Corundum Deposits of Gallatin and Madison Counties Montana

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By S. E. Clabaugh and F. C. Armstrong

ABSTRACT

Corundum occurs in thin, lenticular layers of biotite-sillimanite gneiss in a series of highly metamorphosed pre-Cambrian rocks southwest of Bozeman, Mont., in Gallatin and Madison Counties. Three deposits have been explored and partly developed as potential sources of abrasive corundum. One of these, located on Elk Creek and called the Elk Creek corundum deposit in this report, was operated as the Montana mine from 1901 to 1903. The other two, known as the Bozeman and Bear Trap corundum deposits, have not been productive. During the period 1943–45 the United States Bureau of Mines explored the three deposits, and in 1944 and 1945 the Industrial Minerals Corp. prepared to mine the Elk Creek deposit. There was, however, no production.

The structure and composition of the corundum-bearing lenses suggest that they were derived by metamorphic processes from alumina-rich sedimentary beds in a series of shales and sandstones. The largest known corundum-bearing body in the Elk Creek deposit is a lens at least 800 feet long, 50 feet in vertical extent, and 1 to 3 feet thick. In this lens is several thousand tons of corundum-bearing rock containing about 10 percent corundum. Lenses of corundum-bearing rock at the other two deposits are much smaller.

INTRODUCTION

Abrasive corundum has been mined at only one locality in the western United States, the old Montana mine in the Elk Creek corundum deposit southwest of Bozeman, Mont. The Elk Creek deposit and two related corundum deposits, the Bozeman and the Bear Trap, are described in this report. Corundum was produced from the Montana mine only during the years 1901–03, but all three deposits were actively explored and developed from 1943 to 1945 when there was a shortage of corundum.

The Bozeman deposit is in sec. 31, T. 2 S., R. 4 E., and the Elk Creek deposit is in secs. 22 and 23, T. 3 S., R. 3 E. Both may be reached by road from the town of Gallatin Gateway. The third deposit is on Bear Trap Creek in sec. 6, T. 4 S., R. 2 E., and it may be reached by a ranch road that leaves the Norris-Bozeman road at the east end of the Madison River bridge. Plate 11 shows the location of these deposits and their general relation to the geology of the region.

The Bozeman and Elk Creek corundum deposits are in the northern foothills of the Madison Range in Gallatin County at altitudes of 5,400 to 6,400 feet above sea level, and the Bear Trap corundum deposit is within the margin of the higher, forested mountain country in Madison County at an altitude of about 7,400 feet. The foothills are open, grass-covered grazing land at the southern limit of the broad basin known as the Gallatin Valley. Near the Elk Creek deposit are sparse growths of brush and timber, and the larger valleys are used as farmland, especially where irrigation is possible. Aspen and conifers are plentiful in the mountains, and grass, sage, and other small plants are abundant at lower elevations. The soil cover is well developed, and the less resistant rocks are deeply weathered, so that the bedrock is poorly exposed near the deposits. The winters are often long and severe, and travel in the higher country is impeded by snow. The summer weather, however, is excellent. Bozeman is the center of a productive farming and ranching region.

The Elk Creek corundum deposit was examined briefly in January 1943 by H. L. James and W. R. Jones, of the Geological Survey, and again in August 1943 by S. K. Neuschel and M. D. Crittenden, Jr. Neuschel and F. C. Armstrong prepared a plane-table map of the Elk Creek deposit in November 1943, when they also examined the Bozeman deposit. Armstrong visited the Elk Creek and Bozeman deposits in 1944 and mapped the more important underground workings. In December of that year he examined the Bear Trap deposit and mapped the geology of Bureau of Mines trenches at the Bozeman deposit. In late March and early April 1945 Armstrong and G. M. Sowers mapped new underground workings and revised previous maps of the Elk Creek deposit. During July, August, and September 1945 S. E. Clabaugh, aided by Patricia S. Clabaugh, prepared plane-table maps of the Bozeman and Bear Trap deposits, extended and modified the map of the Elk Creek deposit, and mapped new workings and trenches.

The writers wish to express their appreciation to Neuschel and Crittenden, who contributed a large part of the early field work and supplied numerous specimens for petrographic study. R. D. O'Brien, E. W. Newman, and J. B. Hopkins, all of the United States Bureau of Mines, gave valuable information and assistance in the field. The writers are indebted also to E. N. Cameron, J. B. Hadley, and R. E. Van Alstine, of the Geological Survey, for their helpful suggestions and critical reading of the report.

HISTORY AND PRODUCTION

It is reported that Reno Sales, now a consulting geologist of the Anaconda Copper Mining Co., identified the corundum on Elk Creek prior to 1900. The Montana Corundum Co. worked the Elk Creek deposit during the period 1901–3 and mined more than 300 tons of corundum-bearing rock.[1] The company ceased operations in 1903, and the property remained inactive until 1943. About 1902 the Bozeman deposit was partly developed as the Bozeman Corundum Co. mine,[2] but no production is reported.

In 1943 Leverett S. Ropes, of Helena, Mont., who had been employed as engineer for the milling operations of the Montana Corundum Co. from 1901 to 1903, called attention to the Elk Creek deposit as a possible domestic source of corundum during the war emergency. In October 1943 the United States Bureau of Mines began exploration of the Elk Creek deposit. Less than a year later part of the property on which the deposit occurs was acquired by the Industrial Minerals Corp., a subsidiary of the American Abrasives Co. The corporation undertook further development work in preparation for mining and made plans for a mill, but in the summer of 1945, before any corundum concentrates had been produced, the plans were abandoned because of the small size of the known corundum-bearing lenses and the lessened need for corundum after the end of the war in Europe.

The Bureau of Mines explored the Bozeman and Bear Trap deposits in 1944 and 1945, but neither showed as much promise of yielding corundum as the Elk Creek deposit.

GEOLOGY

The three corundum deposits described in this report occur in the pre-Cambrian metamorphic rocks of the northern part of the Madison Range between the Gallatin and Madison Rivers. The general geology of the region is presented in the Three Forks folio.[3] Major faults and areas of Paleozoic sedimentary rocks separate the three areas of metamorphic rocks in which the corundum deposits occur. Flat-lying lake beds of Tertiary age cover the older rocks north of the foothills of the Madison Range and almost surround the ridge of older rocks at the Bozeman deposit.

METAMORPHIC ROCKS

The pre-Cambrian metamorphic rocks in which the corundum deposits occur are quartzite, gneissic quartzite, and gneisses of varied composition, which together were called the Pony series by Tansley and Schafer.[4] For the most part the gneiss weathers readily, and

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[1] Pratt, J. H., Abrasive materials: Mineral Resources U. S., 1902, pp. 885–886, 1904.
[2] Montana Bureau of Agriculture, Labor, and Industry, 8th Ann. Rept., p. 445, 1902.
[3] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (no. 24), 1896.
[4] Tansley, Wilfred, and Schafer, P. A., in Tansley, Schafer, and Hart, A geological reconnaissance of the Tobacco Root Mountains, Madison County, Mont.: Montana Bur. Mines and Geology Mem. 9, pp. 8, 9, June 1933.

ridges of quartzite dominate the outcrops in the vicinity of the Bozeman and Elk Creek corundum deposits. The layers of quartzite range in thickness from less than an inch to more than 100 feet but in general are 3 to 15 feet. Many quartzite layers can be traced for several hundred feet, but others are short and lenticular. Most of the quartzite is colorless, light brown, or white; it is coarsely crystalline and in hand specimens is not readily distinguishable from some types of vein quartz. The contacts between gneiss and quartzite are generally sharp, although the quartzite is gneissic locally and grades into quartz-rich gneiss. Hornblende, feldspar, quartz, garnet, and mica are abundant in the gneiss, which ranges from light-gray or pink granitelike rock to dark-green or black gneiss composed almost entirely of hornblende. Rutile, chlorite, vermiculite, corundum, sillimanite, magnetite, tourmaline, and other minerals are present locally in the gneiss.

The so-called Pony series, with its alternating layers of gneiss and quartzite, is a series of highly metamorphosed sedimentary rocks that originally consisted of interbedded shales, sandstones, and sandy shales. The foliation of the gneiss and the banding due to differences in composition are generally parallel to the beds of quartzite and therefore parallel to the original bedding of the sedimentary rocks. The lenticular and gradational layers of quartzite and gneiss probably owe their characteristic features both to metamorphic processes and to original lenticularity and gradations in the sedimentary rocks.

Except for the quartzite, the natural exposures of the metamorphic rocks are poor. Outcrops are scattered and small, and exposures of the thin layers of corundum-bearing rock are restricted almost exclusively to trenches, pits, and underground workings. Therefore, only actual exposures have been plotted on the accompanying maps (pls. 12, 14, and 15), and no inferences regarding details of structure and distribution of varieties of metamorphic rocks in intervening areas are made. Recent exploration between older exposures of corundum-bearing rock in widely spaced pits commonly has shown that the layers of corundum rock are discontinuous. A notable exception is the main body of corundum-bearing rock at the old Montana mine, which can be traced or projected with assurance for a distance of more than 800 feet.

Some differences between the metamorphic rocks at the Bear Trap corundum deposit and those in the vicinity of the Bozeman and Elk Creek deposits should be noted. Quartzite is much less abundant than hornblende gneiss at the Bear Trap deposit, and large masses of dense green hornblende gneiss crop out more prominently than at the other two deposits. Three small areas of gneiss of granitelike composition and several areas of an especially fine grained, dense, dark gneiss are distinguished on the map of the Bear Trap deposit (pl. 15), whereas all varieties of gneiss are grouped in one unit on the other maps. The granitelike gneiss and some of the larger areas of dark gneiss may represent metamorphosed sills or irregular intrusive bodies, but field evidence is lacking. The natural exposures of bedrock at the Bear Trap deposit are even less satisfactory than those at the other deposits, and many of the bulldozer trenches were not deep enough to reveal the underlying rock.

PEGMATITES AND LIT-PAR-LIT GNEISS

Small bodies of pegmatite composed chiefly of quartz, perthite or sodic plagioclase, and muscovite are common in the vicinity of the corundum deposits. Near the Bear Trap deposit, larger pegmatites are numerous; some are more than 100 feet long and at least 10 feet wide. A few of the larger pegmatites in the metamorphic rocks west of the Madison River have been prospected for mica, fergusonite, and other minerals.

At all three corundum deposits the pegmatites are commonly small, irregular, and poorly exposed. They were mapped only at the Bear Trap deposit (pl. 15), where some of the pegmatites are dikes that clearly cut across the foliated gneiss. Smaller stringers of pegmatite finger out into the gneiss in a complex fashion, usually forming a banded rock to which the terms "lit-par-lit gneiss," "injection gneiss," and "migmatite" have been applied. The lit-par-lit gneiss is widespread, and about half the "hornblende gneiss" mapped at the Bozeman and Elk Creek deposits (pls. 12 and 14) is of this type. Hornblende, garnet, and other minerals are usually larger and more sharply segregated crystals in the lit-par-lit gneiss than in the unbanded rock. A major part of the coarsely crystalline feldspar and quartz of the light-colored layers is probably material formed by reorganization of the original constituents of the gneiss rather than introduced material. Although the banded and coarser-grained gneiss can be accounted for in large part by recrystallization of finer-grained rocks, the following characteristics are evidence that the metamorphic rocks were penetrated or locally saturated during the process of metamorphism by solutions rich in water, silica, and alkalis: (1) the presence in the gneiss of such minerals as tourmaline, apatite, chlorite, and vermiculite, nests of coarse muscovite and biotite, and perthite; and (2) the abundance of small pegmatites, some of which are very coarse grained and cut across the structure of the gneiss. Banding and coarse recrystallized masses are developed unequally at different places along any one horizon in the gneiss. The irregular distribution of lit-par-lit gneiss can be attributed both to local variation in stresses during metamorphism and to unequal penetration by the solutions that facilitated reorganization and coarsening of the minerals.

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CORUNDUM-BEARING ROCKS

DESCRIPTION

The corundum-bearing rocks of the three deposits are similar in general, although within the limits of each deposit there is wide variety in texture, associated minerals, and corundum content. The corundum occurs in lenticular and tabular bodies of white or gray rock composed chiefly of feldspar, mica, and sillimanite. The lenses or layers range from a few inches to 6 feet in width and from a few feet to more than 800 feet in length. All the bodies of corundum-bearing rock are parallel to the foliation and major compositional layering of the gneiss. Many are bordered by thin zones of vermiculite and friable, altered gneiss. The thicker parts of the bodies commonly are coarse-grained or pegmatitic in texture, but other parts of the rock are schistose. The corundum crystals vary in size from microscopic grains to prismatic crystals several inches in length, and many of the crystals are surrounded by aureoles of feldspar. Most of the larger corundum crystals are euhedral, with a characteristic tapered prismatic or barrel shape, although platy, distorted, and intergrown crystals are not uncommon. The corundum is opaque to slightly translucent, and most of it is light blue, dark blue, or gray. Lilac corundum occurs at one locality. No corundum of gem quality has been found in these deposits.

Although the corundum-bearing rocks are varied in composition and texture, only one occurrence will be described in detail. The others will then be compared with it.

The tabular body that was worked in the old Montana mine in the Elk Creek deposit is the most thoroughly explored and best-known occurrence of corundum-bearing gneiss in the district. Recent exploratory work by the Bureau of Mines and the Industrial Minerals Corp. (pls. 12 and 13) reveals that this body is a lens more than 800 feet long and about 50 feet in vertical extent. The thickness commonly ranges from 1 to 3 feet, and the average corundum content is between 5 and 15 percent. Mine maps, cross sections, and a vertical projection (pls. 12 and 13) show the shape and dimensions of the lens. It is a tabular body essentially parallel to the foliation of the enclosing hornblende gneiss and to the nearby beds of quartzite. No layers of quartzite were observed in direct contact with the corundum-bearing rock. A thin, irregular zone of friable gneiss generally borders the hard corundum-bearing rock. The friable gneiss consists chiefly of feldspar, garnet, and vermiculite; vermiculite is commonly the most abundant constituent. The corundum-bearing rock narrows rather abruptly at its lower margin; corundum decreases in abundance; and the rock grades into one or more wedge-shaped "tails" of garnet-biotite-plagioclase gneiss.

The typical corundum-rich rock is a medium-grained gneiss streaked or spotted with aggregates of coarse crystals. The coarsely crystalline part consists of euhedral, gray-blue corundum crystals surrounded by white to cream-colored perthite. Crystals vary from less than a tenth of an inch to several inches in length, and corundum crystals a foot long have been reported. Biotite is commonly absent from the coarsely crystalline part of the rock, but large flakes of biotite surround corundum in a few specimens. The biotite of the gneiss is commonly most abundant at the margins of perthite and corundum aggregates. Grains of rutile are included in the margins of nearly all the corundum crystals. Many elongate crystals of corundum are oriented with the long axis of the prism in or near the plane of schistosity of the enclosing gneiss, whereas some transverse crystals are thin basal plates. Crystals oriented at random, however, are common. Scattered crystals of corundum with aureoles or halos of perthite give some specimens a pseudo-orbicular structure.

The finer-grained gneiss in which islandlike masses or irregular stringers of coarse crystals occur is composed of biotite, plagioclase, microcline, perthite, corundum, sillimanite, and muscovite, all as crystals a few millimeters or less in length. Some of these fine-grained minerals can be distinguished only under the microscope. Plagioclase (albite to oligoclase) and biotite are the most abundant minerals of the gneiss, and together they generally constitute from 60 to 80 percent of the finer-grained corundum rock. Microcline and perthite are locally abundant in the fine-grained rock, but the perthite is best developed in the coarse aggregate of crystals. Corundum occurs in small grains or platy skeletal crystals, many of which partly enclose adjacent feldspar crystals. Sillimanite occurs in fibrous bundles of fine acicular crystals, commonly intergrown with biotite. Muscovite is less abundant than biotite, but it is the dominant mica in some specimens. Among the minerals that occur in smaller amounts are rutile, sphene, zircon, apatite, tourmaline, and magnetite. Rogers [5] reported that baddeleyite occurs in association with rutile. Secondary minerals formed by alteration of the constituent minerals of the gneiss include sericite, other alteration products of feldspar, and a fine fibrous or platy mineral of high birefringence (probably sericite) to which corundum has partly altered. Alteration of the corundum crystals along fractures, cleavage lines, and twinning planes is common, even in unweathered samples, but the process of alteration evidently has not gone far enough to impair the abrasive efficiency of the corundum.

The smaller bodies of corundum-bearing rock at the Elk Creek deposit are similar in general to the large lens described, except that

[5] Rogers, A. F., Baddeleyite from Montana: Amer. Jour. Sci., 4th ser., vol. 33, no. 193, pp. 54–56, 1912.

coarse-grained corundum-bearing rock is less common and the average corundum content is lower. Some of the thinner layers exposed west of adit 1 are composed chiefly of feldspar, muscovite, and sillimanite, with less than 5 percent corundum. The rock is lighter in color, softer, and more highly altered, and the vermiculite border is absent or poorly developed in many places.

The corundum-bearing rock of the Bozeman deposit differs little from the smaller bodies at the Elk Creek deposit. The average corundum content of the richest body is less than 6 percent, and no layer is as much as 2 feet thick. Most of the corundum-bearing rock is dense, hard, and gray and is composed of feldspar, muscovite, biotite, and minor amounts of sillimanite, gray-blue corundum, and rutile. The relative abundance of the constituent minerals varies greatly from place to place. Locally the rock is weathered and soft. Corundum crystals from adit 2 and from the old pits between the adit and trench 27 are lilac or rose gray. Although they have been called "rubies," they are not of gem quality. The texture of the corundum-bearing rock varies from fine-grained and equigranular to coarse-grained, approaching pegmatitic texture. However, very little of the corundum rock is as coarse-grained as that in the Elk Creek deposit, and aureoles of feldspar about corundum crystals are not so common. The corundum-bearing layers are generally only a few inches thick, and many of them are bordered by thin zones of friable, vermiculite-rich gneiss. The corundum-bearing layers are commonly distinctive enough to be identifiable even where they contain little or no corundum and sillimanite. Some layers that have been traced and mapped in the trenches are barren of corundum for distances of several feet.

In the Bear Trap deposit most of the corundum-bearing rock is different from the main lens at the Elk Creek deposit. The corundum content of the rock is generally lower, and sillimanite is far more abundant, constituting 35 to 68 percent by weight of some samples. (See Bureau of Mines sample data on pl. 15.) Muscovite is the most abundant mineral in part of the corundum-bearing rock; biotite is uncommon. The vermiculite border zone is generally absent. Many corundum crystals in the sillimanite-mica gneiss are irregular and filled with inclusions, although a few large euhedral crystals were found. The largest corundum-bearing body in the Bear Trap deposit is a short lens about 50 feet long and 6 feet wide near its center. The rock is light gray to white. The chief mineral constituents are muscovite, perthite, and albite or oligoclase; other minerals present are small quantities of biotite, rutile, magnetite, pyrite, apatite, and zircon. Corundum crystals range in size from microscopic grains to large prismatic gray crystals more than an inch long. Almost none are free of inclusions, and even the large crystals tend to have irregular outlines. Muscovite and feldspar are the minerals commonly included, and the corundum is partly altered to sericite. Well-developed aureoles of perthite surrounding corundum crystals are rare, and although coarser perthite and muscovite crystals occur with the larger corundum crystals, very little of the rock has a coarse, pegmatitic texture similar to that of the typical coarse-grained corundum-bearing rock at Elk Creek. Although some of the other layers of corundum rock in the Bear Trap deposit were traced for more than 60 feet, they are only a few inches wide.

ORIGIN

Corundum deposits in general are considered to have formed by one of the following three processes:

1. Corundum may occur as a primary mineral in igneous rocks that have a high alumina-silica ratio. The corundum deposits of eastern Canada are examples of corundum in igneous rock, chiefly syenite, according to Barlow [6] and others. The origin of alumina-rich, silica-poor magmas is a major problem. DuToit [7] suggested that reaction between granite pegmatite and ultrabasic rock might result in the formation of an alumina-rich, silica-deficient magma from which corundum might crystallize. Other writers [8] have accepted this desilication hypothesis in accounting for corundum-bearing dikes with walls of ultrabasic rock. The corundum near Bozeman, Mont., was described as an occurrence of corundum in syenite by Pratt [9] and by Rogers,[10] who thereby implied that it crystallized from a silica-deficient, alumina-rich magma.

2. Corundum of unquestioned metamorphic origin is not uncommon; the mineral occurs in many schists and gneisses. Anderson and Chesley [11] found corundum as a common constituent of slate, even in the presence of quartz. Numerous occurrences of corundum in contact-metamorphic rocks have been reported, and gem corundum and emery commonly occur in crystalline limestones and dolomite. In general, corundum may be expected in metamorphosed rocks that were derived from rocks with a high alumina-silica ratio.

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[6] Barlow, A. E., Corundum, its occurrence, distribution, exploitation and uses: Canada Dept. Mines, Geol. Survey, Mem. 57, p. 37, 1915.

[7] DuToit, A. L., Plumasite (corundum-aplite) and titaniferous magnetite rocks from Natal: Geol. Soc. South Africa Trans. 21, pp. 53–73, 1918.

[8] Hall, A. L., Corundum in northern and eastern Transvaal: Union of South Africa Geol. Survey Mem. 15, 1920; Gordon, S. G., Desilicated granitic pegmatites: Acad. Nat. Sci. Philadelphia Proc., pt. 1, pp. 169–192, 1921; and others.

[9] Pratt, J. H., Corundum and its occurrence and distribution in the United States: U. S. Geol. Survey Bull. 269, pp. 48–49, 1906.

[10] Rogers, A. F., On corundum-syenite (uralose) from Montana: Jour. Geology, vol. 19, no. 8, pp. 748–751, 1911.

[11] Anderson, H. V., and Chesley, K. G., X-ray analysis of slate: Am. Jour. Sci., 5th ser., vol. 22, pp. 103–112, 1931.

3. Larsen[12] reviewed the problem of the origin of rocks composed chiefly of sodic plagioclase or sodic plagioclase and corundum. He offered the theory that the deposits "were formed as high-temperature veins and replacements, probably approaching pegmatite or hydrothermal contact metamorphic deposits in their condition of temperature and concentration." He suggested the probability of a genetic relation between the deposits and the ultrabasic rocks in which they occur.

The corundum deposits of Gallatin and Madison Counties are not easily attributed to igneous or hydrothermal origin. Specimens of the coarse-grained perthite-rich rock are pegmatitic in texture and have been called corundum syenite pegmatite and corundum syenite, but other parts of the same bodies from which coarse-grained specimens may be collected are fine-grained schistose rock. A few lenses are dominantly sillimanite, others are dominantly muscovite, and some contain garnet. The corundum content ranges from a trace to more than 25 percent. No normal magma could furnish rocks of such high alumina content and varied mineral character, nor could a magma have acquired the excess alumina by reaction with wall rocks, for the gneisses in which the deposits occur are rich in quartz. Indeed, quartz and quartzite are so abundant that it seems unlikely that silica-deficient fluids (either pegmatitic or hydrothermal) could be emplaced without acquiring sufficient silica to prevent the crystallization of corundum. Either igneous bodies or hydrothermal deposits might be expected to show discordant relations with the gneiss, but the observed absence of cross-cutting structures does not exclude the possibility that the lenses are sills or concordant veins.

Although a small dike of peridotite crops out in the area of the Bear Trap deposit, the corundum-bearing bodies elsewhere do not occur near peridotite, and nowhere do the lenses have walls of basic rock. Hence they are unlike the occurrences for which Larsen suggested a hydrothermal origin.

The schistose structure and variable mineral composition of part of the corundum-bearing rock suggest that the deposits are of metamorphic origin. The hypothesis of origin due to contact metamorphism can be eliminated, for no large igneous bodies occur in the region. The hypothesis that the deposits were formed by regional metamorphism of syngenetic sedimentary concentrations rich in alumina deserves further study, for it seems to explain many of the puzzling characteristics of these deposits. The gneisses in which the corundum deposits occur were derived at least in part from sedimentary rocks. The observed parallelism of the aluminous lenses to the

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[12] Larsen, E. S., A hydrothermal origin of corundum and albitite bodies: Econ. Geology, vol. 23, no. 4, pp. 398–433, 1928.

quartzite beds and the distribution of the lenses in narrow zones with great lateral extent along the strike of the sedimentary rocks suggest strongly that they were deposited as lenticular beds at one or more sedimentary horizons.

The coarsely crystalline texture of part of the corundum-bearing rock and the vermiculite-rich borders of the larger lenses can hardly be ascribed to regional metamorphism. Perhaps the development of large corundum crystals and irregular patches of coarse-textured pegmatitic rock can be attributed to recrystallization under conditions of moderately high temperature and pressure when water and alkalis were available, pegmatites were being formed, and adjacent metamorphic rocks were being converted in part to lit-par-lit gneiss. The marginal layers of friable, vermiculite-rich gneiss may have been formed at that time as reaction zones between the alumina-rich layers and the surrounding hornblende gneiss, which was richer in silica and iron.

INTRUSIVE IGNEOUS ROCKS AND QUARTZ VEINS

Peale [13] mapped numerous igneous rocks in the region surrounding the corundum deposits, including a variety of porphyries that intrude pre-Cambrian and younger rocks. Small dikes and irregular bodies of porphyry occur at a few places in the vicinity of the corundum deposits. Several occurrences are shown on the detailed maps. One of these is an andesite (?) porphyry dike, 5 to 10 feet wide, which is poorly exposed on the hillside above the adit at the Bear Trap deposit (pl. 15). It is weathered and much altered, but a distinctly porphyritic texture can be seen both in hand specimens and under the microscope. It is pale gray green and weathers gray to reddish brown. The phenocrysts are dark, needlelike crystals of altered amphibole or pyroxene and cloudy gray crystals of altered feldspar that average 1 to 3 millimeters in length. The matrix is a felted mass of colorless, almost fibrous crystals (feldspar?) in which apatite crystals are common. Quartz is rare or absent, and recognizable crystals of plagioclase are uncommon.

A dike of peridotite also is exposed at the Bear Trap deposit (pl. 15). Boulders of this rock are heavy and strongly magnetic. The peridotite is banded; its chief minerals are augite, olivine, spinel, magnetite, and possibly some chromite. The dike varies in thickness from a few feet to more than 10 feet. Associated with it are layers of gneiss rich in large garnet crystals, chlorite, limonite, and orthorhombic pyroxene. Similar ultrabasic dikes occur elsewhere in the region.

In adit 2 of the Elk Creek deposit (pl. 13) irregular dikes of dark green-brown, fine-grained, nonporphyritic basalt occur along small

[13] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (no. 24), 1896.

faults in the metamorphic rocks. The basalt is severely fractured and altered, but several minerals can be identified under the microscope. Augite crystals make up about one-fourth of the rock; labradorite is slightly less abundant; and part of the fibrous secondary minerals may have resulted from the alteration of olivine.

A small body of diabase crops out about 1½ miles southwest of the Elk Creek deposit, and basalt occurs south of the Bozeman deposit. Other small bodies of igneous rock undoubtedly occur nearby. The basalt and porphyry intrusives are younger than the corundum-bearing rocks and are unrelated to them.

Quartz veins and mineralized fractures in pre-Cambrian gneiss in the region west and southwest of the corundum deposits have yielded gold and other metals; a few pits have been dug by prospectors along iron-stained fractures and quartz veins in metamorphic rocks near the corundum deposits. Small veins of barren quartz are numerous at the Bear Trap deposit, and boulders of vein quartz were found in the Elk Creek area. These quartz veins and mineralized fractures are evidently younger than the corundum deposits.

STRUCTURE

The major structural features of the region in which the corundum deposits occur are indicated on plate 11. Paleozoic sedimentary rocks are preserved in two belts on the down-dropped sides of the two steeply dipping normal (?) faults. In the vicinity of each of the corundum deposits the metamorphic rocks have a fairly uniform strike and dip except where the structure is complicated by local folds and small faults.

At the Elk Creek deposit the alternating layers of gneiss and quartzite strike about N. 70° E., and the dip ranges from 51° to 68° NW. (pl. 12).

At the Bozeman deposit the average strike of the metamorphic rocks is about N. 65° W. and the average dip about 40° NE. The foliation of the gneiss is generally parallel to the quartzite layers. The rocks of the Bozeman deposit, however, exhibit several structural complexities. Some beds of quartzite thicken and end abruptly, and many others are lenticular. The corundum zones cannot be projected with assurance from trench to trench. Small isoclinal folds occur locally in the gneiss, and the large number of corundum zones in trenches 1 to 4 may be due in part to duplication by folding. Similarly, the thick lenses of quartzite may be beds that have been repeated or thickened by folding. More definite evidence of folding is found in the V-shaped outcrop pattern of the quartzite 160 feet southwest of the south end of trench 21 (pl. 14); however, the exposures are so limited and scattered that no definite pattern of folding is disclosed, and some of the irregularities are doubtless due to original lenticularity and discontinuity of the sandstone and shale beds from which the quartzite and gneiss were derived.

The average strike of the gneiss and quartzite layers at the Bear Trap deposit is N. 70° E., and the dip is commonly between 75° SE. and vertical. Some outcrops of hornblende gneiss show clearly that the banding and foliation of these rocks locally bear a complex relationship to the present regional structure. An early set of contorted and folded bands of gneiss with a distinct alinement of the mineral constituents is transected by a later set of fractures and a crude superimposed foliation. The superimposed fractures and foliation parallel the major structure of the metamorphic rocks as disclosed by the trend of the ridges of hornblende gneiss and the attitude of the quartzite beds.

CORUNDUM DEPOSITS

ELK CREEK DEPOSIT

Part of the Elk Creek deposit was developed and mined during the years 1901–3 by the Montana Corundum Co. The company failed to show a profit on this venture, and the mining claims lapsed during the period of inactivity following 1903. Mineral rights in the area are now held in conjunction with surface rights by private owners of the agricultural and grazing lands.

In 1943 Leverett S. Ropes, of Helena, Mont., leased the mineral rights of part of the deposit in an effort to bring about the reopening of the mine. By the end of the same year the United States Bureau of Mines had begun a program of exploration that continued for more than a year and included bulldozer trenching, sampling, diamond drilling, and underground work. During the summer of 1944 Louis M. Fuller, president of the American Abrasives Co., purchased the Sterling ranch, on which part of the deposit is located.[14] The Industrial Minerals Corp. then was organized as a subsidiary of the American Abrasives Co. to undertake the production of corundum from the deposit. The development of a domestic source of coarse corundum crystals was encouraged by the War Production Board because the requirements of the grinding-wheel industry were not being met by corundum imports.[15] The corporation continued to explore the deposit both by bulldozer trenching and by underground development. Late in the spring of 1945 the Metals Reserve Company took over operations at the Industrial Minerals Corp. property for the purpose of mining and milling a test lot of the ore. Mill tests indicated that a large

[14] Mining World, Sept. 1944, and Business Week, Aug. 12, 1944.

[15] Eagle, J. E., in a report by the War Production Board, Mining Congress Journal, Feb. 1945.

part of the corundum could not be recovered as coarse grains suitable for the manufacture of grinding wheels. No large reserves had been developed at the deposit, and the Industrial Minerals Corp. decided to discontinue preparations for mining and milling.

The Elk Creek corundum deposit has been known by many names. It is commonly called the "Montana mine" as a result of the early operations of the Montana Corundum Co. The United States Bureau of Mines used the name "Gallatin deposit," and the names "Fuller corundum mine" and "Industrial Minerals Corp. property" were later applied to that part of the deposit controlled by the American Abrasives Co. The remainder of the deposit is owned by Flying D Ranges, Inc., and has been called by that name. The name "Elk Creek deposit" is widely known and is perhaps the least confusing designation for the corundum occurrences in secs. 22 and 23, T. 3 S., R. 3 E.

The general nature of the metamorphic rocks in which the corundum deposit occurs has been discussed in the section on metamorphic rocks, and the geologic setting of the deposit is shown on plate 11. Deep weathering has developed a soil cover that obscures most of the underlying bedrock; only exposed rocks have been plotted on the map of the deposit (pl. 12). Ridges and knobs of quartzite crop out most commonly, but trenches indicate the abundance of gneiss. All the gneiss has been grouped under the term "hornblende gneiss" on the map, because hornblende is generally the most prominent and locally the most abundant mineral in the gneiss. The gneiss varies widely in composition, however, and some parts of it consist chiefly of biotite, muscovite, feldspar, or garnet. Lit-par-lit banding is common, and larger stringers and dikes of quartz-feldspar-mica pegmatite are numerous, but the pegmatites are not shown on the map.

Corundum-bearing rock occurs in several thin lenses in the Elk Creek deposit (pl. 12). The largest of these is the lens in which the workings of the old Montana mine are located. It was further explored by the Bureau of Mines shaft and drift and by Industrial Minerals Corp. adit 1. The approximate outline of the lens and its location with reference to the old workings are shown on the longitudinal projection (pl. 12). The underground workings of the Montana mine have caved since the property was abandoned in 1903; the description of the old workings is based on information supplied by Leverett S. Ropes, engineer for the milling operations during the period 1901–3, and taken from published records.[16]

At the Montana mine an inclined shaft was sunk more than 110 feet on a steeply dipping zone of corundum-sillimanite gneiss. Drifts were driven northeast and southwest from the shaft about 50 or 60

[16] Montana Bureau of Agriculture, Labor, and Industry, 8th Ann. Rept., pp. 443–446, 1902.

feet below the surface, and the corundum-bearing rock was stoped out for more than 100 feet in both directions. One hundred feet southwest of the shaft a raise was driven from the drift to the surface, and a winze was sunk below the raise for a few feet. Both were in corundum-bearing rock. On the surface the corundum-bearing zone was prospected by a shallow trench 220 feet northeast of the caved main shaft; corundum crystals and fragments can be picked up along the full length of the caved trench. Southwest of the old Montana shaft the corundum-bearing gneiss horizon was prospected by a short adit and several pits.

The Bureau of Mines sank a shaft 300 feet southwest of the caved shaft of the Montana mine to explore the corundum-bearing lens along its strike and diamond-drilled a hole to intersect the corundum-bearing horizon approximately 150 feet below the surface. The shaft, drifts, and diamond-drill hole are shown by section *A–A′* and the map of underground workings on plate 13. Sample data of the Bureau of Mines are included. The average thickness of the corundum-sillimanite gneiss layer in the Bureau of Mines shaft and drifts is about 2 feet, and the average corundum content is about 12 percent by weight.

Adit 1 was driven by the Industrial Minerals Corp., and a winze was sunk almost to the lower margin of the corundum-bearing lens (pl. 13). The average width of the lens in the winze is about 2 feet, but the corundum content of the rock is lower than in the Bureau of Mines shaft.

Between adit 1 and the northeast end of the old mine workings the main lens of corundum-bearing rock has a length of at least 800 feet, a vertical extent of about 50 feet, and an average width of approximately 2 feet. The average corundum content is probably not less than 10 percent by weight. No other body of corundum-bearing rock at the three deposits approaches this lens in size. The corundum-sillimanite gneiss has been described in the general section on corundum-bearing rocks (pp. 34–35).

All exploration along the main corundum-bearing lens indicates that it rakes about 15° SW. and that its northeast extension has been eroded away. Beyond a point 300 feet northeast of the caved shaft the basinlike upper part of a steep northwest-trending valley cuts across the strike of the corundum horizon, but the dip of the corundum horizon (50° to 60° NW.) is so much greater than the gradient of the valley that the projected trace of the zone is high on the hillside. Two old trenches on the southwest side of the valley do not expose bedrock and are caved and overgrown. The soil cover is estimated to be 5 to 15 feet thick here. Fragments of sillimanite-corundum gneiss are to be seen on the dump of a caved pit 1,400 feet northeast of the old shaft. The rock was not observed in place, but some fragments at least 8 inches wide contain corundum, chiefly as small euhedral grains. A few large crystals of corundum are present also. No other occurrences of sillimanite or corundum were observed between the old mine workings and the exposures of younger sedimentary rocks that overlie the gneiss about three-fourths of a mile northeast.

Southwest of the main corundum lens adits, trenches, and pits have been dug along approximately the same horizon for a distance of more than 5,000 feet (pl. 12). Most of these workings have uncovered one or more thin layers of sillimanite gneiss containing a small percentage of corundum. Adit 2 exposes one thin stringer of sillimanite gneiss, and other thin layers occur in the trench beside the adit at points 26, 28, and 102 feet southeast of the portal. The rocks exposed in this trench and in adit 3 are complexly folded, broken, and locally intruded by irregular dikes of basalt. The scale of folding is so small that the folds cannot be shown on plate 12. Only one 2-inch stringer of sillimanite gneiss is exposed in adit 3. The Elk tunnel explores three layers of sillimanite gneiss, all of which contain corundum, though apparently less than 5 percent, and none of the layers is more than a foot in average width. Most of the trenches and pits between the Elk tunnel and the Sunset shaft expose from one to four thin layers of sillimanite gneiss, but the average width of each of these layers is probably less than 5 inches, and only at a few places do they contain more than 2 or 3 percent corundum. A little sillimanite, but no corundum, was recovered from a depth of 80 feet in diamond-drill hole 7.

The Sunset shaft and the drifts from it follow two or three layers of sillimanite gneiss, the thicker parts of which contain several percent corundum; however, the average width of the corundum-bearing layers exposed underground and in the trenches is only a few inches. Diamond-drill hole 6 intersected only one thin stringer of corundum-sillimanite gneiss. The two trenches at the extreme southwest end of the mapped area (pl. 12) expose one to three layers of sillimanite gneiss or garnet-sillimanite gneiss. Only one layer, a few inches thick, contained corundum.

Diamond drilling proved unsatisfactory because of poor core recovery. All the work tended to show that thin layers of sillimanite gneiss, usually with a little corundum, are common throughout the explored length of the horizon. The work, however, failed to disclose other bodies of corundum-bearing rock comparable in size or corundum content to the main zone in which the old mine workings are located. Further trenching and underground exploration may be expected to extend the area in which corundum is known to occur, but the results of past exploration indicate that the chances of finding minable bodies of corundum-bearing rock are poor.

BOZEMAN DEPOSIT

The Bozeman corundum deposit is in sec. 31, T. 2 S., R. 4 E., on Federal grazing land about 5 miles northeast of the old Montana corundum mine. It was prospected and partly developed about 1902 or 1903, when it was known as the Bozeman Corundum Co. mine. It can be reached by car or truck by driving 2 miles north along the trail in open ranch land from the county road in the northern part of sec. 7, T. 3 S., R. 4 E. The rail terminus at Gallatin Gateway is approximately 8½ miles by road from the deposit (pl. 11).

The corundum prospect is on a low ridge of pre-Cambrian rocks that projects through a cover of Tertiary lake beds and deep soil. Along the projected strike of the corundum zones the older rocks are concealed both to the northwest and to the southeast for a mile or more beyond the limits of the mapped area (pl. 14).

In 1902 the property was developed by five shallow shafts and two tunnels, and "good showings" of corundum crystals were said to characterize all the workings.[17] No production is recorded, but test lots of corundum-bearing rock may have been milled at the nearby Montana mine. The Bozeman deposit was abandoned after the Montana mine was closed in 1903. In the fall of 1943 S. K. Neuschel and F. C. Armstrong, of the Geological Survey, visited the deposit. They observed corundum crystals on the old dumps and found one exposure, a foot wide, of corundum-sillimanite gneiss estimated to contain 10 percent or more corundum. In 1944–45 the Bureau of Mines explored the deposit by bulldozer trenching and extensive sampling. This work revealed an unexpectedly large number of small corundum-bearing lenses and also demonstrated rather conclusively that no zones of minable width and grade are present. In general, the old workings were found to be in the richest lenses of corundum-bearing gneiss.

The geology of the Bozeman deposit is similar to that of the Elk Creek deposit. Thin lenticular layers of corundum-bearing rock occur in pre-Cambrian gneiss that contains numerous beds of quartzite. The natural exposures are poor; only the thicker layers of quartzite and the harder zones of hornblende gneiss or hornblende-garnet gneiss crop out (pl. 14). Exposures in trenches indicate that gneiss is more abundant than quartzite, although quartzite forms most of the outcrops. The quartzite is generally hard, coarse-grained, and almost pure, but locally it is soft, gneissic, and micaceous. The gneiss is characterized by an abundance of hornblende, but its mineral composition is highly

[17] Montana Bureau of Agriculture, Labor, and Industry, 8th Ann. Rept., pp. 445, 1902.

varied and it ranges from nearly pure hornblende rock to mica-feldspar gneiss or garnet-quartz gneiss. Stringers of coarse feldspar and quartz are locally abundant, and small dikes and irregular masses of coarse-grained pegmatite are common. The chief constituents of the pegmatites are quartz, mica, and microcline or albite.

Corundum-bearing layers occur in two areas at the Bozeman deposit. The southern zone, explored by trenches 1 to 16, is separated from the northern zone (trenches 17 to 29) by several hundred feet of barren gneiss and quartzite. Several layers of corundum-bearing gneiss occur in each zone. The distribution of these layers is shown on the map (pl. 14), to which sample data of the Bureau of Mines have been added.

The southern zone includes two groups of corundum-bearing layers. One group, exposed in trenches 1 to 10, consists of two to six distinct lenses, which range from less than an inch to more than a foot in thickness and contain less than 1 to 12.5 percent corundum. Trenches 1 to 4 expose four to six layers of corundum gneiss, but not all the layers can be projected from one trench to the next. One of the layers is probably continuous with the 1-foot bed exposed in the old pit and with the double layer of corundum gneiss in trench 7. Little or no corundum-bearing rock occurs in adit 1, but two layers 25 to 35 feet apart are exposed east of the adit in trenches 8, 9, and 10. The most reasonable interpretation of this group of corundum-bearing layers is that samples 1, 4, 10, 12, 14, 16, 18, and 20 are from a single more or less continuous layer, samples 3, 6, and 9 from another, and samples 15, 17, and 19 from a third. On this assumption the first layer is 600 feet long, has an average width of 0.55 foot, and an average corundum content of 5.5 percent by weight. The second layer is 60 feet long and 0.5 foot wide and contains 5.1 percent corundum; the third is 170 feet long and 0.7 foot wide and contains 0.9 percent corundum. The second group of corundum-bearing layers in the southern zone is exposed in trenches 11 to 16. Samples 21, 23, 24, 25, 26, and 28 are possibly from one continuous layer, but the lenses from which samples 22 and 27 were collected cannot be projected beyond the trenches in which they are exposed. If the corundum layer is continuous, it is at least 650 feet long, has an average width of 0.6 foot, and contains an average of 5.8 percent corundum.

The northern zone also includes two horizons of corundum-bearing rock. One of these is a single layer that extends from the caved shaft northwest of adit 3 to trench 20, where the layer is 0.5 foot thick and contains 6 percent corundum. A possible extension of this layer was identified in trench 21, but no corundum was found in it there. The layer may continue westward beyond the caved shaft, but it was not found in trench 17, where exposures were unsatisfactory because of the deep soil cover. Adit 3 is caved near the portal. The corundum-bearing layer was partly mined out from the old workings, leaving a small caved stope above the adit. The corundum zone is reported to thin eastward in the adit as it does at the surface. The best showings were probably in the old shaft, for the dump contains numerous small corundum crystals and fragments of corundum-bearing rock. Exposures along this horizon are inadequate for an estimate of the dimensions of the corundum-bearing layer, but it is evidently more than 150 feet long. Part of the layer is at least 0.5 foot wide and contains several percent corundum.

The second horizon, exposed in trenches 22, 24, and 26 to 29, is a group of at least three or four lenses, the most persistent of which branches to form a double layer along most of its exposed length. The average width of the main layer, including the combined width of the two segments where the layer is double, is about 1.1 feet, and the average corundum content is less than 0.3 percent. From trench 22 to trench 29 the exposed length is 670 feet, but the layer is barren, thin, or absent at many places. The richest lens sampled in the second horizon was 0.5 foot thick and contained 2.5 percent corundum. Other lenses of corundum-bearing rock in this group are either very lean or discontinuous, and many samples contained no corundum. In the westernmost 25 feet of adit 2 a double layer of corundum rock is exposed. Samples 51 to 56 from these two stringers contained an average of 0.3 percent corundum. East of a transverse pegmatite dike in the adit the corundum-bearing rocks are offset to the north a few feet by a small fault along which the pegmatite was emplaced. This adit and the pits within 100 feet west of it are the source of the "ruby" corundum crystals. A few of the crystals occur in nests of biotite and are irregular in outline, but the corundum rock here is otherwise similar to that found elsewhere in the region.

Resources of corundum in the Bozeman deposit are unimportant because the mineral occurs in thin lenses of corundum-bearing gneiss and the quantity of corundum in the gneiss is small. Although the continuity of many lenses is questionable, other lenses probably occur at depth in both zones with the same frequency as at the surface.

BEAR TRAP DEPOSIT

The Bear Trap corundum deposit is in high mountain country at the northern margin of the Gallatin National Forest in sec. 6, T. 4 S., R. 2 E., Madison County. It is reached by car over a ranch road approximately 9 miles long that branches from the Norris-Bozeman road at the east end of the Madison River bridge. The deposit may also be reached by a ranch road from the Anceney Cow Camp (pl. 11). Although the Bear Trap deposit is in an area of relatively great relief and is at a higher altitude than the Elk Creek and Bozeman deposits, exposures of bedrock are less abundant, and bulldozer trenches or other workings were necessary to explore the lenses of corundum-bearing rock.

Two or more old prospect pits were known to expose corundum-bearing rock in this area prior to the exploratory work of the Bureau of Mines. An old claim, the "Tommy Kay," covers the area in which the adit and compressor house are located. The Bureau of Mines explored the deposit in 1944 and 1945 by about 35 bulldozer trenches, a few hand trenches, and a short adit. Sample data of the Bureau of Mines are included on the map of the deposit (pl. 15).

The rocks exposed in the vicinity of Bear Trap Creek are pre-Cambrian gneiss with quartzite layers, numerous pegmatites and a few quartz veins, and small dikes of younger igneous rocks. A few differences between the geology of the Bear Trap area and that of the other two deposits have been discussed: Quartzite is much less abundant, outcrops of hornblende gneiss are more prominent, and pegmatites are larger and more continuous, although they are not especially abundant in the immediate vicinity of the corundum-bearing rocks. The dikes of andesite porphyry and peridotite have been described, and the occurrence of veins of quartz has been mentioned in the section on intrusive porphyries and quartz veins (pp. 39–40).

On the map of the Bear Trap deposit (pl. 15) several varieties of gneiss are distinguished. Dark-colored hornblende gneiss crops out most abundantly. Typical specimens range in composition from hornblende-garnet-quartz gneiss to hornblende-feldspar gneiss and rarely to almost pure hornblende rocks. The grain size is usually between a half millimeter and 4 millimeters. Included with the hornblende gneiss are lit-par-lit gneiss and lighter-colored biotite-feldspar gneiss. Probably because they weather more readily, they rarely crop out, but both are common in trenches. A very fine grained dense gneiss crops out near the northern edge of the mapped area and is distinguished on the map. It consists chiefly of garnet, hornblende, and feldspar in grains less than half a millimeter in diameter. Three natural exposures of light-colored gneiss, similar in composition and appearance to granite but strongly foliated, were mapped, and trenches and surface debris show that the lighter-colored and intermediate varieties of gneiss are fairly abundant. Several pegmatite bodies are shown on the map, and stringers of pegmatite are common in most of the gneiss. The larger pegmatites consist chiefly of quartz, perthite, and muscovite.

Two horizons of corundum-bearing rock were located at the Bear Trap deposit. Exploratory work failed to find either the eastern extension of the northern horizon or the western extension of the southern horizon, and the two are interpreted as segments of a single horizon offset approximately 300 feet by a north-trending fault. Additional evidence for the existence of the fault is the offset of the ridge along which hornblende gneiss and light-colored gneiss are in contact and the absence of outcrops of fine-grained hornblende-garnet gneiss west of the inferred position of the fault (pl. 15). A few minor faults were noted, but exposures are so poor that the detection of faults with small displacement is difficult.

The best-exposed and probably the largest body of corundum-bearing rock at the Bear Trap deposit is the lens explored by the Bureau of Mines adit and winze (pl. 15). It is approximately 50 feet long, 5 to 6 feet thick near the center, and about 15 feet or less in vertical extent. The lens is an elongated body with an almost vertical dip; it plunges about 20° NE. Bureau of Mines samples indicate that the average corundum content of the lens is 6 to 7 percent by weight, and the average sillimanite content is about 5 percent.

Small stringers and thin lenses of corundum-bearing rock are exposed southwest of the large lens in the wall of the open-cut near the portal of the adit and in the small trench below the dump (pl. 15). In the face of the adit is a thin layer of corundum-bearing rock composed almost entirely of muscovite, and the first trench northeast of the adit exposes about 6 inches of corundum-bearing rock. A few loose pieces of corundum-bearing rock were found in the shallow trench about 50 feet east of the compressor house.

Corundum was found at only one other place in the segment of the horizon west of the fault. Three small, closely spaced, almost continuous lenses totaling about 100 feet in length are exposed in a long trench that is nearly parallel to the road near the crest of the hill. The largest lens in the trench is about 25 feet long and 6 to 12 inches wide and contains more than 10 percent corundum. The other two lenses are narrower, and the corundum content of each is less than 10 percent. Most of the corundum crystals in these zones are small and subhedral. The rock is similar to that of the lens in the adit except that the sillimanite content is highly variable, ranging from a trace to 38 percent in the Bureau of Mines samples. A few unusually large corundum crystals associated with coarse crystals of muscovite and perthite were observed.

Near the road intersection several small lenses of corundum-bearing rock are exposed by a series of bulldozer trenches. The location, approximate extent, thickness, and corundum content of these bodies are shown by the map and sample data (pl. 15). Muscovite is the most abundant mineral in the lenses, plagioclase is less abundant than microcline, and biotite is rare or absent. Corundum occurs in places as small grains enclosed in muscovite and elsewhere in crystals 1 inch or more in length, generally enclosed in augenlike masses of microcline. The average corundum content of the lenses is between 4 and 8 percent, and the average thickness is 4 to 6 inches. Immediately east of the road to the camp on Bear Trap Creek, corundum occurs in two 6- to 12-inch layers of muscovite-feldspar rock separated by about 3 feet of barren hornblende gneiss. The longest of these lenses was traced for about 60 feet, and the two smaller ones for 20 feet. Samples from this area (samples 10 to 26) show an interesting reciprocal relation between the corundum content and the sillimanite content of the rock. Samples 11, 24, 25, and 26 contain considerable sillimanite but very little corundum, whereas the other samples contain little or no sillimanite but considerable corundum.

About 600 feet east of the road intersection, a series of short trenches and an old pit expose a layer of sillimanite gneiss about 50 feet long and 0.5 to 2 feet thick. The two Bureau of Mines samples contained 4 to 6 percent corundum and 56 to 68 percent sillimanite. On the dump of the old pit are a few small specimens of dense, hard gray rock composed entirely of sillimanite and a minor amount of rutile intergrown with an opaque black mineral.

The largest of the four trenches at the eastern margin of the map (pl. 15) exposes a corundum-bearing layer 2 to 3 inches wide that contains from 6 to 11 percent corundum. A few corundum crystals are reported to have been found in the soil within a few hundred feet east of the trenches.

Tonnages of corundum-bearing rock in the Bear Trap deposit are small. The lens in the adit contains only a few hundred tons of rock, and other lenses are narrow and discontinuous. Because of the numerous inclusions of muscovite and feldspar and the moderately extensive alteration to sericite, the corundum may not be of suitable quality for use in abrasives. Sillimanite is more abundant than corundum in the deposit, but the lenses in which it occurs are too small, narrow, and scattered to merit attention as a possible source of that mineral. Although there is a possibility that richer and larger lenses of corundum-bearing rock may be found in or near the Bear Trap deposit, the results of exploration by the Bureau of Mines are discouraging.

OTHER OCCURENCES IN GALLATIN AND MADISON COUNTIES

Pratt [18] reported that the "Anceny corundum deposit," 5 miles west of the Elk Creek deposit, was being developed in 1906, but in 1944 and 1945 it could not be located, and no one in the area knew of its existence. Ray Woodriff, of Montana State College, found a loose piece of corundum-bearing rock near the northwest corner of sec. 16, T. 1 N., R. 6 E., in the foothills of the Bridger Mountains north of Bozeman. Gneiss and marble beds of the Cherry Creek group crop out in that area, and kyanite occurs in some of the hornblende-garnet gneiss, but corundum has not been observed in place. Winchell [19] described an occurrence of

[18] Pratt, J. H., Corundum and its occurrence and distribution in the United States: U. S. Geol. Survey Bull. 269, p. 133, 1906.

[19] Winchell, A. N., Mining districts of the Dillon quadrangle, Montana, and adjacent areas: U. S. Geol. Survey Bull. 574, p. 148, 1914.

corundum associated with contact-metamorphosed limestone near Bear Gulch in the Tobacco Root Range. A. W. Tanner found pale-colored, transparent, industrial sapphires in placer workings on Pole Creek, between the Elk Creek and Bear Trap deposits. This type of corundum in other placer deposits in Montana is derived from dikes rather than from pre-Cambrian metamorphic rocks, and the sapphires in Pole Creek are probably from a similar source.

RESERVES

The main lens in the Elk Creek corundum deposit is the largest and richest body of corundum-bearing rock in the three deposits southwest of Bozeman. Corundum mining from the main lens proved unprofitable during the period 1901–3, and production was evidently considered economically impractical in 1945 when the Industrial Minerals Corp. abandoned plans for exploiting the deposit. Exploration has been adequate to demonstrate that this lens probably includes several thousand tons of rock containing about 10 percent corundum.

A large tonnage of rock containing 5 percent or less corundum undoubtedly occurs in the Bozeman deposit and in the smaller bodies of the Elk Creek deposit, but it is chiefly in discontinuous layers 6 inches or less in average width. The known volume of corundum-bearing rock in the Bear Trap deposit is negligible.

Under emergency conditions the corundum deposits of Gallatin and Madison Counties might be worked to produce about 1,000 tons of abrasive corundum at high cost. Even with the discovery of additional deposits of the same types, the area could supply only a small fraction of the corundum normally required by industries in this country. The recovery of sillimanite from the corundum-bearing rock also has been considered. The average corundum-bearing gneiss in the Bozeman deposit contains less than 5 percent sillimanite; that in the Elk Creek deposit, 5 to 25 percent; and some of the rock in the Bear Trap deposit, as much as 68 percent. Examination under the microscope shows that some of the sillimanite is intimately intergrown with biotite and muscovite, and concentrates of sillimanite were found to have a high iron content.

Further exploration in the vicinity of the three known deposits of abrasive corundum will undoubtedly extend the areas in which corundum is known to occur, and it may disclose new lenses of corundum-bearing gneiss. The bedrock exposures are so poor that extensive trenching and underground work are necessary for satisfactory exploration of the deposits, but it is not likely that corundum-bearing bodies appreciably larger and richer than those already known will be found.

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