GEOLOGY AND PEGMATITES OF THE FOURMILE QUADRANGLE, BLACK HILLS, SOUTH DAKOTA

By Jack A. Redden

Trace Elements Investigations Report 428

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IN REPLY REFER TO:

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WASHINGTON 25, D. C.

April 17, 1959

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Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-428, "Geology and pegmatites of the Fourmile quadrangle, Black Hills, South Dakota," by Jack A. Redden, January 1959.

This report is an abstract of a paper with the same title that is planned for publication as a Geological Survey professional paper. A copy of the entire report is in the TEPCO files.

Sincerely yours,

John H. Eric

for W. H. Bradley
Chief Geologist

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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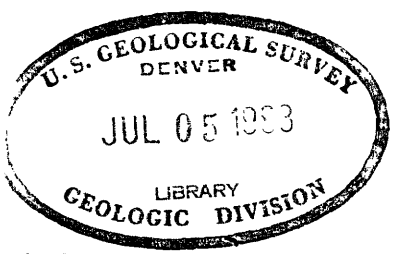

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*This report concerns work done partly on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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Geology and pegmatites of the Fourmile quadrangle, Black Hills, South Dakota

by Jack A. Redden

ABSTRACT

The Fourmile quadrangle, Custer County, S. Dak., is on the southwest side of the Black Hills uplift. About half of the quadrangle has schists and granitic pegmatite of Precambrian age; the other half has Paleozoic and Tertiary sedimentary rocks. Pegmatite mines in the area have produced potash feldspar, sheet and scrap mica, beryl, lithium minerals, and minor quantities of rarer pegmatite minerals.

Three Precambrian metamorphic rock formations were mapped, aggregating at least 15,000 feet in thickness. These are, in ascending order: 1) the Bugtown formation, consisting almost entirely of quartz-mica schists; 2) the Crow formation, a thin unit having various kinds of calcareous and ferromagnesian gneisses and schists; and 3) the Mayo formation, consisting largely of quartz-mica-feldspar schist, but also containing quartz-mica schist rich in garnet, staurolite, and sillimanite, as well as beds of lime-silicate gneiss, metagrit, and metaconglomerate. The Crow formation, although very much thinner than the other two formations, contains many different rock types; the main ones are amphibole schist, calcite-hornblende gneiss, lime-silicate gneiss, cordierite-biotite schist, microcline-biotite schist, and quartzite.

The Bugtown formation was derived largely from graywacke, subgraywacke, and impure sands. The Crow formation was probably in part originally mafic volcanic rock, but some of its units may have been derived from impure carbonate rocks and shale. The Mayo formation consisted of graywackes and silty shales prior to metamorphism. Mafic sills and dikes intruded during metamorphism have the composition of diabase but are now amphibolite.

Most of the metamorphic rocks are in the sillimanite zone but some in the northwest part of the quadrangle are in the staurolite zone. Southeast of the sillimanite isograd a progressive increase in metamorphic intensity is marked by a slight increase in grain size and a decrease in muscovite content.

The major structure of the Precambrian rocks in this part of the Black Hills is a large open syncline that plunges about 40° south. The exposed Precambrian rocks in the Fourmile quadrangle are largely on the eastern limb of this fold. The principal minor structures visible in the Precambrian rocks are an axial plane schistosity and a bedding plane schistosity. A later northeast-trending schistosity that locally has destroyed the earlier foliation appears to have had little effect on the distribution and gross structure of the rock units. It probably was formed during the emplacement of the large masses of granite and pegmatite northeast of the quadrangle.

The Precambrian rocks are overlain by Paleozoic sedimentary rocks that dip gently southwest away from the Black Hills uplift. The Paleozoic rocks are the Deadwood formation of Cambrian age, Englewood and Pahasapa limestones of Mississippian age, and Minnelusa sandstone of Pennsylvanian age. The unconformity between the Deadwood and Englewood is flat and undeformed, but the one separating the Pahasapa from the Minnelusa has numerous irregularities resulting both from erosion and post-burial solution of the upper part of the limestone. The solution may have taken place during the Tertiary uplift and erosion of the Black Hills. Sand, gravel, and volcanic ash of the Oligocene White River formation overlie both Precambrian and Paleozoic rocks. Their distribution suggests little erosion of the Precambrian rocks since Oligocene time.

About 2,300 separate pegmatite bodies are exposed in the quadrangle, chiefly in the eastern and southeastern parts. The pegmatites are classified on the basis of their dominant internal structure as layered, homogeneous, or zoned. The homogeneous pegmatites generally lack internal structure. The layered pegmatites consist of alternating plagioclase-rich and perthite-rich layers that contrast in grain size, mineral composition, or both. The zoned pegmatites consist of concentric zones of different mineralogy and texture in an unrepeated sequence.

The pegmatites consist chiefly of plagioclase, quartz, perthite, and muscovite. The most common accessory minerals are tourmaline, apatite, and garnet. Less abundant accessory minerals include biotite, beryl, lithiophilite-triphylite, amblygonite, spodumene, lepidolite, columbite-tantalite, microlite, pollucite, sphalerite, and some alteration products of the phosphate minerals.

All the pegmatite is related in age and origin to the larger masses of granite and pegmatite to the northeast around Harney Peak. Abundant evidence indicates that the pegmatites were intruded as fluid bodies. This fluid was essentially granitic in composition but was rich in boron, fluorine, and water. The composition of most of the pegmatite falls on the feldspar side of the low temperature part of the quartz-albite-orthoclase-water system, whereas the composition of zoned pegmatites probably falls in the quartz field. Temperatures inferred from various data suggest that most of the pegmatite crystallized below 600° C. and possibly in the range 500° - 600° C. The inner zones of zoned pegmatites may have crystallized as low as 300° C.

The available evidence indicates that the zones of zoned pegmatite crystallized inward from outer zones to the cores without significant addition or subtraction of material after intrusion. Layers also formed inward from the outer contact of individual bodies, but the layered structure is believed to be an effect of changes in the volatile pressures of the fluid part of the crystallizing pegmatite. Alteration of wall rock suggests that some of the volatile material escaped into the surrounding country rock where volatile pressures were presumably lower.

Homogeneous pegmatites crystallized under conditions intermediate between the closed system of the zoned pegmatites and an open system in layered pegmatites in which material periodically escaped.

Layered pegmatite bodies are mostly in areas of abundant pegmatite; homogeneous pegmatites are farther out; and zoned pegmatites are largely near the outer limit of pegmatite. The zoned pegmatites are distributed so that sheet mica mines are in areas of more abundant pegmatite, feldspar mines are farther out, and beryl-scrap mica mines and lithium mines are near the edge of the pegmatite area. The rarer pegmatite minerals are also near the outer limit of pegmatite.

This distribution pattern is believed to reflect the relation of chemical and physical forces resulting from differentiation of the source material and is analogous to the crystallization-differentiation in zoned pegmatites. The latest differentiates, which have the lowest temperatures of crystallization, move further outward and upward from their source, and a zonal pattern results. Local conditions during crystallization of individual bodies modify the generalized regional distribution.

Quartz-rich veins in the metamorphic rocks contain minerals such as feldspar, sillimanite, kyanite, and staurolite, and probably formed during the late stages of the metamorphism. Gold-bearing quartz veins follow fractures and are presumably younger than the other veins but still pre-pegmatite in age.

The value of sheet mica production is greater than that of other pegmatite minerals. Most of the sheet mica, however, came from the New York mine, and no other exposed mica deposit is of significance. The other larger mines are the Tin Mountain (feldspar, beryl, scrap mica, lithium minerals), Helen Beryl (beryl, feldspar, scrap mica), and Tip Top (feldspar). Smaller mines contain deposits of feldspar, beryl, and scrap mica.

Most of the mica and beryl is produced from outer zones, and feldspar and lithium minerals are in the inner zones of zoned pegmatites. In some parts of the quadrangle zoned pegmatites containing these minerals have distinctive structural characteristics that are useful in prospecting for new deposits.