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George T. Mickelson, Governor

STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS
No. 44

Preliminary Report

on some

PEGMATITES OF THE CUSTER DISTRICT

By

D. Jerome Fisher

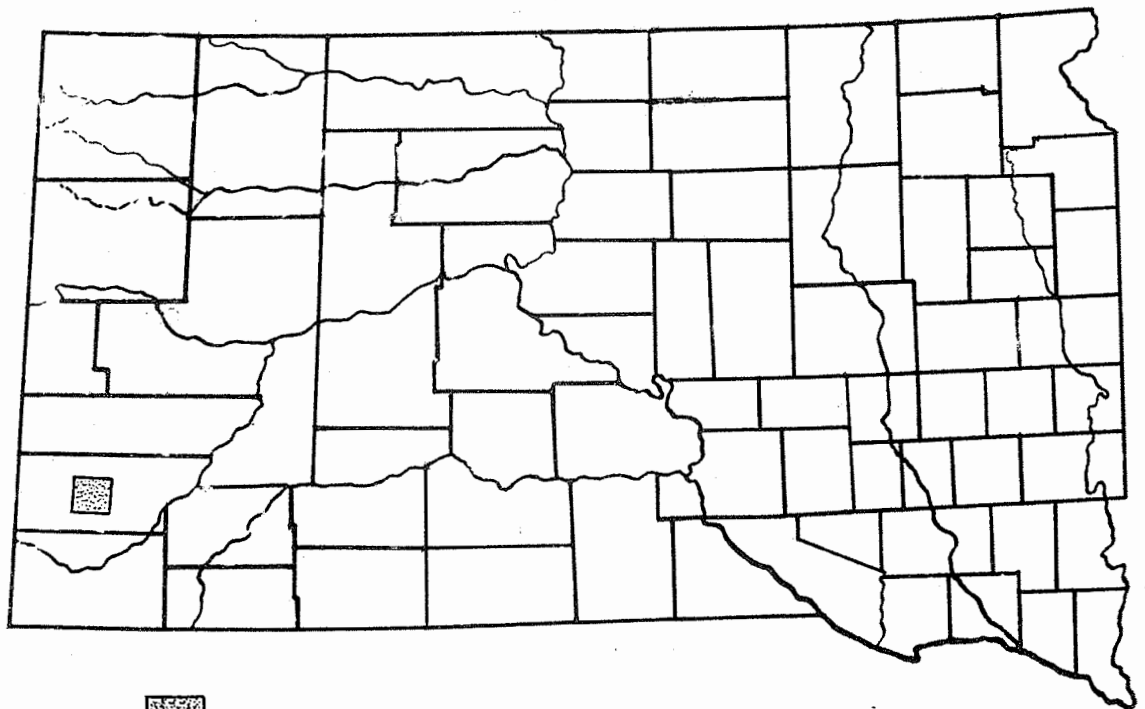University of South Dakota
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PRELIMINARY REPORT

ON SOME

PEGMATITES OF THE CUSTER DISTRICT

by

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PEGMATITES OF THE CUSTER DISTRICT

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INTRODUCTION

Purpose and Scope

The Black Hills are in the southwest corner of South Dakota, in Custer, Pennington, Lawrence, and the southwest corner of Meade Counties. They have a relief of about 4000 feet, extending up to 7244 feet. The latter elevation marks the top of Harney Peak, the highest point east of the Rocky Mountains. Harney Peak is 2 miles northeast of Sylvan Lake, shown at the north edge of Fig. 1.

Important pegmatites are known in the southern part of the Hills; also near Tinton in the northwestern portion. The latter (about 45 miles north-northwest of Harney Peak) have been described by Hess and Bryan* and also by Smith and Page.* The former are found in two main districts centered about Keystone (6 miles east-northeast of Harney Peak) and Custer (**8 miles** south-southwest of Harney Peak) . In the Keystone District some of the pegmatites have long attracted much attention; the Etta Mine in particular is famous in the geological literature. This and other mines of the district have been described by Hess, Schwartz, Landes, Connolly, Lincoln, and Apsouri, among others.

Descriptions of the geology of the pegmatites of the Custer District have never been published, except as incidental remarks in more general reports (e.g., as in Folio 219, or in Connolly and O'Harra), though there are brief treatments of the Tin Mt. Mine (Fig. 1, No. 8) by Schwartz and by Hess and Fahey. Very scanty geological remarks are given by Lincoln et al and by Guiteras, whose report was

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* See bibliography at end.

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of much help to the present writer. One hundred and fifty-four mines or prospects are here listed for the Custer District.

The present preliminary report is in the main concerned with the geology of three pegmatites near Custer. After short, hasty examinations of the pegmatites indicated on Fig. 1, these three were chosen as types taken to represent limits in the variations found in the pegmatites of the district, insofar as only three deposits can represent types for a kind of natural phenomenon subject to almost infinite variation. It is expected that further work in the near future in both the field and laboratory will cause modifications of some of the tentative conclusions here presented.

Field and Laboratory Work; Acknowledgements

The writer lived in Custer from August 1 to September 12, 1941. Mr. Roy E. Leigh faithfully assisted in the field work during this interval; later he also drafted the illus-trations accompanying this pamphlet from copy furnished by the writer. Moreover, he supplied some of the field photo-graphs. The laboratory work involving microscopic study of numerous specimens including 25 thin-sections was prosecuted evenings and rainy days while in the field and in available hours since then when teaching and other duties at the Uni-versity of Chicago would permit. Unfortunately time for a thorough laboratory study has not been available prior to the date when this preliminary report must appear.

The writer is under obligation to the State Geologist, Dr. E. P. Rothrock of Vermillion, who first suggested the problem and who cooperated in every way in pushing it along. Residents of Custer were very helpful. In particular, mention should be made of Mr. Harold R. Eyrich, Mr. W. A. Nevin, Mr. R. L. Gould, Mrs. John Wells, Mr. Scovel Johnson, and Mr. Mont Heumphreus. Mr Lewis Collingwood of Pringle and Mr. George Bland of Hill City also furnished valuable information.

GEOLOGIC SETTING

Outline of Black Hills Geology

The Black Hills represent an earth bulge or blister in the Northern Great Plains which has broken, leaving the normally-underlying material exposed in the central part. This portion is elliptical in shape, extending north-south 60 miles and east-west 25 miles. Fringing this central core is a great series of later (Cambrian and younger) sediments, dipping away from it in all directions, which have accumulated during the last half billion years. See Fig. 7A. These would slightly resemble a giant shingled-roof of elongate-domical shape if the central portion were left open and around this the shingles were placed in oval belts with the thick ends towards the top of the dome. Of course this is the opposite from the proper way to lay shingles on a roof.

This report is concerned only with those rocks of the central core which were formed in pre-Cambrian times; that is, before any "shingles" were laid down on our imaginary roof. Compare Fig. 7A. According to Folio 219 these rocks are mainly metamorphosed sediments consisting of a kernel of coarser material (grit, graywacke, quartzite) surrounded by a heavy shell of finer material (slate and mica schist), except to the southeast where there is a large area of quartzite schist. These rocks were metamorphosed by mountain building action probably more than a billion years ago. Presumably important mountains were formed at this time, but by the ceaseless action of wind and water they were worn down to a plain more than a half billion years ago.

Intruded into these old sediments near the end of the mountain-building epoch were minor amounts of basic (dark colored) igneous rock, diorite-gabbro. In part these suffered squeezing and so were changed into amphibolites, metamorphic rocks dominantly of hornblende or some other amphibole. These vary from fine-grained foliated rocks with quartz to massive faintly-banded crystallines carrying plagioclase.

Somewhat later, but yet well before Cambrian time, very large masses of granitic material were intruded into this older complex. How extensive these were is unknown, as erosion has gone far enough to expose them only

in the southern part of the Hills, near Harney Peak and to the south, except for a minor patch 15 miles southeast of Deadwood* along Little Elk Creek.

The main body of the Harney Peak granite appears on the map of Folio 219 as a roughly circular mass nearly 10 miles in diameter whose center lies near the northeast corner of Fig. 1. It consists of a variable-textured rock, mostly coarse or even pegmatitic, locally rich in inclusions of schist and other rocks, which according to Balk strike at random in the central part, though Runner finds them essentially parallel within restricted areas, and so concludes that they reveal gentle folds. This portion may be regarded as something close to a cupola or giant bubble at the top of the batholith, intricately intruded by pegmatites. The surface of the batholith dips off steeply to the north and northwest, judging by the relative rarity of pegmatites in this area. In other directions, however, and especially to the south and southeast, pegmatites are so thick in the pre-Cambrian core that one tends to feel he is never far above the roof of the batholith. The assumption is that the pegmatites are related to the attitude and altitude of the roof of the batholith about like a series of oil pools might be related to a major structural feature.

Fig. 7B, taken from an aerial photograph by the Department of Agriculture, shows how thickly these pegmatite dikes are concentrated in certain areas. This view covers a district about one mile square immediately west of Mayo (south center of Fig. 1), which appears near the left (east) side of the picture. The numerous dikes here stand up as sloping walls striking N. 25° W. and dipping about 65° to the west. The white line through the lower left portion is the concrete strip of U.S. 85A. The side road leads westerly from this across the railroad in a valley at Mayo and then winds upwards between these pegmatite walls, which appear as a series of short parallel offset white lines. The relatively soft mica schist which controlled the attitude of the pegmatites has eroded away much faster than the latter. Fig. 7C is an ordinary photograph taken of one of these dikes, looking in a general northwesterly direction.

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*Dodge (p. 566) mentions a small outcrop of Harney Peak pegmatite northeast of City Creek (near Deadwood). The pegmatites near Tinton are noted above.

Pegmatites

The pegmatites of the Custer area are coarse to very coarse-grained, unevenly segregated plutonic igneous rocks of modified granitic composition. See Fig. 8A showing black tourmaline two feet long in the Smith Mine (No. 22, Fig. 1). Many of the smaller ones are tabular-shaped bodies, but the larger ones are more commonly bulging, so as to resemble an irregular biconvex lens. With one exception (Fig. 1, No. 4) all those examined have been intruded into foliated metamorphic rocks. They have been pushed in like the water in a blister, causing the schist layers to spread apart. The schist bends out and around the pegmatite, and only very rarely is a cross-cutting relationship observed, such as at the small dike near the northwest end of the Tip Top Lode claim. In the third dimension (along the dip of the schistosity) all but the smaller pegmatites also tend to be shaped like a biconvex lens. There is definite field evidence that these bodies are not shaped like a pane of glass, thus extending down to some mass of parent igneous rock with only minor changes in thickness. Rather they seem to be more or less isolated masses suspended at bulges in the schist. They are thus not dikes in the ordinary elementary textbook sense of the word. In places they are so thick that apparently disconnected bodies may be part of one single mass which has extremely pronounced pinch and swell structure; these may represent truly disconnected bodies (pinched to zero thickness) or they may be connected below the present surface, or they may have been connected above the present surface.

There is no doubt that they came into rocks which were already schists. They show very sharp-wall contacts with the schist, and in general the wall rock is relatively unaffected, even though blocks of it may be engulfed in the pegmatite as shown in Fig. 8B (Smith Mine, No. 22, Fig. 1). Exomorphic changes are limited to a narrow range, and consist mainly in the development of tourmaline and mica (both muscovite and biotite: compare the article by Schwartz and Leonard). An extreme case appears to be represented by the Crown Mine (No. 5 on Fig. 1), where so much muscovite has been developed locally in the schist above the pegmatite that the contact cannot be located exactly. At the north end of the Beecher Lode the schist is locally impregnated with tiny lilac spodumene crystals. The most obvious endomorphic changes are those which result in the concentration of certain minerals as muscovite or tourmaline in the pegmatite near its contact walls. Fig. 8C shows

black tourmalines two or three inches long growing into the Gray Rocks pegmatite (No. 9, Fig. 1) normal to its contact wall; Fig. 8D shows the surface of this pegmatite wall, with the cross-sections of the tourmaline prisms as dark splotches.

The pinch and swell structure is good evidence that fairly high pressures prevailed. It is thus clear that the pegmatites were formed at some considerable depth, well below the surface then in existence. Their dense spacing over such a wide area indicates a fairly large parent source below this district. They did not form by the simple intrusion of dikes or blobs of molten lava-like material, called magma when thus deeply buried. A better concept is that this hot buried magma mass would have been like a boiling cauldron of slag, except for the high pressures which prevailed. Under these conditions certain lighter parts of the magma were pushed into the present pegmatite zone, shoving the schist layers apart, and yielding the bulk of the original pegmatite material consisting of potash feldspar, mainly microcline (locally called "spar"), in considerable part perthitic (with tiny lenses of albite or soda-spar), along with quartz, muscovite, and tourmaline.

Later, as an increasing amount of the magma crystallized at depth, residual relatively fluid portions were forced out and upward, in the main following the paths of the original larger pegmatitic injections. These solutions were relatively rich in water. In part they dissolved out some of the earlier-formed material, replacing it with beryl, muscovite, cleavelandite (tabular soda spar), spodumene, and amblygonite.

As millennia rolled by, these solutions became more tenuous and less hot, and the tendency was to get replacement veins cutting through the pegmatite roughly up-dip and containing apatite, lithiophilite (altered to purpurite), and loellingite in close association with cleavelandite.

The pegmatites of the area may thus consist of material formed at several stages, which in order of time may be distinguished as the pyrogenic (or igneous), intermediate, and hydrothermal. It should be emphasized that this classification is one of convenience for ease in explanation and interpretation. No two pegmatites studied were similar in
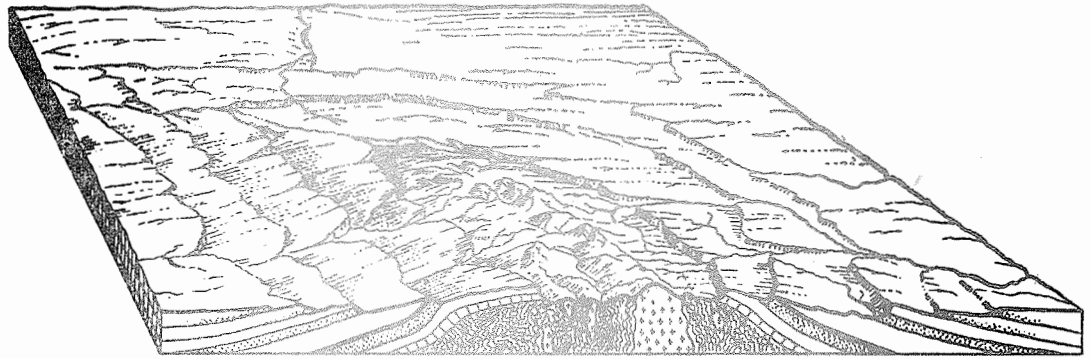
7A. East-west cross-section of the Black Hills. (From
The U. S. Geol. Survey and P. G. Worcester: Geomor-
phology, 1939. D. van Nostrand Co.)

7B. Vertical Aerial view of pegmatites near
Mayo, S. D. (U. S. Dept. of Agriculture)

7C. Pegmatite wall near Mayo

all respects. In some the first stage is greatly dominant or even the only one recognized; in others the intermediate stage has been of very great importance. It is also true that many more stages may be recognized. For any one pegmatite containing 20 or 30 minerals it may be possible to determine a sequence of crystallization that may involve at least a dozen stages (compare Smith and Page). It should also be emphasized that a given mineral may not be limited to any single stage; it may continue through several stages (e.g., quartz), or may occur in more than one stage with intermediate stages in which it did not form.

The object of this generalized explanation is to make clear, however, that in general certain minerals do form in certain stages in the main. All pegmatites do not show important developments of all stages, but there is almost infinite variation. Thus it is essential for the prospector to be able to recognize the various stages in terms of their types of deposits. Thus if one wants spar, he can best avoid those pegmatites in which the later stages were important. The reverse is true if soda spar or beryl is desired.

The remainder of the paper is devoted in the main to a description of three pegmatites studied in detail. As before stated these were chosen not because of any intrinsic importance, but primarily because they seemed to represent types which may be taken as typical of the gamut of these deposits in the Custer area. It is hoped that careful study of this part of the manuscript may aid the prospector or geologist in deciphering the history of any pegmatite of the district he may examine, and thus lead to the most economical exploitation of the pegmatite mineral resources of the area in terms of any available minerals that may be needed.

TIP TOP LODE

Location

This quarry lies five miles southwest of Custer; in the NE. 1/4, SW. 1/4, Sec. 8, T. 4 S., R. 4 E. See Fig. 1, No. 11. Take U. S. 16 southwest 4.65 miles from Custer; turn left at the Fourmile Road Y and go south 0.35 miles to the Y at the schoolhouse. Turn left (southeast) here into the C. E. Rockwell homestead going 0.95 miles from the schoolhouse (to the top of the hill yond the Rockwell house) to the Y, where turn right (south). It is 0.30 miles to the Lincoln Lode, and the Tip Top loader is 0.41 miles beyond the Lincoln.

The Tip Top pegmatite causes a ridge-like hill extending a little west of north which rises nearly 150 feet above the creek to the south. The elevations on the map (Fig. 2) were taken from the altitude of the 1/4-corner along the north side of Sec. 8, given as 5321 on the U. S. Forest Service Map. The location shown on Fig. 2 of the NE. 1/4 NE. 1/4 SW. 1/4 Sec. 8 is based on corners found for H. E. S. (Homestead Entry Survey) No. 224.

This pegmatite is in the main one of the simpler ones observed in the Custer District. Besides spar the product included muscovite, a small amount of which is sacked for non-sheet consumption, and small stock piles of amblygonite and impure beryl. Some lithiophilite was also taken out a few years ago.

History

The lode is owned by W. A. Nevin of Custer who has leased it for the past two years to Ray L. Gould for operation as a feldspar pit. The output was formerly sold to the F. E. Schundler Feldspar Company at Custer; in August, 1941 this was changed to the Consolidated Feldspar Corporation in Keystone. The lode was originally staked by William Nevin of Custer, who worked it for mica (hoping for cassiterite) in the 1880's, opening the small pits along the northeast side and at the northwest end. For many years it lay idle, but about 1925 was restaked by W. A. Nevin, who for development work opened the small
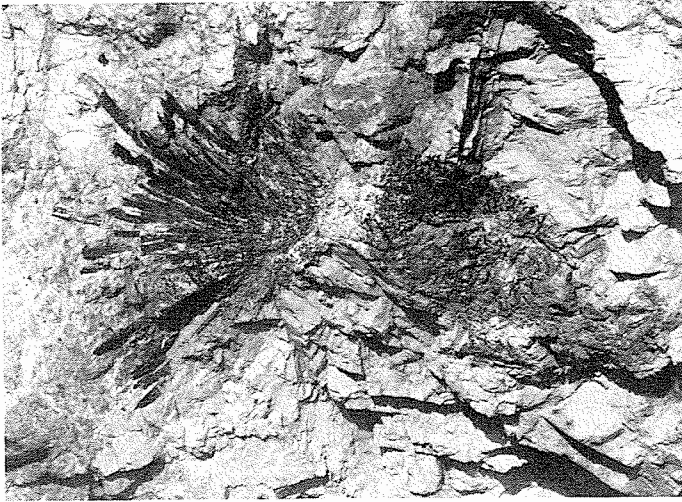
8A. Tourmaline nest
at the Smith Mine

8B. Schist inclusion
at the Smith Mine

8D. Tourmalines in
cross-section seen
looking down on the
footwall, Gray Rocks
Lode

8C. Tourmaline normal to the
footwall, Gray Rocks Lode

pit at the top of the hill, about 100 feet northwest of the present quarry. From this a load of lithiophilite was taken into Custer, but found no market. About 1934 Nevin and John Wells shipped several carloads of feldspar east (via the F. E. Schundler Feldspar Co., until 1936 at Keystone, since then at Custer); this was taken from the small pit 100 feet south of the entrance to the trench (drift) leading into the present quarry. Later the property was leased to Pierce Byers who knocked out the higher (5425 foot) level of the present opening, accumulating the big dump shown on the southeast. The present level (5404 feet) with dump to the southwest was started in September, 1940.

Geologic Setting

The pegmatite is in quartz-2 mica schist about 8 miles southwest of the nearest part of the main Harney Peak granite mass of Folio 219. The schist strikes N. 20 to 30° W. and dips 30 to 40° to the southwest. It would seem that the pegmatite never extended much higher than the present top of the hill (5446 feet). This is indicated by the fact that there are numerous schist inclusions and rolls on both sides of the present quarry at many levels; moreover, some of those along the footwall (northeast) side show near-vertical contacts between schist and pegmatite, indicating that the dike is thickening with depth. This is also shown by the fact that the hanging-wall (southwest) slope of the hill has no gulleys of importance actually incised in the pegmatite itself. This contrasts remarkably with conditions at the Lincoln Lode (Fig. 1, No. 10) $\frac{1}{4}$ mile to the north-east (Fig. 9A). Here the hanging-wall has been stripped free of all schist, and the pegmatite itself is incised by 20-foot deep gulleys running directly down dip along courses no doubt controlled by pronounced near-vertical joint surfaces.

Outcrops of the quartz-muscovite-biotite schist are found on all sides of the main hill around the pegmatite body, but in many places these are not large and probably represent blocks which have slumped a bit or else that are part of rolls or similar contorted variations from the conditions prevailing immediately prior to intrusion. The slope of the hill on the hanging-wall side below the line of outcrop (shown by contours on Fig. 2) is everywhere less steep than the probable actual dip of this wall. The schist near and especially above the pegmatite contact is highly contaminated with finely crystallized black tourmaline.

Three hundred to 500 feet southwest of the present entrance cut is a mass of amphibolite. This is a heavy, nearly-black, slightly-schistose rock composed dominantly of hornblende, with minor quartz as veinlets and isolated grains. It is stained brown on account of limonite development at the surface, but fairly fresh samples were obtained. On the northeast and southwest sides of this body, samples of a light gray quartz-rich, somewhat gneissic rock were found. This carries rather abundant light red-brown translucent garnets about 1/16" in diameter. These appear to be modified dodecahedrons. The rock also carries feldspar and hornblende in significant amounts. Elsewhere analogous material has been found as bed-like masses in the quartz-2 mica schist; e.g., in the Lincoln Lode footwall, and as float along the road up to the High Climb Pit (Fig . 1, No. 3).

The Pegmatite

This body is somewhat crescentic shaped, about 200 feet wide at the center, as seen on the map, Fig. 2. It consists of a major portion which includes the present quarry that strikes about N. 30° W., and a minor portion striking slightly east of north; where these two parts meet along the footwall there is a bulge of the pegmatite to the northeast. Or the shape of the body as a three-dimensional unit may be considered to be something like that of a curved metal rain trough such as hangs along the edge of a roof. This trough must be thought of as nearly 1000 feet across and dipping possibly about 40° to the southwest, with its edges rather thin and its central part thick. Moreover, as before pointed out, there is some evidence indicating that the trough thickens and possibly widens with depth (presumably for only a relatively short distance, however).

As is usual under the conditions here present, there tends to be an excess of mica developed for a foot or two in the pegmatite against the enclosing walls. This is thicker under the hanging wall or where a xenolith or a roll on the footwall overlaps the pegmatite (as is well shown at the back face of the small pit 200 feet west of the tool shed). Within an inch or two of the contact the muscovite tends to grow in plates normal to the contact wall; slightly farther in there is locally a concentration of book mica in sheets up to 8 inches or so across, but

this is not quite good enough for splitting purposes. Where the wall rock lies directly above the pegmatite (where rolls or similar irregularities occur; thus above the richer mica nests), the former is converted into a black granular rock for a foot or more by the addition of fine-grained tourmaline. Xenoliths of schist in the pegmatite are likely to be similarly altered. But in other places where the contact between host rock and pegmatite is about vertical, the former may show no visible signs of metamorphism (under a 10X hand lens).

Outside of these contact phenomena, it seems impracticable to attempt to zone this pegmatite. While it has pronounced sheeted structure, due to steeply dipping joints and faults (with near-horizontal slickensides) which are especially closely spaced 10 to 25 feet north of the switch within the quarry (shown on the map), this seems not to have affected the mineralization process in any important manner. As one looks around the quarry walls they seem monotonously regular in their typical pegmatite irregularity. They are composed dominantly of pale to deep flesh red microcline microperthite in single crystal masses up to at least 12 feet in length and 2 feet across. Actually crystal faces are not present with the exceptions noted below. Single crystals that are essentially pure in one part may grade slowly or rapidly into graphic granite (ribbon spar) containing a notable percentage of quartz. Such material must make up about 70% of the quarry walls. In certain places the graphic quartz is more abundant in that part of a microcline crystal nearer to a quartz-albite-muscovite vein, thus indicating that the quartz was introduced later by replacement. Another 20% or so is largely white (not real milky) to semi-translucent light gray quartz in masses and irregular veins up to two or three feet through; exceptional masses of bull quartz may be even larger. There is perhaps some tendency for this quartz to be concentrated in steeply-inclined crudely vein-like masses, but these have no constancy of strike. A final 10% consists of quartz-albite-muscovite veins and elongated roughly-vertical nests cutting the feldspar-quartz. Associated with these are sub-spherical rosettes of A-muscovite up to a foot through; locally, however, these appear in the quarry wall completely enclosed in feldspar (as seen in two dimensions). Other minerals associated with or actually in these vein-nests include amblygonite, beryl, lithiophilite and purpurite, less commonly with green apatite crystals. Tourmaline, nearly all black (schorl), is associated with all other

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minerals and cuts across all of them except possibly beryl and phosphates. Its distribution is highly irregular: because it ruins the feldspar for commercial use, it is detested by quarry-men.

With one exception the various small pits around the hill do not expose any deviation from the general conditions described above. But the pits at the northwest end of the dike (only the larger one of which is mapped) show somewhat different relationships, in that here the central 25 feet or so of the dike is massive white to rose quartz of various shades. There is a little true milky quartz, and some of the rose quartz shows bands similar to those seen at the Scott Rose Quartz Mine, 5½ miles southeast of Custer. (Fig. 1, No. 14) Also extending in from the mica-rich selvage zone a foot or two thick below the hanging-wall, there are a number of quartz-albite-muscovite veins heading off at a gentle angle into the massive quartz, and these veins have vugs lined with well-developed euhedral microcline microperthite crystals up to 3 inches through of a pale reddish-brown color. It is exceptional to find potash feldspar developing on soda-spar in this manner.

Mineralogy

Pale to rather deep flesh-colored (rarely medium gray) microcline microperthite is the dominant mineral. This is thought to have formed through an un-mixing process which occurred after the material had crystallized but before it had cooled. The rather regular position of the perthite laminae as crudely planar masses approximately parallel to (100), also their equality of distribution and size, all point towards development under uniform conditions (such as would follow after crystallization from a magmatic solution of fairly constant composition), rather than by replacement. This perthite varies from pure material in large crystals to material which carries much quartz in graphic intergrowth, as before pointed out. Locally this perthite shows crystal outlines against massive bull quartz, but this is not very common.

Quartz is the second mineral in importance. It occurs in at least two generations, both anhedral. The first generation quartz is of greatest quantitative importance: it forms the material which "cements" the large perthites and partly fills what might otherwise be open spaces between these.

This quartz and feldspar (perthite) rock, which makes up the bulk of the deposit, locally carries black tourmalines in very irregular distribution. These are always euhedral, and may represent original magmatic crystallizations, though it is essentially impossible to distinguish these from tourmalines that appear to have formed later by replacement, and all tourmalines may be of this latter type. Exception should here be made to those tourmalines formed in and near the contact walls of the host rock. The very large amount of black tourmaline in the wall rock where conditions are favorable (as already pointed out), makes it probable that in the main those tourmalines present in the pegmatite near the wall rock formed very early through endomorphic action. The pegmatite is less coarse-grained for an inch or two at the contact.

This perthite and quartz locally carry a number of other minerals. In the main these seem to have formed by replacements deposited in connection with the quartz-albite-muscovite veins, but there are one or two exceptions to this. Within the perfectly fresh perthite occurs splotches of a soft green mineral taken to represent altered spodumene. This may be in masses up to 2 x 1 x 1/2 inches, with gradational boundaries. This mineral also occurs in the quartz. It has a fibrous to platy (micaceous) to prismatic structure. Perfectly fresh muscovite is occasionally found in juxtaposition with it. Another possibly early mineral found in the perthite is fresh muscovite in small plates of irregular distribution. Like the tourmaline, however, when the host substance is the original perthite-quartz rock one cannot distinguish between possible early muscovite in small crystals and that of similar sized crystals formed later by replacement in connection with the quartz-albite-muscovite veins.

This perthite-quartz rock is cut by irregular replacement veins and vein-nests of quartz-albite-muscovite rock. The albite is white (in part gray and pinkish), and the cleavelandite variety is uncommon, though it is found in the pit 100 feet northwest of the present quarry. The quartz in these veins is not distinguishable from the early quartz except by its association. In the main it is in masses not over a half-inch through, since it is "broken up" by albite and muscovite. Some of this quartz likely represents earlier material which has in part been replaced

by albite and muscovite along vein-like masses or in nests. Masses of perthite associated with these veins as presumed solution remnants bear out this idea. It is clear that albite was deposited first, replacing quartz and perthite, and then muscovite formed, replacing all three, but it is especially prominent in the quartz. Tiny black euhedral tourmalines and green apatites, in small grains or in remnants up to a half-inch through, apparently antedating the albite, are also found in this association.

Some of the albite replacement veins carry two kinds of muscovite. The typical form occurs as small, flat-mica books up to 2 inches across. But a few veins contain large roughly-spherical rosettes of wedge-shaped or A-mica in crystals up to 4 or 5 inches long. Because of their larger size and rather noticeable association with lithiophilite, these are thought to be at least in part slightly younger than the book mica, which agrees with the conclusions of Hinrichs.

One of the albite-muscovite veins just under the hanging-wall in the west corner of the old part of the main quarry carries bladed crystals of biotite up to 3 feet long and 2 inches across. These are surrounded by a medium-gray, dull, brittle material which must be an alteration product of the biotite, since it is in cleavage continuity with it. This in turn is commonly surrounded by an aureole of muscovite in parallel position. Some of the muscovites occur as fracture fillings with cleavages parallel to the walls, and these in particular are rich in black tourmalines in every possible orientation where the c-axis of the tourmaline is parallel (001) of the muscovite. These tourmalines are generally flattened parallel the mica cleavage.

It is rather noticeable that the feldspar in these albite-muscovite veins tends to be less fresh than the main mass of the microcline perthite. Locally the microcline is quite altered for a foot or so near one of these veins. A few samples of dark green tourmaline were found in the albite-muscovite environment, but these are rare and of no gem value. No lepidolite was seen, though a few pieces of yellow scaly muscovite were noted.

The amblygonite forms as nodules of varying size up to a foot or so through, which are coarsely crystalline

(1-2" is common) as shown by the cleavages, though no crystal faces were observed. They mostly have their longer dimensions roughly horizontal and are associated with quartz veins, in which they commonly occur. They enclose blocks and pieces of microcline and quartz, as if they formed around these and were in process of digesting them. One sample shows a rim about 1/4" thick made of albite apparently replacing amblygonite. Therefore if there is but one generation of albite (no evidence to the contrary was found, though albitization was not a short process), the amblygonite antedates it.

Locally associated with the cleavelandite-muscovite nests are found beryls, though these may occur without this association also. In this mine the only pure beryls are the small ones, not over an inch or two through, and many of these and all the larger ones have central cores composed of undigested but corroded fragments of feldspar, quartz, and muscovite. The beryls at least in some cases are clearly later than the major pegmatite materials, including quartz, microcline, muscovite, and even tourmaline. Many euhedral beryls have cores containing these minerals that represent undigested fragments left there when the period of beryl mineralization ceased. One such beryl sample from the Tip Top some 3 inches in diameter has an irregularly-cylindrical quartz-muscovite-feldspar core about an inch in diameter (Fig. 9D), and another $2\frac{1}{2}$-inch crystal has at one end a core of quartz and albite with a little schorl and muscovite, whereas at the other end (4 inches away) it is pure beryl! In short these beryl crystals appear to grow from the outside in, but it must also be remembered that they grow mainly in the direction of the c-axis. This last crystal is from the Crown Mica Mine, two miles northwest of Custer (Fig. 1, No. 5). The photograph shown in Fig. 9C was taken near the footwall at the north end of this mine. To the right of the knife is shown the skeleton of a beryl crystal about 10 inches through. It is surrounded by and includes polycrystalline coarse white cleavelandite, the major feldspar at this property. A smaller beryl crystal is shown just on the left of the knife handle.

That these beryls are euhedral is obvious. But did they form early and were they partially replaced by these common pegmatite minerals? The answer is no, because: 1. The same minerals occur inside and immediately outside the beryls. If these partly replaced the beryls, they completely replaced whatever the beryls were in, a most un-

likely sequence; and 2. In nearly all cases the beryls
are shells while the common pegmatite minerals constitute
the cores. Only the muscovites and (less important) the
schorls are at all common in the shell area. It would be
unreasonable to expect that the beryl cores were more easily
replaced than the shells. The explanation is, that the
beryl had great crystallizing power. It grew, engulfing
everything in its way, though at somewhat different rates.
Like the German tank battle against the French in May, 1940,
it first surrounded and then assimilated or liquidated.

Fig. 9E is a photograph of a thin-section (polaroids
nearly crossed) through such a beryl crystal $1\frac{1}{2}$ inches in
diameter from the Tip Top. The core consists of quartz
(center and left center) and albite (right center). A
fairly large schorl on the upper left is at the inner beryl
surface; immediately below it is a larger crystal of mus-
covite, with an even larger one just to the right and a bit
higher. The line of small schorls in the upper right is
just within the beryl shell. Alfred Anderson and Frank
Hess have previously described such beryls. Fig. 9B is of
a tapering hexagonal beryl crystal 3 inches long found at
the New York Mine (Fig. 1, No. 12). It cuts across a mus-
covite crystal whose cleavage is parallel the paper. To
the left is a black tourmaline crystal 3/4 of an inc h
through; immediately above it is another beryl crystal.

Closely associated with the quartz-albite-muscovite
replacement veins, are rough nodular-shaped masses of lith-
iophilite (more or less altered to purpurite) up to half
a foot through. As this was one of the later minerals to
form, it is clear that the hydrothermal solutions active
at this time continued on the same general pathways along
which the albitizing solutions had been operative. Dark
brownish and greenish stains due to phosphates of Li, Fe,
and Mn are found in this association, which is better devel-
oped at the High Climb Mine.

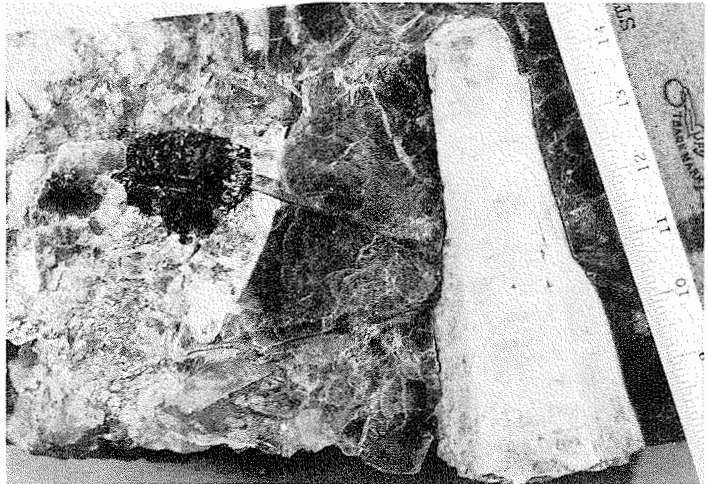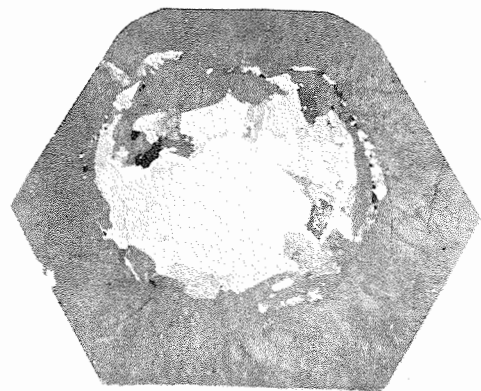9A. Lincoln Lode

9D. Beryl at the
Tip Top Lode

9B. Beryl at the
New York Mine

9C. Beryl at the Crown Mica Mine

9E. Thin section of
a Tip Top beryl

HIGH CLIMB MINE

Location

The High Climb Lode is 6 miles north of Custer; in or near the NE. 1/4 Sec. 27, T. 2 S., R. 4 E. (Fig. 1, No. 3). Take the Tenderfoot Gulch road northwest and north from Custer 5.7 miles, where turn off to the right (east) through the Robinson ranch in Sec. 27. The mine lies fairly well up on the east wall of Tenderfoot Gulch about 1/2 mile to the northeast of the farm house. The contours on **Fig. 3** are based on an assumed elevation.

History

This mine, owned by Mrs. John Wells and Fred Heidepriem of Custer, was first opened about 1932 from the southeast side; the northerly (higher) of the two main dumps on this side (**Fig. 3**) was formed first. About 1937 a new cut was made (at a level about 25 feet lower) from the northwest side, and a dump of considerable size has since been accumulated here. Seven carloads (40 to 50 tons each) of amblygonite in roughly spherical masses up to 6 or 7 tons weight were stated to have been removed between 1934 and 1938, mainly from the upper (older) portion of the mine. Two 30-ton carloads of beryl in masses up to two feet in length were also taken out. At least two carloads of highest grade scrap muscovite were produced, particularly from the footwall area. An average of one ton of spar per day was taken out between May 1 and November 1, 1939. The mine was not operated in 1940; in August, 1941 it was inactive except for spasmodic attempts to collect a pailful or so of muscovite, amblygonite, or beryl. It would seem that by extending the pit both laterally and deeper, considerable production could be maintained for some time.

Geologic Setting

This mine is at the west edge of the Harney Peak granite mass. As is true of many of the pegmatites of the Custer area, the host rock is a quartz mica schist. It strikes within 10° of N. 30° E. at most places near the pegmatite, dipping about 45 to 55° to the northwest. The slope to the

northwest does not show outcrops near the pegmatite, except
for the garnetiferous schist just off the north edge of
the map (Fig. 3). These garnets are sparsely distributed
lilac-colored grains about 1/16" in diameter. The peg-
matite has caused a terrace-like break in the normal val-
ley-wall. On the slope above (southeast of) the quarry,
are seen slightly schistose quartzites. To the north the
valley wall drops off quite steeply with no nearby expos-
ures. To the south as seen along and near the entrance
road there is a good deal of gneissic granite rich in peg-
matite lenses (one of which is large enough to have been
prospected) and schist inclusions. The mine is near the
point of intersection of three of the major rock types of
the central Black Hills as shown on the geologic map of
Folio 219.

The Pegmatite

This body has a dipper-like outline on the map. The
main mass is crudely triangular, extending some 225 feet in
a direction N. 40° E. and about 150 feet at right angles
thereto. As is true of all the pegmatites, the dip tends
to be the same as that of the enclosing schist, except
where locally some blocks of wall rock have been engulfed.
It is thus clear that the development of the schistosity
preceded the injection of the pegmatites. The "handle-like"
extension however may transect the schistosity (no expos-
ures proving this were found) since it appears to be a
dike-like mass about 30 feet wide and 175 feet long strik-
ing N. 40° W. and dipping steeply to the southwest.

The pegmatite has been opened up by the High Climb
quarry and by the three prospect pits indicated on the
map, Fig. 3. The mine cuts approximately through the center
of the pegmatite body, running normal to its strike, con-
trary to most pegmatite openings. No hanging wall schist
in place has been exposed, but a schist block is seen in
the south wall of the west (main) entrance (Fig. 4, upper
left). The footwall schist has been laid bare for a height
of about 25 feet at the rear (southeast) end of the mine.
A sharp roll here is indicative of the great stresses oper-
ative at the time of emplacement of the pegmatite. The
fact that the footwall dip is rather less than the regional
dip seems reasonable indication that the pegmatite body
thins with depth. Since the hanging wall is not exposed,
this inference cannot be proven. This footwall and a two-

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foot thick schist bank (see Fig. 4, right) separated from it by 2 or 3 feet at the east end of the pit (on the north-east side of the roll) carry a large amount of small (1/16-inch ⌀) crystals of dark green and black tourmaline. The schist exposed to the south just outside the pit also contains numerous small rosettes of biotite. There also tends to be an increase in the size and amount of muscovite in the schist quite near the contact. These minerals change and the contortions of the schist are the only signs of metamorphism present in the host rock (exomorphism). The pegmatite itself seems to have had a higher concentration of commercial mica near this footwall, which development may presumably be classed as endomorphic.

Fig. 4 is an attempt to show the structure of the pegmatite as it would appear to one standing at the top of the footwall at the back of the mine and looking N. 60° W. towards the opening to the main dump. There are five main types of rock units composing this intrusive mass. Immediately above the footwall is a soda-aplite, rich in small tourmalines (rock A of the cross sections). A second early rock-type is thought to have consisted of coarse microcline microperthite (rock B_1) and massive quartz (B_2). The time relations between these two rocks could not be determined from the field evidence. Certain areas closely associated with the quartz-perthite rock (B) consist of quartz and cleavelandite (lamellar albite), the latter only moderately coarse (mostly about 1 inch crystals), and this quartz-cleavelandite rock (rock C of Fig. 4) which constitutes the third rock type is clearly later than the perthite, since it occurs as vein-like masses cutting it. Small nests of this quartz-cleavelandite are also found in the aplite. This rock is not sharply separated from the massive quartz rock or from the cleavelandite-muscovite rock (D symbol), which is quite coarse (6 to 12-inch crystals). Finally there are the crudely vein-like phosphatized deposits (E symbol) generally stained dark, due to the presence of Mn-poor iron phosphates such as triplite and heterosite.

The soda aplite (A) appears fine-granular to felty, but under the microscope it is seen to have a coarse crudely trachytic texture of platy albite and minor quartz with a few tiny muscovites cut by prismatic very dark green to black euhedral tourmalines up to 1/8" in diameter. These cut across the albites and engulf them as well as fragments of quartz. Some of the quartz remnants appear crudely graphic or worm-like in shape. This rock also carries

small masses of coarser quartz and platy albite with gradational boundaries. In part these may represent vug fillings, but replacement probably played an important role in their genesis. The aplite also contains and grades sharply into irregular vein-like masses of the very coarse cleavelandite-muscovite rock (D). This rock combination is clearly concentrated in the lower part of the pegmatite near the footwall, though a considerable mass also appears near the center of the southwest face of the quarry (Fig. 4, left). The small mass shown in this face near the entrance (Fig. 4, upper left) seems to be a slumped block. There is a little of the very coarse cleavelandite-muscovite rock in the north face 33 feet in from the entrance not associated with the aplite.

The better microcline microperthite ("spar") deposit (rock B_1) was found in the upper part of the quarry not very near the footwall, so far as could be seen in August, 1941 when the pit was not being worked actively. This perthite is in large blocks showing crystal continuity over distances of two feet or so, but no crystal faces were observed, even where it was found in contact with massive quartz (rock B_2). It shows a relatively poor cleavage, perhaps due to its perthitic nature. The central and upper parts of the pegmatite body contain large blocks of massive, non-banded, anhedral quartz (rock B_2), many of which appear to be relatively pure.

On breaking a cleavage block from a single large crystal of microcline, the inside was found to have a tourmaline-quartz nest. Study of a thin-section of this shows microcline and perthitic albite apparently invading the anhedral cleavelandite. In 1928 Olaf Andersen published identical pictures in which penetration of the cleavelandite was mainly by the perthitic albite (rather than by the microcline, too) and concluded that vein perthites formed not by exsolution, but by solutions attacking microcline and its poikilitic cleavelandite. It also shows a single crystal of schorl with included polycrystalline quartz. There are in addition veinlets of quartz and of schorl penetrating the microcline.

In places, what otherwise looks like the massive quartz is spotted through with cleavelandite (platy "soda spar") in highly irregular fashion but in part as rosettes of radiating crystals surrounding 2 to 3"-diameter spherical masses of quartz, distributed roughly as shown in the cross-sections (Fig. 4) as rock C. These cleavelandites are mostly less than one inch long. Associated with these
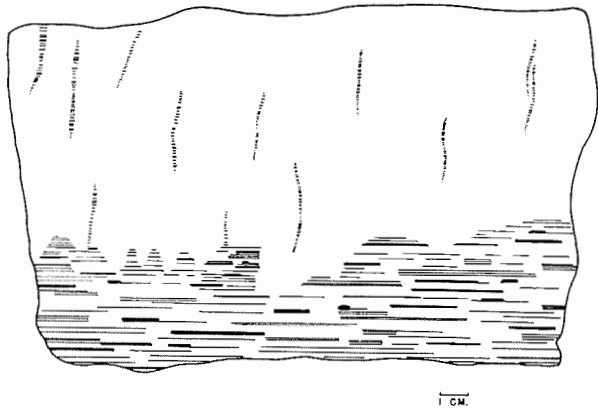
10A. Albitized perthite
at the High Climb

10D. Spod log at
the Beecher Lode
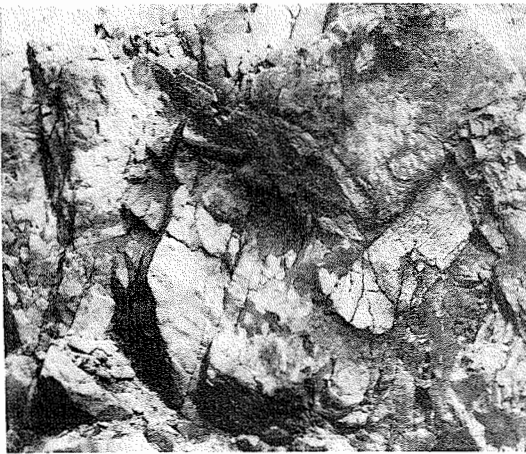
10B. Altered spod logs
at the High Climb

10C. Looking north along Middle Pit of Beecher Lode

are minor muscovites and tourmalines also in relatively
small crystals. Essentially this same sort of material
(rock C) appears to cut the perthite in vein-like masses
high up in the north wall 40 to 50 feet in from the entrance
(Fig. 4, right). Here were found cleavage blocks of per-
thite nearly a foot long, the portions of which for a thick-
ness of an inch or two along the contact with the veins
were completely albitized. This albite is clearly in the
same crystallographic orientation as that of the albite
lenses in the perthite, essentially proving its secondary
(replacement) origin. Fig. 10A shows a diagrammatic sketch
of an 8 by 5 inch hand specimen consisting of a 1-inch-thick
cleavage fragment broken from a single gigantic perthite
crystal. Field evidence is perfectly clear that albitizing
solutions coming from the quartz-cleavelandite vein locale
along the base of the figure penetrated part way into the
perthite crystal, replacing the microcline with albite
which is in optical continuity with the perthitic albite.
As is indicated, the contact between the later albite and
the microperthite is indefinite and variable, with small
islands of microcline remaining within the albitized por-
tion.

The very coarse cleavelandite-muscovite rock (D of
Fig. 4) has been described above. Besides its two major
components, it carries coarse black tourmalines and quartzes
as well as many of the rarer minerals discussed below.

The other major rock-type of importance in the cross-
section (rock E) is that found along the dark-stained vein-
like areas. These seem to be concentrated along joint
or fracture surfaces (many of which are heavily limonite
stained) and so roughly parallel the footwall. These tend
to follow the cleavelandite-quartz-muscovite zones which
are here stained dark brown and dark green due to dark
colored phosphatic alteration products (especially common
is purpurite) which also cover beryls. There are unstained
areas or nests of white cleavelandite and blue to green
apatite with the metallic minerals columbite (?) and loel-
lingite. They likely represent products formed as the
solutions changed from the intermediate type to the hydro-
thermal type.

Mineralogy

The dominant minerals as already outlined are quartz,
feldspar (both "spar," here White microcline microperthite,

and "soda spar," here white to creamy cleavelandite, with very minor amounts of ordinary albite), muscovite in all sizes up to books 5" or more across, and tourmaline (black and dark green) in crystals of all sizes up to several inches. Lepidolite is reported by Guiteras (p. 47) but yellow and gray scaly material found on the second dump resembling this mineral showed on testing to be muscovite. It is closely associated with cleavelandite and quartz and came from the upper part of the pit.

Less abundant minerals include amblygonite (probably really montebrasite), seen in crude crystals with curved faces up to 6" across at the centers of rosettes of cleavelandite, and white beryls, some of which are badly altered to a reddish material, while others were found in the dark stained zones. Neither of these minerals was observed except in small amounts. There was but about 1 cu. ft. of amblygonite in the stock pile noted. Intimately associated with the amblygonite in the quarry north wall were several large masses closely resembling spodumene logs (see Fig. 10B) about 3 feet long and 6" wide. Microscopic examination indicated these to consist mainly of sericite, a shreddy form of muscovite. This contrasts remarkably with the relatively fresh spodumene formerly so abundant in the Louise Lode (Fig. 1, No. 2) on the opposite valley wall less than a mile to the west, and at the Sky Lode (Fig. 1, No. 4) a short distance to the south.

All the other minerals, including those of the green-black phosphatized deposits enumerated above, occur only in relatively minor amounts, and they are closely associated with the cleavelandite. These include blue-green translucent beryls up to 1/4" long growing into small cavities from the surfaces of platy crystals of glassy albite bounded by many faces. These rather resemble the Amelia Court House (Va.) albite so well known, but the latter is less transparent. Both these are coated with an undetermined colorless mineral occuring in cockscomb-like forms, in turn partly limonite-stained. A specimen consisting mostly of cleavelandite found on the dump contained a fine brown tetragonal dipyramid close to strueverite or tapiolite, probably a new variety of rutile. Rose quartz, red feldspar, and ribbon spar (graphic granite) were not observed.

Several other as yet undetermined minerals are probably present in the specimens collected. Noteworthy are

the excellent silvery euhedral crystals of loellingite
($FeAs_2$), which occur in long "prismatic" forms up to 1/4
x 1" with macrodome (101) very dominant. This is unique
material from the crystallographic point of view. It is
part of the phosphate paragenesis.

Paragenetic Relations

Detailed study of this subject must wait on complete
determination of minerals and observations of textures in
thin sections and polished surfaces. The tourmalines are
nearly always euhedral, the beryls commonly so. Micas are
euhedral except when in contact with these two. Quartz
frequently shows grooves apparently caused by solution in
connection with the growth of mica plates. Tourmalines
are often fractured, and these are healed by quartz or
feldspar (cleavelandite). Euhedral perthites or quartzes
were not observed. The apatites often contain inclusions
of other minerals, as do the white beryls.

It is possible that the pegmatite started as a small
mass consisting of the felty soda aplite (rock A). A simi-
lar rock is found along the footwall of the spodumene-
rich pegmatite at the Louise Lode, across the valley less
than a mile to the west. Later the quartz-microcline micro-
perthite aggregate (rock B) may have been intruded. Rocks
A and B apparently constituted the original completed peg-
matite mass, but these were not found in contact with each
other, so their relative ages are purely matters of infer-
ence.

That most of the later components formed by replace-
ment from solutions that continued to penetrate the already
solidified pegmatite is shown by field relations and labor-
atory study. The way the cleavelandite and associated
minerals cut the perthite in vein-like fashion, and the
albitization of the perthite locally bordering these veins
both show epigenetic origin by replacing solutions. It
is thus clear that the soda-rich solutions came later than
the quartz-microperthite, and so it is assumed that cleave-
landite rocks C and D formed at this time. The D phase
presumably formed mairly in the aplite, the C phase in the
quartz-perthite.

The concentration of tourmalines and muscovite near

the footwall indicates interaction between depositing solutions and wall rock. As already outlined, the small tourmalines in the aplite seem clearly to have formed by replacement. Some of the muscovite is as sheets interfingering between plates of cleavelandite in approximately parallel position, indicating simultaneous and controlled crystallization. The cleavelandite rosettes found with amblygonite centers are so related that the former appear to have crystallized around the latter. It seems improbable that the amblygonite replaced the cleavelandite; rather it is likely that the amblygonite replaced earlier pegmatite material and still later cleavelandite replaced material surrounding the amblygonite as well as a little of the amblygonite.

BEECHER LODE

Location

This mine is $4\frac{1}{2}$ miles south-southeast of Custer in
the W. 1/2 of the NW. 1/4 of Sec. 18, T. 4 S., R. 5 E.,
Fig. 1, No. 16. Take the old Pringle Road southeast and
then south from Custer, and turn southeast (left) at the
School House "Y" (4.6 miles from Custer) along the Tanner
Road (to the Flynn Creek Picnic Grounds). Follow this
0.67 miles to the Y where the road to the Beecher Lode
takes off to the right. This is 0.10 miles beyond the
road Y leading to the Long View mine.

History

The writer is indebted to Mr. George V. Bland of Hill
City for most of the data under this heading. The Lode
was named from Beecher Rocks, $1\frac{1}{2}$ miles to the south. These
are after Henry Ward Beecher; they are shown in Plate III
of Folio 219.

About 1900 a shaft some 60 feet deep was sunk at the
north end of the Beecher Lode. This was mainly for mica
obtained in 3 to 4 inch books. Production was probably
not important, as the mine is not mentioned by Sterrett.
The 20 acre claim was patented about 1906 by Bond, Bond,
and Sutherland. At some time from 1910 to 1915 the mine
was leased to Denis Henault (now of Deadwood) who is re-
ported to have subleased it to someone who removed 200 to
300 tons of amblygonite from an opening 20 feet in diam-
eter and 10 feet deep above what is now the north-central
part of the Middle Pit (Fig. 5, right). The claim was
sold about 1924 or 1925 to Collingwood and Green of Pringle,
and extensive but sporadic operations were carried on by
Lewis Collingwood. In 1934 the property was leased by
Lon Pitts and in 1935 by Bland and associates, who later
(in 1937) purchased it. Collingwood also operated in the
north part of the North Pit in late 1935 and 1936.

Most of these operations seem to have been on a semi-
shoestring basis, and openings were made here or there in
more or less haphazard fashion of following "leads" in
hopes of finding a nice deposit of amblygonite or columbite.

In all it is estimated that 1380 tons of amblygonite (1000 from North Pit, 300 from Middle Pit, and 80 from South Pit) and 33 tons of columbite were removed.* Most columbite (25 tons) came from the South Pit, particularly its south end. The rest of the mineral came mostly from both ends of the North Pit and from the northwest end of the trench at the southeast corner of the Middle Pit (See Fig. 5, right). Amblygonite was associated with lavender lepidolite, columbite especially with soda-spar. Fifty tons of beryl were removed, of which 20 tons were shipped. This beryl is low in BeO content, running only 8% according to Dr. Paul Brinton (beryl ideally has 14% BeO, though this is rare as alkalies are commonly present replacing this in amounts up to 7%).

Geologic Setting

The Beecher pegmatite lies in a north-south valley (Fig.5) containing a southward-flowing tributary of Beaver Creek. It is bounded on the east by a quartzite ridge and to the west by a ridge consisting of pegmatite, graywacke, and schist, the latter two locally containing a good deal of bull quartz and pegmatite material. The main country rock thus consists of a monoclinal series of meta-sediments dipping 55 to 65° to the west, except where this attitude is modified near intrusive contacts. The oldest of these rocks is assumed to be on the east side, the youngest to the west. The Beecher Lode is approximately on the boundary between the quartzite schist (to the east) and the mica schist, as shown on the geologic map of Folio No. 219.

The two main ridges are covered with stately pine forest, though the western ridge has been cleared to some extent, especially to the south. The subsidiary ridge made by the Beecher pegmatite in the central part of this valley is, however, mantled with a very dense secondary growth of small timber which is quite difficult to penetrate. A somewhat similar secondary growth is present in the northwest portion of the map, Fig. 5.

The rock types indicated on Fig. 5 are generalized; the map is, however, sufficient to give the broader picture

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*About 6 tons of high grade tantalite were produced from here by Collingwood and Green in 1928 according to Connolly and O'Harra, P. 256.
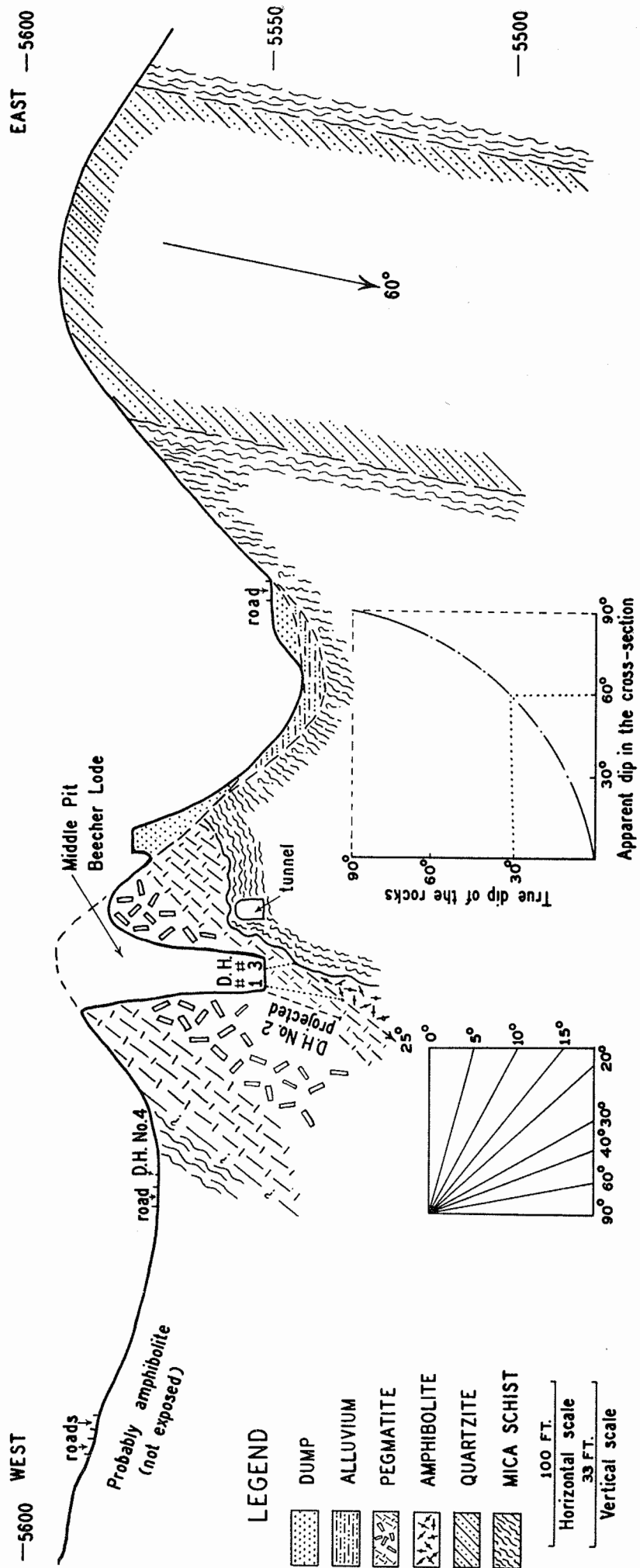
FIGURE 6.—EAST-WEST CROSS-SECTION THROUGH THE CENTER OF THE MIDDLE PIT, BEECHER LODE

of the geologic setting. The mica schist is mainly of quartz, muscovite, and biotite. It is locally heavily tourmalinized near the pegmatite contacts. There are three main bands of this type of schist; one on the east, a second in the east center, and the third on the west. Typically schist of this sort is soft, and so underlies the valleys or makes up the lower portions of the slopes leading up to the ridges which are held up by stronger rock. But the band on the west is locally rich in bull quartz and pegmatitic material, and so has been greatly strengthened. This is particularly true to the north and at the small pegmatite near the southwest corner of the Long View Claim.

The quartzite causing the ridge on the east side of the valley is very hard, brownish-flesh-colored, very fine-grained material with some quite massive layers, but locally thin-bedded and somewhat micaceous. It is a very definite and distinct easily-mappable competent unit.

The graywacke indicated in the southwest portion of Fig. 1 is best exposed in the two small pits along the trail some 150 feet north of the southwest corner of the Beecher Claim. It also appears as float along the top of the ridge for about 100 yards to the north, and may be seen in the east slope of the ridge about 400 feet west of the South Pit of the Beecher. It is an impure, silty, poorly-foliated, fine-grained rock with much quartz and feldspar and some muscovite, and has locally been greatly enriched in quartz. Its color is light greenish-gray where it is not heavily limonite-stained. At the pits mentioned it is capped by a foot or so of residual limonite (possibly formed from weathering of the amphibolite or other previously overlying rock).

The amphibolites of the district are to two types. The elongated patch shown on Fig. 5 on the east side of the Long View pegmatite is massive, only slightly foliated, in the main not greatly different from a feebly-metamorphosed diorite. The other area where amphibolite is well exposed, along the new road leading southwestward to the Black Diamond pegmatite, shows a rock with good foliation containing needle-like hornblendes with much quartz. All other local occurrences of amphibolite in the area are of this foliated type. Such occurrences include float material on the slope west of the South Pit of the Beecher pegmatite, and also in the valley at the road triangle less than 100 yards to the northwest of this pit. Such amphibolite also appears in

the road cut near the tunnel entrance to the North Pit, and
in the cores of drill holes numbers 2 and 3 (garnetized in
the former). Limonite and quartz are exposed at the small
pit in the fence line about 60 yards south of the Beecher
Claim;whether the underlying rock here is graywacke, schist,
or amphibolite was not determined. The amphibolites of the
Lead area are of three types, from fine to coarse-grained,
according to Dodge (p. 569) who concurs with most observers
in considering them to be of igneous origin. He thinks
they were intruded after the main schist-forming epoch,
but that some movement persisted after intrusion. Shortly
following this they were subjected to high-temperature
hydrothermal action, and still later low-temperature hydro-
thermal action.

Three main pegmatites, all of which are spodumene-
rich, are indicated on the map, Fig. 5. From north to south
these are designated as the Long View, Beecher, and Black
Diamond. The last, plus the small subsidiary mass at the
southwest corner of the Long View Claim were given only
very cursory attention, and the map in these areas is very
sketchy. It would take some time and much effort to make
an accurate map of the Long View pegmatite. The boundaries
shown are approximations, except along the amphibolite mass.
Moreover this pegmatite as mapped may consist of a number of
separate intrusions. An area where the rock is in general
finer grained and more like a medium granite rich in schorl
is so designated in rough fashion on the map. The spodumene
observed in the long View pegmatite mass is limited to the
central portion where the workings are indicated. The
schist to the west contains much bull quartz, and slightly
farther west just beyond the edge of the map there is more
pegmatitic material; then the land slopes down rather steep-
ly into the next valley to the west.

The Beecher Pegmatite

This consists of a lenticular mass about 200 yards
long extending north-south; it appears to have a maximum
thickness slightly in excess of 100 feet at the outcrop
(Fig. 10C). The exposures are practically limited to the
three main pits sunk in it (Fig. 5, right), together with
subsidiary "gopher holes" and tunnels, since the surface
is otherwise covered with a very thick scrubby secondary
growth. At first glance one is reminded of a baby dupli-
cate of the famous Etta Mine, because of the rusty appear-
ance and the large powdery spodumene logs, shown especially

well in the east walls of the Middle and South Pits. In general the best specimens can be collected from the numerous small dump piles, since large parts of the mine itself are covered with debris and many of the small holes are badly caved. It is very difficult to find specimens that are free from limonite stains or other alterations. The first impression might indicate that this is because of weathering that has occurred largely subsequent to the time of starting mining operations. However, the persistence of the limonite veinlets and staining films with depth clearly indicates that secondary deposition has been very important, and in the main this antedated man's activities here. One of the important problems in connection with further development, especially as regards possible utilization of the feldspar, is to determine to what depth such alteration has proceeded.

What is known as regards the shape and structure of the Beecher pegmatite in east-west cross-section is shown to scale in Fig. 6. Since the vertical scale is three times exaggerated here, dips appear to be steeper than they really are in the relation shown by the nearly circular curve of the inset graph at the middle of the figure. Thus a contact dipping 30° in the field would appear to dip 60° in the cross-section. The dips of 25° and 60° shown in the cross-section represent true dips of the contacts; if a protractor is laid on the figure it will be seen that these dips appear to be 54° and 79° respectively. The square graph just to the right of the legend shows the true dips of the rocks as they would appear to be in the cross-section.

Little is known of the actual dip of the pegmatite body. Drill holes numbers 1 and 3 shown in Fig. 5 (right) and Fig. 6 were put down in the summer of 1941 and were reported to cut the footwall at depths of 51 feet and 23 feet respectively. No. 1 struck a serpentinized amphibolite with the amount of dip of its schistosity about 20° different from the dip of the hole 65° due west; No. 3 dip 62° due east went into mica schist. The average dip of the base of the pegmatite between these two holes is thus approximately 25° to the west. The collars of these holes were at an elevation of 5551 feet. Drill hole No. 2 in the base of a stope of the North Pit with collar at 5552 feet went through 50 feet of pegmatite and 6 feet of amphibolite carrying small lilac garnets. The dip of the amphibolite schistosity was parallel to the dip of the hole 45° to N. 80° W. This hole projected orthographically on

to the plane of the section is shown in Fig. 6 by a dashed line. While the rock penetrated beyond the pegmatite was probably the footwall, it is barely possible it may have been the nanging wall. Drill hole No. 4 (Fig. 6 and left part of Fig. 5) had not been started when the writer left the field, and the results of drilling this and two later holes were not made available for publications.

Exposures in the three approximately horizontal tunnels which have been put into the pegmatite are significant in this connection. The adit (floor at 5571 feet) to the North Pit is cut through footwall mica schist dipping from 25°to 45° in a westerly direction. The tunnel (floor at 5551 feet) to the Middle Pit shows footwall mica schist with schistosity approximately horizontal; however just inside the pit (well seen near the east side of the north end) this plunges off steeply to the west. In short here the base of the east edge of the pegmatite is nearly horizontal as if it were lying down; this is indicated in Fig. 6. The small tunnel (floor at 5521 feet) near the south end of the Beecher pegmatite (left side of Fig. 5) cuts through pegmatite with many large spodumene logs 10 feet or more long and 1 inches or more through. But at the west end of this adit the floor extends into mica schist with nearly horizontal schistosity. In short here too the pegmatite floor is more or less horizontal, with rolls in the under-lying schist.

At the southwest corner of the Middle Pit there is a remnant of a tourmalinized schist block analogous to a small roof pendant. A few yards to the northwest there are fragments of schist probably not far out of place. There is a large mass of infolded schist at the northwest corner of the North Pit. This carries many tiny lilac spodumenes.

Mineralogy

Although some spodumenes or spodumene remnants are found in many pegmatites of the Custer area, at no other place observed except the Louise Lode (Fig. 1, No. 2) is spodumene so abundant as at the three pegmatites shown on Fig. 5; and the spods are really large logs only at the Beecher. The latter is also unique for the Custer area because of its peculiar milky beryls that lack crystal faces. Moreover the large reported columbite yield could not have been found at any other known Custer-district mine.

The North Pit shows in its west wall large surfaces of rusty microcline, with only a few spodumenes. These are more pronounced in the east wall, where they are of medium to large size, but less thick than in the same wall of the other two pits. Nodules of amblygonite may be seen in the stope in the west wall opposite the tunnel. This slopes down at about 45° and extends from the 5570 level of the main pit to the lower tunnel (running north from the middle pit) at about the 5552 level. A few feet north of the entrance to this stope is a Y-shaped tunnel sloping down from the 5570 level towards the west from which fair samples of cleavelandite cutting the microcline perthite were obtained. Another similar sloping entry is shown on the right side of Fig. 5 at the north end of the pit. Just south of the end of this is where the original shaft opening of the Beecher Lode is reported to have been sunk 60 feet deep; this is now completely covered by debris. A pit just north of the center of the North pit is shown on Fig. 5, right. Three yards north of the North Pit (Fig. 5, right) is a small pit about 10 feet deep; its walls are composed of quartz-cleavelandite-muscovite rock, except near its east side, where the quartz rapidly disappears and cassiterite becomes important. Hand samples with 5% of this tin mineral are easily collected here, presumably not far from the footwall.

The spods of the west wall of the Middle Pit are nearly limited to its lower third; they are much more pronounced in the east wall where they occur in a heavily limonite-stained cleavelandite-muscovite-quartz rock which is locally very rich in muscovite. There is a large mass of limonite-stained bull quartz (translucent whitish, not true milky) in the lower part of the south half of the west wall of this pit. This is cut by the striated molds made by platy euhedral spodumenes, up to 3 feet long and 6 by 2 inches in cross-section, which formerly cut through it at all angles. Such spodumenes commonly show a partial aureole of cleavelandite-muscovite-quartz rock, as is so well exhibited at the Hugo and Etta Mines near Keystone. The upper part of this wall seems to be mainly quartz-cleavelandite-muscovite rock. A sloping entry has been cut off from the north end of this pit as shown in Fig. 5 (right).

The spire between the Middle and South Pits that rises to 5587 feet is capped by about 6 feet of coarse microcline resting on massive whitish quartz; the contact between these two dips about 45° to the west. This same quartz is prominent in both walls of the trench immediately to the east;

much columbite is reported to have been removed from here.

The South Pit, like the North one, has its floor covered with debris. The walls seem to be mainly a quartz-rich cleavelandite-muscovite rock with much spodumene in the east wall (Fig. 10D), considerable less on the west. A couple of "gopher holes" (not shown on the map) extend 4 to 5 yards sloping down 30° into the east wall; they show some large spods. From a shaft sunk in this pit much spodumene is reported to have been removed.

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