has two zones, a wall zone, barren of spodumene, and a core that contains spodumene even in places where they have coalesced and the wall zones are discontinuous. It is believed that each individual pegmatite was completely encased in wall-zone material before coalescence. The order in which the various pegmatites coalesced is not known, but the east-west troughlike structures appear to have formed last but before the others had completely cooled. The wall zones between two bodies of spodumene are not always continuous, and it appears to be the wall zones of pegmatites that trend N. 25° W.

which are most commonly discontinuous (see the area around the shaft in pl. 14). The cross-sections and plans of the adit, 50-ft and 100-ft levels (pls. 14, 15) indicate that the individual spodumene bodies are commonly separated by barren wall-zone rock.

Considerable faulting followed the intrusion of the pegmatite. Four major faults and a number of smaller ones are shown on the map (pl. 14), together with a number of strong fractures or joints, along which there may have been movement. These faults have two effects on the spodumene deposit; they offset individual spodumene bodies, and they acted as channelways for later sulfide solutions which removed Li_2O from the spodumene, coverting it to "green" or "rotten" spodumene, and deposited sulfide minerals. These minerals were later oxidized by surface waters and the adjacent pegmatite was heavily stained with iron oxide.

The three faults that strike nearly parallel to the long axis of the Edison pegmatite are referred to as the East, Central, and West faults. Evidence for the displacements on these faults is poor. Displacements shown on the sections and maps appear to be of the right order of magnitude. The West fault strikes N. 28° W. and dips 65° SW. Nothing is known about its displacement except that its hanging-wall block moved at least 6 ft north relative to the footwall. It is believed that the vertical or rotational displacement is greater, but as evidence is lacking no displacement is shown on the sections and plans (pls. 14, 15). The East fault strikes N. 21° W. and dips 85° NE. On the surface the hanging-wall block appears to have moved northward about 60 ft and the movement may be rotational with respect to the Central fault. Diamond-drill hole data suggest that the hanging wall has an upward displacement of about 40 ft. The Central fault strikes N. 14° W. and dips 78°–80° SW. and is probably a normal fault. Its exact displacement is not known, but the fault appears to be rotational with a hinge near its intersection with the East fault. As shown on section C–C′ (pl. 15) a combination of the displacement and the attitudes of the pegmatite on either side of the fault result in an apparent downward movement of the footwall block. Two other faults intersect the East fault and pass through the glory hole. The southern one strikes N. 55° W. and dips 70° SW., and is apparently a normal fault with the hanging wall displaced 40 ft to the northwest and down about 15 ft. Nothing is known of the displacement of the northern fault, which strikes N. 68° W. and dips 70° SW., but probably it is a small fault. Three other minor faults have been mapped northeast of the glory hole. On the adit level strong fractures are numerous, but probably there has been little movement along them.

MINERAL DEPOSITS

SPODUMENE

Spodumene is the principal product of the Edison mine; a few tons of scrap mica has been recovered. If the spodumene ore were treated in a mill scrap mica, and perhaps columbite-tantalite, could be recovered as byproducts.

The spodumene occurs with quartz and albite, associated with minor quantites of muscovite, columbite-tantalite, and apatite. The length of the crystals ranges from a fraction of an inch to more than 8 ft. It is estimated that spodumene constitutes 20 to 25 percent of the spodumene-bearing pegmatite, although in local areas, some of considerable extent, they make up more than 50 percent. Where albite is as abundant as spodumene the spodumene crystals are fewer and average not more than 6 in. in length.

The spodumene crystals show a wide range in degree of alteration to soft, soapy brown or green spodumene, known to the miners as "rotten" spodumene. If this alteration is complete, only the cleavage and shape of the spodumene crystal is preserved. Incomplete alteration is marked by "green spodumene" veinlets along the cleavage or in a network following fractures. The available analyses of spodumene are tabulated below. These analyses indicate a range in Li_2O content from zero to 7.32 percent Li_2O.

Percentage of lithia in spodumene, Edison mine

Sample No.	Percent Li_2O	Description
U. S. B. M.:[1]		
1	4. 74	Grab sample of hard spodumene from mine face.
1A	6. 28	Sample of hard spodumene from mine face.
2	3. 14	Grab sample of soft spodumene from mine face.
U. S. G. S.:[2]		
1	1. 10	"Green spodumene" crystal from 120-ft level of shaft.
2	5. 74	Partly altered spodumene crystal from 120-ft level of shaft.
Lor Mining Co.:[3]		
1	7. 32	Hard spodumene.
2	4. 54	Yellow-brown partly altered spodumene.
3	0	Completely altered "green spodumene."

[1] Samples taken by Fremont Clarke, Engineer, Bureau of Mines, January 1944. Analyzed at Rolla laboratories.

[2] Samples analyzed for the U. S. Geological Survey by Charles Bently, South Dakota School of Mines, Mining Experiment Station, Rapid City, South Dakota, April 1945.

[3] Samples analyzed by Metalloy Company. Assays furnished by James Savage, superintendent, Lor Mining Company.

SIZE AND GRADE

The spodumene deposits of the Edison mine occur as individual bodies surrounded by albite-quartz pegmatite or albite-quartz-muscovite pegmatite that is barren of spodumene. The percentage of spodumene differs in individual bodies and also within each body. In addition, the alteration of the spodumene itself is irregular. Determinations of lithia by different chemical methods also show wide differences. These factors, and inaccuracies in sampling such a coarse-grained rock, make it difficult to determine accurately the percentage of this mineral from chemical determinations of the lithia content of spodumene-bearing zones, or to estimate accurately the lengths or depths of minable spodumene-rich blocks. However, assays do help determine the probable relative richness of individual spodumene bodies.

In this report the spodumene-bearing pegmatite has been divided into five blocks.

Spodumene block no. 1 is the westernmost spodumene-bearing pegmatite shown on cross-sections A–A′ to E–E′ (pl. 15). On the adit level this block merges with spodumene block no. 2 near the shaft and on the 100-ft level it merges with the same block along cross-section E–E′. On the adit level it is about 250 ft long and as much as 35 ft wide (pl. 14). It splits into two separate bodies on the 50-ft level as shown on plate 14. The northernmost of these bodies is 140 ft long and as much as 9 ft wide, and lenses out down dip. Only the southern branch, which is 210 ft long and as much as 13 ft wide on the 50-ft level, is present on the 100-ft level. There it is less than 150 ft long and 10 ft wide. Probably, it extends about 25 ft below this level. On the adit level this spodumene block is actually two bodies separated by barren pegmatite near the shaft. The shape of this block as shown on level maps and sections is, in part, diagrammatic because the displacement of the West fault is not known.

Spodumene block no. 2 lies east of, or merges with, block no. 1, and also merges with block no. 3 near the shaft, but is cut off on the east by faults (pl. 14). On the adit level it has a maximum length of 250 ft and a width of 30 ft. On the 50-ft level this block is 360 ft long and as much as 35 ft wide, and on the 100-ft level it is 240 ft long and as much as 40 ft wide. This block may extend 60 to 75 ft below the 100-ft level. On the adit and 50-ft levels an eastward-striking barren zone, just south of the shaft, divides the block.

Spodumene block no. 3 lies east of, and parallel to, block no. 2. It is bounded on the east side by the Central and East faults. The block is 100 ft long by 15 ft wide on the adit level, 230 ft long by as much as 30 ft wide on the 50-ft level, and 215 ft long by as much as 35 ft wide on the 100-ft level. On the adit and 50-ft levels it is cut by the barren zone that divides block no. 2.

Spodumene block no. 4 includes all the spodumene-bearing pegmatite between the Central and East faults. Structurally the individual bodies are extensions of blocks 2, 3, or 5. The longest body, on the adit level, is 100 ft long by as much as 15 ft wide. On the 100-ft level there is but one body, 45 ft long by 25 ft wide.

Spodumene block no. 5 lies east of the East fault. On the adit level it is roughly triangular and has a maximum length of 140 ft and a maximum width of 110 ft. This block extends a few feet below the 100-ft level where it is about 25 ft long. Because this spodumene body plunges northwest across the faults, part of it is included in blocks no. 3 and no. 4.

Calculations of grade of these spodumene blocks are only approximate. Each core interval was assayed for Li_2O, but the conversion of any Li_2O analysis to spodumene is dependent on the lithia content of the mineral itself. This content is impossible to determine because individual crystals show different degrees of alteration. In general, hard glassy spodumene from the Edison carries about 6 percent Li_2O; and, if necessary, this figure can be used to compute spodumene content.

RESERVES

The tonnage and grade of spodumene-bearing pegmatite indicated by drilling at the Edison spodumene mine was calculated, in cooperation with Fremont Clarke, project engineer of the Bureau of Mines, on the basis of available assays. The tonnage figures are believed to be reasonably correct. The grade figures are more open to question, but they are probably conservative, and are made so for the reasons given above.

The total indicated reserves of spodumene-bearing rock in the Edison pegmatite are calculated, on the basis of maps and sections (pls. 14, 15) to be 167,500 to 199,000 tons. Bureau of Mines assays of drill cores, and samples of rock from the adit level indicate an average grade of about 1 percent Li_2O. Spodumene blocks no. 3 and no. 5, containing about 71,000 tons of spodumene-bearing rock, are estimated to contain at least 1.15 to 1.28 percent Li_2O.

In addition, stockpiles of rejected material from the sorting plant are available. About 12,000 tons of minus 1-in. material contains according to assays of samples made by the Bureau of Mines 2.64 percent Li_2O.

ELKHORN AND HOT SHOT MINES (CUSTER DISTRICT)

by J. J. Norton

The Elkhorn and Hot Shot mines are on adjoining properties in Custer County, about 5 miles east-southeast of Custer, in the SW¼ sec. 34, T. 3 S., R. 5 E. They consist of a number of abandoned open-pits formerly operated for potash feldspar. The Elkhorn, known also as the Tinsley mine, is a promising prospect for beryl. The Hot Shot has been called the Thelan-Staudy mine.

The topography and geology (pl. 16) were mapped on a scale of 1 in. to 40 ft during August and September, 1943, by J. J. Norton, L. C. Pray, and D. M. Kinney, under the direction of L. R. Page. The topography of the Elkhorn property was revised from a map made by the U. S. Bureau of Mines in June 1943. In June and November 1943, the U. S. Bureau of Mines sampled the dumps and beryl-bearing exposures in the open-pits. The geology of these sample cuts, from which more than 400 tons of rock was removed, is given in plate 17.

The Elkhorn claim is held by C. E. Magneson of Kirkland, Wisconsin, and Dewey C. Tinsley of Guernsey, Wyoming. They operated the mine more or less continuously from 1938 through 1940, and sold nearly 4,000 tons of potash feldspar during this period. They also produced at least 2,800 lb of beryl.

The Hot Shot claim, which adjoins the Elkhorn on the south, was recorded by Victor Thelan and E. A. Staudy in May 1937, and apparently is still in their hands. Robert McRobbie was operating the mine primarily for feldspar at the time of mapping. He sold a few pounds of sheet mica to the Colonial Mica Corporation in 1943.

MINE WORKINGS

The mine workings consist entirely of open-cuts, operated in the past for potash feldspar. The Elkhorn pegmatite has been worked from two pits, one at the east end of the dike and the other near the middle. The eastern pit is 120 ft long, 35 ft deep, and has an average width of 40 ft. The pit to the west is 110 ft long, 20 ft wide, and has an average depth of 18 ft. The Hot Shot dike has been worked most extensively from a single large open-pit near the middle of the dike. The main part of this pit is 100 ft long, 40 ft wide, and has an average depth of 30 ft; it has a narrow eastward extension, 100 ft long, 10 ft wide, and 18 ft deep, which was apparently worked independently of the rest of the pit. A small open-cut has been made near the east end of the Hot Shot dike, and there are numerous prospect pits in the western part of the pegmatite.

GEOLOGY

The Elkhorn and Hot Shot claims contain an irregular group of branching pegmatites intruding schist and quartzite. The two principal pegmatites are tabular bodies, approximately parallel, which strike generally to the east and dip at a high angle to the north.

WALL ROCK

The country rock is principally quartz-mica schist, quartz-mica-sillimanite schist, and quartzite. In the schists the predominant minerals are quartz and mica, with some sillimanite. The general strike of the bedding is N. 80°–85° E. and the dip is about 60° NW. The schistosity has an average strike of about N. 80° W., and the general dip is 50°–60° NE., increasing to nearly vertical toward the south edge of the area mapped. Quartzite lenses are interspersed through the schists.

North of the Elkhorn pegmatite nearly all of the country rock is gray quartzite, much of it rich in mica. South of the Elkhorn dike the quartzite is much less abundant and schist is the principal rock. One narrow lens of quartz-hornblende-garnet gneiss is exposed on the flat, 30 ft southeast of the dump of the west open-pit. The Elkhorn pegmatite was intruded at or near a schist-quartzite contact.

PEGMATITE

Three pegmatite bodies crop out in such fashion as to form three sides of a parallelogram. The Elkhorn pegmatite is on the north side, the Hot Shot is on the south side, and the east side is a pegmatite that trends N. 36° W. and connects the other two. The Hot Shot pegmatite crops out for 700 ft in a N. 89° E. direction and the Elkhorn is exposed for 850 ft in a N. 80° E. direction. At its eastern end the Elkhorn pegmatite bends abruptly to the southeast and joins the third body, which extends 670 ft S. 36° E. and then intersects the Hot Shot dike 80 ft from its eastern extremity. West of the eastern open-pit the Elkhorn pegmatite branches, and the northwest branch divides into two additional pegmatites, forming a Y-shaped exposure about 220 ft in length.

The Hot Shot pegmatite is 40 to 60 ft thick, and the Elkhorn is 17 to 22 ft thick along most of its length, but it thickens to 25 ft at the western open-pit and to 80 ft in the eastern pit.

In these pegmatites the mappable zones are quartz-albite pegmatite at the walls and perthite-quartz pegmatite in the interior, with units of quartz pegmatite within the perthite-quartz core. The contacts of the zones are gradational and less easily mapped than those of many other pegmatites.

The pegmatite trending N. 36° W., which connects the Hot Shot and the Elkhorn pegmatites, has an average width of 15 to 20 ft across the surface exposures, and the contacts, although they are poorly exposed, seem to indicate a nearly vertical dip.

The rock that forms this poorly zoned body is a granular mixture of quartz and albite with large crystals of perthite scattered through the central part of the pegmatite. This pegmatite has been mapped as a unit of quartz-albite-perthite pegmatite. It grades laterally into the well-defined zones of perthite-quartz and quartz-albite pegmatite where it joins the Elkhorn and Hot Shot pegmatites.

Another pegmatite is exposed in the area mapped. It is a narrow dike of quartz-albite pegmatite that was prospected by a small pit north of the western part of the Hot Shot dike.

Quartz-albite pegmatite.—Quartz-albite pegmatite makes up the outer portion of the Elkhorn and Hot Shot dikes. It is composed essentially of anhedral quartz and albite in grains that are generally ½ to 1½ in. across. Perthite, muscovite, beryl, biotite, tourmaline, lithiophilite, löllingite, and pink manganese garnet are minor constituents. The minimum indices of the albite, measured on cleavage flakes from 11 specimens, range from 1.528 to 1.531 (An_4–An_9). Most of the muscovite in the quartz-albite zone is white, and is reeved and irregularly laminated. Flat sheet mica, of light ruby color, occurs in this zone near the foot and hanging walls of the Hot Shot dike, but it is black-stained. Beryl (N_o=1.577) occurs in the quartz-albite zone of the Elkhorn pegmatite as yellowish-green crystals, generally euhedral and as much as 2 in. in diameter. Beryl is rare in the quartz-albite zone of the Hot Shot dike, but most of that which is present resembles the beryl of the Elkhorn dike. Some of the beryl of the Hot Shot quartz-albite pegmatite consists of euhedral rims of beryl surrounding quartz-albite interiors.

Biotite occurs as blades, as much as 3 ft long, filling fractures in the Elkhorn wall zone and in the outer part of the perthite-quartz core. In the Hot Shot dike biotite blades are very scarce. Clusters of small yellow beryl crystals, rarely exceeding 1½ in. in length, occur in intimate association with the biotite. Some of the biotite can be observed to cut across beryl crystals. The refractive index (N_o) for beryl crystals occurring with biotite blades ranges from 1.573 to 1.576. Muscovite is intergrown with some biotite blades. Not uncommonly a group of three biotite blades form a tringular prism.

The quartz-albite zone on the footwall of the body commonly has a few inches to 4 ft of rock containing considerable tourmaline and black inclusions of altered schist.

Perthite-quartz pegmatite.—The quartz-albite wall grades into a very coarse-grained perthite-quartz pegmatite core. The core contains perthite and quartz as essential minerals, with albite, muscovite, beryl, biotite, tourmaline, lithiophilite(?), löllingite, and pink manganese garnet as accessory minerals. The accessory minerals decrease in quantity toward the interior of the dike, and the rock is composed almost entirely of large quartz masses and perthite crystals as much as several feet across. The perthite is white and commonly is intergrown with quartz. Quartz-albite pegmatite occurs interstitial to the perthite and massive quartz, increasing in abundance outward into the quartz-albite wall zones.

The accessory minerals are similar to those in the quartz-albite pegmatite. The muscovite is white, irregularly laminated, and "fishy." Biotite blades with associated beryl (N_o=1.573 to 1.576) and muscovite are common in the Elkhorn dike, and crystals of light-green beryl, as much as 1 ft in diameter, occur in considerable quantities in the outer part of the perthite-quartz core. The refractive index (N_o) ranges from 1.572 to 1.576, essentially the same as that of the beryl in the quartz-albite pegmatite of the wall zone. The few beryl crystals observed in the perthite-quartz core of the Hot Shot dike were as much as 4 in. in diamter, but according to Mr. McRobbie some fairly large crystals have been mined.

Quartz pegmatite.—Mappable units of quartz occur in the perthite-quartz cores of both the Hot Shot and the Elkhorn pegmatites. The quartz is gray, milky, and rose.

Quartz-albite-perthite pegmatite.—The northwestward-trending pegmatites, including the branches north from the Elkhorn pegmatite and also the pegmatite that connects the Elkhorn and Hot Shot bodies, are composed of quartz and albite grains and scattered large crystals of perthite. Muscovite and tourmaline are present as accessory minerals. The minimum indices of the albite (An_6–An_9), measured on cleavage flakes, are 1.529 to 1.531. The perthite crystals are as much as 1 ft across, in contrast with the quartz and albite grains, few of which are more than ½ in. across.

Where the northwestward-trending bodies join the Elkhorn pegmatite the quartz-albite-perthite rock grades laterally into quartz-albite and perthite-quartz pegmatite. A similar but poorly exposed and less well developed gradational zone apparently exists where the quartz-albite-perthite rock intersects the Hot Shot body. Here a sharp fracture forms the contact between the two dikes.

QUARTZ VEINS

Veins of milky quartz are exposed in a few places in the area and quartz fragments are common on the flat, but no vein could be traced more than a few feet.

STRUCTURE

The pegmatites intrude schists and quartzites of pre-Cambrian age. The schists and quartzite are highly folded as shown by the presence of drag folds and by the change in the dip of the schistosity with respect to the bedding across the area mapped. Closely folded drag folds just south of the Elkhorn dike show that the beds are on the north limb of an overturned syncline. A similar structure is indicated by the relationship of the dip of the schistosity, which on the average is 50° NE., to the 60° dip of the bedding. To the south, however, the dip of the schistosity increases to an average of about 90° and the dip of the bedding increases to only about 80°, suggesting that the axis of the syncline crosses the area mapped.

The pegmatites form a single body, but may have originated as separate bodies that coalesced during emplacement. The two principal bodies (the Elkhorn and Hot Shot pegmatites) are conformable with the bedding of the country rock but the other pegmatites are discordant.

The exposures in the west wall of the eastern open-pit on the Elkhorn dike show that the intersection of the main dike and the northwest-trending offshoot plunges west at an angle of 60°. The bedding is approximately concordant at the surface, but the exposures are not extensive. The dike trending N. 36° W. has a nearly vertical dip, so the plunge of its intersection with the Elkhorn pegmatite should be approximately 70° N. 36° W.

MINERAL DEPOSITS

The industrial minerals of the Elkhorn and Hot Shot properties are beryl, potash feldspar, and mica. At the time the properties were examined, beryl was of principal interest. Beryl is scarce in exposures of the Hot Shot dike, but fairly abundant in the Elkhorn pits. Potash feldspar is abundant in both dikes. Most of the mica recoverable from the two dikes is scrap, but black-stained sheet mica occurs in the Hot Shot dike.

BERYL

The Elkhorn beryl is concentrated in the outer parts of the perthite-quartz zone, although some beryl can be found in most parts of the dike. The 3- to 12-ft beryl-rich zones are estimated to contain about 0.6 percent beryl. Although at least 2,800 lb of beryl has been sold from the Elkhorn property, most of the beryl mined seems to have been thrown on the dump as not worth the expense of sorting. Eleven tons of beryl from the Hot Shot property reportedly has been sold. The present exposures show much less beryl than in the Elkhorn open-cuts.

Most of the Elkhorn beryl is in light-green, nearly clear crystals as much as a foot in diameter. The beryl shows numerous microscopic gas and liquid inclusions. The average size of the crystals on the hanging-wall side of the perthite-quartz zone seems to be somewhat greater than on the footwall side. The refractive index (N_o) ranges from about 1.572 to 1.575. A U. S. Bureau of Mines analysis of hand-cobbed Elkhorn beryl (made available to the U. S. Geological Survey by Mr. E. Y. Dougherty, District Engineer) shows 11.26 percent BeO.

Yellow to yellow-green beryl crystals, rarely more than 2 in. long, are sparse in the quartz-albite pegmatite of the Hot Shot dike but fairly abundant in the Elkhorn. The refractive indices indicate a composition similar to that of the beryl in the perthite-quartz zone.

The beryl crystals associated with the blades of late biotite in the Elkhorn pegmatite are locally abundant, but the total amount is very small. They are yellow and generally less than 1 in. long. The refractive indices are not significantly different from those of the beryl elsewhere in the dike.

The grade of the beryl-rich zones has been estimated by measuring crystals on exposed faces in the open-cuts, and the resulting data have been assembled in the table on p. 118. As the richest concentrations of beryl are in the outer parts of the perthite-quartz zone, and the north and south walls of the open-pits cut these parts of the pegmatite, the grade of the beryl-rich rock can be readily estimated. The percentage of beryl on the north walls of the two open-pits is about 0.7 percent over an average thickness of about 10 ft. A similar thickness on the south wall of the eastern open-pit probably contains about 0.5 percent beryl, but in the west pit, where no measurements were made on the south wall, there is probably not more than 0.23 percent beryl. No measurements were made of the beryl exposed in the central part of the perthite-quartz zone at the ends of the two pits, but the quantity of beryl which can be observed is small. At the west end of the east pit, however, where two dikes connect, there may be a rich shoot of beryl pitching down along the intersection. The pegmatite exposures outside the open-pits are weathered and lichen-covered, so that beryl is difficult to distinguish and estimates of grade could not be made. There is no reason to believe that the beryl-bearing rock does not extend both laterally and downward, although it is likely that the grade is lower and that the principal beryl-bearing portions of the pegmatite are in the wide, perthite-rich parts of the dike, such as those in which the open-cuts are located.

Analyses of samples of rock taken from the dumps at both the east and west pits on the Elkhorn property by the U. S. Bureau of Mines have been made available by Mr. Dougherty. Assays were made of the material passing through a 2-in. screen. The BeO content of two samples from the lower part of the east dump is 0.05 and 0.07 percent. A sample from the upper part of this dump showed 0.09 percent BeO, and a sample of the dump from the west pit showed 0.07 percent BeO.

FELDSPAR

The perthite-quartz pegmatite, which crops out as the central zone along the entire length of both the Elkhorn and Hot Shot pegmatites, has furnished considerable potash feldspar. During 1938–40 the two Elkhorn open-pits yielded about 3,500 tons of feldspar from about 12,000 tons of rock. These figures indicate that the feldspar recovered was 29 percent of the original rock, and, probably, the yield of the Hot Shot pits was comparable.

Because the proportion of impurities, such as albite, tourmaline and mica increases toward the edge of the perthite-quartz core, the best feldspar is in the central part of wide places in the pegmatites, and most of the open-pits are located there.

MICA

As much as 3 percent of muscovite occurs in the quartz-albite zones and in the outer part of the perthite-quartz zone. Most of it is a white mica, highly reeved, and useful only as scrap. Considerable biotite is present in the mica-bearing portions of the Elkhorn dike, and would interfere with the recovery of muscovite in a milling process.

A narrow zone of sheet mica occurs along the hanging wall on the north side of the main open-pit on the Hot Shot dike. The mica is light ruby, generally with a black stain which the microscope reveals to be composed principally of a dendritic clay-like material. McRobbie sold 6.12 lb of sheet mica from this zone to the Colonial Mica Corporation.

RESERVES

It is very difficult to make accurate calculations of beryl reserves, but an attempt has been made to compute reserves available above the floors of the Elkhorn open-cuts (see table below). Additional beryl-bearing rock probably extends both laterally and downward, but lack of evidence precludes estimate of reserves beyond the present open-pits. The figures for the percentage of beryl are based on measurements of beryl in exposed faces and visual estimates. The total reserves of beryl in the walls of the two open-pits are estimated to be about 30 tons. Additional reserves of feldspar and muscovite occur below the level of the pits.

Measurements of beryl on exposed faces in the outer part of the perthite-quartz core in the Elkhorn open-cuts

Location	Total area in square feet	Area of beryl in square feet	Percent beryl
North wall of west pit	336	3.28	1.0
North wall of east pit	560	3.25	.6
West side of south wall, east pit	72	.41	.6
West side of south wall, east pit	350	.98	.3
East side of south wall, east pit	60	.83	1.4
East side of south wall, east pit	30	None	--------

ETTA MINE (KEYSTONE DISTRICT)

by W. C. Stoll and L. R. Page

The Etta mine in the NW¼ sec. 16, T. 2 S., R. 6 E., 1 mile south of Keystone, in Pennington County, has been the largest producer of spodumene in the Black Hills. It is owned by the Maywood Chemical Company of Maywood, New Jersey. The property has often been visited by geologists of the U. S. Geological Survey from 1942 to 1945. Smith and Stoll prepared short reports on the spodumene reserves in 1942 but no detailed mapping has been done. Schwartz (1925, pp. 646–659), Landes (1928, pp. 525–527), and others have published descriptions of the mine and the mineralogy of the pegmatite.

In 1943 the Etta mine comprised a large open-pit made by glory-hole mining and a series of underground workings that was 67 ft vertically below the floor of the pit. The open-pit is reached by an adit that connects also with an 80-ft winze or shaft, inclined at 57°, from which the lower level is worked. The open-pit is nearly oval, with a length of 230 ft in a N. 28° E. direction and a width of 220 ft at right angles to this line. It is 100 to 125 ft deep.

The lower level consists of drifts or crosscuts that extend northeast, southeast, southwest, and northwest from a point near the base of the inclined shaft. All except the northwesterly workings end in the plagioclase-quartz-muscovite wall zone of the pegmatite. Raises extend to the open-pit, and in 1945 a glory hole extended to the open-pit. These workings show the pegmatite to be about 125 ft long.

The Etta pegmatite is a pipelike body that plunges steeply north and narrows with depth. It is a well-zoned deposit that in general is conformable to the schistose wall rocks, and where locally it is disconformable, the schist has been altered to granulite. The outer 5 to 15 ft of the pegmatite is plagioclase-quartz-muscovite pegmatite that near the top of the open-cut grades into perthite-quartz pegmatite with scattered crystals of altered spodumene. Below this "cap" of feldspar-rich rock the wall-zone pegmatite grades into quartz-spodumene rock that contains albite. This intermediate zone of quartz-spodumene pegmatite grades into a quartz pegmatite core without spodumene. The quartz core lies below the perthite-quartz "cap."

The spodumene crystals are as much as 40 ft in length, though the average length is about 10 ft. Most of the crystals are hard and fresh, but near the outer edges of the zone some of them are altered or "rotten." This altered spodumene is most abundant in the perthite-quartz pegmatite and where long spodumene crystals extend into the quartz pegmatite core for 4 to 6 ft at their inner end. Some crystals have a complete shell of altered spodumene. Spodumene crystals are estimated to make up 10 to 30 percent of the quartz-spodumene pegmatite.

During 1943–45 a few pounds of sheet mica and a few tons of beryl were sold from the Etta mine. The beryl assayed 10.65 percent BeO.

FORMOSO CLAIM (CUSTER DISTRICT)

The Formoso mica claim, in the SW¼ sec. 25, T. 2 S., R. 5 E., was located by Wilma Dunstan and Ethel Smith of Custer on April 26, 1943. This claim includes part of a large dike of pegmatitic Harney Peak granite which is crossed by narrow pegmatite dikes. Streaks as much as 12 in. thick are rich in muscovite and contain scattered books of ruby mica as much as 5 in. in diameter. No sales of mica have been recorded from the property and in May 1943 only a few small pits prospected the claim.

GAP LODE (HILL CITY DISTRICT)

The Gap Lode, in NE¼ sec. 19, T. 2 S., R. 5 E., Pennington County, was a large producer of mica in 1943. The property is reached by about a mile of poor dirt road leading north from the Harney Peak trail, three-quarters of a mile from Sylvan Lake. The property, held by Francis Michaud and W. W. Wright, was first operated for feldspar and scrap mica. In 1943 it was operated for a few months by Francis Michaud, Harold Duncan, and Floyd Frye of Custer. In the fall of 1944 it was operated for a month by the Custer Mining Account of Custer.

In September 1943 the workings consisted of 3 open-pits on the main pegmatite and one on a parallel pegmatite 135 ft to the north. About 50 ft from the northeast end of the main pegmatite a cut 30 ft long, in a S. 65° W. direction, has been driven into the pegmatite. The cut is 15 ft wide and 8 ft deep at the face. The main cut lies 75 ft S. 65° W. and is 90 ft long, 8 to 10 ft wide, and 40 ft deep at the face. A small cut, 25 ft long, 6 ft wide, and 4 ft deep, crosses the pegmatite at a point an additional 100 ft S. 65° W. The Custer Mining Account is reported to have drifted about 12 ft southwest from the base of the main open-cut and to have crosscut about 12 ft to the north wall of the pegmatite. A pit 40 ft long, 10 to 20 ft wide, and 20 ft deep at the face, prospects the second pegmatite 135 ft N. 30° W. of the northernmost cut on the main pegmatite.

The Gap pegmatite strikes about N. 70° E. and dips 80° N. It crops out between walls of coarse-grained Harney Peak granite as a dike that branches to the southwest. These branches extend about 250 ft S. 50° W. and S. 60° W. from a point 135 ft S. 65° W. of the main open-cut. The north branch is 10 ft thick and the south branch 6 to 9 ft thick. The main part of the pegmatite is about 18 ft thick for 350 ft to the northeast.

The pegmatite grades abruptly into the granite walls. The outer 2 to 3 ft of the pegmatite is a wall zone of plagioclase-perthite-quartz-muscovite pegmatite. Black tourmaline, beryl, and purpurite occur in addition to the essential minerals. The muscovite is in books as much as 15 in. long and 3 in. thick. It is deep ruby, but is highly air-stained and clouded by minute mineral inclusions. The mica is flat and fairly soft. The books in the outer half of the wall zones are badly "tied" and tangled, but those at the inner edge of the zone are readily split.

The core is perthite-quartz pegmatite and as much as 15 ft thick. The perthite is buff to pink and occurs as crystals several feet long.

The parallel pegmatite, 135 ft to the north, is exposed in one cut. The mica occurs in 2- to 3-ft wall zones separated by 3 ft of perthite-quartz pegmatite.

The total production of mica and feldspar from the Gap Lode is unknown. In 1943 Michaud, Duncan, and Frye sold 1,221.04 lbs of small and large sheet before the Colonial Mica Corporation refused to buy mica from this mine because of its low content of no. 1 and no. 2 mica.

During the Custer Mining Account's operation of the property approximately 150 tons of rock were mined and about 6 percent of crude mica was recovered from the rock moved.

Appreciable quantities of mica remain unmined.

GLENWOOD MICA MINE (CUSTER DISTRICT)

The Glenwood mica mine, in the SW¼ sec. 32, T. 3 S., R. 5 E., Custer County, is owned by Lloyd Hampton of Custer. It was operated on a small scale by Hampton in 1944 and was leased to Mineral Mills, Incorporated, February 20, 1945. The production from February 20 to July 20 of that year was 64,000 lb of crude mica. About 21,490 lb was produced prior to April 1 and yielded 992.36 lb of sheet mica (more than 2 sq in. in area) and 4,823.44 lb of untrimmed punch mica. Records of crude and sheet mica produced after April 1 are not available. The mine was mapped (fig. 13) by M. P. Erickson, L. R. Page, and J. B. Hanley, at various times.

MINE WORKINGS

The workings in July 1945 consisted of an 88-ft inclined shaft with levels at 30 and 72 ft vertically below the surface. The 30-ft level extends 22 ft east of the shaft and is connected by a small stope with the old Hampton workings that consisted of two inclined shafts connected by a 15-ft drift and an open-cut. The 30-ft level west of the shaft is about 45 ft long. Small stopes above the level encountered heavy ground and were abandoned. Later work from the 72-ft level connected with, and extended, the west end of the 30-ft level. The 72-ft level extended 44 ft west and 11 ft east of the shaft. The pegmatite west of the shaft was stoped except for pillars, to the 30-ft level.

GEOLOGY

The Glenwood pegmatite did not crop out at the surface; it was found by trenching after mica was discovered in the soil. This trenching exposed the pegmatite or pegmatite debris over a total length of 120 ft. The east end of the pegmatite may have been exposed, but the underground workings have not been extended to the ends of the body.

The pegmatite is generally 5 to 6 ft thick but its thickness ranges from 3 to 10 ft. The average strike is N. 65° E. and the dip is 50° NW. Rolls on the contact cause many local variations.

The pegmatite contains three distinct zones in addition to a 1- to 2-in. border zone. Quartz-albite-muscovite pegmatite forms a wall zone that contains sheet-bearing mica, cleavelandite pegmatite forms a narrow discontinuous intermediate zone, and quartz pegmatite forms a discontinuous core. The wall zone is domi-

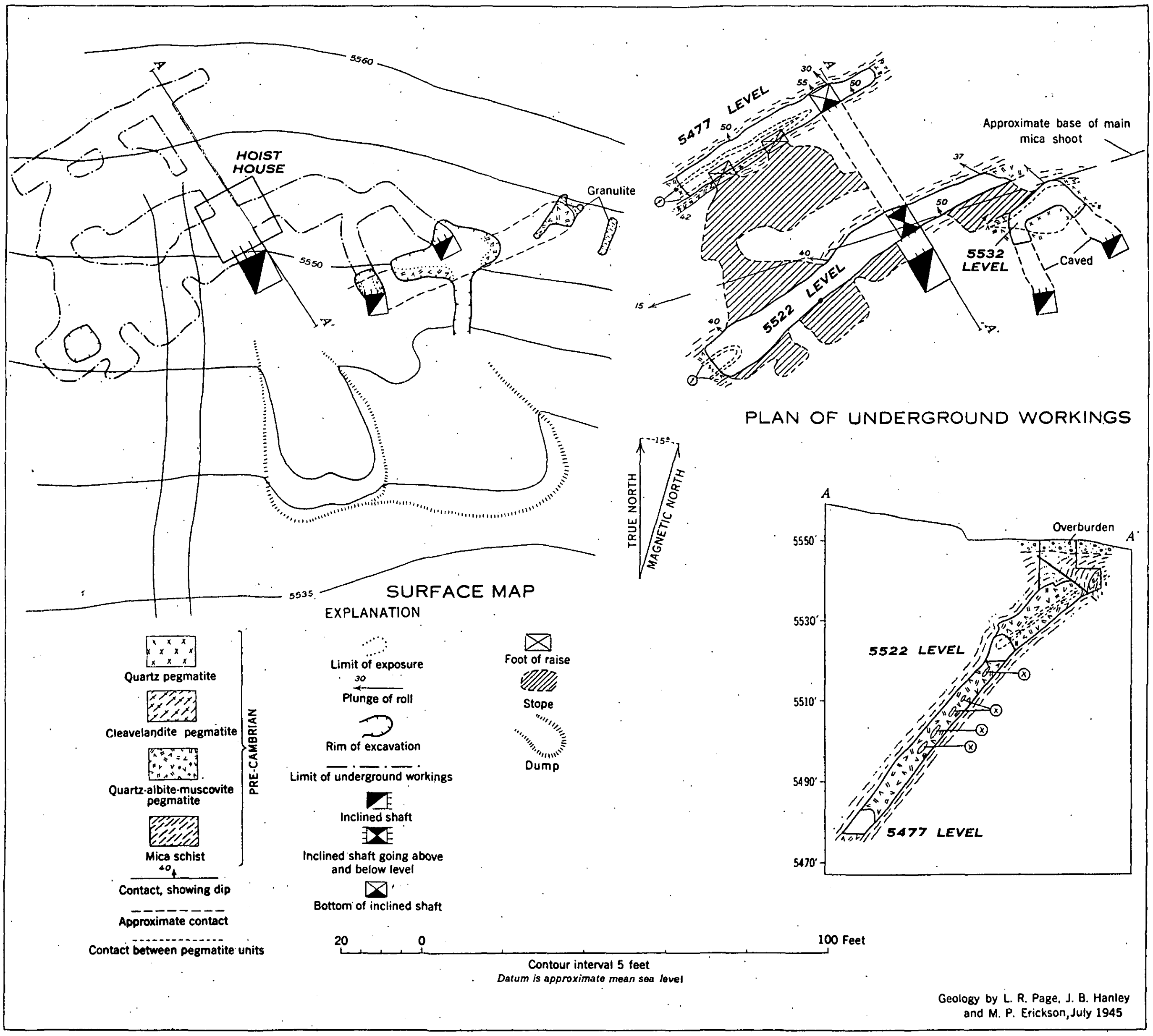


FIGURE 13.—Geologic maps, Glenwood mica mine, Custer County, South Dakota.

nantly quartz and equant albite with 10 to 15 percent of muscovite on the hanging-wall side of the pegmatite, but on the footwall side muscovite is less abundant. Most of the muscovite is in the outer 12 to 18 in. of the wall zone and only the larger books extend to the inner part of the zone. The wall zone rarely exceeds 2 ft in thickness. Tourmaline in masses as much as several feet across was observed in the stope below the old Hampton workings and in the stope between the 72- and 30-ft levels. A few crystals of perthite occur in the wall zone, especially where muscovite is scarce. One small piece of honey-yellow amblygonite and a few beryl crystals have been found.

The intermediate zone is made up entirely of radial aggregates of cleavelandite. It usually encloses the quartz pegmatite core and rarely exceeds 1 ft in thickness. In some parts of the body cleavelandite pegmatite also forms cores that are as much as 2 ft thick. Quartz pegmatite forms a discontinuous core in the pegmatite. Below the 30-ft level, muscovite in the wall zone is less common where the core occurs than in those parts that do not contain quartz pegmatite.

MICA DEPOSITS

The mica deposits of the Glenwood mine are of the wall-zone type. The footwall and hanging-wall parts of the pegmatite both contain muscovite books, but mica is most persistent and concentrated on the hanging wall. Large sections of the footwall part of the zone contain no mica books. The richest mica shoot appears to be the pegmatite mined on the 30-ft level. The structure of this shoot is incompletely known, but its base appears to be about 5 ft below the 30-ft level at the shaft and about 15 ft below the west end of this level. It appears to plunge about 15° N. 70°–80° W. and is marked by a sharp roll of the hanging-wall contact. Below this roll the wall zone is characterized by large barren areas alternating with mica-rich areas of similar size.

Prior to April 1, 1945 about 430 tons of rock was removed from the rich mica shoot and 10.7 tons (3.5 percent) of crude mica was recovered. Because two-thirds of the rock mined was barren of muscovite books, the mica content of the mica zone was in excess of 10 percent. About 4.6 percent of the crude mica was sold as full-trimmed sheet (more than 2 sq in. in area) and about 22 percent was sold as untrimmed punch. Rock mined after April 1, 1945 in the leaner part of the pegmatite contained about 1.5 percent of recoverable crude mica.

The Glenwood mica is a flat, hard, deep-ruby mica. Part of it is strongly air-stained and part is almost free of air-stain. Books from the footwall part of the zone are generally more densely stained. In addition to air-stain there are numerous minute mineral inclusions in part of the mica. The mica books are as much as 2 ft in length and several inches in thickness. Near slips and small faults, the books are strongly ruled and iron-stained. Books that are adjacent to segments of the quartz core or obvious core-segments of cleavelandite pegmatite show "A" structure and many are yellowish at the edges. About 15 percent of the mica sold was of no. 1 and no. 2 qualities. Some no. 3 quality occurs in the more densely air-stained books and in books with iron-stain. Little iron-stained mica occurs below the 30-ft level.

The size pattern of the Glenwood mica is known only from one hand-cobbed lot of 140 lb that was full-trimmed. This lot revealed the following distribution:

Size (inches)	Pounds	Percent
1½ by 2	1. 04	0. 72
2 by 2	4. 01	2. 86
2 by 3	2. 02	1. 46
3 by 3	1. 13	. 81
3 by 4	. 12	. 09
3 by 5	1. 02	. 73
Total sheet	9. 34	6. 69
Total 1-in. punch	34. 00	24. 29
Total scrap	97. 00	69. 12

The mica reserves in the Glenwood mine cannot be calculated because the size of the dike is unknown. Moreover, considerable quantites of the mica lie above or near the 30-ft level where the hanging-wall schist caves badly. The increased cost of holding the hanging wall of the workings prohibits mining much of the mica-rich part of the pegmatite. Extensions of the lower level to the west should develop the mica shoot mined on and near the 30-ft level.

GOOD HOPE NO. 1 AND NO. 2 (KEYSTONE DISTRICT)

The Good Hope No. 1 and No. 2 tin claims, formerly the Samilias or New Hope Nos. 1 and 2, are in sec. 35, T. 1 S., R. 5 E., about 1 mile south of the Rapid City-Hill City highway.

These claims, held by B. A. and H. G. Hardestey, were examined by L. R. Page in July 1942. They have been described by Gardner (1939, pp. 36–38).

The Good Hope No. 1 workings, according to B. A. Hardestey, consist of a small open-cut, and shafts 30 and 100 ft deep, respectively. The vein consists principally of quartz, with a few masses of muscovite and cassiterite crystals as much as 2 in. across along fractures in the quartz. It is as much as 4 ft thick but pinches and swells. The north end of the vein is 6 in. thick and strikes N. 40° E., but at the shafts the vein strikes north. The dips range from 60° NW. at the north end to 75° E. at the shafts. The total length of the vein is about 50 ft.

The Good Hope No. 2 is about 400 ft east of the No. 1 and is on a similar vein. The vein is about 115 ft long and 3 to 3½ ft thick. It is prospected by two shafts, now caved, 100 and 65 ft deep, respectively; they are 60 ft apart. Two small open-cuts and trenches also prospect the vein. The strike is north to N. 10° W. and the dips range from 65 to 80° W. A little arsenopyrite is associated with the cassiterite. The owners state that samples containing as much as 3 percent of tin have been taken from both this and the Good Hope No. 1 properties.

GREENE MINE (CUSTER DISTRICT)

by W. C. Stoll

The Greene mine, known also as the Red Monster and the Pink Monster, is in sec. 11, T. 3 S., R. 5 E., Custer County, 10½ miles south-southeast of Custer, and about 2½ miles northeast of Pringle.

In 1941 the Greene mine was bought by the F. E. Schundler Feldspar Corporation from L. C. Greene of Pringle and on August 17, 1942 it was acquired by the Consolidated Feldspar Corporation.

The mine was operated during June and July, 1942, by the F. E. Schundler Feldspar Corporation. The Greene mine was not being operated in August 1942, when examined by Stoll. At that time about a ton of scrap mica and a few hundred pounds of beryl, spodumene, and amblygonite were stockpiled on the property. In 1944–45 the Greene mine was operated by the Consolidated Feldspar Corporation and in 1944 at least 12.2 tons of beryl was produced, in addition to some feldspar.

The pegmatite forms a long ridge trending N. 30° W. On the sides and top of the ridge, the deposit crops out for a distance of about 1,000 ft along the strike. The pegmatite is 100 to 150 ft wide. In detail, the pegmatite is made up of several elongate bodies separated by masses of schist and quartzite, but in a northerly direction they converge and form what is apparently a single body.

An open-pit, two open-cuts, a tunnel, and a raise have been excavated in the pegmatite. The main pit is situated on the west side of the outcrop and somewhat south of the midpoint of its long dimension. It is 65 ft long, 45 ft wide, and 60 to 70 ft deep at the face. A tunnel 201 ft long has been driven in a northerly direction from the main pit. At a point 160 ft from the portal, a raise branches to the surface. The raise opens in the floor of a second cut, on the east slope of the pegmatite ridge, which is 30 by 40 ft in plan and 30 ft in depth. A third, but small, cut is on the west side of the ridge and about 600 ft northwest of the main pit.

Most of the pegmatite seen in the outcrop consists of pink perthite associated with lesser quantites of quartz and muscovite. Graphic granite is abundant. The grain size of the component minerals differs widely.

The pegmatite in the faces of the main pit is made up of perthite (50 percent), rosy to white quartz, pink to white albite, and yellowish muscovite. About half of the perthite is minable.

Four large beryl crystals were embedded in massive quartz and blocky perthite in the main pit. Part of one crystal was adjacent to pink and white albite mixed with fine-grained mica. This beryl crystal was exposed for a length of 6 ft and its average diameter was 15 in. The other beryl crystals were of comparable sizes. The beryl is bluish-white with a faint greenish tinge, but the crystals faces are stained yellowish to light orange. These crystals were mined in 1944. One lot of 15,740 lb contained 12.25 percent BeO and another lot of 8,699 lb contained 12.70 percent of BeO. About 1.9 tons of beryl was exposed in the walls of the main pit.

Nests of radial tantalite-columbite blades were observed in two places in the same pit. This mineral is associated with pink and white albite, yellowish muscovite, and altered lithiophilite. In all, 20 to 30 lb of tantalite-columbite was exposed.

Within the tunnel, the pegmatite surrounds a mass of schist about 40 ft thick. The pegmatite on both sides of the schist is chiefly a fine-grained mixture of perthite, albite, quartz, and mica. Most of the grains are less than 3 in. across but a few huge blocks of perthite are enclosed in the fine-grained pegmatite. A large aggregate of scrap-mica books at the end of the tunnel appears to have been the source of the small stockpile of this material. Spodumene and amblygonite occur in a small area just within the tunnel entrance.

The middle cut transects pegmatite similar to that exposed in the tunnel. No beryl or tantalite-columbite were seen. The northernmost cut reveals only graphic granite, rose quartz, and red-stained mica.

HARBACH MICA MINE (CUSTER DISTRICT)

by R. F. Stopper

The Harbach or Florence mine is in the NW¼ sec. 30, T. 3 S., R. 5 E., Black Hills Meridian, Custer County.

The first mica produced from the property was in the early 1880's. No records are available, but probably about 300 tons of sheet-mica-bearing pegmatite was mined, and it may have averaged 10 to 15 percent mica. This mica was presumably used by the stove industry. Mr. Walter W. Winters and Mr. Leo Harbach, both of Custer, now own the property. In May 1944, it was leased by them to the Climax Mica Company, a subsidiary of Asheville Mica Company. Winters and Harbach operated the property from July 1943 to May 1944, and produced 147.55 lb of sheet mica from 7.9 tons of crude mica. The Climax Mica Company has produced 6 tons of crude mica. Prior to the Winters and Harbach operation, Louis Schultz of Custer, produced 13.12 lb of sheet mica from 1.7 tons of crude mica.

Geologic maps of the deposit were prepared in June and July, 1944, by R. F. Stopper, Peter Joralemon, and J. W. Adams of the U. S. Geological Survey.

GEOLOGY

PEGMATITES

A series of parallel lenticular pegmatites that conformably intrude pre-Cambrian quartz-mica schist crop out in the area mapped (pl. 18). The pegmatites strike N. 30°–60° E. and dip 80° SE. to 80° NW. Locally the walls of the pegmatites are irregular in detail, with small rolls plunging 58° to 73° SW. The foliation of the schist parallels these rolls. The pegmatites plunge 75° to 80° parallel to the direction of plunge of the rolls.

Four pegmatites of the group—the Florence, Middle, Northwest and Northeast pegmatites—contain muscovite in appreciable quantities.

Seven types of rocks have been mapped within the pegmatites: (1) quartz-albite-muscovite pegmatite, (2) quartz-cleavelandite pegmatite, (3) perthite-quartz pegmatite, (4) perthite-quartz-albite pegmatite, (5) graphic granite pegmatite, (6) albite-muscovite pegmatite, and (7) quartz pegmatite. The quartz-albite-muscovite pegmatite, quartz-cleavelandite pegmatite, and perthite-quartz pegmatite, are zones in the pegmatites. Graphic granite forms a unit in the Northeast pegmatite that may be a zone. The muscovite-albite pegmatite and quartz pegmatite are two zones in fracture-filling bodies that cut graphic granite and perthite-quartz-albite pegmatite in the Northeast pegmatite body.

Graphic granite pegmatite.—This rock is composed mainly of perthite intergrown with quartz and albite. Minor quantities of tourmaline and muscovite are present. The rock is relatively fine-grained, with crystals averaging no more than 1 in. in length, although perthite is as much as 1 ft in length and irregular masses of quartz are as much as several feet in length. A few crystals of beryl are found in this rock type in the Northeast pegmatite.

Quartz-albite-muscovite pegmatite.—Quartz-albite-muscovite pegmatite, the sheet mica-bearing pegmatite, forms a wall zone 1 to 8 ft thick along the walls of the Florence and Northwest pegmatites and comprises the entire Middle pegmatite. The albite occurs as irregular masses as much as several inches in cross-section and is intergrown with quartz and a subordinate amount of muscovite. Tourmaline, beryl, and apatite are accessory minerals.

Quartz-cleavelandite pegmatite.—Quartz-cleavelandite pegmatite comprises the core of the Florence pegmatite. It consists mainly of large irregular masses of white quartz intergrown with radial aggregates of cleavelandite as much as several feet in diameter. Black tourmaline, as much as 4 in. in prism section, and small flakes of muscovite are accessory minerals.

Quartz pegmatite.—Quartz pegmatite occurs as the core of the fracture-filling bodies in the Northeast pegmatite. It is as much as 2 ft thick and of unknown lengths.

Albite-muscovite pegmatite.—Albite-muscovite pegmatite forms a wall zone in the fracture-filling bodies of the Northeast pegmatite. Muscovite (25 percent) occurs as books as much as 5 in. across oriented normal to the wall of the zone. Albite and quartz, in crystals and grains as much as 6 in. long, form the remainder of the rock. The thickness of this zone is rarely as much as 2 ft.

Perthite-quartz-albite pegmatite.—A few pegmatite bodies on the Harbach property are constituted entirely of perthite-quartz-albite pegmatite. This rock occurs not only in the border zone, generally 1 to 2 in. thick, but also in the middle of the pegmatite. It is cut by fracture-filling bodies in the Northeast pegmatite.

Perthite-quartz pegmatite.—Perthite-quartz pegmatite forms the core of the Northwest pegmatite. The perthite occurs in crystals as much as 1½ ft in length, together with irregular masses of quartz. Albite, intergrown with the quartz in crystals as much as ½ in. in length, are interstitial to the larger masses of perthite and quartz. Muscovite, tourmaline, and beryl also occur in this type of pegmatite.

MICA DEPOSITS

Sheet mica occurs in the quartz-albite-muscovite pegmatite which forms wall zones 1 to 8 ft thick at the borders of the Florence and Northeast pegmatites and comprises the entire middle pegmatite. Abundant muscovite has developed along quartz-filled fractures in the Northeast pegmatite.

FLORENCE PEGMATITE

Presumably, John Harbach originally developed the Florence pegmatite in the early 1880's. The workings, prior to May 1943, consisted of a shaft 20 ft deep, an open-cut 85 ft long and as much as 10 ft deep on the southeast side of the pegmatite, and two smaller open-cuts. A shaft 80 ft deep, now filled, is reported to have been sunk by John Harbach in the early days. The Climax Mica Company deepened the shaft to 48 ft and drifted 75 ft northeast in pegmatite. Most of the mica produced from the property has come from this pegmatite. Total recorded production of large and small sheet mica is 181 lb. In 1943, 107 lb of beryl, estimated to contain 8 percent of BeO, was produced.

The Florence pegmatite is 110 ft long and as much as 20 ft wide; the average is 10 ft deep. It strikes N. 40° E. and its steep dips are northwest or southeast. The dike and minor rolls along its border plunge 73°–75° SW. On the surface, the pegmatite has a core of quartz and cleavelandite as much as 15 ft thick, but in the shaft the core pinches out at 38 ft. Quartz-albite-muscovite pegmatite wall-zones, 1 to 8 ft in width on the surface and 12 ft on the drift level, contain the sheet-bearing muscovite.

Most mica books are less than 6 in. in maximum dimension, although a few books as much as 12 in. in length have been found. They show prominent "A" structure, ruling, and many inclusions of quartz and tourmaline. The mica is pale ruby, and in part is strongly air-stained. It is estimated that the sheet mica recovered was less than 5 percent of no. 1 quality and 20 to 30 percent of no. 2 quality; the remainder was of no. 2 inferior quality.

About 188 tons of rock was mined from the shaft; about 50 tons was sheet mica-bearing pegmatite. Approximately 7.9 tons, or 16 percent, of crude mica was recovered; about 1 percent was small and large sheet mica. The ratio of small to large sheet is about 6 to 1.

MIDDLE PEGMATITE

Workings on the Middle pegmatite date from the 1880's. There is no record of production but it was probably on the order of 120 tons of pegmatite estimated to contain 8 to 10 percent of mica.

The pegmatite consists of quartz-albite-muscovite rock, rich in tourmaline. It strikes N. 30°–50° E. and dips range from vertical to 62° SE. Small rolls along the contact between pegmatite and schist plunge 56°–65° SW. The ends of the dike are not exposed but are probably parallel to the small rolls. Exposures of the dike indicate that it has a minimum length of 110 ft and an average width of 3 ft.

As the surface of the dike is largely covered with pegmatite boulders, it is difficult to determine the average quantity and quality of mica in it. Exposed parts reveal mica books that average 2 to 3 in. in length. Mica is estimated to constitute about 8 percent of the rock. The percentage of sheet to crude mica appears to be even lower than in the Florence pegmatite.

NORTHWEST PEGMATITE

The Climax Mica Company developed the northern end of the Northwest pegmatite in May and June, 1944, by an open-cut 40 ft long, 14 ft wide, and 8 ft deep.

The Northwest pegmatite is 90 ft long and 10 to 25 ft wide. It is composed of a core of perthite-quartz rock, 8 to 16 ft thick, surrounded by a wall zone of quartz-albite-muscovite rock, 1 to 12 ft thick. Beryl and a few crystals of columbite-tantalite occur in the wall zone, and tourmaline crystals are scattered through the pegmatite. The pegmatite strikes N. 40° E. and dips from vertical to 80° SE.

The mica is in part air-stained and ruled. Inclusions of quartz and tourmaline are not uncommon, and occasional "silver spots" are found. The mica books range from 2 to 8 in. in maximum dimension and average 4 in.

Four hundred tons of rock was mined from this pegmatite. Of this amount, about 100 tons was sheet mica-bearing pegmatite that yielded 11,360 lb (5.7 percent) of crude mica. This mica contains a very low percentage of sheet, probably less than that mined in the Florence pegmatite. The quantity of sheet recovered is not known.

NORTHEAST PEGMATITE

The Northeast pegmatite (pl. 18 and fig. 14) strikes N. 40° E., dips 70° SE. to 75° NW. and plunges 75°–80° SW. Two sets of rolls along the contact between pegmatite and schist plunge respectively 60° to 65° to the southwest and 20° to the northeast. The northeast plunging set is the more conspicuous. The pegmatite is 120 ft long and 12 to 20 ft wide.

The pegmatite is composed mainly of perthite-quartz-albite pegmatite, and is cut by three fracture-controlled bodies of muscovite-quartz-albite and quartz pegmatite. A patch of graphic granite, 7 by 10 ft in area, occurs near the center of the pegmatite. The orientation of the quartz rods in the graphic granite is normal to the strike of the dike. The main part of the pegmatite is perthite, quartz, and albite, with few grains as much as 1 in. in length, associated with small crystals of muscovite, beryl, tourmaline, and apatite.

Quartz pegmatite, 1 to 12 in. thick, occurs in two sets of late fractures in the pegmatite. One set strikes

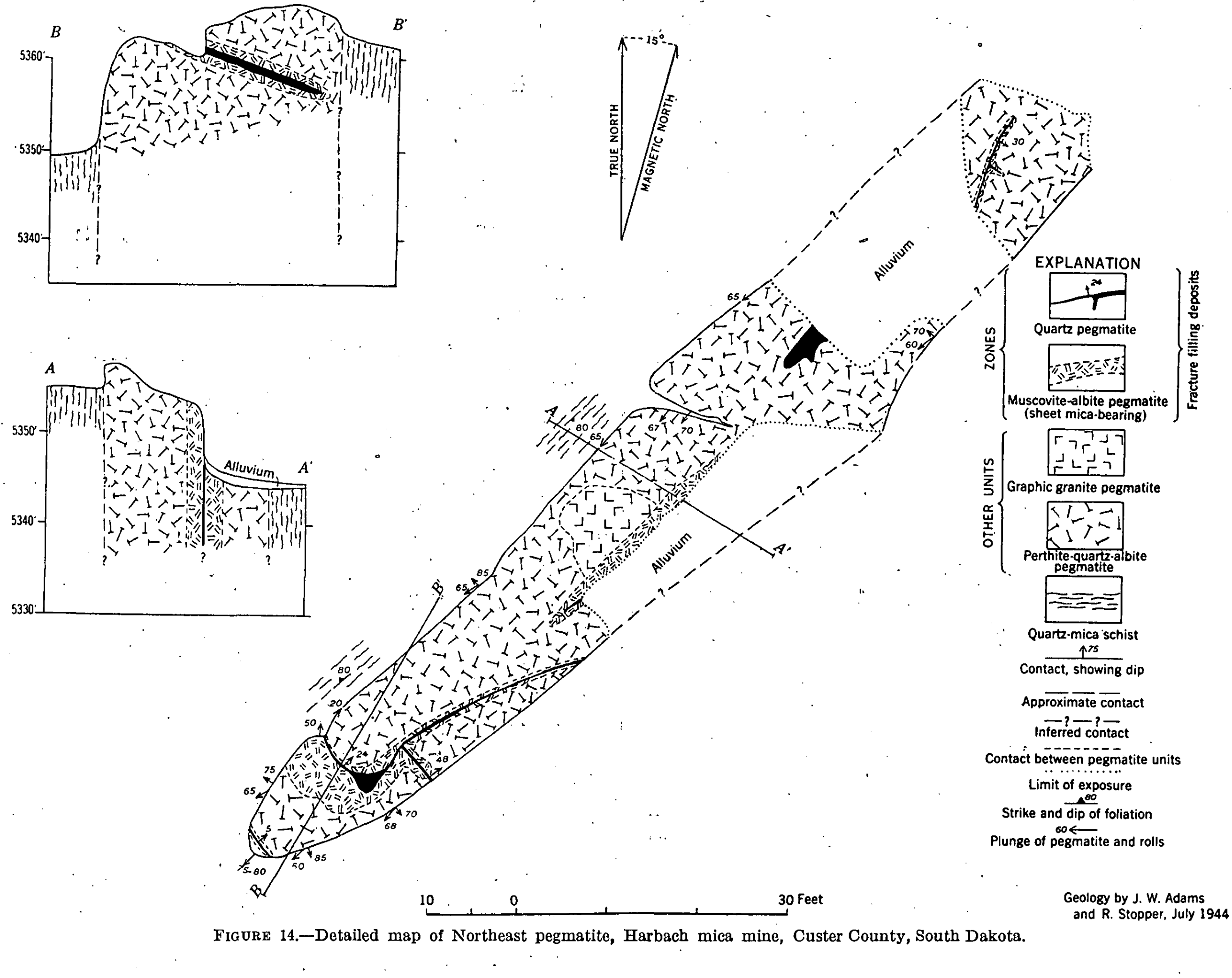


FIGURE 14.—Detailed map of Northeast pegmatite, Harbach mica mine, Custer County, South Dakota.

northwest, normal to the strike of the body, and dips 5°–48° NE.; the other set strikes northeast, parallel to the strike of the dike; its dip ranges from vertical to 30° SE. A wall zone of albite-muscovite pegmatite, 1 to 15 in. thick, occurs along the edges of the quartz. Muscovite is estimated to form 25 percent of the rock along the two most conspicuous fractures (fig. 14, sections B–B′ and C–C′). The long dimensions of the muscovite crystals are normal to the fractures. The mica books average 3 to 4 in. in length. They are badly air-stained and have been split along cleavage planes by frost action. The mica is very soft.

RESERVES

Inferred reserves of mica-bearing pegmatite amount to 4,000 tons at the Florence pegmatite, estimated to contain 16 percent of crude mica, and 3,000 tons at the Northwest pegmatite estimated to contain 5.7 percent of crude mica.

HARDESTEY HOMESTEAD MINE (KEYSTONE DISTRICT)

by L. R. Page and J. B. Hanley

The Hardestey Homestead mine, in the NE¼ sec. 36, T. 1 S., R. 5 E., Pennington County, is about 4 miles northwest of Hill City, Pennington County. It is reached from Hill City by 8.2 mi of paved road (Hill City-Keystone road) and 0.3 mile of dirt ranch road. The pegmatite is on land owned by George Hardestey of Keystone, South Dakota. The property was examined and mapped by the writers July 28, 1942.

The property was operated, prior to 1935, and in 1943–44, by Harley and Bert Hardestey.

The total production of the mine, prior to July 1942, according to Harley Hardestey, was 7 tons of beryl, 25 to 30 tons of scrap mica, 300 to 600 lb of tantalite (estimated to be 50 percent Ta_2O_5), and 5 tons of soda spar. About 20 tons of amblygonite and a few tons each of soda and potash feldspar were stockpiled on the property at the time of the examination. The tantalite produced during the earlier operations had not been sold. During 1943–44 Burt Hardestey sold 4,250 lb of beryl and 749 lb of tantalite to Metals Reserve Company and Colonial Mica Corporation. Incomplete analyses of the tantalite shipments are given below.

	Lot 1 (percent)	Lot 2 (percent)	Lot 3 (percent)
Ta_2O_5	56. 29	55. 87	57. 37
Cb_2O_5	16. 45	15. 81	----------
SnO_2	. 16	. 34	----------
TiO_2	. 19	. 19	----------

GEOLOGY

WALL ROCK

The Hardestey Homestead pegmatite cuts across the structure of biotite-garnet-quartz schists of pre-Cambrian age. The schists have been highly folded and small recumbent isoclinal folds are characteristic of the exposures.

PEGMATITE

The pegmatite is exposed on the north side of the North Fork of Battle Creek as a series of small cliffs totaling 80 ft in height. Erosion has removed most of the pegmatite and the only two exposures are now isolated by the alluvium in the valley.

The contacts of the pegmatite are very irregular and contain a large number of rolls, and variations in strike and dip are common. In general, the southern part of the body strikes about N. 20° W. and the northern part about N. 10° E., and in both parts the pegmatite dips very steeply to the west. The rolls plunge 25° to 30° to the southeast, about parallel to the plunge of the large quartz mass exposed in the open-pit at 4,925 ft altitude (fig. 15). Quartz "veins" extend outward from the quartz pegmatite and strike either N. 5° E. or N. 65° E., and dip 65° to 70° NW. There is no obvious relationship between the structure of the pegmatite and that of the schists, which strike N. 20° E. and dip 20°–30° SE. The pegmatite in general parallels the strike of the schists, but is inclined at right angles to their dip.

In mapping, the dike was divided into five zones: (1) albite-quartz-muscovite pegmatite, (2) albite-quartz pegmatite, (3) "spodumene"-amblygonite-tantalite pegmatite, (4) perthite pegmatite, and (5) quartz pegmatite. The mineralogy of each of the several types of pegmatite is generally distinctive.

Albite-quartz-muscovite pegmatite.—The albite-quartz-muscovite pegmatite that forms the outer zone of the body ranges in thickness from 3 to 9 ft. On the map, this unit, on the south side of the valley, appears much thicker because it was impracticable to distinguish it from albite-quartz pegmatite.

Individual minerals in the albite-quartz-muscovite pegmatite are of various sizes, but the overall texture of the zone remains constant. The beryl crystals range from 0.1 to 0.7 ft in cross-section, and the scrap mica from small flakes to books 8 by 10 by 12 in. The albite feldspar, which is more uniform in size, and quartz make up the larger part of the zone. These minerals have an average grain size of about 2 in.

Albite, the dominant mineral, is dark-gray to white and usually shows streaks of darker material. It has a granitic texture and is intergrown with quartz in the outer part of the zone. Near the inner edge, the albite is platy, and irregular veinlets and patches of cleave-

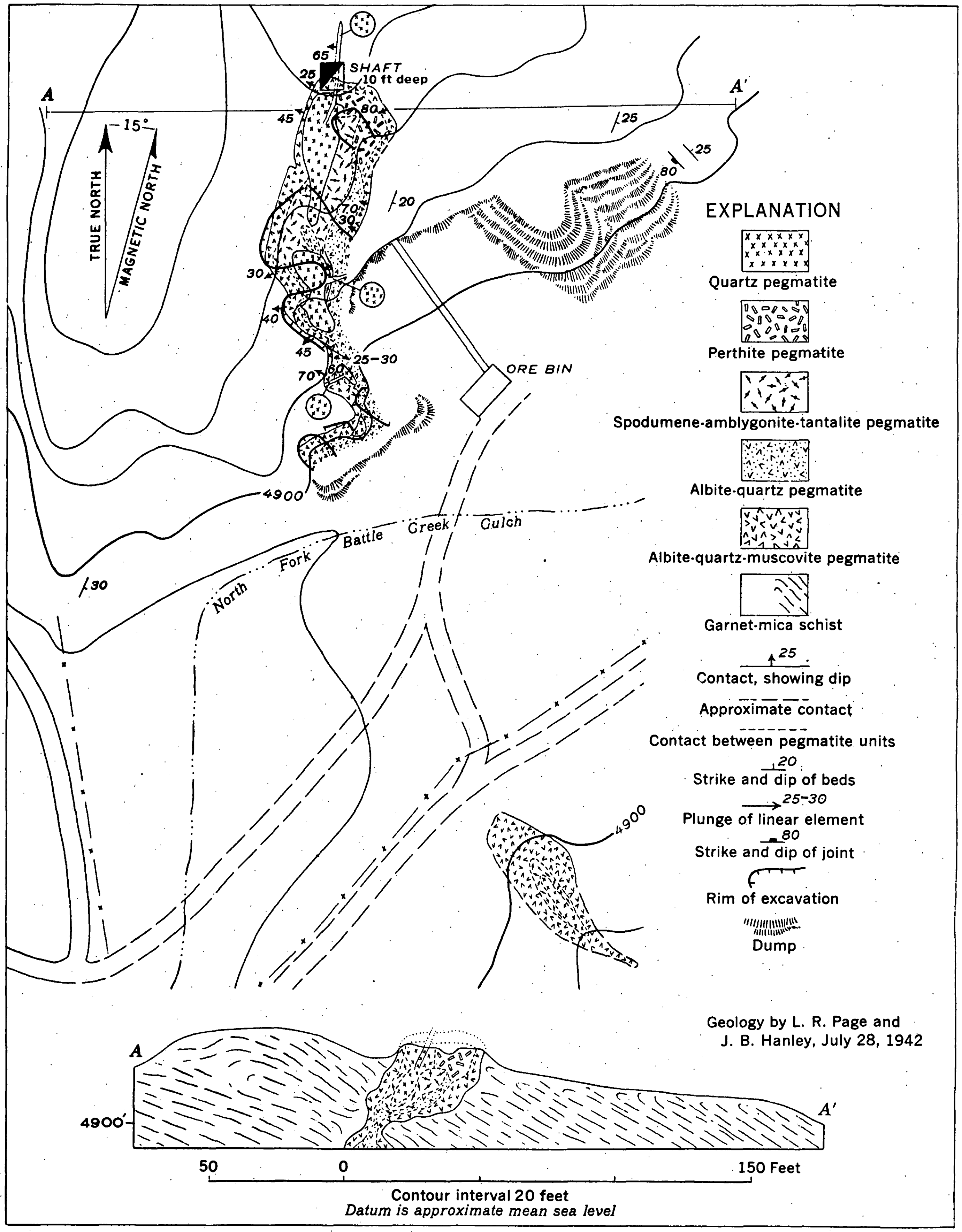


FIGURE 15.—Geologic map and section, Hardestey Homestead pegmatite, Pennington County, South Dakota.

landite extend into the more equigranular variety. The quartz associated with the platy albite appears to have been partly corroded, and rounded masses appear isolated in the albite. This rock is much different in appearance from that in which quartz is intergrown with the other variety of albite. Apparently the more equigranular variety of albite formed simultaneously with quartz and the platy albite was formed later.

The beryl in this zone is opaque white to pale-yellow or green, and has been corroded at the outer edges of the crystals by the platy albite. Irregular veinlets of albite also extend into the beryl crystals. Where the beryl is in contact with the more equigranular variety of albite there is less corrosion.

The muscovite occurs as flakes and books as much as 12 in. in maximum dimension. These books commonly show "A" and wedge structures and are generally highly crinkled. The mica is pale-green to colorless, and is only of scrap grade. The richest pockets are in "rolls" on the hanging-wall contact.

Albite-quartz pegmatite.—The albite-quartz pegmatite is a medium- to coarse-grained granitic rock composed of albite, quartz, and muscovite. The albite and muscovite are stained brownish-gray, and more highly stained spots suggest the former presence of some iron mineral. This facies of the pegmatite grades outward through a narrow zone of platy albite into albite-quartz-muscovite pegmatite. The inner edge of this zone grades into "spodumene"-amblygonite-tantalite pegmatite. Probably the albite-quartz pegmatite developed its finer-grained texture in response to a sudden change in physical conditions during the crystallization of the pegmatite. The range in grain size within the albite-quartz pegmatite zone suggests that uniform conditions of crystallization were not attained until after spodumene and amblygonite had begun to form.

"Spodumene"-amblygonite-tantalite pegmatite.—The "spodumene"-amblygonite-tantalite pegmatite forms a zone inside the albite-quartz pegmatite, except along the west side of the dike, north of the open-pit at an altitude of 4,940 ft. Here the albite-quartz pegmatite did not form or, as appears probable, has been corroded and removed by "spodumene"-bearing rock, perthite pegmatite, and quartz pegmatite. The "spodumene"-amblygonite-tantalite pegmatite is much coarser grained than the earlier zones. "Spodumene" crystals as much as 6 ft in length form an irregular network through smoky quartz, which contains 6- to 8-in. nodular masses of amblygonite mixed with other minerals that probably include rhodochrosite, platy albite, cassiterite, and tantalite grains. The contact of this zone with the quartz and perthite pegmatite is sharp. Near this contact large beryl crystals have been found; the largest, measuring 10 by 10 by 12 in., was not whole.

The spodumene has been highly altered and now appears as a mass of sericite fibers at right angles to the long axis of the crystals. Almost all of the lithia has been leached out. The amblygonite nodules are likewise highly altered and appear brown to black. The alteration extends into the center of the nodules and it is almost impossible to find fresh amblygonite. Because of the freshness of the feldspars and some of the other minerals it is difficult to understand how these alterations could be due to weathering; they are probably the result of deuteric action or hydrothermal alteration.

Tantalite, mixed with tapiolite, occurs as grains—as much as 1 in. across, but averaging about ⅜ in.—scattered through this zone. It is commonly associated with white to gray platy albite. Specimens in the stockpile contain cassiterite also but this mineral was not seen in place. According to Mr. George Hardestey some tantalite was recovered from the albite-quartz-muscovite pegmatite in the pit at an altitude of 4,900 ft. None was observed in place in this zone. A specimen of tantalite collected from the south wall of the pit, at an altitude of 4,940 ft, was examined by Michael Fleischer of the Chemical Laboratories of the U. S. Geological Survey. It was found to contain some tapiolite, and to have a specific gravity of 7.25. If it is assumed that the specimen is a member of the columbite-tantalite series and does not contain tapiolite, it would be approximately 75 percent of Ta_2O_5.

Perthite pegmatite.—At the north end of the dike, perthite pegmatite occurs between the outer zone of albite-quartz-muscovite pegmatite, and either the intermediate zone of "spodumene"-amblygonite-tantalite pegmatite or the quartz pegmatite core. It is very coarse grained, pink to gray perthite with only minor quantities of quartz and other minerals. The small pit on the southwestern part of the zone was made in removing 5 tons of beryl. No beryl is visible in place, but Harley Hardestey, who worked this pit, stated that the beryl occurred at the contact of the quartz pegmatite and the "spodumene"-bearing rock. Some of it probably came from the perthite pegmatite.

Quartz pegmatite.—The last mineral formed in the dike was quartz, which occurs as a large central mass. The larger masses of quartz pegmatite shown on the map were connected before mining and were much thicker. Two smaller patches of quartz pegmatite occur south of these larger ones and a third mass forms the center of the outcrop on the south side of the valley. The quartz pegmatite is almost entirely milky quartz but near its edges there are small quantities of perthite and a few hexagonal rods of muscovite. Beryl crystals are present on the outer edges of the mass.

Quartz "veins," filling fractures, extend from the quartz pegmatite across the older parts of the pegmatite and in places cut the schists. The most conspicuous vein extends north from the shaft at the end of the dike. It can be traced as a distinct unit through the outer edge of the quartz pegmatite, but then fades out near the center of the mass. These "veins" occupy very sharply defined fractures that appear to have formed by movement of the pegmatite mass before complete consolidation.

MINERAL DEPOSITS

In this pegmatite the minerals of possible economic importance are scrap mica, beryl, amblygonite, feldspar, tantalite-tapiolite, and cassiterite. The desirable minerals are sufficiently well segregated so that it would be possible to save the fines or waste from the "spodumene"-amblygonite-tantalite zone for concentration of the tantalite-tapiolite and cassiterite; the remainder of the materials could be hand sorted.

SIZE AND GRADE

The outer border zone of albite-muscovite-beryl pegmatite contains practically all of the scrap mica and much of the beryl. On the basis of the total pegmatite mined to date, and the production figures, about 25 tons of scrap mica was recovered from about 500 tons of rock—a ratio of 1:20. By mining the wall zone separately the ratio of rock to mica probably would be 1:10, and in places 1:5. About 5 tons of beryl were recovered from about 150 tons of rock. Measurements of exposed crystals in the wall zone gave a ratio of beryl to rock of 1:400, though on the basis of production it was 1:75. The ratio for amblygonite to rock is probably about 1:25, and for tantalite 1:2000.

RESERVES

Probably this mine could be worked on a small scale and produce feldspar, beryl, tantalite, scrap mica, and amblygonite. Possibly appreciable quantities of tantalite have been concentrated in the gulch, as the bulk of the tantalite-bearing part of the dike appears to have been eroded.

HELEN BERYL CLAIM (CUSTER DISTRICT)

The Helen Beryl claim, formerly known as the Big Tom and Kem Lode, is about 8 miles southwest of Custer. It is in sec. 7, T. 4 S., R. 4 E., and can be reached by the following schedule of mileage.

Miles	
0.0	Post Office, Custer. Go west on U. S. Highway 16.
5.5	Turn south on dirt road.
5.9	Intersection at school house. Take right-hand road.
7.4	Turn right through gate in fence.
7.8	Helen Beryl claim.

The Helen Beryl claim is held by L. H. Jeffries of Custer, who prospected the claim for mica and beryl in 1943. The property was visited by Hall in 1942. The present report is based on intermittent work done between June 1943 and February 1944 by L. R. Page assisted by L. C. Pray and Peter Joralemon. During this period the U. S. Bureau of Mines and Metals Reserve Company sampled the dike for beryl.

GEOLOGY

METAMORPHIC ROCKS

The Helen Beryl pegmatite is a lenticular mass, which intrudes quartz-mica schists of pre-Cambrian age. The foliation and bedding of the schists generally strike N. 20°–50° W. and dip 40°–70° SW., but near the pegmatite the schists are more highly folded and the foliation appears to be more nearly parallel to the contacts. At the north end of the pegmatite the schists are more strongly folded than in the surrounding areas. The linear structure in the schists is roughly parallel to the rolls in the pegmatite contact, which plunge toward the south.

PEGMATITE

The Helen Beryl pegmatite crops out as an oval mass 250 ft long and as much as 130 ft wide. The surface of the outcrop is very irregular and at the northern end rises 70 ft above ground level. The total vertical distance between the highest and lowest outcrop is 120 ft.

The pegmatite trends north and dips steeply west. The northern end is vertical and the southern end, though not exposed, is believed to plunge south at a moderate angle. Rolls on the contacts plunge southward at 30°–45°. The strong joints that cross the pegmatite strike N. 60°–80° E. and dip 60°–90° NW. Weathering along these joints has made the pegmatite outcrop and the outcrop pattern of the pegmatite units very irregular.

Two main types of rock, albite-quartz and perthite-quartz pegmatite, have been mapped within the Helen Beryl pegmatite (pl. 19), though there is considerable variety of mineralogy and texture within each unit. A third, but minor, unit of quartz pegmatite within the perthite-quartz pegmatite, was mapped where possible. The southern half of the outcrop is predominantly albite-quartz pegmatite, which also crops out as a narrow shell around the coarse-grained perthite-quartz pegmatite that forms the northern half of the mass. Dikes of coarse-grained perthite-quartz pegmatite cut the albite-quartz rock. The distribution of beryl and muscovite are diagrammatically shown by appropriate symbols.

The internal structure of the Helen Beryl pegmatite is complicated by fracture-filling pegmatite dikes that cut across earlier zonal structures. On plate 19 three mineralogic units are shown. If more detailed mapping were desired the albite-quartz pegmatite could be subdivided further into a "chilled" or border zone 1 to 2 in. thick; a discontinuous wall-zone, containing sheet muscovite; and an intermediate zone of albite-quartz-beryl pegmatite, which in turn could perhaps be subdivided into smaller units. The perthite-quartz pegmatite that crops out in the higher (northern) part of the pegmatite apparently is a core from which extend a number of fracture-filling bodies of similar lithology. Within the apparent core a unit of quartz pegmatite has been mapped. With more detailed mapping an intermediate zone rich in muscovite, biotite, and beryl could be delimited at the outer edge of the perthite-quartz pegmatite. This would reflect the shape both of the apparent core and of the fracture-filling bodies rather than the shape of the entire pegmatite.

Residual patches of schist and albite-quartz pegmatite indicate that there has been relatively little erosion at the top of this pegmatite (pl. 20).

Albite-quartz pegmatite.—The albite-quartz pegmatite has a varied texture. Parts of this rock are no coarser than a medium-grained granite whereas other parts contain grains as much as 2 in. in diameter; in general the grains are ½ to 1 in. across. The rock is light gray to pink and is composed of albite, quartz, muscovite, biotite, perthite, beryl, apatite, and tourmaline. Albite ($N_{\alpha'}=1.529$) is the dominant mineral and with quartz makes up most of this type of pegmatite. The mineral composition differs from place to place, and muscovite or beryl locally are more abundant at the schist contact than at other places in this zone.

Perthite-quartz pegmatite.—The minerals in the perthite-quartz pegmatite are generally in grains more than 2 in. in diameter. Pink perthite and quartz occur as crystals and masses several feet across. In part, the perthite is intergrown with quartz to form graphic granite. The outer parts of the perthite-quartz pegmatite contain blades of muscovite and biotite as much as 6 ft long that extend at approximately right angles from the walls across the other minerals. Where these blades are very abundant, the rock appears as a finer-grained aggregate of perthite, quartz, muscovite, and biotite. Quartz lenses and irregular masses of perthite-quartz pegmatite, bordered by crystals of wedge mica and beryl, occur along the center of the bodies.

MINERAL DEPOSITS

The Helen Beryl pegmatite contains beryl, sheet mica, scrap mica, and perthite feldspar, all of potential economic value.

BERYL

Beryl is widely disseminated in the albite-quartz rock as crystals and anhedral grains as much as 6 in. in length, and in the perthite-quartz rock as crystals as much as 12 in. in length. The characteristic distribution and size of beryl crystals in both these rock types are illustrated in plate 21.

The beryl in the albite-quartz pegmatite is green, yellow, white, or smoky, and occurs in crystals and grains as much as 2 in. in diameter and 6 in. in length. The average cross-section is less than 1 in. The beryl has three modes of occurrence: (1) It occurs as very irregular, anhedral aggregates that are interstitial to other minerals. This beryl is generally yellow to white, and commonly stained with limonite. It is most abundant in the finer-grained, more granitic parts of the pegmatite. These aggregates rarely attain a length of 2 in. (2) Shells of beryl occur around central cores of albite, perthite, tourmaline, and muscovite. This type of beryl is most conspicuous in the sheet mica-bearing parts of the pegmatite. It is colorless, white or pale-green. The average diameter of these crystals probably does not exceed 2 in. (3) Euhedral crystals are most common in the less micaceous parts of the albite-quartz pegmatite. From their centers outward or along their length, these crystals range from colorless to opaque white, clear green, or smoky. The average length of these crystals is less than 1 in.

The coarser-grained beryl crystals in the perthite-quartz pegmatite are as much as 8 in. in diameter and 12 in. in length. They are commonly opaque white to pale yellowish-green. Beryl is rare in the perthite-quartz pegmatite at the northern end of the mass, but is fairly abundant in the dikes of this rock that cut albite-quartz-beryl pegmatite at the south end of the mass.

The quantity of beryl that can be hand-cobbed from present exposures is too small to warrant mining, and some form of beneficiation will be necessary before much beryl can be recovered. The average grade of the beryl-bearing rock is in doubt because of variations in assays, but estimates based on actual measurements of beryl exposed in the fresh faces (pl. 21) of the sample cuts suggest that it is probably 0.3 to 0.5 percent beryl. The average of all measurements was 0.34 percent beryl, which is comparable to the U. S. Geological Survey assays of Metals Reserve samples (see tables below). Assays of Metals Reserve Company's samples by the U. S. Bureau of Mines averaged 0.12 percent BeO which is equivalent to 1.2 percent beryl, if the pure beryl is assumed to contain 10 percent BeO. Assays of the same samples by Mineral Separation Company are comparable to those of the U. S. Bureau of Mines. The final results of the more detailed sampling by the U. S. Bureau of Mines were not available in June 1945.

MICA

Sheet mica occurs locally along the contact of the pegmatite in discontinuous zones 1 to 2 ft thick. About 100 lb was produced, but only 7.75 lb were sold to Colonial Mica Corporation in 1943. This shipment was mined from the hanging wall and the remainder, mined from the footwall, was sold as electrical mica. This mica was very heavily air-stained and contained red spots and mineral inclusions. The size pattern and the quantity do not favor the development of this pegmatite for sheet mica, though sheet mica would be a salable byproduct of other operations. During the U. S. Bureau of Mines sampling for beryl the book mica was sorted from the samples and weighed. The mica of some of these samples were trimmed. In

Grade of beryl-bearing pegmatite as determined by measurements on exposed surfaces, Helen Beryl claim

Sample cut number [1]	Perthite-quartz pegmatite		Albite-quartz-beryl pegmatite		Average percentage of beryl
	Area of face measured (sq ft)	Percentage of beryl	Area of face measured (sq ft)	Percentage of beryl	
MR1, BM1	21.4	0.25	59.1	0.25	0.25
MR2, BM2	16	.81	32.6	.52	.60
MR3, BM3	18	.39	46.7	.17	.23
MR4	20	.76			.76
BM4	9	.33	14.1	.11	.20
MR5	94	.23			.23
BM5	5.5	.00	70.5	.10	.09
MR6, BM9			36	.60	.60
BM6	61.75	.00	10	.71	.10
BM7	5.25	.00	34.5	.09	.08
BM8	20	.52	59.8	.18	.29
BM11	52.3	1.72	37.5	.22	.11
BM12			93.0	.22	.22
BM13	16.5	.19	47.0	.16	.17
BM14			54.7	.34	.34
BM15	40	.38	41.3	.36	.37
BM16	24.6	.22	42.8	.10	.15
BM17 [2]	91.8	.44			.44

[1] BM indicates U. S. Bureau of Mines sample cuts (pls. 19, 21). MR indicates Metals Reserve Company sample cuts (pls. 19, 21).

[2] Face in which U. S. Bureau of Mines made drift round, showed 0.34 percent beryl (see pl. 19).

samples 1, 2, 3, 5, 6, and 8, the crude mica averaged 20 lb to the ton and from this total an average of 1.2 lb were produced as finished sheet.

FELDSPAR

The perthite-quartz pegmatite contains pink perthite that is sufficiently free of inclusions to make a salable feldspar product. Probably this dike could not be worked profitably because the coarse feldspar-bearing pegmatite is in narrow and small bodies. About 150 tons of pegmatite was produced from the west side of the U. S. Bureau of Mines adit in 1944.

U. S. BUREAU OF MINES AND METALS RESERVE SAMPLING PROJECTS

During September 1943 the Metals Reserve Company, in cooperation with the U. S. Bureau of Mines, took six large samples of beryl-bearing rock from the Helen Beryl pegmatite. Mr. Leo J. Coady was in charge of the Metals Reserve Company's sampling program. Locations at which samples were taken are shown on plate 19. Samples weighing 2 to 5 tons were crushed to minus 1 in. and a final sample of about 300 lb was obtained by cutting the pulp stream from the crusher at regular intervals. The final sample was quartered and pulps were sent to the American Cyanamid Company, the Minerals Separation Company, and the U. S. Bureau of Mines for assay and beneficiation tests. The results of assaying are shown in the table below, together with the percentage of beryl determined by measurements on the faces of the sample cuts. BeO determinations made in the Chemical Laboratories of the U. S. Geological Survey on samples furnished by Metals Reserve Company are also given in the table.

The U. S. Bureau of Mines took 17 additional large samples at the Helen Beryl pegmatite. The locations furnishing these samples are shown on plate 19. These large samples were run through the U. S Bureau of Mines' sampling plant at Custer, and tests were made on each to determine the feasibility of hand sorting feldspar, mica, beryl, and waste rock (mainly quartz) in the plus 1 in. sizes. The beryl recovered by hand sorting and the residue from sorting operations were assayed for BeO. On the completion of this surface sampling, an adit was made from the southern end of the outcrop northward for 120 ft. (See pl. 20.) The adit started in coarse perthite-quartz pegmatite and entered albite-quartz pegmatite at 43 ft. At the portal beryl is visible in perthite-quartz rock and all the samples that were sorted yielded beryl. The results of sampling indicate that about the same quantity of beryl is contained in the rock cut by the adit as in the surface samples. All rock mined from the drift between 35 and 120 ft was used as samples.

RESERVES

The incomplete results of the U. S. Bureau of Mines sampling program at the Helen Beryl pegmatite do not permit accurate estimates of reserves but the

Beryllium assays, Metals Reserve sample cuts, Helen Beryl claim

Number	Weight of sample in pounds	Area in sample cut (sq ft)	Percent beryl by measurements	MS1 [1]	MS2	BM	GS1	GS2	Amc.	
									Spec.	Wet
1	6,400	80.5	0.25	0.14	0.18	0.11	0.03	0.03	0.09	0.19
2	5,150	48.6	.60	.15	.13	.15	.07	.03	.09	.06
3	6,620	64.7	.23	.12	.12	.09	.04	.03	.05	.16
4	4,000	20.0	.76	.15	.08	.16	.93	.08	.07	.13
5	9,350	94.0	.23	.04	.03	.07		.006	.02	.12
6	7,400	36.0	.60	.33	.34	.14	.10	.08	.09	.16
Composite 1–6			.36	.14	.12	.12	.04	.04	.07	.14

[1] MS1 indicates Minerals Separation "best shift," MS2 indicates Minerals Separation average of three determinations; BM indicates U. S. Bureau of Mines; GS1 indicates U. S. Geological Survey chemical determination; GS2 indicates U. S. Geological Survey spectrographic determination; and Amc. indicates American Cyanamid Company, spectrographic and wet determinations.

possible size of the body and the probable grade is indicated by available information. The amount of rock above an altitude of 5,330 ft is calculated to be 100,000 to 110,000 tons. Exposures and underground work indicate that at least half of this tonnage is beryl-bearing rock. Further exploration will probably add to the known tonnage of rock in which beryl occurs. It is estimated that the ratio of perthite-quartz pegmatite to albite-quartz pegmatite is about 1:3. Measurements of beryl exposed in the faces of sample cuts suggest a grade of about 0.35 percent beryl. Assays by the U. S. Geological Survey of Metals Reserve Company's samples suggest a grade of about 0.4 percent beryl, if the beryl is assumed to contain 10 percent BeO. Assays by the U. S. Bureau of Mines and the Minerals Separation Co. suggest a grade of about 1.2 percent beryl, if the beryl is assumed to be 10 percent of BeO. Tests by the U. S. Bureau of Mines show that the beryl recovered on a picking belt contains 9.05 to 10.30 percent of BeO. These tests also indicate that it would not be economic to use hand sorting at this property to recover beryl. Metallurgical tests may show that this beryl can be concentrated to a suitable product.

HIGH CLIMB MINE (HILL CITY DISTRICT)

by J. W. Adams and W. C. Stoll

The High Climb mine is at or near the boundary between secs. 22 and 27, T. 2 S., R. 4 E., and about 6 miles north of Custer, Custer County. It is owned by Gladys Wells and Fred Heidepriem of Custer.

A detailed report of this mine was written by D. J. Fisher (1942), and the map accompanying Fisher's report was used as a base map in 1942 by Walter C. Stoll of the U. S. Geological Survey (pl. 22).

Development of the property has been by an open-pit and several small cuts. A considerable quantity of amblygonite, beryl, mica, and feldspar was produced prior to 1940, after which little or no work was done.

Several kinds of pre-Cambrian metamorphic rocks crop out in the vicinity of the High Climb mine, but quartz-mica schist is the wall rock of the pegmatite where exposed. Near the pegmatite the schist in general strikes northeast and dips to the northwest.

The pegmatite that has been mined at the property is poorly exposed over a length of several hundred feet, but good exposures are limited to the mine workings. The large open-pit cuts across the pegmatite for more than a hundred feet at right angles to its general direction of strike and extends to the schist footwall on which a very pronounced roll plunges northwest at 42°. The pegmatite is conformable to the schist at this exposure.

The pegmatite is made up of several rock units but their relationships have not been studied in detail. Essentially, these units are as follows: (1) quartz-spodumene pegmatite central zone, (2) perthite-quartz intermediate zone, (3) cleavelandite-quartz-muscovite-amblygonite intermediate zone, (4) cleavelandite-quartz-muscovite intermediate zone, (5) fine-grained albite-tourmaline-quartz pegmatite intermediate(?) zone, and (6) quartz-albite (in part cleavelandite)-muscovite wall zone.

The intermediate zones have been the source of most of the minerals produced, such as amblygonite, beryl, scrap mica, columbite, and feldspar. The spodumene of the central zone is highly altered and has not been mined. Some mica of sheet quality is found, although only a negligible amount has been produced. This sheet mica is white to pale greenish-brown, and although hair cracks and mineral inclusions are common the mica is estimated to contain about 10 percent no. 1 and no. 2 qualities. Mrs. Wells gives the following figures for the approximate total production from the High Climb mine.

Amblygonite	100 to 350 tons.
Beryl	60 tons.
Scrap mica	100 tons (including about 150 lb of punch and plate mica).
Feldspar	150 to 180 tons.
Columbite	100 lb.

Only a small part of the pegmatite has been mined. If the rest is comparably segregated there should be a reserve of valuable minerals well exceeding past production.

HIGHLAND LODE (JOHN ROSS MINE) (CUSTER DISTRICT)

by L. R. Page and W. C. Stoll

The Highland Lode, commonly called the John Ross mine, is in the NE¼ sec. 30, T. 3 S., R. 4 E., Custer County, a few hundred feet from the common corner of secs. 19, 20, 29, and 30. The mine can be reached from Custer by following U. S. Highway 16 west for 1.5 miles and then taking the French Creek road about 3 miles north. The Westinghouse Manufacturing and Electric Company owned and prospected this property in 1907–11, and it is now owned by the New York Holding Association. It was leased to John Ross of Custer, February 18, 1938. The mineral production for 1938–44 as given by Mr. Ross is summarized below. No record of earlier production is available.

The Highland Lode was mapped by W. C. Stoll and J. B. Hanley, July 25–27, 1942, and was described by Stoll in August of that year. Stoll's map was revised (pl. 23) by L. R. Page and L. C. Pray in October 1943 and measurements of beryl exposed in the faces at that time were made. Observations of other geologists of the U. S. Geological Survey made in 1943–45 have been included in this report.

Mineral production 1938–44, Highland Lode

Mineral	1938	1939	1940	1941	1942	1943	1944	Total
Feldspar (tons)	560	1,877	3,563	1,880	587	1,011	?	9,478
Beryl (tons)	8	11	8.25	26	4	15.75	5.7	78.71
Mica:								
Sheet, lb				8	2	21.68	1.12	31.80
Punch, lb				140	7.5			147.5
Scrap, tons	5	3.5	2	37	+214	70	?	331.5
Columbite, lb						100		100.0

MINE WORKINGS

The mine workings on the Highland Lode include a large open-pit, an inclined shaft, raise or stope, an adit, and a small prospect pit. The open-cut, in the main pegmatite mass, is about 120 ft long, as much as 100 ft wide, and as much as 65 ft deep. About 150 ft southwest of the pit, at an altitude of 5,523 ft, a 46-ft shaft, inclined at 44° to the northeast, has been sunk to the hanging wall of the pegmatite. An irregular room about 30 by 30 ft has been stoped out at this level. A 12-ft winze prospects the hanging wall (pl. 23) and a raise or stope has been made for 50 ft up the dip of the pegmatite.

The adit, 375 ft southeast, and the prospect pit 250 ft southeast of the open-pit, were made during the Westinghouse operation in 1907–11. The adit, about 90 ft long, is at an altitude of about 5,470 ft and extends northwest along what is probably the main pegmatite.

GEOLOGY

The Highland Lode pegmatite conformably intrudes quartz-mica schists that strike northwest and dip about 45° to the southwest. It crops out as a roughly oval mass 220 ft long and 150 ft wide on the top of a small knoll. The hanging-wall contact is convex to the southwest and strikes from N. 85° E. to north. The average dip is 50° to the south and west. The footwall is convex to the northeast and strikes from N. 5° W. to N. 65° W. In general its dip is less steep than that of the hanging wall, so the walls of the pegmatite converge in depth. There appear to be extensions of this body for 650 ft to the northwest and for at least 375 ft to the southeast, though pegmatite exposures are separated by areas of alluvium. Near the southeast end of the main exposure there seems to be another pegmatite above and parallel to the main body. Another small parallel pegmatite lies northeast of the main open-cut.

The Highland Lode pegmatite is composed of three units—a wall zone of albite-quartz pegmatite, and a core made up of perthite-quartz pegmatite and quartz-perthite-albite pegmatite.

The wall zone is primarily albite and quartz with pink perthite, black tourmaline, yellowish beryl, and muscovite. The perthite crystals are as much as 4 ft long and on the hanging-wall side of the pegmatite extend to the contact. They are less common in the footwall part of the zone. The other minerals of the pegmatite are less than 2 in. across and their average diameter is about 1 in.

The two core units are much coarser in texture and are composed essentially of pink perthite in crystals as much as several feet long, with interstitial quartz and albite. The perthite-quartz pegmatite is mostly pink perthite, with a little interstitial quartz intergrown with albite and muscovite. The quartz-perthite-albite pegmatite is dominantly quartz, with about 25 percent perthite. Albite, associated with garnet and tourmaline, encloses and replaces many of the perthite crystals. Albite also occurs intergrown with quartz, beryl, columbite, muscovite, and lithiophilite between the perthite crystals. In mapping, the difference in abundance of quartz was used to delimit the two units.

MINERAL DEPOSITS

The Highland Lode is primarily a feldspar deposit, but has produced appreciable quantites of beryl and scrap mica. The production of sheet mica and columbite has been insignificant.

FELDSPAR

The feldpsar is mainly in the perthite-quartz pegmatite, though significant quantites have been produced from the quartz-perthite-albite pegmatite. The largest part of the feldspar body has been mined from the open-cut, and in 1945 intensive mining for feldspar was started underground. The perthite-quartz pegmatite at the open-cut level is about 120 ft long and 10 to 15 ft thick. It pinches out in the underground workings. This deposit and the core appear to plunge steeply to the southwest. The quartz-perthite-albite pegmatite is about the same length as the perthite-quartz pegmatite but has an average thickness of 6 ft. It contains some recoverable potash feldspar, but alone it probably is not sufficiently rich to allow profitable mining.

The over-all recovery of feldspar in the open-pit operations was about 35 percent. Both units of the core were mined. A 300 sq ft face of the cut contained about 42 percent feldspar. Nearly two-thirds of this surface was made up of quartz-perthite-albite pegmatite.

BERYL

Beryl has been produced as a byproduct of feldspar mining. The quartz-perthite-albite pegmatite contains green beryl crystals as much as 4 ft in diameter and 8 ft in length, but the crystals commonly range from 6 to 8 in. in diameter. The smaller crystals are euhedral but many of the larger ones appear to be parallel growths of a number of individuals that combined to give an hexagonal shape. The BeO content of these crystals is about 12.5 percent, according to assays of the U. S. Bureau of Mines (table 4, pp. 49–50). Beryl occurs also in the albite-quartz pegmatite of the wall zone as yellowish crystals ½ to 6 in. in length and ¼ to 1½ in. in diameter. Few of them are recoverable.

The beryl-rich pegmatite of the core is exposed in the open-pit as a crescent-shaped mass. It is actually a flat lenticular body parallel to the footwall contact of the pegmatite (pl. 23). Its thickness in most places is 6 to 8 ft and it is about 150 ft long. The total depth along the dip is 75 to 100 ft. In 1943, measurements of the area of beryl exposed in the underground and surface workings were made by L. R. Page and L. C. Pray. In the underground workings areas of 57 individual crystals ranged from 0.0025 to 0.72 sq ft. About 370 sq ft of quartz-perthite-albite pegmatite was exposed on the southeast and northwest walls of the raise or stope. These walls contain 46 beryl crystals with a total area of 2.63 sq ft, or 0.7 percent of the surface. An area of 48 sq ft of albite-quartz pegmatite contained 5 crystals with a total area of 0.1 sq ft, or 0.2 percent, of beryl.

In the open-cut a vertical face, 48 ft long and 15 ft high, at the northeast corner of the pit was measured. All but a very few crystals of beryl were in the lower 6 ft of the face and most of the upper part was feldspar. Twenty-five beryl crystals, ranging from 0.0075 to 0.49 sq ft in area, were exposed. A total area of 2.9 sq ft, or one percent, of beryl was contained in the 288 sq ft of beryl-bearing rock. This area was all in quartz-perthite-albite pegmatite. An area of 300 sq ft in this same exposure was measured to obtain the perthite content. Two-thirds of the exposure was in the quartz-perthite-albite and the rest in perthite-quartz pegmatite. Twenty-six perthite crystals or masses, ranging in area from 0.9 to 10.5 sq ft, totaled 125.4 sq ft, constituting 42 percent of this area.

MICA

The mica produced at the Highland Lode is mainly of scrap quality, though a few pounds of sheet mica has been sold. The mica comes largely from the quartz-perthite-albite zone, where it occurs in aggregates of small flakes and books, known locally as "bull" mica or "mica schist." In addition, book mica occurs in the albite-quartz pegmatite, especially at the southwest end of the open-pit. These books are tied, wedged, or "A" mica for the most part, but contain a small percentage of sheet mica of good quality. The sheet mica is slightly air-stained, flat, and hard. About 20 percent of that sold has been no. 1 quality and 65 percent no. 2 quality. The remainder was no. 2 inferior quality.

The adit and open-cut northeast of the main open-cut prospect a narrow pegmatite, believed to be an extension of the main one, for mica. Considerable mica occurs in the open-cut, but little shows in the adit.

COLUMBITE

A few hundred pounds of columbite has been recovered as a byproduct of feldspar mining. The specific gravity of one lot which was offered for sale was approximately 5.8. One specimen submitted to Michael Fleisher of the Chemical Laboratories of the U. S. Geological Survey was determined to have a specific gravity of 5.69 indicating a Ta_2O_5 content of 17 percent and a Cb_2O_5 content of 63 percent. The mineral occurs with albite that is interstitial to perthite crystals in the core unit.

RESERVES

The reserves of beryl, feldspar, and columbite appear to occur mainly above the level of the underground workings. The reserves of feldspar appear to be about 3,000 tons. The beryl reserves in the quartz-perthite-albite pegmatite are probably about 50 to 75 tons. The reserves of scrap and sheet mica are less readily calculated, but are probably equal to past production. Development below the level of the underground workings might increase the reserves.

HIGHVIEW BERYL-LITHIA PROSPECT (CUSTER DISTRICT)

by W. E. Hall

The Highview claim, a beryl and lithia prospect, is 5.7 miles west of Custer in sec. 36, T. 3 S., R. 3 E., Custer County. The owner of the claim is the Maywood Chemical Company. The property was not in operation when examined in October 1942.

The workings consist of two open-cuts across the main pegmatite and one small cut on a 4-ft pegmatite 6 ft to the west. The larger cut on the main pegmatite is 20 ft long, 15 ft wide, and 10 to 18 ft deep. A fourth cut, 40 ft long and 15 ft wide, is in the mica schist country rock, approximately 25 ft west of the main pegmatite.

The outcrop of the main pegmatite is 205 ft long, in a N. 3° W. direction, and it ranges in width from 3 to 16 ft. The pegmatite dips steeply westward, concordantly with the mica schist country rock. On each side of the main pegmatite, but separated from it by 8 to 12 ft of schist, are two smaller parallel pegmatites.

The core of the pegmatite in the main open-cut is a medium-grained aggregate of perthite, albite, quartz, muscovite, and lithiophyllite. This is surrounded by 3 to 6 ft of graphic granite. Where the dike is less than eight feet wide, it is nearly 75 percent graphic granite.

Small crystals of beryl, amblygonite, and spodumene are present in minor quantities in the core and are associated with quartz.

Muscovite is concentrated in small bodies and is associated with quartz and albite. These bodies contain about 5 to 7 percent of muscovite that is green and commonly has "A"-structure and ruling. The mica averages 1 by 2 in. in area and is suitable only for scrap.

HOMESTEAD NO. 2 MICA PROSPECT (CUSTER DISTRICT)

by J. J. Norton

The Homestead no. 2 mica prospect, about ½ mile north of Custer, yielded small quantities of sheet mica during 1943. It is in the NE¼ sec. 23, T. 3 S., R. 4 E., Custer County. The prospect can be reached by driving west from the Custer Post Office 1 block, then north 0.5 mile, turning right, and then driving east about 100 yds. The property is held by William Sager and Phil Randall, and it was operated from October to December 1943 by Ira Willey of Custer. The prospect was first examined early in October 1943, and was visited by J. J. Norton and L. R. Page, April 11, 1944.

The prospect is in the westernmost of three parallel bodies separated by schist partings ½ to 1½ ft thick.

The pegmatites strike N. 50° W., and the average dip is 40° SW. The angle of dip reaches 55° at the base of the 35-foot inclined shaft on the west pegmatite. The west pegmatite is about 6 ft thick. The easternmost pegmatite is about 10 ft thick, and the central pegmatite is about 2 ft thick. The length of exposure along the strike is at least 100 ft. The pegmatites are composed principally of quartz and albite, but considerable quantities of perthite occur in the interior of the two larger pegmatites. Muscovite and beryl are among the other minerals present. A few gentle rolls in the hanging wall of the west pegmatite plunge 37 degrees to the S. 65° W.

The workings consist of an inclined shaft, 7 by 12 ft, on the west dike, which at the time the property was visited in October had been sunk only 9 ft down the dip; it has since been extended to 35 ft. The only other work on this pegmatite is an old prospect pit just north of the shaft and a prospect pit on the east pegmatite.

Only 39.99 lb of mica, all of it small sheet, was produced by the Ira Willey operation and sold to the Colonial Mica Corporation in October and December 1943. The mica is light ruby and moderately to heavily air-stained. Three shipments were sampled for quality in December 1943 by the Colonial Mica Corporation. Two of the samples were 2 percent of quality no. 2 and 98 percent of quality no. 2 inferior, and one was 10 percent of quality no. 2 and 90 percent of quality no. 2 inferior. The percentage of recoverable mica in the rock is low, probably about 0.25 percent. In October 1943, about 50 tons of rock had been mined, and the operator reported that from this amount only 300 lb of crude mica, or 0.3 percent, was recovered. The mica is most abundant near the walls of the pegmatite, and decreases in quantity toward the interior. In one place on the surface a quartz mass a few feet across is surrounded by a rich concentration of mica. Mica-rich pegmatite around quartz masses may occur elsewhere in the pegmatite, but such concentrations are not abundant enough to raise appreciably the overall percentage of mica in the rock.

HOMESTEAD NO. 3 MICA PROSPECT (CUSTER DISTRICT)

by J. J. Norton

The Homestead no. 3 mica prospect is 2 miles northwest of Custer, in the NW¼ sec. 23, T. 3 S., R. 4 E. It lies east of the Custer-Oreville-Hill City highway, just east of the Custer cemetery. The claim is held by William Sager and Phillip Randall, who recorded it February 21, 1943. A little prospecting was done on the property by Joseph Buckley in November 1943. A brief visit was made by the writer to the prospect November 16, 1943.

The prospect is in one of several subparallel pegmatites cropping out in this area. It strikes N. 35° W. and dips 58° SW. It is about 8 ft thick, and is exposed for a distance of about 300 ft south and 150 ft north of the prospect shaft. It consists principally of quartz and albite, with scattered crystals of perthite. Muscovite is most abundant near the walls, especially the footwall. The mica is ruby and moderately air-stained.

The production from this prospect is not recorded, but must have been small. The pegmatite is not rich in mica, but possibly enough could be sold at wartime prices to pay for the mining.

HUB MICA MINE (CUSTER DISTRICT)

by J. W. Adams

The Hub mica mine is in the NE¼ sec. 10, T. 4 S., R. 4 E., about 4 miles south-southwest of Custer, Custer County. The most recent operator was John Phelps of Custer. The Hub mine is one of the older producers of the Custer district, but recent production has been small. The property has been visited briefly by geologists of the U. S. Geological Survey, but has not been mapped.

The mine development includes surface pits underground workings of unknown extent along the hanging wall of the pegmatite. The underground workings are now backfilled.

Several parallel pegmatites separated by schist partings are exposed on the property. These pegmatites conformably intrude the schist and strike approximately N. 15° W. and dip from 50°–55° NW. The open pits and underground workings are in a pegmatite that is 20 to 25 ft wide and more than 100 ft long.

Mica is found in much of the pegmatite as isolated widely-scattered crystals that are most abundant along the margin of the perthite-quartz core.

An irregular but well-defined hanging-wall mica zone about 2 ft wide evidently was followed by the underground workings. This zone consists chiefly of plagioclase (albite?), muscovite, and quartz with minor quantites of beryl. The mica along the south wall of the partly filled inclined shaft is abundant but appears to be of poor quality. The mined-out part of this mica zone is adjacent to a conspicuous roll in the hanging-wall schist that plunges 52 degrees S. 60° W. No footwall mica zone is exposed.

In 1943 only a few hundred pounds of mica and a small quantity of beryl was sold to the Colonial Mica Corporation from this property. Production prior to 1943 is not known.

HUGO FELDSPAR MINE (KEYSTONE DISTRICT)

The Hugo feldspar mine, in the NE¼ sec. 17, T. 2 S., R. 6 E., Pennington County, is the largest feldspar mine in the Black Hills. It is about 1 mile south-southwest of Keystone. The mine is owned by Hugo Reinbold and has been operated by the Consolidated Feldspar Corporation since 1929.

The Hugo property was examined by W. C. Stoll in November 1942 and by L. R. Page and other geologists of the U. S. Geological Survey in 1942–45. These examinations were very brief and focussed on the byproduct minerals mica, beryl, spodumene, amblygonite, and columbite. No detailed maps of the property were made. This report is based largely on Stoll's examination. The property has been described by Landes (1928, pp. 527–529), Guiteras (1940), and others.

The production of the Hugo mine is not known in detail. Guiteras gives the feldspar production as about 200,000 tons prior to 1938; records of the production since then are not available. Some spodumene is said to have been produced during the early operations of the mine. The total amblygonite production probably has been between 1300 and 1500 tons. The mica production from 1929–42 has been estimated as 880 tons, of which about 80 tons were cobbed flat mica for sheeting. In 1943 2,519.37 lb of sheet mica and 10,421.81 lb of untrimmed punch mica were sold to Colonial Mica Corporation. The beryl production prior to 1943 was about 20 tons. In that year 2.3 tons was produced. The production of columbite-tantalite is said to have been several thousand pounds.

The Hugo mine is worked by open-cuts at a number of different levels. Two haulage tunnels have been driven to connect with raises to the open-cuts.

The pegmatite is roughly oval in plan with its long dimension nearly 700 ft in a N. 20° W. direction. The maximum width is more than 400 ft, but in the upper workings it is 200 ft and in the lower workings about 360 ft. The pegmatite is enclosed in fine-grained quartz-mica schist, but few contacts are visible. As judged from the zoning within the pegmatite and from the visible contacts, the deposit dips eastward. It may be narrower at depth. The walls are irregular in places, and large salients of the wallrock, some of them thin, extend into the pegmatite.

The Hugo pegmatite is well zoned but detailed studies of the mineralogy have not been made. In general there appears to be a wall zone containing sheet-bearing muscovite and beryl, an intermediate zone or zones that contain potash feldspar and scrap mica and grades into another intermediate zone containing amblygonite, and a core containing spodumene in quartz.

Most of the sheet mica from the Hugo mine was obtained from the flat muscovite books of the wall zone. Some has been recovered from isolated aggregates of books in the potash feldspar-bearing zone. The books are as much as 12 or 14 in. in diameter and 2 or 3 in. in thickness. The mica is silvery because of heavy air-staining. It splits easily and is soft and flexible. It is pale ruby to brownish or greenish. Very little is better than no. 2 inferior quality and the density of air-staining and softness makes part of it of no. 3 quality. Its power factor is low, like that of other Black Hills micas of no. 1 and no. 2 quality.

The beryl in the wall zone occurs partly as "shells" around quartz, albite, and other minerals, and partly as euhedral crystals. These crystals are as much as 10 in. in diameter, though most of them are too small to recover by hand-cobbing. The beryl produced to date has been recovered as a byproduct of feldspar mining.

The amblygonite is in masses as much as 40 ft long that have been recovered from an intermediate zone at the outer edge of the core. It is associated with perthite, quartz, and albite. Most of the amblygonite has come from the upper part of the pegmatite.

The spodumene occurs at the inner edge of the amblygonite-bearing zone as scattered crystals in quartz. Much of the spodumene is altered or "rotten." A shell of cleavelandite, 2 to 6 in. thick, encloses the spodumene in many places. Locally spodumene may form 10 to 15 percent of the core. Analyses of spodumene from the Hugo indicate a Li_2O content at 5.2 to 5.8 percent.

The distribution of the columbite-tantalite minerals is not well known. Two specimens picked from a stockpile in 1942 were tested by Michael Fleischer of Chemical Laboratories of the U. S. Geological Survey. The specific gravity of these specimens, 6.00 and 5.59, indicates a Ta_2O_5 content of 28 and 14 percent, respectively.

There are undoubtedly additional reserves of all the economic minerals produced at the Hugo mine, but these reserves cannot be estimated without detailed mapping.

HUNTER AND LOUISE CLAIMS (HILL CITY DISTRICT)

The Hunter and Louise claims, in the SW¼ sec. 22, T. 2 S., R. 4 E., on the Pennington-Custer County line, are on the west side of the Oreville-Custer road, 7.2 miles north-northwest of Custer. The claims were purchased from Carl A. Hunter, November 25, 1941, by the National Chemical Products Company (Mr. Victor Jepsen, president) of Rapid City, South Dakota. The Hunter claim is on the north end and the Louise claim on the south end of a narrow spodumene-bearing pegmatite that crops out at an altitude of about 5,750 ft, on the west side of a valley. On the Louise claim a narrow tin-bearing pegmatite also has been prospected. About 100 tons of spodumene has been produced.

The Hunter and Louise pegmatite was mapped and examined by W. C. Stoll in September 1942. It was re-examined by L. R. Page and T. A. Steven, September 10, 1944 and the geologic data obtained at this time were plotted on a topographic map made by Paul Pesonen of the U. S. Bureau of Mines in May 1945 (fig. 16).

The Hunter and Louise spodumene pegmatite has been developed by six open-cuts. The largest, near the south end of the pegmatite, is 150 ft long, 30 to 35 ft wide, and 30 to 40 ft deep at the north face. Five small pits prospect the tin-bearing pegmatite.

The spodumene-bearing pegmatite crops out for a length of at least 600 ft and a width of as much as 30 ft. It is conformable with the foliation of the quartz-mica schist and quartzite wallrocks, but cuts across the bedding at a slight angle. The pegmatite strikes N. 25° E. and dips 60°–65° NW. Numerous rolls in the contact parallel folds in the schist, which plunge 35 to 40 degrees N. 10° W.

The Hunter and Louise spodumene pegmatite is well zoned. The wall zone is dominantly plagioclase (albite?) and quartz. Some muscovite occurs as flakes and small books with tourmaline, apatite, and garnet. The hanging-wall part of this zone is fine-grained pegmatite a few inches to 3 ft thick. The footwall part of the zone is a sugary to fine-grained rock as much as 15 ft thick mixed with granulite or assimilated schist. The core of the pegmatite is quartz and spodumene. In the face of the main pit this rock occurs as two bodies separated by wall zone material where the pegmatite body narrows to about 2½ ft.

The spodumene crystals are hard and fresh. They are as much as 2 ft long, 1 ft wide, and 6 in. thick. Analyses by the U. S. Bureau of Mines show that the L_2O content of the spodumene is 5.87 to 6.87 percent. The average of 4 analyses is 6.47 percent L_2O. Visual estimates of exposures indicate the spodumene content of the core is from 10 to 20 percent. Past production suggests a ratio of spodumene to rock of 1:15. Reserves cannot be calculated, but surface evidence indicates that several thousand tons of spodumene-bearing rock is available on this property.

IDA PROSPECT (HILL CITY DISTRICT)

The Ida spodumene-tin prospect, in the SE¼ sec. 28, T. 1 S., R. 5 E., Pennington County, is about 600 ft N. 60° W. of the Addie tin mine. The Ida pegmatite is prospected by two 10- to 15-ft shafts and a third shaft, now caved, that was perhaps 80 ft deep. The pegmatite, which strikes N. 40° E. and dips 60° NW., is about 600 ft long and 5 to 10 ft wide. It is a fine-grained plagioclase-quartz-muscovite pegmatite containing scattered cassiterite and spodumene crystals. The spodumene is in blades 2 in. long and about ½ in. wide.

I. X. L. NO. 3 FELDSPAR PROSPECT (CUSTER DISTRICT)

The I. X. L. No. 3 Lode claim, in the SW¼ sec. 9, T. 3 S., R. 5 E., was located for feldspar in 1937 by Scovel Johnson, who later sold his interest to the Consolidated Feldspar Corporation, Trenton, New Jersey.

There are two open-pits, 250 ft apart, in medium- to coarse-grained pegmatitic Harney Peak granite that trends N. 40° E. up the east side of a valley. The smaller pit, about 400 ft from the road, is 10 ft southwest of the end of a pegmatite that strikes N. 70° E. for 200 ft across the pegmatitic granite. The pegmatite dips about 60° SE. and consists of a wall zone as much as 1 ft thick, containing scattered muscovite books and flakes, and a central core as much as 6 ft thick, containing perthite and quartz. Muscovite occurs as widely scattered books, as much as 3 in. long and 2 in. thick, and as books as much as 8 in. long and ½ in. thick, in fractures normal to the wall of the dike. The perthite is in crystals as much as 2 ft across and makes up perhaps 15 to 20 percent of the core.

JACK RABBIT MICA MINE (CUSTER DISTRICT)

by J. J. Norton and L. C. Pray

The Jack Rabbit mica mine, Custer County, is in the NE¼ sec. 22, T. 4 S., R. 4 E. It is about 5½ miles south-southeast of Custer.

During January 1944, L. C. Pray, assisted by Peter Joralemon, mapped the surface of the Jack Rabbit mine on a scale of 1 in. to 20 ft and mapped the 38-ft level (altitude 5,358 ft) and a sublevel above it (altitude 5,378 ft) on a scale of 1 in. to 10 ft. In February and March the surface map was completed by J. J. Norton and Peter Joralemon, and an underground map was made of the new 54-ft level (altitude 5,342 ft).

HISTORY

The Jack Rabbit pegmatite is said to have been explored about 35 years ago by the Westinghouse Electric and Manufacturing Company, which did a little surface prospecting and sank a vertical shaft to explore the pegmatite on the 38-ft level. Apparently, the property then lay idle until, in January 1943, Francis and Abram Duncan relocated the Jack Rabbit

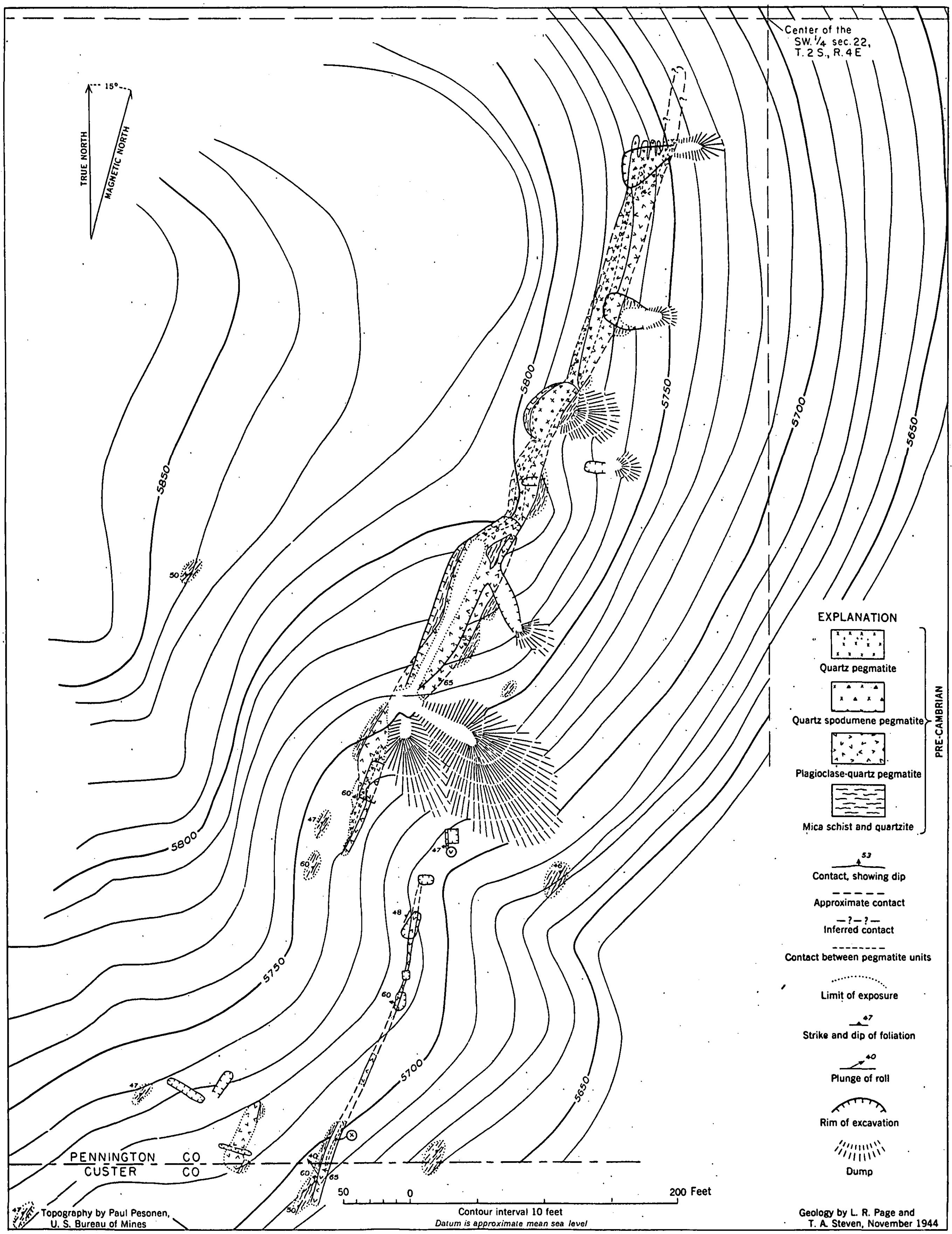


FIGURE 16.—Geologic map, Hunter and Louise claims, Pennington and Custer Counties, South Dakota.

lode claim, putting the discovery pit just south of the area shown on the geologic map (pl. 24). In May 1943 they located the Book Mica lode claim, and put a discovery pit on the pegmatite that is now being worked as the Jack Rabbit mine. The two claims overlap, and the Jack Rabbit mine is said to be on both of them. In the spring of 1943 the Jack Rabbit was worked as an open-pit operation by Francis and Abram Duncan. Underground operations were carried on from July through September by Francis Duncan and Glenn Ventling. In November 1943 the Custer Mica Company leased the property and their operation continued to April 1944.

MINE WORKINGS

An open-pit, lying principally between the quartz core and the hanging wall, has a length of about 90 ft, an average width of about 10 ft, and an average depth of about 7 ft. Underground workings consist of a 54-ft vertical shaft with drifts on the 38- and 54-ft levels (pl. 24). On the 54-ft level the drift extends 63 ft north and 25 ft south of the shaft. On the 38-ft level a 93-ft drift extends to the north. Raises and stopes above this level have worked out much of the mica-bearing pegmatite.

In March 1944, a 10-ft prospect shaft was sunk on the hanging-wall side of the large pegmatite southwest of the Jack Rabbit mine, but insufficient mica was recovered to warrant further work.

GEOLOGY

The Jack Rabbit pegmatite is one of several subparallel pegmatites in this area that intrude pre-Cambrian quartz-mica schist and quartz-mica-sillimanite schist. Most of the pegmatites are poorly zoned, and have been mapped simply as undivided quartz-albite-perthite pegmatite. The Jack Rabbit pegmatite proper, however, has two zones: a quartz-albite-perthite-muscovite pegmatite wall zone and a quartz pegmatite core. The large dike exposed southwest of the mine consists of quartz-albite-perthite-muscovite pegmatite along the hanging wall and part of the footwall, and the interior is composed of quartz-perthite pegmatite with two bodies of quartz pegmatite.

WALL ROCK

Quartz-mica schist and quartz-mica-sillimanite schist.—The country rock is fine- to medium-grained quartz-mica schist with sparse grains of sillimanite commonly altered to muscovite. Surface exposures are few, but the character of the schist is known from the two U. S. Bureau of Mines diamond-drill holes. The foliation is fairly well developed and is essentially parallel to the bedding. The schist strikes N. 15°–35° W. and has an average dip of 50°–55° SW.

PEGMATITE

Undivided quartz-albite-perthite pegmatite.—The pegmatites shown undivided on the area mapped (pl. 24) consist essentially of quartz and various proportions of albite and perthite. The quartz and albite are generally in grains ¼ to 2 in. across. The perthite occurs as somewhat larger crystals, as much as 1 ft in length. Two specimens of the albite were found to have minimum indices of approximately 1.529 and 1.530 indicating a composition of An_6 and An_8. Accessory minerals include muscovite and tourmaline. Some of the pegmatites cut by the drill cores contain oligoclase.

Quartz-albite-perthite-muscovite pegmatite.—Quartz-albite-perthite-muscovite pegmatite occurs as the wall zone of the Jack Rabbit dike and is also found along the hanging wall and part of the footwall of the large pegmatite exposed to the southwest. The quartz and albite crystals are generally ½ to 2 in. across, but perthite crystals attain diameters of a foot or more. The perthite is flesh-colored to pink and is abundant in the wall zone of the pegmatite southwest of the mine, but in the Jack Rabbit pegmatite itself it is less common. Most of the albite is white to light gray, but some has a faint pink tinge. Determination of minimum refractive indices of three specimens of albite from the Jack Rabbit pegmatite gave results from 1.526 to 1.529, indicating a composition of An_0-An_6. Four specimens from the pegmatite to the southwest have indices of 1.528–1.529. Accessory minerals include tourmaline and a little beryl.

Muscovite occurs throughout this zone in both the Jack Rabbit pegmatite and in the pegmatite to the southwest. The mica books are as much as 10 or 12 in. across, but books more than 5 or 6 in. in diameter are not common.

Quartz-perthite pegmatite.—The interior of the large pegmatite southwest of the mine consists of quartz-perthite pegmatite. The perthite is generally pink and in crystals as much as 3 ft across. Many small crystals, measurable in inches, are also present. Most of the quartz occurs in grains only an inch or two across and much of it is graphically intergrown with perthite. Accessory minerals include muscovite, albite (An_4, minimum index of one specimen approximately 1.528), and tourmaline.

Quartz pegmatite.—Quartz pegmatite makes up the core of the Jack Rabbit pegmatite, and forms two bodies in the interior of the large pegmatite to the southwest. The quartz is commonly white to gray, but a little rose quartz occurs. Scattered crystals of perthite and beryl are present, and near the north end of the Jack Rabbit pegmatite the perthite is fairly abundant.

The quartz core of the Jack Rabbit pegmatite has an average thickness of 5 to 6 ft at the surface, but it narrows with depth, so that on the 38-ft level it has an average thickness of about 3½ ft and on the 54-ft level it is 2 ft thick.

STRUCTURE

The pegmatites in the vicinity of the Jack Rabbit mine strike N. 17°–47° W. and dip 49°–80° SW. The average strike is about N. 25° W. and the average dip 50° SW., about parallel to the schistosity of the country rock. The Jack Rabbit pegmatite strikes N. 17° W. and dips about 50° SW. The south end of the pegmatite is exposed at the surface and is apparently not far beyond the south heading on the 54-ft level. The plunge of the end of the pegmatite is 50° S. 79° W., about parallel to the south border of the quartz core between the surface and the 38-ft level. The north end of the pegmatite can be located fairly accurately at the surface but has not been exposed underground.

Small rolls in the walls of the Jack Rabbit pegmatite commonly form the site of rich mica concentrations. They plunge 35°–50° in a S. 20° W. to S. 45° W. direction. It is not possible to correlate the rolls in one wall with those in the other. Rolls are not so strikingly developed on the 54-ft level as they are in the upper workings.

MINERAL DEPOSITS

MICA

Muscovite capable of furnishing sheet mica occurs throughout the quartz-albite-perthite-muscovite zone of the Jack Rabbit pegmatite, but in general it can be mined profitably only in immediate proximity to the quartz core. Elsewhere mica is sparse and the books are small. Even near the quartz core the average crude mica recovered is rarely much more than 1.5 percent, but mica shoots much richer than this occur in the footwall and hanging-wall rolls.

The Jack Rabbit mine produced ruby mica of comparatively high quality, though somewhat wavy and slightly air-stained. A total of 1,647 lb of sheet mica and 1,888 lb of punch was sold to the Colonial Mica Corporation from May 1943 to March 1944.

A few hundred pounds of crude mica was recovered from the prospect shaft on the dike southwest of the Jack Rabbit shaft, but the sheet recovered from this prospect was not recorded separately from the production of the mine. Apparently this mica is similar to the mica produced from the Jack Rabbit pegmatite.

Cracks, rulings, ripples, and inclusions are conspicuous defects in much of the crude mica, especially that from below the 38-ft level, and cut down the recovery of sheet mica. The inclusions are principally tourmaline, quartz, and feldspar.

The sheet mica is preponderantly of the small sizes, and in the lower levels practically nothing but 1 by 1 in. and 1¼ by 1¼ in. full-trimmed sheet was produced. In the open-cut the sheet sizes were larger. The sheet mica sold in May 1943 was 4.9 percent of the total. The size pattern is given below.

Size (inches)	*Pounds*	*Percent*
1½ by 2	15.12	41.3
2 by 2	13.56	37.1
2 by 3	6.62	18.1
3 by 3	.49	1.3
3 by 4	.50	1.4
3 by 5	.31	.8
Total sheet mica	36.60	4.9
Total punch mica	716	95.1
Total processed mica	753	100

Weighted averages of the results of quality sampling by the Colonial Mica Corporation from October 23, 1943, to March 29, 1944, show the mica to consist of 9 percent quality no. 1, 40 percent quality no. 2, and 51 percent quality no. 2 inferior.

The quantity of sheet mica produced from various parts of the Jack Rabbit mine is known with reasonable accuracy, but the quantity of crude mica is known only for the 54-ft level, and even for this level the figures are only approximate. In the open-pit, where the work was along the hanging-wall side of the quartz core, about 500 lb, or 0.06 percent of sheet mica was recovered from an estimated 400 tons of pegmatite. The recovery of sheet from the crude mica is reported to have been about 6 percent, and at this rate the percentage of crude mica recovered from the rock was 1.0 percent. Underground operations from the 38-ft level by Ventling and Duncan from July to November 1943 produced about 1,330 lb of sheet mica from an estimated 700 tons of pegmatite. With a 6 percent recovery of sheet from the crude mica, the percentage of mica recovered from the rock was 1.7. Most of this mica was recovered from near the quartz core, principally on the hanging-wall side but partly on the footwall.

The mica sold during December 1943 and January 1944 was almost all from the north end of the 38-ft level and from the raise above this level. Only 31 lb, or 0.005 percent of sheet mica, was recovered from an estimated 300 tons of pegmatite mined. The crude mica figures are not available.

Although part of work on the 54-ft level and in the stopes above it has been in pegmatite with a quartz core, the recovery of sheet mica has been extremely low. In the drift on the 54-ft level about 400 tons of pegmatite was broken and about 4 tons (1 percent) of crude mica was recovered. The pegmatite in the vicinity of the quartz was found to be of somewhat higher grade. The recovery of sheet from the crude was only 0.9 percent, partly because the mica was ruled, cracked, and contained numerous large inclusions, but partly because of inefficient rifting and trimming. In the stopes above the 54-ft level about 150 tons of pegmatite had been mined by the end of March, producing about 1½ tons, or 1.0 percent of crude mica. Figures on the sheet mica recovered from this rock are not available.

BERYL

A little beryl occurs in the Jack Rabbit pegmatite, generally near the border of the quartz. Most of the beryl observed is in the open-pit. Ninety-two pounds of beryl from the open-pit was sold to the Colonial Mica Corporation in January, 1943. The beryl is light green and contains practically no inclusions, but some of it is altered to kaolin. A specimen from the north end of the open-pit has an index of 1.568 for the ordinary ray, indicating that the content of alkalies replacing BeO is negligible.

FELDSPAR

Perthite feldspar has not been worked commercially at the Jack Rabbit mine. The early prospect pits in the large dike to the southwest of the main pegmatite were evidently for feldspar, but although this pegmatite is undoubtedly the only one in the mapped area that might contain a commercial feldspar deposit, it can hardly be regarded as a favorable prospect. The Jack Rabbit pegmatite proper contains no commercial feldspar deposit.

U. S. BUREAU OF MINES DIAMOND-DRILL PROGRAM

Two diamond-drill holes were drilled in March by the U. S. Bureau of Mines (Clarke, 1945, p. 4) as part of their Black Hills pegmatite project (no. 2503). The sites were located by the U. S. Geological Survey.

Hole no. 1 was drilled at an angle of minus 45° to the N. 67° E. in the plane of a vertical section passing 20 ft north of the shaft (pl. 24). It was expected that the Jack Rabbit pegmatite would be encountered at about 118 ft, but the only pegmatites crossed in the lower part of the hole were a 1-ft pegmatite at 131 ft and two stringers 0.2 to 0.5 ft thick at 122 ft and 126 ft. A fault, represented by a gouge zone encountered at 127 ft, may cut out the Jack Rabbit pegmatite completely. Even if this is so, it is doubtful that the Jack Rabbit pegmatite is very thick at this depth because, if the fault is like the others known in the area, it is probably very small and could not offset a thick pegmatite enough to cause a drill hole to miss the dike entirely.

Hole no. 2, drilled at a minus 60° angle to the N. 80° E., was expected to cross the pegmatite at about 106 ft. (See pl 24.) The only pegmatites in the lower part of the hole are two stringers, each about 1 ft thick, that were crossed at 114 and 116 ft. They are composed principally of fine-grained quartz-oligoclase-muscovite pegmatite, but the upper one has a central zone of quartz-perthite-albite pegmatite. The two dikes bear practically no resemblance to the Jack Rabbit pegmatite, and it seems evident that the Jack Rabbit pegmatite does not extend to the depth of the hole.

The logs of the drill holes given below indicate that the Jack Rabbit pegmatite narrows from an average of 7 ft in thickness on the 54-ft level to nothing, or practically nothing, within a vertical depth of 50 ft, and development work below the 54-ft level is not warranted.

Logs of Bureau of Mines diamond-drill holes, Jack Rabbit mine

Hole No. 1

Feet	*Description*
0–12. 5	Overburden.
12. 5–22. 5±	Quartz-mica schist. Bedding and foliation are at an angle of 72°–88° to the drill core.
22. 5±–25	Quartz-perthite-oligoclase pegmatite. Minimum index of the oligoclase (An_{11}) is 1.532. Accessory muscovite occurs in grains averaging ¼ in. across. The quartz and feldspar crystals are 1/16 in. to 2 in. long. The hanging-wall contact is 88° to the drill core and parallel to the foliation in the schist. One mica book 1.2 by 0.9 in. was recovered at 24 ft.
25–26	A single crystal of perthite.
26–27. 5±	Quartz-perthite-albite pegmatite with flakes of accessory muscovite. Grain size ⅛ in. to 1 in.
27. 5±–30	Gray quartz. Accessory tourmaline and albite (An_4, minimum index approximately 1.528).
30–31	Quartz-perthite pegmatite. Grains ⅛ in. to 2 in. across.
31–34. 5	A single crystal of perthite.
34. 5–37. 5	Quartz-perthite-oligoclase pegmatite with accessory muscovite. Grain size ⅛ in. to 1 in. Footwall of the pegmatite makes an angle of 67° with the drill core.
37. 5–53±	Quartz-mica schist. Bedding and foliation are at an angle of 70° to 75° to the drill core.
53±–54	Quartz-oligoclase pegmatite. Minimum index of the oligoclase is approximately 1.533, indicating a composition of An_{12}.
54–55. 5±	Quartz-mica schist. Bedding and foliation are 78° to the drill core.
55. 5±–56±	Quartz-oligoclase pegmatite. Walls at 85° to the drill core.
56±–121. 9	Quartz-mica schist. Bedding and foliation are 73°–85° to the drill core. Rich in muscovitized sillimanite to 71 ft.
	Quartz vein 2 in. thick, with very irregular contacts at 73 ft. Altered schist at 107 ft, principally quartz with carbonate, clinozosite, and biotite.
121. 9–122. 1	Pegmatite. Drill core consists almost entirely of quartz and perthite.
122. 1–126	Quartz-mica schist. Bedding and foliation at 83° to the drill core.
126–126. 5	Fine-grained quartz-muscovite-oligoclase pegmatite. Many small muscovite flakes. Minimum index of the oligoclase (An_{14}) is 1.534. The hanging wall is at an angle of 80° to the drill core, and the footwall is nearly perpendicular to the core.
126. 5–131	Quartz-mica schist. A fault encountered at 127 ft is represented by a gouge zone consisting of ground up schist and pegmatite.
131–131.1	Quartz-albite pegmatite with accessory tourmaline, muscovite, and fluor-apatite. Minimum index of the albite (An_4) is 1.528. Grains size is ¼ in. to 1 in.
131.1–140	Quartz-mica schist. Bedding and foliation are at 75° to 80° to the drill core.

Logs of Bureau of Mines diamond-drill holes, Jack Rabbit mine—Continued

Hole No. 2.

Feet	*Description*
0–12	Overburden.
12–16±	Quartz-mica schist.
16±–17	Quartz-oligoclase pegmatite with small flakes of muscovite. Minimum index of the oligoclase (An_{11}) is 1.532.
17–114	Quartz-mica schist. Bedding and foliation are at 60° to 75° to the drill core. Veins of quartz, 1 in. thick, with altered schist at 74 and 82 ft. Three-inch vein of quartz with small muscovite flakes at 85 ft, and 6-in. vein of quartz at 86 ft. One-inch quartz-tourmaline vein with scattered muscovite flakes between 102 and 110 ft.
114–114.3	Fine-grained quartz-oligoclase-muscovite border zone. Most grains less than ⅛ in. across. Minimum index of the oligoclase (An_{14}) is 1.534.
114.3–114.6	Quartz-perthite-albite pegmatite with small muscovite flakes and a little limonite. Minimum index of the albite (An_4) is 1.528.
114.6–114.8	Fine-grained quartz-oligoclase-muscovite pegmatite. Most grains less than ⅛ in. across. Minimum index of the oligoclase (An_{14}) is 1.534.
114.8–116±	Quartz-mica schist.
116±–117±	Fine-grained quartz-muscovite-oligoclase pegmatite. Most grains less than ⅛ in. across. The angle between the walls of the pegmatite and the drill core is about 70°.
117±–123	Quartz-mica schist. Bedding and foliation are at 70° to the drill core.

RESERVES

No mica-bearing pegmatite, sufficiently rich to be worked at 1943-44 prices, can reasonably be expected below the 54-ft level. Operations on the 54-ft level were not profitable and as the diamond-drill holes indicate the pegmatite to be very thin or nonexistent 50 ft below this level, it is improbable that work at greater depths can be done with profit. The mica above the 38- and 54-ft levels is worked out.

JOSIE LODE (CUSTER DISTRICT)

by J. W. Adams

The Josie Lode, an unpatented claim held by John Delaney of Custer, is in the NE¼ sec. 34, T. 2 S., R. 6 E., Custer County.

A compass-and-tape map (fig. 17) of the property on a scale of 1 in. to 20 ft was made November 9, 1944.

The pegmatite that has been mined is a segregation in, or intrusion into, the Harney Peak granite. It crops out for about 100 ft along the strike and reaches a maximum thickness of about 40 ft. The dike trends northwest and dips southwest.

An open-cut 50 ft long and from 4 to 20 ft deep has been excavated in the wide part of the dike. Much of this cut was made 40 to 50 years ago.

Two structural units were recognized in the pegmatite. Perthite-quartz-muscovite pegmatite forms a wall zone along the entire hanging wall and part of the footwall. It is the source of book mica, and contains accessory albite, garnet, biotite, apatite and rarely beryl. Contacts with the wall rock are in part gradational. Perthite-quartz pegmatite forms a central zone, and contains local concentrations of biotite. The dike is apparently lenticular.

Mica is the only mineral known to have been sold from the property. From March 1943 to January 1944 a total of 322.6 lb of sheet mica was sold to Colonial Mica Corporation from this deposit. The mica qualified was almost all no. 2 inferior quality and only 2 percent was large sheet (1½ by 2 in. and larger). Mineral- and air-staining are the chief defects. Earlier production from the mine is unrecorded. The property, now idle, is a possible source of electric mica.

KEYSTONE LODE CLAIM (CUSTER DISTRICT)

by W. E. Hall

The Keystone Lode claim is 5½ miles southwest of Custer, Custer County, in sec. 36, T. 3 S., R. 3 E. The owner is the Maywood Chemical Company. The property was examined in October 1942.

The Keystone Lode pegmatite crops out on the crest of a prominent ridge. The outcrop is 200 ft long and 40 to 60 ft wide but, as no contacts were exposed the true width and dip of the body could not be ascertained. The strike of the body appears to parallel that of the schistose country rock, which strikes N. 5° E. and dips 60° NW. The pegmatite is discordant and dips eastward. The workings consist mostly of small, shallow cuts across the outcrop.

The pegmatite is composed of perthite, albite, massive gray quartz, and muscovite. Beryl and amblygonite are associated with the gray quartz. The crystals of beryl are pale yellow and free of inclusions. They are small, averaging 4 in. in diameter.

White muscovite occurs in the pegmatite, associated with quartz. The muscovite, which is mostly of small size, makes up about 5 percent of the quartz pegmatite. Most of it shows "A" structure, and is of scrap quality.

KING LODE SPODUMENE PROSPECT (KEYSTONE DISTRICT)

by W. C. Stoll

The King Lode spodumene prospect (formerly known as the Equality) and four adjoining claims, including the King Lode Fraction, in the SW¼ sec. 15, T. 2 S., R. 6 E., Pennington County, are 2 miles southeast of Keystone. The property is unpatented, and is held by J. Arthur Johnson of Ortho, South Dakota. The King Lode, according to Johnson, has yielded less than 100 tons of spodumene and less than 10 tons each of beryl and amblygonite.

The workings of the King Lode are near the top and at the south end of a small knoll north of a tributary of

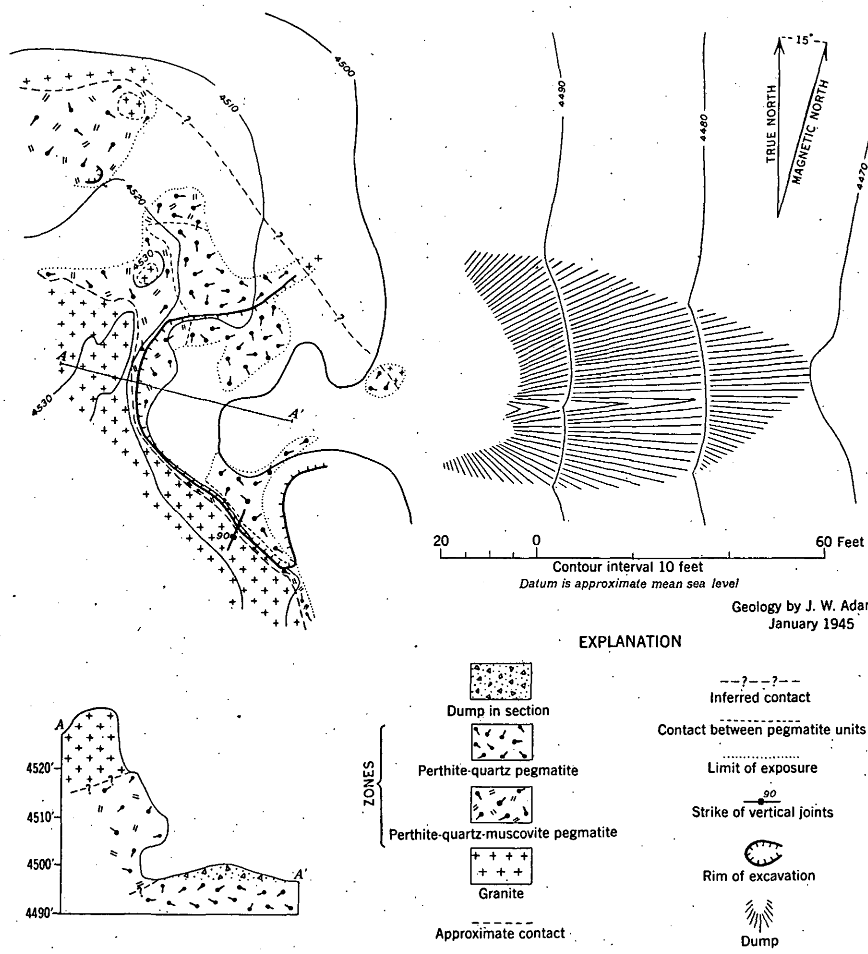


FIGURE 17.—Geologic map and section, Josie Lode pegmatite, Custer County, South Dakota.

Iron Creek. The pegmatite is exposed along the strike (N. 80° W.) in the north wall of a trench 70 ft long, 10 to 12 ft wide, and 10 ft in maximum depth. About 30 ft from the east end of the trench, the pegmatite has been explored for 30 ft down the dip by a shaft inclined 21°.

The King Lode pegmatite is composed chiefly of quartz-cleavelandite-spodumene pegmatite that contains a little small muscovite, beryl, and amblygonite. East of the collar of the incline, the spodumene pegmatite contains 80 percent spodumene in hard, fresh crystals as much as 6 in. by 8 in. by 3 ft. This spodumene-rich rock is exposed for 20 ft along the strike of the pegmatite and is 3½ ft thick. Massive quartz pegmatite overlies and underlies the spodumene-rich rock. The quartz above the spodumene is 1 ft thick and contains scattered beryl crystals. Near the east end of the trench small nodular masses of amblygonite occur in the pegmatite. At the inclined shaft, and west of it, a little spodumene is exposed. The pegmatite in the shaft is a mixture of quartz, cleavelandite, microcline (?), and muscovite, with 5 to 10 percent of spodumene.

A second pegmatite crops out a few feet south and down slope from the King pegmatite. It is slightly thicker than the King pegmatite and contains a very few scattered small spodumene crystals.

The cut on the King Lode Fraction, about 400 ft south of the King Lode across a deep gulch, exposed spodumene-bearing pegmatite. This cut is 10 ft long, about 8 ft wide, and a few feet deep. In it is exposed a fine-grained pegmatite containing 20 to 25 percent hard spodumene crystals 1 to 12 in. long. Locally the rock contains more than 50 percent spodumene. Milling would be required to recover this spodumene. On the King Lode Fraction, in the vicinity of the cut, several westward-trending pegmatites crop out prominently. The spodumene-bearing pegmatite may be part of a body of similar trend. Further trenching is necessary to determine the extent of this pegmatite.

KNOWLES LODE CLAIM (CUSTER DISTRICT)

The Knowles Lode claim, in the SW¼ sec. 13, T. 3 S., R. 4 E., Custer County, is held by Frank Beck of Hill City.

The Knowles Lode pegmatite has been prospected for quartz crystals by seven small open-cuts, of which the largest is 30 ft long, 10 ft wide and a few feet deep. The pegmatite is a tabular to lenticular body 230 ft long and as much as 20 ft wide. The southern half of the exposure trends N. 60° E. and the northern half N. 80° E. The strike is N. 65° E. and the dip is 30° SE. The rock is medium-grained pegmatite composed of perthite, quartz, plagioclase, biotite, muscovite, tourmaline, garnet, and beryl. Quartz crystals are reported to occur in pockets and have been recovered from all seven pits. The distribution of the pits suggests that the pockets are erratically scattered through the pegmatite. No crystals were seen in place, though smoky to milky, zoned and fractured crystals as much as 6 by 4 in. were found on the dumps.

LAKE MICA PROSPECT (CUSTER DISTRICT)

by W. C. Stoll and L. R. Page

The Lake, or Lakeside, mica prospect, in the SW¼ sec. 29, T. 2 S., R. 5 E., Custer County, is owned by Mrs. Gladys Wells of Custer. The mine workings are in three pegmatite dikes that crop out on a granite ridge a few hundred yards east of Sylvan Lake. The property was visited and mapped by W. C. Stoll and W. E. Hall, August 24–26, 1942 and was visited in 1943 by L. R. Page. The mine was operated for a short time by Mrs. Wells in 1943 and for a few weeks by L. H. Jeffries in the fall of that year.

The property has been worked by two open-cuts and a few small prospect pits. The main cut, in the middle dike (fig. 18), is 50 ft long, 8 ft wide, and about 40 ft deep at the face. Two other small cuts have been made in the same pegmatite to the northeast of the cut. The northernmost pegmatite has been prospected by an open-cut 20 ft long, 12 ft wide, and 20 ft high at the face. The outcrop extends 80 ft above the top of the cut.

The pegmatites trend northeast across pink to gray, coarse-grained granite. The granite is composed of plagioclase (40 to 50 percent), perthite (30 to 40 percent), quartz (15 percent), muscovite (2 to 8 percent), biotite (2 to 5 percent), tourmaline (2 to 5 percent) and garnet (less than 1 percent). The average grain size is about ½ in. but crystals as much as 2 in. across are not uncommon. The texture and mineralogy are highly varied.

The three pegmatites are about 50 ft apart and can be traced about 150 ft along a northeast trend. The northern pegmatite strikes about N. 45° E. and dips 55° NW. on the hanging-wall contact and 45° NW. on the footwall contact. The dike is about 20 ft thick at the base of the cliff. On the hanging-wall side there appears to be a mica-rich zone 4 to 6 ft thick. The rest of the pegmatite is mainly perthite, quartz, and some biotite.

The middle pegmatite, which is the main mica prospect, strikes N. 50° E. and dips 80° NW. It is 5 to 8 ft thick and contains both wall zones and core (fig. 18). The wall zones are as much as 2 ft thick and are fine-grained plagioclase-quartz-muscovite pegmatite. The core is composed of coarser-grained gray-white plagioclase, quartz, perthite, muscovite, biotite, and tourmaline. The sheet mica-bearing books occur in the core, although the greatest concentration of mica is in the wall zones. The muscovite

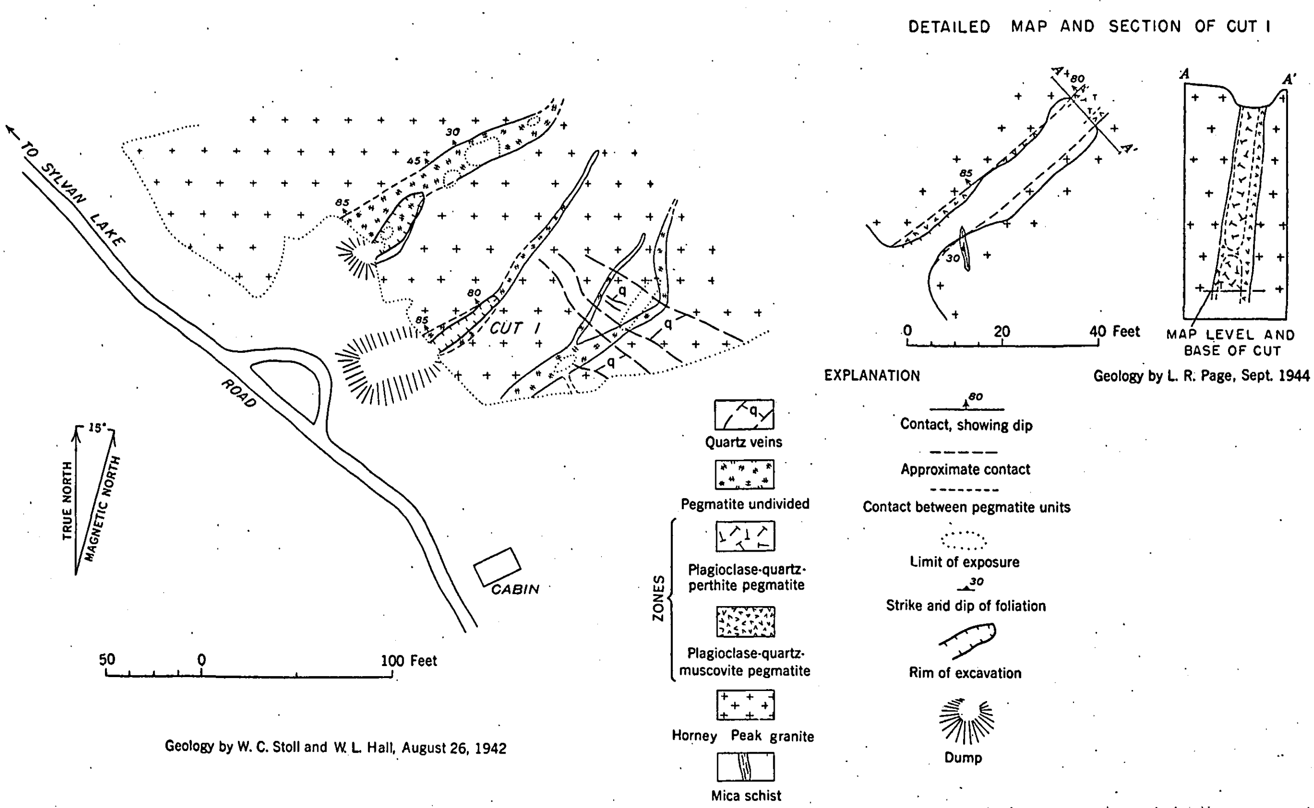


FIGURE 18.—Geologic maps and section, Lake mica mine, Custer County, South Dakota.

books are firm to the edges and some are thicker than they are long or wide. Some books are as much as 12 in. across. The mica is deep ruby, air-stained, and in part intergrown with biotite.

Two small cuts prospect the eastern part of the dike 100 ft northeast of and about 90 ft vertically above the main cut. Biotite and muscovite, intergrown in blades, cut a perthite-rich pegmatite. Mica books are widely scattered in this part of the dike.

The Lake mine produced 261.04 lb of sheet mica in 1943. There is no record of the size pattern of the mica or of the mica content in the rock, though the pegmatite probably contains about 1 to 2 percent of recoverable crude mica. Jeffries mined 1700 lb of crude mica and recovered 71.54 lb of large and small sheet mica. A single book, weighing 36 lb, produced 6 lb of this sheet.

LOFTON (MOUNTAIN ROSE LODE) CLAIM (CUSTER DISTRICT)

by W. C. Stoll

The Lofton (Mountain Rose Lode) claim, in sec. 14, T. 5 S., R. 4 E., Custer County, 1 mile northwest of Pringle, belongs to Lora L. Lofton of Pringle. It is a 20-acre unpatented claim at an altitude of about 5,000 ft. The property was located by Lon Pitts of Pringle, South Dakota, on December 28, 1932, and was sold to Mrs. Lofton in 1940. Between 1940 and the date of examination in 1942, the property was leased for short periods to Ray Mason, formerly of Pringle, and to S. T. Gamber of Custer. The property was idle until in the spring of 1945 a little prospecting for mica was undertaken. According to Lon Pitts, the Lofton claim has produced about 10 tons of beryl, 40 tons of scrap mica, and several hundred tons of feldspar.

The Lofton pegmatite was worked by three open-cuts (fig. 19), one in each of three pegmatite outcrops. The largest pit is about 100 ft long, 15 to 25 ft wide, and 25 ft deep. This cut is in the northernmost pegmatite outcrop on the claim.

The Lofton pegmatite crops out for about 600 ft in a N. 30° W. direction. The three outcrops shown on the map probably represent three high points on the crest of the same pegmatite, but they may be separate lenticular masses. The northern exposure, developed by the largest pit is 150 ft long and as much as 30 ft wide. The strike is N. 50° W. and the east wall dips 35° NE. The contact of the west wall is indistinct but it seems to dip 45° SW. The wall rocks are quartz-mica schists that have been altered to fine-grained quartz-feldspar-biotite rock where the pegmatite is discordant. In general, the contacts parallel the foliation of the schist.

The pegmatite in the walls of the main pit is composed of large crystals of pale to deep flesh-colored perthite in a matrix of massive quartz, pink albite, muscovite, beryl, and black tourmaline. At the north end of the cut rock made up almost entirely of perthite forms the core of the pegmatite. Beryl crystals range in size from 1 in. in diameter by 3 in. in length, to 10 in. in diameter by 2 ft in length. They are in albite associated with muscovite and tourmaline, and also in massive quartz. About 850 lb of beryl was visible in the walls of the main pit at the time of the examination. The muscovite appeared to be of scrap quality but a little of it may have been of sheet quality. The feldspar in the beryl-bearing part of the pegmatite is clean, and forms perhaps 20 to 25 percent of the visible pegmatite. Rock removed from the core reportedly contained much more feldspar. Tantalite-columbite has been reported but none was seen.

The middle pegmatite (fig. 19) is encased in banded, feldspar-rich wallrock. In the available exposures the contact cuts across the more gently dipping banding. The pegmatite north of the pit plunges 39° to the northwest. At the pit the top of the pegmatite seems to be horizontal. The hanging-wall contact of the pegmatite strikes N. 40° W. and dips 70° NE. at the ground level.

The pegmatite is 10 to 15 percent perthite and coarse quartz in a matrix of muscovite, quartz, tourmaline and albite. Muscovite is concentrated in a wall zone, 1 to 3 ft thick, as strongly ruled books that may make up as much as 2 percent of the exposure. A few beryl crystals occur below the wall zone.

The third pegmatite has a fairly distinct wall zone of albite and muscovite along its east wall. The muscovite is abundant but is ruled into pieces less than 2 in. in width. Small beryl crystals were observed near the footwall of this pegmatite.

LOST BONANZA MICA MINE (CUSTER DISTRICT)

The Lost Bonanza mica mine, in the NE¼ sec. 14, T. 3 S., R. 4 E., Custer County, was one of the largest producers of mica during the first period of mica mining in the Black Hills. According to O'Harra (1902, pp. 75–76), 26,000 lb of sheet mica valued at $113,100 was produced from this mine. In 1943 the mine dumps were reworked and more than 1,000 lb of three-quarter trim sheet mica was sold. The present owners, A. W. Schultz and Monte Heumphreus, leased the property to L. H. Jeffries in November 1943 but no mining was done. The property was visited with Jeffries November 8, 1943.

The workings consist of an open-cut about 120 ft long; an adit 85 ft long, connected to the open-cut by a short raise; a shaft, reported to be 50 ft deep; and a trench about 30 ft long at the south end of the pegmatite.

The Lost Bonanza pegmatite is one of several parallel pegmatites that conformably intrude quartz-mica schist along the east side of Buckhorn Mountain. The Lost Bonanza pegmatite strikes about N. 55° W. and dips 40°–45° SW. A large part of the pegmatite was mined

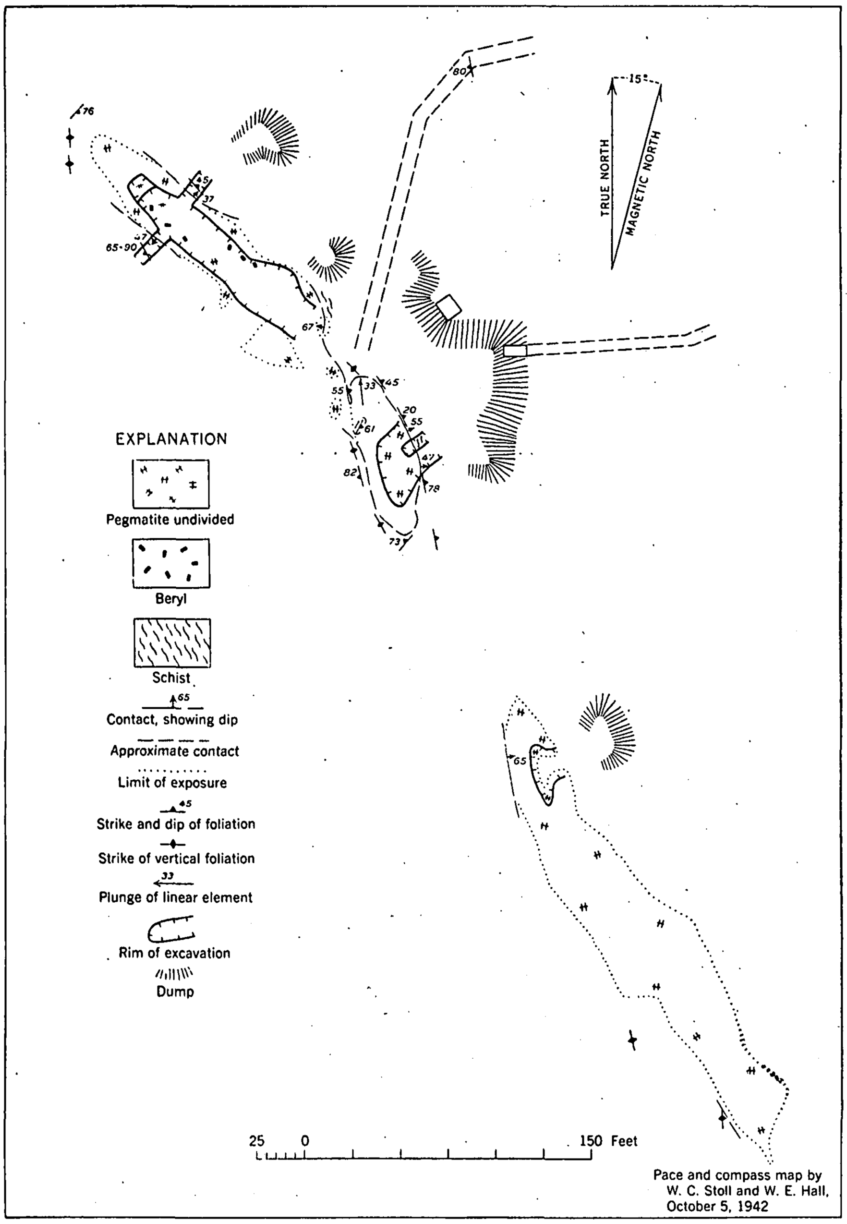


FIGURE 19.—Plan of workings, Lofton claim, Custer County, South Dakota.

out during early operations. Apparently it was a well-zoned pegmatite, but only border and wall-zone rock remain. This is exposed at the south end of the open-cut, where it is 4 to 6 ft thick. The pegmatite is exposed for about 150 ft to the southeast. About 30 ft south of the open-cut the main pegmatite trends southwest for a few feet and a narrow prong extends from the hanging wall of the pegmatite to the open-cut. At the open-cut the two parts of the pegmatite are separated by a few feet of schist. Underground, the main pegmatite is exposed for a length of 45 ft and a width of 6 ft (fig. 20). A second narrow, very fine grained pegmatite is exposed for about 30 ft in from the portal.

The Lost Bonanza pegmatite is fine- to medium-grained plagioclase-quartz-muscovite pegmatite. Tourmaline and apatite are abundant in surface exposures. The muscovite books exposed underground are less than 6 in. in diameter. The mica is hard, flat, deep-ruby muscovite with moderate to strong air-staining. More than 1,000 lb of sheet mica recovered from the dumps is said to have contained less than 10 percent of no. 1 and no. 2 qualities and no no. 3 quality. The rest was no. 2 inferior quality.

LOST INDIAN MICA PROSPECT (CUSTER DISTRICT)

The Lost Indian mica prospect, in the SE¼ sec. 7, T. 3 S., R. 5 E., was operated intermittently for a few weeks in the summer of 1944 by B. W. Bell of Custer. The mine yielded 93.4 lb of large and small sheet mica.

The pegmatite was worked from a pit 10 ft long, 8 ft wide and about 6 ft deep at the north face. Nearly the entire pegmatite was removed. It was an irregular lens about 15 ft long and 2 ft thick. The pegmatite

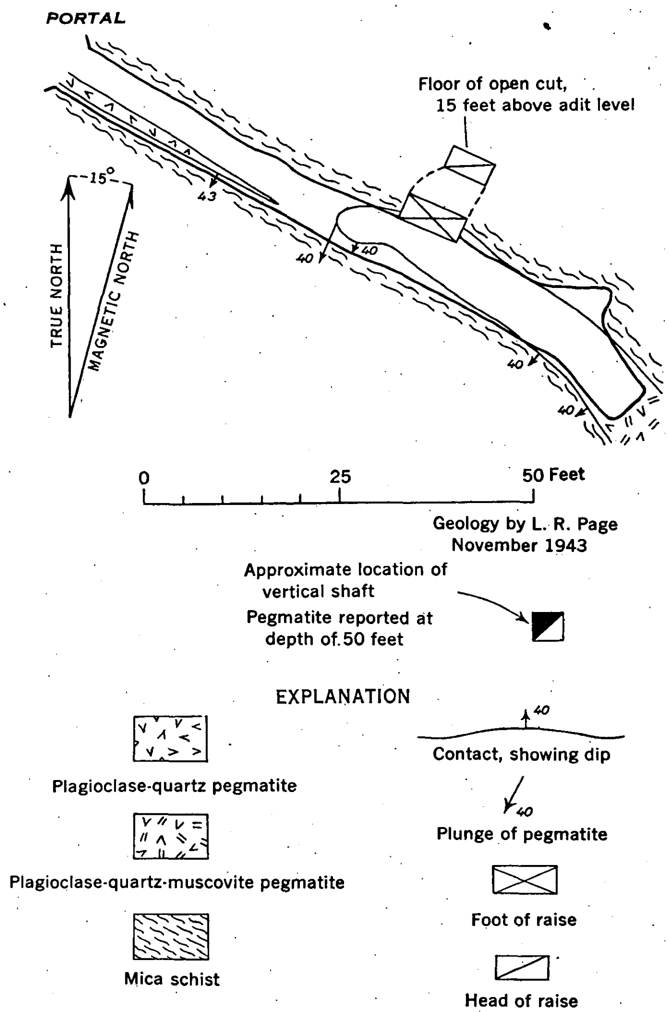


FIGURE 20.—Underground workings, Lost Bonanza mica mine, Custer County, South Dakota.

strikes N. 55° E. and dips 10°–20° SE. In general it is crosscutting, though the lens as a whole is concordant with the coarse-grained sillimanite schist or gneiss wallrock. The pegmatite has a border zone less than 1 in. thick that surrounds plagioclase-quartz-perthite-muscovite pegmatite. Tourmaline is abundant and occurs with muscovite books, as much as 12 in. long, in the center of the pegmatite.

The total pegmatite mined was about 20 tons and contained more than 4 lb of large and small sheet per ton. The mica was flat, hard, and deep ruby. One-fifth of the mica, sold as large sheet, contained 9 to 15 percent no. 1, 17 to 18 percent no. 2, and 60 to 74 percent no. 2 inferior quality. The small sheet contained 17 to 26 percent no. 1, 30 to 36 percent no. 2, and 40 to 44 percent no. 2 inferior quality. One 15-lb lot contained 5 percent of no. 3 quality.

LUCKY STAR MICA PROSPECT (CUSTER DISTRICT)

by Peter Joralemon

The Lucky Star mica prospect, in sec. 35, T. 3 S., R. 4 E., about 2 miles south of Custer on U. S. Highway 85, was first visited on March 6, 1944 with Mr. Slater, the operator. The mica-bearing pegmatite forms a 30-ft cliff and is readily seen from the highway, a few hundred feet to the east.

The Lucky Star claim was originally located by Mr. E. B. Adams of Fall River County, South Dakota, on October 20, 1943, and was leased to a Mr. Harrison of Custer and a Mr. Slater of Wyoming. In 1944 Floyd Frye of Custer operated the mine for a few months.

The Lucky Star pegmatite strikes to the north and dips about 40 to 50 degrees west. Near the northwest end it joins a dike that trends northeasterly. A third pegmatite lies 30 ft to the east of the first. The Lucky Star pegmatite outcrop is 40 to 50 ft wide and 150 ft long to the point where it joins the other dike. A thin veneer of quartz-mica schist is scattered in irregular patches over the top of the dike. The south end of the pegmatite probably plunges south; all outcrops at the southern end are covered with dump material.

The pegmatite appears to have two zones in addition to the border zone. The wall zone, 4 ft thick at the top of the dike, is presumably thicker on both walls where exposures are limited. It is composed of fine-grained quartz and albite with lesser quantities of muscovite and biotite. Tourmaline and beryl constitute a minor part of the rock. The muscovite seen was of the ruby variety and was in part "A" or "fish" mica. It occurs in books several inches thick and as much as 5 in. square and also as blades that fill fractures that are perpendicular to the contact. The core of the pegmatite consists of massive quartz and perthite with some graphic granite. Little or no muscovite occurs in this zone.

The east wall, or footwall, of the Lucky Star pegmatite shows scattered small books of mica for approximately 100 ft along the strike. The percentage of crude mica in the exposed pegmatite is estimated by eye at two percent. According to Mr. Slater the crude mica contains about 4 percent (80 lb) of sheet per ton. About 300 lb of small and large sheet mica was produced in 1943–44. That produced by Mr. Frye from August to October 1944 was 30 to 42 percent no. 1 or no. 2 qualities. The remainder was no. 2 inferior quality.

MacARTHUR MICA MINE (CUSTER DISTRICT)

by J. W. Adams

The MacArthur mica mine, in the NE¼ sec. 15, T. 4 S., R. 4 E., Black Hills Meridian, is 4½ miles southwest of Custer. It may be reached from Custer by the following mileage schedule:

Miles	
0.0	Custer Post Office.
0.6	Left on U. S. Highway 85A.
5.7	Right at Sanator Railroad Station.
6.0	Turn right.
6.6	Turn right.
6.9	Turn left.
7.2	MacArthur mine.

The property was examined by members of U. S. Geological Survey several times during 1943 and 1944. Surface and underground maps on a scale of 1 in. to 20 ft have been prepared (pl. 25). The geology, surface and underground, was mapped by L. R. Page assisted by J. W. Adams. Most of the surface mapping was done in April, 1944; the main level geology and some revision of the surface work were done in July 1944. The topography was mapped by J. W. Adams assisted by R. F. Stopper.

HISTORY AND DEVELOPMENT

The MacArthur mine is one of the older mica mines in the Custer district and was probably first worked before 1908. Sterrett's report (1908, p. 394) on the mica deposits of South Dakota contains a brief description of a mine, then called the Firestone, which is probably the MacArthur. He describes the existing workings as

> a crosscut through the schist and barren portion of the pegmatite, an open cut 20 feet deep, and an incline on the "vein".

The open-cut described by Sterrett was apparently along the hanging wall of the dike and has a floor 5 to 10 ft above the present floor of the cut. Little additional work was done until August 1943, when about 52 lb of sheet mica was produced by the owners, Walter Wright and Francis Michaud, of Custer. In September 1943, the mine was leased to Glenn and Lawrence Ventling of Pringle. During the Ventling operation the old open-cut was deepened and the entire width of the dike was mined. Much material was bulldozed away from the west rim of the cut. The inclined shaft, which then was down about 38 ft below the present collar, was cleared out and deepened by a few rounds, and a small drift was started to the south. The Ventlings discontinued work in February 1944. On March 13, 1944 the lease was assigned to L. H. Jeffries of Custer, who extended the incline to a depth of 52 ft, and then ran drifts north and south along the dike. Two small stopes were made above this level, one north and one south of the incline. The south stope, now backfilled, holed through into the floor of the open-pit along the hanging wall of the dike. In addition to underground mining, some work was done on surface exposures including a small cut across the dike, north of the shaft. Jeffries ceased operations at the mine June 24, 1944.

GEOLOGY

WALL ROCKS

The MacArthur pegmatite is intruded conformably into quartz-mica schist. This rock is exposed on the footwall and hanging wall of the pegmatite in the open-cut and in the underground workings. The schist shows well-developed folds that are parallel to the pegmatite contacts and plunge 40 to 50 degrees S. 12°–25° W. The thickness of the pegmatite and also the local concentrations of muscovite are related to these folds. Some small schist remnants are found enclosed in pegmatite near the walls.

PEGMATITE

The MacArthur mine is in an elongate pegmatite that crops out as a low ridge 320 ft long. The pegmatite strikes approximately N. 30° W. and has an average dip of 50° SW. The contacts show rolls that in general plunge 40 degrees S. 12°–25° W. and cause local variations in the thickness of the pegmatite. Two rock types have been mapped in the dike: albite-quartz-muscovite pegmatite, which is the commercial mica zone, and perthite-quartz pegmatite that forms a core. The core is present in almost all of the surface exposure north of the shaft. Just south of the shaft an unmined part of the core lies above footwall mica zone, and two more small areas crop out near the extreme south end of the dike. Where the pegmatite is narrow, as in the vicinity of the shaft, the core is not present.

Albite-quartz-muscovite pegmatite.—The albite-quartz-muscovite pegmatite wall zone is the commercial mica deposit in the pegmatite. It is composed of individual crystals as much as 6 in. in diameter. The albite (An_6–An_9) is white to flesh-colored and has minimum refractive indices of cleavage fragments of 1.529 ± 0.002 to 1.531 ± 0.002. Muscovite occurs in books several inches across. Perthite is locally abundant but can be considered an accessory mineral. Other accessory minerals are black tourmaline, beryl (N_e= 1.566 to 1.568), and manganese-iron garnet. Minute crystals of a mineral thought to be xenotime are embedded in some of the beryl.

North of the shaft and extending approximately 80 ft along the strike to the northwest, the albite-quartz-muscovite pegmatite is considerably different from other pegmatite in the dike. The rock is finer-textured, and characterized by vuggy albite and green to yellowish flaky muscovite. The muscovite in the books in this part of the pegmatite is tangled and corroded, suggesting that renewed activity of solutions subsequent to the initial crystallization of the albite-quartz-muscovite zone caused a reworking of existing minerals. The depth to which this alteration extends is probably not great, as it is not encountered on the level 52 ft below, and appears to be of limited extent in the north stope 20 ft below the outcrop. Vuggy albite and yellowish-green mica occur in smaller amounts in the albite-quartz-muscovite unit exposed in the south end of the pegmatite and are common along the inner edge of the wall zone in the open-pit. These occurrences suggest that this later phase of the pegmatite development was restricted to certain wide parts of the dike where a central core was present.

Perthite-quartz pegmatite.—Perthite-quartz pegmatite forms the core of the dike. It consists of large masses of quartz and perthite with accessory tourmaline and muscovite. The core is present along most of the surface exposures of the dike, but is very narrow on the floor of the open-cut and at the drift level south of the shaft.

MINERAL DEPOSITS

Mica is the only mineral occurring in commercial quantity in the dike. Some beryl is present, and it is possible that small amounts of both beryl and feldspar may have been sold from the property. Mica occurs in wall zones 2 to 5 ft thick and, where the central core is lacking, may be 4 to 10 ft thick. Part of the albite-quartz-muscovite pegmatite has been severely altered and does not contain a workable quantity of sheet mica. The greatest concentrations of good sheet mica have been found in pegmatite that is adjacent to strong folds in the schist. Mica shoots, developed along these folds, plunge 40° S. 12°–25° W. Several such folds are exposed in the open-cut and others are present along the northern part of the dike.

The mica occurs as books as much as several inches across. About 35 percent of the sheet mica recovered is larger than 1½ by 2 in. It is pale to dark ruby, but a few sheets of white mica are found near the core. Imperfections include ruling, air-stain, "A" structure, corrosion, silver spots, and mineral inclusions—chiefly tourmaline and feldspar. Of these imperfections, air-stain and mineral inclusions are probably the most common defects in the mica thus far mined although, locally, ruling has been a serious defect. In the altered part of the pegmatite, characterized by vuggy albite, the mica has developed "A" structure and the rims of the crystals are so corroded and bleached that this part of the dike cannot be considered as a commercial source of mica.

Mica purchased from Jeffries by the Colonial Mica Corporation contained 8.45 percent of no. 1 quality and 29.68 percent of no. 2 quality. The remainder was no. 2 inferior quality.

About 12.7 lb (6.3 percent) of crude mica was recovered per ton of rock mined. It is estimated that at the MacArthur mine, 0.6 to 0.75 lb of sheet mica has been recovered per ton of rock mined. In the Jeffries' operations the recovery of sheet from crude mica ranged from 2.66 to 9.03 percent, probably because of differences in the physical properties of the mica, in efficiency of the rifters, and in methods of mining. This last factor is an important one; crude mica from which little sheet mica was recovered came from shaft sinking, drifting, or raising operations requiring closer spacing of shot holes and the use of more powder than is used in stoping. A higher proportion of sheet mica was obtained from mica mined in the stopes.

RESERVES

The reserves of sheet mica at the MacArthur mine can be estimated only roughly. Assuming a single mica zone averaging 5.5 ft thick and including only the pegmatite above an altitude of 5,342 feet, it is estimated that 2,000 tons of rock, containing 1,200 lb of sheet mica remains unmined. This estimate does not include a block of about 700 tons north of the shaft that is at least in part altered and too low grade to mine at 1944 prices.

Future operation of the mine would probably entail extending the 5,342-ft level northwest along the dike; the success of the operation depending upon the finding of mica concentrations or "shoots." Surface indications are favorable for the north end of the dike, as several strong rolls and a well-defined mica zone are present in the outcrop for about 80 ft along the hanging wall.

McKIRAHAN MICA PROSPECT (CUSTER DISTRICT)

by W. C. Stoll

The McKirahan mica prospect is in the SW¼SW¼ sec. 6, T. 5 S., R. 6 E., Custer County, about 1 mile south of the southern boundary of the Custer State Park and about ½ mile east of the highway to Hot Springs, South Dakota. Mr. Orien McKirahan of Buffalo Gap, South Dakota is the owner. The pegmatite is on a homestead, patented in 1903 by James Cole and subsequently acquired by McKirahan. Edward C. Gray and Langford Landis of Custer obtained a lease from the owner in October 1942, and were operating the property May 21, 1943 when it was visited by L. R. Page; in October 1942 when Stoll visited the prospect no mining was in progress.

The only opening on the pegmatite is a small cut a few feet east of a frame building on the west side and near the base of a ridge capped by Cambrian quartzite. In May 1943 this cut was 20 ft long, 15 ft wide, and as much as 18 ft deep. The pegmatite as exposed in the cut is an irregular body of unknown shape. It is composed of salmon-pink perthite, smoky quartz, albite, muscovite, and a little biotite. The pegmatite is somewhat iron-stained and softened by weathering, and the mica can easily be picked out of the weathered pegmatite. The wall rock of the pegmatite is quartz-mica schist that has in part been made into a lit-par-lit gneiss by pegmatite stringers.

In October 1942, muscovite comprised about 15 percent of the observed face. The books were as much as 8 in. in diameter. In May 1943 the largest book seen was 4 in. long. The mica was ruby, very hard, and much of it was black-stained, although perhaps 30 percent of the mica seen in place was clear. Weathering has produced red stains in the mica but is probably not deep. A reasonable proportion of the mica is of strategic quality.

Because of poor exposures the structure and extent of the pegmatite could not be ascertained. About 3 tons of crude mica was produced in 1943, of which 87.42 lb was sheet and 587.5 lb was punch mica.

MARYDALE MICA PROSPECT (CUSTER DISTRICT)

by R. F. Stopper

The Marydale mica prospect is in the SW¼ sec. 14, T. 4 S., R. 4 E., Black Hills Meridian, Custer County. The property is owned by A. T. Young of Custer, who operated the property from July to September 1943.

The workings consist of an open-cut, 70 ft long, 10 ft wide, and 20 ft deep; and two smaller open-cuts (fig. 21). About 500 tons of mica-bearing rock mined from the large open-cut yielded about 3¼ tons of crude mica. From this crude mica at least 180.61 lb of small sheet mica (less than 1½ by 2 in.) was sold to Colonial Mica Corporation, and probably an additional 75 lb of mica was produced.

Two large pegmatites and many small associated pegmatite stringers, which conformably intrude pre-Cambrian quartz-mica schist, crop out in the area mapped. They strike N. 20° W. and dip 60°–80° SW. The exposed contacts between pegmatite and schist show even walls. The pegmatites plunge 55° to 65° SE. The north pegmatite is a branching body as much as 14 ft wide, whose northern 70 ft contains sheet mica. The southern part of the east branch is barren of book muscovite. Three pegmatite units have been mapped on the basis of the muscovite distribution.

The pegmatites are composed mainly of quartz and perthite, with some plagioclase and muscovite. The perthite occurs as crystals as much as several feet in length. Locally it grades into graphic granite. A few small muscovite books are distributed throughout the pegmatite, but sheet mica-bearing books occur only

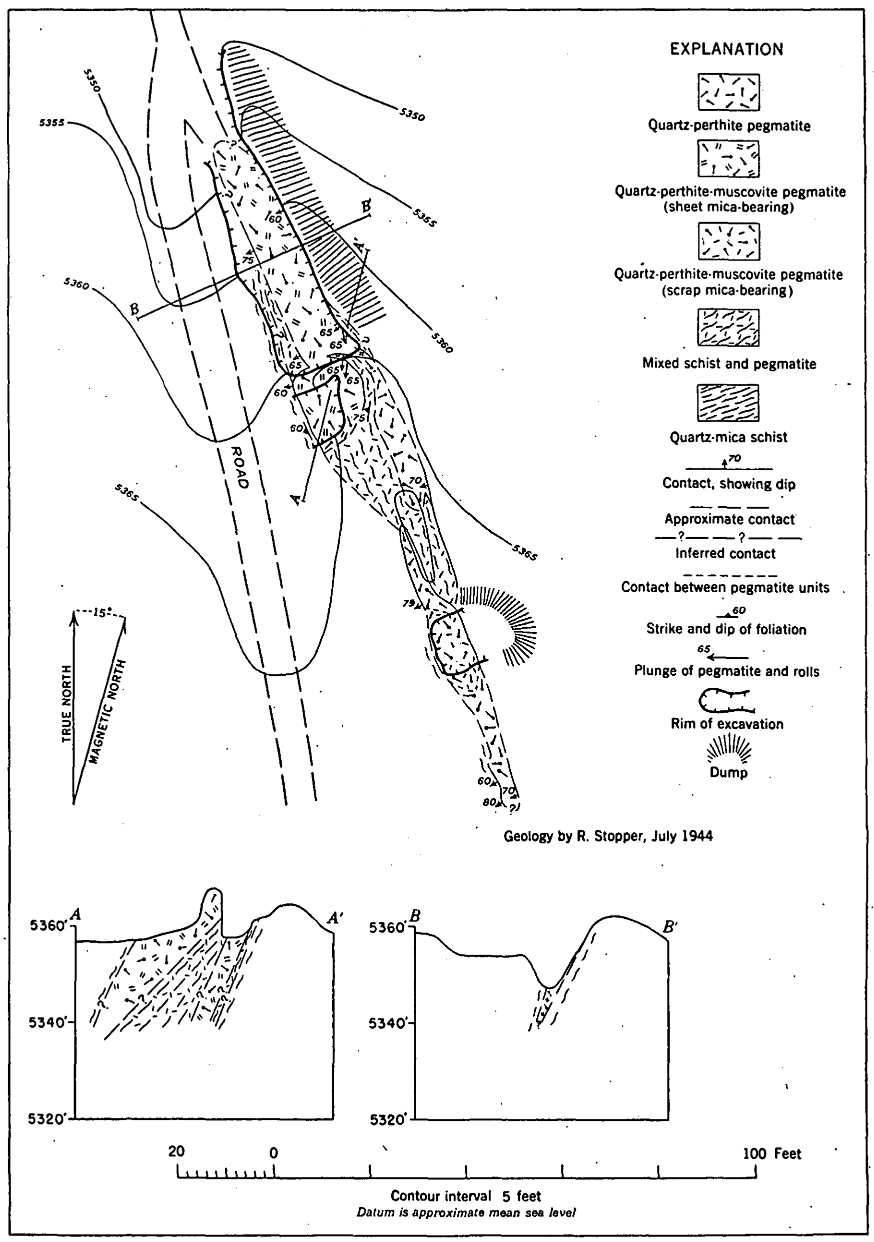


FIGURE 21.—Geologic map and sections, Marydale mica mine, Custer County, South Dakota.

in the north pegmatite, where they are distributed through the entire dike. Associated minerals are biotite, apatite, and abundant tourmaline.

The mica books average 4 in. in maximum dimension. Fresh books are pale ruby but many are strongly air-stained and show a characteristic silver color. The books are in part ruled and badly reeved, and many contain inclusions of biotite, tourmaline, quartz, or feldspar.

MATEEN SPODUMENE PROSPECT (HILL CITY DISTRICT)

by M. P. Erickson and T. A. Steven

The Mateen spodumene prospect, owned by the John M. Kennedy Estate of Philadelphia, Pennsylvania, is in the NW¼ sec. 31, T. 1 S., R. 5 E., about ½ mile south of Hill City, Pennington County. Workings on the property consist of 3 shafts and several open-cut excavations made by the Harney Peak Tin Mining, Milling, and Manufacturing Company during their tin mining ventures in the decade beginning about 1884.

In 1942–44 interest in the property developed as a result of increased wartime demand for lithia. In 1942, Professor Francis C. Lincoln of South Dakota School of Mines sampled the dikes for the Bland Tin and Tungsten Milling Company which held an option on property. In May 1942, W. C. Smith of the U. S. Geological Survey examined the property and in September, W. C. Stoll, assisted by W. E. Hall, mapped the property. The reports by Smith and Stoll are incorporated in this description of the property.

The U. S. Bureau of Mines and the U. S. Geological Survey investigated the property in a cooperative program carried out between August 1944 and April 1945. Sampling and exploration by the U. S. Bureau of Mines was directed by F. F. Clarke, Project Engineer. It was accompanied by geologic mapping and interpretation of diamond-drill cores (pls. 26, 27) by the U. S. Geological Survey.

GEOLOGY

The Mateen property is underlain by metamorphic rocks that are cut by pegmatite dikes and small irregular quartz veins. It is about 3 miles northwest of the nearest known outcrop of Harney Peak granite. On the central and southern parts of the property the metamorphic rocks are fairly well exposed and the pegmatites crop out as prominent ridges. At the lower, northern part of the property bedrock is covered by stream terrace deposits.

METAMORPHIC ROCKS

Quartz-mica schist.—The quartz-mica schist is gray and mostly fine-grained. Some is amphibolitic. Small, red, euhedral garnets are common in numerous thin beds. The foliation is apparently parallel to the bedding and it strikes generally about N. 25° W. but with local deviations. Recorded dips are 28°–54° SW.

The schist has a distinct linear structure caused by the uniform orientation of elongate biotite flakes. The direction of plunge is within a degree or two of S. 65° W. in every instance, but the amount varies with attitude of the foliation. The direction of plunge is approximately at right angles to the length of the pegmatite dikes.

PEGMATITE

Two spodumene-bearing pegmatite dikes with north-northwest trends crop out on the Mateen property (pl. 26). Both dip steeply eastward and are discordant to the schist structure.

The northern dike is exposed for a length of 800 ft and a maximum width of 50 ft. Diamond drilling reveals that the dike is more irregular than the surface exposures indicate. Under the north half of the outcrop the dike is split into two parts and extends downward at least 200 ft (pls. 26, 27). Drill holes and workings indicate that the south part of the dike rapidly thins with depth, and that here the keel of the dike may be less than 100 ft below the outcrop.

The southern dike is well exposed for a length of 300 ft. The hanging wall is exposed in a shaft near the south end to a depth of about 65 ft. This dike was not drilled and nothing is known of its downward extension.

A third pegmatite, cut in diamond-drill hole no. 6 (pl. 26), does not crop out, but it may be connected with the north pegmatite.

Each dike is composed of three zones: a wall zone of quartz-albite pegmatite, an intermediate zone of quartz-albite-microcline pegmatite, and a core of quartz - albite - microcline - spodumene pegmatite. In places along each dike, the wall and intermediate zones form cappings over the core indicating that the crest of the pegmatite and the position of the crest before erosion can be approximated by interpolating between these known points. The restored crest of the northern pegmatite is shown on the oblique projection (pl. 27). The cappings of outer zones on the core are quite closely spaced in the southern dike and the restored crest of the pegmatite is, at the most, only a few feet above the present outcrop.

Quartz-albite pegmatite.—The quartz-albite pegmatite is only 1 to 2 in. thick in most surface exposures, but 2 to 3 ft thick in some of the rolls. Drill holes indicate a thickness of 1 to 3 ft throughout the lower parts of the dike. The average grain size is about ½ in., but a thin, much finer grained selvage occurs at the contact.

Quartz, the most abundant constituent, comprises about 50 percent of the zone. It occurs as irregular grains as much as ¾ in. across, but is generally finer grained toward the outside contact. The albite content varies greatly within the zone: the average is about 40 percent, but it makes up less than 5 percent of the border zone. It occurs in small blades and aggregates, and the grain size ranges from microscopic in the border zone to about ½ in. near the inside boundary of the zone. Muscovite, in flakes as much as ½ in. across, is a minor constituent in most of the zone although it is very abundant in the border zone and locally within the wall zone. Apatite and cassiterite seem to be concentrated in the rolls where the zone is wider than average.

Quartz-albite-microcline pegmatite.—The intermediate zone has the same mineral composition as the inner part of the wall zone except that microcline crystals, from 1 to 3 in. long, are common. The proportion of microcline increases from the outside of this zone toward the core. The average composition is quartz (35 percent), albite (30 percent), microcline (25 percent), and muscovite (10 percent). The quartz and albite grains are slightly larger than those in the inner part of the wall zone. One piece of amblygonite from the zone was found in a drill core.

A coarse micaceous mineral, in masses with the external form of spodumene blades, occurs at the inner edge of the zone. Spodumene formed in this zone was apparently completely altered by deuteric action before the deposition of spodumene in the core.

Quartz-albite-microcline-spodumene pegmatite.—In the quartz-albite-microcline-spodumene pegmatite of the core, spodumene occurs in addition to the minerals of the intermediate zone. The spodumene crystals are on the average about ½ by 1 by 6 in., but many are much larger. The crystals appear to contain much intergrown quartz. Most of the crystals are oriented with their long axes trending about N. 60° E. (nearly at right angles to the trend of the dikes), and plunge 0°–15° to the southwest. This orientation was not apparent in the drill cores, possibly because of the small size of the core and the angle of its intersection with the crystals.

Most spodumene exposed at the surface appears unaltered. Some in the drill cores is fresh and some is altered, but the proportion of altered spodumene is greater in the deeper parts of the dike. The altered spodumene is commonly a very soft greenish or brownish micaceous or clay mineral in which the lithium probably has been replaced by other elements. Completely altered crystals retain the characteristic cleavage and shape of spodumene.

The content of spodumene, both fresh and altered, is estimated to range from about 15 to 35 percent of the rock in various surface exposures and is generally less in the drill cores.

The highest content of lithia is apparently in the upper parts of the dikes. The distribution in the northern dike, based on weighted averages of assays from the spodumene-bearing pegmatite sampled by the U. S. Bureau of Mines in each trench and drill hole, is shown in plate 27. The decrease in the Li_2O content with depth is apparently the result of both a decrease in the proportion of spodumene and a stronger alteration of the spodumene in the lower parts of the pegmatite. The alteration probably is the more important factor.

SAMPLING

The U. S. Bureau of Mines sampling program comprised channel sampling in surface trenches, and subsurface sampling by diamond drilling. The northern dike was sampled in six trenches and the southern dike in one. The trenches are shown on plate 26. The diamond drilling by the U. S. Bureau of Mines was confined to the northern dike. Logs of the diamond-drill holes follow.

Logs of U. S. Bureau of Mines diamond-drill holes, Mateen pegmatite

Hole no. 1

Location: U. S. Bureau of Mines coordinates: North 3781.5, East 678.0.
Bearing: S. 69° 06′ W.
Inclination: Minus 45°.
Altitude: 5,224.6 ft.

Feet		*Description*
0–20		No core.
20–61		Fine-grained quartz-mica schist with some garnet-rich layers. The angle of bedding and foliation to the drill core is 8° at 25, 4° at 35, 3° at 45, 7° at 49, 3° at 51, 8° at 58 ft.
61–73		Pegmatite.
	61	Hanging wall contact is 55° to drill core.
	61–63.5	Quartz-albite-muscovite pegmatite.
	63.5–66.5	Quartz-albite-muscovite pegmatite with spodumene completely altered to white micaceous mineral.
	66.5–68	Quartz-albite-spodumene-microcline pegmatite. Quartz (45 percent), albite (25 percent), microcline (5 percent), spodumene (25 percent).
	68–69	Microcline-quartz-albite pegmatite. Quartz (20 percent), albite (20 percent), microcline (60 percent).
	69–73	Quartz-albite pegmatite. Cassiterite between 70 and 72.5 ft.
	73	Footwall contact 40° to drill core.
73–200		Fine-grained quartz-mica schist with minor garnet-rich layers. The angle of bedding and foliation to the drill core is 40° at 73, 4° at 79, 12° at 86, 15° at 97 and 105, 22° at 110, 28° at 116, 30° at 122 and 136, 35° at 146 and 160, 40° at 165, 55° at 176, 50° at 190 and 200 ft.

Logs of U. S. Bureau of Mines diamond-drill holes, Mateen pegmatite

Hole no. 2

Location: U. S. Bureau of Mines coordinates: North 4043.3, East 563.4.
Bearing: S. 70° 55′ W.
Inclination: Minus 45°.
Altitude: 5,132.9 ft.
Length: 191 ft.

Feet	*Description*	
0–21	No core.	
21–51	Fine-grained quartz-mica schist with minor garnet-rich layers. The angle of bedding and foliation to the drill core is 10° at 25, 6° at 36, 0° at 42, 10° at 47 ft.	
51–52.2	Garnet-mica-amphibole schist.	
52.2–105.5	Fine-grained quartz-mica schist with minor garnet-rich layers. The angle of bedding and foliation to the drill core is 5° at 55, 10° at 58, 5° at 67, 10° at 75, 5° at 86, 38° at 90, 6° at 92, 11° at 105 ft.	
105.5–180	Pegmatite.	
	105.5	Hanging wall contact is 70° to drill core.
	105.5–107.9	Quartz-albite-muscovite pegmatite.
	107.9–111	Microcline-quartz-albite pegmatite. Quartz (25 percent), albite (20 percent), microcline (50 percent), muscovite (5 percent).
	111–129.5	Quartz-albite-spodumene-microcline pegmatite. Quartz (35 percent), albite (30 percent), microcline (15 percent), spodumene (20 percent).
	129.5–130	Quartz-albite-microcline pegmatite.
	130–131.5	Quartz-albite-muscovite pegmatite. Quartz (45 percent), albite (40 percent), muscovite (15 percent).
	131.6–135	Quartz-albite-microcline pegmatite.
	135–177	Quartz-albite-microcline-spodumene pegmatite. Fractured and iron stained, spodumene mostly altered below 169 ft. Quartz (35 percent), albite (30 percent), microcline (25 percent), spodumene (10 percent).
	177–180	Quartz-albite-microcline pegmatite. Poor core recovery.
	180	Footwall contact is about 50° to drill core.
180–191	Fine-grained quartz-mica schist with minor garnet-rich layers. The angle of bedding and foliation to the drill core is 25° at 183, 55° at 185, 67° at 190 ft.	

Hole no. 3

Location: U. S. Bureau of Mines coordinates: North 4155.5, East 445.4.
Bearing: S. 70° 53′ W.
Inclination: Minus 45°.
Altitude: 5,098.9 ft.
Length: 128 ft.

Feet	*Description*	
0–16	No core.	
16–58	Fine-grained quartz-mica schist with minor garnet-rich layers. The angle of bedding and foliation to the drill core is 32° at 22, 30° at 35, 25° at 45, 7° at 50, 15° at 57 ft.	
58–110.8	Pegmatite.	
	58	Hanging wall contact is 90° to core.
	58–63	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (40 percent), microcline (15 percent), muscovite (5 percent).
	63–72.3	Quartz-albite-microcline-spodumene pegmatite. Quartz (35 percent), albite (30 percent), microcline (15 percent), spodumene (15 percent), muscovite (5 percent).
	72.3–78.5	Quartz-albite-microcline pegmatite.
	78.5–108.3	Albite-quartz-microcline-spodumene pegmatite. Spodumene soft and greenish. Quartz (30 percent), albite (40 percent), microcline (15 percent), spodumene (10 percent), muscovite (5 percent)
	108.3–110.3	Quartz-albite-microcline pegmatite.
	110.3–110.8	Quartz-albite pegmatite.
	110.8	Footwall contact is 75° to drill core.
110.8–128	Quartz-mica schist with garnet-rich layers. The angle of bedding and foliation to the drill core is 40° at 117 and 123 ft.	

Logs of U. S. Bureau of Mines diamond-drill holes, Mateen pegmatite—Continued

Hole no. 4

Location: U. S. Bureau of Mines coordinates: North 4298.0, East 394.7.
Bearing: S. 70° 41′ W.
Inclination: Minus 45½°.
Altitude: 5,072.9 ft.
Length: 145 ft.

Feet		*Description*
0–28		No core.
28–51		Unconsolidated terrace deposits. Fragments of quartzite, schist, and pegmatite boulders and pebbles recovered.
51–52.2		Grey to white dense quartzite.
52.2–73.5		Fine-grained quartz-mica schist with garnet-rich layers. The angle of bedding and foliation to the drill core is 35° at 53, 45° at 73 ft.
73.5–145		Pegmatite.
	73.5	Hanging wall contact not recovered.
	73.5–74.5	Quartz-albite-muscovite pegmatite. Muscovite abundant in selvage.
	74.5–82.0	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (40 percent), microcline (15 percent), muscovite (5 percent).
	82–145	Quartz-albite-microcline-spodumene pegmatite. Spodumene (15 percent) is partially altered below 115 ft. Drilling stopped at 145 ft because of caving. Footwall contact not intersected.

Hole no. 5

Location: U. S. Bureau of Mines coordinates: North 3917.6, East 631.7.
Bearing: S. 68° 55′ W.
Inclination: Minus 46°.
Altitude: 5,180.1 ft.
Length: 143 ft.

Feet		*Description*
0–20		No core.
20–114		Fine-grained quartz-mica schist with thin garnetiferous beds. The angle of bedding and foliation to the drill core is 2° at 25, 4° at 48, and 73, 13° at 82, 0° at 87, 2° at 98, 7° at 112, 12° at 113 ft.
114–138		Pegmatite.
	114	Hanging wall contact not recovered.
	114–118.7	Quartz-albite-muscovite pegmatite with accessory cassiterite. Minor albite in first 2 ft.
	118.7–126.7	Quartz-albite-microcline pegmatite. Quartz (50 percent), albite (30 percent), microcline (20 percent).
	126.7–132	Spodumene-quartz-albite-microcline pegmatite. Quartz (30 percent), albite (30 percent), spodumene (35 percent), microcline (5 percent).
	132–138	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (40 percent), microcline (15 percent), muscovite (5 percent).
	138	Footwall contact not recovered.
137.5–143		Fine-grained quartz-mica schist with thin garnet rich beds. The angle of bedding and foliation to the drill core is 60° at 139, 40° at 143 ft.

Hole no. 6

Location: U. S. Bureau of Mines coordinates: North 4075.4, East 642.1.
Bearing: S. 68° 28′ W.
Inclination: Minus 45°.
Altitude: 5,117.1 ft.
Length: 341 ft.

Feet		*Description*
0–30		No core.
30–130		Fine-grained quartz-mica schist with thin garnetiferous beds. Cut by small quartz veinlets. The angle of bedding and foliation to the drill core is 10° at 51, 5° at 80, 8° at 117, 22° at 119, 10° at 130 ft.
130–132.5		Quartz-oligoclase vein.
132.5–168.5		Quartz-mica schist with numerous garnet-bearing beds. The angle of bedding and foliation to the drill core is 11° at 133, 3° at 150, 4° at 168 ft.
168.5–173.6		Pegmatite.
	168.5	Hanging wall contact is 15° to the drill core.
	168.5–173.6	Quartz-albite-muscovite pegmatite with conspicuous accessory cassiterite. Quartz (45 percent), albite (35 percent), muscovite (about 20 percent), cassiterite (between ½ and 1 percent).
	173.6	Footwall contact is 65° to the drill core.
173.6–223.6		Fine-grained quartz-mica schist with thin garnet-bearing layers. The angle of foliation and bedding to the drill core is 0° at 174, 12° at 180, 30° at 185, 35° at 208, 0° at 212, 10° at 213 ft.

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Logs of U. S. Bureau of Mines diamond-drill holes, Mateen pegmatite—Continued

Hole no. 6—Continued

Feet	Description	
223.6–281.3	Pegmatite.	
	223.6	Hanging wall contact is 60° to the drill core.
	223.6–224	Quartz-albite-muscovite pegmatite.
	224–225.2	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (25 percent), microcline (30 percent), muscovite (5 percent).
	225.2–232.5	Quartz-microcline-albite-spodumene pegmatite. Spodumene (5 percent) mostly altered, soft, and green. Quartz (40 percent), microcline (30 percent), albite (20 percent), muscovite (5 percent).
	232.5–239	Quartz-microcline-albite pegmatite. Quartz (45 percent), microcline (30 percent), albite (27 percent), muscovite (3 percent).
	239–258.9	Quartz-microcline-albite-spodumene pegmatite. Spodumene soft and green. Quartz (45 percent) albite (20 percent), microcline (25 percent), spodumene (7 percent), muscovite (3 percent).
	258.9–262.8	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (30 percent), microcline (27 percent), muscovite (3 percent).
	262.8–270	Quartz-albite-microcline-spodumene pegmatite. Minor muscovite. Spodumene altered. quartz (35 percent), albite (30 percent), microcline (30 percent), spodumene (5 percent).
	270–281.3	Quartz-albite-microcline pegmatite. Minor muscovite.
	281.3	Footwall contact is 60° to the drill core.
281.3–286.6	Quartz-mica schist with thin garnet beds. The angle of bedding and foliation to the drill core is 55° at 282, 78° at 286 ft.	
286.6–333.7	Pegmatite.	
	286.6	Hanging wall contact is 70° to core.
	286.6–286.7	Quartz-albite-muscovite pegmatite.
	286.7–290.3	Quartz-albite-microcline pegmatite.
	290.3–293.9	Quartz-albite-microcline-spodumene pegmatite.
	293.9–295.8	Quartz-albite-microcline pegmatite. Has 2-in. schist parting with thin quartz-albite-muscovite selvages at 294.0 ft.
	295.8–330.8	Quartz-albite-microcline-spodumene pegmatite. Spodumene altered and soft. Quartz (40 percent), albite (25 percent), microcline (25 percent), spodumene (10 percent).
	330.8–333.7	Quartz-albite-microcline pegmatite. Pyrite in fractures.
333.7–341	Quartz-mica schist with thin garnet beds. The angle of bedding and foliation to the drill core is 10° at 334, 50° at 336, 55° at 340 ft.	

Hole no. 7

Location: U. S. Bureau of Mines coordinates: North 4202.7, East 561.2.
Bearing: S. 67° 25′ W.
Inclination: Minus 45°.
Altitude: 5,085.3 ft.
Length: 300 ft.

Feet	Description	
0–40	No core.	
40–138.8	Fine-grained quartz-mica schist with occasional garnetiferous beds as much as 2 in. thick. The angle of bedding and foliation to the drill core is 15° at 47, 30° at 70, 17° at 80, 0° at 113, 5° at 138 ft.	
138.8–169	Pegmatite.	
	138.8	Hanging wall contact not recovered.
	138.8–148.7	Quartz-albite-microcline-muscovite pegmatite. Quartz (30 percent), albite (30 percent), microcline (30 percent), muscovite (10 percent).
	148.7–158	Microcline-quartz-albite-spodumene pegmatite. Spodumene mostly fresh. Quartz (30 percent), albite (25 percent), microcline (35 percent), spodumene (10 percent).
	158–159.4	Quartz-albite-muscovite pegmatite. Accessory cassiterite in lower part.
	159.4–164	Quartz-albite-microcline pegmatite with minor altered spodumene.
	164–169	Quartz-albite-muscovite pegmatite. Quartz (45 percent), albite (30 percent), muscovite (25 percent).
	169	Footwall contact is 30° to the drill core.
169–190.9	Quartz-mica schist with thin garnet-bearing beds. The angle of bedding and foliation to the drill core is 20° at 169, 36° at 174, 70° at 183, 90° at 190, 70° at 190.7 ft.	

Logs of U. S. Bureau of Mines diamond-drill holes, Mateen pegmatite—Continued

Hole no. 7—Continued

Feet		*Description*
190.9–230.3	Pegmatite.	
	190.9	Hanging wall contact is 50° to the drill core.
	190.9–191.9	Quartz-albite-muscovite pegmatite. Quartz (40 percent), albite (35 percent), muscovite (25 percent).
	191.9–200	Quartz-albite-microcline pegmatite.
	200–206	Quartz-albite-microcline-spodumene pegmatite. Spodumene green and soft.
	206–215	Quartz-albite-microcline pegmatite. Quartz (40 percent), albite (30 percent), microcline (25 percent), muscovite (5 percent).
	215–228.9	Quartz-microcline-albite-spodumene pegmatite. Spodumene altered. Quartz (40 percent), microcline (30 percent), albite (25 percent), spodumene (5 percent).
	228.9–230.3	Quartz-albite-muscovite pegmatite. Quartz (50 percent), albite (40 percent), muscovite (10 percent).
	230.3	Footwall contact is 50° to the drill core.
230.3–300	Quartz-mica schist with thin garnet-bearing beds. The angle of bedding and foliation to the drill core is 0° at 231, 12° at 242, 15° at 254, 0° at 258, 15° at 264, 0° at 269, 15° at 294 ft.	

Hole no. 8

Location: U. S. Bureau of Mines coordinates: North 4347.1, East 514.7.
Bearing: S. 69° 36′ W.
Inclination: Minus 45½°.
Altitude: 5059.8 ft.
Length: 340 ft.

Feet		*Description*
0–40	No core.	
40–148.8	Fine-grained quartz-mica schist with garnetiferous beds up to ½ in. thick. The angle of bedding and foliation to the drill core is 15° at 44, 5° at 54, 15° at 59, 20° at 67, 25° at 81, 0° at 82, 20° at 107, 50° at 116, 70° at 127, 87° at 144 ft.	
148.8–210.9	Pegmatite.	
	148.8	Hanging wall contact not recovered.
	148.8–150.3	Quartz-albite-muscovite pegmatite. Quartz (45 percent), albite (40 percent), muscovite (15 percent).
	150.3–153.9	Quartz-microcline-albite-muscovite pegmatite. Quartz (35 percent), albite (25 percent), microcline (30 percent), muscovite (10 percent).
	153.9–198	Quartz-microcline-albite-spodumene pegmatite. Spodumene altered. Schist parting and thin quartz-albite selvage at 167.5 ft. Quartz (35 percent), albite (25 percent), microcline (30 percent), spodumene (7 percent), muscovite (3 percent).
	198–207.9	Quartz-albite-microcline pegmatite.
	207.9–210.9	Quartz-albite-muscovite pegmatite.
	210.9	Footwall contact is about 45° to the drill core.
210.9–340	Fine-grained quartz-mica schist with garnet-bearing beds as much as ½ in. thick. Quartz veinlets at 301 to 303, 310.8 to 313.2, 314 to 316, 324 to 326, and 330 to 331 ft. The angle of bedding and foliation to the drill core is 44° at 211, 30° at 226, 0° at 241, 5° at 243, 30° at 251, 20° at 302, 47° at 310, 35° at 314, 45° at 340 ft.	

Ten samples of hand-picked spodumene crystals were analyzed for lithia. Five, collected by F. F. Clarke, were analyzed by the U. S. Bureau of Mines at their Rolla laboratories. The other five, collected by L. R. Page, were analyzed by R. E. Stevens in the Chemical Laboratories of the U. S. Geological Survey at Washington. Each group of five included the most altered and also the freshest spodumene in the trenches. The lithia content of the individual crystals is given below.

Hole no.	*Core interval*	*Percent tin*
5	114.0–118.0 ft	0. 45
6	168.5–173.6 ft	. 25

U. S. Geological Survey samples	*Percent* Li_2O	*Description*
LRP-1M-44	5. 88	Weathered crystal.
LRP-2M-44	6. 20	Hard crystal.
LRP-3M-44	6. 94	Dull white, soft, chalky crystal.
LRP-4M-44	6. 89	Dull white to glassy crystal.
LRP-5M-44	6. 78	Very soft splintery crystal.

Two core samples that contained visible cassiterite which were not sent to Rolla for lithia analyses, but were analyzed for tin by Charles Bentley, Mining Experiment Station, South Dakota School of Mines at Rapid City, for the U. S. Geological Survey. These samples probably represent the higher grade tin-bearing rock. The results were as follows:

U. S. Bureau of Mines samples	*Percent* Li_2O	*Description*
100	5. 36	Soft.
101	5. 00	Altered.
102	5. 68	Hard.
103	6. 24	Hard.
104	5. 61	Hard.

RESERVES

The pegmatite between sections A–A′ and F–F′ (pl. 26) has been sufficiently exposed at the surface and explored by drilling to indicate reserve tonnages rather closely. For tonnage calculations the dike has been divided by the U. S. Bureau of Mines into two blocks (Blocks A and B) with the division 100 ft vertically below the intersection of the hanging wall with the surface. Calculations by the U. S. Bureau of Mines engineers show that block A contains 217,084 tons of spodumene-bearing pegmatite, containing 0.47 percent of lithia. The upper 25 ft of block A was calculated separately and contains 55,918 tons of spodumene-bearing pegmatite, indicated by the surface bulk samples to average 0.77 percent of lithia.

There are 187,600 tons of spodumene-bearing pegmatite in block B, below block A, but the lithia content is less than 0.10 percent.

Lithia was apparently insufficiently concentrated in any large block of the pegmatite to be profitably extracted at 1944 prices. The quantity of lithia in the spodumene is of considerable importance in determining the grade of concentrate that can be produced by milling. The upper 25 ft of block A may possibly be of commercial interest, under favorable conditions, if the spodumene contains about 6.5 percent of lithia as indicated by the first set of analyses of table 39.

The dike was not drilled north of section A–A′, where it plunges below the surface, so its extent in this direction is not known. It can be inferred that a few thousand tons of pegmatite containing about 0.6 percent lithia might occur in the upper portion of the dike just north of section A–A′.

The south dike contains a spodumene-bearing zone but it was sampled by only one trench. The samples in the spodumene-bearing zone cut by this trench averaged 0.40 percent lithia.

MICA KING NO. 1 MINE (CUSTER DISTRICT)

by J. W. Adams

The Mica King No. 1 mine, formerly known as the Cook mine, is in the NE¼ sec. 33, T. 3 S., R. 5 E., Custer County. It is owned by the Consolidated Feldspar Corporation of Trenton, New Jersey. The property has not been mapped and has been only briefly visited by geologists of the U. S. Geological Survey.

The property has been developed by an open-cut 145 ft long, 15 to 30 ft wide, and as much as 80 ft deep. In addition there are several smaller cuts, an old debris-filled shaft, and an adit probably not over 20 ft in length.

The pegmatite that has been mined strikes N. 40°–80° W. and dips from 10° to 45° NE. Where observed, the contact with pre-Cambrian schists is concordant. The pegmatite crops out for over 400 ft, forming a prominent ridge with a north slope developed along the hanging-wall surface. The thickness of the pegmatite appears to be 20 to 30 ft. There is some evidence to indicate that the mass plunges N. 45° E. at about 40°.

Four zones are present in the pegmatite, (1) a narrow border zone characterized by abundant small muscovite crystals; (2) a wall zone of plagioclase-quartz-muscovite pegmatite with biotite, perthite, and minor apatite; (3) an intermediate zone of coarse perthite-quartz pegmatite, commonly of graphic structure, and containing scattered muscovite crystals and minor beryl; and (4) a core of pale-rose to white quartz.

The intermediate zone is the source of the feldspar for which the pegmatite has been mined. It is generally 10 to 15 ft thick and surrounds a quartz core in the lower part of the outcrop. This zone contains many large muscovite crystals, some more than 1 ft across; they are generally badly mineral-stained. The mica books are most abundant near the contact with the wall zone. The abundant muscovite of the wall zone is in smaller crystals, generally intergrown with biotite, with which it develops as long lathlike plates that sometimes extend well into the intermediate zone. Undoubtedly a considerable quantity of deep ruby, air- and mineral-stained, flat mica of electrical quality could be produced as a byproduct of feldspar operations. Mining in the hanging-wall zone probably would be profitable for mica alone. None of this mica was purchased by Colonial Mica Corporation in 1943–45.

MICA QUEEN NO. 1 PROSPECT (CUSTER DISTRICT)

by J. J. Norton

The Mica Queen No. 1 mica prospect, in the NE¼ sec. 19, T. 3 S., R. 5 E., Custer County, is on a claim held by William J. Christie and by Kenneth and Godfried Springs of Custer. It was operated intermittently by Cottrill and King during the summer and early fall of 1943. The property was visited by the writer and Stuart Ferguson of the Colonial Mica Corporation on August 16, 1943.

This property has been prospected in two places. At the time we examined it, work was being done in a small pit on a pegmatite 3 to 5 ft thick, consisting principally of quartz, albite, and muscovite. The average strike is N. 40°–45° W., and the dip is 70°–75° southwest. Additional prospecting has been done about 450 ft southeast of this pit, where two pegmatites separated by a schist parting 1 to 2 ft thick have been explored. The average strike of these bodies is N. 45° W. and the dip is 75° SW. The eastern of the two pegmatites is about 2 ft thick, and the western is 10 to 12 ft thick. Mineralogically they are similar to the pegmatite explored to the north. A prospect pit has been opened on the eastern pegmatite, and about 70 ft to the south an adit has been driven through the western pegmatite to the schist parting that separates the two bodies.

The Mica Queen prospect produced about 250 lb of sheet mica that was sold to the Colonial Mica Corporation between July 28 and October 13, 1943. The entire production was small sheet mica, 1 by 1 in. and 1¼ by 1¼ in. full trim.

Substantial mica reserves are doubtless still available on this claim, but it is likely that the proportion of mica in the rock is too small for profitable mining.

MICHAUD BERYL CLAIM (CUSTER DISTRICT)

by W. C. Stoll

The Michaud claim is in the center of the E½ sec. 14, T. 4 S., R. 3 E., Custer County, about 6½ miles southwest of Custer. The claim is reached by driving from Ninemile Ranch, on the Pleasant Valley road, 3½ miles north on the Lightning Creek road to the Michaud Ranch, and about half a mile farther to where the cuts are visible on the hillside east of the road. In 1942 the owner was the Custer Pegmatite Company, whose local representative seemed to be W. L. Machtle of Rapid City, South Dakota. Francis Michaud sold the property to the present owner in 1930. In 1930 and 1931 about 20 tons of beryl was produced, together with a little feldspar and scrap mica. Beryl is the principal product of this property. Since 1931 assessment work only has been performed, but an additional 5 to 6 tons of beryl was produced. The only openings are two small cuts 60 ft apart. The altitude of the floor of the larger cut is about 5,355 ft.

The Michaud pegmatite is a small body (fig. 22), exposed for 120 ft along its strike of N. 35° W. The width of the outcrop ranges from 5 to 25 ft. The footwall contact of the pegmatite, against biotite-quartz schist, dips 70° N., discordantly with the schist, which strikes parallel but dips steeply southward.

The pegmatite consists of pink perthite and massive quartz intergrown with muscovite, pink albite, and beryl. Most of the beryl is exposed in the larger cut. The mineral is massive or in "shells" which show few crystal faces. The beryl masses range in diameter from 1 to 12 in. and are mixed with abundant pink albite and a little muscovite. Great difficulty has been experienced in cleaning the beryl, but past shipments reportedly have shown that even without much cobbing the ore contains more than 10 percent of BeO. In 1942 it was estimated that one of the walls of the larger cut contained about 20 percent of beryl.

MIDAS MICA MINE (CUSTER DISTRICT)

The Midas mica mine, in the SE¼ sec. 14, T. 4 S., R. 4 E., Black Hills Meridian, Custer County, is owned by Jesse Brocha of Custer. From December 1943 to September 1944 it was operated by Joe Cummings of Custer.

The Midas pegmatite was mapped by L. R. Page and Peter Joralemon May 7 to 9, 1944. A plane-table map of the surface geology and underground maps were made on a scale of 1 in. to 20 ft. The property was diamond drilled in April 1944 by the U. S. Bureau of Mines (Clarke, 1944, p. 9).

MINE WORKINGS

The workings on the Midas property, when mapped, comprised an open-pit 45 ft long, 12 ft wide, and 11 ft

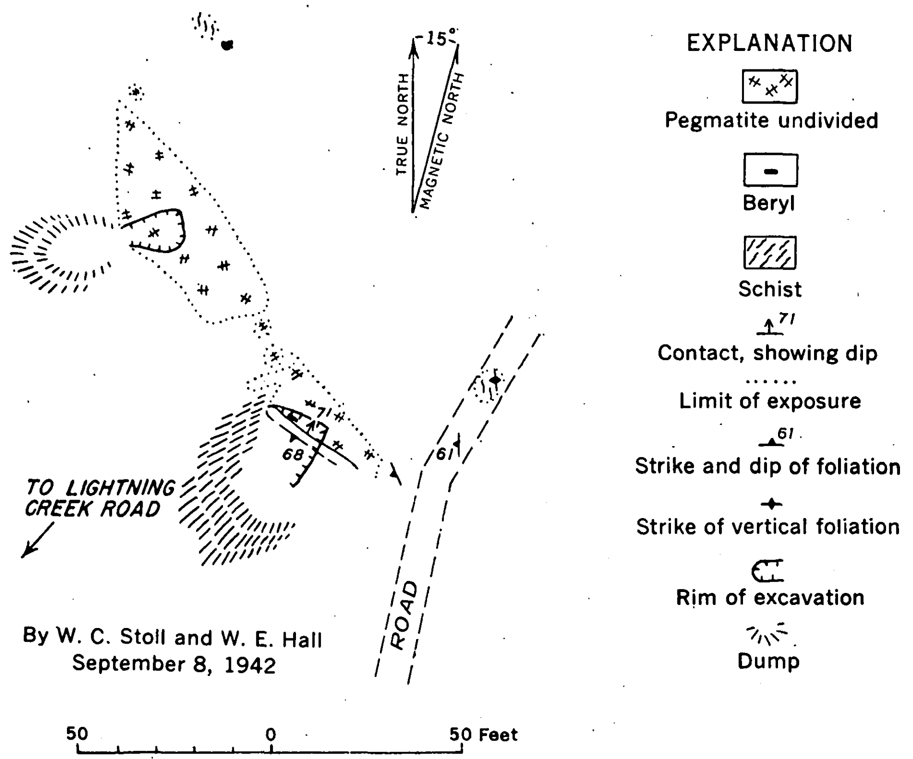

FIGURE 22.—Plan of workings, Michaud beryl claim, Custer County, South Dakota.

deep; a 52-ft shaft inclined 70° to the west; a drift 18 ft north and 66 ft south of the shaft; and two small stopes above the drift (pl. 28). Subsequent to the mapping the shaft was extended about 8 ft and the south drift was extended about 20 ft. Some additional stoping was done above the drift and the level was benched south of the shaft for about 50 ft. A second dike northwest of the mapped area was prospected by an open-cut.

GEOLOGY

The Midas pegmatite is one of a series of parallel pegmatites that in general trend N. 20° W. and dip steeply west. They are intruded into pre-Cambrian mica schists. The Midas pegmatites is the only one that shows sufficient muscovite in books large enough to be a possible source of sheet mica. The group of pegmatites west of the shaft (pl. 28) apparently converges to the south to form a large composite mass of pegmatite. Thin schist partings in this mass, and also abrupt changes in texture and mineralogy, suggest that it has resulted from the coalescing of numerous dikes. These pegmatites have been mapped as perthite-albite-quartz (undivided) pegmatite.

The Midas pegmatite is 570 ft long and as much as 8 ft wide; the average width is about 4 ft. The northern 40 ft of it strikes about N. 20° E. and dips about 50° NW. The central part strikes N. 5° W. and dips about 70° SW., whereas the southern half strikes N. 20° W. and dips 55°–70° SW. In detail the contacts are irregular and the rolls plunge 25°–40° to the southwest; the average plunge is about 30°. The main part of the dike has been mapped as albite-perthite-muscovite pegmatite, and four small areas of quartz-perthite pegmatite are shown. About 60 ft south of the shaft and 5 ft west of the main dike is a parallel lens of mica-bearing pegmatite, 35 ft long and as much as 4 ft wide. Three quartz veins crop out just west of the Midas pegmatite.

Underground, the pegmatite is as much as 6 ft thick and appears to lens out about 55 ft south of the shaft, though a few narrow stringers extend along the drift in altered schist. This zone of stringers in altered schist, a granitic to sugary grained feldspar-rich rock, seems to connect with similar stringers on the surface 70 to 95 ft south of the shaft. Mining completed after the mapping proved that another pegmatite lens extended south of the face mapped.

MICA DEPOSITS

Books of muscovite are scattered through the exposed length of the Midas pegmatite. They are common around the outer edges of the quartz-perthite pegmatite and in general appear most abundant in the northern 200 ft of the pegmatite exposure.

Production records, together with structural considerations, suggest that the open-pit and shaft exposed two mica shoots that pitch about 30° SW. The shoots apparently joined just above the drift level (see longitudinal section in pl. 28).

Apparently, the open-pit and shaft were started in a mica shoot about 12 ft wide and 5 ft thick that pitches about 30 degrees S. 10° W. A second mica shoot, having a similar attitude and a width of 25 to 30 ft, crosses the lower part of the shaft. The north drift appears to have passed through this latter shoot, and to the south of the shaft the shoot apparently joins with the mica shoot worked in the open-pit. In the shaft the upper mica shoot contained at least 0.3 lb of sheet mica per ton of rock and the lower one 0.80–0.85 lb per ton. It is estimated that the rock on either side carries about 0.15 lb of sheet mica per ton. The stope on the south drift encountered little, if any, mica more than 12 ft above the drift except in the south end. However, the drift itself produced more mica between the raise and the end of the pegmatite than did any other part of the workings. This part of the pegmatite contained 1.24 lb of sheet mica per ton of rock.

The mica is in hard, flat, deep-ruby books generally less than 6 in. in maximum dimension. They are in part ruled and contain moderate quantities of mineral inclusions. "Silver spots" are not uncommon.

The pegmatite mined on the property prior to May 15, 1944 is estimated at 709 tons, from which 10,400 lb of crude mica was recovered. From this crude mica 348 lb of small and large sheet mica was recovered, of which approximately 10 percent was larger than 1½ by 2 in.

The mica from the Midas mine is of good quality. Perhaps the best estimate of its quality is based on qualification by Colonial Mica Corporation during the period March 8 to May 13, 1944. The weighted average for this period is 15.5 percent no. 1 quality, 50.8 percent no. 2 quality and 33.7 percent no. 2 inferior quality. The maximum range in recorded qualities of individual shipments is 0–41 percent no. 1, 1–86 percent no. 2 and 3–99 percent no. 2 inferior.

U. S. BUREAU OF MINES DIAMOND DRILLING

Two diamond-drill holes were made on the Midas property by the U. S. Bureau of Mines in their project for investigation of mica pegmatites in 1944. These holes, each 110 ft deep, prospected the downward extension of mica shoots recognized in the Midas mine.

The holes were drilled east at minus 45° to intersect the pegmatite 30 ft below the 52-ft drift level and 60 ft down the plunge of the mica shoots.

Hole no. 1 (pl. 28) intersected the Midas pegmatite from 101–106.1 ft; included in this zone is a granitic rock that appears to be altered schist. Muscovite of possible economic value was cut at 100–101.3 and 102.5–104 ft. Detailed information is given in the logs of the drill holes. At hole no. 2 (pl. 28) the drill intersected the Midas pegmatite at 100–104.5 ft, and cut mica-bearing pegmatite at 100–102.4 ft.

Logs of U. S. Bureau of Mines diamond-drill holes, Midas mine

Hole no. 1

Feet	Description
0–8	No core.
8–12	Biotite-quartz schist. Dark-gray, medium-grained, friable, cross-bedded, and folded.
12–13.6	Pegmatite composed of perthite, quartz, muscovite, albite, tourmaline, garnet, and apatite. At 12–12.5 ft the rock is perthite (50 percent), quartz (40 percent), and muscovite (10 percent). The muscovite is ruby colored but probably would be useful only as scrap. At 12.8–13.3 ft there is as much as 40 percent scrap mica in the drill core. The hanging wall of the pegmatite is 75° and the footwall is 70° to the drill core.
13.6–14.1	Quartz-biotite schist. Light-gray color. Bedding and foliation is 60° to the drill core.
14.1–14.3	Pegmatite. Muscovite (10 percent) in thin flakes. Quartz (80 percent) and feldspar (10 percent) comprise the rest of the rock. The hanging wall is 80° to the drill core.
14.3–15.1	Quartz-biotite schist, light-gray, medium-grained. Foliation is 80° to the drill core.
15.1–15.5	Pegmatite. Feldspar (85 percent), quartz (10 percent), muscovite (5 percent); walls 75° to the core.
15.5–67	Quartz-biotite schist, light-gray, medium-grained. Bedding and foliation 65° to 75° to the drill core.
67–95	Biotite-muscovite schist. Well foliated, dark gray. Foliation 70° to the drill core. Thin quartz veins at 80, 85, and 85.5 ft.
95–100	Quartz-biotite schist, light-gray, fine- to medium-grained.
100–101	Biotite-muscovite schist. Coarse-grained.
101–106.1	Pegmatite. (Midas pegmatite.)
	100–101.3 Border zone of quartz and muscovite; ruby muscovite, strongly ruled, parts of books, 1½ by ½ by ⅛ in.
	101.3–102.5 Graphic perthite and quartz. Part of mica book, 1 by 1 by ½ in., recovered at 102 ft. Showed ruling, but otherwise indicated good quality cutting mica
	102.5–104 Muscovite, gray to buff albite, and perthite. Estimated as 20 to 30 percent muscovite; mostly small books, though parts of books up to 1 by 1 by ¾ in., were recovered. The mica is ruby, hard, flat, and strongly ruled. Some core lost 103.5–104 ft, probably mica zone.
	104–104.7 Quartz-perthite-albite-tourmaline pegmatite with accessory apatite in half of the drill core (lengthwise) and fine grained tourmalinized schist in tae other half.
	104.7–105.9 Granitic rock, medium-grained, light-colored. Perhaps altered schist.
	105.9–106.1 Perthite and quartz. One-inch muscovite zone on lower contact.
106.1–107.7	Feldspathic schist. Feldspar content decreases outward from pegmatite contact.
107.7–110	Biotite-muscovite schist. Coarse-grained. Foliation and bedding 65° to the drill core.

Drill hole no. 2

Feet	Description
0–5	No core.
5–9	Pegmatite. Quartz, perthite, and muscovite.
9–11	Feldspathic schist. Tourmalinized. Fine- to medium-grained.
11–19	Pegmatite. Perthite, quartz, tourmaline, and muscovite. Largest mica book ¾ by ⅜ by ⅛ in.
19–28.5	Biotite-quartz schist. Well foliated, dark-gray. Foliation 60° to the drill core.
28.5–32.5	Pegmatite. Perthite, quartz, tourmaline, muscovite, and apatite. Probably no sheet mica.
32.5–41	Quartz-biotite schist. Light-gray, medium-grained.
41–46	Biotite-muscovite schist. Fine- to medium-grained.
46–70	Quartz-biotite schist. Light-gray, cross-bedded. Foliation 60° to the drill core.
70–99	Biotite-muscovite schist. Dark-gray, fine- to medium-grained. At 79 ft, 2 in. of quartz-biotite-feldspar pegmatite.
99–100	Biotite-muscovite schist. Tourmalinized, coarse-grained.
100–104.5	Pegmatite (Midas pegmatite).
	100–102.4 Quartz-perthite-albite-muscovite pegmatite with scattered tourmaline. Probably the mica zone; estimated to be 10 percent muscovite, part of which is flat, hard, ruby mica. Some books must have been at least 1 in. thick. Poor drill core recovery of this section suggests there is additional muscovite in this zone.
	102.4–104.5 Quartz-albite-perthite pegmatite.
104.5–105.5	Feldspathic schist. Grades into quartz-biotite schist.
105.5–110	Quartz-biotite schist. Light-gray; feldspathic.

RESERVES

The total reserves of mica in the Midas pegmatite cannot be accurately calculated. The mine was a marginal operation under conditions existing in 1944 and required maximum efficiency in mining and preparation. With depth, however, better mica rock was recovered and there is no reason to doubt that it extends downward. Perhaps additional mica shoots can be found south of the present workings. The U. S. Bureau of Mines drill holes (pl. 28) intersected pegmatite that resembles the pegmatite at the surface and in the underground workings. The drill cores indicate that above the 80-ft level there is at least 1400 tons of pegmatite that contains about 1 pound of sheet mica per ton.

MOHAWK MICA PROSPECT (CUSTER DISTRICT)

The Mohawk mica prospect, also known as the Langford claims, is on the top of a ridge southeast of the Walsh Ranch in the SW¼ sec. 27, T. 3 S., R. 5 E., Custer County. The claim was located by W. Langford, who is said to have sold the claim to L. L. Landis and Delbert McKenna in the spring of 1944. In that year L. H. Jeffries prospected two dikes on the property for mica. The production was 767 lb of crude mica that contained 36.63 lb of small and large sheet.

The property was visited by L. R. Page on May 26, 1944.

One of the two pegmatites on the property was worked many years ago for ruby mica. The other has been prospected for feldspar and a white to greenish mica.

The east end of the pegmatite containing ruby mica has been prospected by an open-pit about 50 ft long, 15 ft wide, and 8 to 10 ft deep. The pegmatite is about 270 ft long and as much as 10 ft thick. The western 70 ft is narrow and strikes N. 50° E. and dips steeply northwest, though the wider eastern end strikes east and dips vertically. The eastern 200 ft of the dike has a fine-grained wall zone, 1 to 2 ft thick, around a core of plagioclase, perthite, and quartz in crystals and masses as much as 8 ft in diameter. Books of ruby muscovite as much as 6 or 8 in. across occur in the coarser pegmatite. The mica observed was heavily air-stained.

The pegmatite containing white mica is about 60 ft northwest of the one with ruby mica. The outcrop is roughly oval in plan, with a sharp anticlinal roll (?) projecting from the hanging wall. The footwall of the dike appears to dip 30° NW. and the hanging wall has a general dip of about 50° NW. The exposure is about 100 ft long in a N. 45° E. direction, and 50 ft wide. The white mica apparently occurs with quartz between the large feldspar crystals that form the core of the dike. The wall zone, 1 to 2 ft thick, has little mica. Books 12 in. long and 2 in. thick were seen in places. The mica is in part air-stained, and in part has wedge or "A" structure.

MOHAWK TIN MINE (HILL CITY DISTRICT)

The Mohawk tin mine, in the SE¼ sec. 25, T. 1 S., R. 4 E., is on the north side of Allen Gulch, ½ mi west of Hill City, Pennington County. This patented claim, 300 by 1,500 ft, was located in August 1883 after cassiterite was recognized in concentrates from gold-placer operations. This was the site of the first discovery of tin in the Hill City area. Mr. George W. Coats, Mr. H. G. Mills, and Mr. F. W. Mills held the property until December 1941 when it was optioned to Mines Minerals Metals, Incorporated, pending clearance of the tax title. The property was operated by Barium Stainless Steel Company in 1944. This company rehabilitated the no. 1 shaft and levels. The upper (no. 2) shaft was sunk about 30 ft below the first level before operations ceased.

The property was first worked by the Harney Peak Company, which sank a 42-ft shaft (now covered by dump), and drove the no. 1 adit, which is about 200 ft long. The most extensive work was done by the National Tin Company about 1917. The two shafts, and several hundred feet of drift were made at this time. A drift at the 45-ft level was made from the no. 1 shaft 320 ft north, and a raise (the no. 2 shaft, said to be 86 ft long) was made to the surface (Gardner, 1939, pp. 31–33). This part of the mine was prepared for stoping, but no ore was removed until 1944. The drift was extended south of the no. 1 shaft to where the stope is open to the surface. The rich ore shoot removed from this stope was said to plunge about 45° NW. According to Gardner (p. 31) about 320 feet of drifting was done on the 100-ft level, but Mr. H. G. Mills says that no drifting was done here. The vein is said to be strong on the 100-ft level.

The mine was visited with Mr. George W. Coats and H. G. Mills, July 19, 1942. W. C. Stoll and J. B. Hanley assisted in mapping the surface geology by telescopic alidade and plane table (fig. 23) and the no. 1 adit by tape and compass.

Quartz-mica schist lies close to the surface on most of the Mohawk claim, but alluvium fills the main valley and tributary gulches to a depth of more than 4 ft. Placer cassiterite is found in the alluvium.

The Mohawk tin vein strikes approximately N. 20° W. and dips 45–55° NE. on the west side of the no. 1 shaft, but has a variable dip to the southeast. The vein crops out as two distinct lenses of quartz, muscovite, beryl, and cassiterite, separated by a break of 150 ft just north of the no. 1 shaft. Probably these lenses were never connected. The vein southeast of the shaft is as much as 4 ft thick; the average thickness is about 2½ ft. It is somewhat irregular in strike and dips 60°–75° NE. South of the fault the vein dips 40° NE. and is only 8 in. thick. This part of the vein is mostly milky quartz with thin selvages of muscovite, beryl, and cassiterite. Irregular patches of muscovite and pale-yellow to white beryl, as much as 2 in. in diameter, occur scattered throughout the vein. According to George W. Coats, the ore shoot removed from the stope was composed predominantly of muscovite, with a beryl gangue. Mr. H. G. Mills says the ore milled from the stope contained about 5 percent cassiterite.

The northern lens of the vein crops out as a body less regular in shape and thickness. At the no. 2 shaft the vein pinches and swells from a maximum of 45 in. to less than 18 in. in thickness. The average thickness for about 100 ft is about 24 in. The dip is

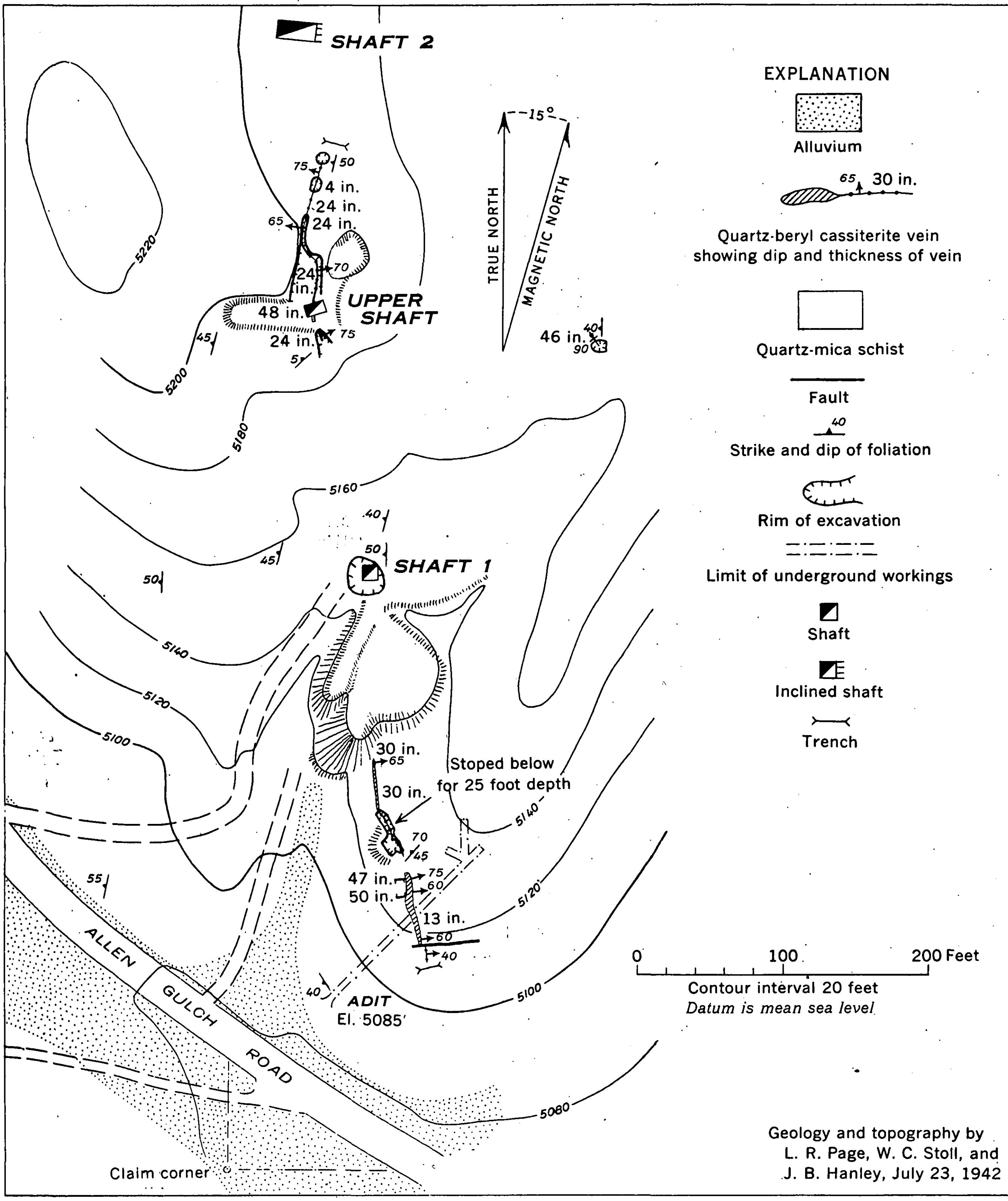

FIGURE 23.—Geologic map, Mohawk tin mine, Pennington County, South Dakota.

45°–75° NW. in the northern part, and 70°–90° E. in the southern part. The westerly dips shown on the map were probably taken on offshoots from the footwall of the main vein. The wider parts of the vein are quartz, whereas the narrower parts are mostly muscovite. Beryl is rare. Cassiterite is most abundant in the more micaceous parts of the vein, although a few large grains occur in the quartz.

The no. 1 adit (fig. 23) is almost entirely in quartz-mica schist, although a quartz vein was observed near the end of the crosscut.

At the surface the vein seems to consist of two lenticular parts that plunge about 25° to the north.

According to H. G. Mills the north drift on the 45-ft level left the vein at about 45 ft, and after passing through about 120 ft of schist followed the vein to the no. 2 shaft. This second vein is apparently the one exposed at an altitude of 5,200 ft. It is reported that this vein was stoped, in part, during 1944.

The reserves of tin-bearing and beryl-bearing vein material are probably too small and too low grade to warrant the expense of mining and milling under present prices.

MONKEY LODE MICA MINE (HILL CITY DISTRICT)

by J. J. Norton

The Monkey Lode mica mine was one of the important mica producers in the southern Black Hills during 1943, but was closed at the end of the year because the quality of the mica was too low to be acceptable to the Colonial Mica Corporation. The operators were Carl Pettit and Basil and Claude Canfield of Hill City, South Dakota. The mine is in the NW¼ sec. 17, T. 2 S., R. 5 E., Pennington County.

The property was examined September 28, 1943, by the writer and Stuart Ferguson of the Colonial Mica Corporation.

The pegmatite at the Monkey Lode is exposed along a steep hillside as a dip slope for a length of at least 100 ft. The altitude of the mine is about 5,400 ft. The pegmatite strikes N. 80° E., and dips about 35° NW. The thickness is at least 15 ft, but the footwall is not exposed. The interior of the pegmatite is composed of coarse-grained quartz-perthite pegmatite. A zone of quartz-albite-muscovite pegmatite lies above the quartz-perthite pegmatite and apparently forms the hanging-wall part of the body. The contact is very irregular, and many schist inclusions lie within the pegmatite.

The mica from the Monkey Lode was produced from open-pits in the quartz-albite-muscovite pegmatite. During 1943 a total of 4,830.50 lb of punch and 1,811.47 lb of sheet mica was produced. (See table below.) Heavy air-stain reduced most of the sheet mica to no. 2 inferior quality. About 5 percent of the mica sold was no. 2 quality, 81 percent no. 2 inferior quality, and 14 percent no. 3 quality.

A small quantity of beryl has been produced at the Monkey Lode. Colonial Mica Corporation, which purchased 2,217 lb of beryl during 1943, estimated that it contained 10 percent BeO.

Mica reserves in the Monkey Lode consist entirely of air-stained mica and considerable quantities of this mica are readily available. A little beryl may be obtained as a byproduct.

Sheet and punch mica production, 1943, Monkey Lode mine

Total production:		
Small sheet	pounds	969.04
Large sheet	do	842.43
Total sheet	do	1,811.47
Punch	do	4,830.50
Proportion of large sheet to punch:		
Punch	do	4,830.50
Large sheet (1½ by 2 in. and larger, ¾ trim)	do	637.75
Total processed mica	do	5,468.25
Percentage punch		88
Percentage large sheet		12
Proportion of large sheet to small sheet:		
Small sheet (1 by 1 in. and 1¼ by 1¼ in., full trim)	pounds	969.04
Large sheet (1½ by 2 in. and larger, ¾ trim)	do	204.68
Total sheet	do	1,173.72
Percentage small sheet		83
Percentage large sheet		17

MOUNTAIN BERYL CLAIM (CUSTER DISTRICT)

by W. C. Stoll

The Mountain Beryl claim, in the NW¼ sec. 11, T. 5 S., R. 4 E., is 1.9 miles northwest of Pringle, Custer County. The claim comprises 20 acres and is unpatented. The owner in October 1942, when the claim was examined, was S. T. Gamber of Custer. About three tons of beryl has been reported shipped from the property.

Two pegmatitic bodies crop out on the Mountain Beryl claim. One of them, which has an average thickness of about 10 ft, can be traced from a point south of the cut on the Bonnie Lode claim N. 20° W. for 426 ft. The pegmatite is vertical, except at the north end, where the dip is 45° E. The schistose wallrocks are partly concordant and partly discordant with the dike contacts. The pegmatite exposed in five shallow cuts is composed of coarse- to medium-grained perthite and massive quartz with local concentrations of muscovite near the contacts.

The south end of the second and larger pegmatite lies only a few feet north of the smaller one. The prominent outcrop of the main pegmatite can be traced N. 20° W. for 463 ft. Its average width is about 50 ft. Two small excavations have been made near the south end of this body. The country rock, which crops out a few feet east of this pegmatite, is a fine-grained quartz-biotite schist. Its foliation strikes slightly west of north and dips 65°–80° W., about parallel to the footwall of the pegmatite.

Except for a central mass of pegmatite, about 15 ft thick, the outcrop is composed of a mixture of pegmatite and country rock which has been modified by pegmatitic solutions. Pegmatite minerals (including flesh-pink perthite, quartz, beryl, and biotite) form porphyroblasts in the enclosing metamorphic rock. The presence of some of these minerals indicates that they have replaced the country rock.

At cut no. 4 (fig. 24) a few beryl crystals occur in wallrock and in pegmatite. A few of these crystals are as much as 2 in. in diameter. A little beryl occurs also in cuts no. 2 and no. 3. Crystals as large as 18 in. in diameter and 4 ft long, are reported to have been mined here, but none approaching this size was seen.

Perhaps the Mountain Beryl pegmatite could be worked for feldspar, with beryl as a byproduct. The outcrop is apparently the top of a large pegmatite body and the open-pits do not thoroughly prospect the inner zones of the pegmatite that might be expected to contain feldspar.

NEW YORK MICA MINE (CUSTER DISTRICT)

by J. J. Norton

The New York mica mine, formerly the Westinghouse No. 1, is on a group of patented claims in the NE¼ sec. 18, T. 4 S., R. 4 E. It can be reached by driving southwest from Custer 4.7 miles on U. S. Highway 16, then south 2.4 miles on a county road, and east on a dirt road 0.4 mi to the mine. It is one of the oldest and largest mica mines in the Custer district, and has been one of the biggest producers in the United States. It was reopened in January 1943, and entered production the following June.

In 1923 Douglas B. Sterrett (pp. 292–295), who visited the property in August 1908, described the geology of the mine and briefly summarized the history of operation to the date of his visit. W. C. Stoll visited the mine in August 1942, and his unpublished report on the geology, mining operations, and reserves, was accompanied by a tape-and-compass map on a scale of 1 in. to 50 ft. At the time of Stoll's visit most of the underground workings were flooded.

The present report is based on field work by J. J. Norton and L. R. Page. L. C. Pray assisted in some of the field work and did the microscopic determinations. Field work was begun May 22, 1943, and continued, with some interruptions, until July 24, 1943. When the mine closed on November 18, 1943, the maps were revised and brought up to date. A surface map (pl. 29) was made by plane table and alidade on a scale of 1 in. to 40 ft. All accessible underground levels were mapped at waist height by tape and Brunton compass, and seven cross sections were made on a scale of 1 in. to 20 ft (pl. 30). A stope map (pl. 31)

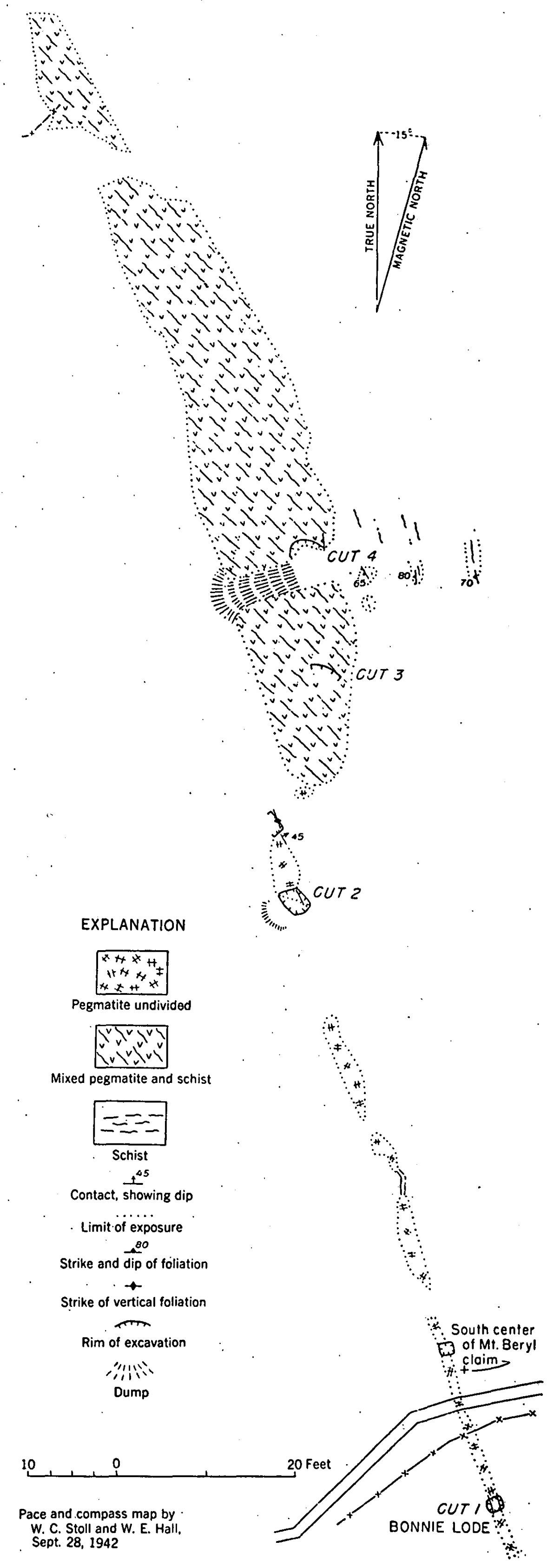

FIGURE 24.—Outcrop map, Mountain Beryl claim, Custer County, South Dakota.

has been prepared on a scale of 1 in. to 40 ft by horizontal projection of the underground workings to a plane striking N. 35° W. and dipping 46° SW. A structure contour map (pl. 31) of the hanging wall of the pegmatite was drawn.

HISTORY AND DEVELOPMENT

The New York mine was first operated in 1879 or 1880. Its early history is summarized by O'Harra (1902, pp. 75-76; Connolly and O'Harra, 1929, pp. 251-252). From the time of its opening to July 1, 1884, it produced 5,700 lb of sheet mica valued at $19,500, ranking third among the mica mines in the district. In 1899, 1900, and 1901 the New York mine was again one of the chief mica producers of the district. During these early years the mining operations were carried on in open-pits, drifts, inclines, and stopes near the surface. Both the hanging-wall and footwall mica zones were worked.

In 1905 (?) the Westinghouse Electric and Manufacturing Company purchased the property and it became known as the Westinghouse No. 1. Most of the underground workings were made by this company and a high rate of production was maintained until the mine was closed about 1911.

In 1934 Westinghouse turned the New York mine over to the New York Holding Association, composed of Gladys Wells, Thomas W. Delicate, Charles E. Perrin, Samuel Coe, and Mrs. M. Ainslee, all of Custer. In 1939 the property was leased to Joseph Buerger and Kem Koch, who drove the crosscut to the footwall near the north end of the main open-pit. In the spring and summer of 1942, Glenn C. Ventling and Lawrence M. Ventling leased the property and mined the hanging-wall mica zone near the south end of the mine. They made the upper 40 ft of the southernmost raise.

In late January 1943, the New York Mine Corporation, under the ownership of A. A. Holland and M. D. McArthur of Denver, Colorado, unwatered the mine and retimbered the shaft. The hanging-wall drifts on the 100-ft level were found to be inaccessible, but a few feet of drifting was done on the footwall mica zone at this level. Mica-bearing pegmatite above the drifts on the 300-ft level were partly stoped out and the old drift was extended 120 ft southward. One raise was made above the new section of the drift (pl. 30).

MINE WORKINGS

The New York mine consists of a 307-ft vertical shaft, about 1,800 ft of drifts, 400 ft of crosscuts, and about 130,000 sq ft of stopes. The principal workings are in the wall zone on the hanging wall of the pegmatite; the same zone on the footwall has been extensively stoped near the surface.

The earliest workings were in the large open-pit on the hanging wall and in a few small pits on the outcrop of the footwall. At a later time inclines were driven down the dip on both mica deposits.

The footwall mica deposit was extensively worked in the early days from a drift 270 ft in length, known as the Savage tunnel (altitude 5,300 ft). Backfilled stopes extend from this level to the surface. The south end of the Savage drift is connected by a short crosscut to the open-pit on the hanging wall of the pegmatite. The Savage level and the open-pit apparently have been known in the past as the "50-ft level" (Sterrett, 1923, p. 294), although they are only 20 ft below the level of the collar of the main shaft and would be more properly termed "20-ft level." At the north end of the footwall workings there is a drift 60 ft long at an altitude of 5,330 ft. This drift is accessible through a crosscut, 40 ft long, that was driven east through the pegmatite in 1939, long after the footwall mica zone had been worked out at this level.

The principal workings in the mine are drifts, crosscuts, and stopes that connect with a 307-ft vertical shaft. The collar of the shaft is in the hanging-wall schist at an altitude of 5,320 ft. Crosscuts to the pegmatite are at depths of 100, 200, and 300 ft. In the hanging-wall mica deposit at each level, long drifts have been run both ways, but the footwall deposit has not been developed extensively.

The hanging-wall drifts on the 100-ft level are mostly caved and inaccessible. The south drift apparently extended about 230 ft along the hanging wall from the crosscut, and the north drift, according to Sterrett (1923, p. 294), extended about 300 ft. The mica deposit has been stoped out and the stope backfilled to the surface. On the footwall the last operator drifted about 15 ft in each direction. The footwall mica deposit has been worked more extensively about 150 ft north of the shaft, where a crosscut was driven from the hanging-wall drift to the footwall and a stope, about 75 ft wide, was extended 75 ft up the dip. These workings are connected to the Savage level by a raise.

On the 200-ft level (altitude 5,120 ft) the south drift extends 250 ft; the north drift has a known length of 130 ft, but it is caved at the end and may extend farther. The hanging-wall mica deposit has been stoped out and the stope backfilled above the 200-ft level for the entire known length of the north drift and for all but the last 50 ft of the south drift. A pillar was left around the shaft where it crosses the pegmatite between the 200-ft level and 100-ft level. Drifts on the footwall at the 200-ft level extend at least 25 ft in each direction. The north drift is caved, and the south drift is cut off at the fault. In 1943 it was filled with debris at the fault, but apparently it once extended to the hanging-wall drift to the south.

The hanging-wall drifts on the 300-ft level extend 100 ft north and 125 ft south of the crosscut. Most of the hanging-wall mica deposit between this level and the 200-ft level has been stoped out and the stope backfilled, but much of the deposit still remains (pl. 31). The footwall mica deposit has not been worked from the 300-ft level. Exploratory crosscuts were driven to the footwall from halfway up each of the two raises connecting the 300-ft and 200-ft levels, but no further work was done in either place.

GEOLOGY

The New York pegmatite crops out in a hogback-like knob surrounded by pre-Cambrian quartz-mica schist with interbedded lenses of hornblende gneiss. The dike and also the enclosing metamorphic rocks have an average strike of N. 35° W. and an average dip of about 45° SW.

QUARTZ-MICA SCHIST AND HORNEBLENDE GNEISS

The quartz-mica schist and hornblende gneiss are exposed principally on the hillside east of the pegmatite and on the long ridge that lies west of the pegmatite knob. Most of the rock is fine- to coarse-grained, dark-gray schist composed of quartz, biotite, muscovite, and a little feldspar. It is of sedimentary origin and the bedding, which is essentially parallel to the schistosity, strikes N. 35° W. and dips 45° SW. The coarser beds contain stretched quartz pebbles ¼ to 1½ in. long whose long axes plunge 34 to 51° S. 14°–40° W.; the average plunge is 41° S. 26° W.

The hornblende gneiss occurs as thin beds and lenses of light-colored rock with irregularly oriented hornblende needles. Probably it is the metamorphic equivalent of calcareous lenses interbedded with the sandstones and shales which produced the quartz-mica schist.

PEGMATITE

The New York pegmatite strikes N. 35° W. and dips 45° SW. The structural evidence indicates that it plunges 41° S. 26° W., and that it was forcefully intruded from this direction. On the surface the pegmatite is 640 ft long and near the north end it attains a thickness of 50 to 60 ft. It narrows gradually to the south, and its average thickness along the central part of the outcrop is about 40 ft. In the crosscut from the shaft on the 100-ft level it is 26 ft thick. In the crosscut on the 200-ft level it is 23 ft thick. Halfway up the raise connecting the north drifts on the 200- and 300-ft levels an exploratory crosscut driven to the footwall shows a thickness of 20 ft. A similar crosscut in the raise that connects the south drifts on these levels is reported to show the pegmatite is 16 ft thick. This crosscut was cleaned out in 1943, but was later backfilled. On the 300-ft level the pegmatite is 18 ft thick south of the fault and 12 ft thick north of the fault. On the basis of these figures, the pegmatite narrows an average of 8 ft for each 100 ft of depth between the surface and the 300-ft level, but the rate of change of thickness is highly varied.

The pegmatite can be divided into five strikingly distinct zones. Quartz-albite-muscovite pegmatite lies at the walls (forming the oldest zone in the dike), and contains the sheet mica for which the mine is operated. It grades toward the center of the dike into a quartz-albite pegmatite that occupies most of the interior of the pegmatite. Quartz pegmatite masses and lenses lie within the quartz-albite pegmatite in a number of places, especially where the large mass of quartz is exposed at the surface (pl. 29). These segments of a quartz pegmatite core are apparently the youngest rock in the pegmatite, and were probably formed from a residual liquid rich in silica. Reaction of this liquid with quartz-albite pegmatite may have formed the intermediate zone of cleavelandite-quartz pegmatite that surrounds each of the quartz bodies. At the north end of the dike the zoning is not so well defined and perthite-quartz pegmatite interfingers with the quartz-albite and quartz-albite-muscovite zones. Part of the perthite-quartz pegmatite probably was formed at the same time as quartz-albite pegmatite.

The plagioclase throughout the pegmatite is albite (An_4–An_9). Tests were made on plagioclase grains from 15 specimens of a series across the pegmatite where a crosscut is driven to the footwall from the north raise between the 200-ft and 300-ft levels, and on 12 specimens from other parts of the pegmatite. Of the 27 specimens, 10 were from the hanging-wall mica zone, 9 were from the footwall mica zone, 7 from the quartz-albite pegmatite, and 1 was cleavelandite from the cleavelandite-quartz pegmatite bordering the quartz core at the surface. The minimum index of refraction of cleavage fragments ranged from 1.528 to 1.531. The indices show little or no differences among specimens from the same zone or from different zones. Apparently there is little zoning within the crystals. The appearance and general character of the albite are fairly uniform in the pegmatite except where it has been developed into cleavelandite. It ranges from white to salmon, and occurs intergrown with quartz as anhedral crystals averaging ½ to 1 in. across.

Scattered patches of a yellowish mica, in crystals as much as ½ in. in diameter, occur in all zones of the pegmatite. They are most abundant in fractures and joints in the surface exposures of the perthite-quartz and the quartz pegmatites. Cleavage flakes of four specimens were found to have the optical properties of muscovite (the beta and gamma indices are about 1.59) but this may possibly be a lithium-bearing muscovite. The yellow mica was formed later than all the other minerals and even followed the development of the shear zones across the pegmatite, as demonstrated by its presence along fractures that cut across shear zones.

Beryl occurs in all zones except the quartz pegmatite.

In the quartz-albite-muscovite pegmatite it occurs as euhedral greenish "shells" of beryl filled with quartz, albite, and muscovite. The index of refraction of the ordinary ray of this beryl ranges from about 1.575 to about 1.583, and the alkali content is accordingly small. The indices increase in the other zones of the pegmatite to as much as 1.590, indicating a rise in the alkali content. The beryl crystals outside the quartz-albite-muscovite pegmatite are generally subhedral to anhedral, and yellow to white.

Quartz-albite-muscovite pegmatite.—The wall zone of quartz-albite-muscovite pegmatite along each contact consists essentially of quartz, white to pink albite, and muscovite, with accessory beryl and considerable tourmaline. The mineral grains in this zone are approximately 2 in. in diameter, but the mica books are as much as 2 ft or more across. The wall zone is 2 to 6 ft thick on the hanging wall, averaging about 4 ft, and 3 to 8 ft thick on the footwall, averaging about 5 ft. The quartz-albite-muscovite pegmatite is not exposed at the north end of the pegmatite, probably because it grades into perthite-quartz pegmatite. Such a gradation can be observed at the north end of the Savage tunnel, where there is a marked interfingering of the two rock types.

A border zone, 2 to 10 in. thick, at the contact of the pegmatite, consists of crystals that are mostly less than 1 in. across. The principal constituents are quartz, albite, and small but very abundant crystals of muscovite.

The larger mica books are generally a foot or more from the wall, so that most of the sheet mica is found between 1 and 4 ft from the contacts of the pegmatite. The mica in the exposed faces in the footwall stopes is probably somewhat larger in average size than that in the hanging-wall exposures. Tourmaline inclusions are common in the footwall mica, but comparatively rare in the hanging-wall mica. Most of the mica books are perpendicular to the wall.

Tourmaline is abundant in the hanging-wall zone, where it occurs as rich patches and streaks generally within a foot or two from the wall at the inner edge of the border zone. In some places areas as much as 2 ft across are composed almost entirely of this mineral. Mica is comparatively scarce in tourmaline-rich portions of the rock. Tourmaline is more common in the hanging-wall zone than it is in the footwall zone, where it occurs only as scattered crystals and as inclusions in the mica.

Beryl occurs in the quartz-albite-muscovite pegmatite as yellowish to pale-green crystals composed of an interior intergrowth of quartz and albite surrounded by a euhedral shell of beryl. In the footwall zone several beryl crystals are inside mica books.

Quartz-albite pegmatite.—Quartz-albite pegmatite occupies most of the interior of the dike and grades outward into quartz-albite-muscovite pegmatite. Bodies of quartz surrounded by cleavelandite-quartz pegmatite lie inside this zone in a few places. At the surface the quartz-albite pegmatite forms the northeastern and northern border of the pegmatite.

The rock is composed mainly of albite and quartz in grains averaging 1 to 2 in. across. The albite is white to salmon-colored, and shows no appreciable difference from the albite in the wall zone. Very little muscovite or tourmaline is present in this zone. Subhedral to anhedral light-yellowish beryl (N_0=approximately 1.585) occurs in small quantities. Perthite occurs in the quartz-albite pegmatite near the north end of the dike, near the gradational contact with the perthite-quartz pegmatite, but elsewhere perthite is very rare. In the adit near the north end of the open-pit, the quartz-albite pegmatite grades into an irregular patch about 8 ft thick containing spodumene and cleavelandite.

Perthite-quartz pegmatite.—Perthite-quartz pegmatite is exposed at the north end of the pegmatite outcrop as an irregular mass about 90 ft across. Underground it grades into the footwall mica-bearing zone at the north end of the Savage tunnel, and in some other places at the north end of the footwall workings perthite crystals occur in the mica-bearing zone.

The principal mineral in this zone is white to pink microcline, with a perthitic intergrowth of pink albite, which occurs in crystals as much as 6 ft across. The other constituents are quartz, a few crystals of spodumene, and white to yellowish anhedral beryl (N_0= approximately 1.586). Some masses of quartz are several feet across. Not uncommonly the perthite is graphically intergrown with quartz.

Cleavelandite-quartz pegmatite.—Cleavelandite-quartz pegmatite encloses the quartz bodies in the pegmatite. The zone consists principally of cleavelandite and quartz, with a little beryl, cassiterite, and columbite-tantalite. In general, the cleavelandite-quartz zone ranges in thickness from a few inches to about 4 ft. The zone is thicker near the north end of the large quartz body on the surface. North of the quartz mass there is a wide triangular exposure of cleavelandite-quartz pegmatite (pl. 29), probably formed along the base of the quartz which has since been eroded away.

The cleavelandite is salmon pink, some of it in radial aggregates as much as 6 in. across. The Ab:An ratio is 96:4, $N\alpha$ being approximately 1.528. The beryl that occurs in the cleavelandite-quartz zone is in light-yellow anhedral crystals and masses with comparatively high indices of refraction (N_0=approximately 1.586).

In the open-cut at the north end of the pegmatite small masses of cleavelandite occur with spodumene, amblygonite, beryl (N_0—1.590) and a lepidolite mica. These masses may be part of the cleavelandite-quartz pegmatite, but its relationship to perthite-quartz pegmatite is not clear.

Quartz pegmatite.—A large mass of quartz pegmatite and a few small quartz veins crop out within the pegmatite at the surface, and a few small lenses have been observed underground. The large quartz body on the surface, where it is cut by a series of shear zones, has been eroded into two outcrops. The borders of this quartz mass dip into the pegmatite at a low angle at the south end and a somewhat higher angle in the north. The low angle of dip at the south end is shown by the fact that erosion to a depth of about 5 ft along the shear zones was sufficient to separate the quartz into two masses, and also by the great width of exposure of the cleavelandite-quartz pegmatite which results from its low angle of intersection with the surface.

The quartz masses consist principally of milky or gray quartz, with some pink albite, cleavelandite, and microcline.

A few quartz "veins" 3 to 12 in. thick, of which only one is large enough and persistent enough to show on the geologic map, lie within the dike, and are enclosed in cleavelandite-quartz pegmatite. Their average strike is N. 35° W. and the dip is approximately 45° NE.

APLITE DIKES

Three aplite dikes, containing blebs and lenses of milky quartz amounting to about a third of the total rock, intrude the schist and gneiss. The aplite is a sugary-textured rock composed of quartz, feldspar, muscovite, and an accessory dark mineral which is probably cassiterite. Cleavage fragments of the feldspar were studied microscopically and found to be almost entirely albite, with little or no potash feldspar.

Two of the dikes crop out discontinuously near the south end of the area mapped (pl. 29). Each dike ranges in thickness from about 2 to 12 in. They are about parallel, with an average strike of N. 55° E. and vertical dips.

The third dike is about 60 ft east of the pegmatite in the east-central part of the area (pl. 29). It is 4 ft wide where exposed near the north end of its known extent, but to the south it can be traced only in the wash, where apparently the width is much less. Its dip is nearly vertical, and its average strike is directly north.

QUARTZ VEINS

In addition to the quartz "veins" within the pegmatite, there are many veins of milky quartz in the country rock, of which seven are as much as 15 in. wide and long enough to trace along the surface and indicate on the map. Countless veins less than 2 in. wide are present.

STRUCTURE

The New York pegmatite and the enclosing schist have an unusually consistent structural pattern. The general strike of the dike is N. 35° W. and the average dip is about 45° SW., conformable with the schist. The large "roll," which sharply offsets the southern part of the pegmatite, is the only major deviation from the general attitude. The principal plunge structures, including the lineation of the schist, the axes of the "rolls" in the pegmatite walls, and the north borders of the mica zones all plunge approximately 41 degrees S. 26° W. The pegmatite itself is believed to plunge parallel to these structures, and to have been forcefully intruded from this direction.

The average of 26 observations of lineation of stretched quartz pebbles in the schist indicates a plunge of 41° S. 26° W. The readings range in angle from 34° to 51° S. 14° to 40° W. The average of 13 readings on the plunge of "rolls" of the dike walls is 38° S. 35° W., but this average is unreliable because the readings are few and the range is from S. 20° E. to S. 80° W. at angles from 10° to 50°. The northern limit of economic mica, which is fairly well established for each level, is about parallel to the plunge of the rolls and the lineation.

The large "roll" in the southern part of the pegmatite, where it is exposed in the 200-ft level, has a plunge that is very nearly the same as the plunge of 41° S. 26° W. shown by the minor structures. The "roll" is essentially a sharp bend in the pegmatite, offsetting the southern part of the dike west of the northern part. Below the 200-ft level this roll plunges more nearly S. 10° W. Men who worked in the mine during the period of Westinghouse operation report that the "roll" extends to the 100-ft level. If it extends N. 26° E. to the surface, it would intersect the fault at the south end of the open-pit (pls. 29, 30).

The pattern of faults, shear zones, quartz veins, aplite dikes, and other structural features fits the concept of intrusion of the pegmatite from a S. 26° W. direction. All these features, except the smaller quartz veins, are shown on the surface map (pl. 29). The attitude of the small quartz veins was measured in 48 places, and the results assembled and compared with the other data below.

Structural data, New York mica mine

System	Set	Average strike	Average dip	Observed structural features
A	1	N. 35° W.	45° SW.	(1) The pegmatite dike, (2) foliation and bedding in the schist and gneiss, (3) quartz veins that are conformable with the foliation.
A	2	N. 35° W.	45° NE.	Quartz veins within the pegmatite occupying tension fractures formed during consolidation of the dike.
A	3	N. 55° E.	90°	Aplite dikes and quartz veins in tension fractures formed during consolidation of the dike.
B	1	N. 58° W.	53° SW.	Numerous small quartz veins above the pegmatite, occupying gash fractures formed by the force of intrusion; 33 strike and dip observations.
B	2	N. 50° W.	41° SW.	Small quartz veins below the pegmatite, occupying gash fractures formed by the force of intrusion; 8 strike and dip observations.
C	1	N. 71° E.	76° SW.	Small quartz veins; 7 strike and dip observations.
C	2	N. 35° W.	90°	Five quartz veins in the southern part of the area (pl. 29).
D	----	N. 55° E.	90°	Faults and shear zones; probably regional.

The vertical faults and shear zones that cross the dike in a general N. 55° E. direction (System D in the table above) are apparently regional in character. A similar set transects the dike on the Helen Beryl prospect ½ mile to the northwest. The occurrence of faults and shears at the New York mine perpendicular to the N. 35° W. strike of the schistosity suggests that they are tear faults developed during the regional movements that formed the foliation.

The fault south of the shaft has the largest displacement. Striations on the fault plane plunge 15° NE., but they record only the last movement on the fault, which may have been different in direction from the earlier movements. On the 300-ft level, the only place where the thickness of the pegmatite can be measured on both sides of the fault, the pegmatite is 12 ft thick on the north side and 18 ft on the south side. Such a marked change in thickness suggests that there was movement on the fault in a direction parallel to the dip of the pegmatite, pulling a relatively narrow part of the dike on the north up against a wider, and higher, part of the dike on the south side of the fault.

On the 300-ft level the hanging wall of the pegmatite is offset horizontally 9 ft to the east on the south side of the fault and the footwall is offset 20 ft. On the 200-ft level the hanging wall is offset about 20 ft. The amount of displacement of the footwall cannot be determined because the wall is inaccessible south of the fault. The drift on the 100-ft level is caved 30 ft south of the crosscut and the fault zone is not accessible. Sterrett (1923, p. 295) makes the statement that, on the 100-ft level, "a few feet southeast of the crosscut the mica schist wall elbows out into the pegmatite for several feet across the strike of the vein." Presumably this "elbow" is bounded on the north by the fault and on the south by the major "roll" (pl. 31). At the surface the fault can be traced where it crosses the schist south of the shaft, and it extends under the dump and through a cut near the south end of the pegmatite. The fault and the "roll" in the pegmatite apparently intersect at the surface, and they displace the pegmatite in opposite directions. The apparent horizontal displacement of the footwall is 5 ft, with the north side offset to the east, which is the opposite direction from that noted underground. Presumably the "roll" extended north of the fault, but it has been removed by erosion.

Vertical shear zones and faults, in which the observed individual displacements are small, cross the dike in a N. 55° E. direction at several places. Shear zones are found in a belt extending 15 to 30 ft on either side of the main fault. Numerous shear zones are also found crossing the middle of the dike, where the south side is generally displaced to the west. The south side was found to be displaced westward 2 ft in one small fault and 5 ft in another. The albite has been kaolinized near the surface in some shear zones.

System A in the table is composed of three sets of fractures. Set 1 consists of features that strike N. 35° W. and dip 45° SW., including the pegmatite dike, the foliation, and a few small quartz veins in the schist. Set 2 is made up of quartz veins, 3 in. to 1 ft wide within the pegmatite, which strike N. 35° W. and dip 45° NE., perpendicular to the dip of the dike and apparently filling tension fractures formed during consolidation of the pegmatite. Set 3 consists of tension fractures perpendicular to the strike made during consolidation of the pegmatite. The fractures, which strike N. 55° E. and dip vertically, are occupied by quartz veins.

Measurements were taken of the strike and dip of 56 small quartz veins, ¼ to 2 in. wide that cut across the foliation of the schist. Forty-five fell into System B of the above table, which apparently was formed as gash veins opened by the force of intrusion of the pegmatite. The average strike of the 33 gash veins west of the pegmatite and above it is N. 58° W., and the average dip is 53° SW. In general, therefore, these veins are inclined downward toward the pegmatite, and lie at right angles to the plunge. The range in strike readings is from N. 25° to 80° W., and the dips were from 40° to 70° SW. The 12 observations on veins on the footwall side of the pegmatite showed an average strike of N. 50° W. and a dip of 41° SW., suggesting that these veins fill gash fractures that lie beneath the pegmatite and intersect it at a very small angle.

A few quartz-filled fractures (System C of the table) seem to have been formed by the intrusive pressure of the pegmatite in two, more or less vertical, planes that make angles of about 45° with the plunge of the pegmatite.

MINERAL DEPOSITS

The New York mine was operated for sheet mica, but the pegmatite also contains potash feldspar and beryl. A little potash feldspar has been mined in the small open-pit at the north end of the dike, but probably no beryl has been sold from this property.

MICA

The northern limit of pegmatite containing sheet mica is fairly accurately known down to the 300-ft level on the hanging wall and to the 100-ft level on the footwall (pls. 30, 31). The southern limit of the mica deposits has nowhere been reached, and it is reasonable to suppose that the mica deposits extend to the end of the pegmatite. The southern limit of the footwall stopes near the surface may be the limit of sheet mica in the footwall deposit, but there is no evidence that sheet mica does not extend to the south end of the pegmatite, though perhaps not in commercial quantities.

The mica deposits may extend far below the 300-ft level. The structural evidence indicates that the pegmatite and the mica deposits plunge about 41 degrees

S. 26° W., and probably can be explored downward. The mica content, however, may be too low for profitable mining. The pegmatite narrows with depth at an average of about 8 ft for each 100 ft of vertical distance between the surface and the 300-ft level, but the rate of narrowing is highly varied. If this rate is maintained downward, the pegmatite ends about 200 ft below the 300-ft level, where its average thickness is approximately 15 ft. When the line on the stope map (pl. 31) which represents the north end of the pegmatite is projected downward, it passes about 350 ft below the intersection of the crosscut and the drifts on the 300-ft level.

The New York mine produces a light-ruby mica. It is hard, splits well, and is generally flat, but with an occasional faint "A" reeve. Air-staining is the most serious defect. The footwall mica is similar to the hanging-wall mica, but its quality is commonly reduced by the more abundant small tourmaline inclusions. In general the books are as much as 8 in. across, but crystals 3 ft long have been reported (Sterrett 1923, p. 293). Parts of a 2-ft crystal were observed in the footwall zone. Much of the mica is ruled near faults and shear zones, especially in the vicinity of the main fault and in the zones of shearing northeast of the shaft.

The last operators kept reasonably accurate records of the amount of rock moved and the mica recovered during their mining operations on the 300-ft level. By July 24, 1943, about 580 tons of rock had been mined and from it 10.5 tons of crude mica was recovered. The recoverable mica in the rock was 1.8 percent. The mining during the time of these records consisted of drifting 4 ft ahead in the north drift and 25 ft in the south drift, and putting in the raises and beginning the stopes in blocks I, II, and III (pl. 31). Probably 1.8 percent recoverable mica is a minimum figure for the deposit. Most of the work has been development preparatory to stoping, and considerably more barren rock beneath the mica zones has been mined than will be removed in actual stoping. The content of mica in the pegmatite north of the fault on the 300-ft level appears, from visual estimates, to be somewhat lower than the grade south of the fault. South of the fault the mica in the rock appears to be less than 2 percent over a 5 ft width. Sterrett (1923, p. 295) says that at the time of his visit, the Westinghouse records showed the grade to be about 6.6 percent over a width of 5½ ft. The difference suggests that the workings on the 300-ft level were in a comparatively barren part of the mine. The mica content may improve to the south near the major "roll."

The mica content of the footwall mica deposit can only be estimated, because records are not available. The exposures above the Savage level reveal considerable mica, and the content may have been greater than 2 percent. However, where the footwall mica deposit is exposed on the three main levels, the recoverable mica content is possibly less than 1 percent.

The mica produced by the New York Mining Company before July 19, 1943, was 0.8 percent sheet and 11.4 percent punch mica. The mica was sold at $5.00 per lb for sheet, $0.40 per lb for punch and $16.00 a ton for scrap. The value per ton of mica recovered from the mine was $172.

After July 19, the punch mica was full trimmed to 1 by 1 and 1¼ by 1¼ in. sheet mica.

The total production of large and small sheet mica from this mine in 1943 was 1,549.29 lb. In addition, 3,480.5 lb of untrimmed punch was sold.

BERYL

By visual estimate, the largest concentration of beryl in the New York dike is in the wall zone, especially along the footwall, but some crystals are found throughout the pegmatite. Most crystals are less than 1 ft long and, as many of them contain numerous inclusions, milling would be required to produce a usable grade of beryl.

The average grade of beryl in the mica zones and in the dumps and backfill is conservatively estimated by visual methods to be about 0.25 to 0.5 percent, though careful measurements on 35 sq ft of a face at the north end of the workings on the footwall mica deposit indicate a grade of about 1.5 percent beryl. The BeO content of the beryl, based on refractive indices, are shown in the table on page 170.

FELDSPAR

Perthite has been mined in the small open-pit at the north end of the body where the dike is composed principally of perthite-quartz pegmatite. The perthite-bearing body has a roughly circular form on the surface and averages about 90 ft in diameter. It is likely that this zone plunges south-southwestward along the north limit of the pegmatite.

The perthite is white to pink microine containing veinlets of pink albite. Crystals as much as 6 ft across are exposed. Masses of quartz-albite pegmatite and of milky quartz occupy about half of the zone, and quartz is intergrown with some of the perthite, so that the proportion of recoverable feldspar is small.

RESERVES OF MICA

The New York mine has extensive reserves of mica above the 300-ft level in both the footwall and the hanging-wall mica deposits. Below the 300-ft level the pegmatite is unexplored. Mining operations were principally in the hanging-wall mica deposit and it is estimated that in this deposit above the 300-ft level, there are 27 tons of crude mica indicated and 330 tons inferred in a total of 19,000 to 20,000 tons of rock.

The footwall mica deposit is almost entirely unworked below the 100-ft level, and not much of it has been

Refractive indices of beryl, New York mine

Specimen No.	Location	Index N_ϵ	Percent alkalies [1]	Percent BeO	Color	Crystal development	Remarks
LRP-3c-43	Dump from perthite-quartz zone	1.587±0.003	2.4	11.6	Yellowish to white	Subhedral to anhedral	Mixed with small muscovite flakes.
LRP-3h-43	Perthite-quartz zone. North end of Savage tunnel.	1.585± .003	2.0	12.0	White	Anhedral	Interstitial with perthite, quartz, tourmaline and muscovite.
LRP-3f-43	Dump. From cleavelandite-quartz zone (?).	1.586± .002	2.2	11.8	Yellowish	Subhedral to andrehal shell.	Irregularly intergrown with quartz and albite.
LRP-3d-43	Dump. From quartz-albite zone (?).	1.585± .003	2.0	12.0	do	do	Do.
LRP-3a-43	Dump. From hanging-wall mica zone.	1.583± .003	1.7	12.3	Greenish gray to white	Subhedral	On hanging wall.
LRP-3e-43	do	1.578± .002	1.0	13.0	Pale greenish	Euhedral shell	Center filled with pink albite and quartz.
LRP-3g-43	Dump. From hanging-wall mica zone (?).	1.577± .002	.7	13.3	do	do	Do.
LRP-3b-43	Footwall mica zone in Savage tunnel.	1.577± .003	.7	13.3	do	do	Included in muscovite book.
LRP-3i-43	do	1.575± .003	.6	13.4	do	do	Center filled with pink albite and quartz.

[1] After Winchell, A. N., 1933.

worked between the 100-ft level and the Savage tunnel. The area of unstoped mica-bearing rock is about 170,000 sq ft, which would yield, at a 5-ft width, 680,000 cu ft of rock or about 50,000 tons. If the grade is 1 percent recoverable mica, the inferred reserve of mica is 500 tons.

NOBLE MICA MINE (CUSTER DISTRICT)

by W. C. Stoll

The Noble mica mine is about ¼ mile west of the Needles Highway at a point on the highway 2.6 miles from Sylvan Lake. At the time of the examination, July 28, 1942, no mining could be legally undertaken on this property because it lay within the Custer State Park, an area withdrawn from mining by regulation of the Park Board. In earlier years some mining for mica was done in the Noble mine and in 1944 the mine was leased to Leon LaRue of Custer. The workings consist of about 100 ft of crosscuts, drifts, and raises.

The mine is in a small pegmatite dike in the Harney Peak granite. The pegmatite ranges in thickness from 6 to about 10 ft. It strikes N. 80° W. and dips 30°–50° NE. In the outcrop and workings the pegmatite is exposed for about 70 ft along its strike, and has been excavated to a maximum depth of about 25 ft on the dip.

Two zones are distinguishable in the pegmatite. A quartz zone 4 to 6 ft thick lies below a wall zone 2 to 4 ft thick that contains mica. The mica is an irregularly textured mixture of plagioclase feldspar, quartz, and blocks of potash feldspar. In the granite country rock close to the workings are small, irregular quartz-mica bodies that have no apparent connection with the principal body of pegmatite.

The visible extent of the mica deposit in the main pegmatite is 50 ft along the strike and 25 ft down the dip. The entire deposit, as exposed in outcrop and workings, probably contains about 5 percent of book mica. The mica-rich pegmatite extends beyond the limits of the workings.

The mica is ruby, heavily air-stained, and contains mineral inclusions.

NOVEMBER MINE (CUSTER DISTRICT)

The November mine, in the NE¼ sec. 32, T. 2 S., R. 5 E., Custer County, was operated in 1943–44 by Harold Eyrick and Monte Heumphreus of Custer. During 1943 both potash feldspar and mica were produced; in 1944 the mine was operated for feldspar and scrap mica. A total of 1,880.59 lb of sheet mica was produced in 1943.

In July 1943, when the property was briefly examined, mica was being mined in an adit, partly open to the surface, which followed the dike about 40 ft N. 80° W. The adit was 15 to 20 ft wide and exposed mica-bearing pegmatite on both the footwall and hanging-wall parts of the dike.

The wall zone, which contains the mica, is plagioclase-quartz-muscovite pegmatite 1 to 4 ft thick. The core of the pegmatite is perthite and quartz. At the west end of the workings the core appeared to be widening to the west and upwards. This body was mined for feldspar for a distance of about 30 ft above the adit leve.

Considerable reserves of sheet-bearing muscovite remain in unmined parts of the pegmatite. The mica is flat, hard, ruby mica, and most of it is densely air-stained.

O. K. NO. 4 LODE CLAIM (CUSTER DISTRICT)

The O. K. No. 4 Lode claim, in the SW¼ sec. 9, T. 3 S., R. 5 E., is on a large outcrop of the pegmatitic Harney Peak granite. One vertical pegmatite 3 to 6 ft wide, strikes N. 60° W. across part of the outcrop. It consists chiefly of perthite and quartz, though two or three small muscovite books were seen.

OLD MIKE MICA MINE (CUSTER DISTRICT)

by L. R. Page and T. A. Steven

The Old Mike mica mine, formerly known as the Great Northern mica mine, is one of the largest producers of sheet mica and beryl in the Custer district. The mine is near the west quarter corner of sec. 2, T. 3 S., R. 4 E., Custer County. It is owned by Edward Wray of Evanston, Illinois, and has been operated since July 1941 by Mineral Mills, Incorporated.

No record of the mineral production of this mine prior to 1941 is available, although it was operated during each period of mica mining activity since its location about 1880. The production in recent years is given in the table below.

The mine has been previously described (Sterrett, 1923; Lincoln, 1935; Lincoln, Miser and Cummings, 1937; Cummings, Harris, and Lincoln, 1937; Sharpe, 1942; and Fisher, 1945). The work of the U. S. Geological Survey has been carried out by various geologists between 1942 and 1945. In July 1942, L. R. Page, J. B. Hanley, and W. C. Stoll mapped the property and at that time the emphasis was on beryl and tantalum. In 1944 Page and T. A. Steven remapped the property on a larger scale (pl. 32). Underground mapping was carried out at different times in 1943 in answer to specific requests of Colonial Mica Corporation, Metals Reserve Company, and the U. S. Bureau of Mines.

MINE WORKINGS

The Old Mike mine comprises open-cuts and underground workings. In 1942 the underground workings consisted of an adit crosscut, 200 ft long, from which drifts extended northwest and southeast along the pegmatite. At the east wall of the pegmatite, about 150 ft in from the portal, an old shaft extended to the surface. The northwest drift extended 210 ft beyond the adit and the footwall of the dike was stoped to the surface. The other drift started at 125 ft from the adit portal and extended 35 ft southeast to a drift along an offshoot of the main pegmatite that strikes about N. 70° E. This offshoot was stoped to the surface where it had previously been mined by an open-pit.

In 1943 a glory hole was made in the vicinity of the old vertical shaft and the pegmatite to the southeast was removed by glory hole and underhand stoping methods. Later a raise was started on the southeast end of the pegmatite and mining was carried on from the surface at about the 6,120-ft level. In 1944 the northwest drift was benched down to the bottom of sheet mica bearing pegmatite and surface operations were undertaken at the north end of the Old Mike pegmatite and in the dike to the northwest. In the fall of 1944 the old northwest drift, glory hole, and stopes were backfilled by working the pegmatite exposed in the cliff above the stoped area. Later in 1944 and until the mine was closed in February 1945, mining was carried out from a new southeast drift that connected with a winze on the N. 70° E. offshoot of the main pegmatite. The maps (pl. 32), shows the mine prior to operations on the cliff and in the winze, though one level map was made during this operation.

Mineral production, in pounds, from Old Mike mine.

	Prior to 1941	1941 [1]	1942 [2]	1943	1944	1945 [3]
Mica:						
Crude	?	167,897	617,145	600,000 (est.)	?	?
Large sheet	?	421	1,951	3,005.83	798.05	1,159.59
Small sheet	?	----------	----------	----------	3,499.55	706.61
Punch, untrimmed	?	7,417	36,265	6,785	----------	4,081.05
Beryl	[4] 58,000	6,000	14,000	15,320	4,440	----------
Tantalite-tapiolite	?	----------	200 (est.)	82.5	----------	----------

[1] July 16–January 31.
[2] January 31–December 13.
[3] In part mined in 1944.
[4] From F. C. Lincoln (personal communication).

GEOLOGY

WALL ROCKS

The Old Mike pegmatites trend northwest across pre-Cambrian quartz-mica schists that contain thin beds of dark-gray quartzite. The schists are highly folded, especially near the pegmatite. In general, the bedding and foliation are nearly parallel. The strike is northwest and the dip is west at less than 45°. At places near the pegmatite contacts the schist is dragged upward or folded parallel to the rolls in the contacts. Except locally where the contacts are conformable to the structure in the wallrocks, solutions have altered the schist into a feldspar granulite, known as "casing" or "sugar" rock. This alteration is very conspicuous in the lower levels of the mine and adjacent to pegmatite outcrops northwest of the main pegmatite. The granulite is a sugary grained, light-colored albite-muscovite-quartz-tourmaline rock that usually contains many thin stringers of pegmatitic material. In places its contact with unaltered schist is very sharp, although most of the contacts are gradational.

PEGMATITE

Two very irregular bodies of pegmatite have been mapped on the Old Mike property (pl. 32). They trend northwest and are nearly vertical, though the irregular offshoots from them are horizontal or have gentle dips. The Old Mike pegmatite, in which most of the mining has been done, is well zoned. It is about 350 ft long and as much as 50 ft thick. The second pegmatite, about 75 ft east of the north end of the Old Mike dike, is discontinuously exposed for 450 ft. Offshoots of this dike, probably exposed as a dip slope, cause the apparent width to be as much as 150 ft. This pegmatite is identical in mineralogy and texture to the outer unit of the wall zone in the Old Mike dike.

The Old Mike pegmatite is lenticular in cross-section, and near the adit level it pinches out to a number of thin pegmatite stringers enclosed in granulite. One offshoot from the footwall contact, though very irregular in shape, trends about N. 70° E., and dips about 30° SE. parallel to a group of folds in the wallrock. Five units have been distinguished in the pegmatite: albite-muscovite-quartz pegmatite, albite-quartz-muscovite pegmatite, perthite-quartz-albite pegmatite, cleavelandite-quartz pegmatite, and quartz pegmatite.

Albite-muscovite-quartz pegmatite.—The wall zone is a fine-grained albite-muscovite-quartz pegmatite, as much as 20 ft thick at the crest of the pegmatite, but thinning downward. At an altitude of 6,120 ft it is only 1 ft thick on the east, or footwall, and about 2 ft thick on the hanging wall. Because it caps the pegmatite, it partly conceals the other zones on the map (pl. 32). It makes up all the Old Mike pegmatite north of the underground workings and the dike to the northwest. The narrow offshoot from the footwall of the Old Mike dike is of this type of rock.

Muscovite, the most noticeable mineral though less abundant than plagioclase, makes up about 25 percent of the rock. It occurs in thin flat books or flakes, mostly less than 2 in. in diameter, in association with quartz, biotite, beryl, tourmaline, apatite, and phosphate minerals.

Albite-quartz-muscovite pegmatite.—The outer intermediate zone is albite-quartz-muscovite pegmatite. In this unit muscovite is in the form of books, as much as 2 ft or more across, that are characterized by "A" structure. The "A" structure is progressively weaker outward in this zone. Beryl, tourmaline, perthite, and phosphate minerals are associated. This pegmatite is coarser than the albite-muscovite-quartz pegmatite, but the average grain size is less than 12 in.

Perthite-quartz-albite pegmatite.—The pegmatite of the outer intermediate zone grades into perthite-quartz-albite pegmatite in the upper part of the Old Mike dike. This rock caps the quartz core and the cleavelandite-quartz pegmatite unit of the intermediate zone. The rock is exposed only in the upper part of the cliff, above an altitude of about 6,120 ft. It is composed of perthite crystals, several feet long with an interstitial intergrowth of fine-grained quartz-albite pegmatite in which the individual grains are less than 2 in. across.

Cleavelandite-quartz pegmatite.—The second intermediate zone in the lower part of the Old Mike pegmatite is composed of cleavelandite and quartz. The cleavelandite is in spherical or ellipsoidal, radial aggregates as much as 6 ft across. The outer edges of these masses, and the rock between them consists of aggregates of fine flakes of muscovite intergrown with albite, quartz, beryl, and columbite-tantalite. Small muscovite flakes are scattered throughout the cleavelandite masses. This zone does not appear to extend above the top of the quartz core and therefore is not conspicuous on the map (pl. 32).

Quartz pegmatite.—Quartz makes up the core of the Old Mike pegmatite. Almost the only mineral associated with the quartz is a yellowish mica that occurs in aggregates of small flakes, locally known as "bull mica" or "mica schist." Tapiolite has been recovered from the quartz core or from the outer edges of the core but has not been seen in place. The keel of the quartz pegmatite above the adit level has been exposed or mined out for its entire length, and the quartz body is known to have been a discoidal mass surrounded by the outer pegmatite zones.

MINERAL DEPOSITS

The Old Mike mine has produced scrap and sheet mica, beryl, and tantalite. It is one of the largest mica and beryl mines in the Custer district.

MICA

The muscovite in the wall and intermediate zones of the Old Mike pegmatite has been the source of all the sheet and scrap mica produced from the mine. Most of the past production has been limited to the lower half of the pegmatite outcrop. Two types of muscovite books occur in the mine. The outer unit (the wall zone) contains hard, flat, deep-ruby books that rarely exceed 8 inches in diameter. The inner unit (the outer intermediate zone) contains pale-ruby to white, "A" books that are as much as 2 ft or more across. Between the two units the mica shows all intermediate variations in color, size, and flatness. The inner unit furnished a large part of the scrap and sheet mica production in 1941–43. In 1943 most of the sheet came from the outer unit, including the narrow pegmatite extending from the footwall of the Old Mike dike and the second pegmatite northwest of the main dike.

The monthly lots of mica sold in 1944 contained 2 to 25 percent of no. 1 quality, 8 to 35 percent no. 2 quality, and 42 to 90 percent no. 2 inferior quality. The average quality was about 35 percent good-stained or better.

The low-quality mica was obtained primarily from open-cuts at the northwest end and top of the Old Mike pegmatite and also from the dike to the northwest. This mica was from the wall zone and contained numerous tourmaline inclusions and was strongly air-stained. It is estimated that this mica was only about 15 percent good-stained or better. Because each monthly lot included some of this type of mica, the over-all quality was lowered. The individual lots of sheet mica recovered from the outer intermediate zone contain as much as 40 percent fair-stained or better.

About one-fourth of the mica produced at the Old

Mike mine in 1944 was sheet mica, three-quarter trim and full trim. The size pattern is indicated by the following figures.

Size (inches)	1941 (percent)	1942 (percent)
1½ by 2	36	34.5
2 by 2	36	35.5
2 by 3	21.4	22.2
3 by 3	3.6	4.6
3 by 4	1.2	1.9
3 by 5	1.5	1.2
4 by 6	.3	.1

During 1941–42 only about 0.3 percent of the mica mined was recovered as sheet, and about 5.5 percent as untrimmed punch. In 1944 the recovery from 34 tons of crude mica, mostly "A" books, was 2.4 percent large and small sheet mica. About 25 percent of the total sheet recovered in this lot was larger than 1½ by 2 in.

The dominant imperfections of Old Mike sheet mica are reeves and air-stains, though locally mineral inclusions may be the most serious defect.

The wall zone contains about 25 percent muscovite. In the past this rock has been ground and screened, on a small scale, to recover scrap mica. Considerable quantity of this rock is available for milling.

BERYL

Three types of beryl deposits occur at the Old Mike mine. The wall-zone pegmatite contains euhedral, subhedral, and "shell" crystals of yellowish to green beryl, associated with sheet-bearing muscovite. These beryl crystals rarely attain a diameter of 6 in. and are difficult to recover by hand cobbing. At the inner edge of the wall zone and also in the outer part of the intermediate zone, beryl occurs in pale greenish crystals as much as 18 in. in diameter. Some crystals are euhedral, but many are subhedral and it is evident that the absence of the crystal form is caused by corrosion of beryl by other minerals. In the cleavelandite-quartz pegmatite intermediate zones, beryl occurs between cleavelandite masses as tabular crystals and aggregates of intergrown euhedral crystals with unusually short "c" axes. Some crystals occur also in the quartz pegmatite, but they are rare. The greatest production of beryl has been from the intermediate zones. Probably the wall and intermediate zones contain no more than 0.5 to 1 percent beryl.

TANTALITE AND TAPIOLITE

Tantalite and tapiolite have been recovered in small quantities at the Old Mike mine. The tantalite is produced primarily from the intermediate zones where it is associated with cleavelandite. The specific gravity and Ta_2O_5 content of the tantalum ore varies widely. In 1944 a lot of 82.5 lb was sold as containing 55 percent Ta_2O_5. The ore sold in 1942 is reported to contain 75 percent Ta_2O_5 and undoubtedly had a larger proportion of the mineral tapiolite in it. The tapiolite specimens seen in the stockpile appear to have come from the inner edge of the inner intermediate zone or from the outer part of the core. None has been seen in place.

Two specimens from the Old Mike pegmatite were examined by Michael Fleischer of the Chemical Laboratories of the U. S. Geological Survey in 1942. These were shown by X-ray data to be mixtures of tantalite and tapiolite with specific gravities of 7.32 and 7.64.

The quantity of tantalum minerals available is not sufficient to warrant their recovery except as a byproduct. They may make up 1 lb per ton of the intermediate zones.

RESERVES

The reserves of mica, beryl, and tantalum minerals at the Old Mike are large compared to that of other deposits of the Custer district, but they can be recovered only under favorable economic conditions.

The scrap mica reserves are large and appreciable quantities of sheet mica could be recovered as a byproduct of a scrap mica operation. It is probably impossible to work the deposit for scrap mica without milling. There may be as much as 75,000 tons of mica-bearing rock suitable for milling. If such an operation were started, beryl, tantalite, and feldspar could be recovered as byproducts. The beryl reserve probably equals past production.

OLD MISSOURI MICA PROSPECT (CUSTER DISTRICT)

The Old Missouri mica prospect, owned by Mrs. Lillian L. Parris of Hillsborough, Oregon, is in the SE¼ sec. 28, T. 4 S., R. 4 E.

It can be reached from Custer by the following schedule of mileage:

Miles

0.0 Custer Post Office. Drive west on Highway 16.
1.7 Turn south on Highway 85A.
7.1 Turn west on dirt road that crosses railroad at Mayo School. Dirt roads branch off to south at 7.8 and 9.3 miles; and to the north at 7.85 and 8.1 miles.
9.5 Follow mine road, 500 feet to southwest. Main road extends 0.25 mile to the northwest end of Old Missouri pegmatite.

The mine was first worked for feldspar by John Ross in the fall of 1942 and for mica by a Mr. Cottrell and a Mr. King in the fall of 1943. There is no record of 1942 production of feldspar or scrap mica. About 200 pounds of sheet mica was sold to Colonial Mica Corporation by Cottrell and King in 1943 and 1944. L. R. Page visited this property briefly on April 23, 1945.

The workings consist of a pit about 60 ft long, 20 to

25 ft wide, and as much as 15 ft deep; the maximum vertical exposure of the pit is about 35 ft. The pegmatite is also prospected by two pits 60 ft and 95 ft S. 50° E. of the main pit, and four others, 10 ft, 70 ft, 145 ft, and 185 ft to the northwest of the main pit.

The main pegmatite is a very large irregularly shaped mass. The main axis trends N. 55° W., but about 200 ft and 300 ft north of the main pit, two prongs, 50 to 60 ft wide, extend N. 60° E. The southernmost prong appears to dip 70°–80° SE. The pegmatite tapers from 100 ft in width at these prongs to 10 ft in width at a point 650 ft to the northwest. Southeast of the main pit the pegmatite extends several hundred feet as a mass as much as 250 ft in width. Another prong extends S. 35° W. of the main open-pit for about 200 ft and then swings abruptly southeast for a few hundred feet.

Most of this body is a fine-grained granitic pegmatite with crystals and grains, as much as 2 in. across, of perthite, quartz, muscovite, tourmaline, biotite, and minor albite. The rock is dark reddish because of the large proportion of deep pink perthite.

The main open-pit and the two smaller cuts to the southeast appear to be on a coarse-grained perthite-quartz pegmatite that contains scattered books of muscovite and biotite, tourmaline, and small quantities of albite. This pegmatite is a fracture-filling deposit striking about N. 55° W. and dipping 50° NE. It is as much as 15 ft thick and 150 ft long. Near the most southerly pit another fracture-filling body, 3 to 5 ft thick, strikes N. 50° E. and dips 80° SE. The three most northerly pits appear to prospect a similar fracture-filling body about 200 ft long that strikes N. 55° E. Its width and dip are unknown.

The mica occurs at the outer edges of the fracture-filling bodies as scattered books as much as 12 in. long. The mica is deep ruby. Most of the books are badly "tied" and the percentage of sheet or punch is low. The mica is in part heavily air-stained, though some specimens are of no. 1 and no. 2 quality. It is estimated that the sheet mica produced in 1943–44 was derived from 250 to 300 tons of rock, most of which was removed from the main open-cut.

The feldspar in the fracture-filling bodies is in blocky crystals as much as 2 ft long. They are deep flesh to reddish perthite. The bodies are narrow, but contain up to 25 percent of recoverable clean feldspar. The largest body is probably 200 ft north of the main pit near the intersection of the pegmatite that trends N. 55° W. and N. 60° E.

OREVILLE SPAR MICA MINE (HILL CITY DISTRICT)

by J. W. Adams

The Oreville Spar mica mine, in the SE¼ sec. 22, T. 2 S., R. 4 E., in Pennington County is owned by Gladys Wells and Fred Heidepriem of Custer. During part of 1944 it was leased by Lewis Collingwood and associates who produced more than 300 lb of sheet mica from the property.

The claim was visited by several geologists of the U. S. Geological Survey during its operation.

Development of the claim has been chiefly by a large open-cut 100 ft long, as much as 30 ft deep, and 10 to 15 ft wide. Several smaller excavations apparently were made during earlier operations.

GEOLOGY

The rocks surrounding the pegmatite are pre-Cambrian mica schists and quartzite. Exposed contacts between the pegmatite and the wall rock are few and information as to the limits of the pegmatite and its structural relationship is meager. However, it appears that the pegmatite has been intruded along an anticlinal structure in the schists. Because of this structure, which trends and plunges westward, erosion has divided the pegmatite outcrop into two lobes conforming to the attitude of the flanks of the anticline. The south lobe, in which the large open-cut is located, strikes northwest and dips to the southwest; it crops out for over 150 ft in the direction of strike. The other lobe, lying along the north flank of the anticline, strikes roughly northeast and dips to the northwest. It crops out for about 100 ft along the direction of strike. The hillside on which the pegmatite crops out is approximately a dip slope, but a considerable thickness of pegmatite may have been eroded from the upper portion of the north lobe and at least a few feet from most of the south lobe. The original thickness of the pegmatite probably exceeded 30 ft.

Preliminary examination of the pegmatite suggests the presence of at least four rock units: (1) a narrow border-zone containing abundant small muscovite crystals; (2) a wall zone, 2 to 8 ft thick, of microcline-quartz-albite-muscovite pegmatite; (3) a core of quartz-cleavelandite-microcline-muscovite pegmatite; and (4) a unit of quartz-muscovite-cleavelandite-microcline pegmatite, 3 to 10 ft thick, that locally contains as much as 20 percent of sheet-bearing book mica. Where this mica-bearing unit is exposed in the open-cut it underlies the central core but it is not clear whether it constitutes an intermediate zone or is a fracture-filling body.

The wall and border zones are mineralogically similar but muscovite is more concentrated in the border zone. Both contain abundant quartz, microcline, and albite.

The core varies locally in composition, but averages about 50 percent of quartz, 20 percent of cleavelandite, 15 percent of microcline, 5 percent of muscovite, 5 percent of alkali tourmaline, and minor quantities of amblygonite, beryl, and apatite. A few crystals of cassiterite were observed. Amblygonite appears to be most common near the contact with the wall zone.

The sheet mica-bearing unit contains about 30 percent of quartz, 30 percent of albite (part of it cleavelandite), 20 percent of microcline, 10 to 20 percent of muscovite and some alkali tourmaline and apatite.

MINERAL DEPOSITS

Sheet mica is the mineral of greatest economic interest in the pegmatite. It occurs in books generally not more than 4 in. across and is colorless to pale green. Defects appear to be air-stain, cracks, and mineral inclusions. A total of 305.81 lb of sheet mica was sold to Colonial Mica Corporation from the property. Of this total, 25.9 lb or 8.5 percent was large sheet (plus 1½ by 2 in.). The qualification of the large sheet showed 0 to 4 percent no. 1 quality, 0 to 17 percent no. 2 quality, and 78 to 100 percent no. 2 inferior quality. The small sheet ranged from 0 to 6 percent no. 1, 2 to 19 percent no. 2, and 76 to 98 percent no. 2 inferior qualities.

Amblygonite in rounded masses as much as 6 in. in diameter occurs in the core, generally near the contact with the wall zone. It probably constitutes about 1 percent of the rock, but it is not known that any amblygonite has been recovered.

A small percentage of beryl occurs in the pegmatite but none is known to have been sold. Specimens found on the dump were white to pale pink and showed indices of refraction (N_0) ranging from 1.582 to 1.591, indicating high alkali content.

No feldspar is known to have been produced in 1944, but some may have been mined earlier.

PAYDAY LODE (CUSTER DISTRICT)

by W. E. Hall

The Payday Lode is in sec. 11, T. 5 S., R. 4 E., Custer County, 1.6 miles northwest of Pringle. The property consists of an unpatented claim of 20 acres, held by Lon Pitts of Pringle. The property was not in operation when visited in October 1942.

The Payday Lode crops out for 310 ft along its strike, N. 30° W. It is a tabular pegmatite that conformably intrudes schists that strike N. 30° W. and dip 60° NE. The pegmatite is 10 to 18 ft thick. Its shape is modified by anticlinal and synclinal rolls on the west side of the pegmatite. The axes of these rolls strike parallel with the pegmatite and plunge 30° N.

Five open-cuts have been made on the pegmatite. Three, made for mica, expose the mica-rich pegmatite for 160 feet along the footwall of the dike. The other cuts are prospect pits.

The pegmatite is composed of a medium-grained mixture of soda-feldspar, perthite, black tourmaline, beryl, and muscovite. Beryl is distributed unevenly throughout the dike. It is pale yellowish-green. A core of quartz, albite, black tourmaline, and mica contains about 18 percent of individual beryl crystals. The crystals are small; the largest observed is 5 in. in diameter, and the average is 1½ in.

A mica deposit, 2 ft wide and exposed for 160 ft, extends along the footwall of the west side of the dike. The mica content of the deposit is 5 to 7 percent. It is clear white mica suitable only for scrap. Ruling and "A" structure are common. The average size of the books is about 2 in. Another mica deposit extends along the hanging wall or east side of the dike and contains about 3 percent of scrap mica. It is not as strong or continuous as the mica deposit on the footwall of the pegmatite.

PEERLESS MINE (KEYSTONE DISTRICT)

by W. C. Stoll

The Peerless mine is near the quarter corner of secs. 8 and 9, T. 2 S., R. 6 E., Pennington County, about ½ mile south of Keystone. The Protector Lode claim, on which the mine is situated, comprises 8 acres. The owner is Keystone Feldspar and Chemical Company, of which Ernest Reckitt, 3900 Board of Trade Building, Chicago, is president, and A. F. Walker, Keystone, is resident superintendent. The Keystone Feldspar and Chemical Company started operations at the Peerless Mine in 1924. Before that year the property was operated by the Rheinbold Metallurgical Company.

The Peerless mine has produced scrap mica, amblygonite, beryl, soda spar, lithiophilite, columbite, and cassiterite. In November 1942, and since the start of this company's operations in 1924, scrap mica has been the main product. The total production of scrap mica is not known to the writer, but is large. Between 1924 and 1942 the total amblygonite production was less than 60 tons, but more was mined earlier by Rheinbold Metallurgical Company. Considerable quantities of columbite-tantalite have been produced in the past; in 1942 the stock of this mineral was only 15 lb. About a ton of cassiterite was mined prior to 1942 and stocked at the mine. Lithiophilite and soda spar are likewise stocked at the mine, but much of the feldspar has been dumped as waste. The sheet mica production was 82 lb in 1943, 135 lb in 1944, and 22.3 lb in 1945. The Peerless mine is the largest beryl producer in the Black Hills. Beryl production data, supplied chiefly by Mr. Ernest Reckitt, are given below.

Year	*Tons beryl*
1918	3
1928	1
1929	[1] 156
1930	36
1932	2.75
1933	28
1937	36
1939	27.25

[1] Accumulated 1924 to 1929.

Year	*Tons beryl*
1940	30.24
1941	25.5
1942	16.5
1943	36.185
1944	8.87
Total known production	407.295

The Peerless mine was mapped with the assistance of W. E. Hall in November 1942. At that time attention was focused on the beryl content of the pegmatite and little attention was paid to the other economic minerals.

MINE WORKINGS

The Peerless pegmatite is now worked from an adit by glory hole methods. The main pit, at the south end of the pegmatite, extends N. 75° W. for 300 feet. It is 150 ft wide and 105 ft deep at the center of the glory hole. At the south and east sides the pit is 30 to 50 ft deep. A high pinnacle of unmined pegmatite stands high above the pit floor, and gives the opening a marked irregularity. A smaller pit near the northwest end of the outcrop is 75 ft long, 30 ft in average width, and 25 to 30 ft in maximum depth. About 330 ft of tunnels give access to the glory hole.

GEOLOGY

The Peerless pegmatite (pl. 33) crops out as a large knob whose long axis strikes N. 40° W. for 465 ft. The outcrop is 100 ft wide near the southeast end, 275 ft at the middle, and about 50 ft near the northwest end. The pegmatite is surrounded by schists that are in part discordant to the pegmatite contacts. The altitude of the pit floor is 4,571 ft and the top of the outcrop stands 110 ft above this level.

The main part of the pegmatite has the shape of a very thick lens that plunges to the northeast at about 50°. At the south end of the main mass, the lens is modified by irregular rolls and branches whose forms are controlled by folds in the schists. One such roll, described to the writer, but not now apparent, yielded large quantities of mica. Underground, in the back of the tunnel, a troughlike roll of pegmatite is exposed. This roll probably plunges slightly west.

Few contacts are visible around the main body of pegmatite. Within the main pit, just north of that part of the excavation above the adit, the footwall of the pegmatite is visible for a short distance. It strikes N. 50° W. and dips 42° NE. Underground, 40 ft below and to the southeast, the same wall strikes N. 7° W. and dips 50° NE. Thus, at the southeast end of the main pegmatite there is a marked curvature of the footwall, from a northwesterly to a northerly strike. On the wall of the main pit, northeast of the first footwall exposure, the hanging wall of the pegmatite strikes in a northerly direction and dips 55 degrees easterly. Visible contacts indicate that the pegmatite at this end, exclusive of the rolls and branches, is about 85 ft thick. The pegmatite thickens toward the northwest, and then thins to about 50 ft at the end.

The Peerless pegmatite is well zoned but the zoning is obscured by the coarse texture. These zones are indicated only in a general way on plate 33. The part of the pegmatite that has been most important from the mining standpoint is composed of a mixture of cleavelandite, quartz, muscovite, and a little perthite in various proportions with patches of fine-grained aplitic rock. From this mixture soda spar, high-quality scrap muscovite, beryl, cassiterite, and columbite-tantalite have been recovered. Within the main part of the pegmatite, this unit overlies the footwall contact which is visible in the large pit. At the southeast end, its thickness would appear to be roughly 50 to 60 ft. It is exposed for nearly 300 ft in a westerly direction, along the lower part of the north side of the main pit. About 170 ft from the east end of the pit, the unit may have a thickness of 80 ft, if dips and strikes remain constant. Beryl is not always visible in this zone, but is scattered irregularly through it. Beryl seems to be more abundant where this unit merges irregularly with an overlying coarse perthite-quartz pegmatite.

In the mica-cleavelandite zone, beryl is irregularly distributed in crystals as much as 12 to 16 in. in diameter, associated with quartz, cleavelandite, and muscovite. Most of the beryl crystals seen were 2 to 5 in. in diameter.

The beryl mined at the Peerless property prior to November 1942, was 382.24 tons. It is estimated that the total rock excavated was 91,500 tons and that beryl constituted 0.42 percent of the rock mined. This does not take into account loss of beryl in cobbing. If it is assumed that a third of the excavation was in schist or barren pegmatite, and that beryl recovery by hand cobbing was 75 percent, then the beryl-bearing part of the pegmatite contained 0.85 percent beryl. An exposure of the pegmatite underground was estimated to contain 0.4 percent beryl but parts of the zone at the surface are richer.

The perthite-quartz zone is of great thickness and extent, but is mined only when unavoidable. Part of the zone is overlain by a thick capping of quartz pegmatite, which forms the top of the pinnacle rising above the floor of the pit. Another unit is composed of quartz, perthite, and muscovite in an irregular intergrowth (pl. 33).

PIGTAIL MICA PROSPECT (CUSTER DISTRICT)

The Pigtail mica prospect, in SW¼ sec. 14, T. 5 S., R. 5 E., was operated by Mr. Leon LaRue early in 1943 but was idle when visited in August. An open-pit, 40 ft long, 20 ft wide, and about 20 ft deep at the face, prospects a well-zoned pegmatite that cuts gray quartzite. The quartzite strikes N. 30° W. and is vertical. The pegmatite strikes N. 50° E. and dips 40° NE. except near the east end where it strikes N. 15° E. and dips vertically. It is 6 to 7 ft thick and probably is less than 60 ft long. Muscovite books were observed along the hanging wall, in a zone 1 ft thick. They are associated with plagioclase, quartz, perthite, and tourmaline. The core of the dike is largely quartz with scattered pink perthite crystals. About 75 lb of sheet mica was produced from this property in 1943.

PINE TOP CLAIM (CUSTER DISTRICT)

by W. C. Stoll

The Pine Top claim is in the SE¼ sec. 3, T. 4 S., R. 4 E., Custer County, about 2.9 miles south-southwest of Custer, Custer County. The property is owned by the Consolidated Feldspar Corporation which leased it as a mica prospect to the Black Hills Mining Company in 1942. The Pine Top claim was examined with W. E. Hall, September 10–12, 1942. The Pine Top claim produced 5 tons of crude mica and a little feldspar, mined prior to 1942 from two small open-cuts excavated in the performance of assessment work. In December 1943, William and Francis Quinn of Custer spent two days prospecting the property and recovered 1 lb of small sheet from 158 lb of crude mica.

Many pegmatite dikes of various sizes conformably intrude gray quartz-mica schist. All strike northwesterly and most of them dip steeply west. The dikes are composed of perthite, quartz, muscovite, albite, garnet, and black tourmaline. Books of muscovite can be seen only in the outcrop of the hanging-wall part of the main pegmatite.

The main dike outcrops for 260 ft along the strike, N. 15° W. It dips 55° SW. Two small open-cuts, one near the north end of the dike and the other 130 ft south of the first, have been excavated in the west side of the pegmatite. In these cuts the pegmatite is composed largely of coarse perthite and graphic granite in a matrix of fine-grained albite and quartz. Muscovite, garnet, and black tourmaline are dispersed scantily through the albite and quartz. Between the two open-pits a 5- to 6-ft layer of rose quartz forms the middle of the pegmatite.

A thin discontinuous wall zone containing muscovite extends from the north cut along the west side of the outcrop to the south end of the pegmatite and then along the footwall for about 50 ft. The mica is associated with fine-grained albite-quartz pegmatite and is irregularly distributed. In places it comprises as much as 5 percent of the visible hanging-wall surface. The books are less easily decomposed than the matrix and they protrude from the weathered surface of the pegmatite.

The mica taken from the outcrop and from loose pegmatite blocks is ruby mica. Most of it is water-stained because of long exposure to the weather but, aside from this defect, an appreciable proportion of the mica is clear, or slightly air-stained, and appears to be of strategic quality. The books are as much as 3 in. wide and 5 in. long.

PLATE LODE MICA CLAIM (KEYSTONE DISTRICT)

The Plate Lode mica claim, in the SW¼ sec. 6, T. 2 S., R. 6 E., Pennington County, 1¼ miles northwest of Keystone, was located by Elmer C. Harris and Vernon T. Leaver August 15, 1941. It is probably on deeded land of the Grass homestead.

The property has been worked for mica from shallow pits scattered over the large irregular pegmatite surface. The pegmatite crops out for 200 ft vertically on the top and north side of a ridge on the south side of Battle Creek. The outcrops appear to be mainly dip slopes of a barren border zone. Where cut by erosion or excavations, mica-bearing wall zones 1 to 6 ft thick are exposed. The mica is in small books that are in part "tied" and wedged. The books that contained flat mica were deep ruby, flat, hard, and moderately air-stained. About 500 lb of crude mica and a few pounds of beryl were produced by Harris in 1943.

The large size, the shape, and the mineralogy of this pegmatite suggest that with exploration appreciable quantities of industrial minerals might be developed.

PLEASANT VALLEY MINE (CUSTER DISTRICT)

by J. W. Adams and Peter Joralemon

The Pleasant Valley mine is in the NE¼ sec. 7, T. 4 S., R. 4 E., about 4 miles southwest of the town of Custer, Custer County. The property is owned by Charles A. Parker Jr. of Custer, and in 1943 was operated by George Bland, Jr. The mine was worked primarily for feldspar but a small quantity of beryl was recovered and sold. It is developed by an open-cut about 75 ft long, 10 to 15 ft wide, and as much as 50 ft deep. The property has been visited at various times by geologists of the U. S. Geological Survey but has not been mapped in detail.

The pegmatite that has been mined appears to be a fracture-filling body developed in a larger poorly segregated pegmatite that strikes approximately N. 65° E. and dips vertically. The fracture-filling body strikes at almost right angles to the large pegmatite and dips approximately 65° NE. Where exposed in the open-cut it consists of a tourmaline-rich border zone a few inches thick, a wall zone, 6 to 8 ft thick, of plagioclase-quartz-muscovite pegmatite with accessory perthite and some beryl, and a central zone of perthite-quartz pegmatite about 15 ft thick. The central zone consists chiefly of coarse crystals of buff-colored perthite and large quartz masses. The other limit of this zone contains abundant lithiophilite-triphylite, clusters of scrap mica, plagioclase, beryl, and rare columbite-tantalite.

Beryl occurs in the pegmatite in pale-green to white, subhedral to anhedral crystals generally about 1 in. in diameter. The mineral is found in the outer edges of the core and in the adjoining 3 or 4 ft of the wall zone. Apparently there is no beryl in the outer 1 to 2 ft of the wall zone. Measurements taken in October 1943 by Page and Leo Coady of Metals Reserve Corporation showed 11.65 sq ft of beryl in the 1,000 sq ft of rock surface measured or slightly more than 1 percent beryl. A determination of 1.93 percent was made by Peter Joralemon of the U. S. Geological Survey, on the surface of a block later mined as a bulk sample by the U. S. Bureau of Mines. The area of this surface was 90 sq ft. The new surface, revealed after removal of the sample, showed no beryl. The bulk sample weighing 34,070 lbs was hand sorted and 70 lbs of beryl was obtained, a recovery of about 0.3 percent. Results of the analyses of the residue of this sample are not known.

Future operation of the pegmatite for feldspar is not likely to result in the recovery of much beryl, for most of the beryl occurs outside the feldspar-rich core, and is less than 1 in. in diameter. The property has been idle since 1943.

PUNCH MICA MINE (CUSTER DISTRICT)

by M. P. Erickson

The Punch mica mine, known formerly as the Wyoming mica lode (Sterret, 1909, p. 396; 1923, p. 302), is 5¾ miles southwest of Custer, in the NW¼ sec. 27, T. 4 S., R. 4 E., Custer County. The property formerly belonged to F. T.(?) Peterson of Custer, deceased. The present owners are Francis Michaud and W. W. Wright of Custer.

The property was visited briefly in August 1908, by Douglas B. Sterrett of the U. S. Geological Survey. In September 1942, W. C. Stoll of the Geological Survey made a preliminary map of the open-cut workings and the mica-bearing zone then exposed on a scale of 1 in. to 50 ft. In July 1943, J. J. Norton and L. C. Pray mapped the shaft and 5,417-ft level which had been reopened since Stoll's visit. A map on a scale of 1 in. to 20 ft, (fig. 25) was made by M. P. Erickson in June 1945, after mining had been discontinued.

DEVELOPMENT

Workings consist of a small north cut, a south cut, and a middle cut formed by the confluence of three smaller cuts. In the middle of the south cut is the collar of a 43-ft shaft with a 15-ft drift at the bottom.

GEOLOGY

Pegmatite is the dominant rock in the area of the mine. A little quartz-mica schist wall rock is exposed but it apparently occurs as inclusions in pegmatite or as partings separating large pegmatites.

METAMORPHIC ROCKS

Mica-quartz schist.—The only wallrock exposed is fine-grained mica-quartz schist. The foliation strikes a few degrees west of due north, and its dip is essentially vertical at the eastern contact. The dip was 60° E. in one schist inclusion in the south pit.

PEGMATITE

The pegmatite body in which the Punch mica mine is situated is about 180 ft wide near the workings at the south end. Here the west half of the pegmatite is covered by dump material but the east half and the east contact are well exposed. The dike apparently ends within 100 ft to the south of the workings but extends at least 1,000 ft to the north.

The pegmatite strikes a little west of north and appears to dip vertically. It is composed predominantly of fine-grained perthite-albite-quartz pegmatite, in which quartz pods are surrounded by zones of muscovite-albite-quartz pegmatite as much as 2 ft thick. The pods lie about midway between the walls and form a discontinuous core. The muscovite-albite-quartz pegmatite makes up the intermediate zone. The quartz pods are known to occur only in the mine area. The largest was about 40 ft long, 25 ft wide, and 15 ft thick.

Perthite-albite-quartz pegmatite.—The perthite-albite-quartz pegmatite wall zone is composed of pink perthite (70 percent), albite (15 percent), and quartz (10 percent) with garnet, black tourmaline, and scattered fine mica constituting the remaining 5 percent. The grain size is generally ¼ in. to 3 in., but some blocky masses of perthite are as much as 1 ft across. These masses are enclosed in the finer-grained rock.

Muscovite-albite-quartz pegmatite.—The muscovite-albite-quartz zone surrounding the quartz pods is about 80 percent muscovite in books as much as about 6 in. across. Albite and quartz in grains as much as ½ in. in diameter are interstitial to the muscovite books. Small quantities of tourmaline and biotite are also present.

Quartz pegmatite.—The quartz pegmatite occurs as pods of massive white and glassy quartz in grains as much as 1 or 2 ft long, but boundaries of grains are not discernible.

MINERAL DEPOSITS

Mica production was almost entirely from the muscovite-albite-quartz zones surrounding two quartz pods in the middle open-cut. The mica is of ruby or red-rum color. Some of it shows air-staining and "A" structure. Much of it is clear or partly clear and all of it is hard. The sheet sizes range from less than 1 by 1 in. to about 4 by 2½ in. Samples collected by W. C. Stoll were submitted for power factor tests. The results are given in the table on p. 27. During 1943–44 the Punch mica mine produced a total of 1,217.28 pounds of trimmed large and small sheet. The ratio of large to small sheet

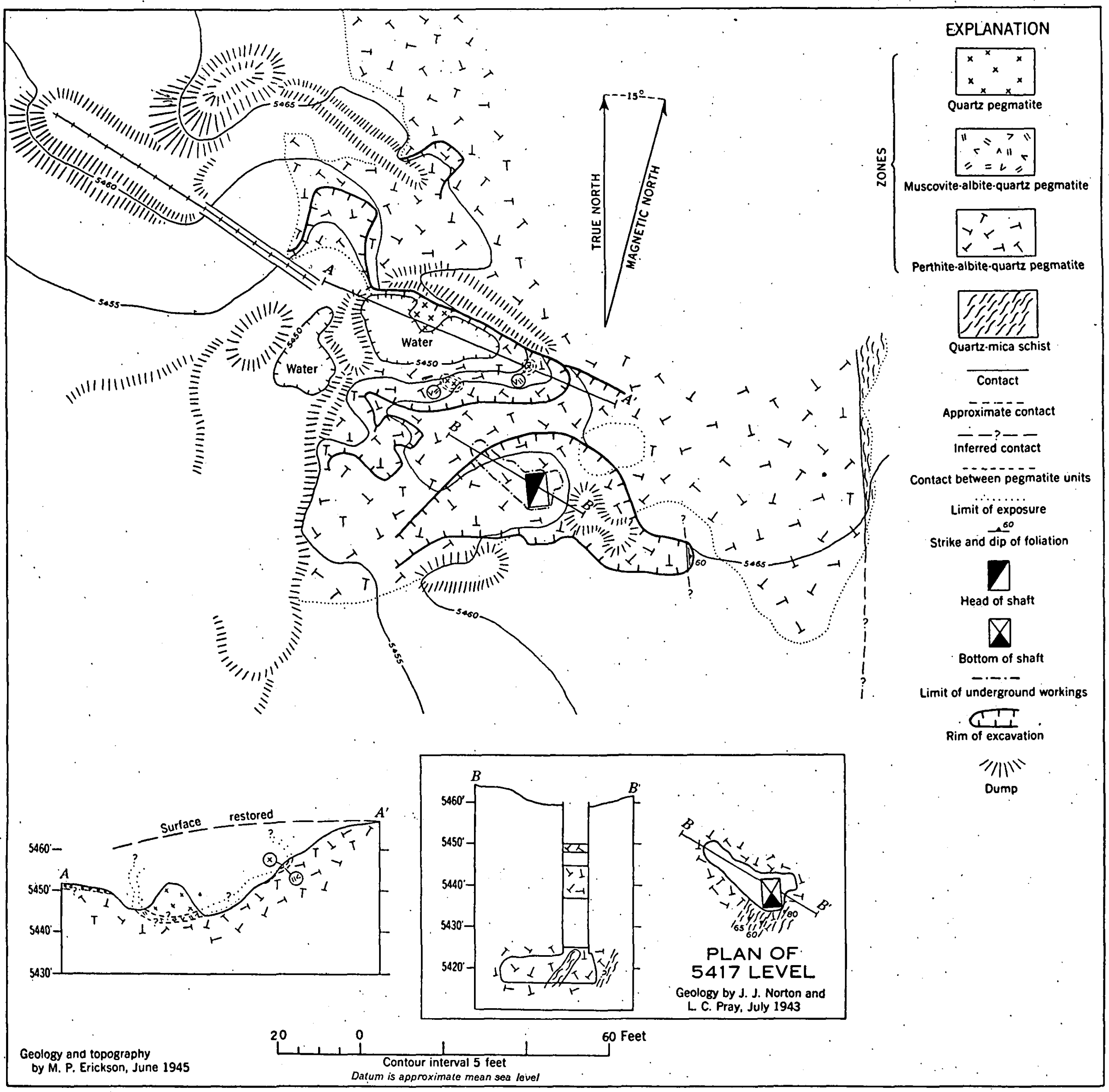

FIGURE 25.—Geologic maps and sections, Punch mica mine, Custer County, South Dakota.

was 1:7.8. The mica sold in 1944 contained as much as 12 percent of no. 1 quality and 10 to 33 percent of no. 2 quality; the remainder was no. 2 inferior quality. The average quality of small sheet was 6.4 percent no. 1 quality and 19 percent no. 2 quality; the average quality of large sheet was 3.4 percent no. 1 quality and 18.6 percent no. 2 quality.

RESERVES

Nearly all the commercial mica, confined to the zone surrounding the quartz pegmatite, has been removed. Other quartz pods may occur within the dike but prospecting for them would be impractical.

RAINBOW MICA CLAIM (CUSTER DISTRICT)

by L. R. Page and Peter Joralemon

The Rainbow mica claim, in the SW¼ sec. 35, T. 3 S., R. 4 W., Custer County, is about 2 miles south of Custer. It is owned by A. L. Harrison of that city and has been operated briefly several times since its discovery; the most extensive operation was during the early part of 1944 when Floyd Frye produced some very good quality sheet mica. In March and April 1944, the U. S. Bureau of Mines explored it by diamond drilling (Clarke, 1944, pp. 4–9). The Rainbow pegmatite was mapped and studied in January 1944 by

L. R. Page and Peter Joralemon. The U. S. Bureau of Mines drill cores were logged and existing maps revised (fig. 26) by Joralemon, assisted by J. W. Adams in April 1944.

The Rainbow pegmatite was first worked from open-cuts, but in February and March, with financial assistance by Colonial Mica Corporation, an inclined shaft, 46 ft deep, was sunk south of the main open-cut. From the base of the shaft, drifts were made 16 ft to the south and 30 ft to the north. The pegmatite was stoped about 20 ft up the dip south of the shaft and about 10 ft up the dip north of the shaft.

The workings are in the center of a series of narrow disconnected pegmatite lenses that trend about N. 25° W. for about 500 ft. The pegmatites north of the workings (fig. 26) are for the most part less than 3 ft thick and are barren of sheet mica. The larger pegmatite to the south contains some sheet mica, but has been prospected only by a shallow pit. It is similar in mineralogy, texture, and attitude to those that have been explored.

Mr. Frye and previous operators confined their work to three lenses of pegmatite (fig. 26) that have a total length of about 150 ft. These lenses have an average strike of N. 22° W., and dip from 50° to 65° SW. The ends of the pegmatite lenses, the rolls in the pegmatite, and the linear structure in the schist have a rather uniform plunge of about 50° S. 20° W. The pegmatites have an average thickness of 4 ft. They conformably intrude an interbedded group of quartz-mica, mica-sillimanite, and sillimanite-garnet schists.

The pegmatites contain four zones but only two have been mapped. The border and wall zone are albite-muscovite pegmatite and contain mica of scrap quality. This part of the pegmatite is very fine-grained at the contact and has an increasingly coarser texture toward the center where the crystals and grains are less than 2 in. across. It is 1 to 1½ ft thick and is

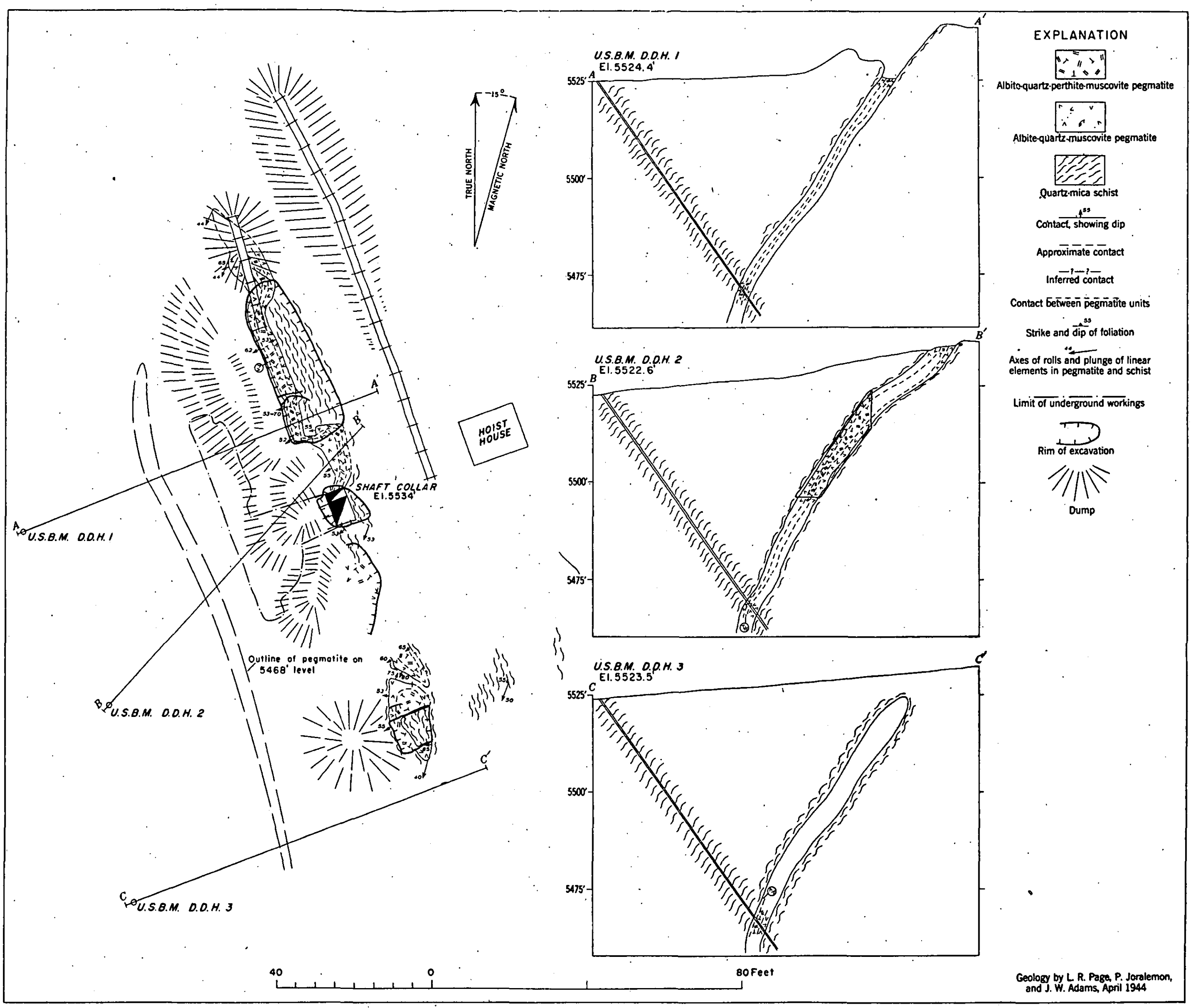

FIGURE 26.—Geologic maps and sections, Rainbow mica mine, Custer County, South Dakota.

the only rock present where the pegmatite is less than 3 ft thick. The center of the pegmatite has been mapped as quartz-perthite pegmatite. Muscovite books occur in the outer 1 ft of this unit and surround the quartz and perthite of the core. Where the entire dike is less than 5 ft thick muscovite-bearing pegmatite forms the central zone of the pegmatite.

The muscovite books are as much as 10 in. in length, but many are smaller. About 2 percent of crude mica was recovered from the open-pit, most of it so strongly reeved and tangled that it is of scrap quality. The rest contains about 5 percent of large and small sheets of colorless to pale ruby, hard, flat mica of good quality. Forty to 46 percent of the large sheet and 50 to 53 percent of the small sheet sold in June and July 1944 was of no. 1 quality. About 30 percent was of no. 2 quality and the remainder was no. 2 inferior quality. Air-staining and reeves were the major defects. A total of 24.9 lb of large sheet and 165.6 lb of small sheet mica was produced in 1944 and about 21 lb in 1943.

The U. S. Bureau of Mines diamond-drilling project indicated that the pegmatite does not change in size and shape down to the 60-ft level and that the mica-bearing zones are not wider. The positions of the drill holes are shown in figure 26 and logs of the drill holes are given below.

Logs of U. S. Bureau of Mines diamond-drill holes, Rainbow mica mine

Drill hole no. 1

Feet	Description
0–14	No core.
14–64.5	Fine-, medium-, and coarse-grained mica-sillimanite schist interbedded with fine- to coarse-grained quartz-mica schist. Bedding and foliation 65°–70° to the drill core.
64.5–68.7	Pegmatite. Hanging-wall contact not recovered. Foot-wall contact 60° to the drill core.
64.5–64.6	Quartz-albite-muscovite border zone.
64.6–65.7	Quartz, albite, muscovite, and apatite. About 5 percent mica in sludge.
65.7–66.9	Coarse gray perthite.
66.9–68.7	Quartz, colorless to gray albite, and muscovite. Last half in. at contact heavily iron-stained.
68.7–71.5	Fine- to medium-grained quartz-mica schist interbedded with thin beds of mica-sillimanite schist. Bedding and foliation 60°–70° to the drill core.

Drill hole no. 2

Feet	Description
0–11	No core.
11–65	Fine-, medium-, and coarse-grained mica-sillimanite schist with interbedded quartz-mica schist. Garnetiferous at 57 ft. Bedding and foliation 60°–70° to the drill core.

Logs of U. S. Bureau of Mines diamond-drill holes, Rainbow mica mine—Continued

Drill hole no. 2—Continued

Feet	Description
65–69.2	Pegmatite. Hanging-wall contact 70° to the drill core. Footwall contact about 55° to the drill core.
65–65.1	Quartz-albite-muscovite border zone.
65.1–65.4	Quartz, gray albite, and small flakes muscovite.
65.4–66.2	Coarse gray perthite, quartz, and muscovite books of undetermined thickness.
66.2–69.2	Quartz, gray albite, small flakes muscovite, and apatite.
69.2–74	Medium- to coarse-grained quartz-mica schist with a few crystals of sillimanite and garnet. Narrow pyrite bands. Bedding and foliation 55°–70° to the drill core.

Drill hole no. 3

Feet	Description
0–13	No core.
13–68.8	Fine-, medium-, and coarse-grained mica-sillimanite schist with interbedded quartz-mica schist. Bedding foliation 70° to the drill core. Garnetiferous at 46 ft.
68.8–73.4	Pegmatite. Hanging-wall contact 60° to the drill core. Footwall contact about 60° to the drill core.
68.8–68.9	Quartz-albite-muscovite border zone.
68.9–69.6	Quartz, gray albite, and flakes of muscovite.
69.6–71.4	Coarse-grained quartz and albite, and small quantity perthite. Parts of several muscovite books were recovered in the core.
71.4–73.4	Fine-grained quartz, gray albite, muscovite and two large tourmaline crystals.
73.4–78.5	Medium- to coarse-grained mica- sillimanite schist. Interbedded quartz-mica schist.

RAINBOW NO. 4 CLAIM (CUSTER DISTRICT)

The Rainbow No. 4 claim, in the SW¼ sec. 6, T. 3 S., R. 4 E., Custer County, is owned by the Consolidated Feldspar Corporation. It has been prospected for feldspar by two open-cuts and in 1943 was sampled for beryl by the U. S. Bureau of Mines. The property was mapped by pace and compass July 1, 1945 (fig. 27). It was previously examined by Peter Joralemon in November 1943 at the time of the U. S. Bureau of Mines work.

The Rainbow No. 4 pegmatite is a very irregular body largely conformable with the enclosing quartz-mica schists. The outcrops appear to be the very top of the pegmatite and the intermediate zone and core have been exposed only in the two open-cuts, the bottoms of which are only about 5 ft below the top of the core. The general trend of the body is about N. 20° E., but offshoots of the pegmatite strike N. 45° E. and dip

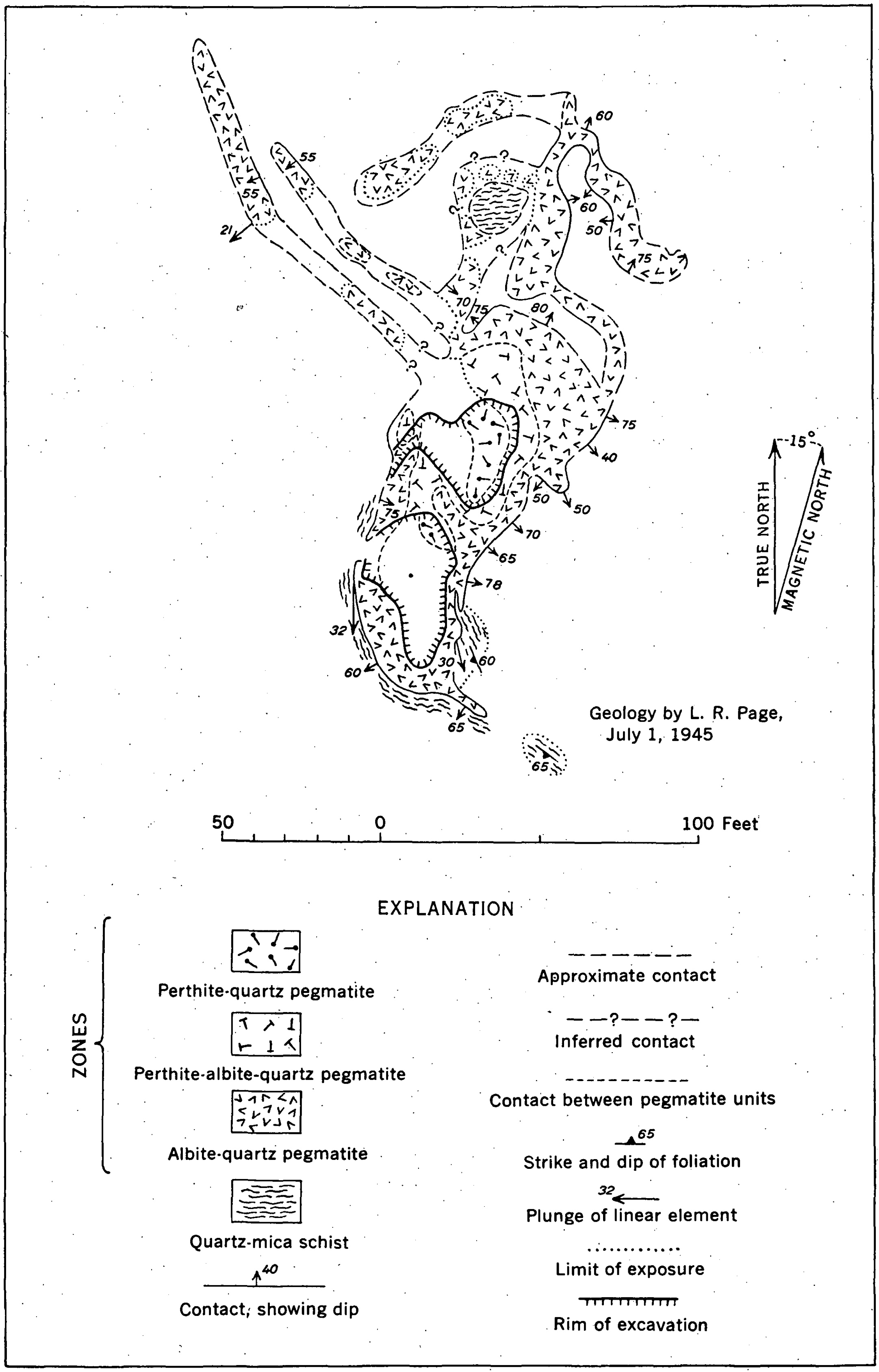

FIGURE 27.—Rainbow No. 4 mine, Custer County, South Dakota.

55°–65° SW. Both parts of the dike are parallel to the foliation of the schist. The main part of the pegmatite appears to be enlarging downward, though the general dip is steeply east.

The Rainbow No. 4 pegmatite, in the thicker, southern part, contains three zones in addition to a border zone ½ to 1 in. thick. The wall zone is albite-quartz-muscovite pegmatite, composed of fine-grained pink albite (50 to 60 percent), quartz (20 percent), muscovite (10 percent), pink perthite (10 percent), and tourmaline and garnet. The zone is 1 to 8 ft thick. Pale-green to white beryl occurs in crystals as much as 1½ in. in diameter. The richest beryl-bearing area measured in this zone contained about 0.02 percent of beryl. The narrow irregular offshoots on the northern end of the pegmatite are finer grained than the albite-quartz pegmatite of the wall zone in the southern part of the body.

The intermediate zone, exposed in the walls of the two open-cuts is coarse-grained perthite-albite-quartz pegmatite. It is about 10 ft thick and encloses a core of coarser-grained perthite-quartz pegmatite. The intermediate zone grades both mineralogically and texturally into the wall zone and core. The perthite-albite-quartz pegmatite consists of pink perthite (30 percent) crystals as much as 2 by 4 ft in a matrix of gray quartz (25 percent), yellowish muscovite (20 percent), pink to white albite (15 percent), black tourmaline (5 percent), lithiophilite (3 percent) and beryl (1 to 2 percent). The average grain size in the matrix is less than 6 in. In the north cut an area of 150 sq ft contained 364 sq in. or about 1.6 percent beryl. The largest crystal measured 18 by 15 in. across. Lithiophilite, in part altered to purpurite, occurs as masses as much as 12 in. across.

The perthite-quartz pegmatite of the core is exposed in both pits near the floor. Perthite crystals as much as 8 ft long are exposed in gray to white massive quartz.

Industrial minerals obtainable from this pegmatite are feldspar, beryl, and mica. The feldspar produced in the past was almost entirely from the intermediate zone as the top of the core is exposed to a depth of not more than 6 ft.

The intermediate zone is also the source of beryl crystals recoverable by hand cobbing. Before the U. S. Bureau of Mines sampled this zone in the south cut during 1943 Joralemon measured the face to be sampled (60 sq ft), and found it to contain 0.39 sq ft or 0.64 percent of beryl. After the sample was taken the face was measured again and was found to contain 0.41 percent of beryl. The U. S. Bureau of Mines sample was 45,680 lb from which a total of 80 lb of beryl was recovered by hand sorting. Analyses of the BeO content of the rest of the sample are not available.

The muscovite in the intermediate zone is white to light ruby. It has a conspicuous A structure and is wedged or "tied." However, about 2 percent of sheet mica can be recovered, and a large proportion of it is of no. 1 and no. 2 qualities; the remainder is no. 2 inferior quality because of air-staining. The zone contains 10 to 20 percent of mica, of which half could be recovered as a byproduct of feldspar mining.

RAY MICA PROSPECT (CUSTER DISTRICT)

by R. F. Stopper

The Ray mica prospect is in the SW¼ sec. 15, T. 4 S., R. 4 E., Black Hills Meridian, Custer County. It is about 1 mile northwest of Sanator, South Dakota.

The claim was located in July 1943, by Louis Stratton and Francis Michaud, both of Custer. L. H. Jeffries, of Custer, purchased the claim in April, 1944. The workings consist of 2 small open-cuts from which about 165 tons of pegmatite, containing at least 53.18 pounds of sheet mica, has been removed. The property was mapped (fig. 28) August 1, 1944.

The pegmatite conformably intrudes pre-Cambrian biotite-quartz schist. It has a minimum length of 100 ft, and averages 8 ft in width. It strikes N. 15° W. and dips 55°–60° SW. The exposed parts of the contact between pegmatite and schist show a remarkably even wall. One small roll plunges 65° SW. and the pegmatite probably plunges in the same direction.

The pegmatite is composed mainly of quartz-albite-muscovite pegmatite, with irregular bodies of graphic granite and perthite-quartz pegmatite as much as 10 ft in length. Most of the perthite and graphic granite is near the center of the dike but some lies near or at the walls. Muscovite is distributed throughout the dike. Some of it has developed along joint planes, especially in the graphic granite. Associated minerals are biotite, tourmaline, garnet, and apatite.

The mica books average 4 in. in maximum dimension but are as much as 8 in. in length. The mica is dark ruby, uncommonly hard, and some is air-stained, ruled, and badly reeved. Many books have inclusions of biotite and quartz. The quality of sheet in one small shipment was 7 percent no. 1 quality, 30 percent no. 2 quality, and 63 percent no. 2 inferior quality. The ratio of small sheet (less than 1½ by 2 in.), to large sheet is about 9:1.

RED DEER MICA MINE (CUSTER DISTRICT)

by L. R. Page, J. J. Norton, and L. C. Pray

The Red Deer mica mine was one of the principal sources of mica in the Custer district during the latter part of 1943. The Red Deer mine is on an unpatented claim, owned by the Consolidated Feldspar Corporation, in the SE¼ sec. 15, and the NE¼ sec. 22, T. 4 S., R. 5 E.

The early history of the Red Deer mine is unknown. It was operated many years ago by an open-pit and by underground work in a 30-ft shaft gently inclined to the east and a 20-ft drift extending north from the base of

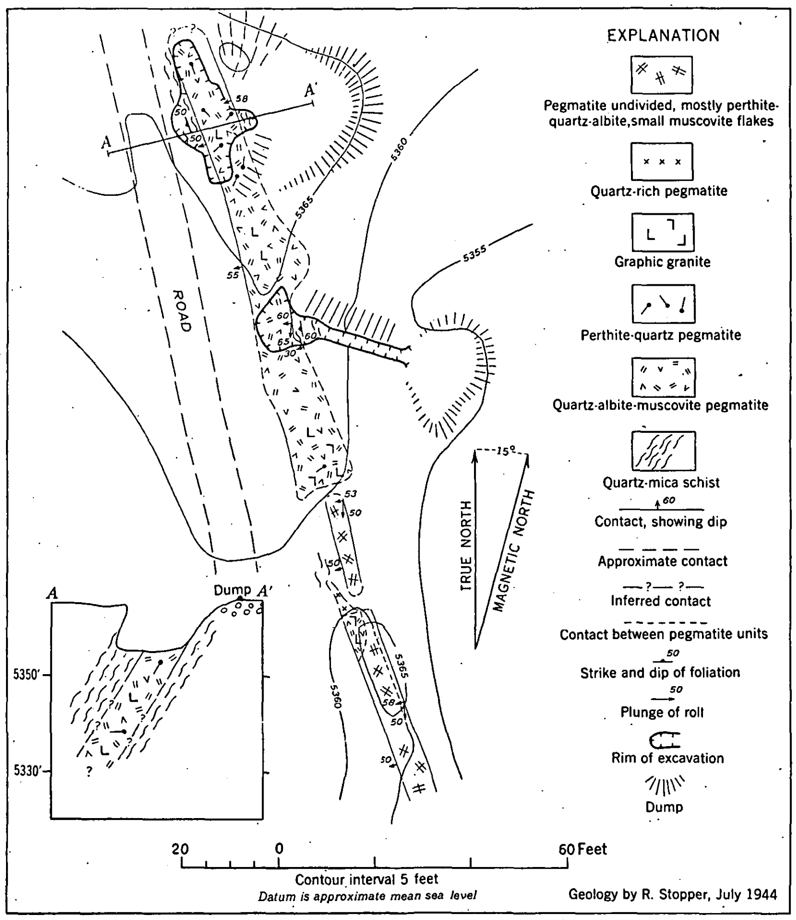

FIGURE 28.—Geologic map, Ray mica prospect, Custer County, South Dakota.

the shaft. Several prospect pits and small open-cuts have been made in search of mica and feldspar. In the spring of 1943 the mine was operated on a small scale by Francis Michaud and Louis Stratton, who made four sales of sheet and punch mica to the Colonial Mica Corporation in June 1943. K. C. Gaynor leased the property in June 1943, and began operation the following month. From August 1943, until the end of the year when the mine was closed down, it was one of the large producers in the Custer district. The main open-cut was enlarged, and the pegmatite was worked extensively from an inclined drift.

The surface and underground workings at the Red Deer mine were mapped in July, 1943 and the mapping was brought up to date when the mine was closed at the end of December 1943. On July 17, L. R. Page with the assistance of L. C. Pray mapped the surface by telescopic alidade and plane table on a scale of 1 in. to 20 ft, and in November, Pray, assisted by Peter Joralemon, brought the surface mapping up to date. J. J. Norton mapped the old underground workings July 17, on a scale of 1 in. to 10 ft. In December 1943, and January 1944, Norton and Pray mapped the new underground workings at the same scale. Plates 34 and 35 show the mine at the time it was closed; the outlines of the open-pit and underground workings at the time Gaynor began work are also shown.

MINE WORKINGS

At the Red Deer mine, mica has been produced both from open-cuts and underground workings. Surface work in 1943 was confined to the main open-cut, which has an area of 2,600 sq ft and an average depth of 10 ft. The underground has been worked from an inclined haulage drift. Five main drifts have been driven from this incline, and the mine has been operated in a more or less room-and-pillar fashion. About 100 ft from the portal the haulage drift intersects the old incline from the open-pit. The total area of underground workings is about 3,000 sq ft.

GEOLOGY

The Red Deer mica mine is in a highly irregular, gently dipping pegmatite which intrudes pre-Cambrian schist and quartzite. At its eastern end the pegmatite grades into coarse-grained granite.

QUARTZ-MICA SCHIST AND QUARTZITE

The quartz-mica schist that forms the wallrock of the Red Deer pegmatite is a dark gray to black, moderately foliated rock containing biotite, muscovite, and quartz. Near the contact it is locally granular and locally contains apatite, tourmaline, and other introduced minerals. The schist is highly folded, but the dip is generally less than 30°.

A dark-gray quartzite crops out in the southwest corner of the mapped area (pl. 34). It strikes N. 10° E. and dips vertically. There are too few exposures to show the relation of the quartzite to the quartz-mica schist.

GRANITE

The southeastern part of the area mapped is underlain by a coarse-grained, light-colored granite that contains irregular pods and lenses of pegmatite, the largest of which are shown on the map (pl. 34). The attitude of the granite body is obscure, but the exposures are believed to be essentially on a dip slope. The Red Deer pegmatite can be traced into the granite area, and the contacts with the granite appear gradational.

PEGMATITE

The Red Deer pegmatite is an irregular, gently pitching, synclinal body, 10 to 17 ft thick, whose shape has been modified by many minor folds and one fault. West of the fault the structure of the pegmatite appears to be anticlinal. Two zones have been mapped within the pegmatite (pls. 34 and 35). The outer zone is quartz-albite-perthite-muscovite pegmatite, which grades inward to a core of quartz-perthite pegmatite. The contact of the pegmatite and schist is in places sharp and clearly defined; in others, pegmatite grades imperceptibly into altered schist; and in still others, tongues and blebs of pegmatite may be so abundant as to obscure the contact.

The structure of the Red Deer pegmatite is very complex. It is essentially a trough-like body whose axis trends northeasterly and in general it conforms with the schist structure. Many small rolls in the contacts complicate the major structure. Most of the mine workings are on the southern limb, which dips in general 15° NW. The northern limb dips about 20° SE.

The contacts of the Red Deer pegmatite are very irregular, with many rolls and with uneven intrusive contacts. On the south limb of the structure there appear to be at least two distinct sets of rolls which cross each other. In addition, there are minor rolls that do not fall in either of the two main groups. The most conspicuous rolls have axes plunging very gently N. 65° E. to S. 55° E. The axes of the second set trend N. 5° W. to N. 20° E., and in general plunge north. Where rolls cross the plunge may be reversed. There is little information concerning the attitude of rolls on the north limb of the structure.

The relationship between the hanging-wall rolls and the rolls in the footwall is not known, but there is no evidence that the rolls in one wall are reflected in the other. In some of the footwall rolls a stringer of schist has been detached from the footwall and circles up through the pegmatite. A typical roll is near the center of Section C–C′ (pl. 35), where the upper layers of a schist roll are separated from the main body of schist by a core of mica-bearing pegmatite.

Quartz-albite-perthite-muscovite pegmatite.—Quartz-albite-perthite-muscovite pegmatite, 2 to 7 ft thick, occurs along both contacts of the main pegmatite. It is composed mainly of quartz and albite (An_4–An_{12}, minimum refractive index of cleavage fragments 1.528 to 1.533) in grains 1 to 2 in. across, associated with scattered crystals of perthite, most of which are less than 1 ft long. Muscovite is most abundant near the schist, and the proportion decreases abruptly toward the center of the pegmatite. Near the hanging wall, blades of muscovite as much as 6 ft long fill cracks formed at right angles to the contact. The accessory minerals occurring in this zone include tourmaline, beryl, red-brown manganese garnet, and apatite.

Quartz-perthite pegmatite.—Quartz-perthite pegmatite forms the interior of the Red Deer pegmatite and grades outward into the quartz-albite-perthite-muscovite pegmatite of the wall zone. The core is 3 to 8 ft thick. Part of it is composed almost entirely of quartz and perthite crystals as much as 4 ft across; quite commonly small quantities of albite, tourmaline, and muscovite are present.

MICA DEPOSITS

The Red Deer mine, during 1943, produced mica from the wall zone on both the footwall and the hanging-wall parts of the pegmatite. More than half of the mica was produced from the footwall deposit.

The footwall mica deposit is 2 to 6 ft thick in the underground workings; the average is 3 ft. It has similar thicknesses where exposed in the open-pit, although here it locally merges with the hanging-wall deposit. Geologic evidence suggests that the footwall deposit is more than 150 ft long and at least 150 ft wide at the axis of the major structure.

The hanging-wall mica deposit crops out for 180 ft along the south limb of the main structure and has a maximum outcrop width of 40 ft on a dip slope. In the open-pit it is 5 to 7 ft thick and averages about 6 ft. This mica deposit has not been mined underground because its nearness to the surface would cause mining difficulties. The probable area of the hanging-wall mica deposit is about the same as that of the footwall deposit.

The mica produced from the Red Deer mine is mostly hard, flat, and deep ruby mica in books as much as 12 in. in diameter. In the hanging-wall zone, blades of mica as much as 6 ft long, 12 in. wide, and 3 to 4 in. thick were observed. Sheet mica was produced both from these blades of late muscovite and from the more normal book occurrence. About 14 percent of the mica sold was large sheet. The major defect is air-staining, though mineral stain is present. In some of the large books the air-stain is greatest at the edges and less intense at the centers. The smaller books are more uniformly air-stained. The mineral inclusions are quartz, feldspar, tourmaline, and probably garnet and magnetite. Under the microscope some of the black stains are found to be aggregates of a fine-grained, dendritic, grayish unknown mineral which resembles some of the clay minerals. This is in part stained with what appears to be manganese oxides.

RESERVES

Probably the total reserves of mica-bearing rock at this mine are large. There is no known reason why the footwall mica deposit should not extend a considerable distance beyond the present headings. Large mica reserves should be available in the hanging-wall deposit, but would require stripping as much as 20 ft of overburden.

ROOSEVELT MICA MINE (CUSTER DISTRICT)

by J. J. Norton

The Roosevelt No. 1 and the Roosevelt No. 2 claims, which have been mined on a small scale for mica, are about 200 yards east of the Buster Dike mine. The claims, in sec. 9, T. 4 S., R. 4 E., have been worked by an extensive, shallow open-cut in the southeastern part of the mapped area on the No. 1 claim (pl. 8) and by a small shaft on the No. 2 claim. Both claims are owned by Margaret Hampton of Custer.

The Roosevelt No. 1 claim was worked intermittently during 1943 by L. S. Allen, who operated by very small scale open-pit methods. The Roosevelt No. 2 claim has been worked only in an inclined shaft sunk 34 ft at an angle of 65°. L. S. Allen is said to have opened the deposit in 1942. E. B. Clifford worked it in the early part of 1943, selling mica to the Colonial Mica Corporation from January to April 1943. Ralph Watwood and two associates worked the deposit in the fall of that year, selling mica to the Colonial Mica Corporation in the months of October and November.

The Roosevelt properties contain many westward-dipping pegmatites that intrude pre-Cambrian metamorphosed sedimentary rocks, principally quartz-mica schist. Pegmatite outcrops are numerous, but very little of the country rock is exposed.

The pegmatites are subparallel, with an average strike of N. 15° W. and a dip of 65° SW. The Roosevelt No. 1 pegmatite has a poorly defined quartz-albite-muscovite zone on the hanging wall. The pegmatite that has been mined on the Roosevelt No. 2 claim probably has a higher proportion of albite and muscovite, and less perthite, than the pegmatite in the No. 1 claim.

The two pegmatites that have been mined on the Roosevelt claims show no structural peculiarities. The shaft on the No. 2 claim is in a nearly tabular pegmatite that strikes from N. 14° W. to N. 22° W., and dips 65° SW. The pegmatite on the No. 1 claim is an imperfectly exposed lenticular body that appears to have no uncommon structural features.

The two Roosevelt claims have produced a small quantity of sheet mica. The mica is ruby, clear, hard, and moderately air-stained. Accurate detailed figures on production are not available for either claim.

E. B. Clifford, who operated the No. 2 claim, is known to have sold 106.44 lb of punch, 81.26 lb of small sheet, and 8.36 lb of full-trimmed large sheet. The Watwood operation subsequently produced 33.43 lb of small sheet. The total known production of the mine, therefore, is only 123.05 lb of sheet mica and 106.44 lb of punch. This amount probably represents about 3,000 lb of crude mica. The estimated total quantity of rock mined from the shaft is about 270 tons. Most of the rock is reported to have been mined during the Clifford and Watwood operations. The grade of the deposit appears to be very low, probably less than 1 percent of recoverable mica.

The Roosevelt No. 1 claim has produced 50.32 lb of sheet mica, according to L. S. Allen, the operator. The mica content of the deposit cannot be estimated from the past production because the mica has been taken from the entire outcrop. It is very unlikely, however, that the mica content is more than 1 percent.

The two Roosevelt dikes contain reserves of mica that probably are of too low grade for profitable mining now, but may produce a small quantity of mica under changed conditions.

RUBY REEF CLAIMS (CUSTER DISTRICT)

by J. J. Norton

The Ruby Reef claims yielded small quantities of high quality sheet mica during 1943. The Ruby Reef and Ruby Reef No. 1 claims are in the E½NW¼ sec. 23, T. 4 S., R. 4 E., Custer County.

During 1943 the large- and small-sheet production was 390.55 lb and in 1944 it was 257.8 lb.

Field work by the U. S. Geological Survey on this property was done principally in April 1944, but the underground maps were revised July 19, 1944. The area was mapped on a scale of 1 in. to 20 ft by J. J. Norton, assisted by Peter Joralemon and J. W. Adams.

The map shows the principal pegmatites on the Ruby Reef claim, the Ruby Reef No. 1 claim, and the 25-ft level at the bottom of the new shaft on the Ruby Reef No. 1 (pl. 36).

MINE WORKINGS

The principal workings are on the main pegmatite of the Ruby Reef No. 1 claim. During 1943 Stratton and Shull made a narrow open-cut, about 45 ft long and 20 ft deep, at the south end of the pegmatite, and a thickness of about 3 ft was stripped off the hanging-wall side of the body. Early in April 1944 L. H. Jeffries began operations and a shaft, inclined at 65° to the west, was sunk 64 ft. At 25 ft, a crosscut has been driven to the hanging wall and a few feet of drifting has been done in both directions (pl. 36). At the 64-ft level a drift extends 58 ft south and a raise connects it with the surface. North of the shaft the pegmatite has not been worked except at the extreme north end, where a small prospect pit has exposed the pegmatite for about 17 ft along the strike.

On the Ruby Reef claim four pegmatites have been explored by prospect pits and small open-cuts. The large pegmatite on the northern part of the map of this claim (pl. 36) has three prospect pits which probably were made for potash feldspar. Three small mica-bearing pegmatites to the south had been worked by open-cuts.

HISTORY

Prior to 1943 only a meager amount of prospecting had been done on the two Ruby Reef claims. In February 1943 the two claims were recorded by Louis Stratton and Francis Michaud of Custer. Prospecting work was done at this time, and a few pounds of sheet mica was produced from the Ruby Reef No. 1 claim. From July to October 1943, Stratton and Ray Shull mined the property. Most of their work consisted of open-pit operations on the hanging wall of the main pegmatite on the Ruby Reef No. 1 claim, but during August considerable work was done on the Ruby Reef claim proper. In December Stratton did additional work on the Ruby Reef No. 1. L. H. Jeffries of Custer purchased the two claims in the early part of 1944. With financial assistance from Colonial Mica Corporation, he began work on the Ruby Reef No. 1 in April, and continued underground operations until August, when the mine closed.

GEOLOGY

The two Ruby Reef claims contain many subparallel pegmatites that strike about N. 15° W. and dip 65° SW. The country rock consists principally of pre-Cambrian quartz-mica schist and quartz-mica-sillimanite schist interbedded with quartzite.

Quartz-mica schist, quartz-mica-sillimanite schist, and quartzite.—Most of the exposed country rock is medium-grained quartz-mica and interbedded quartz-mica-sillimanite schist, with a few beds of quartzite. The sillimanite-bearing schist is like the normal quartz-mica schist except in sillimanite content. The sillimanite is in part altered to muscovite. Schistosity is moderately well developed about parallel to the bedding, and averages about N. 20° W. in strike and 65° SW. in dip. Fragments of hornblende-garnet gneiss, which apparently is interbedded with the schist, were observed on the surface, but not in outcrop.

PEGMATITE

Most of the pegmatites shown on the map (pl. 36) are poorly zoned. In general they are simple mixtures of quartz, perthite, and oligoclase, but some contain appreciable quantities of muscovite, which is generally most abundant near one or both walls.

The plagioclase in the Ruby Reef pegmatites is oligoclase, rather than albite, the chief plagioclase in most pegmatites of the Custer district.

The Ruby Reef claims contain a group of sub-parallel pegmatites striking from N. 8°–30° W. The average dip is about 65° SW., but rolls and other irregularities cause the contacts to range in dip from as little as 40° SW. to 75° NE. The pegmatites are not perfectly concordant with the regional schistosity, but the foliation of schist at the contact is generally parallel to the walls of the body. The pegmatites range from lenticular to tabular. The pegmatite mined on the Ruby Reef No. 1 is a more or less tabular body that strikes N. 10° W. and has an average dip of about 60° SW. The many rolls on the walls of this pegmatite generally plunge to the south at a high angle. The south end of the dike apparently also plunges to the south, but exposures are too poor to permit accurate determination of the plunge. Mica did not appear to be more abundant in the rolls than elsewhere along the outer part of the pegmatite. Rolls are not conspicuous in the walls of most of the other dikes, but the large pegmatite on the northern part of the Ruby Reef map (pl. 36) has strongly developed rolls along the footwall that plunge 35° to 40° in a S. 5° to 22° W. direction.

Quartz-perthite-oligoclase-muscovite pegmatite.—Quartz-perthite-oligoclase-muscovite pegmatite forms a part of the pegmatite mined on the Ruby Reef No. 1 claim, and is also an important constituent of three of the pegmatites on the Ruby Reef claim. The rock consists of quartz and oligoclase grains ¼ to 1½ in. across, with perthite crystals measuring 6 in. or even more in their greatest dimension. The muscovite books are mostly small, and rarely more than 6 in. across. Microscopic determination of the minimum indices of the plagioclase in 5 specimens of this variety of pegmatite show that nearly all of the plagioclase is oligoclase (An_{14}–An_{20}) with minimum indices of the cleavage fragments 1.534 to 1.538. The accessory minerals found are tourmaline, biotite, and apatite. Most of the biotite occurs in the form of blades, and is commonly intergrown with muscovite.

This type of pegmatite was mined for mica where it occurred along the hanging wall at the south end of the main dike on the Ruby Reef No. 1 claim, and it also forms most of the north end of this dike. In the underground workings it occurs as a narrow zone that lies 1 to 3 ft from the hanging wall, with quartz-perthite-oligoclase pegmatite on either side of it. Actually this hanging wall is the wall of a small pegmatite offshoot from the main body and ends only a few feet north of the shaft. Apparently there is no mica zone on the hanging wall of the larger pegmatite. A little muscovite-bearing pegmatite also occurs about 3 ft from the footwall at the base of the shaft.

This variety of pegmatite is the sole component of two of the small dikes on the southern part of the Ruby Reef map (pl. 36), and in addition it forms the wall zones of a well-segregated dike with a core of quartz-perthite pegmatite.

Quartz-perthite-oligoclase pegmatite.—Most of the pegmatite dike in the area mapped (pl. 36) are homogeneous bodies of quartz-perthite-oligoclase pegmatite, with accessory muscovite, biotite, tourmaline, and apatite. Even in the body being mined on the Ruby Reef No. 1 the difference between this type of pegmatite and the mica-bearing rock is very slight.

The pegmatite consists of perthite crystals a fraction of an inch to as much as 2 ft across, in an aggregate of quartz and oligoclase grains that are generally ¼ in. to 2 in. in length. Intergrown blades of biotite and muscovite are common in much of this kind of pegmatite. Minimum indices of cleavage fragments of the plagioclase, determined for 6 specimens from various parts of the two claims, range from 1.534 to 1.538, indicating it is sodic oligoclase. Possibly some of the plagioclase is albite, but it is certain that most of the plagioclase is oligoclase.

Quartz-perthite pegmatite.—The core of a small dike in the southern part of the Ruby Reef map area (pl. 36) is composed of coarse-grained quartz-perthite pegmatite. Accessory minerals include muscovite, oligoclase, and tourmaline. Perthite crystals as much as 4 ft across occur in this zone.

Quartz pegmatite.—Quartz pegmatite, consisting of gray to white quartz with no appreciable quantities of other minerals, forms a zone in the interior of the pegmatite that is exposed south of the main dike on the Ruby Reef No. 1. The quartz body is essentially tabular, with a strike of about N. 65° W. and a dip of about 30° SW.

MICA DEPOSITS

High quality ruby mica and perthite feldspar occur in all the pegmatites on the Ruby Reef claims, but only mica has been produced.

During the Stratton-Shull operations a total of 113.68 lb of sheet mica was sold from the Ruby Reef proper and 564.48 lb from the Ruby Reef No. 1. Figures on scrap mica sales are not available. Most of the mica from the Ruby Reef proper was obtained from the narrow open-cut, just southeast of the center of the map area (pl. 36), but a little was from the pit on the pegmatite to the south. About 250 tons of pegmatite mined on the Ruby Reef No. 1 produced the sheet mica. The production figures indicate that about 2.3 pounds of sheet mica were recovered for each ton of rock mined, but no face in the mine seen in 1944 appeared to be so rich.

During the Jeffries operation on the Ruby Reef No. 1 nearly 200 lb of sheet mica was produced. The first 1,350 lb of crude mica was produced from 250 tons of pegmatite, indicating that the rock contained 0.27 percent of recoverable crude mica. The sheet mica recovered from 855 lb of this crude mica was 35.21 lb or 4.1 percent. On the basis of these figures, about 0.2 lb of sheet mica was recovered per ton of pegmatite. Perhaps the main reason for this low proportion is that much of the rock mined was in the barren interior of the pegmatite, rather than in the mica-bearing zones. A zone extending from 1 to 3 ft from the hanging wall in the underground workings contains appreciable more mica than the interior of the pegmatite, and may contain as much as 1.5 percent recoverable mica, of which about 5 percent would be sheet. There is no evidence, however, that pegmatite of higher grade remains unmined.

The mica-bearing zone probably extends along the hanging wall from the south end of the dike to the north end of the small pegmatite offshoot just north of the shaft. The hanging wall of the main pegmatite has no discernible mica deposit north of the shaft for 80 ft. Discontinuous mica-bearing rock may lie near the footwall, although probably the deposit is not rich enough for profitable mining. At the north end of the pegmatite considerable mica is present and it would yield a pound or so of sheet mica to the ton of rock.

The Ruby Reef mine produced an unusually high quality clear, flat, ruby mica with very little air-stain, but much of it has silver spots. Between May 1 and September 1, 1944, the quality of the small sheet mica ranged from 16 to 37 percent no. 1 quality, from 28 to 40 percent no. 2 quality, and the remainder no. 2 inferior quality. The large sheet, 10 percent of the total sheet, contained 6 to 37 percent no. 1, 32 to 50 percent no. 2, and 30 to 60 percent no. 2 inferior qualities.

RESERVES

It is difficult to estimate reserves available from the Ruby Reef claims because of the uncertainty about the mica content of the rock. Substantial quantities of mica may be available in the mica pegmatites on the Ruby Reef claim proper, especially in the well-segregated dike south and west of the others. If it can be worked profitably, considerable mica may be recovered by underground mining along the hanging wall of the pegmatite. A little mica could be recovered by open-pit work at the north end of the pegmatite.

SEAL MICA MINE (CUSTER DISTRICT)

The Seal mica mine, in the NE¼ sec. 32, T. 4 S., R. 5 E., Custer County, was claimed by right of location by W. A. Fay, June 7, 1944. The property was first worked by Mr. Leon LaRue of Custer in July 1944 and was later operated by Mr. Fay and associates until April of that year. About 600 lb of sheet mica was produced during this period.

The Seal pegmatite was mapped by L. R. Page and T. A. Stevens October 10, 1944 by plane table and telescopic alidade (fig. 29).

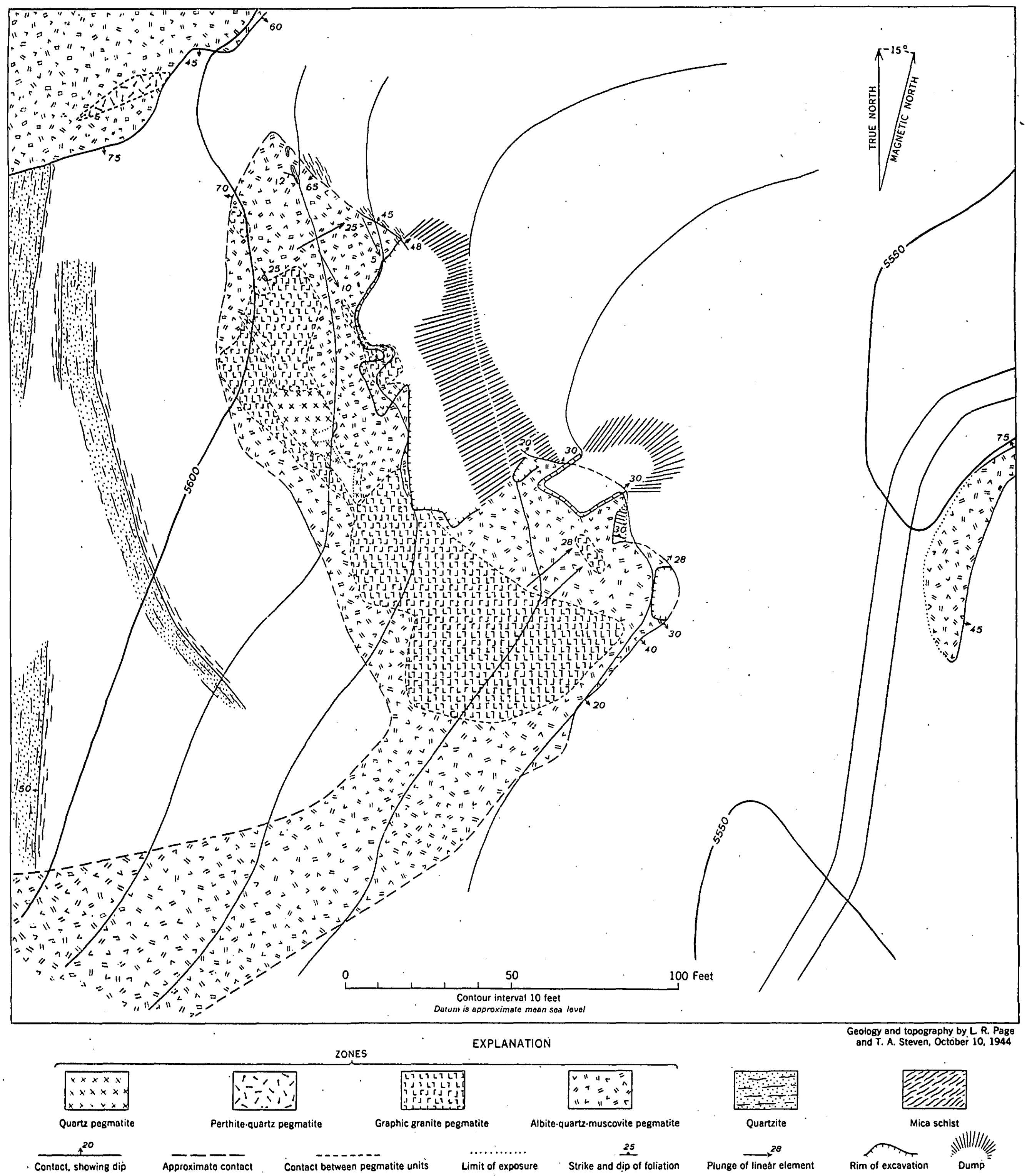

FIGURE 29.—Geologic map, Seal mica mine, Custer County, South Dakota.

The workings at the Seal mica mine are all open-pits, distributed at various altitudes along the dip slope of the pegmatite. Debris from mining obscured much of the geology at the time the property was mapped.

The Seal mine is in the northern end of a large irregularly shaped pegmatite. The pegmatite extends 70 ft west of the area mapped, and then at least 200 ft S. 20° W. Beyond this point it trends south, and two branches split off to the west. The pegmatite at the mine is concordant with the foliation and bedding of the quartz-mica schist and quartzite wallrocks. The trend of the outcrop is N. 25° W. South of the mine the pegmatite swings nearly west to the top of a low ridge. This part cuts across the quartzite and schist, but at the top of the ridge the pegmatite is again approximately concordant. The pegmatite is well zoned at its northwest end but south of the areas mined only the wall zone is exposed.

The part of the pegmatite in which the zoned structure is visible is about 200 ft long and has an outcrop width of as much as 95 ft. This part of the pegmatite strikes N. 20°–45° W., and dips 30°–48° NE. on the hanging-wall contact. The footwall contact is poorly exposed but dips to the northeast. Two sets of rolls were observed on the hanging wall. They plunge about 25 degrees N. 60° E. and 5 to 10 degrees S. 30° E.

In addition to a very thin border zone, the pegmatite has a fine- to medium-grained albite-quartz-muscovite pegmatite wall zone, a graphic granite intermediate zone, and a quartz pegmatite core. The wall zone contains sheet-bearing muscovite books as much as 12 in. across, scattered through pink to white albite, quartz, and perthite. Biotite occurs interlaminated with the muscovite and as large blades that cut across the zone at right angles to the walls. The intermediate zone is almost entirely of graphic granite with some interstitial quartz, albite, and muscovite. This zone grades into the wall zone and into the massive quartz of the core.

The muscovite of the wall zone occurs for the most part as free-splitting, hard books, but near the bulge to the east the pegmatite contains considerable muscovite in tangled books. The mica is deep ruby, moderately air-stained, and contains few mineral inclusions. The books, in part, are strongly ruled, and "ribbon mica" is common. The "ribbons" are as much as 3 in. wide. Large sheet mica comprised about 25 percent of that sold. Individual lots contained as much as 9 percent no. 1, and 8 to 32 percent no. 2 qualities. The remainder was no. 2 inferior quality. The small sheet in these lots contained as much as 12 percent no. 1, 17 to 28 percent no. 2, and 62 to 83 percent no. 2 inferior qualities. The total sale of sheet mica in 1944 was 516.1 lb, and in 1945 was 72 lb. In 1945 at least 405 lb of untrimmed punch also was sold.

The Seal mica-bearing pegmatite has not been mined below the open-cuts, and considerable mica-bearing rock should be available for underground mining.

SILVER DOLLAR MICA MINE (CUSTER DISTRICT)

by Peter Joralemon

The Silver Dollar mica mine is 4.2 miles southwest of Custer, South Dakota, in the NW¼ sec. 11, T. 4 S., R. 4 E., Custer County, at an altitude of 5,400 ft. The property lies a few hundred feet southeast of the Chicago, Burlington, and Quincy Railroad tracks.

The Silver Dollar mica lode was located by Mr. T. S. Gamber of Custer, on May 15, 1942. He worked it until July 1942, when the Black Hills Mining Company secured a lease. This company operated the mine until late 1942, then Gamber carried out intermittent mining operations until October 1943. Mr. L. T. Rodemacher and L. Collingwood of Custer operated the property from October 1943 to April 1944 when their lease expired. The White Bear Mining Company, a subsidiary of Mindak Mines Incorporated, actively developed the property from April until August 1944.

In July 1942, a preliminary report with a pace and compass map of the Silver Dollar Mine was prepared by L. R. Page, and in May 1944, a map (pl. 37) on a scale of 1 in. to 20 ft was made, with telescopic alidade and plane table, by Peter Joralemon and J. W. Adams. On July 20, 1944, just before the mine closed, the underground workings were mapped by L. R. Page and R. F. Stopper.

MINE WORKINGS

The Silver Dollar mine has been worked at the surface by an open-cut 100 ft long, as much as 20 ft wide, and as much as 20 ft deep. This open-pit is in the center of the pegmatite outcrop. At the north end of the open-pit a shaft, inclined at 52° W., prospects the pegmatite to a depth of 71 ft. From the shaft a drift was made 30 ft north and 50 ft south. Two raises prospect the pegmatite above the drift to the south of the shaft. One of these raises broke through to the floor of the old open-cut. North of the shaft a raise and small stope have been made (pl. 37). The final development work done by the White Bear Mining Company was a 25-ft shaft sunk to intersect the large pegmatite about 100 ft northeast of the northwest end of the Silver Dollar pegmatite.

GEOLOGY

The Silver Dollar claim is underlain by pre-Cambrian quartz-mica schist which strikes north to N. 20° W., and dips 45°–75° SW. The foliation is roughly parallel to the bedding and to the contacts of a series of pegmatites that are as much as 270 ft in length and 50 ft in width. These pegmatites are composed of quartz, oligoclase, perthite, muscovite, and biotite, with minor quantities of black tourmaline, green apatite, and beryl. The only concentration of book muscovite is in the Silver Dollar pegmatite; a few books occur in the easternmost dike shown on the map (pl. 37).

The large pegmatite at the north end of the area mapped was designated undivided pegmatite, although it contains a narrow border zone and a core in which perthite is abundant. It is in part covered by a thin veneer of schist and at its north end seems to be a composite of several tabular bodies. The bulk of the dike is composed of coarse-grained perthite, oligoclase, and quartz.

The Silver Dollar pegmatite is a lenticular body 268 ft long and as much as 22 ft thick. The pegmatite strikes N. 20° W., and dips 49°–79° SW. Neither end of the dike is exposed and the plunge of minor rolls in the pegmatite, the only structural information available, suggests that the pegmatite plunges at about 50° SW.

Three mineralogic zones have been recognized in the Silver Dollar pegmatite but only two have been mapped. Oligoclase-perthite-muscovite pegmatite forms the border and wall zones. On the footwall this zone has an average thickness of 8 ft and is several feet thicker than on the hanging wall. Oligoclase is the dominant feldspar at the schist-pegmatite contacts, constituting about 50 percent of the rock, and perthite is the most abundant near the perthite-quartz pegmatite core. The grain size in this zone ranges from a fraction of an inch to several inches. Muscovite and biotite occur as thin sheets coating joint planes and as aggregates of small flakes. Book mica occurs only in the inner foot or so of the zone and the outer foot of the core. The sheet mica-bearing pegmatite, and intermediate zone, has not been mapped separately, but the presence of book mica is shown by an overprint on the map.

Perthite-quartz pegmatite, 5 to 6 ft thick, forms the core (pl. 37). Perthite, the most abundant mineral, occurs in crystals a few inches to several feet long. Quartz occurs as irregular bodies surrounding perthite and graphic granite. Tourmaline aggregates several feet long occur near the outer border of this zone, associated with crystals of beryl and apatite 1 to 3 in. long. The coarse-grained perthite-quartz pegmatite grades outward into the finer-grained wall zone. Muscovite, accompanied by a little biotite, is most abundant in this gradational zone.

MICA DEPOSITS

Book mica occurs near the contact of perthite-quartz pegmatite with oligoclase-perthite-muscovite pegmatite. Both mica zones, each 1 to 2 ft thick, at the edges of the perthite-quartz pegmatite have been mined by workings 6 to 7 ft wide. The mica is deep ruby, flat, and hard up to the edge of the book. The books are relatively small, rarely exceeding 5 to 6 in. wide, but are uncommonly thick for their diameter. The thickness of some books in many cases exceeds their other dimensions. The mica is only slightly air-stained, but a large proportion of the sheet mica contains "silver spots." The quality of individual lots of mica sold between May and September 1944, ranged from 8 to 15 percent no. 1 quality, 12 to 40 percent no. 2 quality, and 47 to 80 percent no. 2 inferior quality.

The Silver Dollar mica mine has produced at least 2,998.87 lb of large and small sheet and 9,496 lb of untrimmed punch mica since the beginning of operations. About two-thirds of the sheet mica was 1½ by 2 in. and very little was larger than 2 by 3. in.

The mica content of the rock cannot be accurately determined but from June to December 1942, about 26,430 lb of mine-run mica was produced. Assuming a 4 percent recovery of sheet from crude mica from January 1943 to May 1944 (the average for this type of mica during this period) about 39,550 lb of crude was produced. Therefore, the total production to May 1944 was 66,000 lb of mine-run mica from approximately 1,000 tons of pegmatite. This figure indicates that the central 6–7 ft of pegmatite contains 3.3 percent recoverable crude mica.

Below the 55-ft level in the shaft, the recoverable mica content of the pegmatite is much less. This low recovery is caused by the ruling and fracturing of books that are in a strong fracture zone related to a fault that strikes N. 10° W. and dips 20° NE. The fault shows little displacement, but the numerous related parallel joints have ruled the mica to such an extent that the last operations were not profitable. Further sinking on the pegmatite might get beyond this broken zone in which the drift was made.

The quantity of mica in the mica-bearing zones is rather uniform throughout the workings, where it is necessary in mining to take a wide core, as in the stope north of the shaft, barren rock may reduce the mica content to below a profitable level. The more profitable operations have been carried on where the core was less than 3 ft thick.

Appreciable quantities of mica, which could be mined under favorable economic conditions, remain in the Silver Dollar pegmatite.

SITTING BULL BERYL PROSPECT (KEYSTONE DISTRICT)

by W. C. Stoll

The Sitting Bull beryl prospect is about 1 mile northwest of Keystone, in the SW¼ sec. 5, T. 2 S., R. 6 E., Pennington County. The Sitting Bull property is a patented claim owned by the Black Hills Keystone Corporation. It adjoins the Lottie, Leota, and two other claims that are held by the same company. Beryl, scrap mica, and feldspar are reported to have been produced from the property. The property was visited and mapped (fig. 30) November 24, 1942 by Stoll and W. E. Hall.

The Sitting Bull pegmatite crops out at the crest of a steep ridge west of U. S. Highway 16. The top of the outcrop is at an altitude of 4,890 ft.

The pegmatite body has a thin, lenticular shape in plan, narrowing at both ends of the outcrop. It is 160 ft long, has an average strike of N. 25° W., and dips about 70° NE. The maximum thickness of the body is 40 ft. Fine-grained quartz-biotite schist encloses the pegmatite and is parallel to the contacts.

An open-cut along the northeast side of the pegmatite is about 75 ft long and as much as 20 ft wide. Debris from the excavation covers part of the hanging wall of the pegmatite.

The pegmatite exposures are composed mainly of medium- to coarse-grained quartz-albite rock containing local concentrations of muscovite, beryl, and

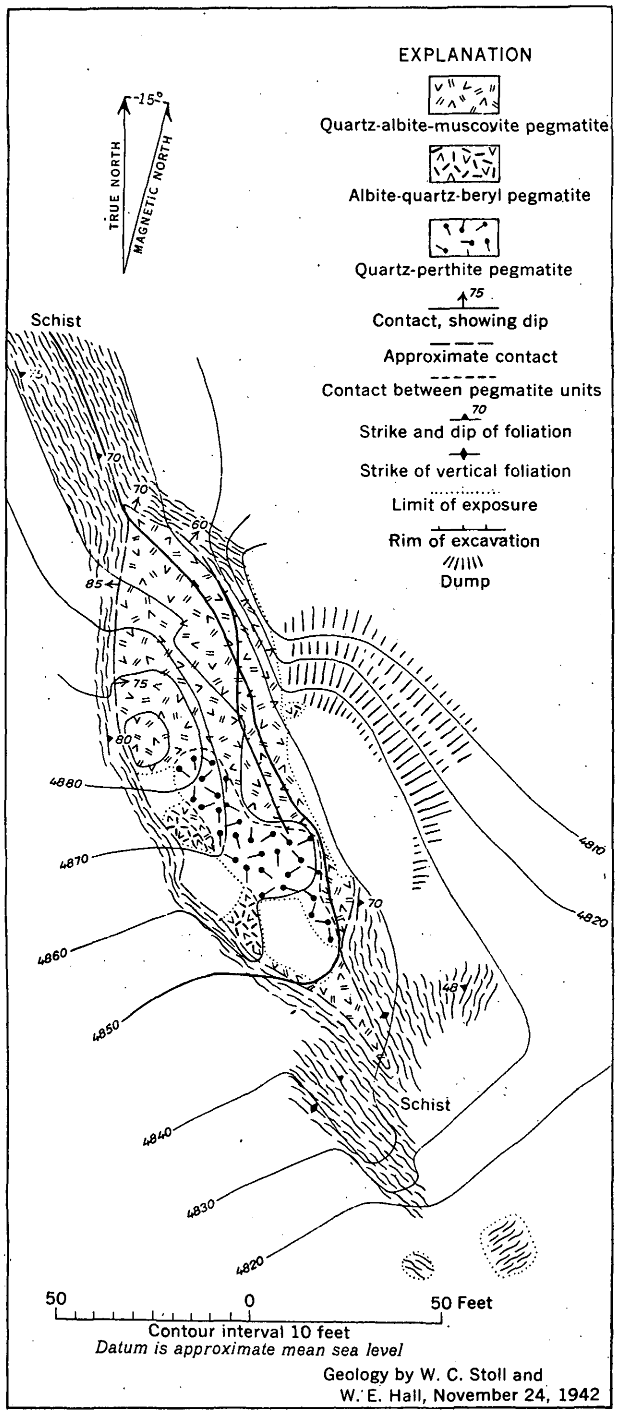

FIGURE 30.—Geologic map, Sitting Bull beryl prospect, Pennington County, South Dakota.

other minerals. Enclosed within this type of pegmatite is a small body of massive quartz and perthite. A third type of pegmatite, now almost entirely removed or covered by debris, lay over the present steep northeast side of the dike, and was excavated from the open-cut. It probably represents a wall zone of albite, muscovite, and beryl. Several small exposures of this material were seen on the footwall side of the dike, but it appears to be discontinuous.

The muscovite is greenish-yellow, soft, fishtailed, and of scrap quality. Some parts of the pegmatite contain small concentrations of this mica.

White beryl, free of inclusions, occurs in crystals that range from ½ to 10 in. in diameter; the average diameter is about 3 in. The richest concentrations of beryl are in albite. In a small exposure along the footwall of the pegmatite, an area of 18 sq ft contains 5 to 6 percent of small beryl crystals. One block of albite-rich pegmatite on the dump contained 30 to 40 percent of beryl in an area of 2 sq ft. The quartz-albite rock that comprises most of the pegmatite seems to contain little beryl. Local concentrations of beryl were seen in the face of the open-cut, but they appeared to be in the unmined part of the wall zone.

SODA SPAR CLAIM (KEYSTONE DISTRICT)

by W. C. Stoll

The Soda Spar claim is 3 miles southeast of Keystone between Glendale and Spokane, in sec. 22, T. 2 S., R. 6 E., Pennington County. The property was located in May 1937 by F. C. Robertson of Spokane, and consists of two unpatented, 20-acre claims. At the time of examination, November 1942, the Soda Spar claim was held under lease by Lewis Collingwood of Pringle, but no work was in progress. According to Mr. Robertson this property has produced about 500 tons of feldspar, 12 tons of beryl, 18 tons of amblygonite, and 5 tons of scrap mica.

The pegmatite outcrop is a steep-sided knob trending N. 20° W. for about 300 ft. It is 100 to 150 ft wide, and rises 60 to 200 ft above the surrounding forested country. The main mass of the pegmatite is a mixture of perthite and finer-grained pegmatite. Scattered widely through this pegmatite are black tourmaline crystals and masses of white quartz. The mine opening is a cut 87 ft long, and 15 to 20 ft wide. It is on the southeast slope of the knob and follows an irregular, but tabular, fracture-filling body of coarse-grained pegmatite, which is enclosed in the fine-grained perthite-rich rock.

The fracture-filling body strikes northeasterly and dips flatly to the northwest. On the footwall a wall zone of muscovite, quartz, and pink albite contains an altered, dark-colored phosphate and a few small beryl crystals. Overlying this wall zone, and forming the rest of the visible part of the body, is an intergrowth of coarse-grained massive quartz and perthite, containing spodumene, amblygonite, beryl, and lithiophilite.

The spodumene crystals, as much as three feet in length, are limited to an area on the walls of the cut 20 ft long by 16 ft high. The deposit contains 7 to 10 percent spodumene which, in part, is "rotten" or altered to a moderate extent. Some of it can be crumbled in the fingers. The Li_2O content of the spodumene is not known. L. R. Page in May, 1943, saw a few white beryl crystals, one 12 in. in diameter, in the wall zone of the fracture-filling body.

The Soda Spar claim could doubtless yield additional spodumene, amblygonite, beryl, feldspar, and scrap mica.

SURPRISE MICA MINE (CUSTER DISTRICT)

by L. C. Pray

The Surprise mica mine is about ½ mile north of Custer, near the west quarter corner of sec. 24, T. 3 S., R. 4 E.

The mine is in one of many pegmatites on the Surprise Mineral Lode claim, held jointly by J. T. Norine and P. D. Peterson of Custer. The claim, located in 1941, was first mined in July 1943. Mica has been the only mineral product sold from the claim. In 1943 the operators sold 484 lb of sheet mica that was obtained from two open-pits and a 52-ft inclined shaft, and in 1944 47 lb was produced. Most of the mica came from drifts at the base of the shaft.

Geologic work on this property by the U. S. Geological Survey was carried out intermittently during December 1943 by L. C. Pray and Peter Joralemon. A plane table map (pl. 38) of the surface and two geologic sections were prepared on a scale of 1 in. to 20 ft.

MINE WORKINGS

In the summer and fall of 1943 two open-pits were worked in the area mapped, and another prospect pit was made 300 ft to the north. In November an inclined shaft was started at the western end of the open-pit in the Surprise pegmatite. This shaft was sunk to a depth of 52 ft, as measured along the hanging wall. Drifts were driven from the base of this shaft after completion of the mapping. The small open-pit 120 ft west of the Surprise shaft was dug several years before.

GEOLOGY

The Surprise mica mine is in an area characterized by many tabular, granitic pegmatites that are essentially concordant with the enclosing pre-Cambrian schists. Near the mine the pegmatites strike approximately east, and dip 35°–40° S. Less than ¼ mile to the northwest, at the axis of an anticlinal fold in the schists, they strike N. 55° W. and dip about 30° SW. A few hundred yards to the east of the mine the pegmatites strike N. 20° E. and dip 55° SE. Some pegmatites show these changes in strike along their length.

Only a small fraction of the pegmatites in the area have been mapped. These pegmatites are 1 to 10 ft thick. Their low dip and superior weathering resistance result in long hanging-wall dip slopes and, as shown on the map (pl. 38), the surface outcrops appear surprisingly wide.

METAMORPHIC ROCKS

The dominant metamorphic rock mapped is a quartz-mica schist composed largely of quartz, muscovite, and biotite, with minor zircon. The bedding is obscure because of the uniform composition and texture, but it seems to be essentially parallel to the foliation. In the area mapped the schist generally strikes east and dips 35°–40° S.

In places the schist adjacent to the contacts of pegmatites is altered to a sugary textured rock composed dominantly of quartz, with subordinate tourmaline, microcline, muscovite, and biotite. Some of the schists contain irregular nodules of microcline as much as ½ in. in diameter, which contain many inclusions, principally tourmaline.

PEGMATITES

In general the pegmatites that have been mapped strike about east and dip 35°–40° S., parallel to the foliation of the enclosing schists. Those in the northern half of the map area strike about N. 80° W. and in the southern half strike slightly south of west. These pegmatites do not terminate abruptly, but instead lens out at a uniform rate of about 1 foot in 10. The only indication of the plunge of the ends of the pegmatites that was detected consists of small anticlinal rolls on the hanging-wall dip slopes of two pegmatites. These rolls suggest that the ends plunge 35 degrees to the S. 36° W. At the southwestern open-pit, tourmaline needles in schist plunge 38 degrees to the S. 45° W. The strongest joints noted in the pegmatites strike N. 55° E. and dip 80° NW. They are so closely spaced in a few areas as to constitute shear zones.

All the pegmatites shown on plate 38 are essentially similar in mineralogic composition and have been mapped as perthite-albite-quartz-muscovite pegmatite. Perthite is the most abundant and the most coarsely crystalline mineral. In the Surprise shaft perthite crystals several feet across are visible, but in general the crystals are less than 1 ft long. Albite crystals are mostly less than 1 in. across, and commonly are intergrown with quartz to form a granitic-textured rock. The albite (An_4–An_8) in all of the pegmatite has a uniform composition (minimum index of refraction of cleavage fragments 1.528–1.530). Most of the quartz is fine-grained, but a few pods are several feet in diameter.

Ruby muscovite is scattered throughout the pegmatites. In the two thicker pegmatites south of the Surprise mine the larger muscovite books appear to be concentrated in a zone 1 to 2 ft thick along the walls. This zone is also richer in quartz. In the Surprise pegmatite the muscovite books, as much as 6 to 8 in. across, occur throughout its width. This is also true of the other mapped pegmatites that are 6 ft or less in thickness. Many of the books of mica from the Surprise mine, throughout the explored depth, are heavily stained with iron oxide.

All of the pegmatites contain minor percentages of tourmaline, garnet, biotite, apatite, and beryl. The pegmatite at the southwestern corner of the area mapped, which has been worked by an open-pit, is characterized by biotite blades occupying late fractures in the pegmatite, and by many irregular inclusions of schist.

MICA DEPOSITS

The Surprise and adjacent pegmatites all contain a uniformly low percentage of muscovite mica. Two of the pegmatites on the Surprise claim produced a total of 484 lb of sheet mica in 1943.

The Surprise pegmatite (pl. 38), which was mined most extensively, is 4 to 7 ft thick. It is 6½ to 7 ft thick throughout the length of the 52-ft inclined shaft. The pegmatite is exposed for 100 ft east and 120 ft west of the shaft. The easternmost outcrop is probably not far from the eastern end of the pegmatite. The pegmatite, which is covered by alluvium, may extend westward and connect with one of the pegmatites that crop out on the west side of the small valley.

Books of muscovite as much as 6 to 8 in. across and 2 in. thick are scattered throughout the length of the pegmatite in a matrix of perthite, albite, and quartz. In places they appear more abundant on the walls, but at the shaft the muscovite is evenly distributed from wall to wall. The mica is deep ruby, and books are frequently heavily stained by iron oxide. The sheet mica from the Surprise pegmatite sampled by Colonial Mica Corporation has ranged from 1 to 40 percent good-stained or better quality in sheets 1½ by 2 in. or smaller. The mica is hard, flat, and moderately air-stained.

The Surprise pegmatite contains less than 1 percent of recoverable crude mica. The open-pit yielded 252.55 lb of sheet mica from an estimated 260 tons of pegmatite. The inclined shaft yielded about 2,800 lb of mine-run mica, or 0.4 percent recoverable crude mica and the first drift round to the east from the base of the shaft contained 0.5 percent mine-run mica. Less mica is visible in the walls near the base of the shaft. About 200 tons of rock was mined in the open-pit 300 ft southwest of the shaft and yielded 122.31 lb of crude mica, indicating about 0.5 percent recoverable crude mica. Considerable tonnages of pegmatite with this content of crude mica remain on the Surprise property.

SUNSHINE MICA PROSPECT (CUSTER DISTRICT)

by J. W. Adams

The Sunshine mica prospect is in the SE¼ sec. 14, T. 3 S., R. 4 E., Custer County. It is about 1½ miles north of Custer and can be reached by following the Sylvan Lake road 1.7 miles from the Custer Post Office, then going westward on a dirt road for 0.6 mile. The prospect is then a tenth of a mile north along a mine road.

The Sunshine claim is held by Howard Townsend and Guy Hendrickson of Custer. It has been developed by two open-pits, 40 and 80 ft in length respectively. The commercial minerals are mica and feldspar. About 60 pounds of sheet mica was sold to Colonial Mica Corporation in 1943–44. It is estimated that about 250 tons of rock was removed from each cut.

A compass and tape map of the property (fig. 31) on a scale of 1 in. to 40 ft, was made on October 26, 1944.

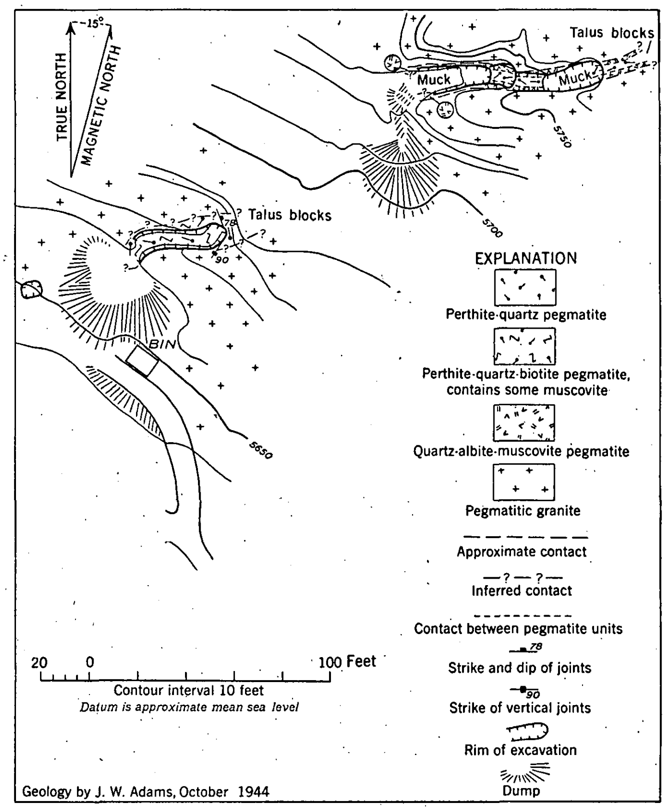

FIGURE 31.—Geologic map, Sunshine mica prospect, Custer County, South Dakota.

The mine workings on the Sunshine claim are in two bodies that are pegmatite dikes, or coarse pegmatite segregations in the Harney Peak granite. The bodies, 6 to 15 ft in width, are of undetermined length (fig. 31). These pegmatites, unlike those in the schistose rocks of the Custer area, have very obscure contacts and in places appear to grade into the enclosing granite.

The pegmatite exposed in the lower cut is an unzoned perthite-quartz-biotite pegmatite striking roughly N. 85° E. and possibly dipping 60° SE. Scattered through the pegmatite is a small proportion of strongly reeved, air-stained muscovite. Some sulfide and phosphate minerals are present. About 250 tons of pegmatite was mined from this dike during feldspar operations. The muscovite content is so low that this dike has not been considered a profitable source of sheet mica.

The upper workings follow an obscurely zoned dike or segregation which strikes east and dips 70°–75° N. It has quartz-albite-muscovite pegmatite wall zones, and a perthite-quartz pegmatite core. The quartz-albite-muscovite pegmatite is the source of sheet mica. Its contacts with the wallrock are poorly defined and are marked by the outer limit of the book mica. The mica-bearing zones are from 1 to 2 ft thick and are exposed for about 100 ft along the outcrop. The greatest concentration of book mica appears to be in the north or hanging-wall mica zone. Accessory minerals in the quartz-albite-muscovite pegmatite are black tourmaline, garnet, and biotite. The central zone of perthite-quartz pegmatite contains perthite, white and rose quartz, and scattered crystals of brownish white to green beryl.

A total of 59.7 lb of sheet mica was purchased from the Sunshine mine by Colonial Mica Corporation. Of this amount, 34.2 lb was produced by the owners during October and November 1943. The remaining 25.5 lb was mined by Martin Racich who worked the property under lease during July and August 1944; it was obtained from about 600 lb of crude mica, a recovery of 4.2 percent. It is estimated that about 90 tons of pegmatite, containing slightly less than 0.3 lb of sheet mica per ton, was mined by Racich. The mica zones exposed in the cut were estimated to contain 1 to 2 percent crude mica.

The mica is pale ruby and occurs in books as much as 6 in. across and several inches thick. The chief defects are heavy air- and mineral-staining, reeves, and cross-grain. The mica found in the core is for the most part cross-grained. Qualification by Colonial Mica Corporation of the small shipments sold shows a great preponderance of no. 2 inferior quality. Twenty-two percent of the mica sold by Racich was 1½ by 2 in. and larger.

Small quantities of feldspar, mica, and beryl could be recovered from this dike.

TERRY AND TERRY NO. 1 CLAIMS (CUSTER DISTRICT)

by L. R. Page and L. C. Pray

The Terry and Terry No. 1 mica claims, formerly known as the Thom Carroll property, comprise 28 acres of deeded land in the SW¼ sec. 19, T. 3 S., R. 5 E., Custer County. It is owned by Phillip Deming and was leased, October 26, 1943, to John Ross of Custer, who rehabilitated the workings. In November 1944 Kenneth Spring of Custer took over the property and operated it until April 1945.

The Terry prospect was mapped by the U. S. Geological Survey November 2, 1943.

The mica-bearing pegmatite on the Terry claim (fig. 32) has been explored by a vertical shaft reported to have been 50 ft deep, but back filled to 22 ft below the surface; an inclined shaft 18 ft deep; and an open-pit that connects with the vertical shaft on the 20-ft level. One short drift, inaccessible on the date of examination, extends east from the vertical shaft, and another, completely caved, extends north from the open-pit.

Mica-bearing pegmatite is not exposed at the surface, though narrow dikes of barren pegmatite can be observed in a few places. The mica pegmatite was encountered 8 ft down from the surface below a fault that strikes about N. 75° E. and dips 0°–15° NW. (Fig. 32). The pegmatite is as much as 7 ft thick and is exposed in the workings for about 60 ft along its strike. It appears to be a composite of at least two dikes separated by schist. The general strike is N. 75° W. and the dip is 65° SW. The pegmatite is very irregular, however, and there are many local variations in dip. The pegmatite terminates abruptly, the end plunging 74° S. 20° W.

The mica is pale ruby, and is badly ruled, probably as a result of faulting. The exposed wall faces contained considerable mica in the east wall of the vertical shaft. Here 25 large books make up 20 to 25 percent of the exposed mica pegmatite. This concentration was mined out by Ross.

In 1944–45 the lots of mica sold were 0 to 9 percent no. 1 quality, 8 to 32 percent no. 2 quality, and 60 to 90 percent no. 2 inferior quality.

The production of this mine in 1943 was 41.12 lbs of sheet and 33 lb of untrimmed punch. In 1944 about 231.4 lb of large and small sheet was recovered, and in the first two months of 1945 the production was 75 lb.

TIN BOOM (GENERAL HARNEY OR TIN SPIKE NO. 1) (HILL CITY DISTRICT)

The Tin Boom (General Harney or Tin Spike No. 1) claim, in sec. 25, T. 1 S., R. 4 E., adjoins the Tin Spike claim on the northwest; it is about 1 mile west of Hill City, Pennington County.

The underground workings on this claim were inaccessible when the property was examined by L. R. Page and J. B. Hanley in July 1942, but are said to include a 100-ft shaft, inclined 60° NE., on a narrow quartz-muscovite-cassiterite vein. According to Mr. George W. Coats there are several hundred feet of crosscuts and drifts from the shaft that prospect the vein and an albite-rich cassiterite-bearing pegmatite known locally as the General Harney dike. The workings are described by Gardner (1939, pp. 33–35).

The Tin Boom quartz vein contains small quantities of cassiterite and beryl associated with muscovite. At the shaft it strikes N. 35° W. and dips 60° NE. The vein is exposed in a trench 80 ft southeast of the shaft where it strikes N. 25° W. across fine-grained mica schist. The schist strikes north and dips 70° W.

The General Harney dike, about 100 ft northeast of the shaft, is a fine-grained albite-quartz pegmatite that contains a little muscovite, apatite, and fine-grained disseminated cassiterite. It is about 240 ft long and at the north end is 10 to 12 ft wide.

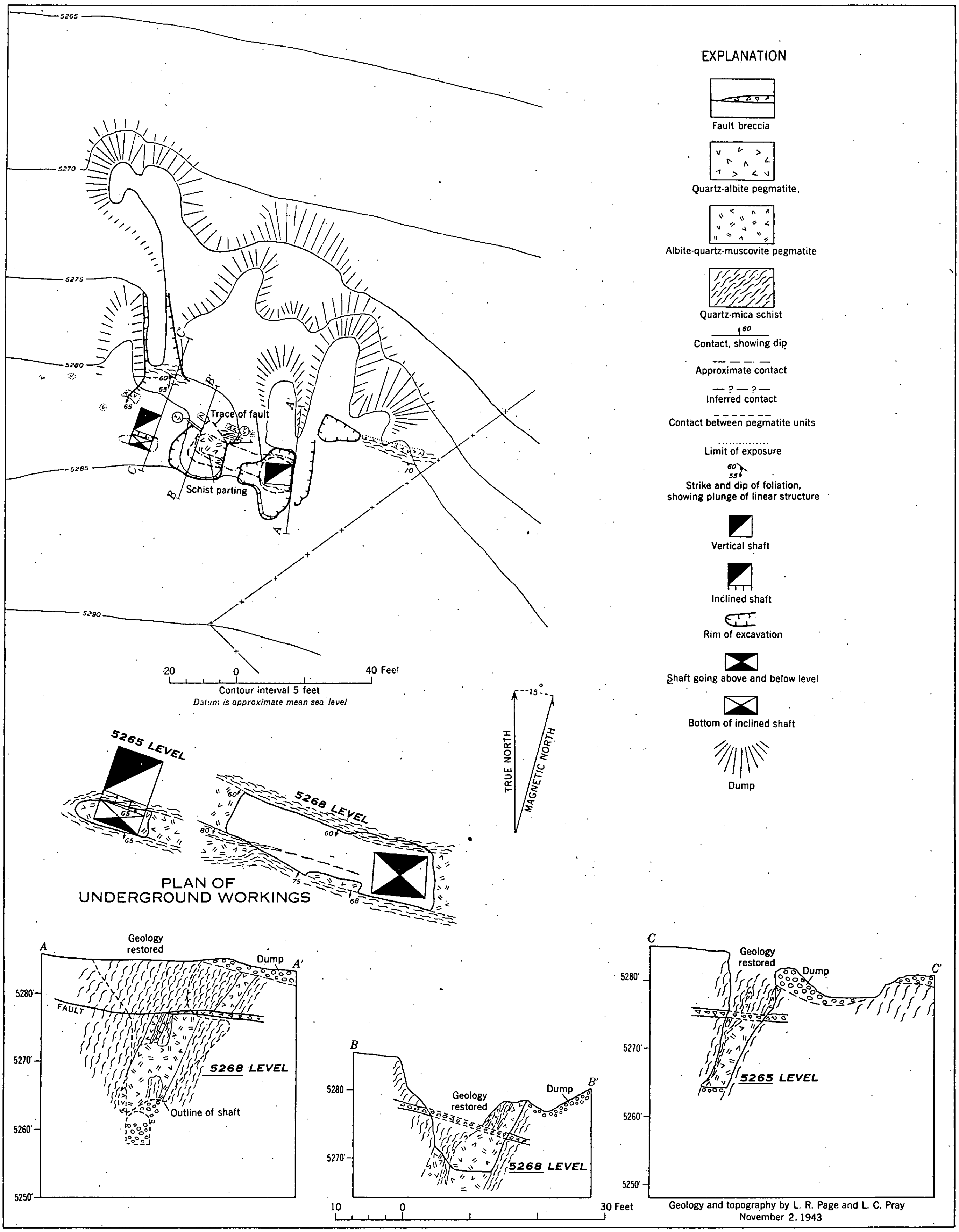

FIGURE 32.—Geologic maps and sections of the Terry (Thom Carroll) mica claims, Custer County, South Dakota.

TIN CHANCE LODE TIN-BERYL PROSPECT (HILL CITY DISTRICT)

The Tin Chance Lode tin-beryl prospect, in the SE¼ sec. 25, T. 1 S., R. 4 E., is about 1 mile by road southwest of Hill City, Pennington County. The claim was located by Mr. George W. Coats and Mr. H. G. Mills of Hill City, who leased the property to Mines Minerals Metals, Incorporated in 1942. In 1943–44 the Barium Stainless Steel Company prospected the property.

In July 1942, the property was examined and mapped (fig. 33) by L. R. Page and J. B. Hanley. The older workings consisted of two shafts or pits, each 10 ft deep; two shallow trenches, 60 ft apart, on separate lenses of the quartz-muscovite-cassiterite-beryl vein, at altitudes of 5,200 and 5,240 ft; and a trench, 180 ft long, at an altitude of about 5,125 ft, along the vein at the main shaft. The main shaft was sunk to 25 ft in 1942 and was deepened in 1943–44.

The Tin Chance vein consists of three individual lenses alined in a N. 45° W. direction. The largest lens, prospected by the 180-foot trench and shaft, is as much as 24 in. thick, and has an average thickness of 12 in. for a length of 70 ft. The other exposures of this lens are ½ to 2 in. thick. The vein at the main shaft strikes N. 57° W. and dips 60° NE. The quartz-mica schist wallrock strikes N. 15° E. and dips 55° NW. The vein is composed of quartz, muscovite, beryl, and cassiterite. Samples of the vein, according to Mr. Coats, have assayed from 1 to 2 percent of tin. Beryl is not particularly abundant in this deposit and visual estimates suggest that it is less than 0.5 percent of the vein material.

The other two lenses are on the hill northwest of the main shaft. The one at an altitude of about 5,200 ft is 50 ft long and as much as 2 ft thick. It is exposed for 30 ft vertically. The lens at an altitude of about 5,240 ft is, on the average, 12 in. thick and 40 ft long.

The size and grade of the veins and also the need for beneficiating the ore preclude profitable recovery of beryl and cassiterite under present economic conditions.

TIN CHANCE NO. 1 LODE CLAIM (HILL CITY DISTRICT)

The Tin Chance No. 1 Lode claim adjoins the Tin Chance Lode on the southwest. This claim was located by George W. Coats and H. G. Mills of Hill City, and during 1943–44 was acquired successively by Mines Metals Minerals, Incorporated, and by Barium Stainless Steel Company.

The Tin Chance No. 1 vein was prospected by two open-pits and a 10-ft discovery shaft. The southernmost pit, 40 ft long and 15 ft wide at the north end, is connected by a shallow trench, 25 ft long with a small open-pit 10 ft deep.

The quartz-muscovite-beryl-cassiterite vein is an irregular body that strikes about N. 45° W. and dips about 70° NE. The vein, which is exposed for about 80 ft, is 2 ft thick in the largest open-cut and narrows to 1 ft in the shallow trench before pinching out in the smaller open-pit. At the discovery shaft a 2- to 6-in. vein is exposed. Beryl crystals as much as 2 in. long and ½ in. across lie perpendicular to the vein wall. Beryl makes up less than 0.5 percent of the vein. Cassiterite, in crystals and masses as much as 2 in. across makes up less than 1 percent of the vein. To the east, on the same claim, are tungsten-bearing quartz veins.

TIN MOUNTAIN MINE (CUSTER DISTRICT)

by W. C. Stoll

The Tin Mountain mine is 6 miles west-southwest of Custer, in sec. 35 or 36, T. 3 S., R. 4 E., Custer County. It is a patented claim of 9 acres owned by the Maywood Chemical Works of Maywood, New Jersey. The portal of the main tunnel of the mine is about 5,595 ft above sea level.

In 1927, the Tin Mountain deposit was purchased from H. W. Fowler by the Maywood Chemical Works and was operated until 1930. Spodumene, amblygonite, beryl, pollucite, columbite-tantalite, and feldspar were mined from underground workings. Since 1930, the mine has been idle.

Exact data as to the past mineral production of the Tin Mountain mine are not available. It is known that one carload of pollucite was shipped in 1928, that the feldspar shipments totaled 365 tons, and that the 1929 beryl production was 27 tons.

The property was mapped (figs. 34 and 35) in August 1942 with the assistance of W. E. Hall.

MINE WORKINGS

Surface workings at the Tin Mountain mine (fig. 34) are a few small pits at the top of the knoll on which the pegmatite crops out. Apparently these were the earliest excavations. Another cut has been made near the foot of the west slope of the knoll, at the extreme end of the westward extension of the outcrop. A short drift branches from this cut. A winze has been made in the drift. The main underground workings (fig. 35), made by the Maywood Chemical Works, are on two levels. The main level is connected with the surface through a haulage tunnel and several raises. The 50-foot level is connected underground to the main level through a stope and a vertical shaft. It is connected with the surface by an incline with a short tunnel at the top. At the time of examination the lower workings were flooded to within 20 ft of the main level.

The haulage tunnel on the main level, 100 ft below the crest of the knoll, extends westward from the east side of the pegmatite outcrop. About 50 ft from the portal a drift, known as the southwest drift, branches from the main tunnel and extends 85 ft to the S. 48°

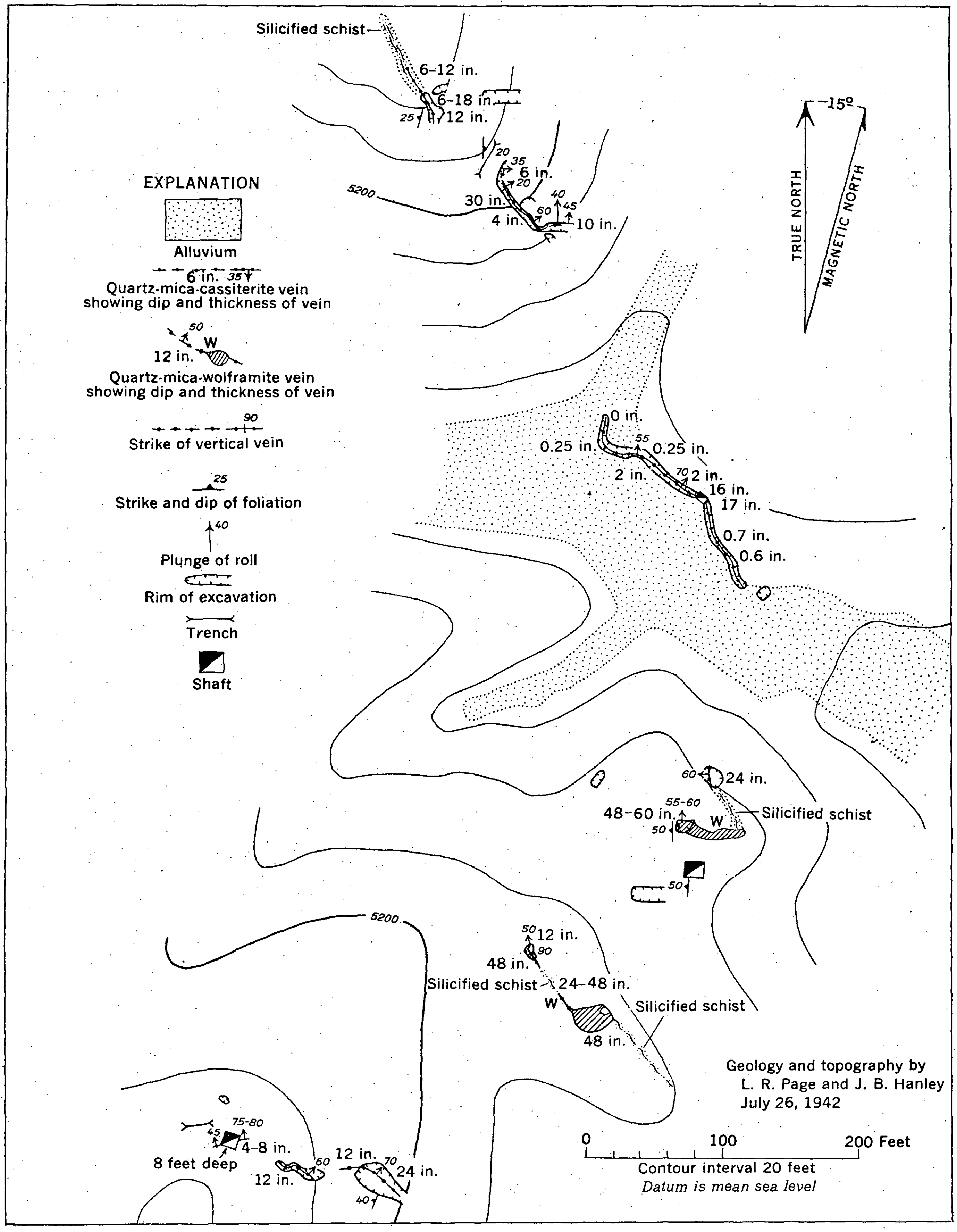

FIGURE 33.—Geologic map, Tin Chance and Tin Chance No. 1 claims, Pennington County, South Dakota.

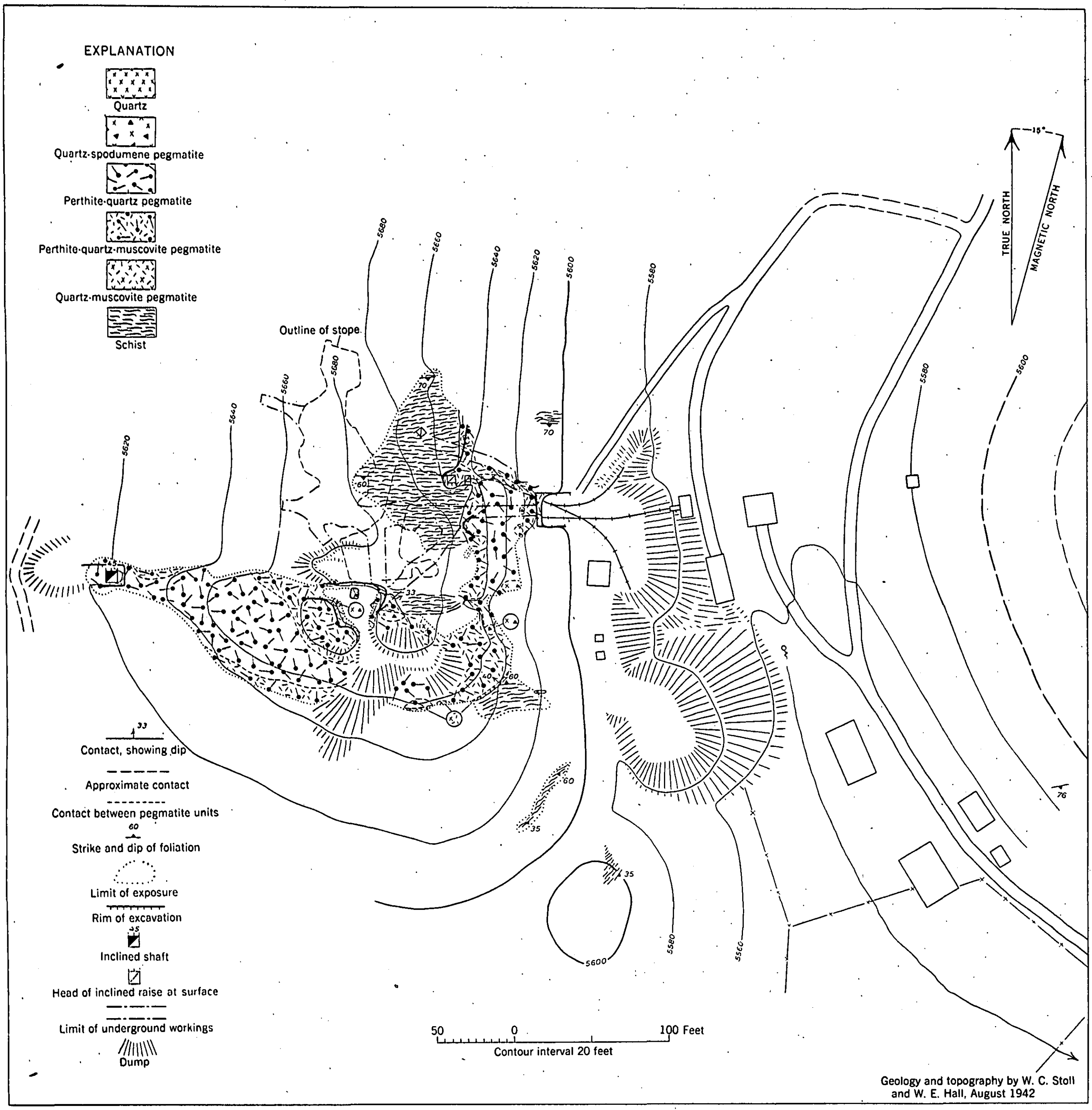

FIGURE 34.—Geologic map, Tin Mountain mine, Custer County, South Dakota.

W. Raise no. 1 connects the southwest drift with stope no. 2 above the main level, and from the bottom of the southwest drift a 2-compartment vertical shaft, 12 by 7 ft, connects with the 50-ft level. The main tunnel, beyond its intersection with the southwest drift, extends about 120 ft farther westward. Raises to stope no. 2 and subsidiary drifts and raises branch from the main tunnel. The main (no. 1) stope is on the north side of the main tunnel and extends northward for 120 ft. It is 30 to 40 ft wide and has a maximum height of about 30 ft above the floor of the main level. This stope is connected with the surface by raise no. 3. The stope extends downward, with diminishing cross-section, to the 50-ft level. It is filled with coarse pegmatite debris from the 50-ft level within 15–20 ft of the back.

Stope no. 2, lying above the main level, is reached through raise no. 1 in the southwest drift. It is about 84 ft long in the direction N. 35° E., and is from 14 to 50 ft wide. The back of the stope is 45–47 ft above the floor of the main level. The floor of the excavation is covered with 8 to 15 ft of coarse debris, some of which rests on a timber above the main level.

The short tunnel (no. 2) and incline, which form a

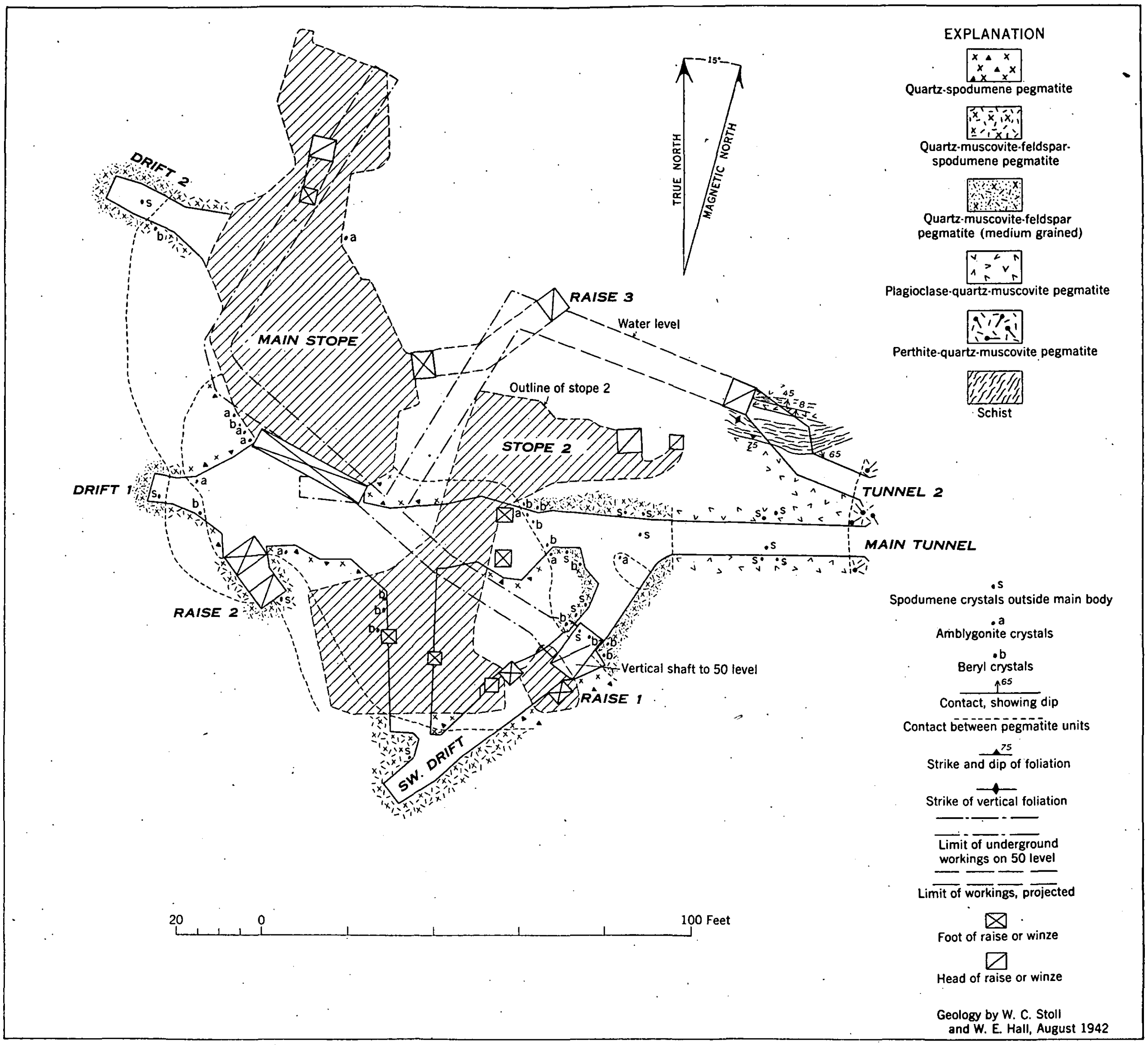

FIGURE 35.—Underground map, Tin Mountain mine, Custer County, South Dakota.

second entrance to the 50-ft level, start at the east side of the outcrop a few feet from the portal of the main tunnel.

Pegmatite taken from the underground workings made by the Maywood Chemical Works is estimated at 19,180 tons including about 1,300 tons for the drifts on the lower level and the connecting vertical and inclined shafts. Of the total, 10,170 tons was excavated from the main, or no. 1 stope, and 5,600 tons from stope no. 2.

GEOLOGY

The Tin Mountain pegmatite crops out on the sides and top of a steep knoll that stand 130 ft above a small valley on the east and about 80 ft above another valley on the west. The knoll forms the south end of a long, north-trending, schist ridge. In plan, the pegmatite outcrop is irregularly L-shaped. One part, about 30 ft wide, extends 190 ft north along the steep east slope of the knoll; the other part, about 70 ft wide, trends west for 280 ft across the brow and down the west slope of the knoll. From a three-dimensional view, the body appears to have the form of an irregular pipe plunging northwestward.

The footwall contact as exposed on the surface strikes N. 58°–75° E. and dips 40° NW. At the time of the examination the lower level was flooded, but Schwartz (1930, pp. 275–284) says the footwall contact in the vertical shaft strikes N. 70° E, and dips 38° NW. The upper contact is irregular. In raise no. 3 it strikes N. 66° E. and dips 15° NW. At the top of the knoll the pegmatite dips under the schist roof in a northerly or northeasterly direction, and in tunnel no. 2 and the connecting incline to the 50-ft level the contact is highly irregular. The country rock is a hornblende-quartz schist that strikes and dips discordantly with the pegmatite contacts.

The Tin Mountain pegmatite is composed of four types of pegmatite: coarse massive quartz, coarse perthite, medium-grained pegmatite of several varieties, and fine-grained contact rock. The coarse pegmatite is in the middle of the deposit and the finer-grained rocks are nearer the schist contacts. The descriptions of these rock types are given below.

(1) Pegmatite composed largely of (a) coarse massive quartz with large spodumene logs, amblygonite, and beryl or, (b) coarse, massive quartz with abundant but scattered mica, spodumene logs, amblygonite, beryl, and a few isolated blocks of perthite.
(2) Pegmatite composed largely of (a) coarse perthite with some massive quartz or, (b) coarse perthite with some massive quartz and large spodumene logs.
(3) Medium-grained pegmatite composed of (a) perthite, quartz, and a variable amount of small muscovite, (b) albite chiefly, with some quartz, fine-grained muscovite, and perthite, or (c) quartz chiefly, with fine-grained muscovite, minor albite, and perthite.
(4) Fine-grained quartz-muscovite-tourmaline rock.

MINERAL DEPOSITS

SPODUMENE

The little spodumene exposed in the outcrop is associated mostly with coarse quartz, or with quartz and perthite. A few small crystals of spodumene occur in the medium-grained pegmatite.

The chief exposure of spodumene is underground in stope no. 1 and the adjoining workings. Here, spodumene logs as much as 15 ft long, but mostly 3 to 5 ft long, occur at random orientations in massive white, rose, or dark gray quartz. The coarse quartz also contains masses of amblygonite and beryl that are less abundant than spodumene. The quartz-rich and albite-rich varieties of medium-grained pegmatite contain scattered, but smaller, crystals of spodumene, though a few large logs are present. Stope no. 2 was excavated in pegmatite consisting of coarse perthite and spodumene, though little spodumene was observed in this stope.

Although large parts of the mine could not be examined because of flooding, it is apparent that the spodumene mining has been limited to the coarse pegmatite zones. The medium-grained pegmatite has not been stoped, although it contains small quantities of spodumene.

Almost all of the spodumene is hard and solid. Its color is generally a dirty white or light-gray; one pink specimen is said to have come from the 50-ft level.

AMBLYGONITE

Amblygonite was not seen in the outcrop, but underground it occurs in the massive quartz pegmatite as brilliant white, rounded masses, as much as 3 ft across, in association with beryl and spodumene. Small nodules were also seen in the coarse quartz, but they occur mainly in the medium-grained pegmatite near its contact with the coarse central quartz body. Amblygonite does not occur with the coarse perthite.

BERYL

Beryl was not seen in the outcrop but in the central massive quartz pegmatite, crystal groups and single crystals are as much as 12 in. in diameter. Considerable numbers of small crystals, with an average length of about 2 in., occur in many places in the medium-grained, quartz-rich pegmatite within a few feet of the contact with coarse quartz pegmatite. The beryl is white, but the exposed surfaces are commonly stained yellowish or light orange. None of the beryl is mixed with other minerals.

OTHER MINERALS

Columbite-tantalite is very sparsely distributed in the coarse quartz pegmatite, in association with beryl and muscovite. Pollucite was mined from the same part of the pegmatite in drift no. 2. Feldspar was stockpiled by a byproduct. Scrap mica has not been produced, but it is abundant in some parts of the mine, and could be separated easily by grinding and screening. Lepidolite and microlite have also been found, but not produced commercially.

TIN QUEEN MICA MINE (HILL CITY DISTRICT)

by J. J. Norton

The Tin Queen mica mine is in the NW¼ sec. 24, T. 2 S., R. 4 E., Pennington County. The owners are Florence and Laura Hebert of San Diego, California. In 1944–45 it was operated by Carl Bourassa of Custer. The mine was worked principally for mica in 1944, and perthite, amblygonite, and beryl were recovered as byproducts. In 1945 the property was worked primarily for feldspar. The total production of sheet mica was 1,597 lb in 1944 and at least 74 lb in 1945. About 900 lb of untrimmed punch was sold during February and March 1945.

The Tin Queen mine was mapped on a scale of 1 in. to 20 ft in May and June 1944 by J. J. Norton and J. W. Adams. Three geologic sections were prepared (pl. 39).

The Tin Queen property has been worked intermittently for many years, and several prospect pits and small open-cuts have been made. Much of the early work was devoted to tin-bearing pegmatites south of the mica-bearing pegmatite. The Tin Queen mica mine is in a large lenticular pegmatite formerly known as the White Blowout. Operations for feldspar, amblygonite, and mica have been carried on in three different open-pits. In the fall of 1943 this pegmatite was worked on a very small scale by Fred Heidman, who produced 26 lb of sheet mica. Carl Bourassa, who leased the property and began work late in April 1944, was operating the mine in July 1945.

MINE WORKINGS

The mine workings at the time of mapping consisted of three open-pits, but later an inclined shaft and glory hole were made. The largest open-cut was an old excavation at the south end of the pegmatite. In the early operations, and again in 1945, underground work was done in the northwest wall of this pit. Most of the mining in 1944 was in an old open-pit on the west side of the pegmatite, from which about 250 tons of rock were removed prior to June of that year. Later this cut was extended to another old open-pit (pl. 39) near the east edge of the outcrop at the top of the pegmatite.

GEOLOGY

The pegmatites on the Tin Queen property intrude pre-Cambrian quartz-mica schist, and are discordant with the average foliation of the country rock. Only two pegmatites are exposed in the area mapped, but a few others crop out nearby. The schist country rock is fine-grained and has moderately well developed foliation. The float suggests that it contains lenses of metamorphosed lime-rich beds that have formed diopside-garnet gneiss with accessory kyanite. The pegmatites in the area mapped and in the immediate vicinity strike N. 5°–45° E., and dip from 30° to 45° NW. The foliation of the country rock strikes N. 20°–65° E., and dips from 13° to 35° NW.; the average dip is about 15 degrees.

The Tin Queen mica mine is in a lenticular pegmatite that has a surface exposure 185 ft long and as much as 120 ft wide. It strikes approximately N. 10° E. The west side of the outcrop is apparently a dip slope along the hanging wall, inclined to the west at an angle of about 30°. In places on the hillside small patches of hanging-wall schist overlie the pegmatite. The footwall is very poorly exposed, but a small prospect pit on the east side of the outcrop possibly has an exposure of the footwall dipping 70° W. The footwall at depth may lie parallel to the hanging wall, which dips about 30° W. In the open-pit at the south end of the pegmatite a schist body with an average dip of 20° W. occurs as a parting in the pegmatite. A similar, but smaller, schist body is exposed within the pegmatite at the north end.

Most of the pegmatite consists of crystals of perthite as much as 5 or 6 ft in their greatest dimension, in a matrix composed predominantly of quartz and albite, with smaller quantities of muscovite, amblygonite, beryl, and minor accessory minerals. Scattered quartz masses, several feet across, occur with large crystals of perthite. Near the schist walls the rock is much finer grained than elsewhere and commonly contains small crystals of perthite with quartz, albite, and small quantities of muscovite. The zonal structure of this pegmatite is indistinct and existing exposures permitted mapping it only as undivided pegmatite. However, the map (pl. 39) shows by symbols the predominant types in each part of the outcrop. The rock types shown are perthite pegmatite, quartz pegmatite, quartz-albite pegmatite, quartz-albite-muscovite pegmatite, and quartz-albite-amblygonite pegmatite. The last three varieties of pegmatite are essentially the same rock type and form a fine-grained matrix between the perthite crystals and the quartz masses. Quartz and albite are the principal constituents, but locally muscovite or amblygonite is abundant enough to warrant use of different symbols. Quartz generally is the most conspicuous constituent of the quartz-albite pegmatite, and in places it makes up more than half of the rock. The minimum indices of cleavage fragments from 5 specimens of albite ranged from 1.529 to 1.531, indicating a composition of An_5-An_9. The quartz-albite-muscovite pegmatite is the source of the sheet mica, but in some places the muscovite books are very small and could furnish only a small proportion of sheet. Amblygonite and scattered beryl crystals also occur in the fine-grained rock. The amblygonite is found as corroded anhedral commonly ellipsoidal crystals. The beryl is white and generally occurs as small crystals or anhedral bodies, rarely more than 6 inches long. The indices of the ordinary ray in fragments from two specimens were 1.571 and 1.576. Many of the beryl crystals are partly sericitized, and some of the beryl from the south pit is almost entirely sericite. The altered beryl is greenish yellow. Other accessory minerals occurring in this rock are tourmaline, lithiophilite-triphylite, purpurite, apatite, biotite, columbite-tantalite, and pollucite.

A few small tabular pegmatites, a few inches to as much as 10 ft thick, crop out on the Tin Queen property, both on and off the mapped area. They strike N. 5°–45° E., and dip 38°–45° NW., markedly discordant with the schist. These dikes consist of comparatively fine-grained quartz-albite-perthite pegmatite showing little or no segregation. Appreciable quantities of accessory cassiterite are present in some of these pegmatites.

MINERAL DEPOSITS

MICA

The Tin Queen produces a white to pale-brownish ruby mica of exceptionally high quality. The mica is clear, with very few mineral inclusions and very little air-stain. Reeves are few, but hair cracks and ruling are conspicuous defects that reduce the percentage of sheet mica recovered from the crude. The mica books in most of the dike seem to be small but, in the large open-pit, books as much as 8 to 10 in. across are not uncommon.

The mica production for the Bourassa operation previous to June 9, 1944, shows that 1.6 percent of the rock mined was recovered as crude mica, and of this amount 4.0 percent was sheet mica, 12 percent washer punch, and the remainder scrap. About 82 percent of the sheet mica was less than 1½ by 2 in. across. On the basis of these figures 1.3 lb of large and small sheet mica was recovered per ton of rock mined. Possibly this rock is richer in sheet mica than other parts of the pegmatite, but it is estimated that the dike as a whole would yield ¾ to 1½ pounds of sheet mica per ton of rock.

The quality figures available for Tin Queen mica show a very high proportion of no. 1 quality and no. 2 quality mica. Individual lots sold in 1944 contained 21 to 40 percent no. 1 quality, 28 to 63 percent no. 2 quality, and 10 to 51 percent no. 2 inferior quality.

FELDSPAR

Perthite crystals as much as 5 or 6 ft across occur throughout the Tin Queen pegmatite. Of the 250 tons of rock mined previous to June 9, 1944, about 55 tons, or 22 percent, was recovered as potash feldspar.

AMBLYGONITE

Amblygonite occurs locally in the fine-grained quartz-albite pegmatite surrounding the perthite crystals. The crystals have been corroded to an anhedral form, characteristically forming ellipsoidal masses as much as 1 ft or more across. It is estimated that 1.5 tons, or 0.6 percent of amblygonite was recovered from 250 tons of pegmatite mined prior to June 9, 1945.

BERYL

Beryl is an unimportant product of this mine, but small quantities are recovered from the fine-grained quartz-albite pegmatite. Much of the beryl is partly or completely altered to sericite, and is not salable, but a few pounds of white beryl was found as crystals and anhedral masses, as much as 6 in. or more across, and beryl will probably continue to be a minor byproduct.

RESERVES

Lack of information concerning the position of the footwall, and the consequent uncertainty about the thickness and shape of the pegmatite at depth, preclude accurate estimate of reserves. Above the level of the western open-cut, at 5,694 feet altitude, the pegmatite is fairly well known, and an estimated reserve of 15,000 tons of pegmatite is available. This rock should yield 11,000 to 22,000 lb of sheet mica, about 3,000 tons of feldspar, and about 100 tons of amblygonite. If the pegmatite continues downward with an average thickness of 35 ft and a length of 180 ft, about 500 tons of rock will be available for each foot down the dip. If the grade of the rock remains the same as it is in the west open-cut, each 500 tons will furnish 380 to 750 lb of sheet mica, about 100 tons of feldspar, and about 3 tons of amblygonite.

TIN SPIKE (ANNIE NO. 1) (HILL CITY DISTRICT)

The Tin Spike (Annie No. 1) claim is in sec. 25, T. 1 S., R. 4 E., a few hundred feet southwest of the Mohawk tin mine. The claim was visited by L. R. Page in July 1942 and has been described by Hess (1909, p. 146) and Gardner (1939, pp. 35–36).

The Tin Spike deposit, a quartz vein containing muscovite, cassiterite, wolframite, and graphite, is exposed at the south end by an open-cut. The open-cut is at the site of a caved shaft, which on the 40-ft level is said to be connected to a 60-ft raise, 105 ft to the northwest. The raise is on a vein dipping 70° NE. and striking N. 20° W. The vein in the open-cut strikes N. 45°–50° W. It pinches out 45 ft northwest of the face and another lens strikes N. 20° W. to the raise (50 ft) where it seems to pinch out on the surface. At the foot of the raise it is about 2 to 3 ft thick. For several hundred feet along the trend of the vein a series of pits expose a vein 1 to 2 ft thick. In most exposures muscovite and very fine-grained beryl are the dominant minerals, but the tonnage and grade of these veins is insufficient to warrant mining and milling at present prices.

TINTON SPODUMENE DEPOSIT (TINTON DISTRICT)

The Tinton spodumene deposit is on the Giant-Volney claims of the Black Hills Tin Company. The claims are at the town of Tinton in the western part of Lawrence County, less than 1 mile from the Wyoming line. The deposit is accessible by surfaced and gravel road from Lead, 25 miles east, and by gravel road from Spearfish, 23 miles north, but for short periods during the winter and spring these gravel roads are nearly impassable.

The Tinton pegmatites were first prospected for tin (Smith and Page, 1941, pp. 595–630) and later were mined for tantalum, amblygonite, and spodumene. After several unsuccessful attempts to mine tin from the pegmatites on the Giant-Volney and adjoining Rough and Ready claims, the property was leased to the Fansteel Metallurgical Company during 1936–38. During this period 21,884 lb of columbite-tantalite, containing an average of 45 percent Ta_2O_5 was recovered, and 3,800 lb of cassiterite. As a byproduct of this operation about 400 tons of amblygonite, containing 8.3 percent Li_2O were also produced. In 1941 the spodumene ores were first treated by milling. About 525 tons of spodumene concentrates were recovered before January 6, 1943, when the mill was destroyed by fire. A new mill was built with financial assistance from the Reconstruction Finance Corporation. Between May 1, 1944 and August 15, 1944, when the mine was shut down, 555 tons of spodumene concentrates were recovered.

The property was first mapped by the U. S. Geological Survey in 1939–40 in conjunction with a U. S. Bureau of Mines diamond-drilling project that explored the pegmatite for tin (Smith and Page, p. 1941). The main spodumene-bearing zone was remapped in October 1943 by L. R. Page and L. C. Pray (pl. 40). At this time the underground workings at the tantalum shaft were mapped. This map was brought up to date shortly after the mine closed in 1944.

MINE WORKINGS

The main spodumene- and tantalum-bearing zone of the Giant-Volney pegmatite has been mined by glory hole methods. The tantalum shaft (altitude 5,965 ft) is 80 ft deep and is inclined at 58 degrees to the S. 68° W. At 65 ft (altitude 5,915 ft) more than 600 ft of irregular shaped drifts and crosscuts are connected to the glory hole by five raises. The drifts prospect the spodumene body for 210 ft along the strike, including 18 ft of drift north of the shaft. Crosscuts prospect the pegmatite for more than 100 ft across the strike (pl. 40). The glory hole was 140 ft long and as much as 65 ft wide in 1943, and it was enlarged slightly in 1944. Most of the rock mined at this time was obtained by deepening the west side of the glory hole about 10 ft, to the base of the spodumene body.

GEOLOGY

The spodumene of the Giant-Volney pegmatite occurs in three separate bodies (Smith and Page, 1941, map), only one of which has been mined. The bodies have been prospected by the Volney No. 1 adit which lies north of the tantalum shaft workings (see section A–A′, pl. 40). The spodumene occurs in an intermediate zone of quartz-spodumene pegmatite that strikes about N. 20° W. and dips 40°–60° W. The main spodumene-bearing rock is about 35 ft thick but lenses out horizontally and vertically (pl. 40). The body can be traced on the surface for 350 ft south of the tantalum shaft. Apparently it plunges to the northwest at about 20°.

The quartz-spodumene pegmatite is enclosed in a wall zone of oligoclase-quartz-muscovite pegmatite that contains cassiterite and scrap mica. Microcline-quartz pegmatite, which forms the core of the pegmatite, occurs as isolated masses of various sizes in the quartz-spodumene pegmatite. (See south drift on 60-ft level.) Thin lenses and stringers of albite-quartz-columbite-tantalite pegmatite also occur in the quartz-spodumene pegmatite.

All the types of pegmatite are cut by monzonite, pseudoleucite, and lamprophyre dikes.

The quartz-spodumene pegmatite is a fine- to coarse-grained rock with gneissic banding. This banding parallels the contacts of the spodumene deposit and also the pegmatite. At least part of the spodumene deposit was formed by the replacement of gneissic oligoclase-quartz-muscovite pegmatite of the wall zone and part at the north end of the glory hole, by the replacement of gneissic, but fine-grained, albite-quartz pegmatite of the intermediate zone. The structure may be inherited or, in part, may have formed with the spodumene. The spodumene itself is sugary grained and crystals as much as ¼ in. long are rare. One 12-in. crystal was found in 1939. Locally this sugary spodumene makes up 80 to 90 percent of the rock, though the average is probably between 20 to 30 percent.

The other two spodumene-bearing pegmatite bodies lie to the east of the main one. In the Volney No. 1 adit all three bodies seem to be exposed (see section A–A′). The middle zone, 40 ft below the main deposit, is about 25 ft thick, and the easternmost spodumene-bearing pegmatite is about 40 ft below the middle one. The extent of these two smaller deposits is not known.

The quartz-spodumene rock is easily followed in mining because of its distinctive texture and banding, except where it has been replaced or cut by lenses of microcline and quartz. These lenses do not have a gneissic banding, and cut the banding in the quartz-spodumene pegmatite. Consequently the microcline-quartz can be easily distinguished from the older banded feldspathic pegmatite of the wall zone.

MINERAL DEPOSITS

SPODUMENE

The main spodumene deposit is 350 ft long at the surface and is about 35 ft thick in the middle part. It appears to lens out to the north and south and also in depth. In detail the body has a very irregular contact because the quartz-spodumene rock interfingers with the oligoclase-quartz-muscovite pegmatite. The deposit seems to plunge northwestward at about 20°.

The grade of this deposit is not known in detail. According to Mr. R. J. Beatty of the Black Hills Tin Company, during their operations from June 1942 to January 1943 specific gravity determinations indicated that the mill ore from the southernmost open-cut contained an average of 2.78 percent Li_2O. From 2,775 tons of rock milled 767 tons of concentrates were recovered. The concentrates ranged from 5.7 to 6.3 percent of Li_2O.

The first ore milled on the property was quartz-spodumene rock that had been stockpiled from the Fansteel operation. This hand sorted ore, totaling 866 tons, yielded 257 tons or 29.6 percent of concentrates that contained a little over 6 percent Li_2O. In 1944, during the last period of operation, 4,150 tons of ore were milled and 555 tons, or 13.3 percent, of concentrates were recovered. These concentrates averaged only 5.6 percent Li_2O, probably because this was the trial period of operation for the mill. Furthermore, the rock treated included considerable debris that accumulated in the glory hole during the period of inactivity. Large quantities of lamprophyre were encountered during this period of mining. By the time the mill closed down the bulk recovery had been improved to 20 percent.

The other two spodumene deposits exposed in the Volney No. 1 adit (not shown on pl. 40) crop out as small bodies east of the glory hole (Smith and Page, 1941, map). They are surrounded by microcline-quartz and albite-quartz pegmatite. The middle body is exposed in a small pit as a lens 25 ft long and

12 ft wide. The eastern deposit is exposed as three separate lenses in an area 65 ft long and as much as 30 ft wide. Faults and igneous intrusions complicate the structure in this area. The only other exposures are in the Volney No. 1 adit, about 100 ft vertically below. The extent of these two deposits cannot be predicted in advance of exploration.

COLUMBITE-TANTALITE

Columbite-tantalite occurs with the spodumene and could be recovered as a byproduct. According to Mr. Beatty, during the Fansteel operation 4 to 5 lb of columbite-tantalite, containing 45 percent Ta_2O_5, were recovered per ton of rock moved. The total production was 21,884 lb. In addition, 3,800 lb of cassiterite containing 70 percent metallic tin was recovered.

AMBLYGONITE

Amblygonite occurs as large, rounded masses, many tons in weight, along the contact of the quartz-spodumene pegmatite with the wall zone. None has been observed below the level of the glory hole, but undoubtedly it will be encountered with continued development. About 400 tons of amblygonite has been produced, mainly from the hanging-wall side of the main spodumene deposit.

CASSITERITE AND SCRAP MICA

The oligoclase-quartz-muscovite rock that occurs above the amblygonite and spodumene deposits contains cassiterite. A pilot mill test of this rock yielded 9.5 tons of scrap mica from 98 tons of rock. From 56.5 tons of this rock 423 lb of tin concentrate, containing about 60 percent metallic tin was recovered, indicating a tin content of at least 4.5 lb per ton.

RESERVES

The reserves of spodumene-bearing pegmatite in the Giant-Volney pegmatite cannot be calculated with accuracy because (1) it is impossible to predict the quantity of microcline-quartz pegmatite, pseudoleucite, monzonite, and lamprophyre that may occur in each spodumene deposit; (2) it is impossible to predict where the deposits will pinch out in depth or along strike; and (3) the two eastern deposits have not been explored along strike. A tentative estimate is that the indicated reserves of the main spodumene deposit are on the order of 25,000 tons. The inferred reserves are probably equal to or double this figure. Additional reserves may be present in the two other deposits, but no estimates are possible. The ore can be expected to contain 20 to 25 percent of recoverable spodumene concentrates containing about 6 percent Li_2O. Four to five pounds of columbite-tantalite per ton might be recovered as a byproduct of spodumene mining.

TIPTOP LODE CLAIM (CUSTER DISTRICT)

by J. J. Norton and W. C. Stoll

The Tiptop Lode claim is about 5 miles southwest of the city of Custer, just east of the center of sec. 8, T. 4 S., R. 4 E., Custer County. The property is owned by William A. Nevin, who leased the mine to Ray L. Gould in September 1940. The main product of the mine is feldspar, but in 1943-44 it was prospected for sheet mica. Scrap mica, beryl, and amblygonite have been byproducts of feldspar operations.

The Tiptop Lode claim was examined by Stoll September 20, 1942 and by Norton on August 16, 1943. No detailed mapping was done on the property.

The main feldspar workings at the south end of the pegmatite are in an open-cut 150 ft long, 40 to 50 ft wide, and as much as 40 ft deep. The mica workings comprise a series of open-cuts, and a shallow shaft along the northeast side and at the northwest end of the body.

The Tiptop pegmatite is a large lenticular body striking N. 45° W. and dipping 40° SW. A schist capping above the pegmatite on the northwest side of the open-pit is apparently at the top of the body. The interior of the dike consists of quartz-perthite pegmatite, which furnished the industrial feldspar and a little scrap mica. Much of the perthite is graphically intergrown with quartz. Patches of quartz and albite, which occur within the quartz-perthite pegmatite as interstitial fillings between perthite crystals, contain small crystals of beryl. Most of the beryl consists of shells around inclusions. It is associated with quartz, albite, muscovite, tourmaline, and lithiophilite-triphylite. Near the hanging-wall contact the dike consists of quartz-albite pegmatite with accessory muscovite that has supplied a little sheet mica. Long biotite blades lie near the hanging wall and extend into the quartz-perthite pegmatite zone.

In 1943 two small pits north of the large feldspar pit were prospected for mica. The two pits are about 50 ft apart on a pegmatite that is about 25 ft thick, strikes N. 45° W. and dips 45° SW. Mica occurs in quartz-albite pegmatite on both the hanging-wall and the footwall side of the pegmatite. In the north prospect pit, which is about 15 ft deep and about 30 by 35 ft in horizontal dimensions at the surface, the pegmatite has a central core of quartz with mica along both walls. A shaft was sunk to a depth of about 35 ft in this pit and short drifts were made along the hanging wall in 1944.

During 1943 a total of 210.56 lb of sheet mica and 105 lb of punch was sold to the Colonial Mica Corporation from the Tiptop claim. Most of the mica came from the main open-pit, but some may have come from the prospect pits. The mica is heavily air-stained, except that from the prospect pit to the north, near the quartz core. Part of the mica near the quartz, however, is a good quality ruby mica.

The principal product of the Tiptop mine has been potash feldspar, with scrap mica and beryl as byproducts. The production data for the years 1938 through 1941 and for seven months of 1942 as given by Mr. Nevin are as follows:

Year	Feldspar (tons)	Scrap mica (tons)
1938	941	2.25
1939	437	2.75
1940	1,068	4
1941	3,079	4
1942	1,562	14
Total	7,087	27

Several tons of amblygonite was produced during this period. About 1 ton of beryl was produced in the seven months of 1942. Several hundred pounds of lithiophilite-triphylite has been stockpiled.

VICTORY MICA MINE (CUSTER DISTRICT)

by L. C. Pray, L. R. Page, J. J. Norton, and T. A. Steven

The Victory (Hedman) mica mine is in the SE¼SW¼ sec. 18, T. 3 S., R. 5 E., Black Hills Meridian, Custer County, about 2 miles northeast of Custer.

The Victory claim was located by J. M. Koch and Howard Roseberry of Custer, and was sold to the Custer Mining Account in 1943. The claim was patented that year. Under the direction of Harold Hedman, the Custer Mining Account operated the property from June 10, 1943, to January 1945. During this period a total of 75,459 lb of sheet mica was produced.

The early history of the claim is obscure, but apparently about 1910 mica was mined in an open-pit from both the hanging wall and the footwall, and from a 20-ft vertical shaft that started on the hanging wall near the center of the dike. No record of production is available.

This report is based on work carried on intermittently during the entire operation of 1943–44. The first maps and reports were prepared by L. C. Pray, assisted by L. R. Page and J. J. Norton in September and October 1943. Later, many underground maps were made by Page, Norton, and T. A. Steven assisted by Peter Joralemon, J. W. Adams and M. P. Erickson. A surface map (pl. 41) was made of the mine area on a scale of 1 in. to 20 ft by telescopic alidade and plane table. The underground workings (pls. 41 and 42) were mapped on a scale of 1 in. to 10 ft or 1 in. to 20 ft and geologic sections (pl. 41) were prepared. The pegmatites just south of the road on the Victory claim were mapped on a scale of 1 in. to 40 ft (pl. 43). Additional maps and sections were prepared to assist the U. S. Bureau of Mines in their diamond-drilling exploration of this property in 1944.

MINE WORKINGS

The Victory mica mine is in two pegmatite lenses and consists of two shafts, three drift levels, stopes between levels, and raises to the surface through which the stopes can be backfilled. The operations carried on before 1943 were confined to small open-pits and a shallow shaft. In June 1943 the Custer Mining Account sank a 40-ft inclined shaft, near the east end of the exposed pegmatite, and mined by glory-hole methods from the 30-ft level. Later that year a vertical shaft (pl. 4) was sunk to a depth of 70 ft and a drift was made at the 60-ft level along the two pegmatite lenses encountered. A raise from this level connected with the inclined shaft and west of the shaft the pegmatite was stoped nearly to the 30-ft level.

Early in 1944 the U. S. Bureau of Mines drilled two diamond-drill holes to prospect the 120-ft level. After completion of the drilling the Custer Mining Account deepened their shaft and made a crosscut to the pegmatite on the 120-ft level (pl. 41). Drifts from the crosscut extended about 30 ft east to the end of the pegmatite and 75 ft west along the pegmatite. A raise was driven along the keel of the pegmatite to connect with the inclined shaft. The pegmatite was stoped to the 60-ft level, above the drift. This stope was backfilled from the surface by means of raises from the 60-ft level to the 30-ft levels and glory hole.

GEOLOGY

METAMORPHIC ROCKS

The Victory pegmatite includes two connected lenses that intrude pre-Cambrian schists. In the diamond-drill holes sillimanite-garnet, quartz-mica, quartz-garnet, garnet-biotite, and muscovite-biotite schists and also garnet-biotite gneiss were encountered. On the southern side of the mapped area thin quartzite beds occur in the schists.

In general, the metamorphic rocks in the southern part of section 18 strike east, but on the Victory claim there are local deviations of 45 degrees north or south. Adjacent to the Victory mine pegmatite, the foliation and bedding of the schists averages about N. 80° E. in strike and dips about 45° SE. Within 300 ft west of the mine the strike changes to the northwest. To the south, across the road, the average strike of the schists and quartzite is N. 75° E. and the dip averages about 50° SE. The lineation in the schists and the schistose quartzite plunges 36° S. 35° W. This coincides closely with the observed plunge of the east end of the Victory mine pegmatite.

Sillimanite-garnet schists.—The sillimanite-garnet schists cut by the diamond-drill holes at the Victory mica mine are light- to dark-gray, or mottled, fine- to coarse-textured rocks of varied mineral composition. The coarser-textured rocks are at the contact of the pegmatites. The rock is composed of quartz, biotite, muscovite, sillimanite, and garnet, in various proportions in individual beds. Quartz is commonly the dominant mineral, but locally other minerals predominate. Sillimanite occurs as needles or bunches of needles as much as ½ in. long. It rarely exceeds 20 percent of the rock and is in part altered to muscovite. The alteration is most noticeable near the pegmatite contacts, where even the garnet is altered (to biotite). The garnet commonly makes up 5–10 percent of the rock, though some beds contain as much as 50 percent. The crystals are generally less than ⅛ in. in diameter, but a few are ¼ in. across. The muscovite occurs as fine flakes parallel to the foliation, and as large crystals or bunches as much as ⅜ in. in length that transect the schistosity.

Quartz-mica and quartz-garnet schist.—The quartz-mica schist is a fine- to medium-grained, gray, well-foliated rock composed of quartz, biotite, and muscovite, with subordinate quantities of garnet and sillimanite. Garnet crystals less than ⅛ in. in diameter make up less than 5 percent of the schist, though thin beds containing 20 to 30 percent of garnet are not uncommon. The larger beds rich in garnet are termed quartz-garnet schist.

Muscovite-biotite schist.—A very fissile, medium-grained, light-colored muscovite-biotite schist occurs interbedded with the quartz-mica and quartz-garnet schist. The dominant minerals are muscovite and quartz, with subordinate biotite and garnet. Few beds of this rock are more than 1 ft thick.

Garnet-biotite schist.—A coarse-grained garnet-biotite schist was encountered in diamond-drill hole no. 2. As much as 75 percent of the rock is red garnet, mostly as crystals ⅛ to ¼ in. across in a matrix of finer-grained biotite and quartz. At a depth of 132 ft this rock was bleached, and impregnated with pyrite.

Garnet-biotite gneiss.—Thin beds of light-brownish, poorly foliated garnet-biotite gneiss are interbedded with the sillimanite-garnet schist. The dominant minerals are brown garnet and quartz. Garnet forms as much as 50 percent and biotite as much as 20 percent of the gneiss. This rock seems to be the metamorphic equivalent of a calcareous sedimentary rock and grades into finer-grained, garnet-rich quartz-mica or sillimanite-garnet schist.

PEGMATITES

Two general types of pegmatites have been mapped on the Victory claim. The first type, represented by the Victory mine pegmatite (pls. 41 and 42), shows a distinct mineralogical zoning. The second type (pl. 43), has a uniform composition except for a narrow border zone, and generally is finely crystalline. These pegmatites are tabular bodies; the approximate ratio of their length to their width is 25:1, whereas for the Victory mine pegmatite the ratio is about 5:1. The two types are probably the same in average composition.

The tabular dikes consist of albite-quartz-perthite pegmatite in which the albite and quartz have an average grain size of 1 in. They are intimately intergrown and form a matrix for the coarser perthite crystals that are as much as 1 ft in diameter. These three minerals are present in about equal proportions. The minimum index of refraction of cleavage fragments of the albite (An_2–An_8) ranges from 1.527 to 1.530 ($\pm$0.002). Black tourmaline is the most abundant accessory mineral and on the average forms about 5 percent of the rock. Near the schist most of the tourmaline crystals show a distinct tendency to be oriented perpendicular to the contact. Muscovite is present in all of these dikes, but none of them seems to hold much promise as commercial sources of sheet mica. Three adjacent dikes were blasted open as mica prospects. Although some books of ruby muscovite as much as 10 in. in diameter were obtained, a test lot of 100 lb of the best books obtained in the sampling yielded less than 2 percent sheet mica, so work was abandoned.

The tabular dikes (pl. 43) occur south of the Victory mine in a band, about 150 ft wide, which trends roughly aest-west. These dikes have an average strike of N. 85° E. and dip about 50° SE. Some of these dikes coalesce on the surface and perhaps also at depth. The dikes do not appear to have a different texture or composition at the points of coalescence. One large dike in the southeastern portion of the area mapped is clearly a composite dike; within it the schist partings are generally parallel to the outer contacts. Small pods of coarsely crystalline quartz and feldspar were observed at the two widest parts of these dikes.

The Victory pegmatite, at the surface, is roughly lenticular in plan, with a length of 90 ft in a direction N. 75° E. and a maximum width of about 23 ft. It dips about 45° SE. Both walls have few irregularities other than gentle undulations, but near the surface on the footwall is a small anticlinal roll, and opposite this roll, on the hanging wall, is a small synclinal roll. The pegmatite mass is gently rounded at the western end and tapers to a sharply rounded eastern end which plunges 34 degrees S. 25° W. The western end of the pegmatite appears to have a similar plunge, which is about parallel to the lineation of the schists in the area.

Underground, just above the 60-ft level, a second pegmatite lens was uncovered; it extends to the 120-ft level. On the 60-ft level (pl. 41) the pegmatite exposed at the surface (known as the "lower dike") was 82 ft long and as much as 13 ft wide. The other pegmatite (known as the "upper dike"), which was encountered in the shaft, is 57 ft long and as much as 17 ft wide on this level. On the 120-ft level the "lower dike" was at least 50 ft long and 1 to 2 ft wide. The "upper dike" was 70 ft long and as much as 5 ft wide. These two pegmatites, though separate on the 60-ft level, were connected below it and on the 120-ft level. The thickness of the pegmatite lenses is shown by isopach lines on plate 41.

The Victory pegmatite contact is essentially concordant with the foliation of the schist. Both the hanging wall and the footwall strike from N. 55° E. to N. 85° E. and dip from 40 to 50 degrees over most of their length. Although the pegmatite-schist contact has few irregularities other than gentle undulations, some rolls have been exposed in the mine workings. A small anticlinal roll in the footwall just west of the collar of the inclined shaft plunges about 40° S. 28° W., becomes sharply defined in the stope at the 20-ft level and dies out before reaching the 30-ft level. A sharp synclinal roll in the hanging wall west of the inclined shaft pillar comes within a foot of meeting the crest of this footwall anticlinal roll at the 20-ft level, and dies out rapidly both upward and downward.

The ends of the pegmatite are blunt. The eastern end is semicircular in outline with a radius of about 1 ft, and it plunges 34° S. 25° W. The western end of the pegmatite is poorly exposed, but appears to be more gently rounded and to plunge 35° S. 40° W. The plunge of the ends of the pegmatite corresponds rather closely to the lineation of the schist, which averages 36° S. 35° W.

Numerous shears and two small faults with displacements of about 1 ft each cut the pegmatite. A strong shear zone that is nearly vertical and strikes N. 12° W. crosses the dike 40 to 50 ft west of the base of the inclined shaft. In this area muscovite books are badly ruled, and of little value for sheet mica.

Two zones, a wall zone of albite-quartz-muscovite pegmatite and a core of quartz-perthite-albite pegmatite, have been mapped in the Victory mine pegmatite. The contact between these zones is gradational and irregular in detail. The wall zone also grades into a border zone 1 to 2 in. thick.

Albite-quartz-muscovite pegmatite.—The albite-quartz-muscovite pegmatite forms both a border zone and a wall zone around the coarsely crystalline core of the pegmatite, and ranges in thickness from 1 to 7 ft. It has an average thickness of about 3½ ft on both the hanging wall and the footwall of the dike. The albite-quartz-muscovite pegmatite appears to thicken toward the ends where the thickness of the separate zones is additive and rich mica-bearing rock was 6 to 8 ft thick.

The rock of the wall zone is mainly albite, quartz, and muscovite, with minor quantities of black tourmaline, perthite beryl, and blue phosphate minerals.

The outer part of the wall zone, as much as 1 ft in thickness, is fine-grained and consists largely of quartz, with minor muscovite, albite, and tourmaline.

The albite (An_4–An_7) is generally light gray and in crystals as much as 1 ft across, although the average is 1 to 2 in. Quartz is subordinate to albite, except in the fine-grained contact zone. Some of the muscovite books are more than 1 ft in diameter and several inches thick. The mica is deep ruby, and some of it shows "A" structure.

Very little perthite is present in this zone, but it increases in quantity at the boundary between this zone and the core. The beryl, which is light-green to yellowish-white, seems to occur at the inside of the albite-quartz-muscovite zone, at the contact with the quartz-perthite-albite core. A few nodules of dark phosphate minerals are present in the upper levels. Microscopic examination indicates this mineral to be triphylite-lithiophylite (70 percent and 30 percent respectively). The phosphate nodules are generally altered to iron and manganese oxides, which stain the surrounding minerals.

Quartz-perthite-albite pegmatite.—The quartz-perthite-albite pegmatite that forms the core of the dike has minor quantities of muscovite, tourmaline, and beryl. This zone is more coarsely crystalline than the albite-quartz-muscovite zone, and some masses of quartz are 8 ft wide. Quartz is the dominant mineral. Crystals of perthite several feet in diameter are not uncommon. The perthite is generally white or gray, with a little flesh-colored mottling. Albite, of the same composition as that in the albite-quartz-muscovite zone, occurs as individual large gray crystals and as finer grains intimately intergrown with quartz. This intergrowth forms a fine-grained matrix for large crystals of perthite and albite. Black tourmaline crystals, mostly less than 1 in. in diameter, are scattered throughout the zone but are not as abundant as in the albite-quartz-muscovite zone. A crystal of beryl, weighing about 400 lb, was mined from the footwall edge of the quartz-perthite-albite zone. Isolated books or clusters of books of muscovite have been found in the core, but they are not abundant enough to make mining of the zone profitable. A few small masses of yellowish-white, finely crystalline muscovite occur in the quartz-perthite-albite zone. This "bull mica" apparently crystallized at a late stage, as shown by its prevalence in fractures that cut across the pegmatite.

QUARTZ VEINS

A few irregular quartz veins, mostly less than 1 in. thick, occur in the schist, and generally are about parallel to the foliation and bedding. Near the southern edge of the area mapped (pl. 43) a poorly exposed quartz vein extends about 100 ft in an east-west direction and has a maximum width of about 20 ft.

MICA DEPOSITS

The Victory mica mine was the largest producer of sheet mica in South Dakota in 1944. During the operations of the Custer Mining Account from June 10, 1943 to January 1, 1945 a total of 711,221 lb of crude mica was produced. This crude mica yielded 75,459.28 lb of large and small sheet mica, valued at $488,255.89; 257,098 lb of washer and other byproduct mica; and 239.3 tons of scrap mica valued at $7,693.17. In addition, about 400 lb of beryl was recovered and sold.

The muscovite mica in the Victory mine occurs as a wall-zone type of deposit in albite-quartz-muscovite pegmatite. This pegmatite completely encloses the core of the two lenses known as the "upper" and "lower" dikes. Because the pegmatites were narrow it was necessary to mine the entire body. It is estimated that 5 to 6 percent of the pegmatite rock moved was recovered as crude mica and that an additional 10 percent of small flakes and books of muscovite was not recovered.

The books recovered were as much as 18 in. in length. The mica was flat, hard, deep ruby with air-stains, silver spots, silver streaks, reeves, and mineral inclusions were the chief defects. The monthly sales during the last 6 months of 1944 comprised 8 to 17 percent no. 1 quality, 22 to 32 percent no. 2 quality, and 53 to 69 percent no. 2 inferior quality. About a third of the sheet mica sold was larger than 1½ by 2 in.

The proportion of sheet mica recovered from crude mica at this mine was entirely dependent on the method of preparation. Mica prepared in different custom rifting shops ranged from 2.5 to more than 17 percent, although the crude mica itself appeared to be very uniform.

U. S. BUREAU OF MINES DIAMOND-DRILLING PROGRAM

The U. S. Bureau of Mines prospected the Victory pegmatite by two diamond-drill holes early in 1944. The results of this work have been summarized by Fremont F. Clarke, project engineer (1945). Later stoping and other underground work allowed a comparison between the geologic conditions inferred from the drill cores and what actually existed.

The logs of the drill holes are given below.

Logs of U. S. Bureau of Mines diamond-drill holes, Victory mine

Drill hole no. 1

Feet	*Description*
0–11	No drill core. Overburden.
11–20	Quartz-mica schist interbedded with sillimanite-garnet schist, muscovite-biotite schist, and garnet-quartz schist. Bedding and foliation are 70° to the drill core. The axes of crinkles are 60° to 70° to the drill core. The long axes of biotite streaks are 35° to the strike of the foliation planes.
20–37	Sillimanite-garnet schist. Fine-, medium-, and coarse-grained texture. Garnet-biotite gneiss beds, up to 0.2 ft in thickness, at about 30, 31, and 37 ft.
37–46	Quartz-mica schist with thin beds of muscovite-biotite and sillimanite-garnet schist. Garnet-biotite gneiss at about 37.5 ft as 2-in. bed.

Logs of U. S. Bureau of Mines diamond-drill holes, Victory mine—Continued

Drill hole no. 1—Continued

Feet	*Description*
46–61	Medium-grained sillimanite-garnet schist. Axis of fold at about 58 ft. Above axis beds are 45° to drill core; below axis, 25° to drill core.
61–63	Quartz-mica schist. Iron-stained and fractured.
63–64	Medium-grained sillimanite-garnet schist.
64–67	Friable quartz-mica schist.
67–68	Medium-grained sillimanite-garnet schist. Fracture zone at 68 ft.
68–75	Friable quartz-mica schist interbedded with garnetiferous muscovite-biotite schist.
75–77	No drill core.
77–81	Friable quartz-mica schist interbedded with muscovite-biotite schist. Fold axes at about 79 and 81 ft. Foliation 70° to the drill core. Bedding 75° to drill core above fold, 0 to 45° between folds, and 65° to the drill core below folds.
81–85	Medium-grained sillimanite-garnet schist.
85–89	Quartz-mica schist with interbedded sillimanite-garnet schist. Bedding 65° to drill core. Foliation 70° to drill core.
89–92	Sillimanite-garnet schist.
92–93	Quartz-mica schist.
93–105	Sillimanite-garnet schist with interbedded quartz-mica schist. Bedding 80° to the drill core. Foliation 65° to drill core.
105–107	Quartz-mica schist. Bedding 75° to the drill core. Foliation 85° to the drill core.
107–112	Interbedded sillimanite-garnet and quartz-mica schist. Bedding 70° and foliation 80° to the drill core.
112–118	Fine-grained quartz-mica schist. 0.8 ft of sillimanite-garnet schist at about 115 ft, and 1 ft of quartz-garnet schist at about 117 ft. Fracture zone at 113 to 115 ft.
118–122	Interbedded quartz-mica, quartz-garnet, and sillimanite-garnet schist. Bedding 60° and foliation 75° to the drill core.
122–123.2	Coarse-grained sillimanite-garnet schist.
123.2–126.1	Pegmatite. Muscovite books in excess of 3 in. in length in white to gray albite, quartz, and tourmaline pegmatite. Hanging-wall contact 75° to the drill core. Footwall contact not recovered. 123.2 to 123.4 ft. Mica-quartz selvage zone; 60 percent muscovite, 40 percent quartz. 123.4 to 125.4 ft. Muscovite was approximately 28 percent (13 oz.) of recovered core. 125.4 to 126.1 ft. Quartz, feldspar, and tourmaline in part iron-stained.
126.1–127	Coarse-grained sillimanite-quartz schist.
127–127.5	Quartz-mica schist.
127.5–130	Coarse-grained sillimanite-garnet schist.
130–141	Quartz-mica schist with beds of quartz-garnet schist.
141–156	Sillimanite-garnet schist with thin beds of quartz-mica schist. Bedding and foliation 80° to drill core.
156–170	Quartz-mica schist. Bedding 70° and foliation 80° to drill core.
164–170	Medium-grained sillimanite-garnet mica schist. One-foot bed of quartz mica schist at about 168. Bedding and foliation 90° to the drill core.

Logs of U. S. Bureau of Mines diamond-drill holes, Victory mines—Continued

Drill hole no. 2

Feet	*Description*
0–10	No drill core. Overburden.
10–25	Sillimanite-garnet schist; medium-grained, well-foliated with thin beds of fissile muscovite-biotite, and quartz-garnet schist. Bedding and foliation 70° to the drill core at 10 ft, and bedding 55° to the drill core at 19 ft.
25–26.7	Garnet-biotite gneiss. Bedding 70° to the drill core.
26.7–29	Quartz-mica and quartz-garnet schist. Fold axis at 27 ft is 40° to the drill core. Schist crumpled and wavy.
29	Fractured zone. Iron-stained garnet-biotite schist.
29–33.7	Quartz-mica schist.
33.7–34	Garnet-biotite gneiss.
34–37	Quartz-mica schist. Bedding 50° to the drill core.
37–40	Coarse-garnet-biotite schist and sillimanite-garnet schist. Garnet-biotite gneiss at 39.3–39.4 and 39.7–39.9 ft. Foliation 75° to the drill core. Linear structure 60° to the strike of foliation.
40–41	Sillimanite-garnet and muscovite-biotite schist in half-inch beds. Bedding 75° and foliation 80° to the drill core.
41–52	Quartz-mica schist interbedded with muscovite-biotite schist. Folded and crumpled from 47 to 49 ft.
52–57	Medium-grained sillimanite-garnet schist. Iron-stained fracture at 56 ft.
57–65	Quartz-mica schist with interbedded muscovite-biotite schist and quartz-garnet schist. Bedding 65° to the drill core.
65–68	Muscovite-biotite schist with thin beds of quartz-mica schist. Iron-stained fragments at 65–66 ft.
68–69	Sillimanite-garnet schist. Coarse-grained.
69–75	Fissile muscovite-biotite schist with thin layers of sillimanite-garnet schist and quartz-garnet schist. Bedding 30° and foliation 80° to the drill core.
75–97	Quartz-mica schist with interbedded quartz-garnet schist. Fractured and bleached zone at about 78 ft and 87 ft. At 76 ft bedding is 50° to the drill core. Foliation 80° to the drill core.
97–118	Medium- to coarse-grained sillimanite-garnet schist with about 1 ft of muscovite-biotite schist at 116 ft.
118–130.5	Quartz-mica schist with more or less sillimanite and garnet. Fine- to medium-grained. Foliation 80° to drill core.
130.5–134	Garnet-biotite schist. Coarse-grained garnets, as much as ¼ in. in diameter, in a matrix of biotite and quartz. Bleached and impregnated with pyrite at 132 ft. At 133 ft, 4-in. bed of fine-grained quartz-mica schist.
134–137	Fine- to medium-grained sillimanite-garnet schist with biotite clots replacing garnet. Iron-stained fracture at 136.5 ft.
137–137.8	Coarse sillimanite-garnet schist.
137.8–138	Pegmatite. Muscovite and quartz with scattered tourmaline. Hanging-wall contact 85° to the drill core. Footwall contact 50° to the drill core.
138–138.2	Coarse sillimanite-garnet schist.

Logs of U. S. Bureau of Mines diamond-drill holes, Victory mines—Continued

Drill hole no. 2—Continued

Feet		*Description*
138.2–142.8		Pegmatite. Hanging wall 30° to the drill core. Footwall 70° to the drill core.
	138.2–138.3	Mica-quartz border zone.
	138.3–138.5	Muscovite books at least 1 by 1½ by ¼ in. in gray albite and tourmaline.
	138.5–139.5	Albite pegmatite with some muscovite.
	139.5–140.6	Muscovite. Fragments up to 3 in. in length.
	140.6–140.9	Gray albite, tourmaline, and muscovite.
	140.9–141.2	Tourmaline granulite, probably altered schist. Hanging wall 20° and footwall 40° to the drill core.
	141.2–141.5	White albite.
	141.5–142.3	Probably muscovite book.
	142.3–142.8	Albite, tourmaline, and lithiophilite-triphylite. Footwall contact 70° to the drill core.
142.8–146		Coarse sillimanite-garnet schist with quartz-mica schist. Bedding 60° and foliation 80° to the drill core.

RESERVES

The Victory mine contains little blocked-out mica-bearing pegmatite. The only area that can be said to contain blocked-out reserves is the shaft pillar which extends from the west side of the vertical shaft to the raise at the east end of the "upper dike." This block is limited on the top by the 30-ft level and at the bottom by the 60-ft level. Perhaps 10 tons of crude mica could be recovered from this block.

Below the 120-ft level some excellent mica probably could be recovered, though the pegmatite is very narrow. Additional prospecting might reveal at depth another pegmatite lens similar to the one found by the vertical shaft.

VICTORY NO. 1 (HOEFERT "ARCADE") MICA PROSPECT (CUSTER DISTRICT)

The Victory No. 1 (Hoefert "Arcade") mica prospect, in the NW¼ sec. 16, T. 3 S., R. 5 E., is owned by H. L. Hoefert of Custer. It can be reached by following U. S. Highway 16, 2.8 miles east of Custer, then the Iron Creek road for 1.7 miles, and then following a dirt road north for an additional 0.5 mile. The workings in the pegmatite, 50 ft from the southeast end, consist of two small cuts from which about $1,000 worth of mica is reported to have been produced in 1943–44.

The pegmatite is an irregular branching body that crops out for a total distance of 250 ft. The southeast end is composed of two pegmatites separated by 10 ft of schist at the workings. They join about 80 ft northwest of the workings and the uppermost pegmatite extends about 90 ft to the northwest. The outcrop is essentially a dip slope, and stands 40 ft above the workings. Where the pegmatites join they strike about N. 55° W. and dip 40°–60° SE.

The main open-cut is 20 feet long, 8 to 10 ft wide, and about 8 ft deep, and trends S. 80° W. across the northeast end of the upper pegmatite. The other cut, 8 ft long, 6 ft wide, and 4 ft deep, prospects the lower pegmatite.

The larger cut in the hanging-wall branch shows perthite-oligoclase-quartz pegmatite with accessory muscovite and tourmaline on either side of a schist parting about 3 ft above the base of the dike. No mica books were exposed, but specimens reportedly from this mine were as much as 12 in. long and 6 in. wide. The mica is hard, flat, and deep ruby, with air-stains and silver spots. One book is said to have produced 5 lb of large sheets. The smaller cut, in the lower dike, exposed sillimanite-bearing pegmatite. The border zone on the hanging wall is fine-grained sillimanite-quartz pegmatite ½ to 1 in. thick. Knobs of this material, extending into the schist, are exposed along the hanging wall of both dikes.

The wall zones, 1 to 3 ft thick, consist of oligoclase (An_{23}, minimum refractive index of cleavage fragments 1.54), quartz (40 percent) and sillimanite (5 to 20 percent) with minor muscovite, tourmaline, biotite, garnet and apatite. The muscovite occurs as fine flakes. The core of the dike consists of a pod, 10 by 3 ft in area, of quartz, perthite, and graphic muscovite and quartz. White to buff oligoclase forms a matrix for other minerals. One book of muscovite 2 by 2 in. was seen. A similar type of pegmatite forms a 1- by 5-ft fracture-filling lens, oriented at right angles to the strike.

The mica mined from the Victory No. 1 was sold to Colonial Mica Corporation under the name of "Arcade", to avoid confusion with other "Victory mines" in the district. The sales of trimmed punch and sheet were 120.86 lb in 1943 and 94.86 lb in 1944. The mica sold in May and June 1944 contained less than 10 percent of no. 1 and no. 2 qualities combined; the remainder was no. 2 inferior quality. According to Mr. Hoefert, about 10 lb of this mica was actually from the Arcade no. 1 claim.

WALSH MICA PROSPECT (CUSTER DISTRICT)

The Walsh mica prospect was discovered in May 1944 by Langdon Landis on the Walsh Ranch in the SE¼ sec. 28, T. 3 S., R. 5 E. The property, about 1,000 ft N. 10° E. of the Earl Lode mica mine, was examined May 26, 1944. About 75 lb of sheet mica was produced by Landis in 1944 from a small open-cut.

The mica pegmatite strikes N. 70° E. and seems to dip 50° NW., but exposures of the wall are poor. The dike can be followed 200 ft west and 55 ft east of the discovery pit. The west end thins to 6 in. and probably western 100 ft of it is less than 2 ft thick. The east end is covered by quartzite talus. The pegmatite is 5 to 6 ft thick at the eastern end and at the discovery pit, where most of the mining was done. The outer 12 to 18 in. part is fine-grained and the central mica-bearing part is coarser-grained pegmatite. The mica is very flat, hard, pale ruby to white mica of excellent quality. Very few of the books show "A" structure.

WAYSIDE MICA PROSPECT (CUSTER DISTRICT)

The Wayside mica claim, also located as the Pine Cone, in sec. 33, T. 3 S., R. 5 E., Black Hills Meridian, Custer County, was examined May 21, 1944. The claim was located by Herman McGuire on May 16, 1936.

The workings consist of three open-pits on a pegmatite north of the road and five open-cuts on a group of pegmatites south of the road. The cuts on the north side of the road are in mica-bearing pegmatite, but the other cuts were made for feldspar.

The two most northerly open-pits are on a pegmatite 5 to 10 ft wide and 80 ft long that strikes N. 70° E. and dips 50°–60° NW. The pit at the east end of the exposures opened up the only mica zone. It is 6 to 12 in. thick and lies on the footwall of the dike. Small books of heavily air-stained mica are scattered through the coarser perthite and quartz that form the core of the dike.

A second mica-bearing pegmatite crops out on the Wayside claim on the north side of the road. It strikes N. 70° E. and dips 40° NW. Small mica books were exposed on a dip slope of the hanging wall. A Mr. H. I. Foram has located this dike (March 20, 1944) as the Pine Cone mica lode.

Probably neither of these two pegmatites can be worked profitably for mica.

WESTERN FELDSPAR LODE (HILL CITY DISTRICT)

by W. C. Stoll

The Western Feldspar Lode is in or near the NE¼ sec. 33, T. 1 S., R. 4 E., 3¼ miles west-southwest of Hill City, in Pennington County. The owners are Andrew Miller, San Gabriel, California, and George W. Coats of Hill City. The property is a 20-acre unpatented claim that was located October 20, 1938. The property was worked before that date but abandoned.

The pegmatite on the property strikes N. 12°–25° E. and dips 75° SW. to vertical. It is 216 ft long and the maximum observed thickness is 18 ft. The pegmatite contacts dip and strike discordantly with the sericitic schist wallrocks.

One cut has been made in the footwall schist near the north end of the outcrop. Three cuts and a 25-ft shaft prospect the pegmatite at irregular intervals along the strike.

The cut in the footwall schist (cut no. 1) near the north end of the dike, exposes only schist and dislodged blocks of pegmatite. On the slope below the cut, are scattered small excavations from which pieces of tin ore float have been taken. Some of this float, which consists of quartz-muscovite pegmatite, contains about 2 percent cassiterite.

Cut no. 2 is a few feet south of no. 1, and is excavated in pegmatite. This hole is 10 ft square and 10 ft deep. The pegmatite exposed is a fine-grained rock composed of quartz, muscovite, and scattered small masses of microcline and quartz. No tin minerals or spodumene are exposed.

Cut no. 3 is 30 ft south of no. 2, and is also in pegmatite. It is 12 ft long, 10 ft wide, and 12 ft deep. The hanging wall of the dike is exposed and strikes N. 20° E., and dips 75° NW. The bordering fine-grained sericitic schist strikes N. 60° E. and dips 80° SE. Near the contact small patches of quartz-muscovite pegmatite contain 0.5 to 3 percent cassiterite. The remainder of the exposed pegmatite is a medium-grained mixture of feldspars, quartz, and fine-grained mica. A few shreds of spodumene occur in the dike a few feet from the hanging-wall contact.

Cut no. 4 is 36 ft south of no. 3. It cuts the pegmatite from wall to wall and is 20 ft long, 6 ft wide, and 8 ft deep. At the west end of the opening, the hanging wall strikes N. 25° E. and dips 90 degrees. The wall-rock is a soft sericitic schist. The hanging-wall zone, 3 ft thick, is composed of fine-grained feldspar with small quantities of quartz and mica. No cassiterite was seen. The core is 11 ft thick; it contains 10 to 15 percent spodumene in crystals as much as 6 in. long in a matrix similar to the rock composing the hanging-wall zone. The spodumene is moderately hard where unweathered. Along part of the cut the spodumene rock overlies a small exposure of barren pegmatite. The footwall zone, 4 ft thick, is similar to the rock on the hanging wall. The total thickness of the dike here is 18 ft.

Between cut no. 4 and the shaft, 90 ft to the south, the pegmatite is 12 to 14 ft thick. Very little spodumene is visible, but the surface is weathered and otherwise obscured. White "bull" quartz veins 1 to 12 in. thick cross the dike.

The shaft is vertical, 10 by 8 ft in plan, and 25 ft deep. The pegmatite at this point is 10 to 12 ft thick. At the top, the shaft penetrates 4 ft of spodumene pegmatite but below reveals only a medium-grained feldspar-quartz-muscovite pegmatite. No cassiterite was seen in place at the shaft, but a little was found in the dump nearby.

Downslope and south of the shaft, the pegmatite thins to its end 60 ft from the shaft. The rock is similar to that exposed in the shaft.

The spodumene zone is thin and is cut off at a shallow depth. Cassiterite is scantily distributed through the wall zones of the dike in quartz- and mica-rich parts of the pegmatite.

WHITE BEAR MICA MINE (CUSTER DISTRICT)

by Peter Joralemon

The White Bear mica mine, in the NE¼ sec. 11, T. 4 S., R. 4 E., Black Hills Meridian, Custer County, is 4.1 miles southwest of Custer. It is at an altitude of about 5,400 ft.

The White Bear claim was originally located by Mr. S. T. Gamber of Custer, in 1935. A year later it was leased to the Schundler Feldspar Company to be worked for feldspar. In the early part of 1943 it was taken over by Consolidated Feldspar, and in November 1943 it was leased to the Minndak Mines Incorporated, of Minneapolis, Minnesota. It was operated by the White Bear Mining Company, a subsidiary of Minndak Mines Incorporated, from November 1943 to June 1944.

The property was first examined and mapped by W. C. Stoll in September 1942. A sketch map of the White Bear pegmatite was made by Peter Joralemon in November and December 1943 and a detailed map and sections (pl. 44) on a scale of 1 in. to 20 ft was completed in April. In April and May, maps of the underground workings (fig. 36) were made on a scale of 1 in. to 10 ft.

MINE WORKINGS

The White Bear pegmatite was first worked by an open-cut, 50 ft long, as much as 40 ft wide, and as much as 25 ft deep, at the south end, and by two smaller cuts on the east and west sides near the northern end. The White Bear Mining Company sank a 76-ft shaft (altitude 5,414 ft), inclined at 59° from the largest open-cut. From the 5,368-ft level drifts were made 10 ft northwest and 40 ft southeast. Short raises at either side of the shaft prospected the pegmatite up dip (fig. 36) from this level. A small drift was made at the 5,358-ft level.

GEOLOGY

The country rock underlying the White Bear claim is pre-Cambrian quartz-mica schist. The foliation in the schist strikes N. 0°–10° W. and dips 40 to 60 degrees to the west, approximately parallel to the bedding. Quartzite and quartz-hornblende gneiss were found as float on the surface but were not seen in outcrops. They are probably interbedded with the schist.

The schist on this claim is intruded by several pegmatites which are conformable to the bedding (pl. 44). These pegmatites, where exposed, range in thickness from 1 to 80 ft, and in length from 20 to more than 400 ft. The pegmatites to the east and north of the White Bear pegmatite are composed of perthite, quartz, and albite in about equal amounts, in grains 1 to 5 in. in diameter. Minor amounts of muscovite, biotite, and tourmaline occur in the pegmatites. This rock appears to be the equivalent of both

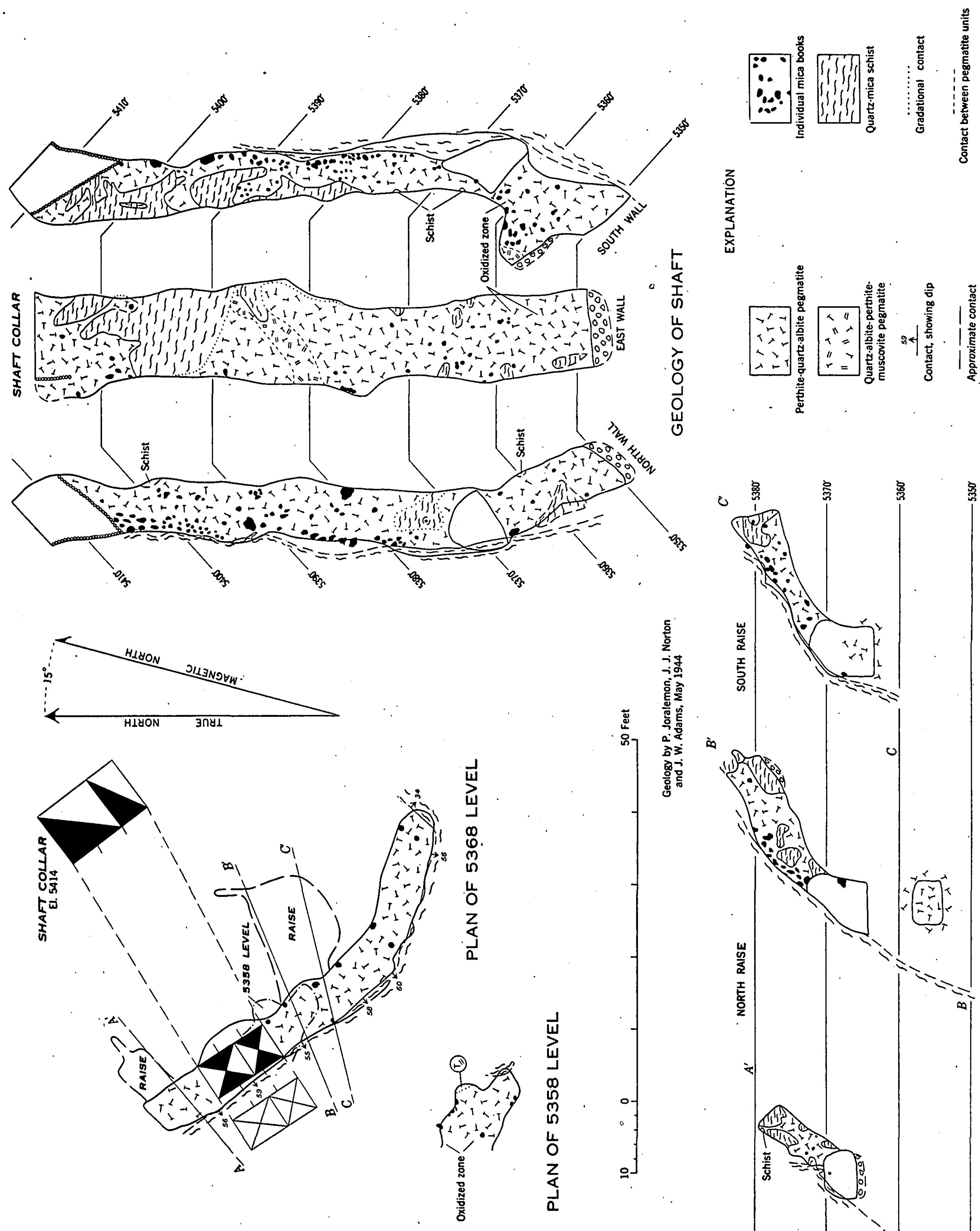

FIGURE 36.—Geologic maps and sections, underground workings, White Bear mica mine, Custer County, South Dakota.

the perthite-quartz-albite and the quartz-albite-perthite-muscovite pegmatite mapped in the White Bear body. A selvage zone too narrow to mine is composed of albite, quartz, perthite, and muscovite (some of it in books). The White Bear pegmatite is the only one on this claim that contains appreciable amounts of sheet mica.

The White Bear pegmatite is a lenticular body as much as 80 ft wide and almost 200 ft long that stands as a prominent knob, almost 50 ft higher than the surrounding terrain. The pegmatite strikes northerly and appears to have an average dip of about 60° to the west, although locally the dip ranges from 40° to the west to 66° to the east. The southern end of the pegmatite plunges S. 5° W. at an angle of 48°. It is largely covered with a thin veneer of schist ranging from a fraction of an inch to several feet in thickness. Schist inclusions occur within the pegmatite.

Three mineralogic zones were mapped within the pegmatite—quartz pegmatite, perthite-quartz-albite pegmatite, and quartz-albite-perthite-muscovite pegmatite. On the map the sheet-mica symbol was superimposed on symbols for other mineralogic zones wherever book mica was observed.

Quartz pegmatite, as bands of massive rose quartz as much as 2 ft thick and 40 ft long, cuts all other types of pegmatite. The quartz pegmatite in the northwest part of the White Bear pegmatite (pl. 44) contains several beryl crystals, as much as 6 in. in diameter, and also a few books of mica. On either end, this zone of quartz pegmatite grades into perthite-quartz-albite pegmatite. Quartz pegmatite also forms a shell around part of the northwestern side of the pegmatite.

The bulk of the White Bear pegmatite is perthite-quartz-albite pegmatite that ranges in composition from a mixture of very large perthite crystals and graphic granite masses on the east side to finer-grained perthite-quartz-albite pegmatite on the west side. Perthite is the predominant mineral in this zone. As the grain size decreases, quartz and albite become more abundant. In the finer-grained facies perthite crystals a few inches in diameter are surrounded by a groundmass of quartz and albite. Several white to gray albite crystals (An_6, $N\alpha=1.529$), a foot or more across, were seen in the coarse graphic granite mixture with large crystals of tourmaline, biotite, and muscovite. The shaft and the drift are almost entirely in coarse-grained perthite-quartz-albite pegmatite.

Quartz-albite-perthite-muscovite pegmatite is the contact facies of the pegmatite and surrounds the schist inclusions. It is fairly even textured, with the grains about an inch across. Quartz is the predominant mineral, and albite is more abundant than muscovite, which occurs as narrow flakes and books of little commercial value. This zone is discontinuous and generally not more than a foot thick, but because of its low angle of dip and its resistance to erosion the zone is exposed as wide patches. Where the zone is absent perthite-quartz-albite pegmatite occurs at the contact.

MICA DEPOSITS

Mica occurs with perthite, quartz, and albite, in books as much as 18 in. in diameter and several inches thick. It is medium- to dark-ruby and is moderately air-stained. In the shaft (fig. 36) where the mica-bearing pegmatite is oxidized, the mica books are soft, wavy, and heavily air-stained. The larger books are generally "A" or "fish" mica and many of the smaller books are flat and clear.

Scattered books of mica occur in the outer 10 to 15 ft of the pegmatite for its entire circumference. One and possibly two rich mica shoots occur in the White Bear pegmatite. The main shoot has been explored by the shaft (fig. 36), and perhaps there is another at the northwestern end of the body.

The mica shoot in the shaft is on the hanging wall just west of the south end of the pegmatite. It is 15 ft wide, 5 to 15 ft thick, and 80 ft long. Below the level of the drift (see shaft map, fig. 36), the mica shoot seems to narrow and to leave the hanging wall.

At the bottom of the shaft, the main concentration of mica is about 6 ft from the hanging wall, and is 8 ft thick. Its width could not be measured, but apparently the shoot is narrower than at the surface. The mica in the oxidized zone at the bottom of the shaft is soft, badly air-stained, and wavy. This oxidized zone may have been a vuggy part of the pegmatite.

The drift and raise to the northwest of the shaft encountered little or no sheet mica, but the southeast raise and the first 15 ft of drift southeast of the shaft were in the mica shoot. Few mica books were observed along the crest of the pegmatite.

PRODUCTION AND RESERVES

The White Bear mica mine produced 73,880 lb of crude mica between November 1943 and May 10,1944. Of this amount, 33,302 lb were sorted at the mine as scrap. From the remaining 40,578 lb, 1,577.4 lb of sheet mica was produced. The recovery of sheet from mine-run mica is 2.1 percent. The rifting house recovered 3.9 percent of the cobbed mica.

The quality of the White Bear mica ranged up to 10 percent of no. 1, 1 to 37 percent of no. 2, and 54 to 99 percent of no. 2 inferior qualities in various shipments. The weighted average was 34 percent no. 1 and no. 2. The remainder was no. 2 inferior quality. The total production of large sheet has been two-thirds that of small sheet (1 by 1 in. and 1¼ by 1¼ in.).

About 900 tons of rock mined from the shaft, drift, and raises, contained an average of 4.1 percent crude mica. Because much of the work was in barren pegmatite, the upper part of the shaft must have contained more than 5 percent of mica. The mica shoot becomes leaner with depth and also appears to become narrower and thinner. The extension of the mica shoot in the lower part of the shaft may have left the hanging wall, but this cannot be determined from the present workings. The northwest drift and the southeast drift south of the raise contained less than one percent of mica.

WHITE CAP MINE (KEYSTONE DISTRICT)

by W. C. Stoll

The White Cap mine, which has been known also as the King Mica and the Primer Lode, is less than a mile southeast of Keystone, in the NE¼ sec. 16, T. 2 S., R. 6 E., Pennington County. The owner is F. G. Robertson of Spokane, South Dakota. The operators are Clark and Watson Butts of Keystone, who obtained a lease on the deposit in March 1939. No data are available on mine production before that date, but according to the Butts Brothers the following tonnages of minerals have been mined from 1939 to October 31, 1942, the date of the examination.

	Feldspar (tons)	Beryl (tons)	Mica (tons)
1939	360	2. 5	8
1940	1, 295	4	15. 52
1941	1, 523	3	17. 12
1942	777	[1] 4	[2] 17. 29
Total	3, 955	13. 5	57. 93

[1] Includes stockpile of 2 tons.
[2] This 34,576 lb of crude mica yielded 27,693 lb or 80.3 percent scrap, 6,797 lb or 19.6 percent untrimmed punch, and 86.5 lb or 0.1 percent sheet mica.

The White Cap pegmatite has been mined at the southeast end by a pit 150 ft long, 15 to 25 ft wide, and 20 to 55 ft deep, and 30 ft northwest a smaller opening has been excavated on the footwall side of the pegmatite. The second pit was 70 ft long, 15 ft wide, and as much as 15 ft deep in 1942. This cut was enlarged by mining operations in 1944–45.

The White Cap pegmatite is well exposed for a distance of about 350 ft along the strike, N. 47°–60° W. The average width of the body is about 25 ft and the maximum width is perhap 35 ft. The average dip is 60° NE., but the contacts curve irregularly parallel with small folds in the mica schist wall rock. At the surface, the top of the dike is partly covered by a roof of steeply dipping schist. At the southeast end of the pegmatite the foliation of the schist curved around the blunt end.

The core of the pegmatite, 15 to 25 ft thick, is about ⅚ potash feldspar and ⅙ quartz. Amblygonite, associated with quartz and aggregates of yellowish muscovite, occurs in the perthite. The core has been mined extensively, and most of the present exposures in the main pit are in the intermediate and wall zones of the pegmatite. The part of intermediate zone nearest the core consists principally of perthite crystals with interstitial massive quartz or aggregates of muscovite, and dark lithiophilite-triphylite minerals with intergrown albite and quartz. Large beryl crystals are associated with these interstitial minerals. Near each wall, but separated from it by fine-grained plagioclase-quartz pegmatite, is a thin but persistent zone of muscovite-rich pegmatite. The muscovite is associated with quartz, lithiophilite-triphylite minerals, and albite. This zone is 1 to 2 ft thick and extends more than 100 ft along both sides of the main pit. At the north end of the pit this zone arches over, beneath schist, from the hanging wall to the footwall. The mica is mostly of scrap grade, but contains appreciable quantities of moderately to strongly air-stained sheet mica. About 270 lb of sheet mica was sold in 1943, though no special attempt was made to mine mica.

The beryl of the pegmatite is in the inner intermediate zone next to the core of perthite pegmatite. It is white to greenish-yellow and for the most part is free of inclusions of other minerals. The individual crystals seen in 1942 ranged from 10 to 14 in. in diameter. Crystals as much as 2 ft in diameter were exposed in July 1945 in the northern pit.

The White Cap pegmatite contains large reserves of feldspar and appreciable reserves of beryl and sheet mica that could be mined under favorable economic conditions.

WHITE DOG MICA MINE (CUSTER DISTRICT)

by J. J. Norton

The White Dog mica mine, a small producer of high quality sheet mica in 1943–44, is about 1 mile southeast of Custer. It is in the SE¼ sec. 27, T. 3 S., R. 4 E., Custer County.

The mine is owned by Ralph D. Turner, Laurence Naimen, and Patrick Dudley, but the operations were under the active direction of Turner, who is the principal owner. Turner worked the property intermittently from April until July 1943 by open-pit methods then began underground operations.

The surface and underground workings of the White Dog mine were mapped and cross-sections drawn (fig. 37), on a scale of 1 in. to 20 ft in December 1943, by J. J. Norton and Peter Joralemon.

MINE WORKINGS

The mine workings on the White Dog pegmatite at the time of examination consisted of an open-pit, an inclined shaft, and drifts on the 33-ft level. Before Turner's work there was an open-pit 77 ft long and about 9 ft in average depth. Early in his work Turner enlarged the part of the pit near the south end of the pegmatite about 8 ft vertically for a distance of 30 ft. A shaft, inclined at an angle of 49°, was sunk along the pegmatite to a vertical depth of 50 ft. At a depth of 33 ft vertically below the collar of the shaft drifts were driven 36 ft to the south end of the pegmatite and 18 ft to the north end. A raise from the south

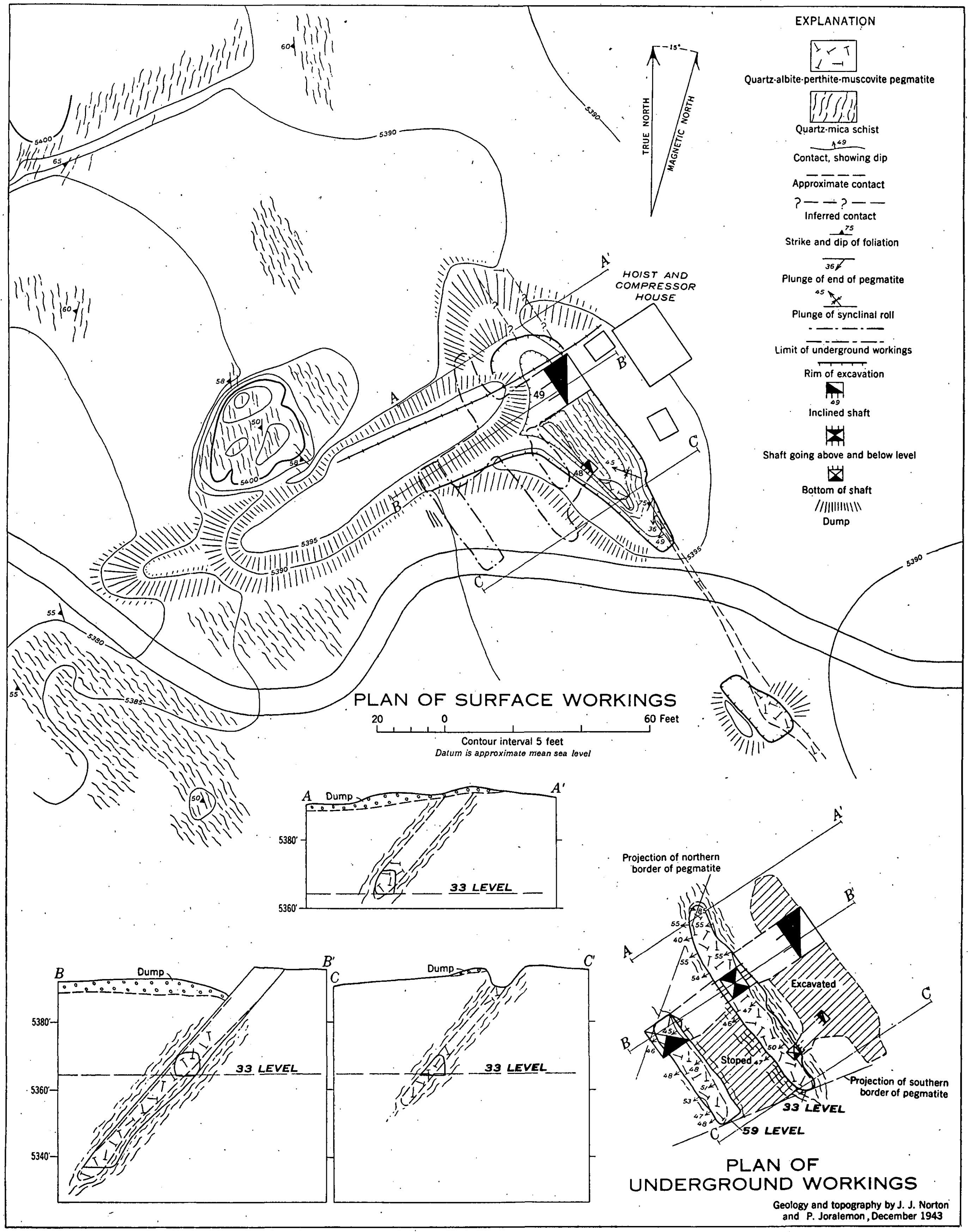

FIGURE 37.—Geologic maps and sections of the White Dog mica mine, Custer County, South Dakota.

drift connected with the open-pit. Subsequent to the mapping the shaft was extended to a vertical depth of 59 ft, and a drift was driven 36 ft to the southeast end of the dike. The rock was stoped above this drift to the 33-ft level.

GEOLOGY

The White Dog property has two small pegmatites intruding quartz-mica schist. The pegmatites essentially conform with the foliation of the immediately adjacent schist, but not with the foliation of the schist some distance away. A few quartz veins, as much as a foot thick, are the only other variety of rock exposed in the area.

Both pegmatites strike N. 33° W. and dip about 49° SW., parallel to the foliation of the adjacent country rock. The directions and amounts of plunge of the ends of the main pegmatite are fairly accurately known. The south end is exposed in the open-pit and in the drift, and a line that connects these two points plunge 48° to the S. 63° W. The north end of the pegmatite plunges 40° to the S. 20° W., where it is exposed in the drift. This line projected comes to the surface just north of the northernmost outcrop of pegmatite.

The north end of the southern pegmatite is exposed in the main open-pit, where it plunges 36° S. 7° W. The south end of this pegmatite is not exposed.

Both of the pegmatites are narrow intrusions composed essentially of quartz and albite with scattered crystals of perthite and appreciable muscovite. Muscovite tends to occur in greatest abundance near the walls. The minimum indices of cleavage fragments of the albite (An_4) are about 1.528. Accessory minerals include beryl, tourmaline, and apatite.

The main pegmatite which is being mined is exposed at the surface for a distance of 83 ft, with an average strike of N. 33° W. and a dip of 49° SW. The pegmatite appears to shorten with depth, the two ends plunging toward each other, because on the 33-ft level the entire length is only 65 ft. The average thickness of the dike is 4 ft, but locally, as in the shaft and in the north drift on the 33-ft level, it is as much as 6 ft or more.

Seven feet east of the south end of the main pegmatite the north end of the second pegmatite is exposed. Intermittent exposures continue for 90 feet S. 33° E. This pegmatite dips about 50° SW., and the northern end plunges 36 degrees S. 7° W. The northern 40 ft of the pegmatite is scarcely 1 ft thick, but the pegmatite thickens to about 4 ft in the prospect pit near the south end of the exposures.

MICA DEPOSIT

Sheet mica is the only commercially important mineral in the White Dog pegmatite. The deposit furnished good quality mica, white to light ruby, only lightly air-stained, and comparatively free of black tourmaline inclusions. As much as 50 percent of some shipments were of no. 1 and no. 2 qualities and the rest was of no. 2 inferior quality.

The rock mined to December 1943 contained an average of 1.1 percent crude mica, and approximately 5.0 percent of the crude mica has been recovered as sheet. Very little mica was recovered in the last 8 ft of the north drift, and this comparatively barren zone extended all along the north end of the pegmatite.

In 1943 this mine produced 533.74 lb of large and small sheet mica and in 1944 it produced 62 lb. Most of this mica was from the main pegmatite, which is mined out above the lowest level, but a small amount was recovered from the smaller pegmatite to the south.

WHITE SPAR MICA MINE (CUSTER DISTRICT)

The White Spar mine, formerly known as the No. 2 mine of the Westinghouse Electric and Manufacturing Company, was reopened in March 1943 and continued in operation until January 1, 1945. The mine is in the NE¼ sec. 34, T. 3 S., R. 4 E., 2.5 miles from Custer, Custer County.

The White Spar mine was acquired by the New York Holding Company of Custer, South Dakota, from the Westinghouse Electric and Manufacturing Company and was leased to L. H. Jeffries, Custer, South Dakota in September 1942. In November 1942, L. H. Jeffries and J. A. Knabe, under the name of the J. K. Mining Company, started rehabilitating the mine. The mine entered production March 15, 1943. Later that year Knabe purchased the mine and operated it until January 1, 1945.

The mine, one of the largest mica mines in the Black Hills, produced at least 21,172 lb of sheet and 9,770 lb of untrimmed punch mica in 1943–44. Data regarding mica production during operations by the Westinghouse Company, 1904–1911, and by P. Stratton in 1940 are not available. According to reports, Stratton also produced some beryl and feldspar from the surface workings.

The White Spar mine was described by Sterrett (1923, pp. 295–297) who visited the property in August 1908. W. E. Hall visited the property October 8, 1942 and the results of his work are incorporated in this report. L. R. Page and other members of the U. S. Geological Survey studied this property intermittently from May 15, 1943 to January 1945. The surface map (pl. 45) was made by Page and J. J. Norton in June 1943, using plane table and telescopic alidade and drawn on a scale of 1 in. to 20 ft. The tape and compass maps of the underground workings and sections (pl. 45) were made by Page. The first underground maps, which show the workings as of June 25, 1943, were revised in 1945. Microscopic determinations of the feldspars and beryl were made by L. C. Pray in 1943.

MINE WORKINGS

The White Spar mica mine workings consist of a 170-ft vertical shaft and crosscuts that have been driven to the pegmatite on the 100- and 160-ft levels. On the 160-ft level the crosscut from the shaft was extended 60 ft beyond the pegmatite. Prior to the 1943–44 operations there were 70 ft of drift on the 160-ft level and 150 ft on the 100-ft level. A raise connected these two drifts near the ends of the crosscuts. North of this raise stopes connected the 100-ft level with the small 50-ft level. Raises and stopes connected the 100- and 50-ft levels at both ends of the dike, and on the north end a raise follows the pegmatite contact to surface. In 1943 the 120-ft and 130-ft levels were driven from the raise between the 100- and 160-ft levels. Later the 160-ft level was driven north to the end of the pegmatite and all rock north of the raise was stoped out to the 100-ft level. Raises were driven above the south drift on the 160-ft level and all rock above the 145-ft level was stoped except about 15 ft at the south end of the pegmatite. Later the footwall mica zone was worked above the 100-ft level to the surface. A winze sunk 50 ft below the 160-ft level revealed no commercial mica.

The dike southwest of the White Spar pegmatite was prospected by a 20-ft shaft and a crosscut from the 100-ft level of the mine. The White Spar property was also prospected by diamond-drill holes from the 160-ft level.

GEOLOGY

QUARTZ-MICA SCHISTS

The wallrocks of the pegmatite are fine- to medium-grained dark gray to black quartz-mica schists of pre-Cambrian age. They have been folded into both isoclinal overturned and open folds. Foliation seems to parallel the bedding even on the crests of the folds. At the contact of the pegmatite the folds in the schist are concordant with the rolls in the dike and plunge 50° to the S. 0–10° E. Below and at both ends of the dike the folds in the schist plunge 50°–55° to the S. 20° E.

PEGMATITE

The White Spar mine is in an irregularly shaped pegmatite that was intruded conformably into highly folded quartz-mica schists of pre-Cambrian age. At least eight other pegmatites crop out on the property, but do not appear to contain concentrations of industrial minerals.

At the surface, the White Spar pegmatite is exposed as a pear-shaped body that extends 130 ft in a N. 30° W. direction. The outcrop is 90 ft wide at its northwesterly end and about 20 ft wide at the southeasterly end where it plunges beneath the surface. The dike maintains this shape to the 50-ft level and then narrows to a sinuous tabular body that extends below the 160-ft level. The north end of the pegmatite appears to plunge about 50 degrees to the south. The southeastern end of the dike, also exposed by a raise, plunges about 50 degrees in a S. 10°–20° E. direction. Below the 50-ft level the rolls on the contact of the dike are parallel to the foliation and bedding of the schists. These rolls plunge south. On both the 100- and 160-ft levels the dike is thickest at the northern end and thins to the southeast, but both ends terminate bluntly against schists. On the 100-ft level the dike has an average strike of N. 55° W. and dips about 50° SW. On the 160-ft level most of the dike has a similar attitude, but in part of the drift the strike changes abruptly to N. 50° E. Minor abrupt changes in strike and dip are the rule on both levels. Between these two levels the dike thins from an average of about 15 ft on the 100-ft level to an average of 8 ft on the 160-ft level, though there is a wide range in thickness at the various levels.

The pegmatite has been divided into three rock units, a wall zone of albite-quartz-muscovite pegmatite, quartz-perthite-albite pegmatite, and quartz pegmatite. The second and third units make up the core. The surface map shows only quartz-perthite-albite pegmatite because the other varieties are not exposed or are too thin to be mapped at the scale used. All three types appear on the underground maps and sections.

Albite-quartz-muscovite pegmatite.—The albite-quartz-muscovite pegmatite (pl. 45) is the sheet mica-bearing deposit and occurs in the outer 6 ft of the dike. At the contact with schist a narrow border zone has formed. It has a sharp contact with the schist but grades into the wall zone which in turn grades into the quartz-albite-perthite pegmatite toward the center of the dike. The albite-quartz-muscovite pegmatite consists of fine- to coarse-grained, white to gray albite, (An_6–An_{12}, refractive indices of cleavage fragments 1.529–1.533), white to gray quartz, ruby muscovite, white, yellow, or greenish beryl (N_0=1.572–1.575), black tourmaline, apatite, and perthite. The grains average 2 or 3 in. across, but some crystals of albite and perthite are 12 in. or more in diameter; muscovite occurs in books as much as 48 in. long, 12 in. wide, and 4 in. thick; beryl occurs in crystals 6 in. across and 15 in. long; and tourmaline occurs in masses as much as 24 by 36 in. Albite generally predominates over quartz, but in some parts quartz is dominant. Microscopic determinations suggest that the plagioclase at the walls of the pegmatite is slightly more calcic (An_{12}) than that at the inner edge of this zone (An_6). Locally, tourmaline makes up more than 50 percent of this rock. Muscovite probably makes up about 10 percent of this unit, but only 3 percent is recovered as mine-run mica. Perthite is a minor constituent of this zone and, where present, generally occurs as large isolated crystals.

The albite-quartz-muscovite pegmatite is poorly exposed on the surface. At the time the area was mapped one small mass cropped out under the platform between the shaft and the hoist house. This was on the footwall of the pegmatite and the zone was 3 ft thick. This part of the zone, which extended around the south end of the dike, was removed in 1944. This zone seems to be absent where the walls of the pegmatite crop out elsewhere.

On the 50-ft level the albite-quartz-muscovite pegmatite is 6 ft thick on the footwall and 3 to 6 ft thick on the hanging wall. These two deposits merge on the 100-ft level so that the entire dike is composed of this type of pegmatite, except in lenses of barren quartz pegmatite in the centers of the larger "rolls."

Quartz-perthite-albite pegmatite.—Most of the pegmatite that crops out at the surface is quartz-perthite-albite pegmatite. It consists of scattered perthite crystals, as much as 10 ft in length, in a fine-grained quartz-albite pegmatite, with associated beryl, tourmaline, muscovite, apatite, and graftonite (?). Two masses of quartz, as much as 10 ft in length, are exposed in the walls of the open-cut. Beryl crystals as much as 8 in. across and 2 ft long occur near the large quartz masses. Finer-grained beryl, in part anhedral, occurs in the finer-textured part of the rock. Muscovite is a minor constituent of this rock and occurs in flakes or books of scrap mica.

At the northern end of the dike the quartz-perthite-albite pegmatite extends to the schist walls, but at the southern end it grades into albite-quartz-muscovite pegmatite. In the raise along the northern end of the dike this gradation into the mica zone occurs at the top of the stope above the 100-ft level.

Quartz pegmatite.—Quartz pegmatite has been mapped as a distinct unit in the stope at the north end of the 100-ft level. Smaller masses occur in the face of the open-pit and in the centers of rolls on the 120- and 130-ft levels, but they are not mappable units. The quartz pegmatite consists of massive, gray to milky quartz and scattered crystals of white perthite. It grades into a fine-grained aggregate of albite and quartz.

MINERAL DEPOSITS

The White Spar pegmatite is chiefly a source of sheet mica, though scrap mica, beryl, and feldspar may be obtained as byproducts. The sheet mica is limited to the albite-quartz-muscovite zone, from which an average of 3 percent mine-run mica was recovered. In 1943 a total of 11,434.69 lb of large and small sheet, and 966.7 lb of untrimmed punch mica were produced. In 1944-45 the production was 9,737 lb of sheet and 103 lb of untrimmed punch mica.

MICA

Sheet mica, above the 100-ft level, occurs in the wall zone on both the footwall and hanging wall of the pegmatite. Below the 100-ft level the entire width of the dike contained sheet mica, but it could not be mined at a profit below the 145-ft level. In this mine, the abundance of tourmaline in parts of the dike does not affect the quantity of mica obtained. Both deposits have been stoped to the surface and backfilled.

The pegmatite on the 100-ft level was 150 ft long and as much as 16 ft thick; the average thickness was about 11 ft. The thickness section of the dike on this level is shown on section B-B′ (pl. 45), where the hanging-wall mica zone was 3 ft thick. The footwall mica zone was not exposed at the time of mapping. South of section B-B′ the dike thinned and in the stopes below this level the mica-bearing zone thickened to the total thickness of the dike. On the 120-ft level the thickness of the dike ranged from 6 to 12 ft over a length of 90 ft and, except for barren quartz near the centers of the rolls, mica is found from wall to wall. On the 160-ft level the dike is exposed for 70 ft south of the crosscut and ranges from 4 to 9 ft in thickness.

The mica is a flat hard ruby muscovite. The chief defect is air-staining, though some reeves, mineral stains, and silver streaks occur. During the last half of 1944 the monthly sales were from 1 to 10 percent no. 1, 15 to 26 percent no. 2, and 64 to 83 percent no. 2 inferior qualities. The sheet mica produced from March 15, 1943 to May 12, 1943 was graded as to size. In the first shipment the 1 by 1 in. and 1¼ by 1¼ in. sizes were trimmed, but the practice was discontinued. The table on page 220 shows the percentages of the various sizes.

Fairly accurate records were kept of the quantity of rock moved and the mine-run mica sold from April 24 to June 26, 1943. The total rock moved was 639 tons, including 81 tons of waste from previous operations which may have yielded 750 lb of mine-run mica. During this period a total of 19.2 tons of mine-run mica was recovered from 577 tons of rock. This tonnage was all mined between the 100- and 130-ft levels. These figures indicate that in this part of the mine the ratio of mica to waste is 1:30.6 or slightly over 3 percent mine-run mica. The mine-run mica over the period March 24 to June 18 contained 2.9 percent sheet and 22.8 percent punch mica.

BERYL

Beryl occurs both in the wall zone and in the core (quartz-perthite-albite pegmatite). In the faces exposed on the 100-, 120-, and 130-ft levels it is estimated that the ratio of beryl to rock is 1:1,500. On the lower half of the east wall of the open-pit 7 beryl crystals 1 to 8 in. across and 12 crystals less than 1 in. across were counted in an area of 500 sq ft. The ratio of areas of beryl to rock was 1:500 in this third of the pit face. Therefore, an estimate of 1:1,500 for the beryl in the whole quartz-perthite-albite pegmatite body seems conservative.

The beryl in this mine appears to be relatively free from inclusions and it has refractive indices N_0= 1.572–1.575.

Production of sheet mica (in pounds), White Spar mica mine, Custer County, South Dakota

Date	Size of sheet (inches) 1 by 1	1¼ by 1¼	1½ by 2	2 by 2	2 by 3	3 by 3	3 by 4	3 by 5	4 by 6	Total
(1943)										
Mar. 24	1. 25	16. 00	17. 00	11. 31	8. 00	2. 00	0. 74	0. 25		56. 58
Apr. 12			35. 49	36. 25	24. 31	7. 62	4. 25	3. 69		111. 89
19			30. 00	27. 25	19. 94	4. 81	2. 56	2. 25		86. 81
May 8			45. 19	44. 69	20. 50	5. 50	2. 37	1. 50	0. 12	119. 87
12			17. 62	14. 44	9. 06	2. 06	1. 12	1. 44	. 56	46. 30
Total	1. 25	16. 00	145. 30	133. 94	81. 81	21. 99	11. 29	9. 13	. 68	421. 45
Percent of total production	. 30	3. 80	34. 50	31. 80	19. 40	5. 20	2. 68	2. 16	. 16	100. 00

FELDSPAR

Perthite feldspar occurs in the quartz-perthite-albite pegmatite. This deposit is about 130 ft long and 20 to 90 ft wide at the surface, but pinches out at depth. More than a third of the exposed area has been worked by an open-pit, 25 ft deep, whose floor is about 20 ft above the 50-ft level. In the faces of this pit the marketable potash feldspar is estimated to make up about 25 percent of the rock.

RESERVES

The only reserves of muscovite mica in the White Spar mine are in a small shaft pillar and one or two small pillars in the backfilled stopes. None of these is large enough to warrant reopening the mine.

WILDWOOD MICA CLAIMS (CUSTER DISTRICT)

by W. C. Stoll

The Wildwood Nos. 1 to 4 claims are adjacent to the Bellmare Nos. 1 to 4 claims, in sec. 22, T. 4 S., R. 5 E., Custer County, South Dakota. They are owned by C. M. Parker of Custer. These properties were examined in October and November 1942. In June 1943, L. R. Page and J. J. Norton investigated some of these pegmatites.

Pegmatites, probably all of dike form, crop out as ridges on the claims. The country rock is mainly quartzite. Schists are present but are less conspicuous because they are less resistant.

The pegmatites are mixtures of granite (or fine-grained pegmatite), coarse perthite, quartz, and muscovite. The minor minerals are black tourmaline and beryl. A few of the pegmatites have been developed to a slight extent.

WILDWOOD NO. 1

The exposures on the Wildwood No. 1 claim are insufficient to show the shape and attitude of the pegmatite, but the deposit appears to be 15 to 30 ft thick and to strike westerly and dip gently in a northerly direction. It forms a low, flat-topped knob about 300 ft long and 100 ft wide. Where a few small openings have been made on the north side of the knob good perthite with quartz and mica was seen. Mica has been found chiefly in the soil at the top and north edge of the knob, and also in a few holes in soil at the top and near the middle of the knob. There is apparently some localization of the mica near the hanging wall. On the south side of the knob the pegmatite is fine-grained with scattered crystals and masses of coarse perthite. The Wildwood No. 1 is probably the best mica prospect in the Wildwood and Bellmare groups.

WILDWOOD NO. 2

The Wildwood No. 2 claim lies southwest of Wildwood No. 1. It was not examined, but C. M. Parker states that a very little mica in very small masses occurs in association with feldspar and quartz in an open-cut.

WILDWOOD NO. 3

The Wildwood No. 3 claim lies northeast of Wildwood No. 4. Pegmatite crops out in places along a ridge striking southeasterly along the length of the claim. It is mainly a fine-grained pegmatite, in which perthite masses of various sizes occur. It is of no present economic value. Locally, a few mica books occur, but little is of sheet quality. Potash feldspar was seen in the discovery pit and at the northeast end of the claim, but probably the perthite constitutes a minable proportion of the pegmatite in small pockets only.

WILDWOOD NO. 4

The Wildwood No. 4 claim adjoins the Wildwood No. 1 to the northwest. Pegmatite crops out along the top of a ridge trending N. 80° E. for nearly the length of the claim. It appears to be a tabular body 10 to 20 ft or more in thickness that dips gently northeasterly, blanketing part of the northeast slope of the ridge. Quartzite underlies the pegmatite. This pegmatite, similar to that on the other Wildwood claims, is a mixture of fine-grained pegmatite and perthite.

Small concentrations of mica are scattered through the outcrop. At the top of the ridge, small prospect pits exposed a mixture of medium-grained quartz and perthite with scattered crystals of black tourmaline and books of ruby muscovite.

Almost all the muscovite books are less than 1.5 in. across, with only a few books more than 3 in. across and probably none of the mica would be large enough for trimming. The mica constitutes several percent of the pegmatite outcrop for about 30 ft. To the southwest, the rock is mainly fine-grained pegmatite, or granite, and no commercial mica was seen. To the northeast, on the slope of the ridge, two open-cuts revealed a pegmatite of perthite, black tourmaline, coarse massive quartz, and a little scrap mica. Four muscovite books, ranging up to 6 in. in diameter, and one beryl crystal were seen in these two cuts.

WONDER LODE (CUSTER DISTRICT)

The Wonder Lode, in the NE¼ sec. 27, T. 4 S., R. 4 E., Custer County, is about 1 mile west of Mayo school and about 6 miles south of Custer. The property was visited briefly in 1943 and again on September 13, 1944. Mr. Harold Duncan of Custer owned the claim and prior to 1943 operated it for feldspar from an open-pit 155 ft long, 25 ft wide, and as much as 30 ft deep. In September 1944 the property was sold to Mr. William Quinn.

The Wonder Lode pegmatite crops out as a lenticular body 480 ft long and as much as 50 ft wide. The southern end is blunt and pitches to the southeast. North of the open-cut, which starts 20 ft north of the southern end of the pegmatite, the body narrows gradually and between 130 and 160 ft north of the pit only about 5 ft of pegmatite is exposed. The northern 145 ft of the pegmatite is as much as 30 ft wide.

The pegmatite strikes about N. 20° W. and dips 60°–70° SW. Rolls on the hanging-wall contact plunge 50° to the S. 10° W. It is distinctly zoned. The wall and border zones of the pegmatite are fine-grained quartz-plagioclase-muscovite pegmatite that contains various amounts of perthite. On the hanging-wall side of the pegmatite the wall zone is as much as 4 ft thick and the very fine-grained border zone is 1 or 2 in. thick. Inside the wall zone there is a concentration of large muscovite books as much as 3 ft in thickness. The mica is strongly air-stained and contains clouds of minute mineral inclusions. A large proportion is of no. 3 quality. Inside the mica-rich part of the pegmatite the rock is largely perthite with interstitial masses of rose quartz, or an intergrowth of quartz, albite, muscovite, and beryl. The muscovite in this intergrowth is useful only as scrap mica. The beryl is in yellowish-green crystals as much as 6 in. in diameter, and though plentiful is usually in crystals or anhedral masses too small to recover by hand cobbing. It is estimated that 0.5 to 1 percent of the pegmatite is beryl, but it would have to be recovered by milling.

The property appears to have considerable reserves of potash feldspar, beryl, and mica.

WOOD TIN MINE (KEYSTONE DISTRICT)

by W. C. Stoll and L. R. Page

The Wood Tin mine is about 3¼ miles east-southeast of Keystone, on Iron Creek between Harney and Hayward, in the SE¼ sec. 14, T. 2 S., R. 6 E., Pennington County. The property is owned by the Maywood Chemical Company of Maywood, New Jersey, and is under lease to Harry A. Linde of Harney. The claim comprises 10 acres, and is patented. Linde started mining in 1938. The chief product is scrap mica, but in 1943–44 Linde mined beryl under a contract with Metals Reserve Company.

The mine was examined in November 1942 by W. C. Stoll, and in the fall of 1943 measurements of the beryl content were made by L. R. Page and Mr. Leo Coady of the Metals Reserve Company.

The Wood Tin mine is on the north bank of Iron Creek. The pegmatite rises steeply as a massive promontory about 140 ft above the creek level. The main part of the body strikes N. 70° W. over an outcrop length of 170 ft and is as much as 80 ft in width. At the east end the pegmatite extends 50 ft northeast as an irregular body as much as 40 ft wide.

Except for a short tunnel and raise driven by Maywood Chemical Company, and a few small cuts on the southwest flank of the promontory, mining has been concentrated at the southeast end of the main body and the projection to the northeast. This end had been excavated about 20 ft beyond the 1942 face and was cut still farther during 1943–44 beryl operations.

The pegmatite is distinctly zoned. The outer zones are mixtures of coarse perthite, massive quartz, cleavelandite, and muscovite. Beryl, in white crystals 10 to 24 in. across, is scattered through this part of the pegmatite, associated with albite, muscovite, and quartz. The beryl has been so corroded and veined by cleavelandite that few crystals are euhedral. Therefore, the hand-cobbed beryl ore is of low grade, although the beryl itself is much purer. Page and Coady measured the beryl exposed in the bottom of the cut at the east end of the pegmatite. In an area of 500 sq ft 26 crystals, with a total area of 7.86 sq ft, made up 1.57 percent of the face. In mining this part of the pegmatite, 4,400 tons of rock was moved and 40.2 tons of beryl recovered. Analyses of beryl revealed 8 to 10 percent BeO.

The mica in the main pegmatite occurs as large plumes and nests, and it is estimated that 3 to 5 percent of the rock moved would be recovered as scrap mica. The pegmatite offshoot from the main body at the east end is very rich in scrap mica, beryl, and cleavelandite.

The core of quartz-spodumene pegmatite is exposed at the top of the promontory, and is more than 40 ft thick. This core is surrounded by the beryl- and sheet mica-bearing pegmatite previously described. Spodumene probably forms less than 5 percent of the core.

According to Mr. Linde, the production prior to November 1, 1942, was 544.79 tons of scrap mica, 230.66 tons of soda feldspar, 36.5 tons of beryl, and 70.66 tons of potash feldspar. In 1899–1901 about two carloads of spodumene are said to have been produced from this property. The beryl production from January to November 1943, was 17.53 tons. Subsequently, under contract to Metals Reserve Company 40.2 tons was produced between November 1943 and August 1944. From August 1944 to January 1, 1945 an additional 7.42 tons was produced.

The reserves of scrap mica and beryl in this property are estimated to be much larger than the total of past production.

SELECTED BIBLIOGRAPHY

Balk, Robert, 1931, Inclusions and foliation of the Harney Peak granite, Black Hills, South Dakota: Jour. Geology, vol. 39, pp. 736–748.

Blake, William P., 1884, Columbite in the Black Hills of Dakota: Am. Jour. Sci., 3d ser., vol. 28, pp. 340–341.

——— 1885, Tin: U. S. Geol. Survey, Mineral Resources of the United States, calendar years 1883 and 1884, pp. 592–637.

Cameron, E. N., Larrabee, D. M., McNair, A. H., Page, J. J., Shainin, V. E., and Stewart, G. W., 1945, Structural and economic characteristics of New England mica deposits: Econ. Geology, vol. 40, pp. 372–373.

Carpenter, F. R. and Hoffman, H. O., 1888, Preliminary report of the Dakota School of Mines upon the geology, mineral resources, and mills of the Black Hills of Dakota, pp. 1–52, 107–177, Rapid City, S. Dak.

Chowdhury, R. F., 1941, Handbook of mica: Chemical Publishing Co., New York.

Clarke, F. F., 1944, Beecher Lode and Beecher Lode no. 2, Custer County, South Dakota: U. S. Bur. of Mines, War Minerals Rept., Ms. rept., Nov.

——— 1945, Southern Black Hills mica, South Dakota: U. S. Bur. Mines War Minerals, Rept. 324, p. 4; Jan. 1945.

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

Crosby, W. O., 1888, Geology of the Black Hills: Boston Soc. Nat. History Proc., vol 23, pp. 488–517.

Cummings, J. B., Basham, Lester, and Lincoln, F. C., 1936, Tin deposits in South Dakota, pp. 1–4, 15: State Planning Board, Brookings, S. Dak.; June, 1936.

Cummings, J. P., Harris, Wilbur, and Lincoln, F. C., 1937, Pegmatite mining in South Dakota: pp. 4, 20, 40–43, 53, South Dakota State Planning Board, Brookings.

Custer Chronicle, 1881, Custer, South Dakota, June 18, 1881.

Darton, N. H., 1909, Preliminary description of the geology and water resources of the northern portion of the Black Hills and adjoining regions of South Dakota and Wyoming: U. S. Geol. Survey Prof. Paper 65.

Darton, N. H., and Paige, Sidney, 1925, Central Black Hills, South Dakota: U. S. Geol. Survey Geol. Atlas, folio 219.

Dougherty, E. Y., Munson, G. A., and Cummings, A. M., 1945, Cowboy Tin mine, Pennington County, S. Dak.: U. S. Bur. of Mines War Minerals Rept. 377; April 1945.

Fisher, D. J., 1942, Preliminary report on some pegmatites of the Custer district: South Dakota Geol. Survey Rept. Inv. no. 44; July 1942.

——— 1945, Preliminary report on the mineralogy of some pegmatites near Custer: South Dakota Geol. Survey Rept. Inv. no. 50.

Gardner, E. D., 1939, Tin deposits of the Black Hills, South Dakota: U. S. Bur. Mines Inf. Circ. 7069.

Guiteras, J. R., 1940, Mining of feldspar and associated minerals in the southern Black Hills of South Dakota: U. S. Bur. Mines Inf. Circ. 7112, 104 pp.

Gwynne, C. S., 1944, Pegmatites in the Beecher Rock basin: South Dakota Geol. Survey, Rept. Inv., no. 48.

Headden, W. P., 1890, Notes on the discovery and occurrence of tin ore in the Black Hills: Colorado Sci. Soc. Proc., vol. 3, pt. 3, pp. 347–350.

Hess, F. L., 1909, Tin, tungsten, and tantalum deposits of South Dakota: U. S. Geol. Survey Bull. 380, pp. 131–163.

——— 1911, Lithium: Mineral Resources of the United States, calendar year 1909, pt. 2, pp. 649–653.

——— 1919, Tantalum: Mineral Resources of the United States for the calendar year 1918, pt. 1, pp. 807–808.

——— 1925, The natural history of the pegmatites: Eng. and Min. Jour.-Press, vol. 120, no. 8, pp. 289–298.

——— 1933, The pegmatites of the Western States *in* Ore deposits of the Western States (Lindgren volume), pp. 526–536, Am. Inst. Min. Met. Engineers.

Johannsen, Albert, 1932, A descriptive petrography of the igneous rocks: vol. 2, Chicago, Univ. Chicago Press.

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

Kemp, J. F., 1924, The pegmatites: Econ. Geology, vol. 19, pp. 697–723.

Landes, K. K., 1925, The paragenesis of the pegmatites of central Maine: Am. Mineralogist, vol. 10, pp. 353–411.

——— 1928, Sequence of mineralization in the Keystone, South Dakota, pegmatites: Am. Mineralogist, vol. 13, pp. 519–558.

Lincoln, F. C., 1934, Beryl in the Black Hills: Eng. and Min. Jour., vol. 135, pp. 202–203.

——— 1943, Spodumene production of South Dakota: U. S. Bur. Mines, Ms. rept.

——— 1944, Report on the lithium resources of the Black Hills: U. S. Bur. Mines, Ms. rept.

Lincoln, F. C., Miser, W. C., and Cummings, F. B., 1937, The mining industry of South Dakota: South Dakota School of Mines Bull. no. 17.

Munson, G. A., 1943, The Beecher property, Custer County, South Dakota: U. S. Bur. Mines, War Minerals Rept., Ms. rept., Jan. 1943.

Newton, Henry, and Jenny, W. P., 1880, Geology and resources of the Black Hills of Dakota: U. S. Geog. and Geol. Survey Rocky Mtn. Region.

O'Harra, C. C., 1902, Mineral wealth of the Black Hills: South Dakota School of Mines Bull., no. 6, pp. 75–77, 79.

Olson, J. C., 1942, Mica-bearing pegmatites of New Hampshire, a preliminary report, U. S. Geol. Survey Bull. 931, pp. 376–382.

Page, L. R., and Joralemon, Peter, 1944, Sheet mica at the Beecher Lode, Custer County, South Dakota: U. S. Geol. Survey, Ms. rept., March 12.

Runner, J. J., 1928, Intrusion mechanics of the Harney Peak batholithic granite: Geol. Soc. American Bull., vol. 39, p. 186.

Runner, J. J., 1943, Structure and origin of Black Hills pre-Cambrian granite domes: Jour. Geology, vol. 51., pp. 431–457.

Schaller, W. T., 1925, Genesis of lithium pegmatites: Am. Jour. Sci., 5th ser., vol. 10, pp. 269–279.

——— 1927, Mineral replacements in pegmatites: Am. Mineralogist, vol. 12, pp. 59–63.

——— 1933, Pegmatites: Ore deposits of the western states, A. I. M. E. Lindgren volume, pp. 144–145.

Schwartz, G. M., 1925, Geology of the Etta spodumene mine: Econ. Geol., vol. 20, pp. 646–659.

——— 1930, Tin Mountain spodumene mine: Econ. Geology, vol. 25, pp. 275–284.

Schwartz, G. M., and Leonard, R. J., 1926, Alteration of spodumene in the Etta mine, Black Hills, South Dakota: Am. Jour. Sci., 5th ser., vol. 11, pp. 257–264.

Sharpe, J. W., 1942, The Old Mike and its products: Black Hills Engineer: South Dakota School of Mines, pp. 207–210.

Smith, W. C., 1942, Spodumene in the Beecher pegmatite dike, near Custer, South Dakota: U. S. Geol. Survey, Ms. rept., May, 1942.

Smith, W. C., and Page, L. R., 1941, Tin-bearing pegmatites of the Tinton district, Lawrence County, South Dakota: a preliminary report. U. S. Geol. Survey Bull. 922–T.

Sterrett, D. B., 1908, Mica deposits of South Dakota: U. S. Geol. Survey Bull. 380.

——— 1923, Mica deposits of the United States: U. S. Geol. Survey Bull. 740.

Taylor, G. L., 1935, Pre-Cambrian granites of the Black Hills: Am. Jour. Sci., 5th ser., vol. 29, pp. 278–291.

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

Wierum, H. F., and others, 1938, The mica industry: U. S. Tariff Comm., Rept. 130, 2d. ser., pp. 11–26.

Winchell, A. N., 1933, Elements of optical mineralogy, pt. 2: John Wiley and Sons, New York.

Ziegler, Victor, 1914, Mineral resources of the Harney Peak pegmatites: Min. and Sci. Press, vol. 108, pp. 604–608; 654–656.

Anonymous, 1945, Regional News: Eng. and Min. Jour., vol. 146, no. 2, p. 163.

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