STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Director

MISCELLANEOUS CONTRIBUTIONS NO. 11

THE CAMP CREEK CORUNDUM DEPOSIT NEAR DILLON, BEAVERHEAD COUNTY, MONTANA

By

E. Wm. Heinrich

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
1950

C O N T E N T S

I L L U S T R A T I O N S

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INTRODUCTION

GENERAL STATEMENT

The existence of the mineral corundum as the variety sapphire in the state of Montana has been known since the early 1870's, and for a long time Montana ranked among the leading producing areas of gem quality corundum. Sapphires first were noticed in gold placer operations, and probably many stones hai been discarded before their value was discovered. The first published description of the occurrence of corundum in the state was by J. L. Smith (18)* in 1873, who stated:

"These pebbles are found on the Missouri River near its source, about 61 miles above (Fort) Benton; they are obtained from bars on the river, of which there are some four or five within a few miles of each other. Considerable gold is found on these bars, it having been brought down the river and lodged there; and the bars are now being worked for gold. The corundum is scattered through the gravel (which is about five feet deep) upon the rock bed. Occasionally it is found in the gravel and upon the rock bed in the gulches from forty to fifty feet below the surface, but it is very rare in such localities."

The purpose of this report is to describe the geology of a newly discovered corundum deposit that was found by the writer during the course of field work for the Montana Bureau of Mines and Geology in the summer of 1949 in the southern part of the Ruby Mountains southeast of Dillon, Beaverhead County, Montana. At the same time it seems desirable to present a brief summary of the geological characteristics of the other types of corundum deposits in Montana in order to be able to compare the new deposit with those previously recorded, descriptions of which are scattered widely throughout the geological literature.

*Numbers in parentheses refer to the list of references at the end of this report.

FIELD AND LABORATORY WORK

Since 1946 the writer has been engaged in a systematic investigation of the mineral resources and geology of the pre-Beltian rocks of southwestern Montana (3, 4, 5, 6, 7, 8, 9). This work has been under the general direction of Dr. Francis A. Thomson, Director of the Montana Bureau of Mines and Geology, to whom the writer is greatly indebted not only for the opportunity to undertake and continue this investigation but also for continuous active encouragement and co-operation throughout its course. Grateful acknowledgement is also made to Dr. E. S. Perry, Chief Geologist of the Montana Bureau of Mines and Geology, who has given considerable assistance to the writer through field work and general discussions. Thanks are also due to Mr. James E. Bever of the Department of Mineralogy, University of Michigan, who served as the writer's field assistant during the summer of 1949, and to Mr. M. V. Denny and Mr. Alfred Levinson of the same Department, for help in photographing specimens.

The deposit, which was found early in the summer of 1949, was mapped during August, 1949, by plane table and telescopic alidade methods on a scale of 1 inch to 40 feet. During the same summer the entire southern part of the Ruby Mountains also was mapped on aerial photographs furnished in part by the United States Department of Agriculture and in part by the United States Navy. These photographs are on a scale of approximately 2.65 inches to one mile.

Laboratory work, which was completed at the Department of Mineralogy, University of Michigan, consisted of the examination of the various rock and ore samples from the deposit by means of thin section and crushed fragment methods.

GENERAL INFORMATION ON CORUNDUM

PROPERTIES

Corundum, which is a rather widely distributed mineral of considerable economic significance, is aluminum oxide. It crystallizes in the hexagonal system, and well-developed crystals are not only common but often are large, sometimes attaining a length of several inches. The habit of the crystals varies considerably; many of them are prismatic and taper slightly at both ends. These are commonly known as "barrel-shaped" crystals. Another common habit is that in which the crystals are flattened parallel with the base; such crystals appear as thin six-sided plates. The crystals are often irregular and somewhat distorted and many times show striations upon the base.

Corundum is among the hardest of known natural substances, with a hardness of 9 on the Mohs scale. Because of this property it is highly desired as an abrasive material. The specific gravity is high, ranging from 3.9 to 4.1, a fact which often permits corundum to be concentrated along with other heavy minerals in placer deposits.

Several varieties of the mineral corundum are well established: 1, Common corundum, which includes crystals and granular aggregates that are not translucent or transparent and which usually have dull gray or blue-gray colors; 2, Ruby, the transparent red variety of corundum, which, when free from fractures and other flaws, is highly desired as a gem stone; 3, Sapphire, ordinarily considered to be the transparent blue variety of corundum, but some corundum stones of gem quality that are pale yellow or colorless also are included in the designation sapphire; 4, Emery, which consists of a very fine-grained mixture of corundum with quartz, magnetite, hematite, and spinel*. This mixture is also mined as an abrasive material but its aggregate hardness is less than the hardness of corundum alone.

Corundum also is produced artifically, both as the gem stones, ruby and sapphire, and as ordinary abrasive material of non-gem quality, which is called alundum.

USES

The uses of corundum depend upon the variety of corundum employed. Three general types of uses may be defined under the categories:

1. Gems
2. Instrument bearings ("jewels")
3. Abrasives

Both in the uses for gemstones and for instrument bearings natural corundum meets strong competition from the artificial stones, which are manufactured by the Verneuil process**. Recently even star sapphires and star rubies have been duplicated artificially:

Alundum, the artificial abrasive variety of corundum, has displaced natural abrasive corundum from some of its former uses. For certain specialized applications, however, particularly in glass and metal finishing, the natural substance still is preferred. Coarse particles find employment in the manufacture of segments, sticks, and wheels in the grinding wheel industry. For the rough finishing (grinding) of glass the optical industry uses fine sizes, which process results in the production of a secondary abrasive corundum powder, referred to in the industry as "superfine flour". This minute-sized material is extensively employed in finishing optical surfaces to precision specifications. In such very fine grained powder natural corundum maintains an advantage over the synthetic product in that the former tends to retain a slightly rounded form as the grain size is reduced. This is of particular importance in the grinding and polishing of lenses and other optical surfaces where scratch-free glass parts are required.

*For the benefit of those readers who are not familiar with the minerals mentioned in this report, their composition is given in the Glossary at the end of this report.

**For complete descriptions of both natural and artificial gem-quality corundum and of the Verneuil process, see Kraus and Slawson, Gems and Gem Materials, pp. 150-167, 5th Ed. 1947, McGraw-Hill Book Co.

OCCURRENCE

Most of the corundum of abrasive quality that has been used in the United States since 1921 has been obtained from Transvaal in the Union of South Africa. Smaller amounts have also been shipped from India, Rhodesia, and Madagascar. After 1905 and previous to 1921 most of our corundum was obtained from Canadian deposits, but before 1905 domestic production was the most important source. During this initial period Georgia, North Carolina, South Carolina, and Montana all contributed to the production.

In the South African deposits, which are the most important in the world at the present time from the standpoint of production, corundum occurs both in a type of pegmatite and in eluvial (residual) placers derived from the weathering of these pegmatites. This particular type of pegmatite consists chiefly of sodic plagioclase feldspar with varying amounts of corundum, margarite, and several other accessory minerals. The pegmatite deposits are found typically within dark-colored, hornblende-rich, igneous or metamorphic wall rocks. In a few places in South Africa, corundum also occurs as an important constituent in biotite-feldspar gneiss. One of the major advantages enjoyed by the South African corundum industry is the plentiful supply of cheap native labor, which makes it possible to continue small scale mining at sporadic intervals in irregular and unevenly distributed deposits of limited extent. The South African deposits do not appear to be larger or of higher grade than some of those that have been mined in Montana or elsewhere in the United States, but the African ones are apparently distributed over a considerably larger area. Since they can be worked at low cost, it is possible to import corundum from South Africa at a price at which domestic or even Canadian corundum cannot compete. The deposits of corundum in this country must, therefore, be regarded, at least under the present conditions, as potential reserves that may be utilized principally under conditions of national emergency.

Most of the Canadian deposits, which occur in Ontario in the Haliburton-Bancroft area and in other nearby districts, are found in syenites, nepheline syenites, and their pegmatitic equivalents. During World War II production from these previously important deposits was revived. In this country also, considerable war-time interest in corundum was aroused when the possibility of interruption of the South African importations became evident. This led to a considerable program of prospecting of the known United States deposits and their re-evaluation as corundum reserves. Many of the Montana deposits were prospected and studied in detail (1, 6, 10, 11, 12).

MONTANA CORUNDUM DEPOSITS

I. In andesite dikes
   1. Ruby Bar (Magpie Gulch), Lewis and Clark County.
   2. Eldorado Bar, Lewis and Clark County.
   3. Rock Creek, Granite County (?).

II. In lamprophyre dikes
   4. Yogo Gulch, Judith Basin County.

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morphous after hornblende; this, however, could not be definitely determined. The minerals just mentioned are embedded in a groundmass of brown glass which is everywhere speckled and dotted with microlites of a lath-shaped plagioclase feldspar."

IN LAMPROPHYRE DIKES

Corundum, as the variety sapphire, also forms accessory crystals in dikes of lamprophyre. This type is represented by the world famous Yogo Gulch occurrence in Judith Basin County. The rock has been described as follows (13):

"In thin section the rock at once shows its character as a dark basic lamprophyre, consisting mainly of biotite and pyroxene. There is a little iron ore present, but its amount is small and much less than is usually seen in rocks of this class. The biotite is strongly pleochroic, varying between an almost colorless and a strong clear brown tint. It occurs in ragged masses, rarely showing crystal outline, and it contains a large amount of small apatite crystals. The pyroxene is of a pale green tint, with the habit of diopside, and is filled with many inclusions, now altered, but possibly originally of glass; in some crystals these inclusions are so abundant as to render the mineral quite spongy. The grains sometimes show crystal form, but are mostly anhedral and vary in size, though the evidence is not sufficient to show two distinct generations.

"These two minerals lie closely crowded together, and no feldspars are seen in the rock. The interstices between them consist of a small amount of clouded, brownish kaolin-like aggregate, which appears to represent some former feldspathoid component, possibly leucite, perhaps analcite.....Some calcite in agglomerated granules is also seen in the section."

IN SYENITE PEGMATITES

Non-gem quality corundum in barrel-shaped crystals occurs in syenite and in syenite pegmatite. This type of occurrence is represented in three deposits southwest of Bozemen in Gallatin and Madison Counties (6, 7, 10, 11, 12, 15, 16). The rock in which the corundum occurs is (6),

"...syenite pegmatite intruded along the foliation and between layers of the metamorphic rocks. Individual bodies may be as much as 1,000 feet long; the maximum thickness is about 5 feet. However, many of the sills are only a few score feet long and 1 to 2 feet thick. They tend to occur in swarms of 10 to 15.

"The texture is medium- to coarse-grained and generally somewhat foliated due to biotite orientation; the main mineral constituents are abundant microcline microperthite, some orthoclase, corundum, plagioclase (Ab 90), and biotite. Plagioclase is subordinate to potash feldspar. The accessory minerals are black tourmaline, apatite, zircon, magnetite, kyanite, quartz, and a mineral that resembles rutile but has been identified as baddeleyite. In some of the pegmatites sillimanite and muscovite become very abundant. The blue-gray, opaque corundum occurs in an unusual, characteristic fashion. It forms euhedral hexagonal prisms as much as eight inches long, which commonly include grains of baddeleyite or have grains of baddeleyite along their margins. The prisms are almost invariably set in a shell of microcline whose thickness is porportional, in a rough way, to the size of the prism. The crystals generally lie across the foliation; a few are curved.

"The microscope reveals that the smaller corundum crystals commonly are skeletal with numerous inclusions of baddeleyite and perthitic microcline and that the shell consists almost exclusively of perthitic microcline. Corundum hardly ever is in contact with biotite, quartz, or plagioclase.

"Many of the sills contain abundant sillimanite and muscovite, which are clearly later than the other minerals and have been developed at their expense. The conspicuous replacement by muscovite begins along the contacts between corundum crystals and their microcline shells and engulfs first the shell; then the rest of the potash feldspar in the matrix is replaced selectively.

"The more general replacement by sillimanite produces a strong schistose appearance in the rock. All gradations exist from normal syenite pegmatite without muscovite or sillimanite through varieties in which sillimanite is a subordinate constituent of the matrix and muscovite rims the corundum, to those that consist essentially of coarse, radiating needles of sillimanite and plates of muscovite with corroded relicts of corundum and very minor residual biotite, sodic plagioclase, baddeleyite, and zircon."

Another, non-pegmatitic, origin has been postulated for these deposits by Clabaugh (2).

IN PLACERS

Much of the production of sapphire in Montana has been as a by-product in gold placer operations. The corundum in the placers of the Missouri River has apparently been derived chiefly from the weathering of andesitic dikes. The main placer area along this river begins about 20 miles east of Helena near Canyon Ferry and continues down the river for approximately 20 miles. The sapphire gravels are in layers ten to fifty feet thick and form bluffs extending 50 to 130 above the river. During World War II sapphire mining was conducted at Eldorado Bar by the Perry-Shroeder Mining Company who operated a six-foot Yuba dredge on Hauser Lake, which is an artificial lake formed by Hauser Lake dam. This company avoided the general ban on war time gold mining because of the by-product sapphire that they produced. Sapphires for bearings were considered an essential war mineral. Other placers are in Granite, Judith Basin, and Deer Lodge Counties.

IN IMPURE MARBLES

The Camp Creek corundum deposit in the Ruby Range near Dillon, which is described in detail further on in this report, occurs in an impure marble that contains various calcium-magnesium silicates. A few float pieces of corundum also were found by the writer on the northwest flank of the Ruby Range, several miles southwest of Carter Creek. Although no corundum was discovered in place here, these float fragments may be derived from small deposits similar to that on Camp Creek, for the general geology is the same.

C A M P   C R E E K   C O R U N D U M   D E P O S I T

GEOLOGY OF THE AREA

The Camp Creek corundum deposit, which is in the NE. 1/4 of sec. 36, T. 8 S., R. 8 W., lies about a mile southwest of the Crystal Graphite mine at an elevation of about 7,000 feet. (See fig. 1). It is on a shoulder along the south side of the Camp Creek drainage, overlooking the valley of Blacktail Deer Creek to the south and southwest. The deposit was discovered by the writer in June 1949, and to the best of his knowledge has not been previously reported.

The deposit occurs within the Cherry Creek series, which is one of the major subdivisions of the Montana pre-Beltian rocks. The pre-Beltian rocks in this area can be divided into the following major units (from oldest to youngest):

1.--The Pony series, which consists largely of various gneisses and contains relatively few layers of metasedimentary rocks.

2.--The Cherry Creek series, composed in the main of marbles, schists, quartzites, and gneisses of metasedimentary origin.

3.--A series of hornblende gneisses and amphibolites that originally were basic sills and lava flows within the Cherry Creek series.

4.--The Dillon granite gneiss, a large, generally conformable intrusive mass of granitic composition which intrudes the lower part of the Cherry Creek series. Its intrusion was accompanied by swarms of pegmatites, aplites, and granite dikes and sills, which are now also metamorphosed.

5.--Ultramafic bodies consisting of various types of peridotites. These masses were intruded after the final period of metamorphism that transformed the Dillon granite into a granite gneiss and are thus unmetamorphosed.

6.--Large and persistent dikes of diabase that transect the other pre-Beltian units including the peridotites and are also unmetamorphosed. Some of these dikes have been emplaced along faults, and in the Dillon area their general trend is north-northwest.

In general in the southern part of the Ruby Range the layers of Cherry Creek rocks strike to the northeast and dip northwest at moderate to steep angles. The strata are transected by a large vertical diabase dike that strikes north-northwest, is several hundred feet thick, and has been traced in both directions from the deposit for a distance of several miles. The dike weathers more rapidly than the surrounding metamorphic rocks and has thus localized the drainage of

Camp Creek. About one-half mile northwest of the deposit, along the Camp Creek drainage, the diabase dike makes a right-angle bend and follows the strike of the metamorphic layers for about 100 yards to the northeast. There it makes another right-angle bend and resumes its former trend, cutting across the marbles and schists in a north-northwest direction.

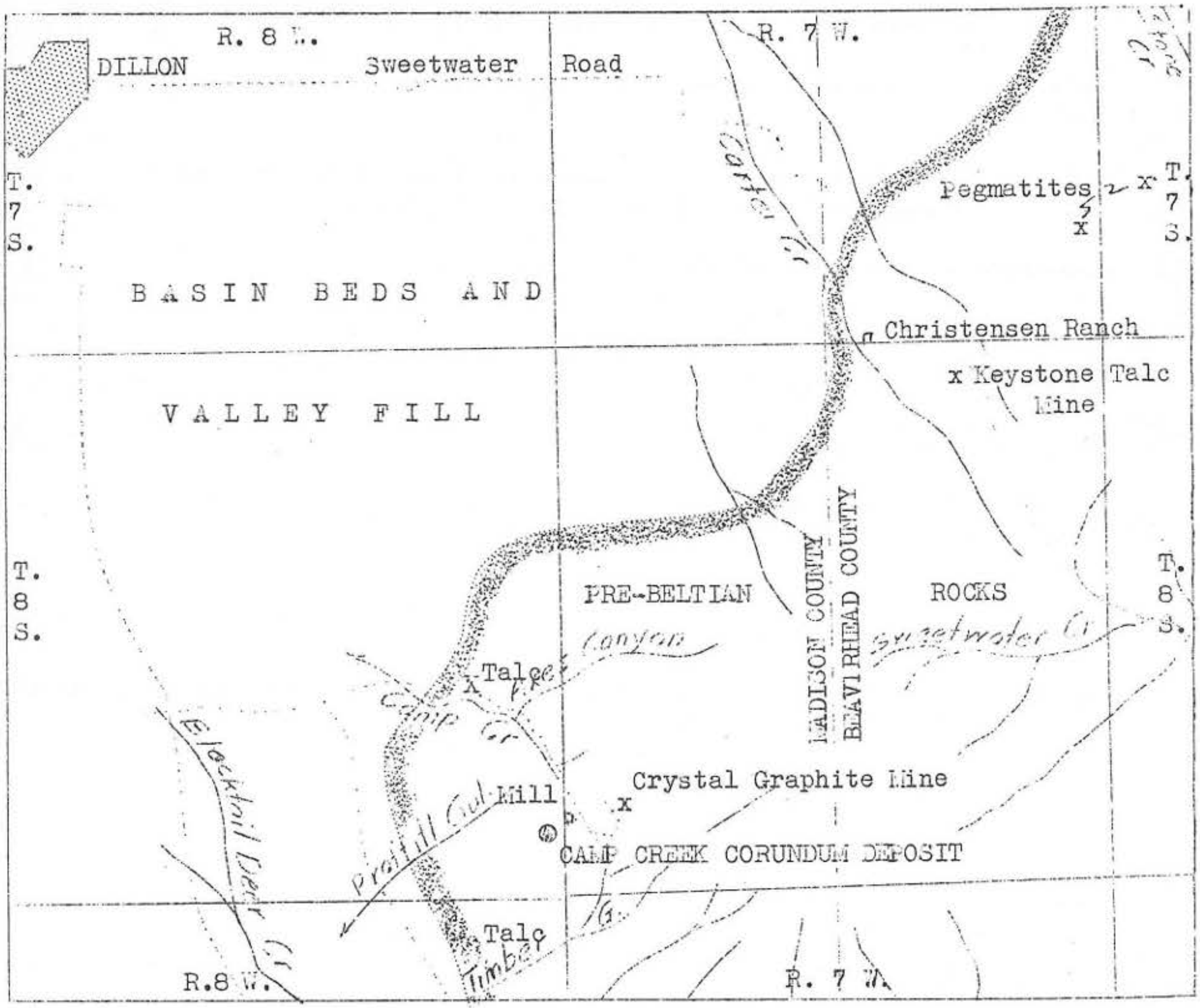


Figure 1.--Index map showing location of Camp Creek corundum deposit, Montana

To the southeast of these bends, the diabase has been emplaced along a fault, and as a result the succession of metamorphic units at the corundum deposit is considerably different from that found on the other (northeast) side of the Camp Creek drainage. The succession on the northeast side of the Camp Creek is as follows (youngest to oldest):

Marble, 1200 feet thick.

Gneiss, 1500 feet thick.

Marble, 200 feet thick; with a thin layer of sillimanite gneiss at the base.

Gneiss, 3200 feet thick; contains granitic gneiss, biotite gneiss, and local layers of sillimanite gneiss.

Marble, 800 feet thick: This is the marble unit along which the Crystal Graphite deposit has been developed.

Granite Gneiss, which is more than one-half mile thick and extends southeastward to the edge of Timber Gulch.

This sequence may be compared with that found on the southwest side of Camp Creek:

Marble, 200 feet thick: This is the same layer as the initial unit in the sequence on the northeast side of the valley.

Mica schist, 400 feet thick.

Hornblende gneiss, 450 feet thick.

Marble, 250 feet thick.

Hornblende gneiss, 200 feet thick.

Quartzite, 100 feet thick.

Marble, 450 feet thick.

Hornblende gneiss, 350 feet thick.

Marble and biotite schists, 200 feet thick: This is the zone in which the corundum deposit occurs.

Granitic gneiss, 225 feet thick.

Hornblende gneiss, 200 feet thick.

Granite gneiss, with some inter-layered hornblende gneiss, which continues to the edge of Timber Gulch to the southeast.

GEOLOGY OF THE DEPOSIT

A section from northwest to southeast across the deposit is as follows:

Hornblende gneiss.

Marble, 0 to 140 feet thick.

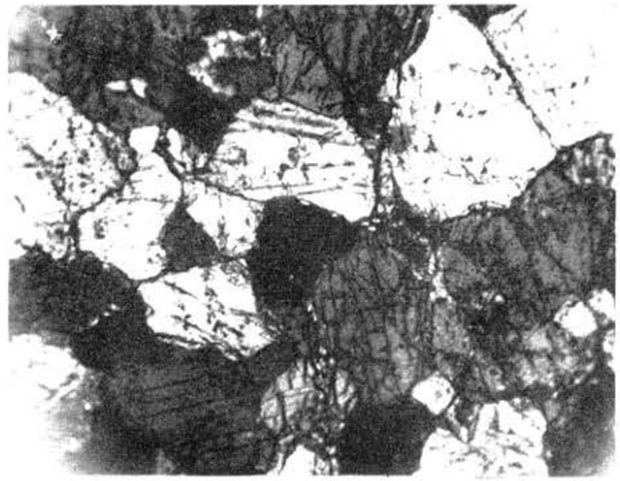
Biotite schist, 75 to 180 feet thick.

Marble, 40 to 120 feet thick.

Granite gneiss.

A

B



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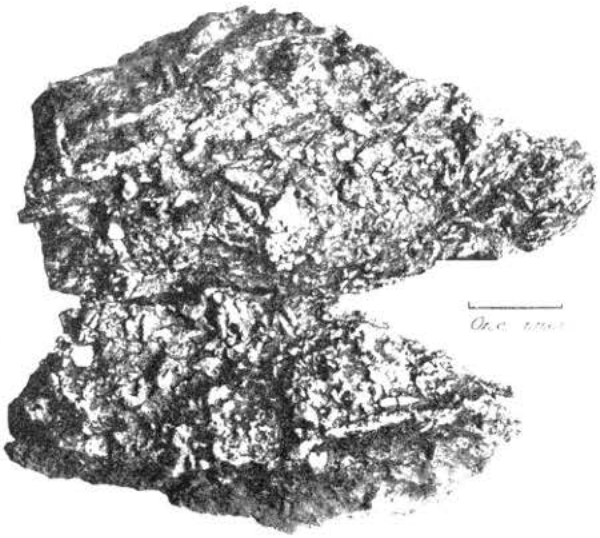

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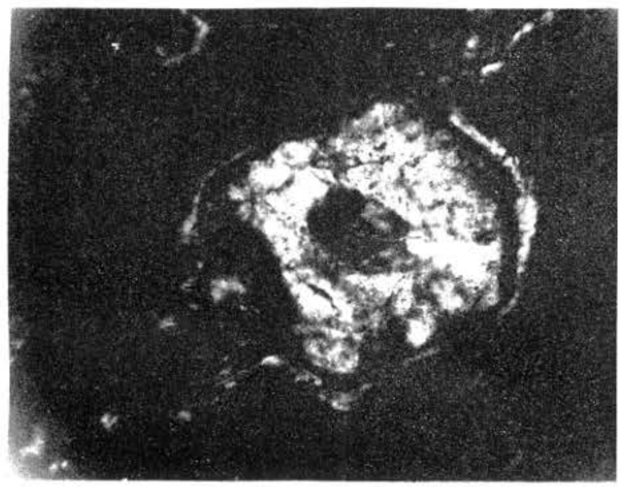
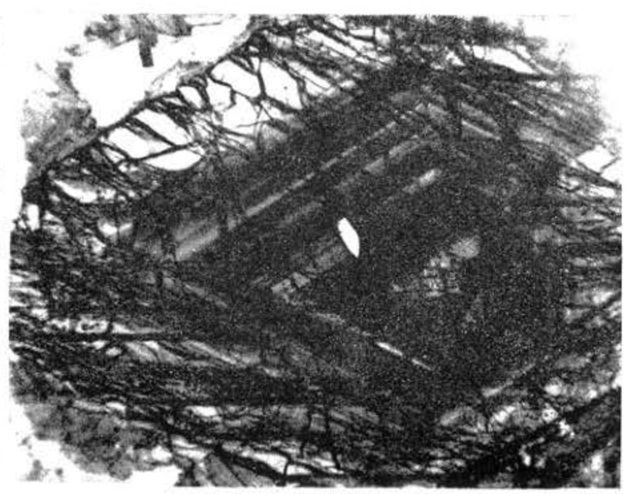


E

F



G

PHOTOGRAPHS AND PHOTOMICROGRAPHS OF ROCK SPECIMENS.

PLATE 1

A. Typical exposure of corundum rock.

B. Typical exposure of corundum rock.

C. Photomicrograph of diopside marble. (Magnification 33X).

D. Corundum ore in hand specimen.

E. Zoned corundum crystal with sapphire core (Type I) in very fine grained, nearly isotropic, mixture of calcite, sericite, and chlorite. (Crossed nicols, magnification 66X).

F. Photomicrograph of radial aggregate of thulite. (Crossed nicols, magnification 33X).

G. Zoned corundum crystal (Type II) showing alternation of light bands with brown bands. (Magnification 33X).

Within the layer of biotite schist there occurs a lens-shaped body of marble that is 280 feet long and 100 feet thick in its central part. Within this lens, near its upper contact with the biotite schist, are exposed three lenticular masses of corundum-bearing rock, which range in length from 20 to 130 feet and in thickness from 4 to 20 feet. In general they lie along the foliation of the surrounding marble and schist and strike northeast and dip at a moderate angle northwest. These are the principal corundum ore units, but considerable disseminated corundum also occurs within the biotite schist at scattered localities near the large marble lens. These occurrences also are recorded on Plate 2. Much float corundum is also concentrated as eluvial material in the mantle overlying the marble and the schist.

The metamorphic layers are transected by two narrow dikes of diabase which trend to the northwest, are apparently vertical, and average only a few feet in thickness. (See Pl. 2). These unmetamorphosed dikes also cut across the corundum lenses. The rock of these thin dikes is very similar to that of the very much larger diabase dike along the Camp Creek drainage a short distance to the northeast.

PETROLOGY OF THE DEPOSIT

Marble

The marble, which weathers to a granular light-brown well-exposed rock, ranges in composition from a nearly pure dolomite to a calcium- and magnesium-silicate gneiss. Most of the silicate minerals are concentrated in the upper part of the marble band near its contact with the overlying hornblende gneiss.

The principal silicate minerals found in the impure marble are diopside, tremolite, phlogopite, pink zoisite (thulite), and chlorite. The proportions of these minerals differ widely. Some varieties of the rock consist almost entirely of large blades of very pale green tremolite, some of which attain a length of six inches. In other outcrops the rock consists almost exclusively of brownish weathering, granular diopside. (See Pl. 1, C).

Locally throughout this rock thulite* becomes an important and conspicuous constituent. It varies in color from very pale pink to deep rose and occurs as irregular grains, small needles, and rarely as striking radial aggregates (Pl. 1, F) that may be as much as two to three inches across. Microscopic examination of the thulite rock shows that the mineral is conspicuously twinned and zoned and displays the characteristic anomalous interference colors (Berlin blue and tobacco-brown) under crossed nicols. The zoning is of two types: one is revealed only by variations in the birefringent colors with crossed nicols, whereas the other type is displayed without crossed nicols by the blades in radial aggregates, which often have a pink color near their central juncture and are colorless near their extremities.

*Thulite has been reported from only one other locality in Montana, in the Philipsburg district, Granite County, by Schaller and Glass (17).

In addition to the thulite, the rock also contain much basic plagioclase (calcic bytownite), scattered large anhedral grains of sphene, and layers and lenses of diopside. The diopside lenses may show banding, with alternation of coarse and fine grained layers of the pyroxene. Scattered small crystals of zircon appear throughout the thulite-plagioclase phase and, where included in the thulite, have produced pleochroic halos in that mineral. A few nest of biotite flakes also occur locally. Replacing the thulite-plagioclase-diopside aggregate, in wholesale fashion, is a generally very fine-grained mixture that contains sericite, chlorite, and locally some calcite and granules of magnetite. Most of the plagioclase is at least partly replaced by the sericite, and many of the thulite blades are corroded by chlorite, which also replaces diopside to a limited extent. Even microscopically this replacement aggregate is usually so fine-grained that the individual constituents can be distinguished only locally wherever a slightly coarser development has taken place. In hand specimen, this matrix has a dense gray-white porcelainoid appearance. In some outcrops it effervesces to varying degrees with hydrochloric acid, indicating the presence of fine-grained calcite in the mixture.

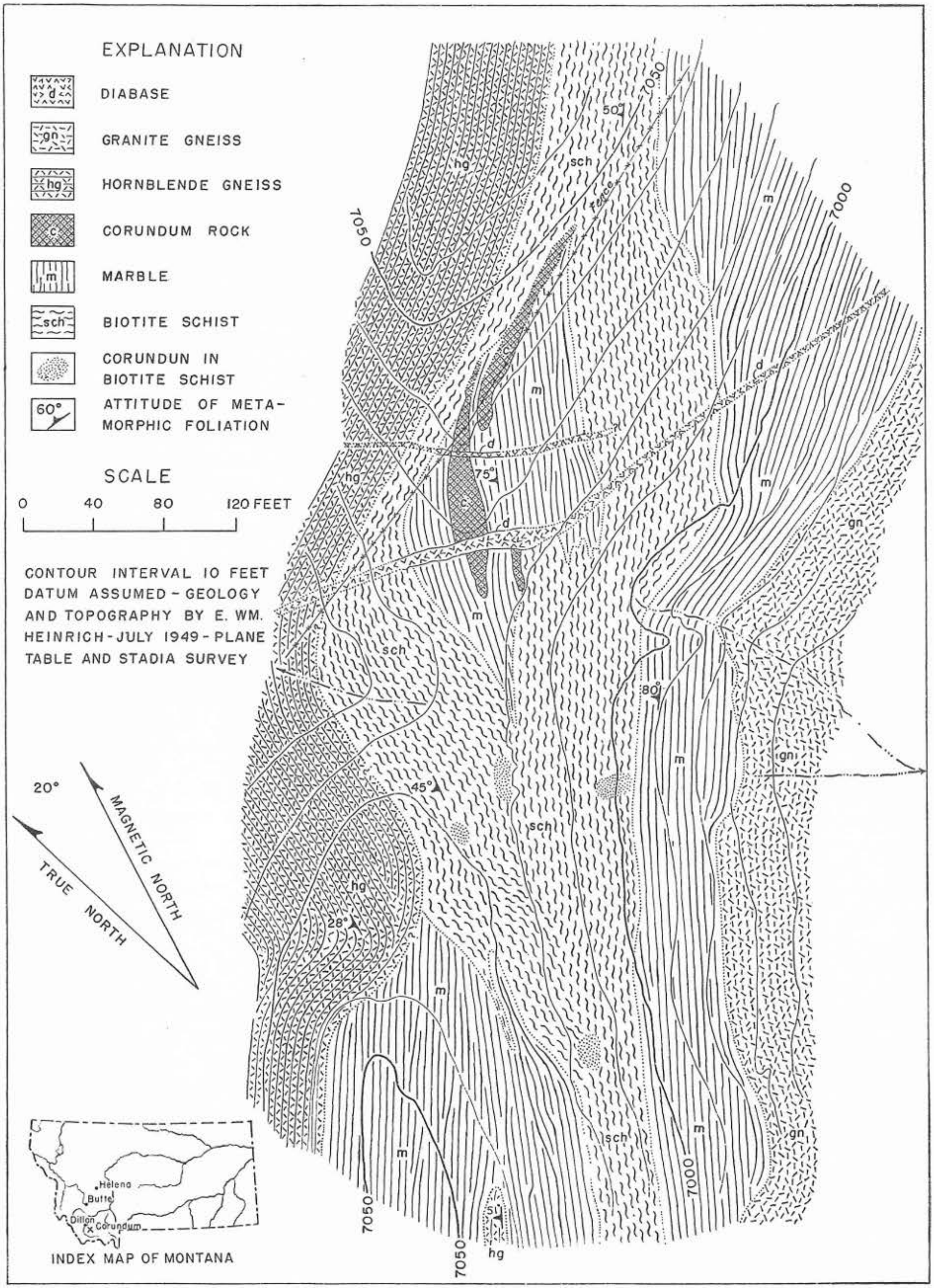
In a few outcrops of the impure marble there appears a dense, waxy material with a striking rose-lilac color. It forms small irregular masses which are rather soft, despite their very compact structure. Under the microscope this material appears as a tightly felted aggregate of minute shreds of a micaceous mineral, with a general index and birefringence that fit either sericite or talc, but a strong test for magnesium was obtained, indicating that the mineral is talc.

Biotite Schist

The biotite schist is a well-foliated dark-colored rock in which biotite is the principal mineral that can be recognized megascopically. Under the microscope the chief minerals that appear are biotite, quartz, and slightly zoned andesine (Ab 62). Accessory constituents are orthoclase, magnetite, diopside, epidote, sphene, tourmaline, and corundum. With an increase in the amount of diopside and epidote the rock grades toward the impure marble. Locally the epidote grains, which show marked zoning, become relatively abundant.

The biotite schist has also been partly altered with the formation of much sericite at the expense of plagioclase, some calcite which replaces diopside, and chlorite after biotite. In several places the fine-grained replacement aggregate of sericite-chlorite-calcite appears as lenses within the schist. The microscopic layered structure consists of thin bands rich in biotite that alternate with thicker feldspar-quartz bands that contain less biotite. Large net-like crystals of diopside and very large wedge-shaped crystals of sphene occur scattered throughout.

In several outcrops the rock contains large tourmaline crystals or clusters of tourmaline crystals. Individual crystals are as much as 1/4 inch in diameter and one inch long, and groups may be several inches across. Tourmaline is particularly abundant where stringers of granitic material or pegmatites from the underlying granite gneiss have invaded the schist. In a few places large disseminated crystals of corundum, oriented within the biotite-rich layers, form a conspicuous element of the schist.



GEOLOGIC MAP OF THE CAMP CREEK CORUNDUM DEPOSIT, NE. ¼ SEC. 36, T. 8 S., R. 8 W., BEAVERHEAD COUNTY, MONTANA.

Hornblende Gneiss

The hornblende gneiss is a dark well-foliated rock consisting chiefly of aligned needles and blades of glistening black hornblende with interstitial plagioclase. Although in general this unit is conformable to the regional layering, locally along the marble contact at its footwall the carbonate rock is cut by small apophyses from the body of gneiss. From this relation it seems probable that the hornblende rock represents a metamorphosed mafic sill. This interpretation is born out by the structural relations of other similar hornblende gneisses throughout the entire region.

Granite Gneiss

The granite gneiss, which underlies the corundum-bearing sequence of metamorphosed-sedimentary rocks, is a large sill-like mass that is one of the outlying granite bodies on the northwest side of the main Dillon granite gneiss batholith several miles to the southeast. The rock is poorly foliated, fine-grained to pegmatitic in texture, and contains chiefly quartz and potash feldspar with variable amounts of biotite. Stringers and lenses of this rock have produced metacrysts of tourmaline within the biotite schist.

Diabase

The diabase is a dark-colored brown-weathering rock, which shows the typical ophitic texture under the microscope. The chief minerals are plagioclase (Ab 41) and augite. Minute tangential flakes of biotite have been formed around the edges of some of the pyroxene crystals. Accessory constituents are magnetite, in both euhedral and skeletal crystals, grains of pyrite, grains of pyrrhotite rimmed by magnetite, and needles of apatite. Small vesicles throughout the rock have been filled by secondary minerals. A typical filling is with chlorite along the walls of the cavity, calcite in an intermediate layer, and quartz filling the center. The diabase has also been extensively altered with the formation of chlorite and calcite after pyroxene and zeolites after plagioclase.

CORUNDUM ROCK

The gray corundum rock consists mainly of elongate corundum crystals scattered abundantly throughout a dense, exceedingly fine-grained matrix, the constituents of which cannot be recognized without the microscope. The material is very resistant to weathering and persists as boulders and good outcrops (Pl. 1, A and B). Locally, however, a few other minerals can be identified megascopically in addition to corundum. These are: 1, margarite in pearly gray flakes, interstitial to corundum and partly replacing it; 2, a few scattered crystals and needles of black tourmaline; 3, irregular aggregates of pale-blue apatite grains; 4, needles and radial groups of thulite; and 5, clusters of biotite flakes. In some of the rock, diopside becomes an important constituent.

Most of the corundum crystals are concentrated in rudely defined layers parallel with the foliation of the surrounding rocks. Some of the bands are several inches thick (Pl. 1, D). Much of the mineral occurs in rather well-formed crystals which may be as large as an inch in diameter, but average about 1/4 inch in diameter. They are blue-gray in color and show the typical tapering, barrel-shaped habit. In addition to these euhedral crystals, some of the corundum occurs in narrow vein-like masses consisting of small anhedral grains and also to a lesser extent in rather large irregular clusters of coarse anhedral grains. The percentage of corundum is estimated to range from 5 per cent to about 35 per cent. Local masses of the rock may be even richer.

The corundum is strongly zoned, a feature that can be observed megascopically and microscopically. In one type of zoning (Type I) a narrow zone of the crystal is dull blue-gray, whereas the center is a brilliant, deep, gemmy sapphire (Pl. 1, E). In other crystals the zoning (Type II) is formed by alternating colorless and dark-brown bands rich in minute inclusions (Pl. 1, G).

Under the microscope the corundum-bearing rock can be seen to consist of individual grains and crystals of corundum, often zoned, set in a generally fine-grained matrix that consists of sericite, chlorite, margarite, calcite, and rare granules of magnetite. In addition to the corundum crystals, corroded blades of thulite, elongate crystals of epidote, patches of biotite, irregular bands of calcic plagioclase, and grains of rutile and zircon appear, set in the fine-grained alteration matrix.

The corundum, which is typically euhedral, shows strongly developed zoning (usually of Type II) and twinning. Some of the crystals are veined by chlorite and others are strongly embayed and corroded by chlorite, margarite, and the fine-grained matrix mixture. A few pseudomorphs (false forms) of chlorite after corundum were noted. In one case, although the entire corundum crystal had been replaced, the zonal structure was preserved in the chlorite aggregate. The rutile grains are usually closely grouped around the corundum and a few are included. In general, however, the corundum is free of inclusions.

The andesine is sericitized and corroded by the fine-grained matrix phase. Biotite is in part altered to chlorite.

ORIGIN

The rock in which the corundum occurs has most of its constituents except corundum so extensively altered that it is difficult to estimate their former relative abundance. In general, however, the rock shows affinities to both the schist through biotite and zircon, and to the silicate marble, through the presence of thulite, epidote, diopside, plagioclase, and apatite. The relationship of the corundum bodies to the biotite schist is further emphasized by the local occurrence within the schist of scattered crystals and concentrations of crystals of corundum. If the definitely later fine-grained sericite-chlorite-calcite phase of mineralization is for the moment ignored, it appears likely that the corundum rock previous to this alteration consisted mainly of corundum, plagioclase, thulite, with minor amounts of epidote, apatite, and diopside and locally concentrations of biotite. The most abundant constituents have the compositions:

Corundum - aluminum oxide, Al_2O_3

Plagioclase - sodium-calcium-aluminum silicate, $(Ca,Na)Al(Si,Al)_3O_8$

Thulite - calcium-aluminum-manganese hydrous silicate, $Ca_2(Al,Mn)_3(SiO_4)_3(OH)$

Thus the original rock prior to metamorphism contained chiefly aluminum, silicon, calcium and minor sodium and manganese. It seems probable that the aluminum and silicon were present in the form of the aluminum silicates, clay minerals or clay minerals plus quartz, and the calcium present as calcite. From this it may be suggested that the corundum lenses were originally aluminous shales containing some calcite, which were deposited as local sedimentary layers of limited extent within the sequence of limestones (now marble) and normal shale (now biotite schist). This entire sequence was subsequently transformed through regional metamorphism in pre-Beltian time. It is interesting to note that many of the Cherry Creek marbles both in this region and in other regions, contains small amounts of manganese. In some places small deposits of low grade manganese ore have been prospected. The presence of this widely distributed element resulted in the formation of thulite instead of normal zoisite. Occurrences of corundum in marble together with calcium or magnesium silicates are know from many localities over the world.

At a subsequent period, possibly at the time of intrusion of the diabase dikes*, the high-temperature silicates and oxide were transformed, under much lower intensity conditions, to the low-temperature minerals, margarite, chlorite, sericite, and calcite.

ECONOMIC SIGNIFICANCE

Although the grade of the deposit is apparently high and the corundum is coarse and generally free from inclusions, the size of the deposit is rather limited. A program of trenching is necessary in order to determine the complete extent of the ore-bearing lenses. The discovery of this type of corundum deposit is an encouraging clue that points to the potentialities for other and possibly larger similar deposits in some of the large unexplored pre-Beltian areas of southwestern Montana. The fact that the occurrence lies within a short distance of a graphite deposit mined sporadically since 1899 emphasizes the lack of attention heretofore given to many non-metallic minerals in these rocks.

GLOSSARY OF MINERALS AND GEOLOGIC TERMS

AMPHIBOLE, important group of rock-forming minerals of similar physical form, mainly calcium, magnesium, and iron silicates. Usually dark-colored.
ANALCITE, hydrous sodium-aluminum silicate.
ANDESINE, see PLAGIOCLASE.
ANDESITE, a volcanic rock of intermediate composition, devoid of quartz.
APLITE, an igneous rock of sugary texture composed of quartz and feldspar.
AUGITE, aluminous PYROXENE.
BADDELEYITE, zirconium dioxide.
BIOTITE, magnesium-iron MICA.
BYTOWNITE, see PLAGIOCLASE.
CALCIC, containing calcium.
CALCITE, calcium carbonate.
CHLORITE, green mica-like mineral.
CORUNDUM, aluminum oxide.
DIABASE, basic igneous dike rock.
DIOPSIDE, calcium-magnesium PYROXENE.
EPIDOTE, green calcium-aluminum-iron silicate.
FELDSPAR, important group of rock-forming minerals with similar physical properties but variable chemical composition, light colored, silicates of aluminum with either potassium, sodium, or calcium.
FELDSPATHOID, alkaline aluminum silicate.
HEMATITE, iron oxide, usually red.
HORNBLENDE, aluminous AMPHIBOLE.
KAOLIN, hydrous aluminum silicate.
KYANITE, aluminum silicate.
LAMPROPHYRE, basic igneous dike rock.
LEUCITE, a feldspathoid.
MAFIC, composed chiefly of dark-colored iron-magnesium minerals.
MAGNETITE, black magnetic iron oxide.
MARGARITE, brittle calcium MICA.
METACRYST, large individual crystals in a metamorphic rock.
METAMORPHIC, changed by heat and/or pressure.
MICA, group name for minerals of similar physical properties but variable chemical composition. Characterized by a thinly foliated (scaly) or micaceous structure.
MICROCLINE, variety of potash FELDSPAR.
MICROPERTHITE, microscopic intergrowth of MICROCLINE and ALBITE FELDSPARS.
MUSCOVITE, white potassium MICA.
ORTHOCLASE, variety of potash FELDSPAR A silicate of aluminum with potassium and sometimes sodium.
PEGMATITE, acidic dike rock characterized by coarse crystallization.
PERIDOTITE, intrusive basic igneous rock of mainly OLIVINE and PYROXENE with little or no PLAGIOCLASE.
PERTHITIC, showing intergrowth of MICROCLINE and ALBITE.
PHENOCRYSTS, large crystals or grains in a finer grained matrix.
PHLOGOPITE, magnesium MICA.
PLAGIOCLASE, variety of FELDSPAR embracing a group of minerals with similar physical properties. Composition varies uniformly from ALBITE, sodium-aluminum silicate, to ANORTHITE, calcium-aluminum silicate. OLIGOCLASE, ANDESINE, LABRADORITE, and BYTOWNITE are intermediate varieties.
POTASH, potassium oxide.
PYRITE, iron sulphide.
PYROXENE, important group of rock-forming minerals of similar physical properties, mainly calcium, magnesium, and iron silicates, usually dark-colored
PYRRHOTITE, magnetic iron sulphide.
QUARTZ, silicon dioxide (silica).
RUBY, red gem variety of CORUNDUM.
RUTILE, titanium dioxide.
SAPPHIRE, blue gem variety of CORUNDUM. Also includes other colors except RUBY.
SERICITE, fine-grained scaly variety of MUSCOVITE.
SILLIMANITE, aluminum silicate.
SODIC, containing sodium.
SPHENE (TITANITE), calcium-titanium silicate.
SPINEL, magnesium-aluminum oxide.
SYENITE, igneous rock, mainly FELDSPAR. with little or no QUARTZ
TALC, hydrous magnesium silicate.
THULITE, rose-red ZOISITE, hydrous calcium-aluminum silicate.
TOURMALINE, complex silicate of boron and aluminum.
TREMOLITE, variety of AMPHIBOLE.
ZEOLITE, secondary hydrous silicates of aluminum with calcium and alkalies.
ZIRCON, zirconium silicate.
ZOISITE, hydrous calcium-aluminum silicate.

R E F E R E N C E S

1. Clabaugh, S. E., Corundum deposits of Montana: Manuscript Report in files of U. S. Geol. Survey and Montana School of Mines Library, 1949.

2. ______________, Pegmatites of Montana - Discussion: Econ. Geol., vol. 45, pp. 254-257, 1950.

3. Heinrich, E. Wm., Petrology of the Montana pre-Cambrian carbonate rocks, (abstr.): Geol. Soc. Am., Bull. 58, p. 1191, 1947.

4. ______________, Deposits of the sillimanite group of minerals south of Ennis, Madison County, with notes on other occurrences in Montana. Montana Bur. Mines and Geol., Misc. Contr. 10, 1948.

5. ______________, Pre-Beltian rocks near Dillon, Montana, (abstr.): Geol. Soc. Am., Bull. 59, p. 1329, 1948.

6. ______________, Pegmatites of Montana: Econ. Geol., vol. 44, pp. 307-335, 1949.

7. ______________, Pegmatite mineral deposits in Montana: Montana Bur. Mines and Geol., Memoir 28, 1949.

8. ______________, Sillimanite deposits of the Dillon region, Montana: Montana Bur. Mines and Geol., Memoir 30, 1950.

9. ______________, and Perry, E. S., Non-metallic mineral deposits in Montana pre-Beltian Rocks: Am. Inst. Min. Eng., Tech. Publ., (in press).

10. Hopkins, J. B., and Taber, John., Bear Trap corundum deposit, Madison County, Montana: U. S. Bur. Mines, Rept. Invest. 4039, 1947.

11. O'Brien, R. D., Gallatin corundum deposit, Gallatin County, Montana: U. S. Bur. Mines, Rept. Invest. 4113, 1947.

12. ______________, and Taber, John., Bozemen corundum deposit, Gallatin County, Montana. U. S. Bur. Mines, Rept. Invest. 4050, 1947

13. Pirsson, L. V., On corundum-bearing rock from Yogo Gulch, Montana: Am. Jour. Sci., 4th ser., no. 4, pp. 421-423, 1897.

14. Pratt, J. H., Corundum and its occurrence and distribution in the United States: U. S. Geol. Surv., Bull. 269, 1906.

15. Rogers, A. F., On corundum-syenite (uralose) from Montana: Jour. Geol. 19, 748-751, 1911.

16. ______________, Baddeleyite from Montana: Am. Jour. Sci., vol. 33, pp. 54-56, 1912.

17. Schaller, W. T., and Glass, J. J., Occurrence of pink zoisite (thulite) in the United States. Am. Mineral. vol. 27, pp. 519-524, 1942.

18. Smith, J. L., Notes on the corundum of North Carolina, Georgia, and Montana, with a description of the gem variety of the corundum from these localities: Am. Jour. Sci., 3rd. ser., vol. 6, pp. 180-186, 1873.