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CORUNDUM

AND

ITS OCCURRENCE AND DISTRIBUTION IN THE UNITED STATES

(A REVISED AND ENLARGED EDITION OF BULLETIN NO. 180)

BY

JOSEPH HYDE PRATT

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CORUNDUM AND ITS OCCURRENCE AND DISTRIBUTION IN THE UNITED STATES.

By Joseph Hyde Pratt.

HISTORICAL SKETCH.

Ruby and sapphire, the corundum gems, have been known since prehistoric times. Our earliest accounts tell of their use among the ancients, both as ornaments and as money. The early Greeks and Romans were not only familiar with these gems, but made considerable investigation into their physical properties and described their occurrences.

Of the use of corundum as an abrasive, there is no record until recent years. Some believe, however, that the perfection of the engravings upon monuments of the Egyptians is due to the use of emery, which they might have obtained from the large deposits of the Grecian Archipelago.

The first known discovery of corundum in quantity sufficient to make it of value as an abrasive was that of the emery fields of the Grecian Archipelago, and up to 1847 all the corundum used as an abrasive was obtained from these islands, principally from the island of Naxos. In that year Dr. J. Lawrence Smith, the American pioneer in corundum mining, then in the employ of the Turkish Government, discovered important emery deposits in Turkey. The importance of this discovery was clearly realized when, in 1850, on account of the working of these deposits, the price of emery dropped from $140 to $70 and $50 a ton. Since that time both the Turkish and the Grecian emeries have been mined and exported.

In India, besides the occurrence of gem corundum, there have been known for many years various localities where corundum not of a sapphire variety exists, but only in the last few years have these deposits been developed and the corundum mined and exported for abrasive purposes.

So far as can be learned from the literature on the subject, corundum was first known in America in 1819. In that year Mr. John Dickson, of Columbia, S. C., sent a lot of minerals which he had collected on a tour through the Carolinas to Prof. B. Silliman, of Yale University. In the collection there was a well-formed six-sided crystal of blue corundum, three-fourths of an inch long and an inch in diameter, with parting striæ developed similar to those of the East Indian corundum. The crystal was sent without label, and, in reply to an inquiry as to its locality, Mr. Dickson wrote:[a] "I think it was Laurens district; at all events, it was picked up by my own hands, if not in situ, in a place * * * which it could have reached only by one of the usual and natural accidents which displace minerals of all kinds. * * * I am sure it is American and Carolinian."

In 1822 both Profs. Edward Hitchcock and Parker Cleaveland[b] described a mass of cyanite found at Litchfield, Conn., "associated with talc, sulphuret of iron, and corundum * * * supposed to weigh 1,500 pounds." The corundum was massive and in six-sided prisms, of a dark grayish-blue color, and embedded in cyanite. Both of these authors attribute their information to Mr. John P. Brace.

Mr. Samuel Robinson in 1825 mentions corundum in the list of minerals occurring in the vicinity of Franklin, N. J.[c]

In April, 1827, at a meeting of the Lyceum of Natural History, New York, "Major Delafield[d] * * * exhibited crystals of sapphire from Newton, Sussex County, N. J." In 1832 Doctor Fowler[e] described this locality, pointing out the geologic and mineralogic relations of the corundum. It is found along the border of crystalline limestone.

According to Mr. W. W. Jeffries, as quoted by Mr. Joseph Willcox, Messrs. John and Joel Bailey claim to have discovered corundum in the serpentine region of Chester County, Pa., about 1822 to 1825. Dr. Thomas Seal collected specimens at Unionville about 1832; Mr. Jeffries himself saw large lumps in the fields there in 1837 or 1838;[f] and a ton of surface fragments and bowlders was collected about 1839 and shipped to Liverpool. But the search for the source of this material was unsuccessful till 1875, when a large lenticular mass was found in place. This consisted chiefly of corundum and margarite and carried some fine specimens of diaspore.[g]

In a report on the mineralogy of New York, in 1842, Mr. Lewis C. Beck mentions the occurrence of corundum in the white limestone near Amity, in Orange County.

The discovery in North Carolina was of a large detached block of dark-blue laminated corundum, found on the French Broad River 3

[a] Am. Jour. Sci., 1st ser., vol. 3, 1821, pp. 4, 229, 230.

[b] Am. Jour. Sci., 1st ser., vol. 6, 1823, p. 219; Cleaveland's Mineralogy and Geology, Boston, 1822.

[c] A Catalogue of American Minerals, with Their Localities, Boston, 1825, p. 165.

[d] Am. Jour. Sci., 1st ser., vol. 13, 1828, p. 380.

[e] Am. Jour. Sci., 1st ser., vol. 21, 1832, pp. 319, 320.

[f] Second Geol. Surv. Pennsylvania, C, 1883, pp. 346–351.

[g] Second Geol. Surv. Pennsylvania, B, 1895, pp. 31–33.

miles below Marshall, in Madison County, in the spring of 1847.[a] Gen. T. C. Clingman, after considerable search, found another piece in the same vicinity in 1848, about a year after the first discovery of emery in place in Asia Minor by Dr. J. L. Smith.

The first authenticated record of the occurrence of corundum in Georgia[b] was made in 1852, when Mr. Plant, a banker of Macon, Ga., sent a ruby crystal to Professor Shepard at Amherst. This, like others, had been found in washing for gold.

In 1852 Mr. W. P. Blake[c] described corundum from the new locality at Vernon, Sussex County, N. J. In the spring of the same year Dr. C. L. Hunter[d] discovered corundum and emery in place in Gaston County, N. C.

The first record of the occurrence of corundum in Canada was made in 1863. The report of the Geological Survey of Canada for that year (p. 499) describes the occurrence of corundum in Burgess.

In 1864 the occurrence of emery at Chester, Mass., was predicted by Dr. C. T. Jackson because of his discovery there of margarite, a mineral which Dr. J. L. Smith had just found to be characteristic of the emery deposits of Asia Minor. On the 6th of September of the same year Dr. H. S. Lucas[e] discovered emery in what had before been considered only deposits of magnetic iron ore. Two years later distinct crystals of corundum were found in the same deposits.[f] This discovery of emery soon led to the establishment of active mining, the first of its kind in America. This mine is still worked, and though it has not been operated continuously from the beginning, it is still the main producer of corundum in this country.

In 1870 Mr. Hiram Crisp found the first corundum that attracted attention to the present mining regions of North Carolina, at what is now the Corundum Hill mine (Pl. IX). A specimen was sent to Prof. W. C. Kerr, then State geologist of North Carolina, for identification, and considerable interest was aroused upon discovering that it was corundum. In the same year Mr. J. H. Adams[g] found corundum in a similar occurrence at Pelham, Mass.

In 1870–71 considerable activity was displayed in the search for corundum in the peridotite regions of the southwestern counties of North Carolina, and new localities were soon brought to light in Macon, Jackson, Buncombe, and Yancey counties. In 1871 Dr. F. A. Genth[h] also discovered the emery of Guilford County. About this

[a] Bull. U. S. Geol. Survey, No. 74, 1891, pp. 29–31.

[b] Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 109; and Geol. Surv. Georgia Bull., 2, 1894, p. 18.

[c] Am. Jour. Sci., 2d ser., vol. 13, 1852, p. 116.

[d] Am. Jour. Sci., 2d ser., vol. 15, 1853, p. 376.

[e] The exact date was furnished by Doctor Lucas.

[f] Am. Jour. Sci., 2d ser., vol. 39, 1865, pp. 87–90; vol. 42, 1866, p. 421.

[g] Am. Jour. Sci., 2d ser., vol. 49, 1870, p. 271.

[h] Rept. Geol. Surv. North Carolina, vol. 1, 1875, p. 246.

time Mr. Crisp and Dr. C. D. Smith began active work on the Corundum Hill property, and obtained about a thousand pounds of corundum, part of which was sold to collectors for cabinet specimens. Some of the masses that were found weighed as much as 40 pounds.

Systematic mining for corundum did not begin until the fall of 1871, when the Corundum Hill property was purchased by Col. Charles W. Jenks, of St. Louis, Mo., and Mr. E. B. Ward, of Detroit, Mich., and work was soon begun under the superintendence of Colonel Jenks. This was the first systematic mining of common corundum as distinguished from emery and the gem varieties ever undertaken in this country, the mining at Chester, Mass., being for the emery variety of corundum.

In the following spring (1872) the Laurel Creek or Pine Mountain mine, in Rabun County, Ga., was opened by Colonel Jenks. This was the beginning of corundum mining in Georgia, although about the time that corundum was first found at Laurel Creek (1870) Mr. William R. McConnell, of Hiawassee, Towns County, had obtained a considerable quantity of surface corundum on his estate. In the spring of 1875 both the Corundum Hill and the Laurel Creek mines passed into the hands of Dr. H. S. Lucas, of Chester, Mass., who for many years was the main promoter in extending the corundum industry.

In 1874 or 1875 corundum was discovered near Statesville, in Iredell County, N. C. In a letter in regard to this discovery Mr. J. A. D. Stephenson writes:[a] "The first corundum found in Iredell County was found by myself near where the Collins (Acme) mine is now located, either late in 1874 or early in 1875. It was a mass weighing probably 2 pounds. I also found a lot of pink fragments near by." Soon afterwards corundum was discovered on the surface at many other points in this county and in the adjoining (Alexander) county on the west.

Since these early discoveries prospecting for corundum has been carried on very vigorously in the peridotite belt of Georgia and North Carolina, and many deposits have been located, but because of their remoteness many of them have been but little developed.

Until the year 1899 the corundum deposits of Georgia and North Carolina furnished nearly all the corundum (exclusive of emery) used in this country. A very small quantity was obtained from Pennsylvania. Many localities throughout the Eastern States had been prospected for corundum, and at a number of places in Alabama, South Carolina, Pennsylvania, and Massachusetts mining on a small scale had been undertaken; but although in most cases a little corundum was shipped, none of these localities developed commercial mines of this mineral.

[a] Letter to Prof. J. Volney Lewis, Rutgers College.

In 1899 mining was begun on the corundum deposits in Ontario, Canada (p. 151), and these have since become the chief producers of this mineral in America.

Work on the Montana corundum deposits (p. 133) began in 1900, and they are now in such condition that their product can be shipped in competition with that from other localities.

The latest discovery of corundum in America was in Plumas County, Cal. (p. 42). It was prospected to some extent in 1901, but no commercial quantities of corundum have been located.

NOMENCLATURE OF CORUNDUM.

There are now recognized three varieties of corundum, depending on purity, degree of crystallization, and structure. These are: (1) Sapphire, including all the highly colored varieties of corundum which are transparent to translucent and are of value as gems; (2) corundum, including all those varieties of dark and dull colors and also the massive lighter-colored varieties that are not transparent, as the blue to gray, brown, and white; and (3) emery, including the intimate mixture of very fine granular corundum with magnetite and sometimes with hematite, in appearance very similar to a fine-grained iron ore, with which it was at first often confused. These varieties are described in detail on pages 22 to 26. In 1805 Haüy formally united these different varieties under the one species, corundum.

Various names derived from its color, hardness, parting, structure, etc., have been applied to corundum. The following names have been used to designate the different varieties of this mineral: [a]

Names that have been applied to corundum, sapphire, and emery.

SAPPHIRE.

Amethiste orientale.
Anthrax (Theophrastus).
Apyrote.
Asterie.
Asteria (Pliny).
Asteriated sapphire.
Barklyite (Stephen).
Bleu du roi.
Blue sapphire.
Bronze corundum (p. 104).
Carbunculus (Pliny).
Cat sapphire.
Chlor sapphire.
Corindon hyalin (Haüy).
Corindon perfect.
Corindon telesie (Brongniart).
Emerald.
Emeraude.
Emeraude orientale.
Green sapphire.
Hyacinth.
Hyacinthos (Pliny).

[a] The list has been compiled from Dana's System of Mineralogy, sixth edition; Dictionary of the Names of Minerals, by Chester; Catalogue of Minerals and Synonyms, by Egleston, and from the names used by the lapidaries.

Hyaline.
Jacut (Arabian).
Lichnis (Pliny).
Luchs saphir.
Luchs sapphire.
Lychnis (Pliny).
Lynx sapphire.
Occidental amethyst.
Opalescent sapphire.
Opaline.
Oriental aquamarine.
Oriental chrysolite.
Oriental emerald.
Oriental hyacinthe.
Oriental peridot.
Oriental ruby.
Oriental sapphire.
Oriental topaz.
Orientalisk rubin (Wallerius).
Pink sapphire.
Pearl corundum (p. 104).
Rubiė étoile.
Rubin.
Rubis.
Rubis oriental (Werner).
Sagenite corundum (p. 104).
Salamstein (Werner).
Salamstone.
Saphir (Werner).
Saphir asteria.
Saphir blanc.
Saphir de chat.
Saphir etoile.
Sapphire.
Sapphirus (Wallerius).
Spath adamantine (Delameth).
Star sapphire.
Star stone.
Telesia (Haüy).
Telesie (Haüy).
White sapphire.
Yellow sapphire.

CORUNDUM.

Adamant (Kirwan).
Adamantine spar (Kirwan).
Adamas siderites (Pliny).
Alumina.
Anthrax.
Armenian stone (King).
Corindon (Haüy).
Corindon adamantine (Brongniart).
Corindon harmophane (Haüy).
Corivendum.
Corivindum (Woodward).
Corundite.
Corundum (Greville).
Demantspath (Klaproth).
Diamond spar.
Gyrasole (Kirwan).
Hard spar.
Imperfect corundum (Greville-Bournon).
Karund (Hind).
Korund (Werner).
Kurund (India).
Rhombohedral corundum (James).
Rhombohedrischer corund (Mohs).
Soimonite.
Spath adamantine (Delameth).
Thoneride.

EMERY.

Acone ex Armenia (Theophrastus).
Armenian stone.
Armenian whetstone.
Corindon granuleux (Haüy).
Emeri.
Emeril (Haüy).
Emerite (Shepard).
Emery.
Fer oxyde quartzifère (Haüy).
Granular corundum.
Grinding spar.
Naxium (Pliny).
Naxium ex Armenia (Pliny).
Pyrites vivus (Pliny).
Schmergel.
Schmirgel.
Smergel (Wallerius).
Smirgel.
Smiris (Agricola).
Smiris ferrea (Wallerius).
Smyris (Agricola and Dioscorides).

PHYSICAL PROPERTIES OF CORUNDUM.

CRYSTAL FORM.

Corundum crystallizes in the rhombohedral division of the hexagonal system. There is considerable variation in the form of crystals from different localities, but in their common development they usually show the forms of the prism and the pyramid of the second order, $a(11\bar{2}0)$ and $n(22\bar{4}3)$, in combination with the base $c(0001)$, and the rhombohedron $r(10\bar{1}1)$. This unit or fundamental rhombohedron differs but little in angle from the cube.

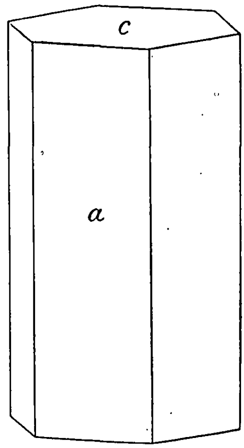

FIG. 1.—Corundum crystal, prism terminated by base, Cowee Valley, N. C.

There are two common types of crystals. One is prismatic, in which the prism $a(11\bar{2}0)$ is the prominent form and is sometimes terminated simply by the base $c(0001)$, fig. 1, and again by the base and the rhombohedron $r(10\bar{1}1)$, or by the base, the rhombohedron, and the pyramid $n(22\bar{4}3)$, fig. 2. The other is flat and tabular, in which the basal plane is the prominent form, the crystals being often a combination of the base and the rhombohedron, r, fig. 2, Pl. V, or of the base and the prism, fig. 16, B, or a combination of the two, fig. 4 of Pl. V.

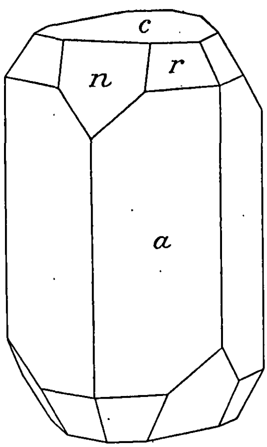

FIG. 2.—Corundum crystal.

Pyramidal crystals in which the pyramid of the second order $n(22\bar{4}3)$ is the prominent form (fig. 3) are common in but few localities. The more complicated forms of crystals, as in fig. 4, are rarer, and it is the simple crystals that are the most often observed.

When the crystals are small they are usually well developed, with smooth faces and sharp edges; the larger crystals are rough, striated, often rounded, and taper slightly toward the end, like a barrel, so that they are sometimes called "barrel corundum."

The basal plane often shows characteristic striations which are parallel to the intersections of the base c and the three faces of the rhombohedron r, as shown in fig. 5 of Pl. V. The lines are often very sharp and distinct, especially on the tabular crystals. In other cases the basal plane is marked by a series of concentric hexagons whose sides are parallel to the intersection of the base c with the prism of the second order *a*, fig. 5. These hexagonal markings vary considerably in size, distinctness, regularity, etc. This zonal structure has been observed on many varieties of corundum. Sometimes the base is divided into sections by lines radiating from a point at the center to the edges of base *c* on the prism *a*, fig. 5.

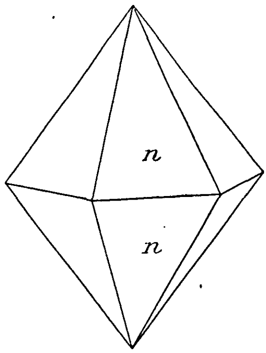

FIG. 3.—Pyramidal crystal of Ceylon corundum.

TWINNING.

Penetration twins of corundum have been observed, but they are not at all common. The most common twinning plane of corundum is parallel to the rhombohedron *r* $(10\bar{1}1)$. The most prominent twinning is polysynthetic; that is, the twinning has been repeated, forming a series of plates or lamellæ in twin position. This type of twinning often produces a laminated structure, and sometimes it gives rise to a surface that is distinctly striated, consisting of minute reentrant and salient angles. This twinning also produces the rhombohedral parting described below.

Recently[a] a new twinning plane has been identified in corundum which is parallel to the base *c* (0001). The crystals in which this twinning plane is developed were gray and ruby red in color, and have been found sparingly in the Ruby mine on Caler Fork of Cowee Creek, Macon County, N. C. They were first observed by Mr. W. E. Hidden, and, as stated by him, the two best crystals measured 6 mm. in diameter and length. They are characterized by reentrant angles $(n, 22\bar{4}3)$ on the prismatic faces $(a, 11\bar{2}0)$ and some slight natural corrosion.

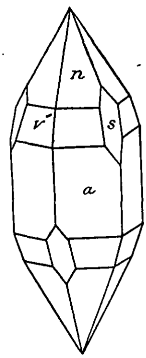

FIG. 4.—Corundum crystal, India (after Mallet).

PARTING.

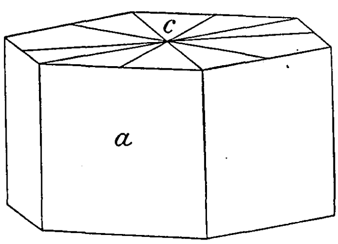

FIG. 5.—Corundum crystal illustrating radial lines in a basal plane extending from center of base to edges of prism.

What was considered by the earlier mineralogists to be a cleavage in corundum has been shown to be a parting produced by the action of mechanical or chemical forces or, perhaps, of both acting together.

As early as 1802 Count de Bournon[b] had pointed out that certain corundums, especially sapphires, did not

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[a] Hidden, William E., Am. Jour. Sci., vol. 13, 1902, p. 474.

[b] Description of the corundum stone and its varieties: Philos. Trans. Royal Soc., London, vol. 92, 1802, pp. 233–326.

show any cleavage, but broke with a conchoidal to splintery fracture. Prof. J. W. Judd[a] has shown that unaltered corundum does not exhibit any trace of cleavage.

There are three crystallographic planes along which parting has been observed:

1. Parting has been observed parallel to the base *c* (0001). Judd[b] says: "That this basal plane is a solution plane of corundum is shown by the fact that the crystals from Burma and other localities which have undergone partial conversion into diaspore and hydrous silicates exhibit a remarkable step-like structure (resembling that of the 'Babel quartz' on a very minute scale), showing that the chemical disintegration of the crystal has been governed by the existence of these solution planes. This fact is beautifully illustrated in the fine ruby presented to the British Museum by Mr. Ruskin, which exhibits the shaly structure due to corrosion and the natural etched figures in a very striking manner. I have no doubt that this fine ruby came from Burma, and many small specimens which I have examined from the same locality exhibit similar characters. As in the case of murchisonite and diallage, the multiplication of cavities along certain planes gives rise to a plane of weakness or a parting scale in the crystal along which it readily divides."

The basal parting plane often shows a pearly, or sometimes submetallic, luster, which is decidedly different from the vitreous to adamantine luster of the crystal faces. This basal parting, although perfect over a portion of the crystal, may be interrupted, and its continuation will be step-wise along a nearly parallel plane. In general, crystals can not be broken into plates with parallel faces, as would be the case if the mineral possessed a cleavage.

2. The parting planes parallel to the unit rhombohedron *r* $(10\bar{1}1)$ are twinning planes, which, it is believed, have been caused by pressure. It has been observed that a crystal without this rhombohedral parting may be destitute of any lamellar structure; or, as Tschermak has pointed out, it may be developed on two of the rhombohedral planes and be almost or entirely lacking on the third.

3. This parting plane, which is parallel to the prism *a* $(11\bar{2}0)$, is seldom observed by the actual breaking of the corundum crystals, but can be seen in thin sections under the microscope. It is best seen in the corundum from the Chantabon Hills, in Siam.

The parting planes developed in corundum have a marked effect upon its value as an abrasive. Many corundums which exhibit this parting in the larger fragments soon begin to break with irregular

[a] Mineral. Mag., vol. 11, 1895, p. 50.
[b] Loc. cit.

fracture, so that only the higher numbers of the commercial corundum (coarser grades) show the traces of this parting developed in them. In some the parting is so developed that even in the finer numbers the particles of corundum still show parting, which destroys greatly their cutting quality or efficiency. In crushing the ores in which the parting is developed to this extent, a great deal of fine powder called flour corundum is produced, thus causing a waste of considerable material.

If this parting is developed in corundum which has been made into a wheel, the cutting power is greatly reduced, for the corundum grains, instead of breaking with an irregular fracture and producing a cutting edge, split along the planes of parting, and thus tend to produce a smooth surface.

FRACTURE.

The fracture of corundum is irregular to conchoidal, and it is this kind of fracture that is necessary to give the best cutting power to the grains. If, however, the parting planes exist, the corundum grains will break along them, since they offer the least resistance, and the value of the corundum is thereby materially decreased.

HARDNESS.

Next to the diamond, corundum is the hardest mineral known. The hardness varies, although but slightly, with the different varieties. The value usually ascribed to corundum is 9, which is that of the blue sapphire variety, but all corundums do not reach this value. The ruby is slightly less hard, ranging from 8.8 to about 9.

In emery it is the corundum which causes the high degree of hardness, even though the grains of corundum themselves can not always be distinguished.

ABRASIVE EFFICIENCY.

The hardness of corundum must not be confused with its abrasive efficiency, for, although most corundums vary but slightly in hardness, there is often a wide variation in the amount of abrasion that they are able to accomplish. The hardness represents the resistance offered by the corundum to abrasion or to being scratched by other substances and also its power of scratching other substances. Any fragment of corundum that is entirely free from alteration or decomposition will, when tested as to its hardness, be found to be close to 9, and will scratch any of the minerals, except the various varieties of corundum and the diamond. This same material, however, may have a cutting efficiency that is very much below that of another corundum whose hardness is just the same.

The abrasive efficiency of a mineral is dependent on its hardness and its fracture. If the mineral is hard and the grains break and wear away in such a manner that instead of becoming rounded good cutting edges are kept exposed, the abrasive efficiency is high. This efficiency is measured by the amount of abrasion upon a given surface in a given time.

Many experiments have been made, and in a number of ways, to measure the abrasive efficiency of a corundum; but it is becoming apparent that the only safe method to determine its cutting power is to have it made up into wheels and to have these tested as if they were in actual use.

SPECIFIC GRAVITY.

The specific gravity of corundum is about 4, varying from 3.95 to 4.10. This high specific gravity is of considerable assistance in recognizing corundum in the field, for there are but few of the nonmetallic or light-colored minerals that have a specific gravity as high as this, and none of these are liable to be found in the corundum regions.

OPTICAL PROPERTIES.

The luster of corundum is adamantine to vitreous, while that of emery is metallic to submetallic. On the basal surface of corundum the luster is sometimes pearly.

Pleochroism in ordinary light is very strongly marked in the deeply colored varieties, especially the sapphires and rubies, the ruby showing a deep red color when viewed in the direction of the vertical axis, and a much lighter color to nearly colorless in some instances when viewed at right angles to this axis. The sapphire exhibits a deep blue color when viewed in the direction of the vertical axis, and a greenish to greenish white or bluish white when viewed at right angles. By means of this pleochroism exhibited by corundum, the stones are readily distinguished from spinel, garnet, and other gem minerals, which resemble some of the corundum gems.

The action of the Roentgen rays or X rays upon corundum gems is another means of distinguishing the ruby and the sapphire from other minerals which resemble them, and from artificial or imitation stones. Corundum allows these rays to pass through it freely, being exceeded in this respect only by the diamond, which allows the passage of ten times as much light. According to their resistance to the passage of the X rays, Doctor Doelter[a] has arranged the minerals into the fol-
the X rays, Doctor Doelter[a] has arranged the minerals into the following groups, the diamond allowing the most light to pass through it:

[a] Separat Abdruck aus Mittheil. naturwiss. Ver. f. Steiermark, Jahrg. 1895, Mar. 26, 1896; and Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895–96, p. 922.

Rank of minerals according to resistance to passage of X rays.

1. Diamond.
2. Corundum.
3. Talc.
4. Quartz.
5. Rock salt.
6. Calcite.
7. Cerussite.
8. Realgar.

Corundum is normally uniaxial with negative double refraction. The mean index of refraction is high, being about 1.765. For the various indices, see page 23. The double refraction of corundum is 0.008 to 0.009, or about the same as quartz. Some varieties of corundum have been observed that are abnormally biaxial.

CHEMICAL COMPOSITION OF CORUNDUM.

Theoretically pure corundum contains only alumina, Al_2O_3; but with few exceptions, all the specimens that have been examined show the presence to a greater or less degree of other chemical compounds, the principal ones being silica (SiO_2), water (H_2O), and ferric oxide (Fe_2O_3). Water is almost always present in amounts from a trace to 2 per cent or more. The silica and ferric oxide also vary from nothing in some corundums to as much as 5 per cent in others. Of course this does not apply to emery, which is a mechanical mixture of corundum and magnetite; but it does apply to the corundum when separated from the mixture, and the impurity in this corundum is usually ferric oxide. The purest known form of corundum is the transparent crystallized variety, or what might be called the sapphire or gem variety.

In the following table a few analyses are given of both American and foreign corundums:

Analyses of corundum.

Locality.	Al_2O_3.	Fe_2O_3.	SiO_2.	H_2O.	Insoluble residue.	Total.	Analyst.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		
Hastings County, Ontario	96.92			2.43	1.36	100.71	Wells.
Sapphire from India	97.51	1.89	0.80			100.20	Smith.
Ruby from India	97.32	1.09	1.21			99.62	Do.
Corundum Hill mine, North Carolina	98.79	.75	.90	.78		101.22	Emerson.
Laurel Creek mine, Georgia	95.51	.88	1.45	.74		98.58	Do.

These analyses are of selected pure material, and not of the commercial product, which contains besides corundum varying quantities of other alumina and iron minerals. In the analysis of a commercial corundum the percentage of alumina found does not indicate the percentage of corundum in the sample, for many other minerals, as spinel, amphibole, pyroxene, chlorite, garnet, etc., that are in the sample contain more or less alumina, which would also be included in the percentage obtained. To determine, therefore, the percentage of corundum in a sample, it must be directly separated from the rest of the minerals that are a part of the sample. A number of bad errors and erroneous statements have been made regarding commercial corundum by estimating the quantity of corundum by the percentage of alumina obtained in the chemical analysis, which rated the sample altogether too high. This mistake has been made in regard to the emery from near Peekskill, N. Y., described on pages 137–138. In this emery there is sometimes a larger per cent of spinel than of corundum, but in the chemical analysis of the commercial product the percentage of alumina would not be very much below a good emery, for the mineral spinel contains nearly 72 per cent of alumina. The abrasive efficiency of such an emery would be considerably lower than that of a true emery, as the cutting quality of the spinel is much lower than that of the corundum.

DETERMINATION OF PERCENTAGE OF CORUNDUM IN AN ORE.

The material is crushed in an iron mortar so as to go through a 14-mesh sieve and sampled. Two grams of the material are taken and treated with concentrated hydrochloric acid on the water bath for two hours. The residue is then filtered off, dried, and fused one-half hour with 6 grams of sodium-carbonate mixture (two parts Na_2CO_3, one part K_2CO_3) in a platinum crucible over an ordinary Bunsen burner. The fused mass is digested with hot water, and the solution is decanted through a filter. The residue is treated with a large excess of dilute hydrochloric acid, and this solution is decanted through the same filter. The filter paper is dried and ignited in a platinum dish, the residue from treatment with hydrochloric acid is added to the dish, and the whole treated with an excess of concentrated hydrofluoric acid. The excess of hydrofluoric acid is evaporated off on the water bath, the residue is treated with hot water, and is finally transferred to an ashless filter paper. This paper and its contents are dried and then transferred to a weighed platinum crucible. The paper is removed by ignition; the crucible is cooled and weighed. The increase in weight (residue) is calculated as pure corundum.

DESCRIPTION OF THE THREE VARIETIES.

SAPPHIRE OR GEM CORUNDUM.

ESSENTIAL PROPERTIES OF A GEM.

As the terms "gem mineral" and "precious stone" are used at the present time they apply to three classes of minerals: (1) Those which are of value for cutting and use in jewelry and are commonly designated as gems, as diamond, ruby, beryl, amethyst, etc.; (2) those which are used, after cutting or polishing, for ornamental or decorating purposes, as quartz, jade, agate, malachite, etc.; and (3) those which from their rarity and beauty are of ornamental or mineralogical value, as quartz crystals, rhodochrosite, calcite, etc. As is evident, these divisions so overlap that no sharp lines can be drawn between them. The word "gem" is used ordinarily to designate any precious stone when cut or polished. In mineralogy the term is often used for a class of minerals whose hardness is over 7 (or harder than quartz) and which are without metallic luster and are brilliant and beautiful. The unit of weight of gems is designated by the term "carat," and the international carat is equal to 3.168 grains or 250 milligrams. This meaning of the word should not be confused with that which refers to the fineness of a gold alloy.

The properties of a mineral that determine its value as a gem are its rarity, hardness, color, index of refraction, and luster. As an illustration of how the hardness affects the value of a mineral for gem purposes, sphalerite might be cited. This mineral, with an index of refraction and luster not far from that of the diamond, has a hardness of only 3.54, which effectually excludes it from being a gem mineral.

SAPPHIRE AS A GEM.

Corundum has properties that place some of its varieties among the most valuable gems. With the exception of the diamond, it is the hardest mineral known, and the rarity and color of the ruby, the red corundum, has made that gem, when more than a carat in weight, more valuable than a diamond of corresponding weight. Corundum has been found in almost all the colors of the rainbow, and in the following list its gems have been classified according to color. They are very often designated by the prefix "oriental," to distinguish them from gems of the same name whose mineral composition and character are entirely different.

Sapphires or corundum gems.

Oriental or true ruby	Red of various shades.
Pink sapphire	Rose or pink.
Oriental amethyst	Purple.
Oriental sapphire	Blue of various shades.
Opaline Girasol Hyaline	Pale blue or bluish white.
Oriental emerald	Green.
Oriental topaz	Yellow.
White sapphire Diamond spar	Colorless.
Star sapphire Chatoyant Asteria	Opalescent.

All these varieties of corundum gems have been found in the United States. The North Carolina and Montana corundums excel in variety of color those from other localities in this country, having been found ruby-red, rose, and all intervening shades, pink, sapphire-blue, dark-blue to pale-blue, emerald-green, and green of various shades, violet to purplish, yellow of various shades, brown, gray, black, and colorless.

INDICES OF REFRACTION OF GEMS.

In index of refraction corundum is lower than a number of the commoner gem minerals. In the following table the relative position of the corundum is shown:

Gem.	Li=Red.	Na=Yellow.	Tl=Green.	
Diamond	2.4135	2.4195	2.4278	Descloix.
Zircon		ω ε 1.9236–1.9682		
Almandite (garnet)	1.8000	1.8056	1.8113	Pratt.
Pyrope (garnet)	1.7776	1.8141	1.8288	Descloix.
Sapphire (corundum)	ω ε 1.7678–1.7598			Do.
Ruby (corundum)	1.7675–1.7592			Do.
Rhodolite (garnet)		1.7496		Pratt.
Spinel ruby (spinel)	1.7121	1.7155		
Hiddenite		β=1.669		
Topaz		β=1.615		
Tourmaline	ω ε 1.6347–1.6172	ω ε 1.6374–1.6196	ω ε 1.6409–1.6232	Do.
Aquamarine (beryl)	1.5862–1.5791	1.5893–1.5821	1.5921–1.5848	Dufet.
Emerald (beryl)		1.5841–1.5780		
Amethyst	1.5391–1.5480	1.5441–1.5532	1.5542–1.5636	

HARDNESS OF GEMS.

The next table shows the relative position of corundum with respect to hardness:

Gem.	Hardness.	Gem.	Hardness.
Diamond	10	Zircon	7.5
Sapphire	9	Rhodolite	7.5
Ruby	8.8- 9	Pyrope	7.5
Spinel ruby	8	Almandite	7.5
Topaz	8	Amethyst	7
Emerald beryl	7.5- 8	Hiddenite	6.5-7
Beryl	7.5- 8		

As is shown by the above tables, sapphire is fifth in refractive index and second in hardness. Ruby is sixth and third, respectively; but, as is well known, it is not its brilliancy (which is dependent on index of refraction), but its rich pigeon-blood color, luster, and transparency which are so highly prized. It is these qualities, together with its hardness and rarity, that make the pigeon-blood ruby, when of more than one carat and free from flaws, the most valuable of gems.

The gems occur in the mines in three forms: First, as crystals, of which there are two distinct types—the hexagonal prisms terminated by rhombohedrons and pyramids, sometimes with basal plane, the larger crystals being often rounded or barrel-shaped, and the flat, tabular crystals in which the basal plane is very largely developed; second, as transparent colored portions of larger massive pieces of corundum; and third, as nodules of finer and clearer material in a mass of corundum in which parting has been highly developed. The nodules, when separated from the mass of corundum, often have the appearance of rolled pebbles.

CORUNDUM.

The varieties that are brought under this head are, with the exception of emery, all those that can not be used as gems. As a commercial product there are differences, such as texture, purity, etc., that have considerable influence upon its value, in the same way in which color and transparency affect the gem corundum. Although the hardness of the pure corundum is practically the same—that is, 9—the cutting qualities of corundum vary, as has already been stated, according to the alteration that has taken place in the mineral and to the development of parting planes. The usual colors of this ordinary corundum are gray to white, shades of blue, white mottled with blue, and also the darker colors, brown to black.

According to its structure, corundum is divided into three groups, known as (1) block corundum, (2) crystal corundum, and (3) sand corundum. These three varieties of corundum, which are present at the different mines, are sometimes all three found in the same mine, although not all three in the same vein.

BLOCK CORUNDUM.

Block corundum includes the massive corundum, whether in small or large masses. A mass of block corundum weighing over 5,000 pounds has been reported to have been taken from the Laurel Creek mine, Rabun County, Ga. This mine has probably furnished the largest blocks of corundum of any in the world. In some of the deposits the block corundum is often intermixed with feldspar, hornblende, muscovite, margarite, or chlorite, etc., according to the character of the rock in which it occurs, so that the separation of the corundum from these foreign minerals is sometimes a rather difficult process. Where the corundum occurs in masses of considerable weight, there is often great inconvenience in mining, as, on account of its toughness and hardness, it is not always readily broken and it is almost impossible to drill through it. The block corundum, which shows but little development of the parting planes already referred to and no ingrowth of muscovite, margarite, or chlorite in cracks or seams, makes the best corundum ore, and the difficulty of cleaning is reduced to a minimum.

CRYSTAL CORUNDUM.

Under this head are included all the crystal varieties of corundum. These are present in deposits of both sand and block corundum. At many of the localities the crystals show the hexagonal prism merging into the pyramid, thus causing the crystal, as it tapers toward the end, to assume the form known as "barrel corundum." At a number of mines loose, tapering crystals of rather indefinite form are found, which are inclosed by compact margarite. At many of the veins the crystals occur in a mass of feldspar, at others in biotite or muscovite, and at still others in chlorite.

SAND CORUNDUM.

Sand corundum consists of very small to minute crystals and small irregular grains, such as are found in the chlorites and vermiculites developed in the ore bodies occurring between the peridotite and other rocks, such as gneisses and schists.

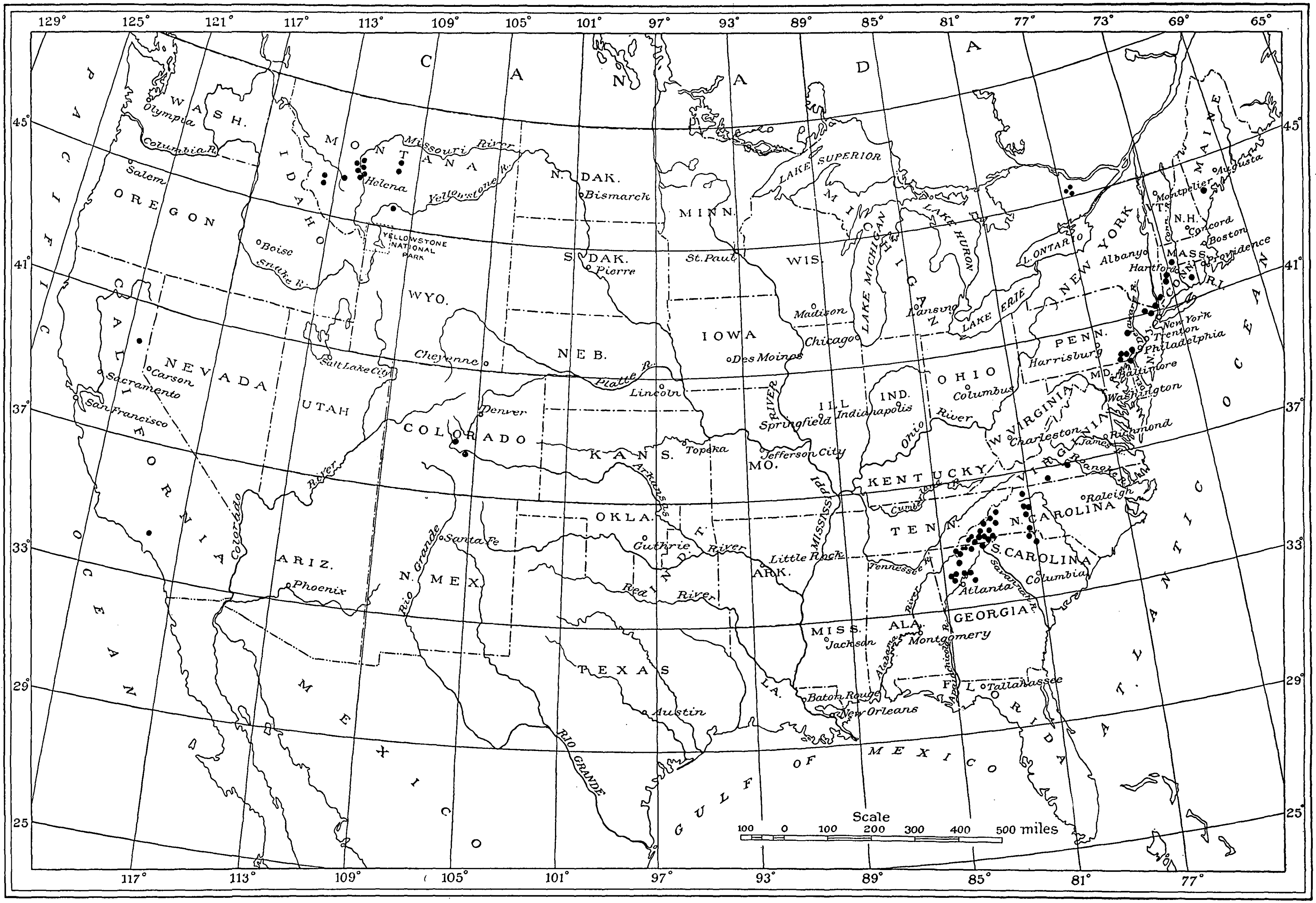
EMERY.

Emery is the intimate mechanical admixture of corundum and either magnetite or hematite. Its value as an abrasive is dependent upon the percentage of corundum, for it is to the presence of this mineral that the emery owes its abrading qualities. This mechanical admixture of corundum and either hematite or magnetite is usually so intimate that no separation of the two on a commercial basis can be made, and emery can therefore not be used as a source of corundum. When very finely crushed, the iron oxide can be separated from the emery by means of an ordinary electromagnet. Examined under the microscope, the two minerals can be seen distinctly. Sometimes the corundum is in coarse grains or distinct crystals. At Chester, Mass., emery has been found containing crystals of corundum nearly half an inch in diameter.

In appearance emery is very similar to fine-grained iron ore, and when it contains the iron oxide, magnetite (Fe_3O_4), it is almost identical in appearance with that ore itself. Its color is blue-black to black, and it has a metallic luster. When emery was first discovered, it was mistaken for an iron ore, and a number of cases might be cited where attempts have been made to work deposits of emery for iron ores. At the largest American deposit, which is located at Chester, Mass., it was first thought to be a magnetic iron ore, and blast furnaces were erected and the mine was operated as such. At the first attempt, however, to smelt the ore in the furnaces they became clogged up, and the mine was condemned as containing a very refractory ore. The mine remained idle for a number of years. Dr. H. S. Lucas then bought it and began to operate it as a source of emery. This mine, which is now owned and operated by the Ashland Emery and Corundum Company, and the mines at Westchester, N. Y., produce all of the emery that is mined in this country.

Spinel sometimes is associated with emery. At times the spinel is largely in excess of the corundum, and the mineral then might well be called a "spinel emery." This is well illustrated at the Westchester mines, in New York State, and in some of the emeries from the Grecian islands.

Emery is sold on the market under the head of Turkish, Naxos, Chester, and Peekskill emery, according to the locality from which it is obtained. It was first obtained from the Grecian islands, the principal one of which is Naxos, upon which there have been seventeen deposits of emery located. This locality controlled the emery market until the important explorations of Mr. J. Lawrence Smith developed the large deposits in Asia Minor. By these discoveries a new source of emery was opened, which at once reduced the price. The best Turkish emery is thought to be that which is found in the Abbot mine, and it



GENERAL MAP SHOWING LOCATION OF CORUNDUM DEPOSITS IN THE UNITED STATES.

is considered by many to excel in quality the best Naxos emery obtained from the Grecian islands. The Chester emery, which was at one time considered not to be a true emery, has taken its place with the Naxos and Turkish emery, and is considered by many to be superior to these. For a description of the foreign emeries, see pages 155-157.

CORUNDUM-BEARING ROCKS IN THE UNITED STATES.

A generation ago corundum was regarded as a comparatively rare mineral, whereas now it is known to be widely distributed in nature. With the exception of emery, it was thought to occur in quantity only in the basic magnesian rocks, such as the peridotites and their serpentine derivatives. Now it is known to occur abundantly in syenites and other igneous rocks, as well as in various gneisses and schists. It has been found in many crystalline rocks, and in some of them as an original mineral, but only within the last few years has it come to be regarded as an essential rock constituent, as in the syenites of Ontario, Canada, and of Montana, and in similar rocks of California and Colorado. In some cases it is undoubtedy a product of metamorphism.

Corundum has been found in igneous and metamorphic rocks and in alluvial deposits. Where it occurs in the igneous rocks it is either as a direct constituent of the more acid intrusive rocks, or it occurs as segregated masses near the periphery of the basic intrusive rock, or is associated with inclusions that have been picked up by the intrusive rocks. In the metamorphosed rocks the corundum is either one of the original constituents of the igneous rock that has been subjected to metamorphism or the result of regional metamorphism by which shales, bauxite, or other rich aluminous minerals have been converted into corundum, or it may be due to contact metamorphism, the corundum occurring simply in the narrow zone adjoining the intrusive rock. In the alluvial deposits the corundum is found either in the recent alluvium composed of soil, or in sands, or in gravels.

There a large number of rock types in which corundum has been found, and although they do not represent entirely different modes of occurrence of corundum, as perhaps the classification given above indicates, still in the present paper the descriptions of the modes of occurrence of corundum are given according to the type of rock in which the corundum is found, and no attempt has been made to classify them directly according to the outline given above. They are, however, divided into those which occur in igneous rocks, metamorphic rocks, and alluvial deposits.

Descriptions of these various modes of occurrence are given below, some of which are discussed in connection with the question of the origin of corundum. The descriptions are taken up in the following order: Modes of occurrence in the United States and occurrences not found in the United States.

At the present time corundum is known to occur in the United States in the following rocks, descriptions of which follow in the order given in the subjoined list:

Corundum-bearing rocks in United States.

Igneous	Peridotite. Pyroxenite. Amphibolite. Anorthosite.	Norite. Plumasite. Andesite. Monchiquite.	Granite. Syenite. Pegmatite.
Metamorphic	Serpentine. Gneiss. Mica-schist. Crystalline limestone.	Quartz-schist. Amphibole-schist. Chlorite-schist.	
Alluvial	Gravel deposits.		
Undetermined	Emery.		

CORUNDUM IN IGNEOUS ROCKS.

CORUNDUM IN PERIDOTITE.[a]

Extending from Tallapoosa County in east-central Alabama into the Gaspe Peninsula on the Gulf of St. Lawrence, a distance of more than 1,600 miles, there is a narrow belt of disconnected outcrops of peridotites and closely allied basic magnesian rocks, which cut the ancient crystalline belt of eastern North America. These basic rocks can be traced north more or less continuously to near Trenton, N. J., where the crystalline rocks pass under the younger formations. The crystalline rocks again make their appearance south of Hoboken, N. J., and at this place and on Staten Island there are large masses of serpentine. Many other outcrops of serpentine, and in some cases of unaltered peridotites, have been observed in Connecticut and Massachusetts, but it is not until central Vermont is reached that the belt again forms a more continuous line, and then continues through southeastern Quebec into the Gaspe Peninsula. The large areas of serpentine that are known to exist in the western part of the island of Newfoundland extend the belt about 400 miles farther.

Throughout nearly the entire southern portion of the belt, in North Carolina, Georgia, and Alabama, the peridotite rocks show a freshness almost to the surface of the exposures, and there are few localities where there is any considerable area of peridotite entirely altered to serpentine. Under the microscope thin sections of the dunite show an alteration to serpentine between the particles of

[a] Corundum and the peridotite of western North Carolina: North Carolina Geol. Survey, vol. 1, 1905.

OUTCROP OF PERIDOTITE AT BUCK CREEK, CLAY COUNTY, N. C.

olivine. These peridotite rocks have been shown to be of igneous origin.[a] The blunt lenticular form in which they are found would be difficult to associate with any origin but that of an intruded igneous mass, which would also account for the apophyses that have been observed extending into the inclosing gneiss. At Webster, Jackson County, N. C., a large block of gneiss is completely inclosed by the peridotites in such a manner as could be attributed only to the intrusion of the latter while in a molten condition. The line of separation of the peridotites and the gneisses is always sharp, and there is no transitional zone from the acid gneiss to the basic peridotite. Under the microscope the latter rock shows the granular structure characteristic of plutonic origin, the grains fitting perfectly into one another without cementing material.

Associated with all these peridotites is the mineral chromite, which occurs as disseminated particles near the borders of the lenticular masses of the peridotites. There is very little calcite found associated with these rocks, and what has been observed is unquestionably of secondary origin.

Five years ago the common occurrence of corundum (not including emery), and the occurrence in which the mineral had been found in commercial quantity, was in association with these basic magnesian rocks—peridotites, principally dunite. The dunite variety of peridotite is the more common one throughout the southern area, and it is with this variety that most of the corundum is associated. Pl. II is a reproduction of a photograph of an outcrop of peridotite (dunite) at Buck Creek, Clay County, N. C.

The peridotites and associated basic rocks occur as oval, lenticular, and irregular masses and sheets in a region of metamorphic rocks composed chiefly of biotite-gneiss. As subordinate facies of this normal gneiss, however, more or less extensive areas of hornblende-gneiss, mica-schist, and quartz-schist are developed. Peridotites are found inclosed by or in contact with all of these various types. On account of greater resistance to weathering it often happens that hornblende-gneiss is most conspicuous in outcrops, even where relatively unimportant in extent. Hence it has often been reported that the peridotites are always, or at least in most cases, associated with hornblende-gneiss.

The gneiss is usually considerably decomposed near the contact, and, while retaining the appearance of the unaltered rock, it readily crumbles when handled. The peridotite is also generally altered near the contact, but in quite a different manner from the gneiss. In fact, it usually shows a strong tendency to undergo complete decomposition, in which only a residue of quartz or chalcedony and an

[a] Lewis, J. V., Elisha Mitchell Sci. Soc. Jour., pt. 2, 1895, p. 35. Pratt, J. H., Am. Jour. Sci., 4th ser., vol. 6, 1898, p. 50.

ocherous clay-like substance remain. This contact decomposition is altogether different from and independent of the alteration to serpentine which almost universally characterizes the peridotites of this region. Only a moderate degree of serpentinization, however, is usually observed, not enough in the majority of cases to be visible to the naked eye; and in only a few localities has it proceeded to the extent of entirely replacing the original rock.

The corundum found in these peridotites does not occur as accessory mineral or as rock constituent, but is concentrated either near the contact of the peridotite and the inclosing gneissic rocks or in pockets within the mass of the peridotite. A series of secondary minerals, however, has been developed both along the contacts and with the corundum masses within the peridotite, so that the corundum is not found in direct contact with either the peridotite or the gneiss, nor are these rocks in contact with each other. The secondary minerals are chiefly chlorites, vermiculites, enstatite, and talc, and are not in any sense the results of contact metamorphism. It is customary to refer to these corundum-bearing zones as "veins," and that term is used here merely for convenience, without implying any particular character or origin. Those occurrences about the borders of the peridotites are designated as "border veins," and those wholly within the peridotite as "interior veins."[a]

The appearance and general character of the veins differ somewhat in these two classes. The interior veins trend approximately toward the center of the peridotite mass, generally growing gradually thinner in this direction until they pinch out altogether. This character was distinctly observed at Buck Creek, Clay County, N. C., and at Laurel Creek, Rabun County, Ga. (Pl. XIII, *B*, and Pl. XVII, *B*). In the border veins, however, the corundum seems to extend downward indefinitely along the plane of contact, varying irregularly and sometimes very greatly, both vertically and horizontally, but exhibiting no marked tendency to thin out in any particular direction. The border veins often give off branches into the peridotite, which gradually thin out toward the center of the mass and exhibit the usual characteristics of interior veins. These distinctions between the two types of veins have been observed by many of those who have mined and prospected for corundum in this region.

In a cross section of a border vein extending from the gneiss to the peridotite (dunite) the following sequence is often observed:

a. Gneiss, hornblendic or micaceous, apparently unaltered.

b. Gneiss with same general appearance as *a*, but so decayed that the particles readily separate from one another.

[a] In Bulletin 180 on The occurrence and distribution of corundum in the United States. "contact vein" was used instead of "border vein," and "dunite vein" instead of "interior vein." Bull. U. S. Geol. Survey, No. 180, 1901, p. 12.

c. Yellowish vermiculites, varying considerably in thickness, the maximum being 6 to 8 inches; in places absent, so that *b* comes directly in contact with *d*: where present, *c* often merges into *d*.

d. Green chlorite, varying in thickness much like *c*, and in places absent.

e. Chlorite and corundum, sometimes with a little vermiculite. In places this mass may be largely corundum, and it is what is called the "corundum vein," varying in thickness from a few inches to 12 or 15 feet.

f. Green chlorite; so far as observed always present, and varying in width from 1 to 12 inches.

g. Enstatite; in places hard and compact, and in widths of several feet: usually merges into *h*.

h. Talcose rock, usually fibrous, varying in thickness from a few inches to several feet.

j. Dunite, more or less altered, friable, and stained with ferric oxide.

k. Dunite, apparently unaltered, quite extensive.

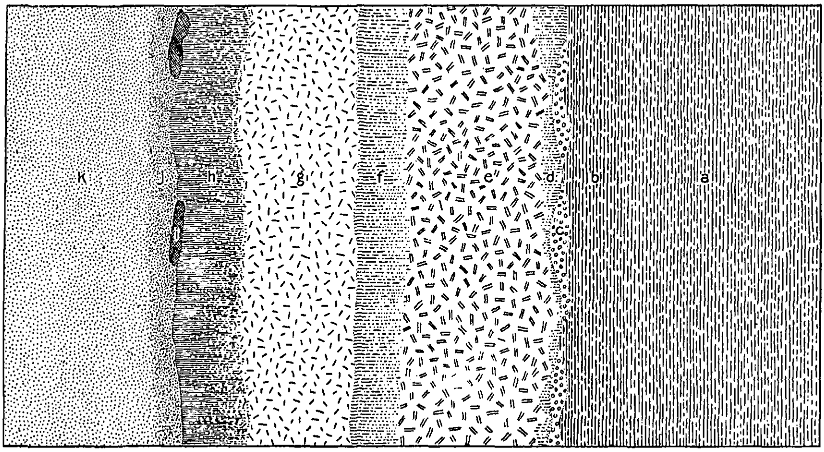


FIG. 6.—Ideal cross section of a corundum border vein at the Corundum Hill mine, North Carolina. *a*, Fresh and unaltered gneiss; *b*, decayed and unaltered gneiss; *c*, vermiculites; *d*, green chlorite; *e*, corundum-bearing zone; *f*, green chlorite; *g*, enstatite; *h*, talcose rock; *i*, clay; *j*, altered dunite; *k*, unaltered dunite.

Between *h* and *j* a seam of yellowish clay (*i*) is sometimes observed which often contains a narrow seam or fragments of chalcedony.

From what could be learned by actual observation and inquiry among the miners, *c* and *d* are sometimes absent, and when this is the case, *e*, a mixture of chlorite, vermiculite, and corundum, is seemingly in direct contact with *b*. The chlorite, however, on the dunite side of the section is constant. The thickness of the several zones (*a*, *b*, *c*, etc.) in such sections varies greatly at different places, and the distance across the sections may be said to vary at different points, even in the same region, from a few feet to 30 or 40 feet. The accompanying diagram (fig. 6) represents the cross section of a border vein observed at the Corundum Hill mine, Cullasagee, Macon County, N. C.

The line of contact between the zone of alteration products and the gneiss was very sharp and distinct in all the contact veins examined. The minerals developed between the corundum-bearing zone and the dunite are in great abundance and differ from those between that zone and the gneiss.

In a cross section of an interior vein at a shaft near the southern part of Corundum Hill, in a distance of from 20 to 25 feet, the following has been observed:

1. Dunite, hard and apparently unaltered.
2. Dunite, somewhat friable and discolored, passing into 3.
3. Talcose rock, fibrous, merging into 4.
4. Enstatite, grayish and somewhat fibrous.
5. Green chlorite, 6 to 15 inches in width.
6. Green chlorite, corundum, and spinel, 6 to 8 feet wide.
7. Chlorite, same as 5.
8. Enstatite, same as 4.
9. Talcose rock, same as 3.
10. Dunite, same as 2.
11. Dunite, same as 1.

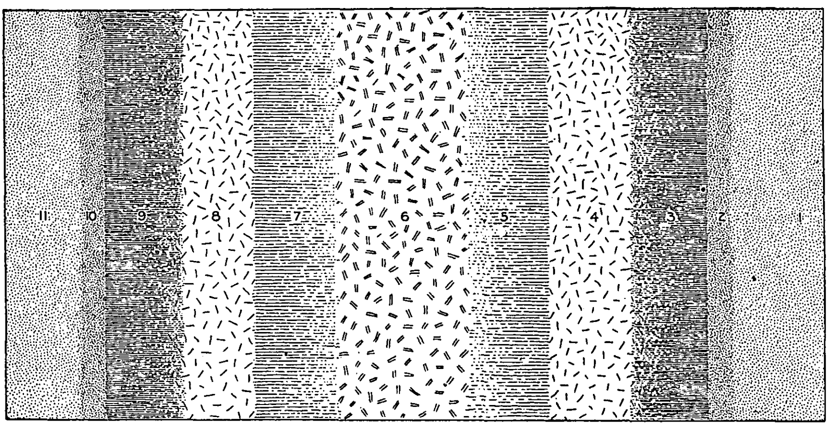


FIG. 7.—Cross section of an interior vein at a shaft near southern part of Corundum Hill, North Carolina.

The similarity of the two parts of the vein separated by the corundum zone, as already described and as illustrated in fig. 7, is very apparent.

Although the section just described is a special case, it was observed that all of the interior veins had the same character on both sides of the corundum-bearing zone. As has been already stated, either a talcose or a serpentine rock may be the limit of the cross section. In one of the interior veins at Corundum Hill near the west end of the outcrop, the zone of corundum, chlorite, and vermiculites is in direct contact, both on the hanging and on the foot wall, with a serpentine rock. This zone is divided—in one place almost pinched out—by a mass of serpentine.

It is to be noted that the zones 1, 2, 3, 4, 5, and 6, of fig. 7, are practically identical, respectively, with the zones *k*, *j*, *h*, *g*, *f*, and *e* of fig. 6. This marked similarity is noted further on page 85, under the discussion of the origin of corundum in the peridotites.

An important variation from the normal modes of occurrence with peridotite, as just described, has been observed at a number of localities by the development of a zone of corundum-bearing plagioclase. This is found either in the corundum-bearing zone of chlorites and vermiculites (*e* and 6 of cross sections given in figs. 6 and 7), or entirely replacing these zones. The feldspar, in the specimens determined, is a basic lime-soda species; is sometimes fine grained and compact; at other times it is very coarsely crystallized, and varies in different localities from a few inches to several feet in thickness. In addition to the corundum, it is found to contain, in different localities, large masses of zoisite, coarse black hornblende, and other minerals. Examples of these zones of feldspar and corundum are found at a number of places on Shooting and Buck creeks, Clay County; at the Bad Creek mine, Sapphire, Transylvania County, and at the Carter mine, Madison County, N. C.; and also at the Track Rock and Laurel Creek mines, Rabun County, Ga. A similar interior vein at the Hamlin mine, on the headwaters of Ellijay Creek, in Macon County, N. C., contains, as its central member, a band of pegmatite 4 inches thick, but not bearing corundum, so far as observed. This occurrence is very similar to the occurrence of corundum in plumasite described on page 42.

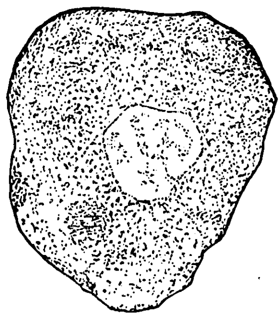


FIG. 8.—Corundum crystal inclosed in granular dunite, Egypt mine, Yancey County, N. C.

At all of the corundum localities examined a careful search has been made to find corundum directly surrounded by the peridotite, but this has been observed at only one locality—the Egypt mine, on the western slope of Sampson Mountain, in Yancey County, N. C. The few specimens obtained were collected by Mr. U. S. Hayes, who developed the corundum property in that section. One specimen shows a prismatic crystal of the corundum surrounded by a granular peridotite (dunite), but with none of the chlorite minerals which usually intervene. The dunite is not quite fresh, but is stained a yellowish brown by iron oxide and is rather friable.. On the basal surfaces of the corundum a little muscovite is developed. This has been observed on corundum from other localities.

Soon after the discovery of corundum at Buck Creek, Clay County, N. C., Dr. C. D. Smith,[a] in describing the minerals associated with corundum at this locality, stated that he found "chrysolite attached as an enveloping matter to considerable masses of corundum." But neither Dr. Smith nor any other writer who has described this locality since that time and while mining operations were carried on has made any further mention of this occurrence. A careful search has failed to discover any further specimens showing this association; thus the occurrence at the Hayes mine is the only one known at the present time.

Corundum has been observed, however, in serpentine, which is one of the most common alteration products of the peridotites. Specimens of this nature have been found at the Cullakeenee mine, Buck Creek, Clay County, N. C. Some of them show small particles of corundum either partly or wholly surrounded by serpentine, and the whole mass of corundum and serpentine surrounded by clinochlore. In one specimen a streak of corundum about an inch thick lies between two zones of serpentine which are from one-quarter to three-quarters of an inch thick, and these zones are bordered, in turn, by talcose and enstatite rock.

Spinel has been found at a number of the corundum veins, and in a few cases it is very intimately associated with the corundum. At the Carter mine, near Democrat, Buncombe County, N. C., the corundum is found, in masses of a white and pink color, intergrown with a greenish-black spinel. The masses of corundum and spinel are partially surrounded by a deep-green chlorite, which has also been developed in places between the corundum and the spinel, although this contact of the corundum and the spinel is usually very sharp and distinct. A massive, coarsely to finely granular spinel is found at the Corundum Hill mine, Macon County, N. C., which has disseminated through it small grains and fragments of pink and white corundum.

The mineral chromite, which has always been found associated with these peridotite rocks, occurs sparingly in many of the corundum veins. It is a well-observed fact[b] that where there is any quantity of corundum found in the peridotite rocks there is a scarcity of chromite, and where there is a large quantity of chromite there is a scarcity of corundum. The chromite does not occur in as well-defined veins as the corundum, and is often in masses or pockets which apparently have no relation whatever to one another. Between the chromite and the peridotite there is not developed a large series of alteration products, as has been observed with the corundum, and the chromite is very commonly found inclosed directly by the fresh peridotite.

An occurrence of corundum with peridotite that is very different

[a] Report Geol. Survey North Carolina, 1875, App., p. 95.

[b] Am. Inst. Min. Eng., vol. 29, 1899; February meeting.

from the usual one observed in North Carolina and Georgia is found near Pelham, Mass.[a] A lenticular mass of harzburgite (saxonite) about 40 feet in width of outcrop and about 200 feet long is inclosed by gneisses. A zone of bronze-colored biotite, usually 4 by 8 inches thick, which incloses the corundum is developed along portions of the peridotite boundary. (See page 53.)

CORUNDUM IN PYROXENITE.

At many of the corundum-bearing peridotite localities in North Carolina, such as those of Macon, Jackson, and Transylvania counties, a pyroxenite composed of interlocking, coarse-bladed, gray enstatite constitutes an important part of the outcrop; and at a number of places the pyroxenite alone forms oval and lenticular masses in every way similar to those composed of peridotite. In both cases corundum-bearing zones of secondary minerals are frequently formed along the borders of the pyroxenite and intersect the mass of the rock in exactly the same manner as described above for peridotite. Enstatite rocks are somewhat common in North Carolina, but accessory minerals in them are rare, and the most common one observed is chromite, in small grains. In a few instances corundum has been found in them.

Corundum has also been observed sparingly in the enstatolite variety of pyroxenite itself in at least two localities, namely, at the Rattlesnake mine, near Sapphire, Jackson County, and at a locality on the West Fork of French Broad River, in Transylvania County.

Corundum is also intimately associated with a hypersthenite (pyroxenite) dike cutting the gneisses on Thumping Creek, Clay County, where it occurs in a zone of fine, scaly, brown mica developed along the plane of contact between the dike and the gneiss. It is also found in a very small amount in the hypersthenite itself. The dike is a very dark, fine-grained rock, which the microscope shows to be composed of strongly pleochroic hypersthene about half altered to a green amphibole.

CORUNDUM IN AMPHIBOLITE.

Associated with the peridotite rocks of Clay County, N. C., and of the adjoining Towns County, Ga., are dikes of amphibolite, which are for the most part between the peridotite and the gneiss, although in some places they cut the peridotite formation close to the contact of that rock with the gneiss. These dikes vary in width from 25 to over 300 feet, their average width being from 75 to 100 feet. The relation of these amphibolite dikes to the peridotite formation at Buck Creek, Clay County, N. C., is shown in fig. 9.

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[a] Mon. U. S. Geol. Survey, vol. 29, 1898, pp. 47–54.

The groundmass of this amphibolite is a grass-green amphibole, containing 17 per cent of alumina, nearly 12 per cent of lime, and one-half of 1 per cent of magnesia, which is best classified under the edenite variety of aluminous amphiboles. The rich green color of the edenite is undoubtedly due to the presence of a small amount of chromic oxide, the analysis showing the presence of 0.38 per cent of this oxide. Many microscopic grains of picotite or chromite are scattered through the groundmass of edenite. There is also present, in widely varying proportions, the plagioclase feldspar anorthite. The feld-

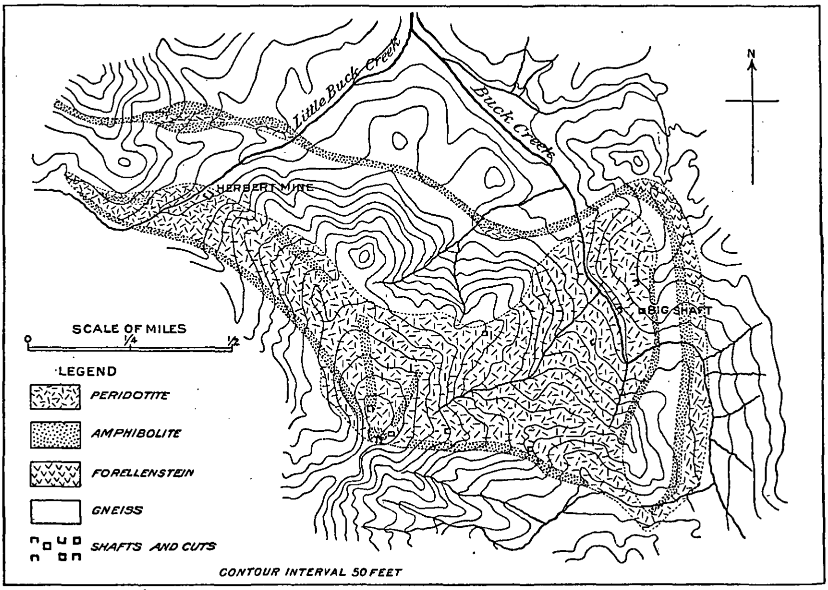

FIG. 9.—Map of the Buck Creek peridotite area, showing the relation of the amphibolite dikes.

spar is not constant in all of the amphibolites, but where it does occur it varies in size from minute particles to masses as large as a pea.

The rock has often a strikingly laminated structure, and grades from this extreme to a structure showing no lamination at all. It is exceedingly tough and very fine grained. The corundum, which occurs in the amphibolite as an accessory mineral, varies in size from minute particles to masses several inches in diameter, in which there are usually developed parting planes parallel to the unit rhombohedron. In color it varies from almost white to a deep ruby-red, but the prevailing color is a deep pink. Very rarely deep blue corundum has been found in these amphibolites.

On account of the exceeding toughness of the rock, and more particularly on account of the low percentage of corundum, these amphibolites are not of commercial value as a source of corundum; they do, however, make handsome mineral specimens. In fig. 10 there is illustrated a mass of corundum in amphibolite from Buck Creek. Near Elf, Clay County, N. C., a similar occurrence of corundum in amphibolite has been observed where this rock cuts a typical dunite.

At the Isbel mine, at the head of Shooting Creek, in Clay County, N. C., corundum occurs irregularly, and is sparingly disseminated through a decomposed hornblendic rock in small grains and masses. The least decayed portions of the rock seem to possess the characters of an amphibolite, but this could not be determined with certainty. The corundum occurs through the mass of this rock across an outcrop about 153 feet wide. In most of it the rhombohedral parting is distinctly developed.

Three miles east of Marshall and half a mile northeast of the mouth of Ivy River, in Madison County, N. C., numerous crystals of corundum have been found over the surface of a large outcrop of coarsely crystallized dark-green amphibolite. In places the rock is of finer texture and contains some feldspar and biotite, passing into a dioritic facies. The country rock inclosing the amphibolite is a biotite-gneiss. Most of the corundum is in large, rough, hexagonal prisms. A crystal with three smaller prisms in twin position on alternate hexagonal edges was found which weighed 17 pounds.

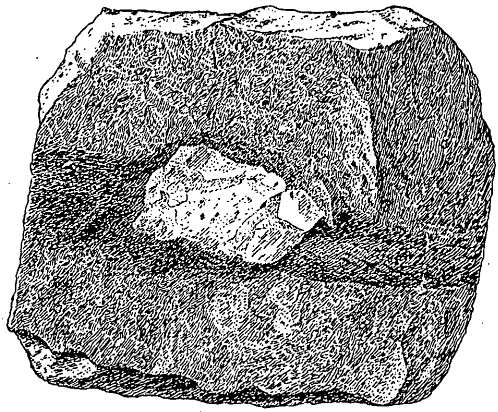

FIG. 10.—Mass of corundum in amphibolite from Buck Creek, North Carolina.

Doubtless many of the occurrences of corundum with chlorite-schist (described herein) would be found, if explored to some depth, to belong with the amphibolites, as at the Track Rock mine, in Union County, Ga., where extensive outcrops of chlorite-schist have been found to consist chiefly of bright-green hornblende in the tunnel driven into the mountain side. Some portions of it also carry small quantities of olivine, possibly passing into amphibole-peridotite.

On the eastern slope of the Blue Ridge, in the vicinity of Statesville, Iredell County, N. C., corundum has been found associated with an amphibolite composed of a dark-green hornblende. On account of the thickness of the soil and the depth to which these rocks have been decomposed, there are few places where the fresh rocks are exposed, and little is known of their extent. At Hunters, 7 miles west of Statesville, the amphibolite was exposed during exploration for corundum, which, according to Lewis,[a] was found to occur in fine brown vermiculite, developed in zones along the borders of and penetrating the amphibolite, and varying in thickness from a few inches to 3 or 4 feet. Fig. 11 is an ideal illustration of the occurrence of corundum in the amphibolite at Hunters. In this figure, *a* represents a feldspar zone that is sometimes encountered in the midst of the vermiculites, *b*; the feldspar is more or less altered to kaolin, and often bears corundum, although most of it was found in the vermiculite zones. *b* represents the vermiculite zones carrying the corundum, which is in crystals and in rounded masses of crystals clustered together. Margarite sometimes accompanies it, and large masses

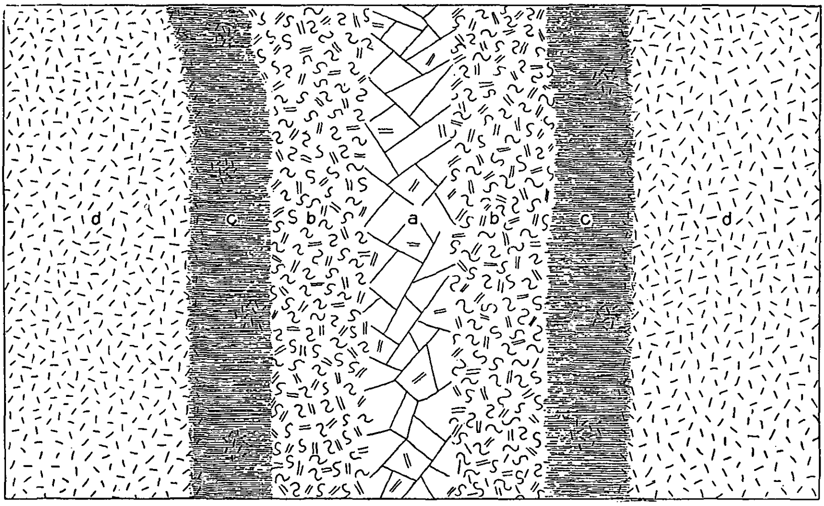

FIG. 11.—Ideal vertical cross section of corundum in amphibolite at Hunters, Iredell County, N. C.

made up almost entirely of these two minerals have been found on the surface in this region. *c* represents radiating borders of actinolite that inclose large masses of what was once amphibolite, but what is now nothing but a mass of ocherous clay, bearing occasional needles of hornblende and scales of vermiculite. The outer portions, *d*, are dark-green amphibolite.

CORUNDUM (EMERY) IN AMPHIBOLITE AT CHESTER, MASS.

The most widely known occurrence of corundum in amphibolite is that of the emery at Chester, Mass., an elaborate description of which is given by Prof. B. K. Emerson[b] in his exhaustive work on the geology of old Hampshire County, Mass.

[a] Bull. Geol. Survey North Carolina No. 11, 1896, p. 59.
[b] Mon. U. S. Geol. Survey, vol. 29, 1898.

A band of amphibolite that is conformable throughout its entire extent with the sericitic schists of this section of the State extends almost continuously across the State, north and south of Chester. The strike of this band of amphibolite is dependent upon the windings of the schists, and its dip is approximately 90°. Its width will average only a few rods, but in the vicinity of Chester, a few miles both north and south of the town, it is three-quarters of a mile wide, and it is in connection with this broad band that the emery is found. The emery occurs on the eastern side of the amphibolite, and is separated from the sericitic schists by a narrow band of amphibolite, which varies in width from an inch or two to nearly 18 feet. Sometimes there has been considerable serpentinization of the amphibolite, and the emery is separated from the schists by serpentine. Across the Westfield River from the point where the emery is first encountered the amphibolite is replaced by serpentine, and it is in this bed of serpentine that crystals of emery, pseudomorphous after olivine, are said to occur, specimens of them being in the geological collection at Amherst College.

The amphibolite is in appearance a finely laminated rock made up of interrupted thin sheets of feldspar grains and of jet-black needles of hornblende, and usually contains more or less green epidote.

The sericitic schists on the west of the amphibolite, which are described by Professor Emerson under the head of the "Rowe schist,"[a] are biotitic and feldspathic, and often contain garnets that are more or less altered to chlorite. The schists on the east are described as the "Savoy schist,"[b] and are chloritic sericite-schists, mostly of a light-gray color, with a shade of green, due to the chlorite that is mixed with the muscovite. When the chlorite can not be seen with the eye, it is readily detected under the microscope. In some places the proportion of chlorite has increased until there are considerable aggregations of this mineral along the planes of lamination. Garnet and pyrite are also abundant in certain portions of the schist.

The emery vein can be followed for a distance of nearly 5 miles, starting from a point at the north end of the broad band of amphibolite, on the left bank of the Westfield River, just above the railroad bridge of the Boston and Albany Railroad. The general strike of the vein is a little east of south and runs for the most part parallel to the line of contact of the amphibolite and schist. Emery is not found throughout the vein, but the vein can be traced almost continuously by means of streaks of chlorite. The vein varies in width

[a] Mon. U. S. Geol. Survey, vol. 29, 1898, p. 76.
[b] Ibid., p. 156.

from a few feet to 10 or 12 feet, the average width of the emery being about 6 feet. Upon both sides of the emery there are usually developed thin seams of chlorite, varying from 1 inch to 6 inches or more in width. During the early history of the mine a seam of feldspar was encountered, about 12 inches wide, lying to the east of the emery and bordered on both sides by chlorite 3 or 4 inches wide. There is also more or less chlorite developed in the mass of the ore body, which varies from an almost pure magnetite to an intimate admixture of magnetite and corundum. At the Sackett mine (described on p. 135) the corundum, of a bronze color and luster, is coarsely crystallized, giving the ore a porphyritic appearance. Sometimes the corundum has crystallized out in blue and white crystals and in masses of a pound or two in weight.

Dr. F. Von Camerlander[a] describes the occurrence of corundum in the amphibolites of the northwestern part of Austrian Silesia. It is found in white or bluish grains and masses up to the size of a hazelnut. Corundum with hercynite also occurs in the amphibolites at Ronsberg, at the eastern foot of the Böhmerwald, in Bohemia.

CORUNDUM IN ANORTHOSITE.

The amphibolite, with its prevailing light-green amphibole and small amount of feldspar, that so frequently accompanies and intersects the peridotites of Clay County, N. C., and of Towns County, Ga., becomes in places highly feldspathic, and by the dwindling and disappearance of the amphibole it passes into the anorthosite facies at several localities.

Anorthosites of this character, with more or less corundum in grains and irregular masses distributed through the rock, are found on the western slopes of Chunky Gal Mountain, Clay County, N. C., and in association with some of the amphibolites of the Buck Creek area in the same county. These rocks are always greatly subordinate in quantity to the associated amphibolites and peridotites, and never constitute more than an insignificant part of the outcrops.

An occurrence that may be contrasted in some respects with the anorthosites of North Carolina and Georgia is found in South Sherbrooke, Lanark County, Ontario, Canada, where the rock is composed largely of basic plagioclase and a little green hornblende, but is somewhat more basic than the typical Canadian anorthosite. The corundum occurs sparingly in the rock in crystals of almost uniform size, about half an inch in length. Their color varies from light gray to almost white, and sometimes to light pink.

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[a] Verhandl. K.-k. geol. Reichsanstalt, Wien, 1886, p. 356.

Similar to this Canadian occurrence is the corundum-anorthite rock, described by Doctor Morozewicz,[a] from a locality on the Barsowka River, in the Urals, Russia. The percentage of corundum in these rocks of the Urals seems to give promise of economic importance.

CORUNDUM IN NORITE.

In the vicinity of Peekskill, Westchester County, N. Y., corundum has been found associated with norites, which have been described by Mr. G. H. Williams.[b] These rocks belong to the Cortlandt series, of which the prevailing rock type is characterized by the presence of the mineral hypersthene. But though this mineral is there so abundant, a normal norite, containing nothing but plagioclase feldspar and hypersthene, is extremely rare. There is more or less biotite, hornblende, or augite developed in nearly all rocks of this class, so that there is a gradual transition from normal norite to mica-diorite, hornblende-diorite, and gabbro. The intermediate varieties are much more common than the extremes, and they have been classified by Williams according to the prevailing nonfeldspathic mineral. Where hypersthene prevails the rocks are grouped as norites, being subdivided into normal norite, hornblende-norite, mica-norite, and augite-norite, according to the presence of these different minerals in the rock. These so grade into each other that no sharp line can be drawn between them.

Associated with the norites, 3 and 4 miles southeast of Peekskill, N. Y., are deposits of magnetite and emery. These deposits are not in a continuous vein, but are more like segregated masses. Attempts have been made to work these for both iron and emery, but as iron-ore deposits they were soon abandoned. They are still worked to a considerable extent for emery by the Blue Corundum Mining Company, of Boston, Mass.; the Tanite Company, of Stroudsburg, Pa., and H. M. Quinn, of Philadelphia, Pa. An examination of the emery ore by Messrs. J. D. Dana[c] and G. H. Williams[d] has shown that the corundum component is often scattered rather sparingly through the ore, and what had formerly been supposed to be green chlorite was found to be the iron-magnesian spinel, pleonaste. The corundum in the emery varies from small colorless grains and larger bluish grains to crystals 7 mm. in diameter, which show a hexagonal outline.

The pleonaste, which is so commonly associated with the emery, has been found at the Cruger iron mine, in the eastern part of the township, as veins in a nearly normal norite, into which it passes by gradual transitions. The most compact specimens of the ore at this

[a] Tschermaks mineral. und petr. Mittheil., vol. 18, heft 1.
[b] Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 135, 199.
[c] Idem, 3d ser., vol. 20, 1880, p. 199.
[d] Idem, 3d ser., vol. 33, 1887, p. 194.

mine are found to contain the various mineral components of the norite, i. e., hypersthene, feldspar, biotite, and garnet, no corundum having been observed here.

This gradual transition of the pleonaste and iron ore into the normal norite and the occurrence of the norite minerals in the compact ore are strong evidence that these ore bodies were formed by the differentiation of the molten norite magma.

In the vicinity of these norites there are small masses of peridotite, but no corundum has been found associated with them.

Fragments of mica-schist included in the eruptive are altered into a great variety of metamorphic minerals arranged in more or less distinct zones. Beginning at the exterior, these zones consist of corundum and pleonaste followed by quartz with magnetite, pleonaste, zircon, apatite, sphene, garnet, tourmaline, and many others.

Very similar to the spinel emery of the Cortlandt norites are the occurrences of granular corundum and spinel in the basic aggregates of gabbros at Frankenstein and Veltlin, Germany, referred to on page 63.

CORUNDUM IN PLUMASITE.

An interesting discovery of corundum was made in Plumas County, Cal., about 1½ miles northwest of the Meadow Valley post-office, by Mr. J. A. Edman, of Meadow Valley, and to him belongs the credit of the discovery of this new locality and new occurrence of corundum. The corundum-bearing rock was observed on the eastern and lower flank of Spanish Peak at an elevation of about 4,100 feet, and about 2 miles due east of the summit and near the southwest margin of a broad belt of peridotite. The first specimens of the corundum were found by Mr. Edman as float in an adjoining gulch, and he traced it to its source. The corundum rock is composed of about 84 per cent of oligoclase and 16 per cent of corundum. The latter is in crystals varying in size from a fraction of an inch to 2 inches in length and 1 inch in diameter. The general form of the crystals is pyramidal, due to acute rhombohedrons. There are but few of the crystals, however, that are well defined, and in most cases they are imperfectly formed, and the faces are rough and corroded. There has been some alteration in the corundum crystals, which is apparent when these are broken, and on the fractured surface are observed small scales of a pearly mica, the laminæ of which are brittle. This has been determined by Prof. A. C. Lawson to be margarite.

Professor Lawson[a] has made an examination of this occurrence of corundum, and states that there occurs through the feldspathic part of the rock a secondary mineral similar in appearance to corundum

[a] Bull. Dept. Geol. Univ. California, vol. 3, No. 8, pp. 219–229.

and in the form of small veinlets or patches. In this case, however, the luster is more waxy and the color somewhat greenish. The mineral is foliated, and the scales, when examined under the microscope, show it to be uniaxial and positive and to have a feeble double refraction. Its specific gravity was found to be 2.74. Although these data are not sufficient to identify this mineral, they resemble closely the characteristics of some one of the chlorites, and, from the analogy of the common occurrence of the chlorites with the corundum in the basic magnesian rocks throughout the Appalachian region where these rocks are abundant, these data seem to indicate that this mineral is one of the chlorites.

In describing the occurrence of the corundum, Professor Lawson[a] states that the peridotite rock may be found both in a fairly fresh condition and also largely serpentinized.

> The fresh rock has a well-marked but rude schistosity. On fractures transverse to this schistosity it is of a dull, greenish-gray color and compact texture, relieved by long, narrow blades of a light-colored, cleavable mineral and showing irregular partings in the plane of schistosity. On the cleavage surfaces the rock presents a silver-gray, spangled appearance as a groundmass, with numerous cleavage blades of the same light-colored material. These blades lie with their axes of elongation rudely parallel to the schistosity.

When examined in thin section, the rock is seen to be made up of but two primary minerals. The more abundant of these agrees with olivine in its optical properties and forms a mosaic of rather angular or occasionally subrounded anhedrons. These are traversed by irregular sharp cracks, along which incipient serpentines may be observed; this process has occasionally proceeded so far as to give rise to distinct patches of serpentine. The other mineral observed lies in the mosaic of olivine in the form of colorless, elongated prisms, and has the optical characters of tremolite. This mineral makes up about 20 per cent of the rock. The chemical analysis of the rock[b] leaves no doubt of its peridotitic character and can probably be best referred to an amphibole-peridotite similar to those occurring in North Carolina and Georgia. Some portions of this rock have been altered to such an extent that serpentine is the predominating mineral.

According to Professor Lawson's observations—[c]

> The dike of corundiferous rock which cuts this amphibole-peridotite is of quite limited extent. The strike of the dike is about NNW., or transverse to the axis of the ridge upon which it is found. There are but three exposures, and these do not extend for more than 125 feet along the strike. The width of the dike is about 15 feet, but its dip is difficult to determine, owing to the imperfections of the exposures. The slope is mantled with soil and with fragments arising from the disintegration of the amphibole-peridotite, and the

[a] Bull. Dept. Geol. Univ. California, vol. 3, No. 8, pp. 222, 223.
[b] Ibid., p. 224.
[c] Ibid., p. 225.

exposures of the dike project through this covering of loose material. The rock of the dike is composed chiefly of feldspar and is white in color, being thus in marked contrast to the darker rock mass which it cuts.

Professor Lawson regards the corundiferous rock as a separate dike cutting the peridotite and as a new type of rock, for which he proposes the name *plumasite*, from Plumas County, in which it occurs. Without having made any personal examination of this occurrence, but judging from hand specimens of the feldspathic portions of the rock containing the corundum, from specimens of the serpentine and of the peridotite rock, which were kindly sent to me by Mr. Edman, and from the descriptions of Professor Lawson, I find this oligoclase-corundum rock similar to the zone of corundum and oligoclase feldspar which is believed to have separated from the peridotite magma at Buck Creek, Clay County, N. C.

CORUNDUM IN ANDESITE.

The occurrence of corundum in andesite in the United States was first described by Mr. G. F. Kunz, in the case of a dike of andesite at Ruby Bar, near Eldorado Bar, on the Missouri River, 12 miles northeast of Helena, Mont.[a] As described by him, this rock is in a dike cutting the slates of the country and is a vesicular mica-augite-andesite, which is made up of a groundmass of feldspar microlite and a brownish glass in which are many particles of biotite and crystals of augite.

A similar occurrence has been observed by myself on the river 6 miles above Eldorado Bar, at French Bar, which is nearly 12 miles due east of Helena. At this locality a narrow dike, 3 to 6 feet wide, was found cutting through the slates of this section. The trend of the dike is N. 5° to 10° E., and it dips about 45° E. It was encountered by miners who were working the gravels of the bar for sapphires, and it has been exposed at but one point, so that its extent is not known.

The rock is fine grained, of a rather light-gray color, and a decided basic appearance. Biotite is the most conspicuous mineral, and occurs in small, flat, tabular plates, sometimes with distinct crystal outline, and up to a millimeter or two in diameter. In some specimens of the rock there are nodules, 5 to 10 mm. in diameter, that appear to be partially decomposed feldspar. The augite, which is prominent in the thin section, is not very apparent in the hand specimen.

Prof. L. V. Pirsson, of Yale University, has kindly examined thin sections of this rock for me, and says that the rock is an altered augite-mica-andesite. It contains unaltered phenocrysts of a clear

[a] Am. Jour. Sci., vol. 4, 1897, p. 418; Mineral. Mag., vol. 9, 1891, p. 396; Seventeenth, Eighteenth, Nineteenth, Twentieth Ann. Repts. U. S. Geol. Survey.

brown biotite, which are well crystallized and which sometimes show slight resorption. It also contains phenocrysts of augite of a pale-brown color, variable in size, the largest 2 mm. across, replaced in the majority of cases by pseudomorphs of calcite. Besides this pseudomorphous calcite there is also a considerable amount of this mineral in irregular masses or streaks, which may in part be the filling of steam pores and in part be pseudomorphous after hornblende; this, however, could not be definitely determined. The minerals just mentioned are embedded in a groundmass of a brown glass which is everywhere speckled and dotted with microlites of a lath-shaped plagioclase feldspar. These are small and somewhat altered, so that their determination is not entirely satisfactory, but they appear to be oligoclase.

The rock is thus porphyritic, and the structure of the groundmass is typical of the hyalopilitic structure of Rosenbusch. In many respects it closely resembles the augite-porphyrite of Weiselberg, weiselbergite.[a]

One feature that is brought out in the thin sections is the somewhat laminated character of the rock in one direction, while in the slide cut at right angles a well-characterized flow structure is observed, all the longer axes of the minerals pointing in the same direction. This indicates movements of flowing lava after the components had formed.

The corundum crystals occur very sparingly in the rock, and those that were observed were not so sharp and distinct as the blue sapphires found in the gravels.

No definite information regarding the location of Ruby Bar could be obtained, and no one of the bars is now called by that name. It is possible that the bar described by Mr. Kunz is the same as the one now known as French Bar, though from the description given of Ruby Bar, it is apparently not so far up the river as French Bar.

Corundum in andesite has also been described from several European localities. Osann[b] found corundum associated with spinel, biotite, sillimanite, andalusite, rutile, zircon, etc., in a mica-pyroxene-andesite in the vicinity of Cape de Gata, in southeastern Spain. The corundum forms flat, basal plates with striations parallel to the rhombohedron. The rock also contains numerous dark micaceous inclusions.

Dr. A. Lacroix[c] describes the occurrence of corundum in the trachytes, andesites, and basalts of the volcanic district of the Auvergne Mountains in the central plateau of France. The corundum is associated with zircon, diaspore, sillimanite, etc. The rocks also contain numerous acid inclusions that have been more or less

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[a] Rosenbusch, Massige Gesteine, 3d ed., 1896, p. 953.
[b] Zeitschr. Deutschen geol. Gesell., Berlin, vol. 41, 1889, p. 297; vol. 43, 1891, p. 688.
[c] Bull. Soc. minéral. France, vol. 13, 1890, pp. 100–106, etc.

completely destroyed by fusion or solution in the inclosing magma. When not completely destroyed, the inclusions also frequently contain corundum associated with numerous metamorphic minerals.

The trachytes, andesites, and basalts of the Siebengebirge, in Germany, as described by Dannenberg,[a] also contain corundum, spinel, magnetite, sillimanite, and numerous inclusions of sandstone, schist, and granulite.

A hornblende-andesite of the Eifel, Germany, as described by Dr. F. Vogelsang,[b] contains numerous granular aggregates of cordierite, andalusite, sillimanite, feldspar, biotite, corundum, spinel, rutile, quartz, zircon, and magnetite, without recognizable inclusions of older rocks.

CORUNDUM IN MONCHIQUITE.

Near the entrance of Yogo Gulch, in Fergus County, Mont., two parallel dikes of igneous rock have been observed cutting through the limestones. These dikes are about 800 feet apart, and can be followed for over a mile in a nearly east-west course. Their general width is from 6 to 20 feet, but they are occasionally 75 feet wide. They are much decomposed near the surface, but in working them for the sapphires which they contain the nearly unaltered rock has been encountered.

The rock has a dark-gray, decidedly basic appearance, and is very tough, breaking with an uneven fracture. Scattered through it are light-green and white fragments, which are by far the most conspicuous of any of the mineral components of the rock. These are a pyroxene that is more or less decomposed into calcite. Some of these white fragments are probably the barium carbonate witherite, for in the concentrates obtained from washing the decomposed portions of the dike a considerable quantity of this mineral was found. Numberless crystals of pyrite, not over a millimeter in diameter and almost perfect trapezohedrons, were also found in these concentrates. A few scattered tablets of biotite, from 2 to 3 mm. in diameter, were observed. The sapphire variety of corundum is found rather sparingly in this rock in well-formed, flat, tabular crystals, some of which are half an inch in diameter.

Professor Pirsson, of the Sheffield Scientific School, has made a petrographical examination of this rock, and describes it as follows:[c]

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 color-

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[a] Tschermaks mineral. und petr. Mittheil., vol. 14, 1894, p. 17.

[b] Zeitschr. Deutschen geol. Gesell., vol. 42, 1890, p. 1; Am. Naturalist, 1892, pp. 165–166 (Abst.).

[c] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 421.

less 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 probably 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 a 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.

This calcite does not appear to be of secondary origin, and is probably due to fragments of limestone that were picked up as the igneous mass forced its way up through the limestones and were converted into calcite.

In regard to the classification of this rock, Professor Pirsson[a] says:

The rock appears to have its closest affinities in the monchiquite group, of which it may be considered a basic, somewhat altered type. The abundance of biotite shows its relation to the minettes, but the rock is much richer in the ferromagnesian components and lacks the feldspar of the minettes. It has evidently a close affinity with the minettes and shonkinite of the region, and is clearly a more basic form of the same magma. It has the same richness in biotite and pyroxene as these, but differs in the feldspathic component.

If Rosenbusch's classification is followed, this rock would seem to be a basic member of the monchiquite-camptonite series of lamprophyres, one end of which is characterized by an abundance of biotite and augite or hornblende. The rock is too rich in ferromagnesian and too poor in feldspathic constituents to be called a minette or kersantite, and the total absence of the feldspar and the small quantity of feldspathoid make it a very basic member of the general monchiquite group of Rosenbusch.

The sapphire corundum occurs rather sparingly in this rock in well-formed, tabular crystals of a blue color. They vary in size from very minute to half an inch in diameter and are of gem quality. The mineral does not occur in sufficient quantity to constitute a source of corundum for abrasive purposes, but it is of importance as a source of the sapphire gems.

A kersantite described by Doctor Lossen, which cuts sedimentary rocks of Lower Devonian age at Michaelstein, in the Harz Mountains, Germany, and contains numerous inclusions, has also been found to carry corundum. This seems to be a closely parallel case to the one described above, except that the corundum occurs in such minute quantities as to be of only scientific interest.

[a] Am. Jour. Sci., 4th ser., vol. 4, 1897, pp. 421–423; and Twentieth Ann. Rept. U. S. Geol. Survey, part 3, 1900, pp. 552–553.

CORUNDUM IN GRANITE.

At Nannies Mountain, 12 miles northeast of Yorkville, S. C., corundum occurs in considerable quantities in a light-gray biotite-granite. It forms irregular masses of a black color, varying from small grains to several inches in thickness, and usually has a well-developed parallel parting. It is invariably embedded in muscovite, which varies from fine scaly aggregates to compact massive damourite. At the Rickard mine, at the north end of the mountain, a shaft 35 feet deep has been sunk, and several drifts have been made from it; but, as operations have been suspended, these workings can not be examined. Hence the exact relations of the corundum masses to the granite can not be made out. Only granite, however, in various stages of disintegration, and masses of corundum and muscovite were taken from these workings.

Dr. A. Lacroix [a] found corundum in masses of granite included in the volcanic rocks of Auvergne, France; and its occurrence as an occasional accessory in normal granites is mentioned in the petrographical works of both Zirkel and Rosenbusch.

CORUNDUM IN SYENITE.

Deposits of corundum have recently been located in the south-central part of Gallatin County, Mont., on the headwaters of Elk Creek, in a group of foothills between the Gallatin Valley and Spanish Creek basin. The locality is about 23 miles south of Belgrade, Gallatin County, which is on the Northern Pacific Railroad. The corundum has been found in a rock that is composed essentially of orthoclase, feldspar, corundum, and biotite, with the feldspar predominating. The rock for the most part has a somewhat gneissoid structure, and in these portions the corundum is more or less finely divided, being in fine grains and small crystals. In other portions, where the corundum is coarsely crystallized, the rock has something of a pegmatitic character, and the corundum is surrounded by the orthoclase. This rock is called a corundum-bearing biotite syenite, yet from the number of occurrences that are recorded of this mineral acting as a component of these rocks, as in the case of those in Canada and in the Urals, it would seem desirable to recognize rocks of this type as corundum-syenites.

The crystals of corundum vary from a fraction of an inch up to 8 inches in length, and some have been found that weighed 1½ to 2 pounds each. They are fairly well developed in the prismatic zone, but many of them, especially the larger ones, are rounded. In color they vary from bluish gray to almost colorless.

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[a] Bull. Services Carte géol. France, No. 11, vol. 2, 1891.

Somewhat similar to this is the occurrence of corundum in dikes of syenite which penetrate the gneisses over extensive areas of Haliburton, Peterboro, Hastings, and Renfrew counties, Ontario, Canada. The corundum occurs in white or gray to bronzy crystals in the rock, varying from half an inch to 2 or 3 inches in diameter and from 1 to 4 or 5 inches in length. It is very variable in quantity, ranging from less than 10 per cent to 30 or 40 per cent of the rock mass. An average of 12 to 15 per cent has been reported from some localities. Besides corundum, the syenites carry small amounts of magnetite, pyrite, garnet, zircon, and sodalite.

My attention was first called to this occurrence of corundum by Prof. F. W. Traphagen, to whom I am indebted for the first specimens of this corundum sent to me.

CORUNDUM IN PEGMATITE.

Occurrences of corundum in pegmatite are extremely rare, but it has been found in this rock in two localities in Haywood County, N. C. One is at Retreat, on Pigeon River, 6 miles southeast of Waynesville, where corundum occurs in small pegmatite dikes, cutting the saprolitic, garnetiferous gneisses or schists. Accompanying these dikes are thin seams of vermiculites that also carry corundum. The other locality is 3 miles northeast of Canton, at the Presley mine, where corundum occurs in a pegmatite dike which intersects a mass of dark-green amphibolite. The corundum is found surrounded by both feldspar and mica.

An interesting occurrence of corundum that has recently come to the writer's notice is in Fremont County, Colo., about 7 miles from Canyon, which is also the nearest railroad station. The corundum occurs in a matrix composed of quartz, plagioclase feldspar, and mica (muscovite and biotite). The maximum width of this rock that has been observed is 3 feet, and it has been traced for a distance of 3,000 feet. The corundum is thickly scattered through the rock, and is in small particles and fragments up to half an inch or more in diameter. It does not occur in good crystals, but some rough hexagonal prisms half an inch in diameter were observed. Its color varies from nearly colorless through a pale bluish to a rather deep blue and to a pale greenish. There is but little development of parting planes in the corundum, and it shows on nearly all its exposed surfaces a rough conchoidal fracture. In the specimens that have been examined the quartz forms a considerable percentage of the rock, while the corundum sometimes appears nearly as prominent. The feldspars and micas are developed to a less extent. The corundum is transparent to semitransparent, and some is of gem quality.

Near the head of Muskrat Fork of Shooting Creek, Clay County, N. C., and extending about halfway up the adjoining slope of Chunky Gal Mountain, there are two parallel dikes of dark, fine-grained hypersthenite, which are from 550 to 600 feet apart, and each about 10 feet thick. The dike rock consists of rounded, irregular grains of strongly pleochroic hypersthene, nearly half of which has been altered to a green amphibole. Corundum occurs in the gneiss between these dikes, and also in a band of black biotite, which is intimately associated with a small vein of pegmatite 2 feet in thickness. The biotite is developed in large scales and plates and contains nodules of corundum up to half an inch in diameter, which are surrounded by scales of a white mica, muscovite.

CORUNDUM IN METAMORPHIC ROCKS.

CORUNDUM IN SERPENTINE.

At a number of peridotite localities in North Carolina and Georgia crystals and fragments of corundum have been found that were surrounded by serpentine, but nowhere in the Southern Appalachian region has corundum been found associated with the larger masses of serpentine that have been derived from the alteration of the peridotites, as at several localities in Buncombe County, N. C. In Chester and Delaware counties, Pa.,[a] there is a long belt of serpentine rocks, part of which, at least, have been derived from peridotite rocks, and in connection with these, in the eastern part of Chester County and the western part of Delaware County, corundum has been found. In this the corundum occurs near the contact of the country rock, and its occurrence in the serpentine is almost identical in conditions with those of the corundum in the peridotites and pyroxenites of North Carolina and Georgia. Considerable plagioclase feldspar is associated with the corundum in the vein in a manner somewhat similar to the occurrence of this mineral at the Cullakeenee mine, Buck Creek, Clay County, N. C.

CORUNDUM IN GNEISS.

Corundum has been found in North Carolina in the ordinary gneiss of the same belt of crystalline rocks in which the peridotites occur. As observed, these gneisses are often very variable, passing frequently into mica-schist and sometimes into quartz-schist. Such transitions are occasionally quite sudden, but usually there are thin zones of more or less intermediate character; and sometimes it is difficult, if not impossible, to decide what should be called gneiss and what mica-schist, etc. A number of occurrences, part of which may be corun-

[a] Geol. Survey Pennsylvania, C4, 1883, p. 351.

dum in gneiss, are described under the head of mica-schist; some of the rock that was at first thought to be a gneiss is now known to be a quartz-schist.

In the eastern part of Clay County, N. C., on the southern slope of Gross Ridge of the Chunky Gal Mountains, just above Thumping Creek, corundum has been found in the gneiss at a number of points. The rocks are so covered with soil and decomposed rock that the exact relation of the corundum-bearing gneiss to the normal gneiss can not be determined, but from what can be seen the former appears to be in narrow bands cutting through the latter. In structure the gneiss is distinctly laminated and very fine grained, except the portions immediately surrounding the corundum, where its constituents are much more coarsely crystallized, especially the biotite. It is a hornblende-gneiss, showing but little mica except where associated with the corundum.

The corundum occurs in nodules and crystals, half an inch and smaller in diameter, sometimes wrapped with muscovite in a manner similar to that described for the corundum in the chlorite-schists (p. 59). The crystals are prismatic, with the length of the prism usually two or three times its diameter. Occasionally they are very flat, with the prism not over a quarter of an inch in length and half an inch in diameter, and from their appearance these crystals are known locally as "button" corundum.

The occurrence of corundum in the gneisses of Clay County is illustrated in Pl. III, *B*, from a photograph of a mass of gneiss containing corundum from the Meminger and Hooker mine, Muskrat Fork, Clay County.

In Buncombe County, N. C., on the Elk Mountain range, a few miles north of Asheville, corundum has been found associated with garnet, sometimes being entirely inclosed by the garnet and at others inclosing the garnet. The corundum occurs in a garnetiferous gneiss, and although it is somewhat abundant it is very doubtful if this will prove to be a commercial source of corundum. As described by Mr. C. E. Lyman, of Asheville, the corundum is found in crystals that sometimes measure as much as an inch in diameter. They are prismatic and are terminated by the basal plane. They vary considerably in color, from blue to red, and a few gems have been cut from some of them. The corundum is found in the gneiss near its contact with a pegmatitic dike.

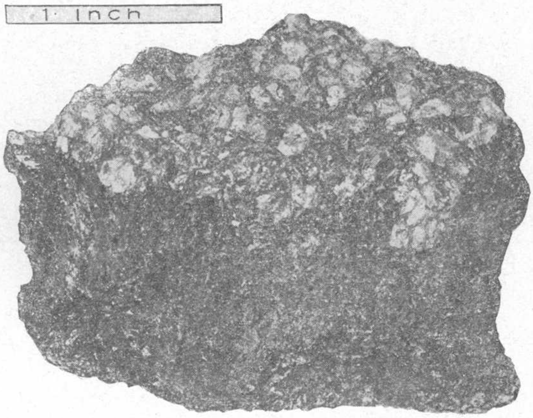
In Jackson County, N. C., just north of Betts Gap, in the Cowee Mountains, splendid grayish, translucent crystals of corundum have been found in a garnetiferous gneiss. On Caney Fork of Tuckasegee River, Jackson County, at the mouth of Chastains Creek, and also at a point 2 miles up Chastains Creek, corundum surrounded by muscovite is found in small grains and nodules up to an inch in diameter in biotite-gneiss. The nodules are often drawn out into small lenticular "eyes." The corundum is chiefly confined to the micaceous bands of the gneiss, and, on account of the greater resistance of its muscovite coating, it stands out in prominent knobs over the weathered surfaces of the gneiss. A similar occurrence is found in the gneiss at the mouth of the North Fork of Ellijay Creek, in Macon County. Also, 3 miles north of this, corundum is found in a decomposed hornblende-gneiss on the summit of Turkey Knob. In this same general vicinity corundum has been found in chlorite-schist, as described on page 59.

Six miles southeast of Burnsville, Yancey County, N. C., on Celo Ridge, near South Toe River, corundum is found in almost the same relations as described on page 118 on the mountain north of Corundum Hill mine. An enstatite rock partly altered to talc appears in an outcrop about 50 feet wide. Along its eastern border some chlorite is developed, and in the adjacent decomposed gneisses corundum is found for a distance of 2 or 3 feet from the contact. The corundum is in irregular masses and imperfect crystals up to 2 or 3 inches long, and is often more or less inclosed in radiating muscovite.

Corundum occurs in decomposed gneiss associated with no other recognizable rock three-fourths of a mile northwest of Bakersville, Mitchell County, N. C., on the Johnson road. So far as could be ascertained, the conditions here are very similar to some of those on Shooting Creek, in Clay County, already described.

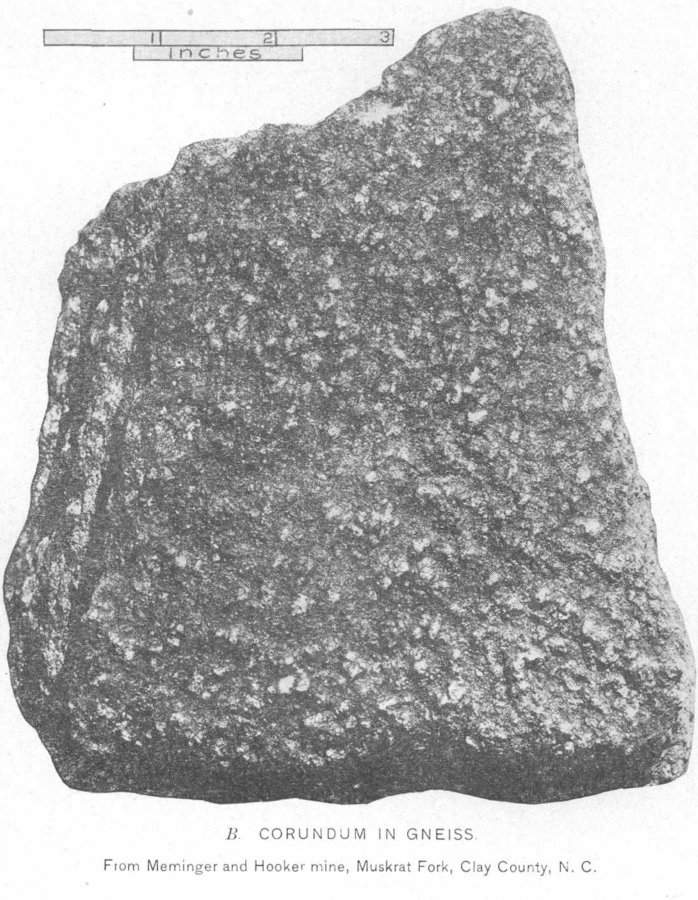
At Corundum Hill mine, Macon County, N. C., one of the chief sources of corundum has been the peripheral or border vein developed along the southeastern border of the peridotite. (See map, Pl. XV.) When this mine was visited, in 1895 and 1896, the tunnel following this vein had encountered a tough hornblende rock in the gneisses adjoining the peridotite, varying in character from a hornblende-gneiss to a massive amphibolite and bearing corundum in considerable abundance in grains and small crystals. At the time mentioned this material was one of the principal sources of corundum, the rock being blasted out and hauled to the mills on wagons for crushing and cleaning. The exact nature of this rock is in doubt. The peridotite is everywhere bounded by biotite-gneiss and mica-schist, so far as appears at the surface; but as bands of hornblende-gneiss frequently appear in the biotite-gneiss it might very well be a member of the gneisses proper. On the other hand, its occasional massive character and its abundance of corundum make it closely resemble the amphibolites that form dikes in and about so many of the peridotites in Clay County and the adjoining portions of Georgia.

On top of the mountain spur 2 miles north of the Corundum Hill mine, Macon County, N. C., an outcrop of enstatite-talc rock about 50 feet wide occurs. The partly decomposed, friable gneisses at the



A. CORUNDUM IN CHLORITE.

From Corundum Hill, Macon County, N. C.



B. CORUNDUM IN GNEISS.

From Meminger and Hooker mine, Muskrat Fork, Clay County, N. C.

eastern border of this mass are corundum bearing for a thickness of about 6 feet. The corundum occurs in small grains and is not abundant.

Near the confluence of Owens and Parker creeks, which form West Fork of French Broad River, in Transylvania County, N. C., several large bowlders of cyanite have been found on the surface which bear grains and small crystals of a deep sapphire-blue corundum. The rocks of the vicinity are gneisses, and these are undoubtedly the source of these cyanite-corundum aggregates.

CORUNDUM IN METAMORPHOSED ZONE BETWEEN HARZBURGITE AND GNEISS.

An important variation from the usual mode of occurrence of corundum with the peridotites in the southern portion of the United States is found near Pelham, Mass. At the asbestos quarry near Pelham there is a lenticular mass of the harzburgite (saxonite) variety of the peridotite rocks about 40 feet in width of outcrop and 200 feet in length, penetrating the acid gneiss of the country. The harzburgite is very much altered to a depth of 3 to 12 feet, when the hard, nearly fresh rock is encountered, which is of a dull black color and is made up of grains of olivine and the orthorhombic pyroxene, bronzite. The black color of the rock is due to disseminated particles of chromite and magnetite. Part of the magnetite may be due to an alteration of the grains of olivine similar to that observed in the dunites of North Carolina, where, at the beginning of its alteration, there is a deposition of magnetite in fine grains, which forms a network of black lines often outlining the grains of olivine.

Professor Emerson has made a petrographical examination of this rock and describes it as follows:[a]

> This is a very fresh mixture of olivine and enstatite, both dusted through with black ore, largely chromite. It is a dull-black rock of very great toughness. The olivine grains have often many crystalline faces. The enstatite is in rare, small plates, with parallel sides and irregular ends, and with a fine wavy lamination, which is often marked by lines of black ore, generally concentrated in some part of the plate, especially the center. Although nearly colorless or pale bronzy in common light, it has marked pleochroism. It is plainly rhombic, and grades into the asbestiform decomposition product in veins running through the section.

None of the anthophyllite that is so abundant in the decomposed portion of the harzburgite was observed in the fresh rock.

From the fresh rock to the surface and the contact with the gneiss the harzburgite is more or less completely altered, and penetrating through it there is a network of veins of anthophyllite, which are more or less asbestiform. These veins vary in width from very thin

[a] Mon. U. S. Geol. Survey, vol. 29, p. 52.

seams to 8 inches, with some that are very much wider, from which fibrous masses have been obtained 20 to 30 inches long. It is these veins of fibrous anthophyllite that constitute the asbestos of the Pelham quarry.

The harzburgite is separated from the gneiss by a band of bronze-colored biotite, usually 4 to 8 inches thick, but in places reaching a thickness of 4 feet. In this wider portion there are nodules or imperfect crystals of corundum of a grayish color mottled with blue. These are often wrapped with chlorite. Nodules of a black-green hornblende and an emerald-green actinolite are also found in the biotite. There has been no great quantity of the corundum found.

This zone of biotite is probably the result of contact metamorphism of the harzburgite on the gneiss, and the inclosing corundum was formed at the same time. This is similar to the large quantity of corundum occurring in biotite at the contact of harzburgite and gneiss of the Bad Creek mine, Sapphire, N. C. (See p. 125.)

CORUNDUM IN MICA-SCHIST.

Occurrences of corundum in mica-schist have been observed at a number of widely separated localities, but at none of them has the corundum been found in large quantity.

In North Carolina, just south of the divide in the Cowee Mountains, in a gap at the head of Ellijay Creek, Macon County, corundum occurs in a decomposed, friable, garnetiferous mica-schist. The corundum is bluish gray and occurs in grains and small nodules. The schist sometimes carries scales of graphite, and in places is quite gneissic in character. Limestones occur within half a mile southwest of this locality and at intervals for 2 miles in the same direction. Some years ago this deposit was worked to a limited extent; it is known as the "Haskett mine."

Two miles southwest of Balsam Gap, in Jackson County, N. C., masses of cyanite with some corundum are to be found in the mica-schist in a railroad cut a few hundred feet east of a large body of peridotite. The schist is in some places garnetiferous; sometimes it shows also small amounts of scaly graphite; and in some portions a gneissoid character is developed. Similar masses of corundum-bearing cyanite have also been found on the surface in the vicinity.

An occurrence in many ways similar to the last is found at Retreat, 6 miles southeast of Waynesville, on West Fork of Pigeon River, in Haywood County, N. C. Corundum, with and without associated cyanite, is found over the surface in irregular masses and barrel-shaped crystals. The rocks are garnetiferous mica-schist with gneissic facies, as at Balsam Gap, and are intersected in places by small pegmatite dikes. Much of the corundum is wrapped in a thin coating of a very compact material resembling damourite.

In a region of garnetiferous mica-schist tapering prismatic crystals of grayish-blue corundum are found on the surface on the ridge leading northwest from Carpenters Knob, along the borders of Burke and Cleveland counties, near the corner of Catawba County, N. C.

There are two localities in South Carolina where corundum has been found more or less abundantly on the surface and in the gravels of the streams; one about 8 miles northwest of Gaffney, Cherokee County, on the Island Ford road, near Maud post-office on the Turner Phillips farm; and the other about 1¼ miles northeast of the town of Laurens, Laurens County. At neither locality has the corundum been found in place, but crystals of corundum surrounded by scales of mica have been observed at both Gaffney and Laurens, and at the latter place fragments of what had all the appearance of a mica-schist were found that contained crystals of corundum. (See pp. 149–150.)

Seven to 8 miles southwest of Thomaston, Union County, Ga., corundum has been found on the surface over a considerable area, and, although it has not been found in place, some specimens of corundum were found enveloped in a matrix of mica-schist. (See p. 143.)

Genth[a] has described an occurrence of corundum in Patrick County, Va., about 2 miles from Stuart, where it has been found in the mica-schists on a knob of Bull Mountain. Here the mica-schists, sometimes garnetiferous and gneissic, are intersected by granite, which separates the schist into narrow bands that can be followed for some distance across the country. The corundum is found associated with andalusite, cyanite, chloritoid, and mica. It occurs in rough crystals and nodules up to 1 inch in length and half an inch in diameter, of a grayish-white to white color and colorless. Sometimes it is so finely divided that it appears as microscopic grains inclosed in the mass of associated minerals. It is readily cleaned, and tests made upon the cleaned product show that it is well adapted for the manufacture of the vitrified wheel.

At the Calumet iron mines in Chaffee County, Colo., corundum crystals have been found in the mica-schists at their contact with intrusive dikes of diorite.

It is quite possible that some of the corundum schists of South Africa, described on page 158, may be highly corundiferous facies of mica-schists or quartz-schists, and hence comparable to some of the United States occurrences described above.

CORUNDUM IN QUARTZ-SCHIST.

It has recently been observed that portions or bands of the crystalline rocks of the southeastern part of Clay County, N. C., and the

[a] Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 4.

northeastern part of Towns County, Ga., are corundum bearing. These rocks vary in composition from those that are a normal gneiss to those that contain no feldspar and can best be described as quartz-schist composed of quartz and biotite mica. Some portions of the rock are rich in garnet, others are almost entirely free from this mineral, and occasionally there are also small bands of white quartzite. The rocks are distinctly laminated and are frequently intersected by granitic dikes some of which are coarsely crystallized and of a pegmatitic character. These dikes are often parallel with the bedding of the schists, although many of them cut irregularly through the schists. Where these dikes are parallel to the bedding of the schists, the laminated structure of the latter is much more apparent. The general strike of these crystalline rocks is about northeast and southwest and the dip is about 30° NW.

Portions or bands of these schists are corundum bearing, but they are irregularly defined and gradually merge into the normal rock. They have a relation to the normal schists similar to that of the garnet-bearing bands of a gneiss to the normal gneiss in which they occur. These bands are not veins in any sense of the word, but are simply portions of the same mass of crystalline rocks in which corundum occurs as a constituent of the rock. They vary in width from a foot or two to 12 or 15 feet, but in these wider bands the corundum-bearing portion is not continuous and is intercepted by streaks of barren rock and granitic dikes. The bands can be traced for a distance of 5 or 6 miles in a northeast-southwest direction, sometimes outcropping continuously for nearly a mile. There are at least two of these corundum-bearing bands which are parallel to each other and about 2 miles apart. The only variation that has been observed in them is in the percentage of corundum and garnet; otherwise they are identical. The amount of corundum is never large, and from determinations made on samples from various parts of the deposits it will not average over 2 to 3 per cent.

The corundum occurs for the most part in small particles and fragments that have no regular shape and are of a gray, white, and bluish-white color or almost colorless. It is also in crystals which vary in size from some that are very minute to some that are 2½ inches long and about one-half inch in diameter, and that are usually fairly well developed in the prism zone. Suggestions regarding the origin of the corundum in these schists are given on pages 96–97.

Near Teltonville, Forsyth County, Ga., surface specimens of corundum have been found that evidently originated in the quartz-schists of that region.

CORUNDUM IN AMPHIBOLE-SCHIST.

At the Sheffield mine, in Cowee Township, Macon County, N. C., corundum has been mined in a saprolitic rock at various times for a number of years. In a shaft sunk to determine the depth of the corundum-bearing saprolite, solid, unaltered rock was encountered. The shaft, which was 87 feet deep, passed through the following rocks: The first 12 feet (*a*) was through the saprolite, in which there were seams of kaolin; the next 2 feet (*b*) were corundum bearing. From 14 to 28 feet (*c*) the same saprolite was encountered; the next 2 feet (*d*) were corundum bearing, followed by 10 feet (*e*, from 30 to 40 feet) of the saprolite, and 2 more feet (*f*) that were corundum bearing. From 42 to 63 feet (*g*) the rock began to be less decomposed, and from 63 to 66 feet (*h*) another seam of corundum-bearing rock was encountered. From this point to the bottom of the shaft the rock became more and more solid, until at 77 feet (*i*) the fresh rock was encountered. These various seams in the rock are very pronounced. They dip 30° toward the west near the top, but become nearly horizontal near the bottom of the shaft. The seams of decomposed feldspar observed in *a* become less and less kaolinized, until in *i* the seams are of pure plagioclase feldspar. In *i* there are two seams of corundum similar to *b*, *d*, and *f*, although in the fresh rock the corundum seams are not as pronounced as in the saprolitic rock. There is often a considerable amount of feldspar bordering the seams of the corundum. The general trend of the rock is about N. 5° to 10° E.

From what could be seen of the solid and the saprolitic rocks, it is evident that the corundum occurs at intervals in the rock in seams a few feet in width. The corundum may comprise 10 per cent or more of the veins, but the quantity in the rock that it would be necessary to mine would probably not be over a few per cent. The actual width of the dike is not known, but the saprolitic rock has been cut across for about 100 feet in a direction nearly at right angles to its strike.

The fresh rock at the bottom of the shaft is somewhat varied in appearance, and though it does not show any definite gneissoid structure, it sometimes closely resembles it. There are streaks in the rock a few inches thick, the more finely divided portions of which are distinctly gneissoid.

Some portions of the rock are decidedly porphyritic, and contain phenocrysts of a light-gray amphibole, a centimeter in diameter, in a groundmass of feldspar. A large part of the rock is made up, however, of small, roughly outlined prismatic crystals of an amphibole, probably hornblende, and of irregular fragments of plagioclase feldspar. The hornblende is almost black in color, but in thin splinters it has a bronze luster and a deep resinous color. Biotite of a deep-brown color occurs sparingly, and a pink garnet is rather abundant. This part of the rock has a gneissoid structure and contains the corundum. The corundum is of a light to a purplish-pink color and occurs in nodules up to 2 or 3 cm. in diameter. Some streaks in the rock are highly garnetiferous, and are composed essentially of garnet and plagioclase feldspar or of garnet and biotite. Chalcopyrite occurs very sparingly in these portions of the rock. Small particles of graphite have been observed in the coarsely crystallized portions.

Professor Pirsson has kindly made a microscopical examination of this rock, the results of which are embodied in the following paragraphs:

In thin section the microscope disclosed the minerals hornblende, plagioclase feldspar, garnet, biotite, muscovite, staurolite, and rutile. Hornblende is the most common, forming about two-fifths of the section, while of the remainder plagioclase and garnet occur in about equal quantities and the others in comparatively insignificant amounts.

The hornblende is formless, but tends to irregular columns, almost invariably extended in the plane of schistosity. It has very rarely a somewhat stringy tendency in its cleavage, but is usually homogeneous in broad plates. Its color is a clear olive-brown, and it is somewhat pleochroic, but not strongly so. It is everywhere dotted by the small grains of garnet, which rarely show good crystal form. The garnet occurs associated also with the plagioclase.

The plagioclase occurs twinned according to the albite law only. In sections perpendicular to 010 the lamellæ show extinction as great as 30°, and the plagioclase is therefore rich in lime and as basic as labradorite, which it probably is. It shows strong evidence of shearing movement in the rock; it is often broken, exhibits rolling extinction, and the albite lamellæ are curved and bent. It runs along the planes of schistosity between the feldspars and forms a mosaic of angular broken grains.

Staurolite was found in rather broad, irregular grains, and rutile in small, irregular grains and well-crystallized prisms.

Professor Pirsson has indicated that the character and structure of this rock, composed chiefly of amphibole, labradorite, and garnet, suggest most strongly that it is a metamorphosed igneous rock of the gabbroid family. During metamorphism the augite of the gabbro would be converted into the brown hornblende; any iron ore that was present would be taken up by the hornblende and the garnet. The rutile would have resulted from the titanic acid that is a regular component of the iron ores in these gabbro or diabase rocks. Staurolite is a mineral that would be rather naturally expected, as it is usually a mineral of metamorphism, and its natural home is in the schistose rocks. The feldspar has suffered the least (except the corundum) chemically, and shows only the shearing of dynamic processes.

The corundum does not occur in crystals, but in small fragments and in elongated nodules, which are cracked and seamed and appear to have been drawn out by the shearing processes. The general character and shape of the fragments of corundum would indicate that they were original constituents of the igneous rock and were not formed during its metamorphism.

The exact classification of this rock is not apparent, and it is here simply designated an "amphibole-schist," according to its present character.

CORUNDUM IN CHLORITE-SCHIST.

Besides being associated with chlorites in the peridotites and pyroxenites, already described, corundum is found in the long belts of chlorite-schist that traverse the country 10 or 12 miles southeast of Webster, Jackson County, N. C. These chlorite rocks, which sometimes attain a width of several hundred feet, are traceable for miles across the country. Almost the only constituent of these rocks is a green, scaly chlorite, though sometimes there are present small grains of feldspar, and occasionally needles of amphibole. The chlorite is in small scales, never very coarse, as is sometimes the case in the zones about the peridotite, and often these scales are so minute as to give the rock a very compact appearance.

In one of these belts, on Caney Fork of Tuckasegee River, Jackson County, N. C., corundum is disseminated through the chlorite for a thickness of 8 feet, in small, rounded masses, ranging in thickness from minute grains to an inch, and there the chlorite is not so compact as elsewhere. The corundum is usually wrapped with a white coating of mica, which is a secondary mineral derived from the corundum. The mica is often in radiating scales perpendicular to the outer surface of the corundum, and while in some cases it is very thin, in other cases it has replaced nearly all of the corundum, leaving but a grain of that mineral in the center.

In Towns and Union counties, Ga., near the North Carolina line, numerous outcrops of chlorite-schist occur on the waters of Brasstown and Arkaqua creeks, many of them corundum bearing. In some cases these schists are associated with outcrops of recognizable peridotite or troctolite, but in the majority of cases only the chlorite-schist is visible. To all appearance these outcrops are similar in character to those just described in Jackson County, N. C. At one of these localities, however, at the Track Rock Gap corundum mine, it has been shown that the chlorite-schist is an alteration production of amphibolite or an amphibole-peridotite,[a] specimens only partially altered being brought to light in the deeper workings.

In Pl. III, *A*, there is illustrated the occurrence of corundum in chlorite at the Corundum Hill mine, Cullasagee, Macon County, N. C.

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[a] King, F. P., Bull. No. 2, Geol. Survey Georgia, 1894, pp. 92–95.

CORUNDUM IN CRYSTALLINE LIMESTONE.[a]

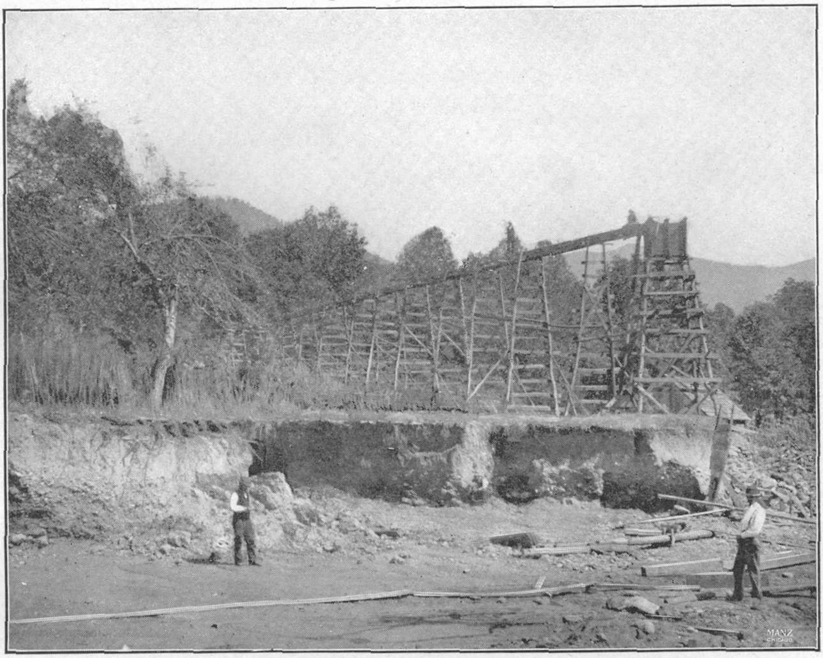
Extending from Byram, Sussex County, N. J., to Warwick Township, N. Y., a distance of about 25 miles, there is a belt of limestone having a general northeast-southwest strike, which widens out toward its northern end. About 1828 a specimen of sapphire corundum was found at Franklin Furnace in a detached piece of rock composed essentially of feldspar; but, although search was made, no more specimens were found in this vicinity. A few years later sapphire corundum was found in Newton Township, about 6 miles from Franklin Furnace, embedded in a feldspar and partly surrounded by a carbonate. Prof. W. P. Blake[b] has described the occurrence of red sapphire corundum in the white crystalline limestones in Vernon Township, Sussex County, N. J. The finest specimens were ruby-red in color, and the others were of various shades of purple. The crystals were translucent, but no transparent ones were observed. Dana reports the occurrence of sapphire corundum in these limestones near Newton and Vernon, Sussex County, N. J., and near Amity, Orange County, and Crugers Station, Westchester County, N. Y.

The corundum found in these limestones of New Jersey and New York is near dikes and bosses of intrusive granite, and in the form of hexagonal crystals and irregular grains and masses of various colors—white, blue, red, purple, etc. Associated with it are spinel, chondrodite, phlogopite, graphite, ilmenite, rutile, sphene, zircon, and many other minerals. The contact phenomena of the granite of Mounts Adam and Eve, in Orange County, N. Y., are described by Prof. J. F. Kemp and Mr. Arthur Hollick.[c] Numerous silicates and other minerals occur in nodules or disseminated grains through the limestone, as hornblende, dark mica, augite, titanite, scapolite, pyrite, chondrodite, spinel, and fluorite, with occasionally sussexite, vesuvianite, tourmaline, and corundum.

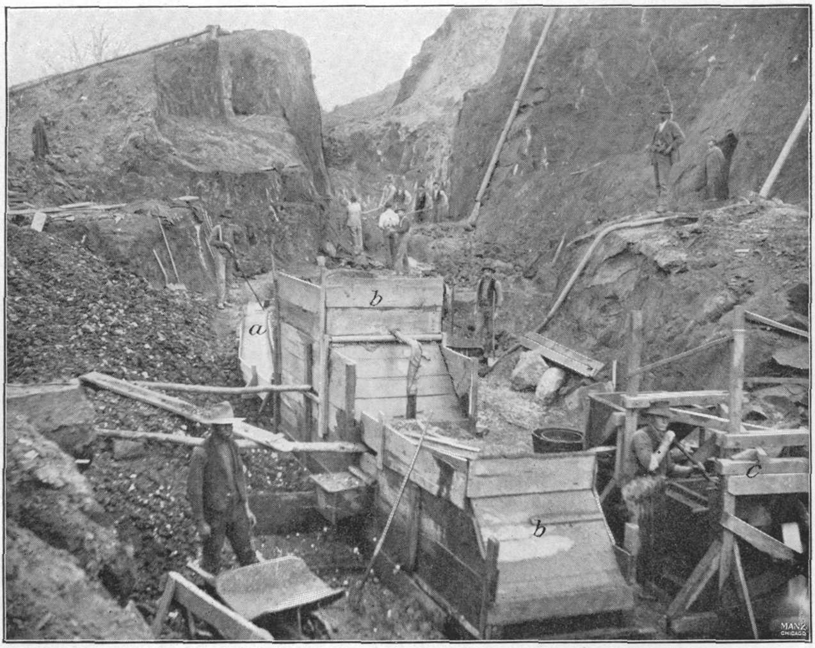
The crystalline limestones of Burgess Township, Lanark County, Ontario, Canada, also contain small grains and crystals of rose-red to sapphire-blue corundum in association with quartz, feldspar, calcite, muscovite, sphene, etc.

Dr. A. Lacroix[d] has described the occurrence of corundum with humite, brucite, amphibole, phlogopite, scapolite, spinel, sphene, rutile, zircon, and other minerals, in the marbles of Mercus and Arignac, Ariège, France. Red and blue corundum has also been found associated with tourmaline in the dolomite at St. Gotthard; and the

[a] Am. Jour. Sci., 1st ser., vol. 21, 1832, p. 319.
[b] Idem, 2d ser., vol. 13, 1852, p. 116.
[c] Annals New York Acad. Sci., vol. 7, 1893, pp. 638 et seq.
[d] Bull. Services Carte géol. France, vol. 2, No. 11; Am. Naturalist, 1891, pp. 138–139 (Abst.).



A. BED OF RUBY-BEARING GRAVEL AT CALER FORK, COWEE VALLEY, MACON COUNTY, N. C.



B. RUBY MINE AT COWEE VALLEY, NORTH CAROLINA.

Plant for washing gravel is shown in foreground; *a*, sluice box; *b*, sieve boxes; *c*, rocker.

extensive occurrences of large irregular masses of emery in the white crystalline limestone of the province of Aidin, in Asiatic Turkey, are well known.

CORUNDUM IN ALLUVIAL DEPOSITS.

The gem varieties of corundum are found chiefly in the soil and in gravel beds, as those of Burma, Ceylon, Siam, and other regions of southern Asia; the saphire deposits of Lewis and Clark, Granite, and Deerlodge counties, Mont., and the ruby deposits of Macon County, N. C. Together with these are also found the commoner varieties of crystallized corundum. In some of these localities the mineral has been traced to its origin in the crystalline rocks.

The gravel beds represent the result of ages of concentration. During the time that the rocks were slowly decomposing and crumbling away through the agencies of air and water, the stream beds furnished a natural system of sluices, in which the heavy and more resistant minerals were caught and retained, while the lighter materials were carried farther down the valley. Thus, if all the material transported by the streams had been of about the same degree of fineness, there would have been an almost perfect deposition of the different minerals according to their specific gravity, the heavier ones being deposited higher up the stream and nearer their origin; or, if the materials transported had been of various degrees of coarseness, but about the same specific gravity, there would have also been an almost perfect sorting of the materials according to sizes, the coarsest farthest up the stream. Since both of these kinds of deposition have been going on at the same time, the heavy minerals and the bowlders and large fragments of the lighter ones are found intermingled, thus forming the alluvial gravel deposits as they are seen at the present time. (See Pl. IV, *A*.)

Although the corundum gems may have been quite rare in the original rock, they have been concentrated in these gravel deposits, and are thus found in comparative abundance. Even after the corundum of the gravel deposits has been traced to its original source in the rocks, the gravels often still remain the principal commercial source of the gems.

EMERY IN UNDETERMINED ASSOCIATION.

In 1852 Dr. C. D. Hunter[a] observed masses of emery associated with crystalline corundum in granular quartz-mica aggregates at Crowders Mountain, in Gaston County, N. C.; in 1875 Dr. F. A. Genth[b] described emery associated with the titaniferous iron ores

[a] Am. Jour. Sci., 2d ser., vol. 15, 1853, pp. 373–378.
[b] Rept. Geol. Survey North Carolina, 1875, p. 246.

near Friendship, in Guilford County; it has been found associated with staurolite on Mine Fork of Jacks Creek, 3 miles north of Burnsville, in Yancey County; and extensive deposits have also been observed 5 to 7 miles southeast of Franklin, in Macon County.

FOREIGN OCCURRENCES OF CORUNDUM.[a]

A number of foreign occurrences of corundum, especially those that are of economic importance, have already been referred to in connection with descriptions of similar occurrences in this country. There are, however, several other modes of occurrence of corundum of scientific interest that have been observed in foreign localities, but have not yet been found in the United States. These are briefly mentioned below in order to make the list of known corundum-bearing rocks as nearly complete as possible:

Corundum-bearing rocks not found in the United States.

Igneous	Kyschtymite. Diorite. Tonalite. Gabbro. Nepheline-syenite. Syenite-pegmatite. Quartz-porphyry. Trachyte. Basalt. Contact zones and inclusions in igneous rocks.
Metamorphic	Corundum-schists and porphyroids. Graphite.

CORUNDUM IN FOREIGN IGNEOUS ROCKS.

CORUNDUM IN KYSCHTYMITE.

Morozewicz has differentiated what he considers a new type of rock and has given it the name kyschtymite, after the Kyschtym district of the Urals.[b] The rock is medium grained and is composed of idiomorphic corundum of a pyramidal habit, anorthite, and biotite, with accessory dark-green spinel, apatite, and zircon.

CORUNDUM IN DIORITE.

Teller and von John [c] found corundum associated with tourmaline, spinel, ilmenite, rutile, biotite, and occasionally zircon, in the borders of the quartz-mica-diorites that penetrate the gneisses and

[a] This part of this paper was especially prepared by Prof. J. V. Lewis and the writer for Bull. No. 19, Geol. Survey North Carolina.

[b] Tschermaks mineral. u. petr. Mittheil., vol. 18, pts. 1, 2, 3, 1898, and review of same in Jour. Geol., vol. 7, 1899, p. 304.

[c] Jahrbuch K.-k. geol. Reichsanstalt, vol. 32, 1882, pp. 589–684.

schists at Klausen, in southeastern Tyrol. The same minerals were also found associated in the contact zones of the schists and gneisses. The corundum is in colorless or bluish crystals of microscopic dimensions, only the tourmaline, in fact, being visible to the naked eye.

CORUNDUM IN TONALITE.

Zirkel[a] notes the occurrence of corundum in the tonalite of the Eifel, Germany.

CORUNDUM IN GABBRO.

Andreas and König[b] describe an extremely basic facies of saussuritic hornblende-gabbro at Frankenstein, Germany, in which masses and streaks of magnetite, sillimanite, and tabular crystals of colorless corundum occur in large, allotriomorphic plagioclase feldspars. In every way comparable to this is the occurrence of nodules and masses of spinel and corundum in coarse, irregular feldspars in the somewhat amphibolized gabbro of Veltlin, Germany, described by Linck.[c] Attention has already been called to the similarity of these occurrences to the spinel-emery in the norites of the "Cortlandt series" of eruptives, in Westchester County, N. Y.

CORUNDUM IN NEPHELINE-SYENITE AND SYENITE-PEGMATITE.

In the province of Ontario, Canada, corundum occurs as a primary constituent of a series of rocks which vary from a normal syenite through a mica, hornblende, and nepheline-syenite; it is also found in a syenite-pegmatite. These syenites vary greatly in size of grain and mineralogical composition in different parts of the field, and in some cases the syenite masses appear to merge gradually into garnet; but when this is the case corundum is absent in the rock. These rocks are found in the eastern portion of Ontario in three belts. One belt lies to the north and has been traced for a distance of over 50 miles; to the south of this main belt are two smaller belts, one lying to the southwest and the other to the southeast. It is not improbable that these two smaller belts are connected with the larger belt in some way, perhaps in circular form; or it may be found that they are roughly parallel bands. The three belts taken together partly surround a region with a diameter of about 50 miles. These rocks have been described by Mr. W. G. Miller and others in the various reports of the Geological Survey of Canada and in the reports of the Ontario bureau of mines, Toronto.

Commercial deposits of corundum have thus far been found only in the normal syenites which are corundum bearing. In some of the

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[a] Lehrbuch der Petrographie, 1893, p. 461.
[b] Abhandl. Senck. Gesell. Frankfurt, 1888, p. 62.
[c] Sitzungsber. K. preuss. Akad. Wiss. zu Berlin, vol. 6, 1893, p. 47.

nepheline-syenites a nearly transparent corundum of gem quality has been found. A further description of these deposits and the names of the companies operating corundum deposits are given on pages 151–153.

CORUNDUM IN QUARTZ-PORPHYRY.

The only instance of corundum in quartz-porphyry that has been noted is that described by Von Foullon[a] from Teplitz, in Germany. After subjecting the rock to the action of hydrofluoric and sulphuric acids an insoluble residue was obtained consisting of small grains of corundum.

CORUNDUM IN TRACHYTE.

Hussak[b] described corundum from the trachytic bombs of the volcanic region of the Laacher See, in Germany. Porlig[c] found green corundum in a bomb from the trachyte-tuffs of Königswinter; and Dana[d] mentions a similar occurrence in bombs at Niedermendig.

CORUNDUM IN BASALT.

Besides the occurrence of corundum in metamorphosed inclusions in the volcanic rocks of the Auvergne, France, Lacroix[e] also found the mineral extensively in the rocks themselves, trachytes, andesites, basalts. Similar mineral associations, both in the inclusions and in the volcanic rocks, are described by Dannenberg[f] in the trachytes, andesites, and basalts of the Siebengebirge, Germany.

CORUNDUM IN CONTACT ZONES AND INCLUSIONS.

Busz[g] has also observed corundum as a contact product of granite on clay-slate at Dartmoor, in Devonshire, England. Barrois[h] describes banded violet and green hornstones produced by metamorphism in granite at Pont-Paul, near Morlaix, in Finisterre, France. The violet layers consist of biotite, magnetite, pleonaste, corundum, andalusite, staurolite, quartz, and pyrite, and are thought to have been originally a highly aluminous shale.

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[a] Verhandl. geol. Reichsanstalt, Wien, No. 8, 1888, p. 178; Am. Naturalist, 1889, p. 524 (Abst.).

[b] Sitzungsber. K. Akad. Wiss., Wien, vol. 87, 1883, p. 358.

[c] Sitzungsber. Niederrhein. Gesell., Bonn, May 7, 1888.

[d] System of Mineralogy, 6th ed., 1895, p. 212.

[e] Sur les enclaves acides des roches volcaniques de l'Auvergne: Bull. Soc. mineral. France, No. 15, 1890, pp. 100–106; Am. Naturalist, 1891, p. 140 (Abst.); Mem. Acad. Sci., Paris, vol. 31; Am. Naturalist, 1895, p. 657 (Abst.).

[f] Min. und petr. Mittheil., vol. 14, 1894, p. 17; Am. Naturalist, 1894, pp. 946–947 (Abst.).

[g] Geol. Mag., vol. 3, 1896, pp. 492–494.

[h] Bull. Soc. géol. France, vol. 14, 1886, p. 888.

Ramsay[a] has described corundum from the Kola Peninsula, Archangel Province, Russia. A mass of nepheline-syenite occurs in Umptek, with border facies comparatively free from nepheline (umptekite). On the east side this rock is bordered by sillimanite-gneiss, between the layers of which the syenite is intruded in sheets of variable thickness down to microscopic dimensions; but in all cases the boundaries of the two rocks are clearly defined. The gneiss contains, besides sillimanite, zoisite, garnet, spinel, corundum, and magnetite. The last three occur in elongated masses in quartz-feldspar aggregates.

CORUNDUM IN FOREIGN METAMORPHIC ROCKS.

CORUNDUM-SCHISTS AND PORPHYROIDS.

Salomon[b] found corundum in the phyllites metamorphosed by quartz-mica-diorite and tonalite in the vicinity of Mount Adamello, in the Alps of Lombardy, Italy. The phyllites have been converted into hornstone containing cordierite, andalusite, sillimanite, tourmaline, spinel, zircon, corundum, and other minerals. Some layers of the rock are rich in corundum.

Molengraaf,[c] in an account of the geology of the gold fields about Pretoria, in South Africa, describes the oldest rocks as granites, sericite-schists, actinolite-schists, and amphibolites. Above these lie quartzites, clay slates, corundum-schists, and porphyroids, and chiastolite-schists, cut by diabase dikes. The corundum-porphyroid resembles feldspar-porphyry, consisting of large crystals of biotite and large corundum individuals in a groundmass of quartz and chlorite.

CORUNDUM IN GRAPHITE.

Wichmann[d] describes corundum from the graphite of Mühldorf, near Spitz, in lower Austria. Scales of graphite are found with corundum in the peridotites at the Bad Creek mine, Sapphire, Jackson County, N. C., and are often associated with the corundum of the mica-schists of the State; and surface specimens of corundum found in a region of garnetiferous mica-schists 8 miles northwest of Gaffney, S. C., sometimes have scales of mica and graphite attached to them; but the Austrian occurrence seems to be the only instance thus far observed where the corundum is embedded in graphite.

[a] Fennia, Helsingfors, vol. 11, 1894, pp. 2, 77, 197.

[b] Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 42, 1890, p. 450; Tschermaks Mineral. Mittheil., vol. 12, 1892.

[c] Neues Jahrbuch für Mineral., vol. 9, 1894–95, pp. 174–291; Am. Naturalist, 1895, pp. 470–471 (Abst.).

[d] Verhandl. K.-k. geol. Reichsanstalt, Wien, 1884, p. 150.

MINERALS ASSOCIATED WITH, AND ALTERATION PRODUCTS OF, CORUNDUM.

Ore deposits seldom show on the surface and in their upper portions the same mineralogical and physical characteristics that they do at greater depths, and their outcrops are apt to be stained a brownish color, due to the oxidation of iron from the deposit. These same phenomena are observed in connection with corundum deposits, especially those in which the mineral is associated with peridotite or other basic magnesian rocks. Both the alteration products of corundum and the minerals associated with corundum will vary according to the type of rock in which the corundum occurs and to the extent of alteration that the inclosing rock has undergone. Thus in granite, syenite, or gneiss the associated minerals would be radically different from those occurring with corundum in peridotites. Moreover, the minerals resulting from the alteration of the mineral constituents of the original rock will be more numerous and very different in the peridotites (the basic magnesian rocks) from those in the first-named, more acid rocks. Although corundum is one of the most stable minerals at the earth's surface, as is well illustrated by the fragments of this mineral that are found in the stream and river gravels exhibiting no sign of chemical alteration at their surface, yet, on the other hand, conditions have existed that have brought about extensive alterations in the corundum even when found in place, this being illustrated by the finding of many undoubted pseudomorphs after corundum.

These associated minerals of corundum are readily divided into groups as follows:

1. Primary or original minerals.
2. Minerals that are the result of contact metamorphism.
3. Minerals that have been produced by regional metamorphism.
4. Minerals that are due to the alteration of the foregoing minerals.
5. Minerals that are the direct result of the alteration of corundum.

1. The primary or original minerals which accompany corundum include those minerals that are constituents of the rock in which the corundum occurs, together with any primary accessory minerals occurring in this rock. Thus there will be a great variation in the primary minerals according to the type of rock in which the corundum occurs. Where corundum occurs in gneiss and granite, beyond the mineral constituents of the rock, there would be usually garnet, magnetite, pyrite, zircon, and rarely monazite and sodalite.

Where corundum occurs in the peridotites and other basic magnesian rocks, the rock constituents are entirely different, consisting mostly of olivine, magnesia amphiboles, pyroxenes, and rarely plagioclase feldspar, while the accessory primary minerals are usually chromite and spinel, the former having been found in nearly every peridotite that has been examined. These in turn are different from the minerals in other rocks, such as the limestones.

2. The minerals that have been produced by contact metamorphism will, in some instances, include the corundum itself and other minerals, such as biotite, muscovite, garnet, staurolite, tourmaline, rutile, etc. These minerals would result in such cases as that described on page 53, where corundum is found in a zone of biotite, which is the result of contact metamorphism produced by the intrusion of the harzburgite (saxonite) on the gneiss.

3. The minerals produced by regional metamorphism would be those found with corundum in rocks such as the schists and gneisses, and would include biotite, muscovite, amphibole (uralite), sillimanite, cyanite, etc.

4. From the minerals mentioned in these three groups others would be produced by direct or indirect alteration. The minerals resulting from the alteration of the mineral constituents of granites, syenites, gneisses, schists, etc., are not abundant, as neither these minerals nor the corundum itself has usually suffered any very great alteration. The feldspar is sometimes more or less kaolinized, and this would represent the chief alteration product.

5. Minerals that are direct alterations of corundum are not common, the principal ones being diaspore, muscovite, and magnetite. With the peridotites and other basic magnesian rocks, however, the alteration products are much more numerous, and thus the associated minerals of corundum, which are directly the result of the alteration of the mineral constituents of the peridotite, are also numerous. These, again, will depend upon the character of the peridotite or other basic magnesian rock as to whether it is dunite, composed almost entirely of chrysolite (olivine), or enstatolite, composed almost entirely of enstatite, or one of the other peridotites or pyroxenites, which are composed of two or more minerals.

The primary minerals occurring with the corundum also cause a considerable variation in the alteration minerals, as, with feldspar, kaolin will be a common alteration product, and, more rarely, such minerals as wellsite and chabazite, two zeolites found at Buck Creek mine, Clay County, N. C. At nearly all of the corundum deposits occurring in the peridotites, pyroxenites, and amphibolites some minerals of the chlorite or clintonite groups are common alteration products, and there is a noticeable absence of any quantity of quartz or of the micas of the muscovite group. There is, however, a considerable variation in the minerals associated with the corundum at various localities. Thus corundophilite, which has been so commonly observed associated with corundum and emery at the localities in Asia Minor and at Chester, Mass., has not been identified in

North Carolina or Georgia; but, on the other hand, clinochlore is the common chlorite found associated with corundum in these States. Then, again, zoisite is a very common associated mineral at some of the localities in North Carolina and Georgia, while epidote is almost entirely wanting. Of the feldspars, albite and oligoclase are the more abundant associates in North Carolina and Georgia, while anorthite is more commonly associated with the corundum in other localities. Another noticeable difference is in the mineral diaspore, the hydrous oxide of aluminum, which is very commonly associated with the corundum in Asia Minor and at Chester, Mass., but which up to the present time has been identified at but one locality in North Carolina, and then there was but one specimen reported. It may be, however, that the diaspore is formed in minute quantity as a direct hydration of corundum. This would account for the water that is shown in many analyses of corundum and would also explain the comparative softness of some specimens of corundum.

Another very commonly associated mineral of corundum and emery is margarite, which occurs perhaps as universally as any of the directly associated minerals. It occurs very abundantly with the emery at Chester, Mass., with the corundum at many localities in North Carolina and Georgia, and with the corundum in California, and it is in some cases due to the direct alteration of corundum.

The carbonates are extremely rare associated minerals of corundum, except when corundum occurs in limestone. In the peridotite and pyroxenite rocks there are traces of magnesium carbonate observed, developed in the cracks of the rocks, and at a few localities crystals of aragonite have been found.

Phosphates are sometimes observed in the zone of alteration products, and in a number of localities, as at Corundum Hill, Macon County, N. C., and the Bad Creek mine, Sapphire, N. C., crystals of apatite were found that measure nearly 1½ inches in length and half an inch in diameter.

Some of the minerals known to occur with corundum have been found only at one locality, such as wellsite, a new mineral described from the Buck Creek mine, Clay County, N. C., and a number of the vermiculites, as lucasite, kerrite, willcoxite, etc.

There is given in the following table an alphabetical list of the minerals that have been found associated with corundum at the various localities in the United States. As far as possible it is indicated whether the minerals are primary associated minerals, rock constituents, or alteration products. It has also been indicated whether the mineral has been found at only one locality.

LIST OF MINERALS ASSOCIATED WITH CORUNDUM IN THE UNITED STATES.

1. Actinolite. Georgia and North Carolina. In peridotite. Primary mineral.
2. Albite. Georgia, North Carolina, and Pennsylvania. Rock constituent and with peridotite.
3. Almandite (var. garnet). Georgia, North Carolina, Colorado, and New York. In gneisses and schists; regional metamorphism.
4. Amphibole. Rock constituent; primary and regional metamorphism.
5. Andesine. North Carolina. In peridotite. Primary mineral.
6. Andradite. North Carolina, New York. In peridotite, due to metamorphism; also in gneisses—regional metamorphism.
7. Anorthite. North Carolina and Georgia. Rock constituent.
8. Anthophyllite. North Carolina and Georgia. In peridotite. Primary.
9. Apatite. North Carolina. In peridotite. Secondary product.
10. Arfvedsonite. North Carolina. In peridotite. Primary.
11. Aragonite. North Carolina. In peridotite. Alteration product.
12. Asbestos (var. amphibole). Georgia, North Carolina. In peridotite and pyroxenite. Primary.
13. Beryl. Greenwood, Me. In mica-schist.
14. Biotite. Colorado, North Carolina, and Massachusetts. Rock constituent. Contact and regional metamorphism.
15. Breunnerite (var. magnesite). Georgia, North Carolina. In peridotite. Alteration product.
16. Bronzite (var. enstatite). Georgia and North Carolina. Rock constituent.
17. Calcite. Rock constituent.
18. Cerolite. Corundum Hill mine, Macon County, N. C. In peridotite. Alteration product.
19. Chabazite. Buck Creek mine, Clay County, N. C. In peridotite. Alteration product.
20. Chalcedony (var. quartz). Georgia, North Carolina, Pennsylvania. In peridotite. Alteration product.
21. Chalcopyrite. In gneisses.
22. Chlorite. California, Georgia, North Carolina, Pennsylvania, and Massachusetts. In peridotite, amphibolite, etc. Common alteration product.
23. Chloritoid. North Carolina. In peridotite. Alteration product.
24. Chromite. Georgia, North Carolina, and Pennsylvania. In peridotite and pyroxenite. Primary.
25. Chrysolite (or olivine). Rock constituent.
26. Chrysotile (var. serpentine). Georgia, North Carolina, and Massachusetts. In peridotite. Alteration product.
27. Clinochlore. California, Georgia, North Carolina, and Massachusetts. Alteration product.
28. Culsageeite (var. jefferisite). North Carolina. In peridotite. Alteration product.
29. Cyanite. Connecticut, Georgia, North Carolina, and Virginia. In gneisses and schists. Regional metamorphism.
30. Damourite (var. muscovite). Rock constituent; also alteration product.
31. Deweylite. Georgia and North Carolina. In peridotite. Alteration product.
32. Diallage (var. pyroxene). Rock constituent.
33. Diaspore. California, Massachusetts, North Carolina (rare), and Pennsylvania. In peridotite, amphibolite, etc. Alteration product of corundum.

34. Diopside (var. pyroxene). Rock constituent.
35. Disthene (or cyanite). In gneisses and schists. Regional metamorphism.
36. Dudleyite (vermiculite). Buck Creek mine, North Carolina. In peridotite. Alteration product.
37. Edenite (var. amphibole). Rock constituent.
38. Enstatite. Rock constituent. Primary. Alteration product.
39. Epidote. In peridotite and amphibolite. Alteration product.
    Euphyllite. See Paragonite.
40. Fibrolite (or sillimanite). Rock constitutent. Regional metamorphism.
41. Fuchsite (var. muscovite). Georgia and North Carolina. In peridotite.
42. Gahnite. With corundum in gravels at Cowee Creek, North Carolina.
    Garnet. See varieties. Contact metamorphism.
43. Garnierite (var. Genthite). Georgia and North Carolina. In peridotite. Alteration product.
44. Genthite. Georgia and North Carolina. In peridotite. Alteration product.
45. Gibbsite. Pennsylvania. In serpentine. Alteration product.
46. Graphite. In schists and gneisses. Product of metamorphism.
47. Hematite. Constituent of emery. Primary. In peridotite. Alteration product.
48. Hornblende (var. amphibole). Rock constituent.
49. Hyalite (var. opal). North Carolina. In peridotite. Alteration product.
50. Hypersthene. Rock constituent.
51. Ilmenite (or menaccanite). North Carolina. In peridotite. Primary.
52. Kämmererite (var. penninite). Georgia and North Carolina. In peridotite. Alteration product.
53. Kaolin (or kaolinite). In feldspar. Alteration product.
54. Kerrite (vermiculite). North Carolina. In peridotite. Alteration product.
55. Labradorite. North Carolina. Primary. In peridotite and amphibole schist.
56. Lazulite. North Carolina. Alteration product.
57. Lepidolite. Greenwood, Me. In mica-schist. Regional metamorphism.
58. Limonite. Georgia, North Carolina, Massachusetts, and Pennsylvania. Alteration product.
59. Lucasite (vermiculite). North Carolina. In peridotite. Alteration product.
60. Maconite (vermiculite). North Carolina. In peridotite. Alteration product.
61. Magnesite. Georgia and North Carolina. In peridotite. Alteration product.
62. Magnetite. Constituent of emery. In peridotite. Alteration product.
63. Margarite. California, Georgia, North Carolina, Massachusetts, and Pennsylvania. In peridotite, amphibolite, etc. Alteration product.
64. Marmolite (var. serpentine). North Carolina. In peridotite. Alteration product.
65. Meerschaum (or sepiolite). North Carolina. In peridotite. Alteration product.
66. Meionite. North Carolina. In peridotite. Alteration product.
67. Muscovite. Rock constituent. Contact and regional metamorphism. Also alteration product of corundum.
68. Oligoclase. Rock constituent. Primary mineral in corundum vein in peridotite.
69. Opal. North Carolina. In peridotite. Alteration product.
70. Orthoclase. Rock constituent.
71. Painterite (vermiculite). Pennsylvania. Alteration product.
72. Paragonite (euphyllite variety). Unionville, Pa. Alteration product.

73. Pattersonite. Pennsylvania. Alteration product.
74. Penninite. Georgia and North Carolina. In peridotite. Alteration product.
75. Picotite (var. spinel). In peridotite. Primary.
76. Picrolite (var. serpentine). Georgia, North Carolina, and Pennsylvania. In peridotite and serpentine. Alteration product.
77. Prochlorite. Most common chlorite in Georgia and North Carolina. In peridotite. Alteration product.
78. Pyrite. Gneisses and schists.
79. Pyrophyllite. Rock constituent. Regional metamorphism. Alteration product.

Pyroxene. See varieties. Primary.

80. Quartz. Rock constituent. Also in peridotite. Alteration product.
81. Rhodolite (var. garnet). Cowee Valley, Macon County, N. C. Embedded in ruby corundum crystals.

Ripidolite. See Clinochlore.

82. Rutile. In amphibole-schists, etc. Contact metamorphism.
83. Serpentine. Rock constituent. Also in peridotite. Alteration product.

Sepiolite. See Meerschaum.

Sillimanite. See Fibrolite.

84. Spinel. Virginia and North Carolina. In peridotite. Primary.
85. Staurolite. North Carolina. In amphibole-schist. Contact metamorphism.
86. Talc. Common in peridotite and pyroxenites. Alteration product.
87. Tourmaline. Contact metamorphism. Also (in North Carolina) alteration product.
88. Tremolite. Rock constituent.

Vermiculite. See varieties.

89. Villarsite. North Carolina. In peridotite. Alteration product.
90. Wellsite. Buck Creek mine, North Carolina. In peridotite. Alteration product.
91. Willcoxite (vermiculite). North Carolina. In peridotite. Alteration product.
92. Zircon. Greenwood, Me. In mica-schist.
93. Zoisite. Georgia and North Carolina. In peridotite. Alteration product.

ORIGIN OF CORUNDUM.

During recent years synthetical mineralogy has come to play a very important part in the study of mineralogy and geology, and has aided considerably in the solving of many geological problems. Thus, in working out the problems relating to the origin of corundum in the various rocks, the different methods of producing corundum artificially have been of material assistance. For this reason these methods are briefly described before a discussion of the origin of this mineral is taken up.

ARTIFICIAL PRODUCTION OF CORUNDUM.

The methods by which corundum has been produced artificially are very varied and the results very satisfactory, the corundum being obtained in many forms and colors. The artificial production of corundum gems was the motive for the first attempts of this kind, and excellent results have been obtained in the manufacture of sapphires and rubies.[a]

In 1851 De Senarmont[b] obtained rhombohedrons of corundum by heating a solution of aluminum chloride or nitrate in a sealed tube to 350° C. During the same year Ebelmen[c] produced hexagonal plates of corundum by exposing to a very high temperature in a porcelain kiln a platinum crucible containing one part of amorphous alumina and three or four parts of borax. Carbonate of soda can replace the borax in this preparation of corundum. By the addition of small quantities of different metallic oxides, various colors of corundum were obtained.

In 1857 Gaudin[d] found that after heating a closed crucible containing equal parts of alum, sulphate of potash, and charcoal before the oxyhydrogen blowpipe corundum was one of the products of the reaction.

Elsner[e] obtained red crystalline grains of corundum by fusing before the oxyhydrogen blowpipe anhydrous alumina with bichromate of potash.

H. Saint-Claire Deville and Caron,[f] in 1858, produced magnificent hexagonal plates of corundum by heating to a white heat for an hour anhydrous aluminum fluoride in the bottom of a charcoal crucible, suspended in the center of which was a cupel of the same material filled with boric acid. By adding a little chromium fluoride in varying amounts, red, blue, or green corundum was obtained.

In the year 1861 Debray[g] found that corundum was formed by passing a slow current of chlorhydric acid over aluminate of soda at a red heat, or over a mixture of aluminum phosphate and lime. He also produced crystals of corundum by melting phosphate of alumina with three or four times its weight of potassium or sodium phosphate.

Hautefeuille,[h] in 1865, produced corundum crystals by slowly passing hydrofluoric-acid gas, previously diluted with nitrogen and steam, over amorphous alumina heated to a bright red in a platinum tube.

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[a] Bourgeois, L., Reproduction artificielle des minéraux: Encyclopédie chimique, vol. 2; Kunz, G. F., On the new artificial rubies: Trans. New York Acad. Sci., October 4, 1886.

[b] Comptes rendus, Acad. Sci., Paris, vol. 32, 1851, p. 762; L'Institut (Paris), 1851, p. 165; Annalen Chem. und Pharm., vol. 80, p. 214; Pharm. Centralbl., 1851, p. 518.

[c] Annales de chim. et de phys., 1851, vol. 33, p. 34.

[d] Comptes rendus, Acad. Sci., Paris, vol. 44, p. 999; L'Institut, 1857, p. 110; Jour. Prakt. Chem., vol. 70, p. 381; Bull. Univ. de Genève, vol. 34, p. 68; Jahrbuch für Mineral., 1857, p. 444.

[e] Jour. Prakt. Chem., vol. 17, p. 175.

[f] Comptes rendus, Acad. Sci., Paris, vol. 46, 1858, p. 764; L'Institut, 1858, p. 133; Annalen Chem. und Pharm., vol. 108, p. 55; Jour. Prakt. Chem., vol. 74, p. 157.

[g] Comptes rendus, Acad. Sci., Paris, vol. 52, 1861, p. 985; L'Institut, 1861, p. 165; Annalen Chem. und Pharm., vol. 120, p. 184; Jahrbuch für Mineral., 1861, p. 702; Bull. Soc. Chimique, 1865.

[h] Annales de chim. et de phys., vol. 4, 1865, p. 153.

Gaudin,[a] during 1869, obtained corundum by the decomposition of potash alum by charcoal, and also by fusing amorphous alumina in the oxyhydrogen blowpipe flame. The melt, when cooled, has the hardness of corundum, but a specific gravity of only 3.45.

Fremy and Feil [a] produced a corundum in 1877 by fusing together minium ($2PbO.PbO_2$) and alumina in siliceous earthen crucibles. In this reaction a lead aluminate was first formed, and this, uniting with the silica of the crucible, formed a lead glass, liberating at the same time the alumina, which crystallized out as corundum in the form of hexagonal plates. The specific gravity of these crystals was 4.0–4.1. By the addition of a chromium salt a ruby corundum was produced which had the color and hardness of the natural ruby and which, like the natural ruby, was decolorized temporarily by heating.

They also obtained corundum in the form of sharply crystallized rubies by fusing together in a clay crucible, covered with another inverted one, equal weights of alumina and barium fluoride with a little potassium bichromate.[b]

St. Mennier [c] in 1880 heated to redness in a porcelain tube alumina chloride, magnesium, and water vapor, and obtained a very minute crystal which resembled corundum, but he was not able to determine it exactly. By substituting zinc for the magnesium in a similar experiment, and also by leaving out the metal altogether, similar results were obtained.

In 1882 H. Grandeau [d] obtained corundum in the same manner as Debray in 1861, and he called attention to the formation of a double phosphate of alumina and potash with the corundum.

By treating freshly precipitated alumina, $Al_3(OH)_3$, at a temperature of 300°, with water containing a trace of ammonium fluoride, Bruhms [e] in 1889 obtained small hexagonal crystals of corundum with pyramidal terminations.

Lacroix [f] has shown that by the destruction of acid inclusions in certain magmas, as basalts, trachytes, and andesites, corundum, zircon, diaspore, etc., were produced. He states that this may be the origin of the corundum and zircon in Haute-Loire.

Friedel [g] in 1891 described experiments in which amorphous alumina was heated in a closed tube in a solution of soda to a tempera-

[a] Comptes rendus, Acad. Sci., Paris, vol. 85, 1877, p. 1029; Dana, Mineralogy, 1892, p. 213.

[b] Fouqué and Lévy, Synth. min. et roches, p. 223.

[c] Fouqué and Lévy, Synth. min. et roches, p. 223; and Comptes rendus, Acad. Sci., Paris, vol. 90, p. 701.

[d] Comptes rendus, Acad. Sci., Paris, vol. 95, 1882, p. 921.

[e] Neues. Jahrbuch für Mineral., vol. 2, 1889, p. 62; Am. Naturalist, July, 1890, p. 671.

[f] Bull. Soc. franç. de minéral., vol. 12, 1890, p. 100.

[g] Bull. Soc. franç. de minéral., vol. 14, 1891, p. 7.

ture of 530°. In this reaction the excess of alumina separated out as corundum. When the temperature was raised to 400° only diaspore was produced, at 450° to 500° both corundum and diaspore were obtained, and at 530° to 535° only corundum. When the soda contains a small amount of aluminum and calcium carbonates small crystals of calcite are obtained with the corundum.

By the action of alumina, with more or less potash, and barium fluoride heated to a very high temperature in an earthen crucible, Fremy[a] obtained in 1891 ruby corundum that was well crystallized, clear, and of a brilliant color, potassium bicarbonate having been used as a coloring matter. Corundum[b] has also been produced by the action of aluminum chloride on lime.

Some of the more instructive artificial productions of corundum are those which have been obtained from molten magmas whose chemical composition was approximately that of known rocks. This synthetic production of corundum has aided very materially in solving the problems relating to the origin of corundum in nature.

Hautefeuille[c] has described the production of corundum by dissolving alumina in nepheline, whence resulted a vitreous paste from which many hexagonal plates of corundum separated.

Morozewicz[d] in his recent elaborate work on the Experimental Investigation of the Formation of the Minerals in an Igneous Magma describes the formation of corundum from many of the magmas that were supersaturated with alumina. The supersaturated alumina-silicate magmas have the general composition $MeOmAl_2O_3nSiO_2$ ($Me=K_2$, Na_2, Ca, but not Fe or Mg; $n=2$—13). These magmas in cooling, when magnesia and iron are not present, throw out all their excess of alumina (over $m=1$) in the form of corundum crystals. (See also p. 89.)

In the crystallization of an anorthite-nepheline magma which did not contain any magnesia, the principal products were corundum, anorthite, and nepheline.

Another interesting method of producing corundum is in the reduction of certain of the rarer metallic oxides by the aid of powdered metallic aluminum, corundum being one of the products of the reaction, which is dependent upon the strong affinity of the aluminum for oxygen. In this reaction the metallic oxides are mixed in a refractory crucible with finely powdered aluminum and barium peroxide, the latter containing an excess of oxygen and being readily

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[a] Synthèse des Rubis (Paris), 1891.
[b] Dana, Mineralogy, 1892, p. 213.
[c] Bull. Soc. franç. de minéral., vol. 13, p. 147; Am. Naturalist, Nov., 1890, p. 1076.
[d] Tschermaks mineral. und petrog. Mittheil., vol. 18, 1898, pp. 1–90, 105–240; and review of same in Jour. Geology, vol. 7, 1899, pp. 300–313.

ignited. Barium peroxide is also added to the top of the mixed oxides and aluminum, and then a little more of the powdered aluminum is placed on top of the barium peroxide. The barium peroxide is readily ignited by a wax taper or other fuse, and the heat generated, together with the excess of oxygen, is sufficient to ignite the powdered aluminum. This at once oxidizes, and the reaction continues throughout the mixture in the crucible, the aluminum readily taking up the oxygen from the metallic oxides present and reducing them to pure metallic state. The heat generated by the reaction leaves the mass in a molten condition, the metals settling to the bottom and the alumina separating out as corundum. Metals such as chromium, titanium, tungsten, vanadium, molybdenum, etc., that it was formerly considered almost impossible to reduce to the metallic state, can now be obtained with comparative ease and at small expense. The corundum obtained varies in color and is dependent to a certain extent upon the metallic oxide reduced; thus in the reduction of chromic oxide the resultant corundum slag is ruby red; of nickel oxide, it is blue; of titanium oxide, it is brown; and of manganese oxide, it is yellow to greenish yellow.

Within the last four years a process has been devised for manufacturing corundum out of bauxite. This method consists essentially of subjecting the bauxite to very great heat in an electrical furnace. The idea that bauxite can be changed into corundum by intense heat is not new, for in 1861 Prof. T. Sterry Hunt, of the Geological Survey of Canada, in an article on "The origin of some magnesium and aluminous rocks,"[a] described the occurrence of bauxite at Baux, in the south of France, and stated that "by an intense heat this substance is converted into crystalline corundum resembling emery in its physical character."

Corundum is now being made commercially from bauxite by the Norton Emery Wheel Company at their plant at Niagara Falls, N. Y. The principle of their method is the heating of bauxite in a specially constructed furnace about 4½ feet in diameter, using some of the bauxite itself as a lining for the furnace. Before the bauxite is added to the furnace it is thoroughly heated, in order to drive off not only the moisture, but also the water of composition, so that the product actually added to the furnace is a nearly anhydrous aluminum oxide. The heat generated is sufficient to fuse the bauxite, which recrystallizes as corundum. The pig as it is taken from the furnace has an outer layer of nearly unaltered bauxite. A portion of the corundum is well crystallized in hexagonal plates, which are very similar in form to those obtained in the reduction of the metallic oxides, as described above.

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[a] Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 288.

ORIGIN OF CORUNDUM IN IGNEOUS ROCKS.

That there are several modes of origin of corundum would seem clear from the various ways in which it occurs, as shown in its association with plutonic and metamorphic rocks, such as granites, gneisses, and crystalline schists, and with the basic magnesia rocks, which have been described above. Alumina is now known to be soluble in many basic magmas, and as these cool corundum separates out. Furthermore, not only can the manufactured hydrous oxide of aluminum be converted into corundum by means of heat and pressure, but also the mineral bauxite, the natural hydrous oxide of aluminum.

From what has been stated under the section on modes of occurrence of corundum it is seen that there are many widely separated localities which contain rocks in which corundum is one of the essential constituents and not simply an accessory mineral. Thus there have been described corundum-syenites from India,[a] Russia,[b] Canada,[c] and Montana,[d] corundum-pegmatite from Russia,[b] and plumasite, an oligoclase-corundum rock, from California.[e]

It is very evident, then, that there are magmas that contain an excess of alumina, just as there are magmas with an excess of silica, and that the alumina separates out as corundum in the same manner that silica separates as quartz in granitic rocks.

The different methods of formation of the corundum associated with the various rocks in the United States are discussed in the following paragraphs.

ORIGIN OF CORUNDUM IN PERIDOTITE.

REVIEW OF LITERATURE.

Although many writers in their papers on the occurrence of corundum and the peridotites mention what they consider might be the probable origin of this mineral, they do not take up any discussion of the problem.

In 1872, Mr. C. U. Shepard,[f] in an extended article on the corundum of North Carolina and Georgia, describes the occurrences of corundum and chrysolite, the associated minerals, and what he calls the development of the "strata," which "exhibit the following order of formations: (1) Chrysolitic rock somewhat mixed with anthophyllite; (2) a layer of micaceous rock; (3) a seam of chalcedony; (4) a

[a] Man. of Geol. India, Economic Geol., pt. 1, 1898, and Mem. Geol. Survey India, vol. 30, pt. 3, 1901.

[b] Experimentelle Untersuchungen über die Bildung der Minerale im Magmas: Tschermaks mineral. und petrog. Mittheil., 1898, pp. 1–90, 105–240.

[c] Rept. Bureau of Mines, vol. 8, 1899, pt. 2, p. 207.

[d] See p. 48.

[e] Bull. Dept. Geol., Univ. California, vol. 5, No. 8, pp. 219–229.

[f] Am. Jour. Sci., 3d ser., vol. 4, pp. 109–114, 175–177, 1872.

stratum of chloritic rock (ripidolite); (5) the same, through which the corundum is regularly diffused, sometimes in narrow veins or widening out to several feet." Nowhere in this article does he suggest the probable origin of the corundum.

Mr. J. Lawrence Smith,[a] in describing the occurrence of corundum associated with the peridotites of North Carolina and Georgia, speaks of all the localities of corundum that he has observed or examined as exhibiting certain prominent characteristics common to all, but with each locality having its own peculiar characteristics. He says that in all cases, however, the masses of corundum give evidence of having been formed by a process of segregation, which he has described in a memoir[b] on the Asia Minor emery, and that by the exercise of homogeneous and chemical attractions the minerals which constitute and are associated with emery were separated out from the calcareous rock before it consolidated.

Dr. F. A. Genth,[c] although not touching directly on the origin of corundum or giving any evidence to sustain his statement, says that "at the great period when the chromiferous chrysolite beds were deposited a large quantity of alumina was separated, which formed beds of corundum;" that the corundum was subsequently acted upon and altered and changed into various minerals; that the "veins" of chlorite, etc., are alterations of the original mass of corundum; and that the corundum might be found in a less altered or wholly unaltered condition when the vein was explored below the action of surface influences. In speaking of the corundum crystals embedded in the chlorite, Doctor Genth says the crystals "appear to have formed after a great portion of the original corundum has changed into chlorite, as if there had been an excess of alumina ready for combination, which, not finding a supply of the requisite amount of silicic acid and bases, had again crystallized as corundum."

In an article on corundum and its associated rocks Mr. C. D. Smith[d] points out, but does not discuss, the facts that led to his belief in the igneous origin of the peridotites. He calls attention to the occurrence of corundum chiefly in chlorite veins and says: "The chlorite seems to have been first crystallized; and then the alumina, of which the corundum is composed, was evidently in a state of solution and must have permeated the chlorite either in thermal waters or steam." The only points given to sustain this theory are that plates or scales are sometimes inclosed in the corundum and that corundum has been observed that conforms in its faces and general shapes to the chlorite that is present. The other points

[a] Am. Jour. Sci., 3d ser., vol. 6, pp. 180–186, 1873.
[b] Idem, 2d ser., vol. 10, p. 354, 1850.
[c] Proc. Am. Philos. Soc., vol. 13, pp. 361–406, 1873; Am. Jour. Sci., 3d ser., vol. 6, pp. 461–462, 1873 (review).
[d] Rept. Geol. Survey North Carolina, vol. 1, 1875, p. 91.

bearing on the origin of the corundum that he undoubtedly had in mind he does not mention in his article. Doctor Smith also states that he found "chrysolite attached as an enveloping matter to considerable masses of corundum." He makes, however, apparently no further mention of this occurrence in any of his writings.

In a description of the "Jenks corundum mine" Mr. R. W. Raymond [a] calls attention to the occurrence of transparent nodules of corundum in a matrix of the same material, and also of the great variation in the appearance of the corundum from the different veins. One of the veins has produced more of the gem material, while it contains but few large masses of the corundum.

Mr. A. A. Julien, in a paper published in 1882,[b] considers the corundum in all cases a secondary or alteration product, and explains all the phenomena of alteration in the veins by the introduction of a solution of soda and alumina into the fissures during the period of alteration and metamorphism, believing at the time that the peridotite was of sedimentary origin.

In an article commenting on Julien's theory regarding the origin of the peridotites, Wadsworth,[c] in speaking of the corundum, says that it is looked upon as a secondary mineral, and not, as Genth held, as the primary material from which many minerals originated.

Mr. T. M. Chatard [d] made a very careful chemical study of the material collected across the contact between the gneiss and the peridotite at Corundum Hill. He points out as a result of his chemical analyses that, starting from the gneiss, there is a progressive increase of magnesia in the vein material as the peridotite is approached, and that there is an approximate decrease in the percentage of alumina. According to these analyses the series from the section across the vein are divided into three groups—aluminum silicates, aluminum-magnesium silicates, and magnesium silicates. The middle term of this chemical series is also the middle number of the field series. He regards the corundum as an accessory mineral, frequently not being found at all in the vein and sometimes in but small quantity, and therefore to be considered as the result of a certain balance between the magnesium and the aluminum silicates, which have by their union produced the chlorite and the vermiculites.

In describing the occurrence of corundum in Chester County, Pa., Mr. J. P. Lesley [e] says that it seems difficult to imagine its excessive compact hardness as produced in any other way than by heat.

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[a] Trans. Am. Inst. Min. Engs., vol. 7, 1879, 89.
[b] Proc. Boston Soc. Nat. Hist., vol. 2, 1882, p. 141–149.
[c] Science, vol. 3, 1884, p. 486.
[d] Bull. U. S. Geol. Survey No. 42, 1887, pp. 45–63.
[e] Geol. Survey Pennsylvania, C4, p. 352, 1883.

The report[a] of Mr. J. V. Lewis on "Corundum and the basic magnesian rock in North Carolina" is mainly a report of field observations and does not take up any discussion of facts bearing on the origin of the corundum, though many points of interest and importance are brought out regarding the alterations of the peridotite and of the character of the vein and vein materials, and also concerning the alteration of corundum.

Mr. F. P. King,[b] in his report on the corundum deposits of Georgia, which is principally devoted to the description of localities, occurrences, and varieties of corundum, etc., comes to the conclusion that corundum is an accessory mineral and that its presence is occasioned by an excess of alumina present in the rock masses, "chrysolite, gneiss, and hornblende-gneiss." This is explained by the alteration of these rocks into magnesium silicates, alkaline salts, and ferrosilicates, which, in conjunction with the carbonic acid of percolating waters, would dissolve the combined alumina and produce on crystallization all the minerals associated with corundum, and when the alumina is in excess would produce corundum itself.

As has been shown, a number of theories concerning the origin of the corundum have been advanced. With one exception, however, they were all prior to the numerous and elaborate experiments that have been made by different investigators on the solubility of alumina in a molten basic glass and the separating out of corundum and spinel crystals from this molten glass on cooling. They were also prior to Vogt's[c] very important investigations into the igneous origin of certain ore deposits. All these experiments have aided very materially in solving the numerous problems in relation to the origin of many of the ores; and in the present investigation the facts proved by these experiments have been of exceptional assistance in the compiling of evidence to substantiate the theory proposed.

RELATIONS OF CORUNDUM TO PERIDOTITE.

In all the field observations a careful search was made to find the corundum directly in contact with the peridotite, and this contact was observed at one locality. At the Egypt mine, on the western slopes of Sampson Mountain, about 10 miles west of Burnsville, in Yancey County, N. C., several specimens have been found with the corundum crystals entirely surrounded by granular peridotite (dunite), and without any of the chloritic minerals usually present with the corundum. (See fig. 8, p. 33.) Both the peridotite and the corundum have altered somewhat, the corundum having a little muscovite developed on its basal termination, while the peridotite is stained a yellowish brown and is rather friable. The specimens that were

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[a] Geol. Survey North Carolina, Bulletin No. 11; see also Bulletin No. 19.

[b] Geol. Survey Georgia, Bulletin 2.

[c] Zeitschr. für prakt. Geol., Nos. 1, 4, and 7, 1893.

examined were collected by Mr. U. S. Hayes, who was prospecting in the vicinity of the mine, and were loaned to the author by Mr. J. V. Lewis,[a] who has described this occurrence. There was no mining being done when this locality was visited by the writer, but miners living in the vicinity, who have worked in the mine, report the finding of many fragments of corundum in the peridotite similar to the one here figured.

Although this is the only locality where the corundum has been found directly in peridotite, it has been observed in serpentine, which is the commonest alteration product of the dunite variety of peridotite. At the Cullakeenee mine, Buck Creek, Clay County, N. C., corundum was found that was bordered with serpentine. Some of the specimens observed show the small particles of corundum either entirely or partially surrounded by serpentine and the whole mass of corundum and serpentine surrounded by clinochlore. In another specimen a streak of corundum about an inch wide lies between two zones of serpentine from a quarter to three-quarters of an inch wide, and these in turn are bordered by a talcose and enstatite rock.

Crystallized corundum has been observed where the crystals, one end of which merges into the massive corundum, project out beyond the mass, and these projecting portions are often partly or entirely surrounded by chlorite; in other cases separate corundum crystals are embedded in the chlorite. The best crystals of corundum have been found at Corundum Hill, Macon County, N. C., where they occur in the conditions just mentioned.

Many of the crystals, especially those free from alteration and decomposition, or those only slightly altered, are usually well developed, with smooth, even faces and sharp edges.

In a number of the mines corundum is found in contact with and surrounded by spinel. At the Carter mine, near Democrat, Buncombe County, N. C., the corundum is found in masses of white and pink color, intergrown with a greenish-black massive spinel. In thin splinters the spinel is of a very handsome emerald-green color. The masses of the corundum and spinel are partially surrounded by a deep-green chlorite, which latter has also in places been developed in small greenish scales between the corundum and spinel, though the contact of the spinel and the corundum is usually sharp and distinct, showing no sign of alteration. The presence of minute scales of greenish chlorite is still more rare in the corundum and spinel near the junction of these minerals with the external mass of the chlorite. All the massive corundum shows the characteristic parting lines, and the spinel shows distinctly the conchoidal fracture.

[a] Geol. Survey N. C., Bull. No. 11, 1896, p. 60.

A massive, coarsely to finely granular spinel is found at the Corundum Hill mine, Macon County, N. C., having disseminated through it small grains and fragments of pink and white corundum. The spinel and the corundum are closely associated with chlorite, which is here more generally developed between the corundum and the spinel and in the spinel (between the granules) than it was at the Carter mine. The spinel in the mass appears black, but in small splinters it shows a green color.

The corundum is found in the peridotite in two different relations, one in the zone of alteration products developed at the contact of the peridotite and the gneiss, and the other in a similar zone of alteration products, bounded on both sides by the peridotite.

The line of contact between the zone of alteration products and the gneiss was very sharp and distinct in all the border veins examined. The minerals developed between the corundum-bearing zone and the peridotite are of great abundance and different from those between this zone and the gneiss. In the veins that are entirely within the mass of the peridotite, the zones of alteration products are the same on each side of the seam of corundum and similar to those on the peridotite side of a border vein. These phenomena are described and illustrated on pages 28–33.

The appearance and character of the veins vary according as they are border veins or interior veins. In an interior vein the approximate trend of the vein is toward the center of the mass of peridotite. As these veins penetrate the mass they usually grow less and less in width until they pinch out. This is especially a prominent feature at Buck Creek, Clay County, N. C., and at Laurel Creek, Rabun County, Ga.

In a border vein, however, the corundum seems to extend downward indefinitely along the line of contact. Supplementary veins are often encountered branching off from a border vein toward the center of the peridotite, and these, like the true interior veins, grow less and less in width until they pinch out entirely. This variation in the occurrence of the corundum in the different veins has been observed by many of those who have prospected for and mined corundum in this region.

THEORY OF ORIGIN IN PERIDOTITE.

The theory advanced in this paper is that the corundum was held in solution in the molten mass of the peridotite when it was intruded into the country rock and that it separated out among the first minerals as the mass began to cool.

The peridotite magma holding in solution the chemical elements of the different minerals would be like a saturated liquid, and as it began to cool the minerals would crystallize out, not according to their infusibility, but according to their solubility in the molten magma. The more basic portions, according to the general law of cooling and crystallizing magmas, being the most insoluble, would therefore be the first to separate out. These would be the oxides containing no silica, which in the present case would be chrome spinel and corundum.

Morozewicz[a] has shown by some very important experiments that molten glass of a character similar to the basic magnesian rocks would dissolve alumina readily, and as this molten mass began to cool corundum and spinel were the first minerals to separate out. According to this, the corundum and spinel would be the first to crystallize or solidify out from the molten mass of the peridotite as this began to cool, and this crystallization would take place first on the outer border of the mass, because here it would cool first. Convection currents would then tend to bring a new supply of material carrying alumina into this outer zone, and when this was reached crystallization would take place and the alumina would be deposited as corundum.

This is essentially the idea advanced by Becker[b] in a paper on fractional crystallization of rocks, and where this process has taken place in dikes and laccolites a concentration is observed of the earlier and more basic minerals at their outer boundary.

The more basic the magma the more fluid it is apt to be, and the more tendency there is for this process to take place, as is shown by many well-known instances of the separation of ilmenite, pyrrhotite, etc., from gabbro magmas, as described by Vogt,[c] Adams,[d] and others.

Fig. 12 is a diagrammatic vertical cross section of the writer's idea of the appearance of a mass of peridotite soon after its intrusion into a gneiss, the peridotite holding a large amount of alumina in solution, which afterwards separated out as corundum. In this figure the corundum zone has been greatly exaggerated in order to better illustrate the cross section. The corundum would be concentrated toward the borders of the peridotite, and would make a sharp and nearly regular contact with the gneiss. With the peridotite, however, the contact would sometimes be sharp and regular; at other times there would be an irregular line of contact and masses of the corundum would penetrate into the peridotite.

The rapid erosion to which the rocks in this mountain region have been subjected would readily wear them down to their present condition, represented by the dotted lines in fig. 12.

[a] Zeitschr. für Krystall., vol. 24, 1895, p. 281.

[b] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 259.

[c] Zeitschr. für prak. Geol., Nos. 1, 4, and 7, 1893.

[d] Paper read before the Gen. Min. Assoc. of the Prov. of Quebec, Montreal, Jan. 12, 1894.

The interior veins, I, II, and III, in fig. 12, which at the present time have no connection with each other, but are each separate and distinct, were at the time of their formation part of the corundum concentrated along the border of the peridotite. Some of these veins would soon be worked out, while others might be explored for a hundred feet or more without any apparent change in their width.

This explanation will account for all the variations in the occurrence of the corundum in the different veins.

The corundum crystallizing out from the molten peridotite, which would be a very basic magma, would be concentrated toward the

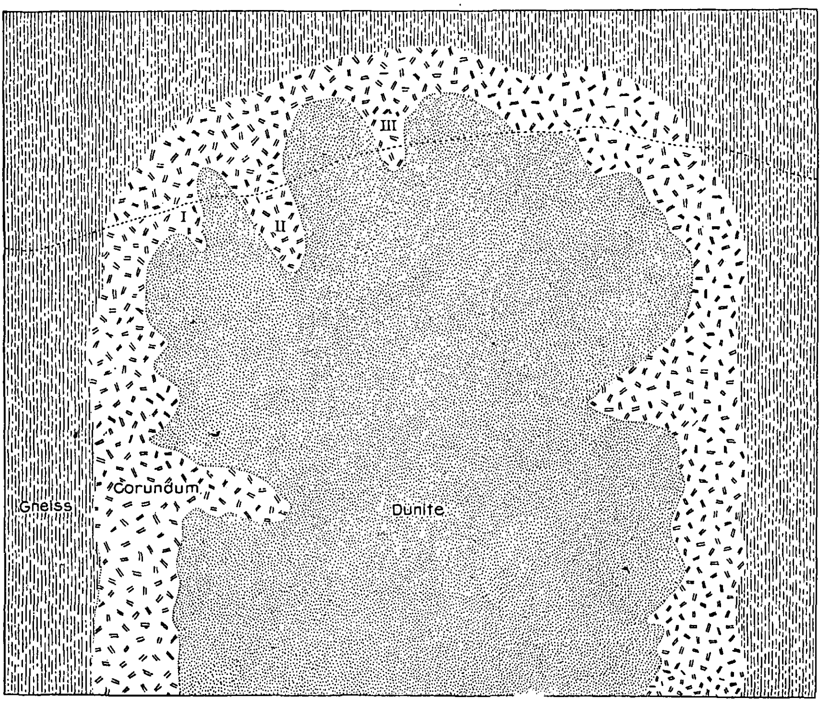

FIG. 12.—Ideal vertical cross section of mass of peridotite soon after its intrusion into gneiss.

margins; and though in many cases there would be a sharp separation (at the time of formation) between the corundum and the peridotite, in others there would be more or less corundum, in the form of masses and particles, that would extend beyond the main masses into the peridotite and thus give the appearance of a somewhat gradual passage from corundum to the pure peridotite, as illustrated in fig. 13.

The varying pressure, temperature, and other physical conditions during and after intrusion would affect the crystallizing and the separating out of the mineral from the molten mass, and this will explain the great variation observed in the corundum found in the same mass of peridotite. Thus, at Corundum Hill, North Carolina, there occur masses of block corundum, large rough crystals, small, well-developed crystals, and particles or grains of corundum.

The differentiation of the basic peridotite magma, upon cooling, is similar to what Vogt[a] and Adams[b] have described in the case of the separation of sulphide deposits from a molten gabbro magma. The

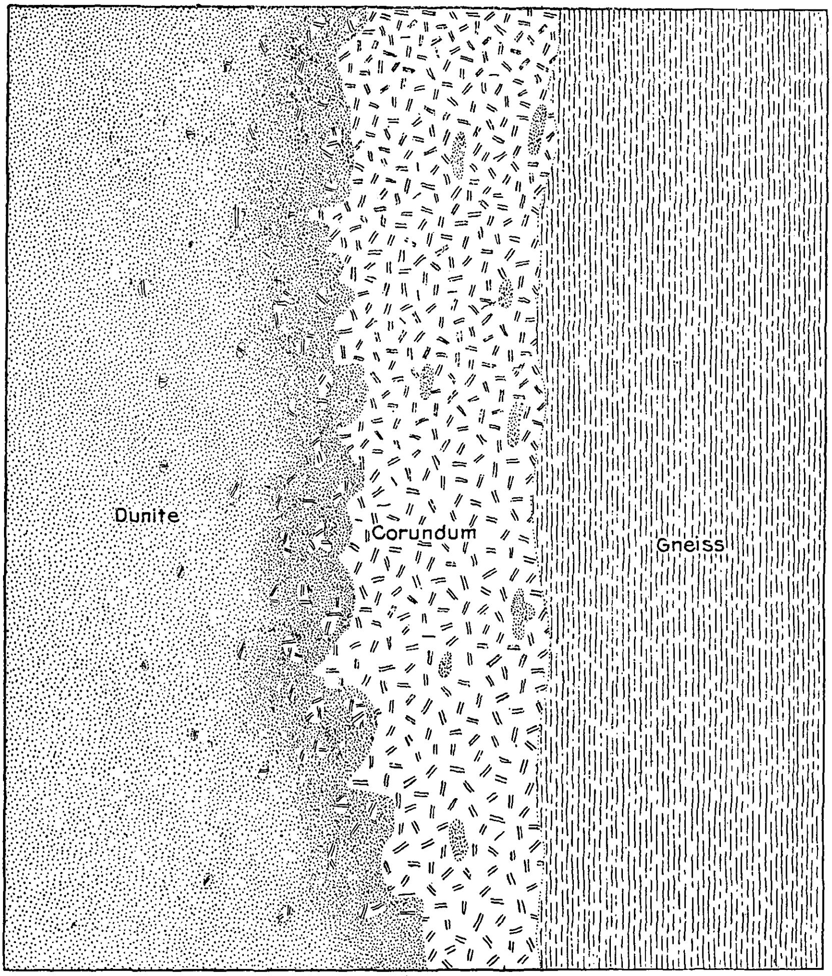

FIG. 13.—Ideal vertical cross section showing a somewhat gradual transition from corundum to peridotite.

segregation or concentration of these ores is usually near the contact of the gabbro with the gneiss and is always sharply separated from the gneiss. While there is sometimes a distinct line of separation between the ore and the gabbro, at others there is a gradual transition from the ore to the pure gabbro. It might be expected that the

[a] Zeitschr. für prak. Geol., Nos. 1, 4, and 7, 1893.

[b] On the Igneous Origin of Certain Ore Deposits; read before the Gen. Min. Asso. of the Prov. of Quebec, Montreal, Jan. 12, 1894.

corundum would be found surrounded by the peridotite, but, as was stated on page 80, there is but one locality known to the author where the corundum is found thus directly surrounded. The absence of any general occurrence of the corundum in peridotite is readily explained by the ease with which the peridotites themselves suffer decomposition.

The corundum concentrated in the peridotite near its contact with the gneiss, where the thermal waters coming in contact with the heated masses would have the best chance to act, would furnish alumina for reacting with the magnesian minerals to form the aluminum-magnesium silicates found surrounding the corundum. That the peridotites decompose very readily is apparent from the numerous specimens of these rocks found completely surrounded by foreign material that must have been formed at their expense. The corundum has been found in serpentine, but this is often surrounded by chlorite.

The descriptions of the cross sections of the corundum veins, given on pages 30–32, are similar to those described by Shepard,[a] Chatard,[b] and Lewis,[c] and show practically the same sequence.

As the peridotite and the corundum began to alter and decompose under the influence of atmospheric agencies and thermal solutions, there would be formed a series of decomposition minerals on the peridotite side of the vein and only a few on the gneiss side. The decomposed material that would be found on the gneiss side of the vein would vary according to the amount of the peridotite that had been held between the corundum and the gneiss (fig. 13). The common decomposition product surrounding the corundum is chlorite (clinochlore) or a further alteration of the mineral to vermiculite.

Between the corundum embedded in chlorite and the gneiss there is often very little and at times no chlorite or vermiculite developed, the corundum-bearing portion of the zone being apparently in direct contact with the gneiss (*b* of cross section, fig. 6, p. 31).

In the interior veins the alteration products developed are the same on both sides of the corundum-bearing zone and are in most cases nearly an exact reproduction of the peridotite side of a cross section of a border vein (figs. 6 and 7). This demonstrates that the gneiss had little or no influence in the formation of the alteration products of the border veins.

The analyses of Chatard,[d] which show the chemical character of the vein to increase in magnesia and decrease in alumina as the peridotite is approached, are in accord with the present theory regarding the formation of the alteration products.

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[a] Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 111.
[b] Bull. No. 42, U. S. Geol. Survey, 1887, p. 49.
[c] Bull. No. 11, Geol. Survey North Carolina, 1896, p. 93.
[d] Bull. No. 42, U. S. Geol. Survey, pp. 50–56.

The penetration of molten material carrying corundum into the gneiss during the differentiation of the molten peridotite would explain the occurrence of any corundum found in the gneiss adjoining a border vein. There is a similar occurrence of the sulphides penetrating into the gneiss during the cooling and differentiation of a molten gabbro, which is well illustrated in Vogt's[a] article and has been reproduced by Adams.[b]

SUMMARY.

This theory of the igneous origin of the corundum associated with the peridotites is in accord with the field observations and laboratory experiments of Morozewicz[c] and Logorio[d] on the solubility of alumina in a molten basic glass, and the separating out of the corundum and spinel as the first minerals when the glass began to cool also gives strong support to the igneous theory of the origin of the corundum here advanced.

Thus both the facts observed in the field and those obtained in the laboratory point to the same conclusion regarding the origin of the corundum associated with the peridotite rocks.

At Pelham, Mass., and at Bad Creek, Sapphire, N. C., where the corundum is found in a zone of biotite between the harzburgite (saxonite) and the gneiss, it is undoubtedly the result of contact metamorphism of the igneous rocks on the gneiss.

At a number of the corundum veins in these peridotite rocks, feldspar, which is undoubtedly one of the original minerals of the rock and not a secondary product, is found associated with the corundum. There is a marked difference noticed in the associated minerals when the feldspar is present; chlorite is not thoroughly developed, and enstatite is not so common, while margarite is quite abundant and zoisite is not uncommon. These last two minerals are rarely met with at the corundum veins which are free from feldspar.

The separation of alumina from these peridotite magmas has given rise to some interesting problems[e] bearing directly upon the occurrence of the associated minerals spinel, chromite, and feldspar in a corundum vein.

At the various peridotite localities in North Carolina and Georgia the following phenomena have been observed:

1. Peridotite rocks containing small particles and grains of chromite, but no corundum or spinel.

2. Peridotite rocks containing deposits of chromite (which upon

[a] Zeitschr. für prakt. Geol., Nos. 1, 4, and 7, 1893.
[b] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 422.
[c] Loc. cit.
[d] Zeitschr. für Krystall., vol. 24, 1895, p. 285.
[e] Pratt, J. H., Am. Jour. Sci., 4th ser., vol. 8, 1898, p. 227.

analysis showed a variable per cent of alumina and magnesia), but no corundum or spinel.

3. Peridotite rocks containing chromite, corundum, and spinel.

4. Peridotite rocks containing chromite and corundum, but no spinel.

5. Peridotite rocks containing corundum and feldspar.

A brief review of these phenomena in the order stated gives the following conclusions:

1 and 2. Of the analyses of the chromites that have come under the writer's notice, all but two show the presence of alumina and magnesia in varying quantities. In some of them the percentage of alumina and magnesia is very large, and whereas in the ordinary chromite the formula may be represented by $9(FeO,Cr_2O_3)$, (MgO,Cr_2O_3), $2(MgO,Al_2O_3)$, at one locality near Webster, Jackson County, N. C., a chromite (mitchellite) was found which had the formula (FeO,Cr_2O_3), (MgO,Cr_2O_3), $2(MgO,Al_2O_3)$. Thus, when there is considerable chromite found in these rocks there is usually no corundum, or at most but a trace of corundum present; and from what has been said above regarding the analyses of chromite, it would seem to be the case that when there is but little alumina and only a small excess of magnesia in peridotite magmas which contain considerable chromic oxide they unite to form the spinel molecule, and that this molecule, instead of separating out independently as the mineral spinel, enters into combination with the FeO,Cr_2O_3 molecule in the mineral chromite.

3. At a few of the peridotite localities both corundum and spinel have been found, as at the Corundum Hill mine, Macon County, N. C., where a fine-grained, almost black spinel occurs, through which are scattered particles and masses of corundum; and at the Carter mine, near Democrat, N. C., where there is a great abundance of corundum and a green-black spinel. In peridotite magmas of this type it would seem that there has been an excess of magnesia present, which has united with a portion of the alumina present to form the molecule MgO,Al_2O_3, which separated out as spinel. The remaining portion of the alumina formed corundum. Undoubtedly there is a strong affinity between magnesia and alumina, which tends to form the spinel molecule; but in these peridotite magmas it is only the excess of magnesia over that required for the normal magnesian silicates that has united with the alumina. Except alteration products, there are no alumina-magnesia silicates found in these rocks, which shows that in magmas of this type there is no tendency for the alumina to unite with the magnesia in forming double silicates.

4. At most of the peridotite localities there has been no spinel at all observed, but there is often a considerable quantity of corundum

found. The chromite at all these localities shows the presence of a certain percentage of alumina and magnesia. Thus the small excess of magnesia unites with a definite amount of the alumina, but instead of separating out as spinel it separates out in the chromatic molecule, as previously mentioned. The greater part of the alumina separates out as corundum.

5. In a number of these peridotite formations feldspar has been found, which is undoubtedly one of the original minerals of the rock and not a secondary product. At the Cullakeenee mine, Buck Creek, Clay County, N. C., there is at one of the border corundum veins a large amount of feldspar and hornblende which have separated out with the corundum. Again, at the Bad Creek mine, Sapphire, Jackson County, the corundum is found associated with feldspar and biotite mica. In both places they are lime-soda feldspar, and this occurrence of feldspar and corundum in a peridotite rock indicates that the molten magma contained some of the alkali and alkali-earth oxides, as Na_2O, K_2O, and CaO; that a portion of the alumina united in the formation of the feldspar molecule, and that the rest of it separated out as corundum—these minerals separating out from the still molten magnesian magma. In a magma of this type there is present a large amount of magnesia, which forms the magnesian silicates, but apparently has no tendency to unite with the alumina to form the spinel molecule; but, on the other hand, the small amount of the alkalies and alkali-earth oxides do unite with a definite amount of the alumina to form the feldspar molecule. This, again, would seem to indicate that in the presence of a certain amount of the alkali and alkali-earth oxides and silica, provided there is enough silica present to unite with both these oxides and the magnesia, there is no tendency for the magnesia to unite with the alumina to form any type of magnesia-alumina minerals. That the feldspar in these peridotites is a contemporaneous mineral with the corundum and not due to its alteration is clearly demonstrated by the examination of thin sections of the rock under the microscope, which shows the sharp, angular masses and fragments of corundum embedded in the feldspar, and also the intimate mixture of the feldspar and the corundum with large porphyritic feldspar crystals in a groundmass of the finer-grained olivine. Dr. G. H. Williams[a] has investigated a feldspathic peridotite of eastern Maryland, and his investigations are in accord with the conclusions drawn above—that the feldspar is older than the olivine and separated out from the still molten magnesian magma. He says:[b] "The structure of these rocks is therefore quite an exceptional one for the family of peridotites; first, on account of the porphyritic

[a] Bull. U. S. Geol. Survey No. 28.

[b] Ibid., p. 53.

character, which is rare in members of this class; and, second, because of the unusual position of the olivine in the groundmass, indicating that it is here the youngest instead of the oldest constituent, as is generally the case."

As has been stated on page 74, Morozewicz[a] has described the formation of corundum from a number of magmas that were supersaturated with alumina. The supersaturated alumina-silicate magmas had the general composition $MeO,mAl_2O_3,nSiO_2$ ($Me=K_2$, Na_2, Ca, and $n=2$—13). In these magmas, on cooling, all the excess of alumina (over $m=1$) separates out in the form of corundum crystals, this taking place when magnesia and iron were not present.

In these experiments the silicates that were used to form the magmas were for the most part those of calcium, sodium, and potassium. When alumina was present in them in excess of $m=1$, it would separate out in the form of corundum; but when the magma was not saturated with alumina or m was equal to 1 or less, all the alumina was used up in the formation of double silicates. When magnesia was present, the excess of alumina united with the magnesia to form the mineral spinel, and if not enough magnesia was present to unite with all of the alumina some corundum was formed. When there was an excess of silica, or n was greater than 6, the excess of alumina united with the silica to form the mineral sillimanite, and if alumina still remained it separated out as corundum. When, however, magnesia and iron are present with the excess of silica and alumina, cordierite and spinel are the minerals formed.

From these experiments it would seem that when a magma is composed of silicates of the alkali and alkali-earth metals—sodium, potassium, and calcium—the alumina dissolved in this magma will, to a certain point, unite to form double silicates of alumina with these other bases; but when the ratio of alumina to these bases is greater than 1:1 the excess of alumina will separate out as corundum, except when influenced as just described. Magnesia, it would seem, does not have so strong an affinity for the formation of silicates, and when present in the magmas influences the separation of alumina as a double salt of magnesia and alumina in the formation of the mineral spinel, or with an excess of both alumina and silica in the presence of iron in the formation of the mineral cordierite.

In some earlier experiments Morozewicz[b] has shown that alumina will readily dissolve in a molten magma having a composition approximately that of the basic magnesian rocks, and that upon cooling the alumina separates out as corundum and spinel.

[a] Tschermaks mineral. u. petrogr. Mittheil., vol. 18, 1898, pp. 1–90 and 105–240.
[b] Zeitschr. für Krystall., vol. 24, 1895, p. 281.

There seems to be but little tendency for the alumina to unite with the magnesia to form the double silicates, except where the magma contains but little magnesia and some iron, where the mineral cordierite is found, or with the magnesia alone to form the mineral spinel, MgO,Al_2O_3, except when there is an excess of MgO, when some spinel is formed; but the greater portion of alumina separates as corundum. This would seem to show that the affinity of magnesium for silica in the formation of a silicate molecule is stronger than for alumina to form the aluminate molecule.

From what has been observed in nature and from the experiments that have been made in the laboratory, therefore, it seems that the separation of alumina as corundum from molten magmas is dependent upon the composition of the chemical compounds that are the bases of the magmas, upon the oxides that are dissolved with the alumina in the magma, and upon the quantity of alumina itself, and that the following conclusions are justified:

1. When the magma is a calcium-sodium-potassium silicate, no alumina held in solution by such a magma will separate out as corundum, except when the ratio of the alumina to the other bases is more than 1:1 and the ratio of the silica is less than 6.

2. If magnesia and iron are present in the magma thus composed, corundum will not form unless there is more than enough alumina to unite with the magnesia and iron.

3. When the magma is composed of a magnesium silicate without excess of magnesia, all the alumina held by such a magma will separate out as corundum.

4. Where there is an excess of magnesia in the magma just described, this excess of magnesia will unite with a portion of the alumina to form spinel and the rest of the alumina will separate out as corundum.

5. Where there is chromic oxide present in a magma composed essentially of a magnesium silicate (as the peridotite rocks) and only a very little alumina and magnesia are present, these, uniting, separate out with chromic oxide to form the mineral chromite, and no corundum or spinel is formed.

6. When peridotite magmas contain, besides the alumina, oxides of the alkalies and alkali earths, as soda, potash, and lime, a portion of the alumina is used in uniting with these oxides and silica to form feldspar.

7. There is a strong tendency for the alumina to unite with the alkali and alkali-earth oxides to form double silicates like feldspars, whether such silicates form the chief minerals of the resulting rock or are present only in relatively small amount. There is, however,

but little tendency for the alumina to unite with magnesia to form double silicates when the magma is a magnesium silicate.

In the following table these same phenomena have been summarized in a way that perhaps makes the various results stand out more prominently.

Separation of alumina from molten magmas.[a]

Magma silicates.	Dissolved oxides.	Minerals formed.
Ca-Na-K (silicates)	Al_2O_3: R=1:1	Corundum.
	+ excess SiO_2	Sillimanite.
	R=other bases.	
	Al_2O_3-MgO-FeO	Spinel.
	+ excess Al_2O_3	Corundum.
	+ excess SiO_2	Cordierite.
	Al_2O_3 No excess MgO	Corundum.
	Al_2O_3	Spinel.
	+ excess MgO	Corundum.
	+ excess Al_2O_3	Do.
	Al_2O_3-Cr_2O_3	Do.
(Mg,Fe)SiO_4	No excess MgO	Chromite.
	Al_2O_3-Cr_2O_3	Corundum. Picotite.
	+ excess MgO	Mitchellite. Chromite.
	CaO-Na_2O-Al_2O_3-SiO_2	Plagioclase feldspar.
	+ excess Al_2O_3	Corundum.

It is very evident that there are a series of magmas that contain an excess of alumina, just as there are magmas containing an excess of silica, and that the alumina separates out as corundum according to the same laws that govern the separation of silica as quartz in granitic rocks.

In the case of the amphibolites and pyroxenites the general laws given above will apply to the separation of the alumina as corundum from these rocks when they were in a molten condition. As they are for the most part in narrow dike-like formations instead of lenticular masses, the corundum would be generally distributed through them rather than concentrated along their borders.

[a] For comparison see on p. 94 the origin of corundum in plumasite.

ORIGIN OF EMERY IN AMPHIBOLITE AT CHESTER, MASS.

It is difficult to decide from an examination of the amphibolite and the surrounding rocks at Chester, Mass., whether the amphibolite is of sedimentary or igneous origin, for some indications point to one and some to the other; hence it is not improbable that some portions of this band of amphibolite, which extends across the State, may have been formed in one way and other portions in the other way. Professor Emerson has examined this belt of rocks for practically its entire distance across the State, and while he is inclined to consider the amphibolite of sedimentary origin, he does not, if I understand him correctly, see anything antagonistic to the view that at least a portion of it is an intrusive igneous rock. I have examined only that portion of the amphibolite adjacent to the emery vein, and from my observations I have come to the conclusion that this part of the amphibolite band is an igneous rock that has been intruded into the schists along their line of weakness, and that the magnetite and emery are the first minerals to separate out from this magma. The reasons that have led me to this conclusion are given briefly in the following paragraphs.

The position of the amphibolite, with a dip of practically 90°, lying between the Rowe and the Savoy schists, which would have been a line of least resistance, suggests an igneous origin. What seems to me opposed to the acceptance of a sedimentary origin for this broad band of amphibolite is the separation of the vein of emery and magnetite from the sericitic schist on the east by a band of the amphibolite, varying in width from a few feet to 18 feet, which, as far as can be judged superficially, is identical in every way with the amphibolite on the west of the vein. Yet, if the amphibolite and emery are of igneous origin, it would naturally be expected that emery would occur on the west side of the amphibolite, but none has been found there, although it is not certain that it does not occur.

Only a small amount of carbonates has been found in connection with the amphibolite and emery—no more than could readily be accounted for as secondary minerals.

Moreover, chromite has been found in connection with the serpentine that is associated with the amphibolite, some of which serpentine is undoubtedly an alteration of this rock. The presence of the chromite in the serpentine is to me a very good indication of its igneous origin, and of its being the alteration product of a basic magnesian rock. This, then, would indicate the existence of former masses of a basic magnesian rock which have been changed into serpentine, the serpentinization continuing into the amphibolite for some distance.

The emery is not continuous along the strike of the vein, but occurs in a series of pockets in the vein that dip about 30° to the north. In going from one pocket to another along the strike there is often nothing to indicate the vein but a small seam of chlorite. The pockets are almost continuous in the direction of the so-called dip and hold this dip very constantly.

It seems to me that this portion of the amphibolite band was an igneous mass intruded after the formation of the sericitic schists, and either after or at the time when these schists were already tilted to their present position, and that the emery bed is the result of the differentiation of components of the mass that were held in solution by the igneous magma.

The theory that Professor Emerson[a] proposes is also probable, viz:

> That the emery-magnetite vein was originally a deposit of limonite which was formed by the replacement of limestone and into which alumina was carried by infiltrating solutions and deposited as allophane and gibbsite. The subsequent metamorphism of the bed, although it may well have been intimately connected with the extremely violent mechanical forces to which the strata have been subjected, was largely completed before these forces had ceased their activity, as is shown by the jointing and brecciation of the magnetite and emery. * * * The less altered ferruginous limestone below was changed into the epidotic amphibolite.

Many points that can be noticed support this conclusion, but these also indicate an igneous origin for the amphibolite. No fresh peridotite rocks have been observed in this section, and the nearest are probably across the Connecticut River at Pelham, where an igneous mass of saxonite occurs. However, as stated above, the presence of chromite in the serpentine associated with this amphibolite seems good evidence that the serpentines have an igneous origin, and it is very probable that they are alterations of former masses of an intruded peridotite.

If any deep mining is undertaken on the emery, new evidence may be brought to light that will determine decidedly what may have been the origin of these amphibolites and emery deposits.

ORIGIN OF CORUNDUM IN NORITE.

The emery variety of corundum, which is found associated with the norites in the vicinity of Peekskill, Westchester County, N. Y., shows a gradual transition of the spinel (pleonaste), iron ore, and emery into the normal norite. It is not at all unlikely that the segregated masses of these basic minerals are the products of differentiation of the molten norite magma by which the basic portion of the magma has been concentrated near its outer surface and makes a gradual transition toward the center to the more acid norite. This occurrence would be similar to that of the pyrrhotites which have separated out from the norites of Norway, as described by

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[a] Mon. U. S. Geol. Survey, vol. 29, 1898, p. 145.

Vogt.[a] In that case the pyrrhotite is concentrated toward the border of the norite, and there is at some places a gradual transition from the pure pyrrhotite through pyrrhotite-norite to the pure norite, while at others there is a sharp contact between them.

ORIGIN OF CORUNDUM IN PLUMASITE.

Plumasite has been described on page 43 as an oligoclase-corundum rock which is either a separate dike rock cutting through the peridotite, or is a differentiated zone that has separated out from the original peridotite magma. Whichever of these two may be the exact origin of the oligoclase-corundum rock, it is very evident that the corundum has separated from a molten magma which contained the chemical compounds of plagioclase feldspar with an excess of alumina. Upon the cooling of this magma a sufficient portion of the alumina would be utilized in forming the oligoclase molecule, and only the excess would separate out as corundum. This would take place whether the magma had simply the composition of a medium acid plagioclase with an excess of alumina, or whether the magma had principally the composition of olivine with a certain amount of alkalies, lime, and alumina, the three latter in sufficient quantity to make the oligoclase molecule with an excess of alumina. This formation of the corundum is in accord with the experimental work of Logorio.

ORIGIN OF CORUNDUM IN MONCHIQUITE.

The sapphires which are found in the monchiquite of Yogo, Mont., are all of some shade of blue, and they occur rather sparingly in the rock; but, from their sharp, distinct crystals and their general distribution in this rock, it is just as evident that they have crystallized out of a molten magma as that the well-formed phenocrysts of feldspar in porphyry have crystallized out from a molten magma. As stated by Prof. L. V. Pirsson,[b] however, the general character of the rock shows that it could not originally have been sufficiently rich in alumina to have allowed a general separating out of corundum. The molten magma during its intrusion undoubtedly took up great quantities of inclusions from the sediment through which it passed. The Belt formation, consisting of clay shales of great but unknown thickness, probably underlies the limestones of this district, and the included fragment of these shales would be the source of the alumina of the sapphires.

It may be, as some believe, that the Belt formation is absent, but it is known that the Cambrian beds, which contain almost every

[a] Zeitschr. für prakt. Geol., Nos. 1, 4, and 7, 1893.

[b] Pirsson, L. V., Geology of Little Belt Mountains, Montana: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898–99, p. 554.

possible variety of calcareous, siliceous, and argillaceous rocks, do underlie at this location the rocks exposed at the surface, and these would probably be capable of furnishing material that could be the source of the sapphires. The parallel dike of nearly similar rock which cuts the limestones about 600 feet north of the sapphire dike does not, however, contain any gems, and this has been thoroughly prospected. It may be that the shales of the Belt formation underlie the limestone and Cambrian rocks in such a position as to be cut by the sapphire dike and that they stop before reaching a point where the parallel dike has been intruded. Such beds of shale would be readily shattered by the intrusion of igneous rocks, and portions of the shattered shales would naturally be included in the intrusive mass. These included fragments of shale would be dissolved by the molten magma, its heat being very naturally maintained, as it is in the form of an intruded mass. Local areas would be formed in the magma that would be very rich in alumina, and as the magma began to cool corundum crystals would separate out in these alumina-rich areas. Such a formation of the corundum is in accord with the laboratory experiments, as described under the artificial production of corundum, and the form of the crystals is also in accord with that of pyrogenetic corundum.

Mr. W. H. Weed[a] makes the following statement regarding the igneous origin of these sapphires:

> It is apparent from a study of the sapphires themselves that they crystallize out of the rock; but it is also evident that partial resorption took place before final consolidation, since many of the sapphires show deeply corroded surfaces; others are rounded masses whose crystalline outline is nearly effaced, while many of them are surrounded by a blackish crust. If the molten rock could dissolve the sapphires at this stage, it is certain that it could dissolve clay shale as well.

As has been stated, the upper portion of these dikes is thoroughly altered and decomposed, so that their original character is obscured, and they are now ocherous, clayey bodies. Where the dikes are less decomposed they begin to have a brecciated appearance, which is undoubtedly due to the fragments of limestone that have been broken off during the intrusion of these dikes through the limestone. At depths varying from 30 to 50 feet the unaltered rock begins to be encountered.

ORIGIN OF CORUNDUM IN METAMORPHIC ROCKS.

ORIGIN IN AMPHIBOLE-SCHIST.

The occurrence of corundum in the amphibole-schist of Cowee Valley, Macon County, N. C., has been described in detail on pages 57–59. The rock is composed chiefly of labradorite, amphibole, and garnet,

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898–99, p. 458.

with staurolite and rutile, muscovite, and biotite as accessory minerals. The labradorite of this rock is often broken, exhibiting rolling extinctions, and the albite lamellæ are curved and bent, strongly indicating a shearing movement in the rock. The corundum does not occur in crystals, but in small fragments and in elongated nodules, which are cracked and seamed, as if they had been drawn out during the shearing process. The staurolite is in rather broad irregular grains, and the rutile in small irregular grains and well-crystallized prisms.

From the character and structure of this rock, as noted above, it is very probably a metamorphosed igneous rock of the gabbroid family. During metamorphism the augite of the gabbro would be converted into the brown hornblende. Any iron ore that was present would be taken up by the hornblende and garnet. The rutile would have resulted from the titanic acid that is a regular component of the iron ores in these gabbro or diabase rocks. Staurolite is a mineral that is rather naturally expected, as it is usually a mineral of metamorphism, and its natural home is in the schistose rocks. The feldspar has suffered the least chemically (except the corundum), and shows only the shearing of dynamic processes. The general character and shape of the corundums would indicate that they were original constituents of the igneous rock and were not formed during its metamorphism.

ORIGIN OF CORUNDUM IN QUARTZ-SCHIST.

These rocks, which are found in Clay County, N. C., and in Rabun County, Ga., are described at length on pages 55–56. They vary from those that are a normal gneiss to those that contain little or no feldspar, and they can be best designated as quartz-schist.

The corundum occurs for the most part in small particles and fragments that have no definite shape, and are of a gray, white, and bluish-white color to almost colorless. It is also in crystals varying in size from minute ones to some that are 2½ inches long and about one-half an inch in diameter, which are usually fairly well developed in the prismatic zone.

It is probable that these schists are the result of the metamorphism of sandstones and shales formed from alluvial deposits of many thousand feet in thickness, that were formerly the bed of the ocean. By lateral compression these have been folded and raised into the mountain ranges of this section. That these were much higher than at the present time is very evident from the granitic dikes that are of deep-seated origin. By decomposition and erosion the mountains have been worn down to their present condition, thus exposing the schists in contact with granitic dikes which have aided in their thorough metamorphism. The shales were rich in alumina, which possibly was in the form of bauxite, and during their metamorphism the excess of the alumina crystallized out as corundum. This mineral has crystallized out along the planes of lamination, so that during the subsequent weathering of the rock the corundum has been left in knotty nodules, studding the surface of the rock and giving it the appearance of containing a high percentage.

This view of the conversion of rich aluminous shales or bauxite into corundum is strengthened by the experiments made in the artificial production of corundum from bauxite, a hydrous aluminum oxide, by means of very great heat and pressure in an electrical furnace, as described on page 75.

DISTRIBUTION OF CORUNDUM IN THE UNITED STATES.

Although there are many localities throughout the United States where corundum has been found, only a few of these contain this mineral in quantity, and still fewer give evidence of developing into commercial deposits. Most of the corundum that has been mined in the United States for abrasive purposes has been obtained from the Eastern States, principally from Massachusetts and New York, which furnish the emery variety, and from Georgia and North Carolina, which furnish corundum. During the last two years the corundum deposits of Montana have been developed, and their product has been put on the market. The sapphire variety of corundum has been mined quite extensively in Montana, and to a more limited extent in North Carolina. The general location of the corundum deposits of the United States is indicated on the map, Pl. I. With the exception of a few localities in Montana, two in Colorado, one in Idaho, and one or two in California, all the known occurrences of corundum in the United States are confined to the Appalachian belt.

In the following descriptions of localities, those that contain the sapphire variety are first taken up, then those containing corundum, and last, those containing emery.

SAPPHIRE OR GEM CORUNDUM.

RUBY.

Sapphire or corundum gem occurs in the mines in three forms: First, as crystals, of which there are two distinct forms, (1) hexagonal prisms terminated by rhombohedrons and pyramids, sometimes with basal plane, the larger crystals being often rounded or barrel shaped, and (2) flat, tabular crystals, where the basal plane is very largely developed; second, as transparent colored portions of larger massive pieces of corundum; third, as nodules of finer and clearer material in a mass of cleavable corundum, often having the appearance of rolled pebbles when separated from the mass of corundum.

The most important of the sapphire gems is the oriental ruby, which varies from rose, pinkish, dark red, and purplish to pigeon-blood color, the most highly prized. The rubies are very likely to be flawed, and when examined many of the cut stones are found to contain flaws of one character or another. The stones are often so cut that these flaws are distinguishable only by the aid of a magnifying glass.

The finest rubies of pigeon-blood color are those found in the Mogok district, about 90 miles north-northeast of Mandalay, in upper Burma. Small but fine rubies, often, however, of a pink color or a purplish tint, are found at Ratnapoora, in Ceylon, and of a dark-red color, similar to that of a garnet, in Siam. The rubies of the Burma district are found in place in limestones, but the mining is confined almost entirely to the gravels.

NORTH CAROLINA.

At the Corundum Hill mine, Cullasagee, N. C. (see description, p. 117), various shades of ruby-gem corundum have been found. Two of the best rubies of good color that have ever been found at this mine are in Clarence S. Bement's collection. There are also a number of fine ones in the United States National Museum at Washington. Many of the smaller crystals of various shades of pink to red are transparent near the outer surface and near their extremities, and from these small gems can be cut; but few that are worth $100 have been obtained from them. These smaller crystals are usually well developed and have a clean-cut form. The faces commonly developed on these are the base *c* (0001); the unit prism, *m* $(10\bar{1}0)$; the unit rhombohedron, *r* $(10\bar{1}1)$, and the pyramid, *n* $(22\bar{4}3)$, more rarely observed.

The North Carolina locality for corundum gems which has attracted the most attention is the tract of land between the Caler Fork of Cowee Creek and Mason Branch, tributaries of the Little Tennessee River.[a] This tract is situated in Macon County, almost 6 miles north of the town of Franklin. The nearest railroad station is Dillsboro, Jackson County, on the Southern Railway, about 12 miles to the east. The bottoms of the valleys are about 2,500 feet above sea level, and the mountain peaks or knobs in the immediate vicinity rise to a height of 3,000 or 3,500 feet.

In the gravels of Caler Fork Valley pieces of crystals of red corundum were picked up by the people of the district, which led to the driving of two or three tunnels with the expectation of striking the

[a] Am. Jour. Sci., 4th ser., vol. 8, 1899, p. 370.

vein and finding the corundum in sufficient quantity for commercial purposes. Work in this direction was soon abandoned, and for a number of years there were only prospecting and a little mining for the red corundum for gem purposes.

Systematic search, however, finally revealed the fact that ruby corundum was to be found in the gravels of Caler Fork Valley for a distance of 3 miles. In 1895 the American Prospecting and Mining Company, of New York, bought out the old claims and began work on a systematic basis. The property owned by the company is a large tract on both sides of Caler Fork of Cowee Creek and nearly all the land in the northern part of the watershed of Mason Branch, a total area of about 5,000 acres.

The gravels in which most of the rubies have been found are covered by soil averaging about 2 feet in depth, but varying from 1 to 5, and they are about 3 feet higher than the present alluvial gravel of the stream. Pl. IV, *A*, is a view of one of the gravel beds that is being worked for rubies, just west of the company's office. The gravel in this part of the valley, which is overlain with 3 to 5 feet of soil, is composed of waterworn masses of quartz and small pebbles of gneiss and quartz, and is much cleaner in appearance than the gravels a mile farther up the creek, at In Situ Hill, where most of the mining was carried on during 1898. Fifty feet above the level of this gravel another bed was discovered at In Situ Hill which carried ruby corundum.

In washing these gravels for the rubies, hydraulic processes have been used very similar to those used in the West in washing gold-bearing gravels. All the soil, as well as the gravel, is washed into a short line of sluice boxes (*a* of Pl. IV, *B*) which lead into a large sieve box (*b* of Pl. IV, *B*), where the large pieces of rock and bowlders are removed and most of the dirt and fine gravel is washed out. They are then shoveled into a rocker (*c* of Pl. IV, *B*), where they are further cleaned and concentrated, the final concentration of the rubies being done by hand.

No basic magnesian rocks or serpentine derived from them, in which most of the corundum of North Carolina occurs, have been found in this valley. Corundum Hill and the Ellijay corundum regions are, however, less than 10 miles to the south.

Although in many respects the occurrence of the rubies and their associated minerals in the Cowee Valley is similar to the occurrence of the ruby in Burma, no limestone has been found near the alluvial deposits, the nearest point at which limestone has been found being at Cullowee Gap, about 8 miles to the southeast.

The country rock of the district is a gneiss, of a gray fine-grained variety, which has a great many small garnets disseminated through it. The rock for the most part is in a highly decomposed condition, but there are small exposures of the undecomposed rock in many places. The gravels in which the rubies are found rest on a soft saprolitic rock which is the result of weathering of the basic silicate rocks in place. By means of shafts and of the workings at the gravel washings it has been shown that at a depth of 35 feet or more these saprolitic rocks contain fragments of the undecomposed rock and pass into such rocks as eclogite-amphibolite and hornblendic gneiss.

A narrow dike of hornblendic eclogite a few feet in width is exposed near the present workings of the company and can be traced for about 100 yards.

No rubies have been found in the undecomposed rock, but at In Situ Hill small rubies of a rather pale color were found in a narrow band of saprolitic rock. This band was, however, cut off by slickensides so that it could not be followed in any direction. There are four parallel slickensides that have been exposed at one place in the workings, the general direction of the slickensides being N. 75° E. Some of these are 70 feet in length and of unknown depth. It is very evident that there has been a great deal of disturbance in this immediate vicinity through the breaking of the rock masses by faulting, the ready influx of water having caused the reduction of the rocks to their saprolitic condition.

In washing the gravels and bodies of saprolitic rock, masses of undecomposed rock have been uncovered, and in the center of these nodules of the pure hornblende rock have been found. The saprolite bordering these nodules often contains particles and crystals of corundum.

Less than 2 miles to the east of In Situ Hill, beyond Betts Gap of the Cowee Mountains, corundum of a gray to bluish color, but highly crystallized, has been found in hornblende-gneiss. One mile a little north of west, at the Sheffield mine, pink corundum has been found in amphibole-schist. (See pp. 57–59.)

An association of corundum peculiar to this locality is with the garnet rhodolite.[a] Corundum and garnet (almandine and rhodolite) not only occur constantly together in the saprolitic material and in the gravels, but corundum crystals have been found that bear the impression of the garnet. By means of wax a mold was taken of these impressions, and they were shown to be either the dodecahedron or trapezohedron. On the other hand, some of the ruby crystals when broken are seen to have a rhodolite garnet inclosed, and the garnet can often be seen in the transparent ruby crystal and the cut gem.

The peculiarities which distinguish this garnet from the ordinary occurrences of the species are its variety of shades and tints, for the

[a] The name rhodolite was selected for this mineral as describing its most prominent character, namely, its delicate rose-like color.

most part similar to those belonging to the rhododendrons and roses; its surprisingly small amount of coloring matter; its gem-like transparency; its freedom from internal imperfections, microscopic inclusions, and striæ, the characteristic imperfections of common garnets; also its remarkable brilliancy when cut as a gem. There is but one variety of garnet now known which approaches it, when in gem form, in this last respect, and that is the green demantoid of Siberia, which often vies with the diamond in its luster and dispersive effect upon light. Most garnets are beautiful only by transmitted light, and then exhibit only dark shades of color, but these new garnets give most beautiful effects of brilliant and varied coloring by reflected light alone, thus proving the uncommon purity and great clearness of this new material.

As has been said, there is no limestone in this immediate vicinity, and these rubies were probably derived from an amphibolite or eclogite. The usual tabular form of the crystals is one that seems to be characteristic of the gem corundum when found in igneous rocks.

The Cowee Creek rubies frequently contain inclusions, some of which are very minute, known to jewelers as "silk," and these give rise to a cloudiness or sheen in the polished gem. Some gems from this mine have been cut that were 3 or 4 carats in weight, free from inclusions, of fine color, and transparent. A great many smaller ones have been cut that are perfect gems. In color and brilliancy these gems are equal to the Burma ruby, and if the percentage of the unflawed, transparent material increases but little, this new field will be a worthy rival to the Burma field. A considerable percentage of the transparent material is often very badly flawed by cracks due to parting and injured by the inclusions of rutile or menaccanite, so that the percentage of perfect stone from this mine is small. This, however, is true of the rubies from the Burma field also, for a large proportion of the rubies on the market to-day are usually more or less flawed with the parting cracks.

The pleochroism exhibited by the Cowee rubies is very marked, some of them being a very rich pigeon-blood red in the direction of the vertical axis—that is, looking down upon the basal plane—and changing to an almost pinkish-white color when viewed at right angles to this or looking through the prism. The pleochroism which nearly all the deep-colored varieties of corundum gems exhibit is one of the means of identifying a corundum gem. This often interferes with the cutting.

The ruby crystals[a] from the Cowee Valley show a very wide variation in their development. Although many of the crystals are so striated that no crystallographic measurements were possible on the

[a] Am. Jour. Sci., 4th ser., vol. 8, 1899, p. 379.

reflecting goniometer, the faces were readily identified by means of the contact goniometer. On some of the crystals the faces were bright and smooth, making them well adapted for measurement on the reflecting goniometer. These crystals are shown on Pl. V.

In the crystals examined two common habits were noticed; one is shown in figs. 1 and 2 of Pl. V, and is a combination of the base *c* (0001) and the unit rhombohedron *r* ($10\bar{1}1$); the other is represented by figs. 3–6 of Pl. V, where the prism *a* ($11\bar{2}0$) is very prominently developed. The rhombohedral crystals vary from those in which the base and the rhombohedron are disproportionately developed, the base having a diameter of 12 mm. and the rhombohedron of only 1.5 mm., to some (fig. 1 of Pl. V) in which the base and the rhombohedron are nearer one size. The majority of these crystals have, however, the base more largely developed, thus giving the crystals a flat, tabular appearance. This rhombohedral development is very similar to the sapphires from Yogo Gulch, Montana, described on pages 113–114.[a]

On some of the prismatic crystals the prism reaches a length of nearly 15 mm. in the direction of the *c* axis and has the rhombohedron *r* but slightly developed (fig. 3 of Pl. V), while on others the prism is very short and the rhombohedron is sometimes wanting, as represented in figs. 4 and 5 of Pl. V.

Another habit of these crystals is shown in figs. 7 and 8 of Pl. V, where the pyramid *n* ($22\bar{4}3$) is well developed. This face was identified by means of the contact goniometer, the measured angles approximating closely to those calculated. The usual form of these crystals is shown in fig. 7 of Pl. V, where the faces *c* (0001), *a* ($11\bar{2}0$), *r* ($10\bar{1}1$), and *n* ($22\bar{4}3$) are nearly equally developed. On some of the crystals the prism is very prominent, being 8 mm. in length in the direction of the *c* axis, while the pyramid is only 1.5 mm.; on others the pyramid is only very slightly developed. A few crystals were examined which showed only the presence of the base, the rhombohedron, and the pyramid, as represented in fig. 8 of Pl. V. The crystals, measuring up to 7 mm. in diameter, were doubly terminated and nearly perfect in their development.

The crystals represented by fig. 7 of Pl. V are similar to those described by Bauer[b] from the Burma district, and are almost identical in form with the sapphire crystals figured by me, from Emerald Bar, Canyon Ferry, Meagher County, Mont. (p. 109).

Although both the basal and rhombohedral planes are very often striated, it is only on the basal planes that the striations are sharp and distinct and can be measured. The striations are parallel to the three intersections of the base *c* and the rhombohedron *r*, as shown in fig. 5 of Pl. V.

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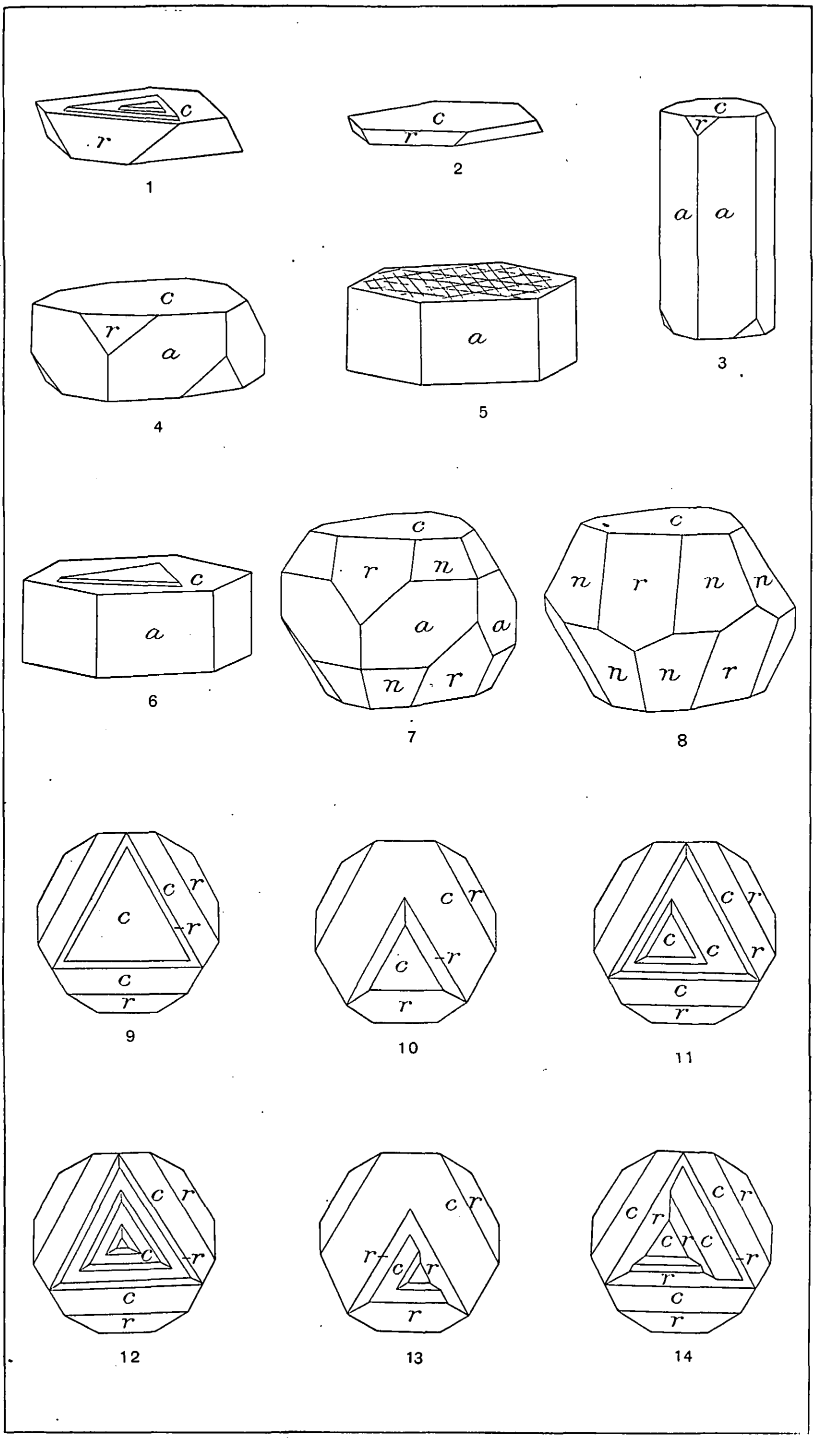
[a] See also Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 424.
[b] Neues Jahrbuch für Mineral., Geol., und Pal., vol. 11, 1896, p. 209.



RUBY CRYSTALS FROM COWEE VALLEY, NORTH CAROLINA.

A very common development that was noticed on nearly all the flat rhombohedral crystals and on many of the prismatic crystals is a repeated growth on the basal plane of the rhombohedron r $(10\bar{1}1)$ and the base c (0001), as represented in figs. 1–6 of Pl. V.

To illustrate better the variation in these growths, a series of drawings, figs. 9–14 of Pl. V, have been made in basal projection. In figs. 9 and 10 of Pl. V, which represent the more common development of these repeated growths, there is but one secondary rhombohedron and base, which sometimes has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal. Figs. 11 and 12 of Pl. V represent the repeated growths, the faces of which are separate and distinct from one another and from the faces of the main crystal. In the crystals represented by fig. 12 of Pl. V, the basal plane of the crystal has the appearance of being striated with triangular markings when the secondary growths are but slightly developed. In figs. 13 and 14 of Pl. V is represented a series of growths where a number of the rhombohedral faces coincide.

Some of the pyramidal crystals (figs. 7 and 8 of Pl. V) also show the development of the secondary growth of rhombohedron and base. The thickness of the rhombohedron of the secondary growth varies greatly; some are so thin that they appear like striations; some are 2 mm. in thickness. A few crystals were observed on which there was a secondary growth parallel to the prism a $(11\bar{2}0)$. This same style of development has been described by Bauer[a] as occurring in the Burma rubies.

The sapphire crystals from Montana, described on page 109, are strikingly similar in this respect to the Cowee rubies. Among the most noticeable associated minerals of these Cowee rubies is the delicate rose-colored garnet, rhodolite, which has already been mentioned. It usually occurs in waterworn pebbles, but it has also been found in very small dodecahedrons. The other accompanying minerals are: Quartz, rarely as pseudomorphous dodecahedrons; corundum crystals, of pale blue, amethystine, and pink shades; spinel (pleonaste); gahnite, in octahedral crystals; chromite (rare); rutile; menaccanite; bronzite (transparent); tremolite; hornblende; iolite (colorless); cyanite; fibrolite; staurolite, in perfectly transparent fragments of a garnet-red color; monazite in small crystals; zircon, small brilliant crystals, and also the variety cyrtolite; pyrite; chalcopyrite; pyrrhotite; sphalerite; sperrylite in minute crystals; and gold.

Much of the work that has been done in Cowee Valley has been in the nature of prospecting to locate the extent of the ruby-bearing gravel, and, if possible, to locate the origin of the rubies themselves.

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[a] Loc. cit., p. 209.

At the Mincey mine, Ellijay Creek, ruby corundum has been found from which several small stones could be cut. This ruby corundum occurs at the same locality as the bronze corundum described below.

Another locality that is worthy of mention, and one that gives some promise of making a satisfactory showing in course of development, is the so-called gem mine on the property of Dr. C. Grimshawe, of Montvale, Jackson County, N. C. Rubies of good color, from which a number of very small but fine stones have been cut, have been found in the gravels of the stream. Blue and yellow corundum of gem quality is associated with the rubies. By following up the gravels the corundum was located in a small vein in the decomposed peridotite.

At the Cullakeenee mine, Buck Creek, and near Elf, on Shooting Creek, Clay County, N. C., masses of emerald to grass-green amphibolite are found, through which are disseminated particles of pink and ruby corundum, ranging in size from that of a pea to that of a hickory nut. The corundum is not of gem quality, but the combination of the green amphibolite and the pink corundum makes very beautiful specimens, and as the rock is hard enough to admit of a good polish this occurrence might furnish a decorative or ornamental stone of some value.

At the Mincey mine, on Ellijay Creek, Macon County, and about $2\frac{1}{2}$ miles northeast of Corundum Hill, there occurs a peculiar brown or bronze corundum, known locally as "pearl corundum," which shows distinct asterism, both by natural and artificial light, when the stone is cut en cabochon. In natural light these corundums all show a bronze luster and are somewhat similar to the cat's-eye, but in artificial light the star is more distinct. Most of the bronze corundum is in rough crystals, but some have been found that have the prismatic faces smooth and well developed, and these are often dark, almost black, in color.

Asterism has been noticed in many of the rubies and sapphires from Cowee Valley and in a few of the sapphires from the Montana deposits. This asterism, according to Von Lasaulx, is sometimes produced by rifts due to the basal parting. These rifts, when examined with the microscope, are seen to be very thin, sharp, and rectilinear, and are parallel to the intersection of the prism and the base.

In other cases asterism is undoubtedly due to the rutile or other mineral that is inclosed in the sapphires, which intersect each other at angles of 60°, and form a "sagenite web" or similar structure.

On many of the corundum crystals, especially of the sapphire variety, concentric hexagons were observed on the basal plane as represented in fig. 14. The edges of the hexagon are parallel to the intersections of the prism faces and the base, and the plane of the hexagon is parallel to the base. In a few of the transparent crystals this hexagon was observed as a web in the midst of the crystal, the plane of the web being parallel to the basal plane.

GEORGIA.

There are a few localities in Georgia where a ruby-red corundum has been found, but none of these have as yet produced a stone of any real merit as a ruby gem. At the Laurel Creek mine, Rabun County, at the Hiawassee mine, Towns County, and from near Caldwell, Union County, pink to ruby-red corundum of good color has been found, some of which is translucent to semitransparent, making very handsome mineral specimens.

MONTANA.

Montana has, next to North Carolina, been the most productive State in rubies, and it is the first State in the total value of its production of corundum gems, of which the oriental sapphire constitutes the largest amount. Rubies of a rich red color have been found in the gravels of the upper waters of Rock or Stony Creek, Granite County, and in less amount in the gravels of Cottonwood Creek, Deerlodge County. The rubies are found in these gravels associated with other colors of corundum, and they form but a very small percentage of the total corundum gems obtained. The majority of the gems found at these two localities are pale-green, yellow, pink, or from bluish-white to nearly colorless.

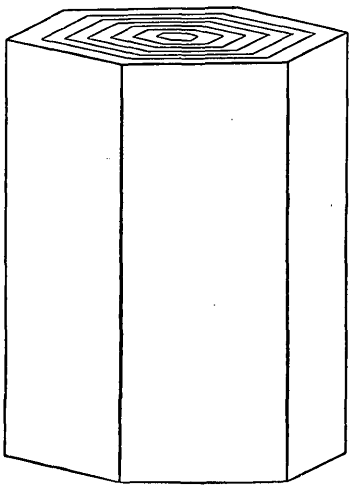


FIG. 14.—Corundum crystal, showing concentric hexagons on basal plane.

SAPPHIRE.

NORTH CAROLINA.

No corundum gems were found in the United States until the opening of the Corundum Hill corundum mine at Cullasagee, Macon County, N. C., in 1871. This corundum is mined for abrasive purposes, but in certain parts of the deposit crystal corundum is occasionally found that is of a decided gem character, and, again, many of the fragments of the corundum have certain portions that are transparent. A number of very handsome dark-blue sapphires from this mine are in the United States National Museum, one of which weighs a carat.[a]

[a] Kunz, G. F., Gems and Precious Stones of North America, 1890, p. 40.

Yellowish and blue colors in the same specimen are rather common, and are sometimes sharply separated into consecutive bands, while in other specimens the colors merge into one another.

Sapphire gems of all the different colors have been found at Corundum Hill, and I have in my collection cut gems representing all these various colors. Many of them are, however, very small.

During the last fourteen years but few gems have been obtained from this mine, for the reason that the portion of the deposit from which these crystals were formerly obtained has not been worked. In the alluvial deposits below this portion of the mine many handsome crystals can be obtained by washing the gravel.

The green sapphire, which is the oriental emerald, is one of the rarest of gems. The Corundum Hill mine is the only place in this country at which the emerald-green sapphire has been found, and it occurs very sparingly here, although the yellowish and light-green varieties are not uncommon. What is probably the finest known specimen of oriental emerald in the world came from this mine and is now in the Bement collection. It is a crystal 4 by 2 by 1¼ inches; part of it is transparent, and several very fine gems could be cut from it.

At the Sapphire and Whitewater corundum mines, near Sapphire, Jackson County, N. C., fragments of sapphire of a fine blue color have been found, from which small but good gems have been cut.

Associated with the green amphibolite rock near Elf post-office, Clay County, N. C., deep-blue sapphires have been sparingly found. These bear the same relation to the amphibolite as the red and pink sapphire described on page 104.

MONTANA.

MISSOURI RIVER.

Systematic mining for sapphires in the United States has been undertaken only in Montana. Sapphires were first found in this State by miners who were washing the gravels of the bars on the Missouri River, east of Helena, for gold. These were first described in 1873 by Dr. J. Lawrence Smith,[a] but it was not until 1891 that actual mining was begun. During that year a number of companies were organized to work these bars for sapphires.

These bars are located from 12 to 18 miles east and northeast of Helena, and have been followed for a distance of about 12 miles from Canyon Ferry down the river to American Bar. At various intervals the bars have been worked for the sapphires and are designated by the following names, starting with the one that is farthest up the

[a] Am. Jour. Sci., 3d ser., vol. 6, 1873, p. 185.

MAP SHOWING LOCATION OF MONTANA SAPPHIRE DEPOSITS

BY

JOSEPH HYDE PRATT

Scale

10 0 10 20 30 40 50 miles

× INDICATES SAPPHIRE DEPOSITS.

1905.

JULIUS BIEN & CO. LITH. N.Y.

river: Emerald Bar, Cheyenne Bar, French Bar, Spokane Bar, Metropolitan Bar, Eldorado Bar, Dana Bar, and American Bar. The location of these bars is shown on the map (Pl. VI).

A few sapphires have been found as far down the river as Beartooth, but sapphires have not been found in large quantity below American Bar.

Above Emerald Bar no sapphires have been found on any of the bars, but in the gravel of Magpie Gulch, less than a mile above Emerald Bar (at Canyon Ferry), many have been found by miners who were washing the gravel for gold. No sapphires have been found in place in this gulch, but Kunz[a] has noted the occurrence of some in a dike of vesicular mica-augite-andesite which is about 6 feet wide and cuts through the green slate below the gravels. At French Bar, about 3 miles below Canyon Ferry, a narrow dike, 3 to 6 feet in width, that had greenish sapphires scattered sparingly through it was found in 1900. This dike was encountered about 50 feet above the river and its strike as it cuts through the slate is N. 10° E., the dip being about 45° W. This rock is undoubtedly of the same character as that described by Kunz as occurring at Ruby Bar.

From the occurrence of these two corundum-bearing dikes of andesite it would seem that the source of the sapphires found in the various bars along the Missouri River is a series of small parallel dikes with a slight northeast-southwest trend, like those described. As the sapphires are scattered so sparingly through these dikes, the amount of decomposition and erosion that was required to liberate those that are now found in the gravels must have been enormous.

The beds of gravel in which the sapphires occur are from 10 to 50 feet thick and rest for the most part upon slate, in bluffs that rise nearly 50 feet above the river. At Emerald Bar the gravel beds are nearly 130 feet above the river and rest upon granite rock.

Most of the mining has been done at Spokane and Eldorado bars. The former locality is near the center of the sapphire deposits and on the west side of the river about 16 miles due east of Helena. In 1895 these beds of gravel, which are 8 to 18 feet thick, were extensively mined by an English company known as the Montana Sapphire and Ruby Company. The gravels were washed by hydraulic methods and a great many gems were obtained, most of which were sent to England. This company also controlled or owned French Bar and Dana Bar on the west side of the river and Eldorado Bar on the east side. It was reorganized in 1897 as an American company, known as the Eldorado Gold and Gem Company, with A. N. Spratt, of Oakland, Cal., president, and Frank Spratt, of Helena, Mont., manager. No

[a] Mineral. Mag., vol. 9, 1891, No. 44, p. 396.

work has been done at any of the bars by the present company. This bar is shown in fig. 15, the bluff rising from the river being 30 to 50 feet high.

Directly across the river from Spokane Bar, but about three-fourths of a mile from the river, is Metropolitan Bar, which was worked during the summer of 1899 by different men who had staked out individual claims. The gravels are from 6 to 20 feet thick, and are washed in hand rockers, the water being obtained from shallow wells. Several of the claims were owned by Robbin Bird, Charles Johnson, and John Durrant, of Helena, Mont.

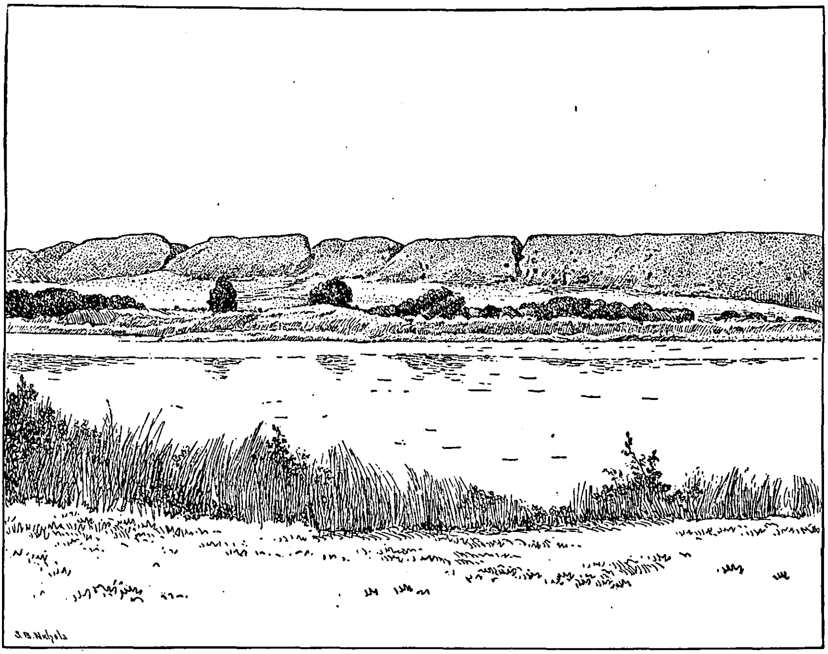


FIG. 15.—Spokane Bar sapphire deposits, Lewis and Clark County, Mont.

Above Spokane Bar, at French Bar, Cheyenne Bar, and Emerald Bar, no regular mining has been done during the last few years, but frequently different persons have worked in the old drifts for a few days at a time, washing by hand the gravel obtained.

A large part of the work done at Emerald Bar has been under ground, by means of shaft and drifts. Henry Crittenden, of Canyon Ferry, has done a large part of the work here, and still controls the deposits.

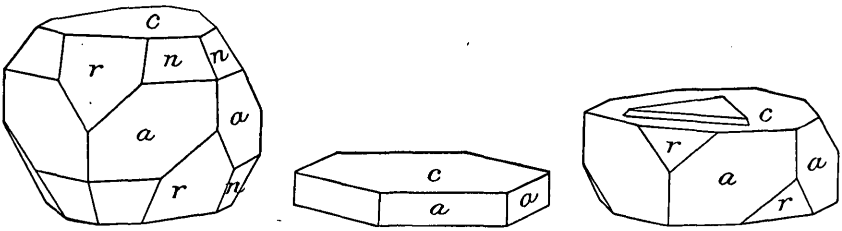
Below Spokane Bar, at Dana Bar, Eldorado Bar, and American Bar, there has been no mining for sapphires for a number of years.

As mining investments these sapphire deposits have not thus far been financially successful, partly on account of the heavy capitalization of the companies which have bought the mines and partly on account of the color of the stones. They are, for the most part, of a pale-greenish or greenish-yellow color, and do not command a very high price in the market. Occasionally pink and yellow ones have been found that have cut good gems. Stones approaching a red or blue color are, however, extremely rare.

There are still a great many sapphires in the gravels that have not been worked, but on account of their color it is rather doubtful whether under the most favorable conditions it will pay to mine them.

The crystals from all these bars show the same development, and are prismatic in habit. The prism, *a* ($11\bar{2}0$), is always present, and is usually in combination with the base, *c* (0001), and the unit rhombohedron, *r* ($10\bar{1}1$), as represented in fig. 16, *A*. Some of the crystals have the prism very short and the rhombohedron is wanting, giving the crystal a very tabular appearance (fig. 16, *B*). A pyramid of the second order, *n* ($22\bar{4}3$), was observed on some of the crystals in addition to the base and unit rhombohedron, and is represented in fig. 16, *C*.

The crystals are usually rough and more or less striated, so that no measurement could be made upon the reflecting goniometer, but suf-



A. *B.* *C.*

FIG. 16.—Sapphire crystals from Missouri River bars, Montana.

ficiently accurate measurements could be obtained with the contact goniometer to identify the faces.

The largest crystal that has been observed from any of these bars was one from Eldorado Bar that was nearly an inch long and three-eighths of an inch in diameter.

A repeated growth was observed on some of these crystals, but not in the variety of forms seen in the Cowee rubies (p. 101) and the Yogo Gulch sapphires (p. 113). Only one form of growth was observed, represented in fig. 16, *A*, which is a combination of the unit rhombohedron and the base.

Since the discovery and mining of sapphires from the Missouri River bars sapphires have been found at three other localities in Montana—at Rock Creek, Granite County; at Cottonwood Creek, Deerlodge County, and at Yogo Gulch, Fergus County.

The first two localities are about 80 and 30 miles, respectively, southwest of those on the Missouri River, and the last one is about 80 miles to the northeast. From these sapphire deposits stones of deeper colors have been obtained. Those from the first two are of all colors from blue to red, and those from the last are all blue.

ROCK CREEK.

For information concerning the sapphire deposits of Rock Creek I am indebted to Mr. William Knuth, of Helena. All the sapphires that have thus far been found in this section are in the gravel deposits on the West Fork of Rock or Stony Creek, in the southern part of Granite County, about 25 miles southwest of Philipsburg, the county seat, and 30 miles nearly west of Anaconda, Deerlodge County. (Pl. VI.)

The sapphires are found in a rather limited area, which is bounded roughly by the gravels of Cold Creek, Myers Creek, tributaries of the West Fork of Rock Creek, and that portion of Rock Creek lying between them.

These gravels were extensively worked during the summers of 1899 and 1900, principally by Messrs. William Knuth, of Helena, and William Moffitt, of Philipsburg. Altogether about 400,000 carats of rough sapphires were obtained. Of these about 25,000 carats are fit for cutting. In color they are much more varied than those from the Missouri River bars, and the prevailing color, which is greenish to bluish green, is deeper. No deep-blue sapphires like the oriental stones have been found, but paler blue ones have been obtained, from which very handsome sapphires 2 or 3 carats in weight have been cut. Some of the finest yellow sapphires (oriental topaz) that I have ever seen have been found at Rock Creek. One of these weighed nearly 2 carats when cut. Pale green and bluish green are among the common stones, some cutting gems of 5 to 8 carats in weight. A number of beautiful pink sapphires have also been found.

Few red and ruby-colored crystals have been found, and none that would cut a gem over a twelfth of a carat in weight. These colors are extremely rare in the Montana sapphire deposits.

The crystals and fragments of sapphires that are found in these gravels do not show as much abrasion as those from the Missouri River, probably because they have been carried a shorter distance from where they originated.

In habit the crystals are very similar to those already described from the Missouri River, and fig. 16 will also illustrate very well the character of the Rock Creek crystals. One type that is very noticeable is a short prismatic crystal whose diameter nearly equals its length. A parallel growth on the basal plane is only occasionally observed, and is composed of the basal plane and unit rhombohedron.

No sapphires have as yet been found in place, but a few have been found in the gravels that were embedded in the original matrix. Mr. Knuth, to whom I showed a specimen of the andesite containing sapphires from French Bar, said that it very closely resembled the small fragments of rock carrying sapphires that he had found at Rock Creek. It is not at all improbable that these sapphires originated in the same type of rock as those of the Missouri River and that small dikes of andesite will be found in the divide between Myers, Cold, and Quartz creeks. A very few sapphires have been found on Quartz Creek.

Although the sapphire gems from Rock Creek do not command so high a price as the ruby and the deep-blue sapphires, and are regarded more as fancy stones, they are coming to be quite highly prized by many who are acquainted with them. As yet but few of the Rock Creek sapphires have been put on the market except locally at Helena.

COTTONWOOD CREEK.

The sapphire deposits on Cottonwood Creek are in Powell County, about 30 miles southwest of Helena and 10 miles east of Deerlodge, the county seat. There has not been a great deal of work done on this creek, so that the extent of the sapphire-bearing gravels is not known. The sapphires are similar in character to those of Rock Creek, but they are apt to be of lighter color and not of such a variety of colors. Not sufficient work has been done at this locality to determine the importance of the deposits.

YOGO GULCH.

The sapphires that are the most widely known and that have attracted the most attention have been obtained in Fergus County, near the entrance of Yogo Gulch, on the Yogo Fork of Judith River. This locality is on the eastern slope of Prospect Ridge of the Little Belt Mountains, about 75 miles northeast of Helena and 15 miles a little south of west of Utica, which is the nearest town, and which is on the Judith stage line. The sapphires were first found in the gravels of Yogo Fork, and in following these up the creek their original source was located in dikes that extend across the country for a mile and a half.[a] The location of these deposits is shown in fig. 17.

In Pl. VII, *A*, is shown the appearance of the country in which these mines are located. In the foreground is one of the shafts; it was started in 1897.

There are two parallel dikes about 800 feet apart, with a general east-west trend, which vary in width from 15 to 75 feet. The mineralogical composition of the rock shows that it has a close affinity with minette and shonkinite, as described on page 47.

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[a] Weed, W. H., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1899, pp. 454–460.

The alluvial deposits below these dikes have been pretty thoroughly worked for the sapphires, and mining operations are now confined

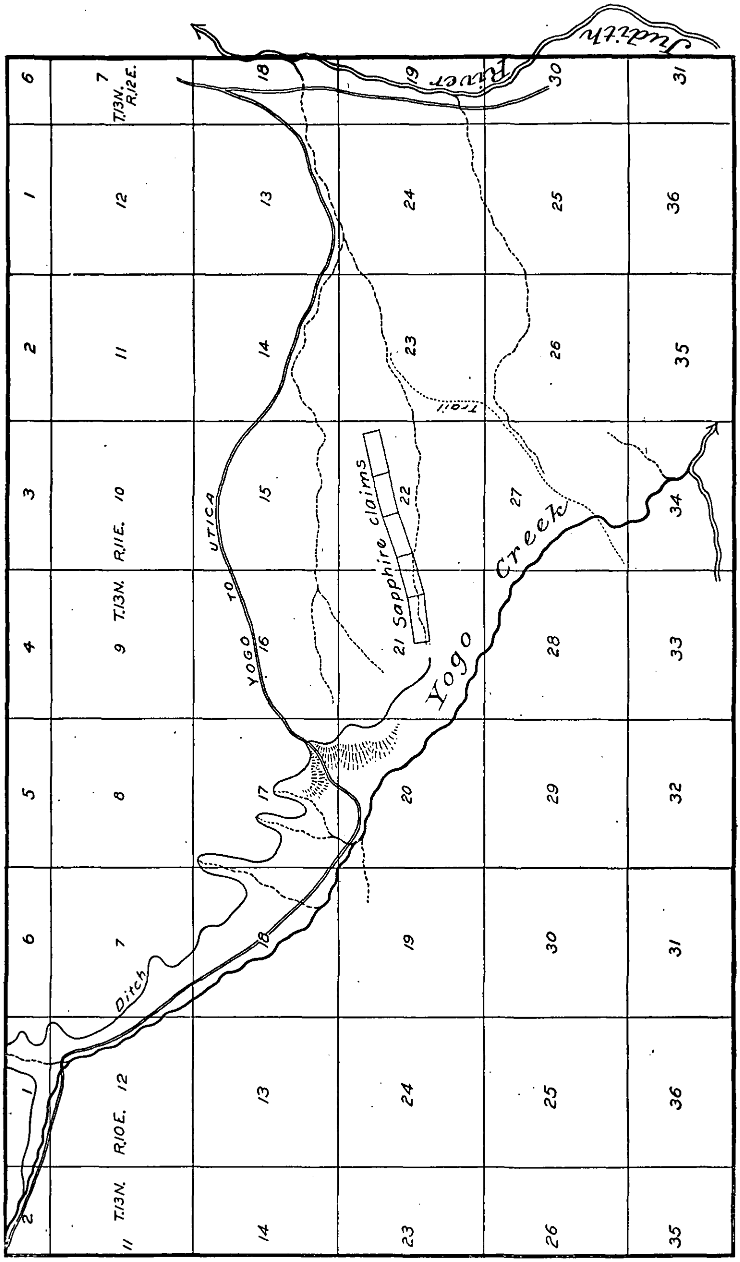
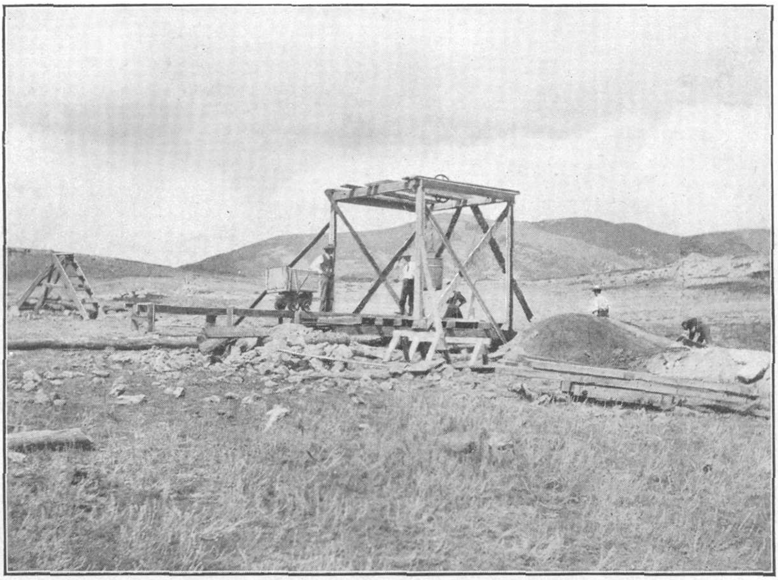
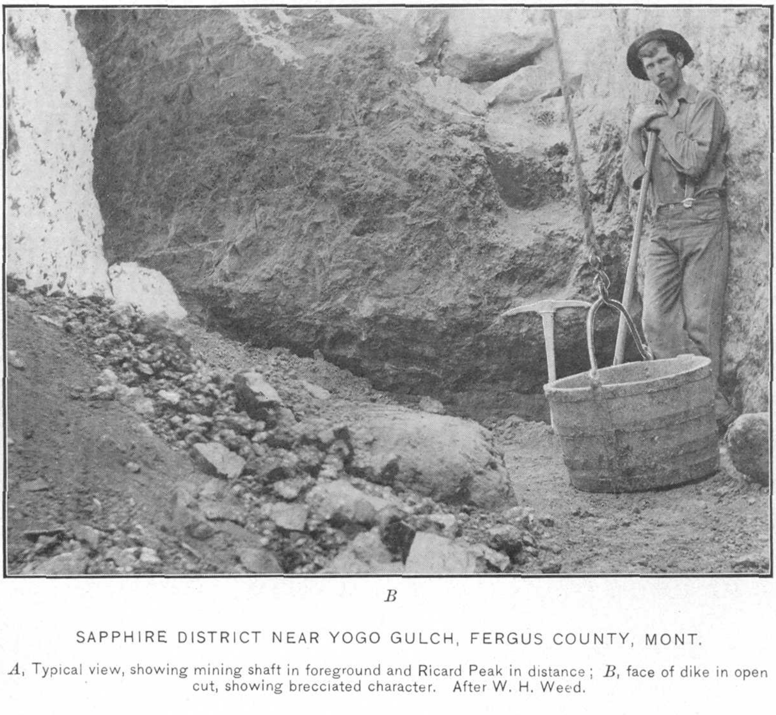


FIG. 17.—Map showing location of sapphire mines, Yogo district, Montana (after W. H. Weed).

almost entirely to the dikes themselves. These dikes, the upper portion of which is thoroughly decomposed, have been worked by means



A



B

SAPPHIRE DISTRICT NEAR YOGO GULCH, FERGUS COUNTY, MONT.

A, Typical view, showing mining shaft in foreground and Ricard Peak in distance; *B*, face of dike in open cut, showing brecciated character. After W. H. Weed.

of shafts and open cuts, the limestone making fairly firm walls. By hydraulic processes the decomposed rock was readily broken up and washed into sluice boxes. As the mining extended deeper the rock was much less altered, and it was necessary to leave a great deal of it exposed to the atmosphere from one season to the next before it could be broken up and run through the sluice boxes. At a number of points the almost perfectly fresh rock has been encountered, and from this it will be a difficult problem to separate the sapphires. The percentage of sapphires in the rock is small, and if it were the unaltered rock that had to be worked for them the deposit would not be of economic importance. This dike as exposed in the main workings of the mine is illustrated in Pl. VII, *B*, which shows the brecciated character of the dike, as described.

The sapphires occur embedded in this rock in distinct crystals from less than a millimeter in diameter to some that were over 15 mm. Their color, as far as I have observed them, is always a blue, varying from light blue to a very few that showed the dark blue of the Ceylon stone. The prevailing color is a bright blue.[a]

Although the color of these sapphires is not as dark as the highly prized Ceylon and Siam stones, they show a richness and brilliancy not equaled by the oriental stone. They not only show a strong, rich color by transmitted light, but their color is almost as good by reflected light. Then, again, although many blue sapphires make beautiful day stones, but are dull at night, the Yogo sapphire is very brilliant at night as well as in the day.

The crystallography of these sapphires is markedly different from that of the sapphires of the Missouri River and Rock Creek (p. 109). The latter all show a prismatic development, while the former are all rhombohedral crystals, none of which show the presence of any prism face.[b]

The crystals are etched and striated to such a degree that no crystallographic measurements on the reflecting goniometer were possible; but sufficiently accurate angles were obtained with the contact goniometer to permit the identification of the faces. The only two faces that could be identified were the base c (0001) and the rhombohedron x $(30\bar{3}2)$, which is a new face for corundum. On one crystal two very small faces were observed, which were too small to be measured with the contact goniometer, but were probably the faces of a pyramid of the second order.

In determining the rhombohedron, ten or more independent measurements were made of $c \wedge x$. These varied from 66° to 68°, but

[a] Kunz, G. F., Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 420.
[b] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 424.

approximated closely to 67°, which agrees very well with the calculated value, 67° 3′, for 0001>30$\bar{3}$2. These crystals are represented on Pl. VIII.

The crystals are developed as shown in figs. 1, 2, and 3, of Pl. VIII, the prevailing type being like fig. 3 of Pl. VIII. The crystals vary from those where the base is very largely developed, having a diameter of 8 mm., while the rhombohedron is only 1 mm., to those that have the base and the rhombohedron equally developed (fig. 1 of Pl. VIII). Where the faces are more equally developed, the rhombohedral faces are generally rounded.

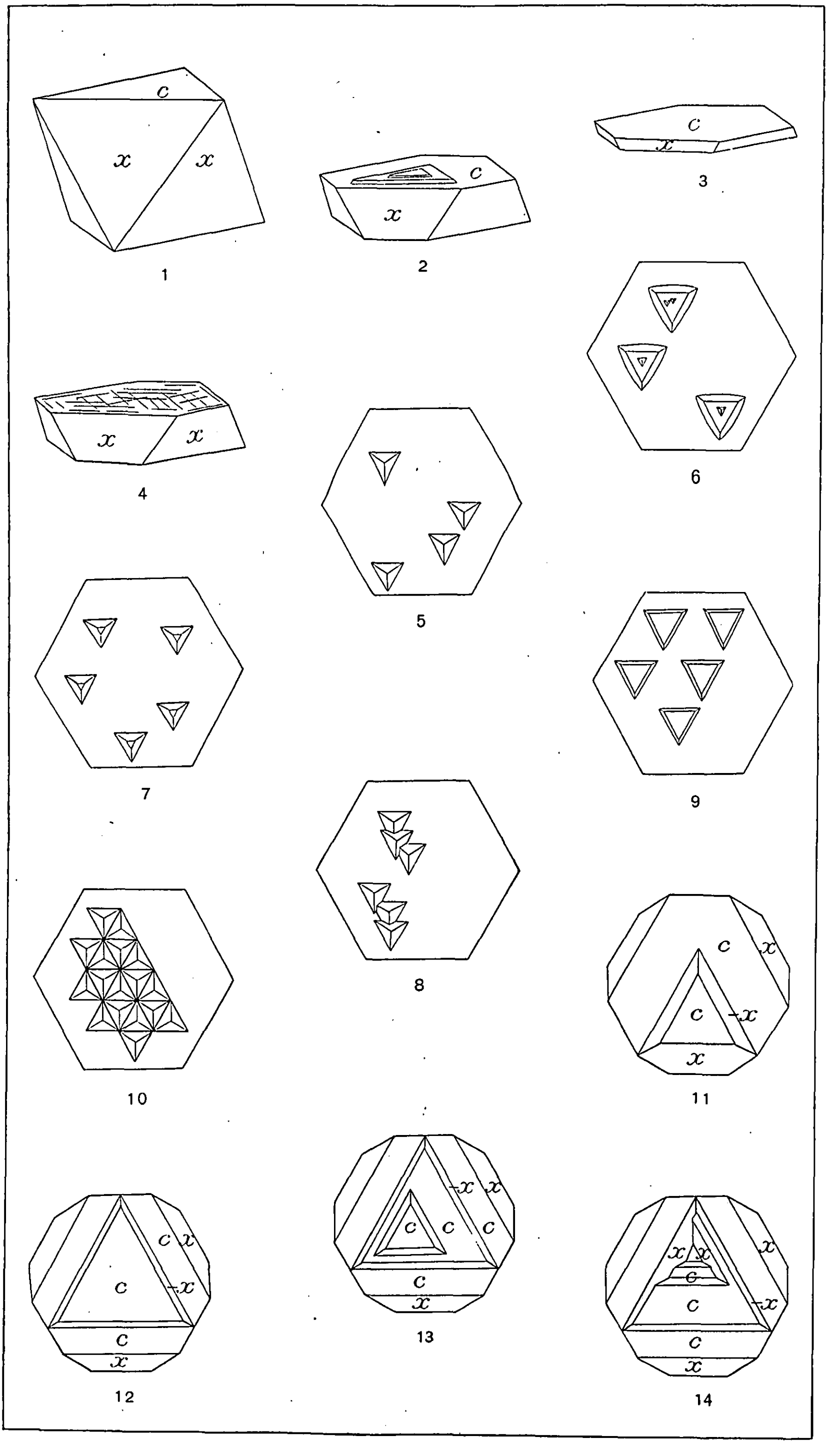
The basal plane often shows characteristic striations which are parallel to the three intersections of the base c and the rhombohedron x, as shown in fig. 4 of Pl. VIII. These lines are sharp and distinct, and on the very flat crystals can easily be measured when examined under the microscope. The rhombohedral faces are very roughly striated without showing any distinct parallel lines.

One very common development of these crystals is a repeated growth on the basal plane of the rhombohedron x (30$\bar{3}$2) and the base c (0001), as represented in fig. 2 of Pl. VIII. These growths are exceedingly varied, as shown in figs. 11–14 of Pl. VIII, where they are drawn in basal projection. In fig. 11 of Pl. VIII there is but one secondary rhombohedron and base, which has one of its rhombohedral faces a continuation of one of the rhombohedral faces of the crystal. Fig. 12 of Pl. VIII represents a repeated growth, each face of which is entirely distinct from the faces of the main crystal. In fig. 13 of Pl. VIII there are represented two, and in fig. 14 of Pl. VIII a series of such growths, where a number of the rhombohedral faces coincide. These growths occur most frequently on the flat crystals. The thickness of the rhombohedrons rarely reaches 1 mm., and often they are so thin that they appear like striations.

This repeated growth is very similar to that described as occurring on the Cowee rubies (p. 103). Bauer,[a] in an article entitled "Ueber das Vorkommen der Rubine in Birma," has described this same style of development as occurring on the Burma rubies, but it is not so general as on the Montana corundums.

Etching figures.[b]—The etching figures which were observed on nearly all the crystals examined were on the basal plane. The figures are very perfect, and although showing many different forms, they all have a rhombohedral symmetry. Fig. 5 of Pl. VIII represents the common etching figure, which is a rhombohedral depression terminating in a point. The edges of the depression are sharp and

[a] Neues Jahrbuch für Mineral., Geol. und Pal., vol. 11, 1896, p. 209.
[b] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 426.



SAPPHIRE CRYSTALS FROM YOGO GULCH, FERGUS COUNTY, MONT.

well defined, as are also the intersections of the rhombohedral faces of the depression. These rhombohedral faces were smooth and gave fair reflections of the signal on the reflecting goniometer. In measuring them the entire crystal except the depression to be measured was covered with a thin coating of wax. Two different crystals were measured, which gave for rhombohedron on rhombohedron 22° 30′; this corresponds to the rhombohedron $10\bar{1}7$, for which the calculated value is 21° 50′. Figures of the same style were observed whose edges were parallel to those of the negative rhombohedron; these, however, are not common in isolated forms.

Another common form is represented in figs. 7 and 9 of Pl. VIII, where the depression is bounded by the basal plane, which at times is so large that the rhombohedral plane is hardly visible. Fig. 6 of Pl. VIII represents etching figures, where, on the basal plane of a shallow depression, there is one additional etching figure and sometimes two. These second etching figures are like the common ones shown in fig. 5 of Pl. VIII. The outer rhombohedral contour of these figures is generally rounded. This is also usually the case with the deeper depressions.

Often the etching figures are intergrown (fig. 8 of Pl. VIII), and when many of these occur together they have the appearance of raised figures rather than of depressions. This raised appearance is very striking when there is a combination of the plus and minus rhombohedron in parallel position and without overlapping (fig. 10 of Pl. VIII).

The figures vary considerably in size, but most of them are about 1 mm. in diameter. A few were observed that were nearly 2 mm. in diameter.

Bauer[a] has described etching figures that he observed on the base 0001 and the pyramid $22\bar{4}3$ of the Burma rubies. Those on the base are similar to the figures in fig. 5 of Pl. VIII, except that the outside contour of the rhombohedron is rounded.

The largest rough stones that have been found weighed 11 to 12 carats, and from these were cut gems weighing 5 to 6 carats. One of the better stones taken out during the season of 1899 weighed 4 carats when cut and is valued at over $75 a carat. All of the material is shipped to London.

The two companies operating these sapphire deposits are the New Sapphire Mines Syndicate and The American Gem Company.

That the American gems are appreciated is shown by the large orders that are received for them from Paris, London, and New York.

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[a] Loc. cit., p. 213.

NORRIS.

Near Norris, Madison County, Mont., Mr. A. W. Tanner reports the finding of considerable corundum of gem quality in his concentrates from gold-placer mining. One piece of corundum showing good red and green colors weighed 8 ounces, and one piece of ruby corundum weighed 588½ carats.

IDAHO.

Semitransparent to translucent corundum of various shades of blue and green has been found in many of the gravel deposits in the vicinity of Pierce, Shoshone County, Idaho, especially those on Rhodes and Orofino creeks. Associated with the corundum are rutile, menaccanite, and garnet. This corundum was discovered by Mr. Victor C. Heikes in connection with the black-sand investigations at Portland, Oreg.

CORUNDUM.

Under this head are included all the translucent to opaque varieties of all colors, subdivided into block, crystal, and sand corundum. A sharp line can be drawn between corundum and emery, but no such distinction can be made between corundum and sapphire; for many pieces of corundum are found that have transparent portions, and many sapphire gems have been found in masses of corundum that were being mined for abrasive purposes.

In the following descriptions corundum deposits have been taken up by States, approximately in the order of importance. Many of the localities are briefly noticed, but the larger and more important deposits are described in detail.

NORTH CAROLINA.

This State presents the greatest development both of peridotite and corundum. The peridotite belt here attains its greatest width, and the largest outcrops of chrysolitic rocks in the Atlantic States are found in its southwestern counties. As indicated on the map (Pl. XV), corundum occurs in Clay, Macon, Jackson, Haywood, Transylvania, Buncombe, Madison, Yancey, and Mitchell counties along the belt of basic magnesian rocks; and it is found east of the Blue Ridge in the counties of Cleveland, Burke, Gaston, Alexander, Iredell, and Guilford, these localities east of the Blue Ridge, however, not appearing on the map. In the following descriptions only those deposits have been considered which have been mined for corundum or which hold out a promising prospect for the mineral. These will be taken up by counties, beginning with the more important ones.

GENERAL VIEW OF THE PERIDOTITE FORMATION AT CORUNDUM HILL, MACON COUNTY, N. C.

MACON COUNTY.

Corundum Hill mine.—Corundum was first discovered in Macon County in 1870 at what is known as the Corundum Hill mine, and mining was begun here about a year later. This mine has become one of the most important corundum deposits in this country. It is situated about 8 miles southeast of Franklin, the county seat, on the northeast side of Cullasagee Creek, a tributary of the Little Tennessee River.

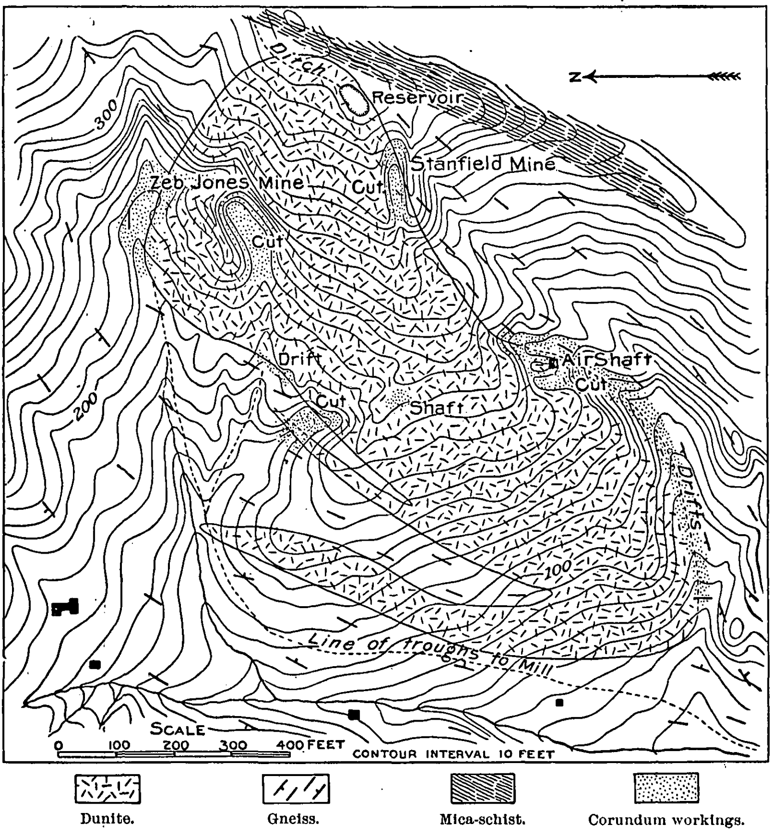


FIG. 18.—Map of the peridotite formation at Corundum Hill, Macon County, N. C.

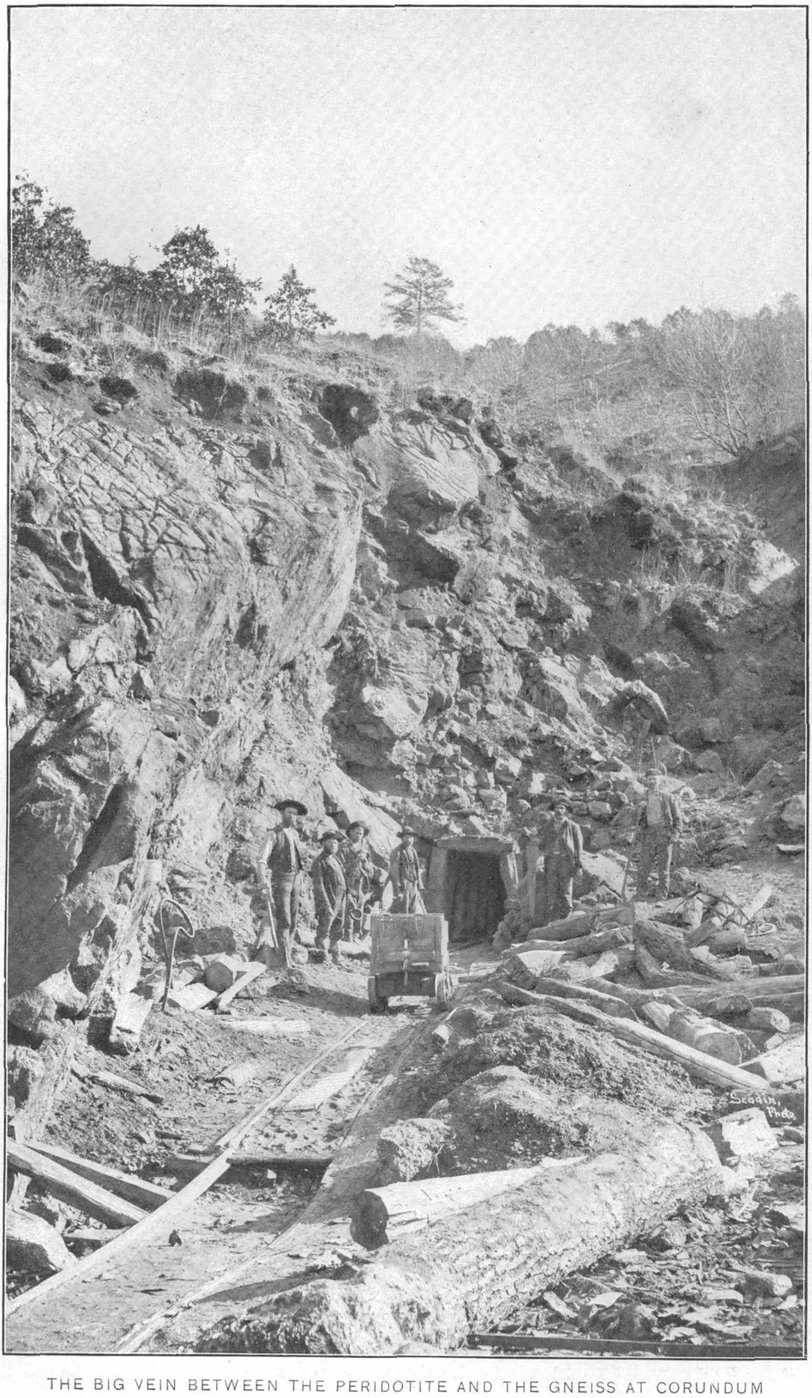
The corundum found at this mine occurs in peridotite rock, which has been worked very extensively, especially near the contact of this rock with gneiss. Pl. IX gives a general view of this peridotite formation, and shows to a certain extent the number of openings that have been made in it. The hill is about 350 feet high, the summit being about 500 feet above the level of Cullasagee Creek. Fig. 18 is a topographic map of this same peridotite formation, and shows the location of the various mines. The formation is a rather blunt lens-shaped mass of the dunite variety of peridotite, and has about 10 acres of surface, over most of which the rock is exposed. As is seen from this map, most of the mines are located near the contact of the dunite with the gneiss or schist, and follow contact veins of corundum. A number of interior veins have been worked within the formation, but, with the exception of the one marked "Shaft" on the map, they have all soon pinched out.

Most of the mining has been done on the south side of the formation, where was encountered what is known as the Big vein. This was first mined by means of open cuts and later by tunnels, the last one being about 300 feet below the summit of the hill. Pl. X is a view of the entrance to this tunnel, and shows the peridotite rock on the left and the gneiss on the right beyond the cut. For nearly the whole distance of the southern boundary of the dunite formation a cut has been made following the contour of the hill. This cut was sometimes wholly within the gneiss, at other times wholly within the peridotite, and again cutting directly on the contact. The tunnels are all to the left of the cut, and they have encountered corundum almost continuously for a distance of 1,280 feet, reaching nearly to the southeast boundary of the formation. Pl. XI is a view of the upper or southeastern end of this cut, showing the peridotite on the left and the gneiss and schist on the right. The upper part of this cut is known as the Stanfield mine. A tunnel has been run into the hill near the contact, at the head of which the vein of corundum is 8 to 10 feet wide. No work has been done at this mine for a number of years.

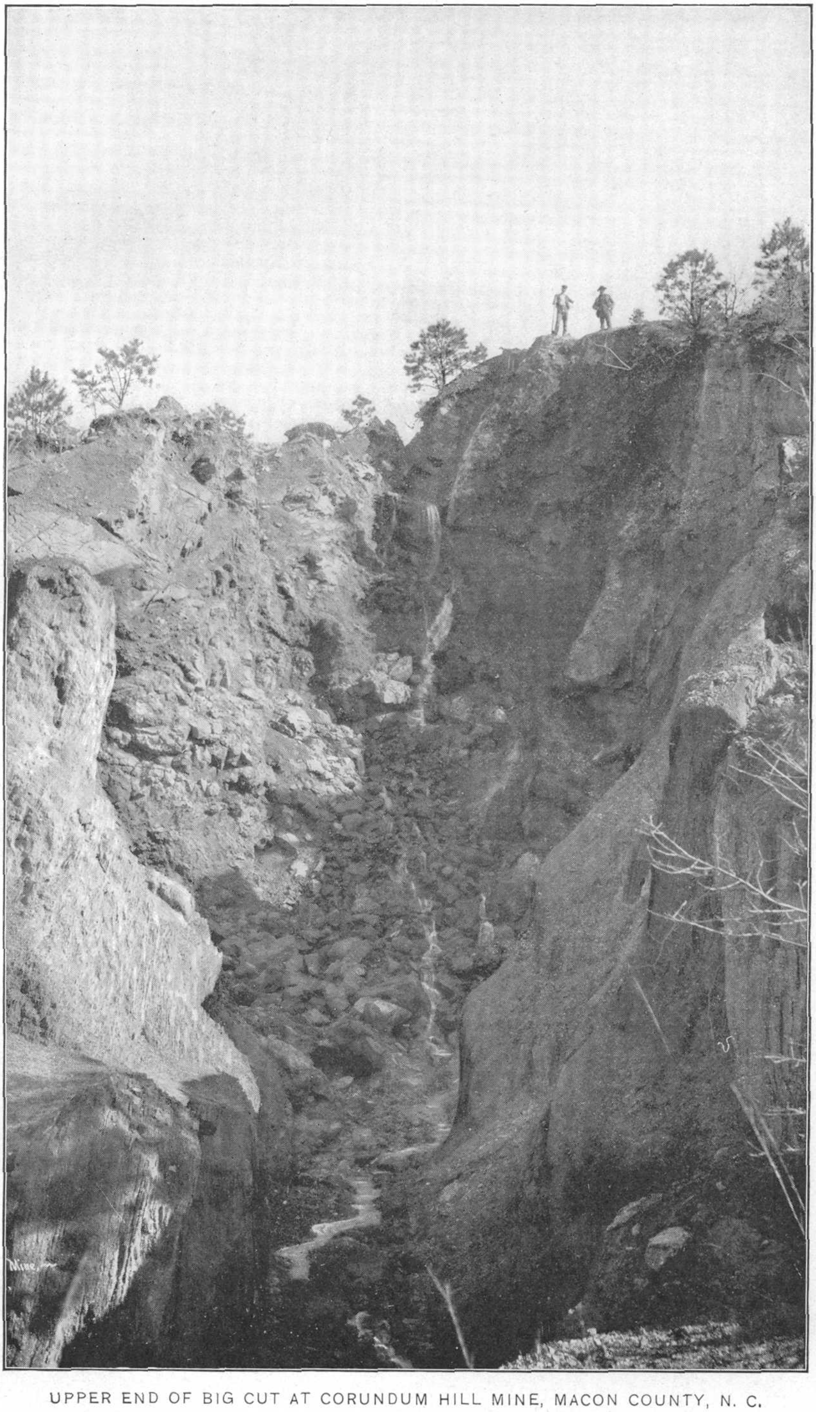
On the northeast side of this formation is what is known as the Zeb Jones mine, where there was exposed (July, 1899) a bench of ore 25 feet in depth and 2 to 5 feet in width, uncovered for a distance of 50 feet, which averaged very close to 50 per cent corundum. This vein carries what is known as "buckwheat" corundum, which, as its name suggests, is made up of small, irregular particles of corundum about the size of buckwheat grains.

Numerous interior veins have been found and worked, but they can be mined profitably only when they are worked in conjunction with large border veins, for the reason that they are very likely to pinch out after being worked for a short time.

From these various openings, collectively known as the Corundum Hill mine, block, crystal, and sand corundum ores have been obtained, all of which can be readily cleaned to make a commercial product that can be used in the manufacture of any kind of corundum wheel. A small quantity of garnet is occasionally found associated with the corundum in the vein along the southern contact, but this portion of the ore can be readily eliminated by hand cobbing at the mine. This property is now owned by the International Corundum and Emery Company, of New York, N. Y.



THE BIG VEIN BETWEEN THE PERIDOTITE AND THE GNEISS AT CORUNDUM HILL, MACON COUNTY, N. C.



UPPER END OF BIG CUT AT CORUNDUM HILL MINE, MACON COUNTY, N. C.

Peridotite on left and gneiss and schist on right.

OPEN CUT ON INTERIOR VEIN AT THE MINCEY MINE, MACON COUNTY, N. C.

The water of Cullasagee Creek is utilized for the washing and cleaning machinery of the mill, which is located about a mile and a half below the mine, at Cullasagee. A line of sluice boxes connects the mine with the mill, and all the corundum ore that can be readily broken to pieces is carried down to the mill in these boxes.

There are many outcrops of peridotite on Ellijay Creek, a few miles north of Cullasagee, and at many of them corundum has been found. The most work that has been done is at the Mincey mine, which is 2 miles northwest of the Corundum Hill mine. At this locality a considerable quantity of corundum has been taken out, which was carried to the mill at Cullasagee and cleaned. Pl. XII is a view of this open cut, which was entirely within the formation. Judging by the quantity of corundum obtained and by that found near the contact of the peridotite with the gneiss, there are good indications of the existence of corundum in quantity along the contact. The corundum that was obtained at this mine was hauled by wagons to the Corundum Hill mine, where it was cleaned. This property is owned by the International Corundum and Emery Company, of New York, N. Y.

Between the Corundum Hill and Mincey mines there is a bold outcrop of peridotite on the Gray property, covering about the same surface as that at Corundum Hill. Although there has been no mining here, the little prospecting that has been done has shown corundum to be very thickly scattered along the lower borders of the formation, and many small pits that have been sunk within the formation have encountered corundum. This, in my opinion, is one of the most promising prospects for corundum in Macon County.

A great many of the peridotite formations along Ellijay Creek have been worked a little at different times, and these are mentioned in the lists of corundum localities (p. 147).

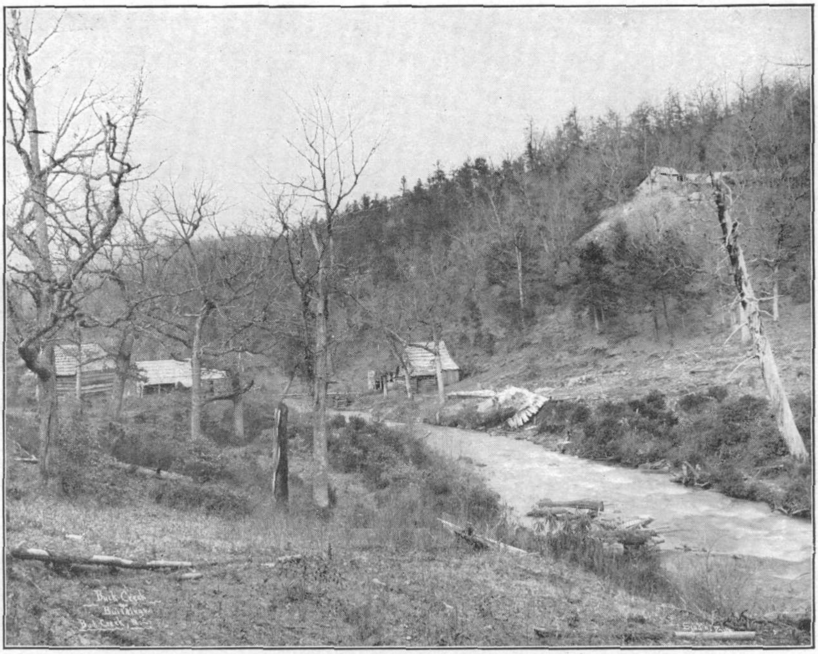
Sheffield mine.—This mine is in Cowee Township, about 7 miles northeast of Franklin, the county seat, just north of Cowee Creek. The corundum occurs here in amphibole-schist, and is described on pages 57–59. On account of the depth to which decomposition has extended, the solid rock was observed only in the lower portions of the 87-foot shaft, so that nothing definite is known of this corundum-bearing amphibole-schist. The corundum, which is pink in color and which occurs in oval-shaped nodules up to an inch in diameter, has been pretty thoroughly mined down to the hard rock. The corundum is of good quality, and some preliminary tests have shown that it is well adapted to the manufacture of the vitrified wheel. On account of the low percentage of corundum in the rock, it is not at the present time a profitable corundum ore.

The saprolitic ore is readily cleaned, and furnishes a nearly pure commercial product. A small mill has been erected here.

Reed or Watauga mine.—At this mine, which is 6½ miles east of Franklin on the Dillsboro road, just above Watauga Creek, corundum has been found in a dike of saprolitic rock that was very probably originally an amphibolite. The country rock is a hornblende-gneiss, but in the direct vicinity of the dike no solid rock is encountered. The general occurrence is somewhat similar to that at the Isbel mine, in Clay County, and at the Acme mine, in Iredell County. The corundum is in prismatic crystals from the size of buckwheat grains to some that were nearly half an inch in diameter. The crystals are of an almost uniform pale-bluish color and some are semitransparent to transparent. The ore was readily cleaned and furnished a nearly pure product. The mill at this mine had a capacity of 3 tons per day. As at all the localities where the occurrence is in an amphibolite, the quantity of the corundum is very limited. On the opposite side of Watauga Creek, 100 to 200 feet up the mountain slope, corundum has been found in a number of places in the gneiss. No work has been done at this mine since 1898.

CLAY COUNTY.

Buck Creek or Cullakeenee mine.—This mine is in the Buck Creek Valley, about 20 miles southwest of Franklin, Macon County, and 21 miles a little north of east of Hayesville, the county seat of Clay County. These corundum deposits are associated with a compact mass of peridotite, covering about three-quarters of a square mile, the largest mass that is known in the Appalachian belt. Fig. 9 (p. 36) is a topographic map of this formation, and shows the relation of the amphibolite to the peridotite and the location of the various openings that have been made for corundum. There has been but very little systematic mining for corundum in this locality, and most of the work has been in the nature of prospecting. Numerous cuts and pits have been made at a great many points on the formation, most of which have shown the presence of corundum. The principal work is at the east end of the formation, near the contact of the peridotite with the gneiss, where a shaft 40 feet deep was sunk partially on the border vein. A number of open cuts in this same vicinity have penetrated into the same vein. This vein is different from most of the corundum veins in the peridotite rocks, in that it is composed essentially of plagioclase feldspar and hornblende, which bear a similar relation to each other as the feldspar, quartz, and mica in the pegmatitic dikes. Pl. XIII, *A*, is a general view of the Buck Creek formation, showing the shaft mine and the location of the border vein that has been opened. With this exception all the pits and cuts that have been made are within the forma-



A. GENERAL VIEW OF THE BUCK CREEK CORUNDUM MINE AND OF THE PERIDOTITE FORMATION, CLAY COUNTY, N. C.

B. INTERIOR VEIN OF CORUNDUM IN THE PERIDOTITE FORMATION AT BUCK CREEK, CLAY COUNTY, N. C.

tion itself, and where they encountered corundum it was in small pockets, the remains of larger interior veins. Pl. XIII, *B*, shows one of these interior veins. From the quantity of corundum exposed by prospecting and the work done in the shaft, there is without doubt a large quantity of corundum associated with these peridotite rocks, and if the mine were more accessible to the railroad it would offer one of the best corundum properties in the State. The nearest point on the Murphy branch of the Southern Railway is 18 miles, over a good road. Buck Creek offers ample water supply for running a mill sufficient to clean whatever corundum would be mined here. This property is also owned by the International Corundum and Emery Company, of New York. The ore is not difficult to clean, and, as far as can be judged from a superficial examination, should make a commercial product that can be used in the manufacture of the vitrified wheel.

In the green amphibolites lying between the peridotite and the gneiss and penetrating into the peridotite, corundum of a delicate pink to ruby-red color is found quite abundantly. At the top of the ridge on the west side of the creek several tons were mined. On account of the refractoriness of the amphibolite it is not a profitable ore to work.

Herbert mine.—Near the northwestern end of this peridotite mass, which extends out from the main mass, is the Herbert mine, which is owned by the North Carolina Corundum Company and is indicated on the map, page 36. The corundum has been found in a number of veins containing seams from 3 to 6 inches wide of almost massive corundum. As the main portion of the peridotite mass is farther to the east, the largest deposits of corundum will undoubtedly be associated with this main mass of the peridotite, but there is evidence from the work done by this company that there is a commercial deposit of this mineral at the Herbert mine. Pl. XIV gives a view of the main workings of this mine. The North Carolina Corundum Company has erected a complete mill for cleaning and preparing the corundum for market. This company has also constructed a graded road 18 miles in length from the mine to the railroad. A mass of solid yellow corundum weighing 125 pounds was found near this locality on the property of Mr. Hugh Ferguson, of Pittsburg, Pa.

Isbel mine.—This mine is at the foot of the southern slopes of the Chunky Gal Mountain, and was formerly known as the Shooting Creek mine. It is on the headwaters of Shooting Creek and along the side of the Macon-Clay county road. The corundum occurs in an amphibolite dike, which is so badly decomposed that very little of it remains, except as included masses of the original rock. The surrounding rock is also very badly decomposed. The tenacious character of the material inclosing the corundum renders washing it out difficult, for it becomes packed and clogs the rolls even in a strong current of water. This deposit of corundum has been developed by means of a large open cut and some tunneling, but the amount of corundum ore exposed is not encouraging, and there is no evidence whatever of a commercial deposit of corundum being developed. A very extensive plant has been built at the mine by the Isbel Corundum Company, of New York, and it is the largest and the best equipped corundum mill in the State.

Behr mine.—This mine is located 5 miles east of Hayesville, at Elf post-office, on Shooting Creek. Both sand and massive corundum, with feldspar, are found at this mine, in the same peridotite formation with which the amphibolites just referred to are associated. It was first opened in 1880 by Dr. H. S. Lucas, but was soon afterwards bought by Herman Behr & Co., of New York. A steam cleaning plant was erected at the mine and considerable work, more of the nature of prospecting than mining, was done. Several carloads of cleaned corundum are reported to have been shipped. The last work done at the mine was in 1890. The location of the mine was not very favorable for work, as it was in a low place by the side of a stream, which necessitated the constant use of pumps. The nearest shipping point on the railroad is 25 miles. There are practically no indications at this locality of the occurrence of corundum in quantity.

Blue Ridge corundum tracts.—Under this head are included the long bands of corundum-bearing quartz-schist that have been found in the southeastern part of the county and in the adjoining county of Georgia, Rabun County. Parallel bands of this corundum-bearing schist have been followed for a number of miles close to the summit of the Chunky Gal and the Yellow mountains. As is stated on page 56, the amount of corundum in this schist is probably not over 2 to 3 per cent, and with such a low percentage of corundum these rocks are not to be considered, at the present time at least, as a source of this mineral. There are four tracts included under this head. The Scaly Mountain tract is near the headwaters of Beech Creek, a prominent eastern tributary of the Tallulah River, on the southern and southwestern slopes of Scaly Mountain, at the elevation of about 4,500 feet. The corundum-bearing bands of schist have been traced for the distance of about 2 miles, with a general strike of N. 40° E. and with a dip approximately 20°–30° NW. Considerable prospecting has been done in tracing this band of schist. Assays show that there is less than 5 per cent of corundum in this schist, although some specimens have yielded 12 per cent. The latter were probably pieces broken off along planes of lamination of the schist, while the rest of the piece from which they were broken off carried but little corundum.

CORUNDUM DEPOSIT OF HERBERT MINE, OF THE NORTH CAROLINA CORUNDUM COMPANY, BUCK CREEK, CLAY COUNTY, N. C.

The Foster tract is in Georgia, about 1¼ miles from Scaly Mountain, and the State line forms its northern boundary. It is on both sides of Falls Branch, one of the smaller western tributaries of the Tallulah River, and is about 3,500 feet above sea level. Here a number of pits have been made and samples of corundum have been obtained which have assayed on an average about 5 per cent of this mineral. There is more garnet associated with the corundum in this ore than in that from any of the other localities.

The Yellow Mountain tract is on the north of Scaly Mountain, on the northern slopes of the Yellow Mountain. No prospecting has been done here, and from the indications the ore is the same in grade as at the other localities.

The Chunky Gal tract is at the summit and along the western slopes of the Chunky Gal Mountain, near the headwaters of Sugar Cove Creek. With a few interruptions, the corundum-bearing schist has been traced for over 2 miles, with a strike and dip approximately the same as on the other tracts. A number of pits and cuts have been made, from which considerable ore has been taken out and tested, and the tests show the percentage of corundum to be practically the same as at the others.

The corundum bands of the schist in all the tracts vary considerably in width, some being not over a foot or two wide, while others are 18 feet. In these wider bands, however, there are apt to be bands of the normal schist. More or less garnet has been found associated with the corundum in all the schist, and if in any quantity it would have to be eliminated or it would prevent any corundum obtained from these ores being used in the manufacture of the vitrified wheel.

From the extent of the corundum-bearing schist, there is undoubtedly a large quantity of corundum in this section, but the low percentage makes it very questionable whether the rocks can be profitably worked.

One company, the Corundum Mining and Manufacturing Company, of Philadelphia, was organized in 1900 to work the Scaly Mountain and Foster deposits, and spent a great deal of money in developing the deposits and in erecting a crushing and cleaning plant. On account of the small percentage of corundum and because of the associated garnet the company could not produce the corundum profitably, and for the last two years there has been no work done on the property.

JACKSON COUNTY.

Perhaps the most important corundum locality in this county is in the extreme southeastern portion, in the vicinity of Sapphire, extending over into the adjoining county, Transylvania. In this section there is a series of about thirty outcrops of peridotite, which extend in a general northeast-southwest direction. All these outcrops are small, and corundum has been found associated with many of them. The location and relative size of the larger of these outcrops and the places where corundum has been mined are represented on the map, fig. 19. Most of this has been at the Bad Creek and Socrates mines, but the greater part of the work done at any of them has been in the nature of prospecting.

Burnt Rock mine.—At the Burnt Rock mine, which is located about 5 miles northeast of Sapphire, all the mining has been done

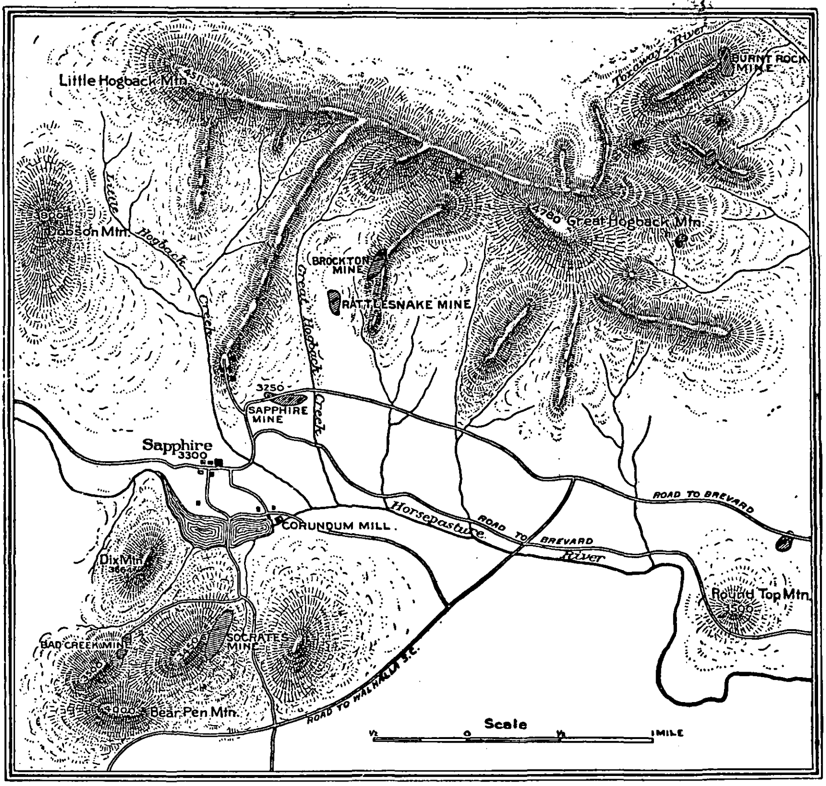


FIG. 19.—Map of the peridotite areas in the vicinity of Sapphire, Jackson County, N. C., showing the location of the different corundum mines.

within the peridotite formation, and about 10,000 to 12,000 pounds of corundum have been taken out. It is of good quality and occurs in white crystals and knotty nodules. The ore is free from garnet and can be readily cleaned. From the amount of work done here the indications are that there is a considerable quantity of good corundum associated with the peridotite near its contact with the gneiss. The mining at the Brockton mine was also within the peridotite, and about the same amount of corundum was taken out as at the Burnt Rock mine. The corundum occurs in dull-gray crystals, which are easily cleaned and separated from the gangue. These two mines are in Transylvania County. Just below this mine, on the slopes of Poplar Ridge, a vein of corundum was exposed in October, 1900, by workmen who were making a new road. The corundum is massive, and gives good indications of occurring in quantity.

Sapphire mine.—The little work that was done at the Sapphire mine shows a considerable quantity of white and gray corundum, often speckled with blue, very similar to the corundum found at the Whitewater mine, 6 miles south of the Sapphire mine. The Socrates mine is about three-quarters of a mile southwest of the Sapphire, in a bold outcrop of peridotite. The corundum is in small, knotty nodules, and is easily cleaned. A border vein was encountered, but little work was done to develop it.

Bad Creek mine.—The Bad Creek mine has been worked more than any other in this section, and is located about three-quarters of a mile nearly south of Sapphire. The work done at this mine has been almost entirely on a border vein which has been exposed for the distance of 130 feet and has been worked at one point to a depth of 60 feet. The corundum ore that was encountered in this vein is of two distinct kinds; in one the corundum is associated with garnet and hornblende, and in the other, which is free from garnet, it is found in a matrix of biotite-mica. These two ores should always be kept separate, for the corundum can readily be cleaned and separated from the associated minerals in the biotite ore and will yield a product that can be used in the manufacture of the vitrified wheel, but the corundum can be separated only with difficulty from the ore that contains the garnet. Unless the garnet can be entirely eliminated this ore will not make a product that can be used for making the vitrified wheel. The vein has an average width of nearly 9 feet, and will carry from 15 to 20 per cent of corundum. All the mines just referred to belong to the Toxaway Company, Sapphire, N. C.

Corundum has been found at a number of the peridotite outcrops between the Bad Creek and the Whitewater mines; and though this does not by any means indicate that there are large deposits of this mineral in these rocks, it does indicate, taking into consideration the corundum deposits already found northeast and southwest of them, that there is a possibility of such deposits, and it makes this section a promising one for systematic prospecting.

During the summer of 1903 considerable work was done at the Sapphire corundum localities by Mr. Walter G. Chandler, with a view of ascertaining whether or not there were commercial deposits of corundum at these various mines. His work, while it showed the presence of corundum at all the localities examined, did not develop any deposits in commercial quantity, with the exception of the Bad Creek mine. It is not improbable that in some instances the deposits developed by Mr. Chandler are interior veins and that the border vein was not encountered. In other cases it is very probable that the corundum exists in but very small quantity in the rock, and is not sufficient to make profitable mining.

MADISON COUNTY.

It is interesting to note here that the first corundum found in North Carolina was picked up in this county in 1847, about 3 miles below Marshall and just above the mouth of Little Pine Creek. It was a large mass of dark-blue, cleavable corundum, and was found on the surface. The next year a smaller piece was similarly found. A strip of peridotite crosses the river near this point, but, as far as is known, no corundum has been found with it.

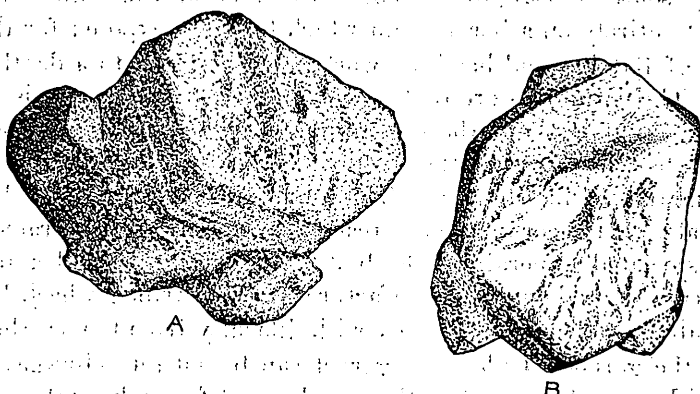
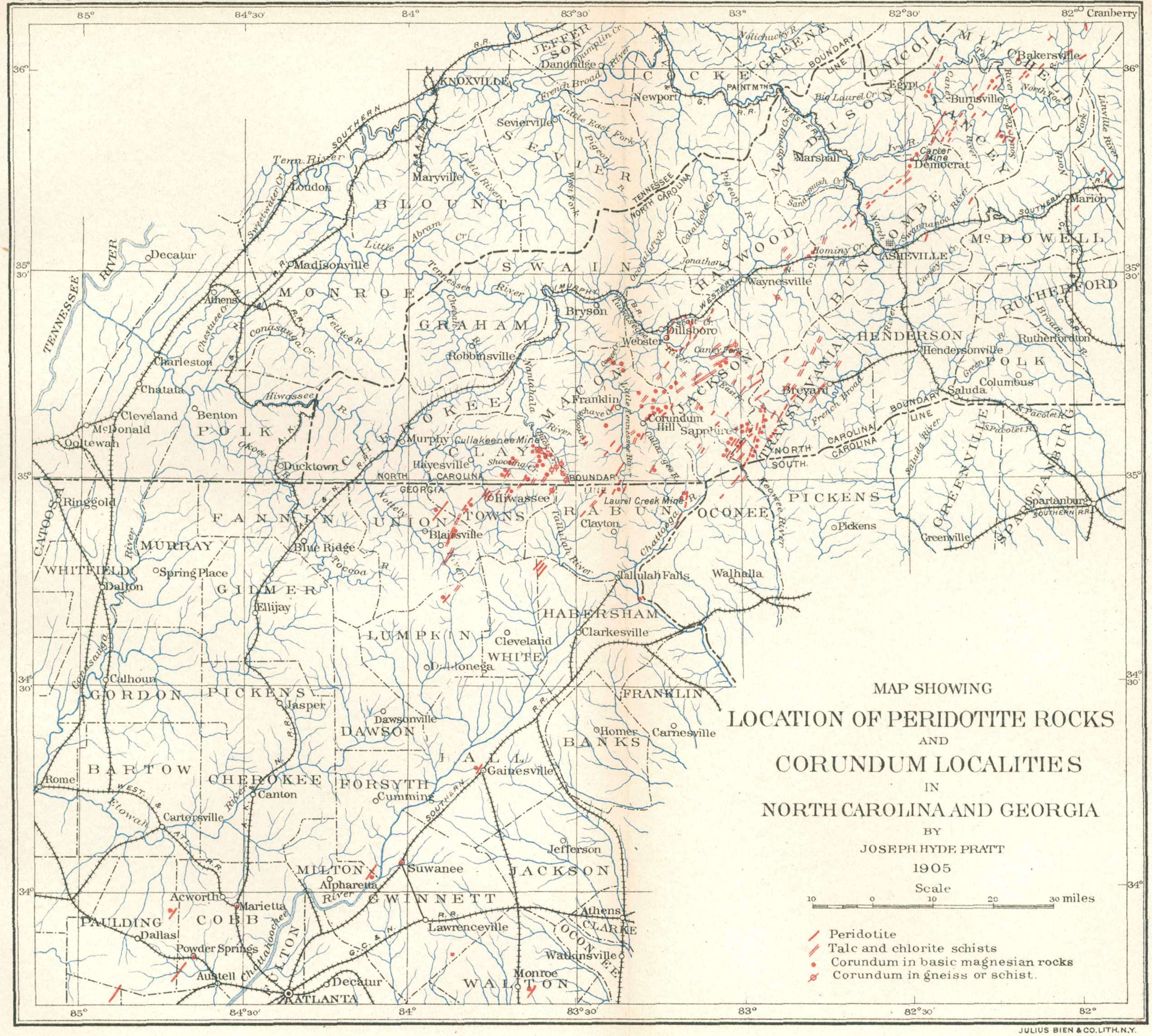


FIG. 20.—Corundum crystal from near Marshall, Madison County, N. C.

Corundum has been found in large gray crystals on the surface of a large outcrop of amphibolite, which is 3 miles above Marshall and half a mile north of the mouth of Big Ivy River. Mr. G. C. Haynie, of Marshall, the owner of the property, has in his possession a crystal from this place that weighs 17 pounds. (See fig. 20.)

Carter mine.—This mine is in the southeastern corner of the county, very close to the Buncombe County line. It is located on Holcombe Branch, a tributary of Little Ivy River, and near the northern end of a strip of peridotite, which extends from Morgan Hill, in Buncombe County, a distance of more than 2 miles, and which has an average width of about one-fourth of a mile. The corundum that has been mined was found in what is probably an interior vein, and was inclosed by chlorite and vermiculite. It was obtained in masses of white, pink, and blue colors, which were intimately associated with greenish-black spinel and feldspar. While there has been some



JULIUS BIEN & CO. LITH. N.Y.

mining done here, the deposit has not been thoroughly prospected, and future developments may show the existence of a large deposit of corundum near the contact of the peridotite with the gneiss.

There is no obvious reason why this ore could not be used in the manufacture of any kind of an abrasive wheel. Although the corundum can not be separated from the spinel, this should not interfere with its use for this purpose.

Corundum was first found at this mine by Dr. C. D. Smith about 1880, and soon afterwards work was begun by Mr. William Carter and Dr. H. S. Lucas, who took out a few tons in prospecting. Afterwards a little prospecting was done by Mr. M. E. Carter, and by Messrs. Rice and Coleman, who sold the property to Tarr, Hamilton & Co., of New York, who began regular mining about 1886. A steam crushing and cleaning plant was erected at the mine, and about 20 tons of corundum were cleaned and shipped from Marshall. Mining continued only about six months, and has not since been resumed.

The corundum localities of North Carolina and Georgia are indicated on the map (Pl. XV).

GEORGIA.

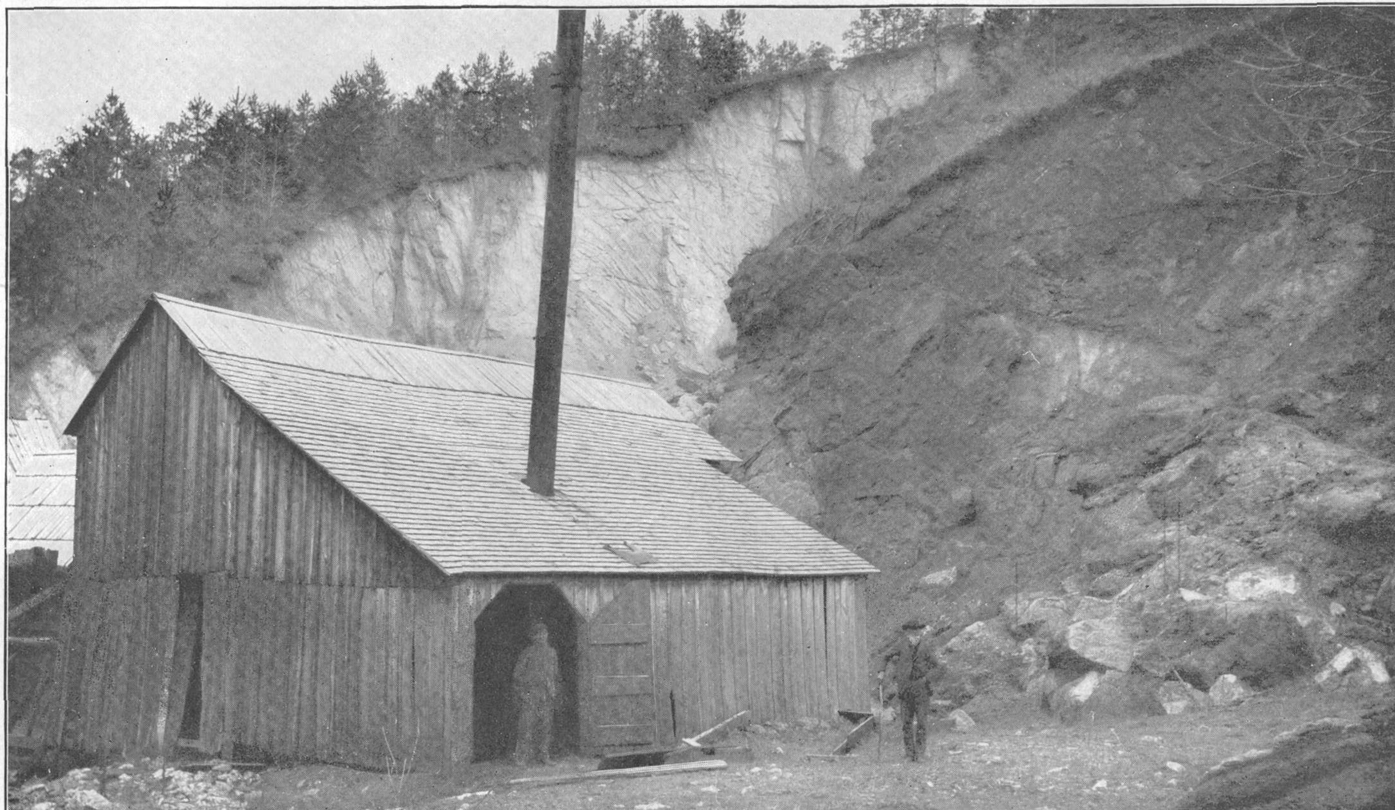
There are scattering deposits of peridotite extending across this State in a northeast direction, passing in a general way up the valley of the Chattahoochee River to the western extremities of North and South Carolina. Along this line corundum has been found in the following counties: Rabun, Towns, Union, Lumpkin, Habersham, Hall, Cobb, Paulding, Douglas, Carroll, Heard, Troup, and, somewhat off the line to the east, in Walton. In Forsyth County surface specimens have been found that evidently originated in the quartz-schists of the region. Surface specimens of corundum that originated in a mica-schist have been found in Upson County. Considerable work has been done along this belt in the nature of prospecting, and for a number of years a productive mine—the Laurel Creek—was operated at Pine Mountain, in Rabun County.

The corundum localities are shown on the map (Pl. XV), which also gives the general location of the peridotite formations that have been observed in this section. Although there is considerable peridotite occurring in the northern portion of the State, it is at but few places thus far that corundum has been found in any quantity, and these are at the extreme northern part, not far from the North Carolina line.

Georgia corundum is well known, and perhaps has the best reputation of any on account of that obtained from the Laurel Creek mine, which, with the exception of the Track Rock mine, is the only one that has produced any considerable quantity of corundum. The peridotite formations are not so large as in North Carolina, nor are the corundum localities so numerous, and it is not probable that there is as much corundum in this State as in North Carolina, although the Laurel Creek mine may be superior to any one thus far located in North Carolina.

Laurel Creek mine.—This mine, which is owned by the International Corundum and Emery Company, is located at Pine Mountain, Rabun County, and is 18 miles from Walhalla, S. C., the nearest point on the railroad at present, although a railroad now in construction from Tallulah Falls to Rabun Gap will pass within a few miles of this mine. At this locality there is a large outcrop of peridotite, covering several hundred acres, and along the contact of this with the gneiss large deposits of corundum have been found. Several openings have been made, some of which have been worked very extensively. Fig. 21 is a topographic map of this peridotite formation, showing the general location of the cuts and shafts that have been made. As is seen from the map, the formation extends over two small hills, which, on account of their rough and barren nature, offer a sharp contrast to the surrounding country. There is a large open cut (1 in fig. 21) on the west side of the formation, which follows for the most part along the contact; is 200 feet in depth at the lower end, and gradually rises until at the upper end the surface is reached. At its lower end this cut encountered what is known as the Big vein of massive corundum, the cut having followed on a border vein of crystal corundum. Pl. XVI is from a photograph of this cut, which shows the gneiss very distinctly on the left and the peridotite on the right, with the shaft house in the foreground.

The Big vein of massive corundum, for which this mine is noted, is at the foot of the south slope of the hill, and has been followed from the lower end of the cut (1, fig. 21) for a distance of over 300 feet, represented by the dotted lines, with the shaft house (4, fig. 21) near the western end. Although this vein is near the contact of the peridotite with the gneiss, it is separated from it by a band of peridotite and a small vein of sand corundum. There is some doubt whether the block of gneiss (2, fig. 21) is entirely surrounded by the peridotite or whether it penetrates the peridotite from the main mass of gneiss. From what could be seen, and from information obtained from Mr. A. Evans, foreman of the mine, it has very much the appearance of being entirely inclosed in the mass of peridotite. The Big vein, which has been worked by an inclined shaft 116 feet deep, with tunnels 300 feet in length, has brought the work up to the block of gneiss just referred to, and, according to Mr. Evans, a little work was done farther to the east which showed the corundum vein to extend on the south side of the block of gneiss, and it is not at all improbable that



OPEN CUT ON PERIDOTITE-GNEISS CONTACT AT LAUREL CREEK, GEORGIA.

Shaft house in foreground.

this vein continues as represented by the dotted line 3. Open cuts on the east and west side of this block of gneiss have followed border veins of corundum. Pl. XVII, *A*, gives a view of the peridotite formation near the cut on the east side. Little work has been done at Laurel Creek except on border veins, the principal exception being a small interior vein (6 in fig. 21) near the east end of the formation, from which considerable corundum was obtained, but the vein soon began to pinch out. Pl. XVII, *B*, gives a view of this vein, showing both the hanging and foot walls of peridotite. At 5, fig. 21,

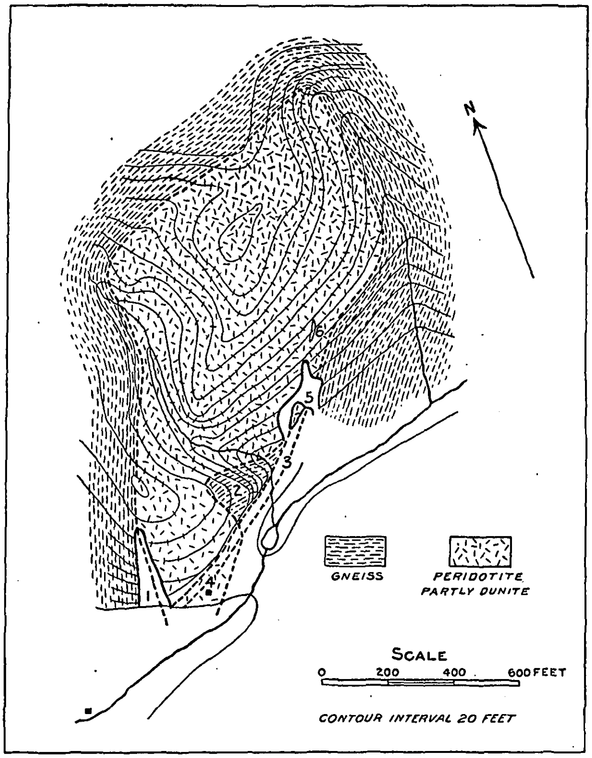


FIG. 21.—Map of the peridotite formation at Laurel Creek, Rabun County, Ga.

considerable work has been done, and some large crystals, for which this mine is noted, were obtained here.

This is perhaps the most famous corundum mine in this country and has furnished ore from which an exceptionally good commercial product has been obtained.

It has not been worked since 1894, when the tunnels and shafts of the Big vein were cut off by the slipping of a large block of the peridotite formation, nearly a 200-foot cube. It is that portion of the formation represented on the map (fig. 21) between the open cut (1) and the cut to the west of the block of gneiss (2).

Track Rock mine.—The location of this mine is in the northeastern part of Union County, Ga., on the south side of Track Rock Gap. The corundum occurs in a peridotite formation, which is very much decomposed on the surface, there being very little visible but a mass of chlorite-schist containing more or less actinolite. A tunnel, having its upper end 75 feet below the surface, has been run in on the formation for about 200 feet, with short branching tunnels at several points. From the material cut through by the tunnel, which was examined by Mr. King,[a] of the Georgia Geological Survey, the rock was found to be an altered peridotite, made up of small grains of chrysolite surrounded by actinolite and containing many grains of magnetite. It may be that the original of this rock was the peridotite-amphibole-picrite.

All the work that has been done at this mine has been entirely within the formation, and the best results would be obtained near the contact of this rock with the surrounding country rock.

Foster mine.—This mine, which is located in the northeastern part of Towns County, Ga., just over the North Carolina line, has been described with the other mines occurring in this vicinity under the head of "Corundum in North Carolina," on page 123. The corundum occurs in a quartz-schist, and the property is owned by the Corundum Mining and Manufacturing Company, of Philadelphia, Pa.

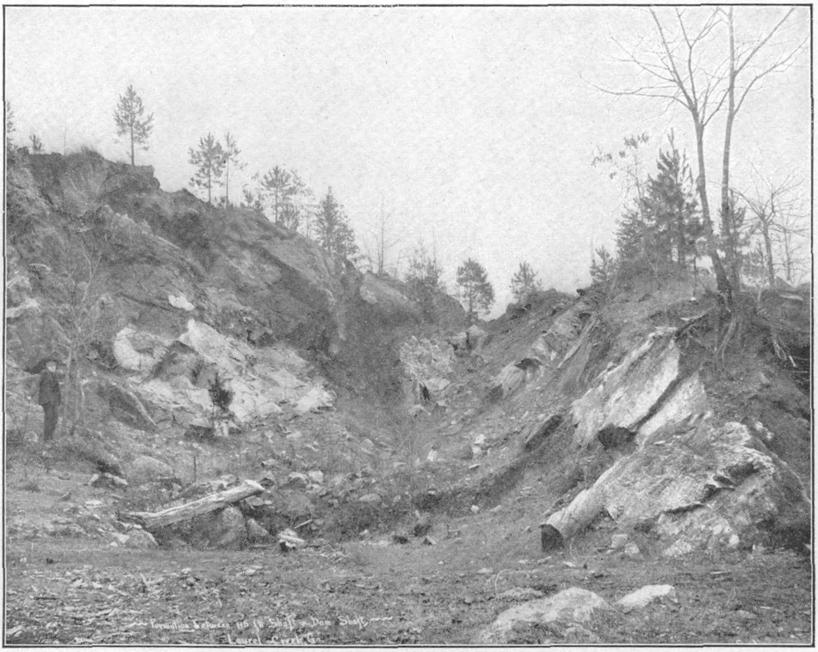
SOUTH CAROLINA.

Corundum is found in Laurens, Anderson, Oconee, York, and Spartanburg counties. The western portion of this State is in the line of peridotites as indicated by the direction of the belt in Georgia and North Carolina, and these rocks are known to exist along the border in the northwestern corner; but no work has been done to trace out their distribution nor to develop the corundum deposits, if such exist.

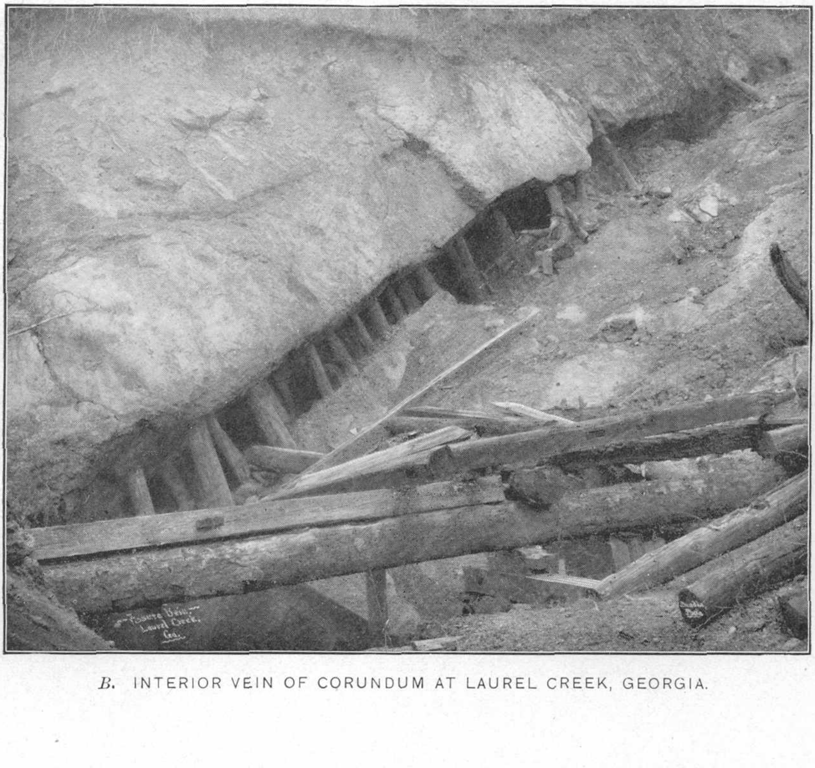
In the northeastern part of York County, from 3 to 4 miles west of the Catawba River, on the land between Allison and Crowder creeks, corundum has been found in a belt about 200 to 300 yards wide which skirts along the western slopes of Nannies Mountain. This locality is about 12 miles northeast of Yorkville, S. C., and 25 miles southwest of Charlotte, N. C.

Mining operations have been carried on at two distinct portions of this belt, one a mile north of the summit of Nannies Mountain, on the property of Alexander Rickard. The work done here consists of a shaft about 35 feet deep, from which several drifts have been run, which penetrate what is probably a light-gray granite, but it is much decomposed and of a sandy constitution. The only solid materials encountered were irregular masses of black, cleavable corundum associated with muscovite mica. In the surrounding fields float corun-

[a] Bull. Geol. Survey Georgia No. 2, 1894, p. 93.



A. PERIDOTITE FORMATION AT LAUREL CREEK, GEORGIA.



B. INTERIOR VEIN OF CORUNDUM AT LAUREL CREEK, GEORGIA.

dum ranging in size from small particles to masses of several pounds in weight are abundant, and many tons of this have been picked up and shipped.

A little to the west of the south end of Nannies Mountain, about 1½ miles from the Rickard mine, there is a similar occurrence of corundum. There have been a number of shallow cuts, ditches, and pits made in prospecting for corundum, but apparently none was found in place. The corundum that is found is often wrapped in mica.

ALABAMA.

The Appalachian crystalline belt passes under the Cretaceous and later sedimentary formations in the central part of the State near Montgomery. Representatives of the peridotite belt have been found in the vicinity of Dudleyville, in Tallapoosa County, and corundum has been found in fragments on the surface both in this and Coosa, the adjoining county on the west. No corundum has as yet been found in place, but it evidently originated in the peridotite rocks. Nothing that indicates a workable deposit has been found in the State.

VIRGINIA.

The only records that could be found show corundum to have been found in only two localities in the State. The first is a large deep-blue crystal found in Louisa County by Mr. Louis Zimmer, and reported by Mr. George F. Kunz.[a] The second is that described by Doctor Genth in 1890, from Patrick County, and noted above on page 55. The peridotite belt is continued through the State by a great number of talc and serpentine rocks, but no corundum has been reported from any of these localities.

PENNSYLVANIA.

The serpentine belt that comes diagonally across Maryland is continued through the counties of Lancaster, Chester, Delaware, Montgomery, and Bucks in Pennsylvania. Corundum is found associated with it in many places, especially in Chester and Delaware counties, and, a few years ago, was mined to some extent in Chester County. It is found here in chloritic zones about the serpentine, and in larger amounts in granular albite, much like the occurrence in feldspar veins at Buck Creek, in Clay County, N. C. It is near the contact of the serpentine with the gneiss.

Zones of chloritic minerals along the borders of the serpentine masses and in the larger joints are constantly present in these corundum localities, and chromite is found in the mass of the serpentine

[a] Mineral Resources U. S. for 1883–84, U. S. Geol. Survey, 1885, p. 735.

itself. Considerable prospecting has been done in Pennsylvania, and corundum has been mined in one or two places, but these are now abandoned.

Corundum has been found more abundantly near Unionville, in Newlin Township, Chester County. It is found here in a mass of serpentine rock, with an average width of about 800 feet and a length of 1 mile. A number of tons of corundum have been obtained from this mine, but during the last ten years little or no work has been carried on. Associated with the corundum are tourmaline and spinel.

NEW YORK AND NEW JERSEY.

The only corundum, except the emery variety, that has been found in New York or New Jersey is in association with the crystalline limestone, described on page 60. The occurrences are of no commercial importance, but are of considerable scientific interest.

No corundum whatever has been found associated with any of the peridotite rocks or their altered facies that have been located in these States.

CONNECTICUT.

The first corundum discovered in Connecticut was only surface specimens and nothing of commercial importance was developed. Early in the century, a mass of cyanite was found at Litchfield, "associated with talc, sulphuret of iron, and corundum—reported to weigh 1,500 pounds." It has also been found sparingly with sillimanite in the vicinity of Norwich. In 1902 Prof. B. K. Emerson, of Amherst College, described corundum from Barkhamsted, Conn., where it occurs in association with cyanitic mica-schist and fibrolite gneiss. The corundum forms a bed between 2 and 3 inches thick, and is of a dark-blue to blue-black color, with occasional patches that are decidedly green. There is no commercial quantity of corundum at this locality.

MASSACHUSETTS.

As has been stated on page 53, corundum has been found near Pelham, in this State, occurring in a zone of biotite, which has resulted from the contact metamorphism of a peridotite on gneiss. Incidental to the mining of asbestos at this locality several tons of corundum ore were taken out and shipped. The deposit has not developed into one of any economic importance. The emery deposits of the State are, however, among the most important corundum deposits in the United States, and these are described on pages 134–137.

MONTANA.

To the west of the Appalachian Mountains there are but four States in which corundum is authentically known to occur, namely, Montana, Colorado, Idaho, and California. It has been reported from Nevada, but no definite information or reference to the locality can be obtained. The only localities of any commercial importance are those in Montana, and these are the only ones that are described here. The California deposits have been described on pages 42–44, those from Idaho on page 116, and those from Colorado on page 49.

The corundum deposits in Montana are located in the south-central part of Gallatin County, on the headwaters of Elk Creek, in a group of foothills between the Gallatin Valley and Spanish Creek Basin. They are about 23 miles nearly south of Belgrade, Gallatin County, a station on the Northern Pacific Railroad. The corundum occurs in a seynite, as described on page 48. The crystals of corundum vary from a fraction of an inch up to 8 inches in length, and some have been found that weighed 1½ to 2 pounds. This mineral is not distributed evenly throughout the syenite rock, but is sometimes concentrated into seams or streaks from a few inches to 34 inches in width. Some of the smaller seams are almost pure corundum, and in the larger ones the percentage varies from 10 to 70 per cent. The full width of the corundum-bearing syenite is from 8 to 10 feet, and it will average from 5 to 10 per cent of corundum. There are three companies which are developing corundum properties in this general district, of which the largest and at the present time the most important is the Montana Corundum Company. This company is working a property that has been developed by means of shafts, tunnels, pits, and crosscuts which show the deposit to be very persistent and regular for over 1,000 feet. The property has been thoroughly equipped with machinery for mining, cleaning, and preparing the corundum for market. The cleaned corundum makes a good abrasive; it has been tested by a number of users of this kind of abrasive material, and they have reported favorably regarding it. A fire test has been made on this corundum by the author, and it was proved that it could be used in the manufacture of a vitrified wheel.

The Bozeman Corundum Company has been developing a property about 14 miles southwest from Bozeman. The corundum seams vary from a few inches to 3 feet in thickness, and are being exploited by shafts and drifts. Five miles to the west of the property of the Montana Corundum Company is the Anceny corundum deposit, which is now being developed.

EMERY.

Until recently the only emery known to occur in the United States was that at Chester, Mass., and at Peekskill, N. Y., the principal mining being done at the latter place. Emery has now been found in North Carolina in a promising prospect, and also at one locality in Virginia. As is stated on page 26, emery is a mechanical mixture of corundum and magnetite, or sometimes hematite. Because of its striking resemblance to iron ore, especially where it is a mixture of corundum and magnetite and is therefore magnetic, the deposits at both Chester and Peekskill were first worked as iron ores, and it was not for some time that their real nature and value were understood. Since then the deposits at Chester and Peekskill have been worked continuously and extensively.

Spinel is sometimes associated with the emery and increases in amount until it is largely in excess of the corundum, and the ore passes over into what might well be called a "spinel emery."

MASSACHUSETTS.

The only deposit of emery that has been found in this State is in the vicinity of Chester, where the emery vein has been traced for nearly 5 miles. The vein is first encountered about 2 miles northwest of the village of Chester, in a ledge that projects into Westfield River from its left bank. The vein can be followed almost continuously along the line of the strike—south to a little east of south. It extends across the east slope of Gobble (North) Mountain, drops down into and crosses the narrow valley of Walker Brook, and then rising, it crosses South Mountain and can be followed for over 2 miles to the south. The map (fig. 22) shows the general position of this emery vein, the places that have been opened along it, and the location of the different emery mills. The emery occurs in an amphibolite, which has been described on page 39.

The first work was done toward the southern end of the vein, about half a mile north of where it disappears, at what is known as the Wright mine. About twenty years ago rather extensive mining was carried on here, the work consisting of an open cut nearly 1,400 feet long that was worked to a depth of 6 feet at its southern end and of about 30 feet at its northern, with probably an average depth of 20 feet for the entire distance. Emery varying in width from 3 to 20 feet was encountered throughout nearly the entire length of the cut.

This mine was reopened in 1899, a shaft 87 feet deep having been sunk on the vein near the southern end of the cut and drifts run out from it. Margarite is the most conspicuous accessory mineral, and specimens that can rarely be excelled have been found here.

Continuing nearly half a mile to the north on the vein and near the top of the mountain is the Melvin mine. There is a shaft here 40 feet deep, from which drifts are run. This shaft is but 1,250 feet from the head of the upper tunnel of the Old mine, the next one to the north. It is in this Old mine that the most extensive work has been done. Fig. 23 is a cross section of its underground workings in 1899. The mouth of the lowest tunnel is but 8 feet above Walker Brook and 75 feet to the south of it. As is seen from the diagram, the emery does not occur continuously throughout the vein, but in pockets or chimneys which dip into the vein about 30° N. From the work already done these seem to hold this direction rather constantly, so that the pockets can be approximately located at a given depth. It was in the first chimney of emery (see map, fig. 22) that the beautiful specimens of diaspore for which this mine is noted were found.

North of Walker Brook and about 500 feet from the Old mine is the Macia mine, where a small amount of surface work has been done. Near the head of a small ravine a tunnel was started on the west of the vein to intercept it, but work was discontinued before the vein was reached.

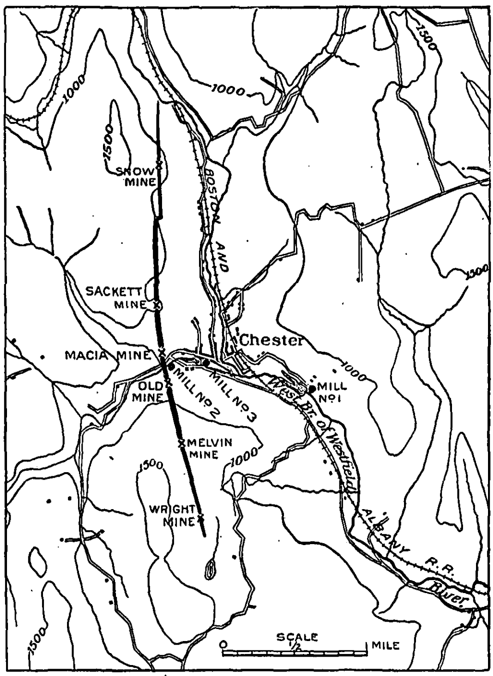


Fig. 22.—Map showing the location of the emery deposit at Chester, Mass.

The next opening is near the highest point of the vein on the eastern slope of Gobble (North) Mountain, about three-fourths of a mile north of the Macia mine, and is known as the Sackett mine. At this part of the vein there was a considerable quantity of magnetite that was practically free from corundum and was mined as an iron ore. This mine was worked very extensively between twenty and thirty years ago, but had been abandoned until 1899, when it was reopened. The old works were near the highest point of the vein, on the slope of the mountain, and were worked for about 30 feet. The new work was started 117 feet below the mine, and a tunnel from the east side was run 114 feet to the vein. When this was reached a shaft and tunnels were started. At this mine the corundum occurs in what might be called porphyritic crystals of a bronze color, which are from 5 to 15 mm. across. Here blue and white masses of corundum weighing several pounds have been found, and small, well-formed blue crystals are also frequent. A little north of this mine, in an old opening, a cross vein of chlorite was encountered which carried a great many almost perfect cubes of pyrite and radiating groups of black tourmaline.

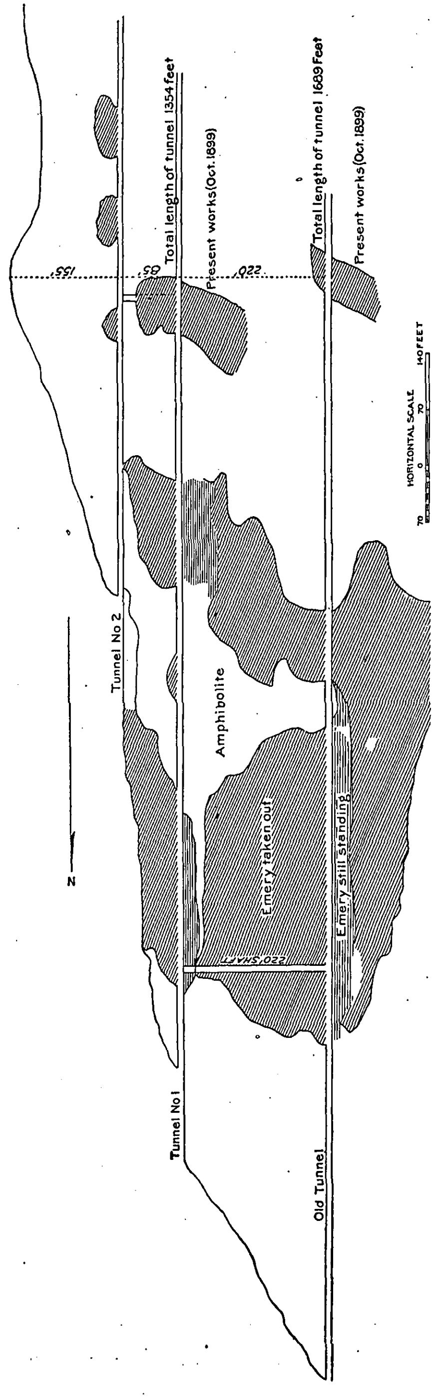


Fig. 23.—Cross section of the Old mine, at Chester, Mass., showing the quantity of emery taken out to April, 1899.

The last opening on the vein where there has been any work is at the Snow mine, over a mile north of the Sackett mine. A small open cut was made that exposed the vein, 3 feet in width. Between these two mines and also from the Snow mine north to the river the vein can be followed almost continuously.

Although the vein can be followed nearly the whole distance, the emery does not occur throughout its entire length, for it is often in a series of pockets that are frequently connected with each other along the strike by a thin streak of chlorite and have a general dip in the vein of about N. 30°. In the direction of the dip, however, the emery is more or less continuous. The width of the vein varies from a few feet to 10 or 12, with an average width for the emery of about 6 feet. This is the most extensive deposit of emery known in this country.

From the beginning of mining at Chester up to two years ago the deposits there yielded the largest production in the United States. Now, however, they are exceeded by those at Peekskill.

Emery has also been discovered in the vicinity of Huntington, Mass., but no development work has as yet been done.

NEW YORK.

The emery deposits of this State occur associated with the norite rocks in Westchester County that have been described on page 41. Deposits of magnetite and emery have been found at a number of places 3 to 4 miles southeast of Peekskill. These deposits vary considerably in character, some being a nearly pure magnetite, others containing magnetite and spinel, and still others magnetite, spinel, and corundum. Those within a mile north and northeast of Crugers Station have been worked for iron ore, while those worked for emery are in the southeastern part of Cortlandt Township. The principal openings have been made on a ridge running north from Colabaugh Pond, and it is here that the ore has been mined. The iron ore and emery appeared to be very rich, but it was found upon examination that there was present more or less of a dark-green mineral mixed with magnetite, and this mineral was shown by Williams[a] to be the pleonaste variety of spinel. There is also considerable spinel in the emery, and even when the emery is abundant the ore can not be distinguished in the hand specimens from that in which there is almost none of the spinel.

At the emery deposits in the southeastern part of Cortlandt Township the percentage of corundum varies considerably at different openings, and it is sometimes observed in small blue, white, and colorless crystals. Associated with most of the corundum there is spinel, and much of the ore that has been mined for emery has contained little or no corundum and has been made up of magnetite and spinel. An ore of this sort would have most of the requisite properties of a true emery except the high degree of hardness due to the corundum; and when made up into a wheel it would not have the cutting efficiency of a true emery wheel. The spinel, which is 8 in hardness (corundum being 9), would play the same part in this ore as corundum in the true emery, and although not so hard as corundum it has the cutting qualities which would give the ore considerable value as an abrasive. For many purposes wheels made from this material could be used fully as well as emery or corundum wheels, and for some purposes they might be used to better advantage. The spinel

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[a] Am. Jour. Sci., 3d ser., vol. 33, 1882, p. 194.

would not interfere at all in the manufacture of a vitrified wheel. Some of the ore that has been mined here carries a very high percentage of garnet.

The analyses that have been made of this ore all show a high percentage of alumina, which was to be expected, as the spinel is an alumina mineral, $(MgFe)O,Al_2O_3$, and contains about 50 per cent of this oxide. An error is very often made in judging the percentage of corundum in an ore by calculating as corundum the total percentage of alumina obtained in a chemical analysis, which would represent, however, the alumina contained in all the aluminous mineral components of the ore. (See p. 21.)

Some of the ore at these mines is undoubtedly a true emery, but a considerable portion of it is a mixture of spinel and magnetite, which, while not a true emery, will make a useful abrasive. This whole ore body might be called a spinel-emery.

From what has been said regarding the occurrence of the emery in these Peekskill deposits, their pockety nature is what would be naturally expected, and this has been characteristic of all the mining that has been done in this district.

The Blue Corundum Mining Company, of Boston, Mass., is one of the largest miners in this section. It has leased the emery deposits on the land of Isaac McCoy, 3 miles southeast of Peekskill. Its principal work is on the summit of a hill about half a mile south of the McCoy house and consists of an open cut 40 to 50 feet deep, 40 feet long, and 12 to 20 feet wide. The emery ore is from 4 to 6 feet wide, but it is broken up by bands of serpentine and chloritic rocks. In some of the ore the corundum is very distinct, occurring in elongated bluish-white crystals up to 5 mm. long. This ore is very free from garnet.

Another deposit of emery has been encountered 50 feet below the summit, and still another 25 feet farther down. No mining has been done at either of these points.

The ore is hauled by teams to Peekskill, where it is shipped by rail to Easton, Pa.

On a hill 1 mile east of the McCoy mine H. M. Quinn, of Philadelphia, Pa., has mined on the land of John H. Buckby. Pockets of emery were encountered on the summit of the hill and at a number of points on its western slope, but they soon pinched out. About 50 feet below the summit a face of rock 15 to 20 feet high and 40 feet across has been exposed. The only emery seen here is the remnant of a pocket.

As far as could be learned the emery deposits of the Tanite Company, of Stroudsburg, Pa., are also leased. They are on the lands of Henry Heady, Oscar Dalton, and David Chase, and are for the most part similar to the deposits just mentioned. The ore on the land of

Henry Heady is composed largely of garnet, and a considerable portion of it has been shipped by the Tanite Company to their mill at Stroudsburg.

NORTH CAROLINA.

Corundum has been known to occur in quantity in this State for over thirty years, but emery has until recently been known from only one locality, and here the quantity was not apparently sufficient to be worthy of any development. This deposit has been described by Genth[a] as occurring at the McChristian place, 7 miles south of Friendship, Guilford County.

During the last few years emery has been found in Macon County in what appears to be considerable quantity. Nothing definite can be stated regarding the rock in which it occurs, as it is greatly decomposed as far as it has been exposed by the excavations. It does have, however, very much the appearance of a decomposed basic magnesian rock. There are a number of small outcrops of this saprolitic rock about 5 miles southwest of Franklin, the county seat, and emery in varying quantity occurs at all of them.

These outcrops, as far as could be judged, are isolated and in no way connected with one another. They are lenticular in form and but a few hundred feet wide, the longer axis having sometimes two or three times this length. While the general direction of the strike of these outcrops is nearly the same, they are not in even an approximate line as regards one another. For nearly 15 miles south of them and following the valley of the Little Tennessee River small isolated outcrops of peridotite are numerous. The country rock through which these have forced their way is a hornblende-gneiss.

Considerable mining was done in 1898 by Dr. H. S. Lucas, of Franklin, at the Fairview mine, near North Skeener Gap, about a hundred tons of ore having been taken out and cleaned. The vein has been tapped at intervals for a distance of nearly 200 feet, good emery being encountered at each opening. All the work done was near the summit of Fairview Knob.

One mile N. 25° W. of the Fairview mine, on the southwest slopes of Dobson Mountain, another opening has been made for emery in an outcrop of the same rock on the land of J. A. Waldroop. A vein of emery ore was uncovered here that was 15 feet wide. No mining has been done here, all the work being in the nature of prospecting.

Emery has been found in similar outcrops on the lands of William Mann, three-fourths of a mile south, and of James Ledford, 1¼ miles S. 30° E. of the Fairview mine. Preliminary fire tests were made upon the cleaned product of this ore, which proved it to be well

[a] Bull. U. S. Geol. Survey No. 74, 1891, p. 30.

adapted for use in the manufacture of the vitrified wheel. With the completion of the railroad to Franklin, which follows down the valley of the Little Tennessee River, from the Georgia line, all of these deposits will be in close proximity to railroad transportation.

Six miles north of Burnsville, Yancey County, on the south side of Mine Fork, half a mile above its mouth and 300 feet above it, corundum has been found which is in very finely divided particles, intimately mixed with magnetite, menaccanite, and staurolite. The staurolite is transparent and of a rich brownish color, and has been mistaken for corundum. The staurolite and corundum together constitute from 5 to 10 per cent of these mixed minerals. The only work that has been done here is the sinking of two small openings, 75 feet apart, on the strike (N. 25° E.) of the ore, which has exposed it for a width of 6 to 10 feet. Nearer the summit of the ridge, and to the west, a similar outcrop of ore has been found. Unless it is found by further work that the percentage of the corundum increases, this deposit will have little or no commercial value. The railroad is now within 3 miles of this deposit, and will give good transportation facilities if a large deposit of commercial ore should be developed.

VIRGINIA.

In Pittsylvania County, about 1¾ miles nearly due west of Whittles, a station on the Southern Railroad, emery has been found at a number of localities on the lands of Messrs. Richard C. Keatts, J. D. Craddock, J. H. Hargeaves, and J. W. Nance, and on the John Yeates estate. Surface emery is quite abundant on many of these farms. The only place where any attempt has been made to explore the emery is on the Keatts farm, where two openings, about 300 feet apart, have been made, on what are apparently parallel veins. Each opening is about 20 feet deep. From the lower one two drifts, 10 to 15 feet long, followed on the vein. All the rocks are saprolitic, but those inclosing the emery have the appearance of altered amphibolites or pyroxenites, and the occurrence is similar to that near Franklin, Macon County, N. C.

The emery occurs in seams and loose fragments, which are badly stained, but on a fresh fracture it is black and has a metallic luster.

CORUNDUM LOCALITIES IN THE UNITED STATES.

Under this head are included practically all the localities in the United States at which corundum has been found. If the localities have already been described in the foregoing pages, they are simply mentioned here. Otherwise, in most cases, the mode of occurrence and also some idea of the extent and character of the corundum are given.

This list is probably not complete, but it represents all those localities that I have visited and those of which an authenticated record could be obtained.

ALABAMA.[a]

Dudleyville.—Between this town and Perry Mills, Tallapoosa County, corundum has been picked up at a number of places in the soil, but none has been found in place. Peridotite rocks have been found in the vicinity, and it is not at all improbable that the corundum was derived from these rocks.

Hanover.—Corundum has been found sparingly in Coosa County in the vicinity of this town.

CALIFORNIA.

Meadow Valley.—Near this town corundum has been found in plumasite. (See p. 42).

Plumas County.—(See p. 42.)

Los Angeles County.—Corundum is reported as having been found in the drift of San Francisquito Pass.[b]

COLORADO.

Canyon.—In a granitic rock. (See p. 49.)

Chaffee County.—Corundum crystals have been found at the Calumet iron mines in the mica-schists at their contact with intrusive dikes of diorite. Mr. R. C. Hills, geologist to the Colorado Fuel and Iron Company, writes that the ore occurs in a band of rock 6 inches to 2 feet thick that has been followed for a distance of 500 feet, and that it averages 40 per cent of corundum.

Saxon Mountain.[c]—Corundum has been found by Mr. F. A. Maxwell on Saxon Mountain, near Georgetown, Clear Creek County.

CONNECTICUT.

Barkhamsted.—Near this town, in Litchfield County, corundum has recently been discovered. (See p. 132.)

Litchfield.—Corundum was found here associated with talc and pyrite in a mass of blue cyanite. Only surface specimens were found.

Norwich.—In the vicinity of this place corundum was found sparingly with sillimanite.

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[a] Rept. Geol. Survey Alabama, 1875, p. 85.
[b] Dana's Mineralogy, 6th ed., 1902, p. 213.
[c] Min. and Sci. Press, September, 1903.

DELAWARE.

Corundum has been found in this State in the serpentine rocks near the Pennsylvania border. The only locality definitely known is near Chandlers Hollow, in Newcastle County, about 2½ miles south of Concord, Delaware County, Pa. It has been found only in small quantity.

GEORGIA.

Acworth.—Seven miles southwest of Acworth, Cobb County, there is a large peridotite formation which is entirely within Paulding County. From a pit sunk within this formation about 1,000 pounds of corundum were taken out. It is of poor quality, but makes handsome mineral specimens.

Bell Creek mine.—This mine is 4 miles north of Hiawassee, Towns County, and the corundum, mostly of a pink color, occurs in peridotite. The work done consists of a pit 12 feet square by 12 feet deep. Only a small quantity of corundum was found.

Caldwell.—On the property of Mr. R. J. Cook, of Caldwell, Union County, pieces of sapphire corundum weighing 10 pounds and upward have been picked up on the surface. (See p. 105.)

Centralhatchee.—At this place, which is in Heard County, grayish, white, and blue corundum has been found in a matrix of hornblende, which is associated with basic magnesian rocks.

Douglas County.—Blue corundum in a pale-greenish cyanite.

Foster mine.—The corundum occurs in quartz-schist. (See p. 123.)

Gainesville.—Beautiful specimens of red corundum have been found in the peridotite formation 1 mile east of Gainesville, Hall County.

Habersham County.—Corundum has been found as surface specimens at a number of localities in this county, and at one place in the peridotite formation. There have been no developments and there are no indications of any quantity.

Hamilton mine.—The corundum occurs in a peridotite formation about 5 miles north of Young Harris, Towns County. No large quantity has been found.

Hiawassee.—Corundum has been picked up on the surface at a number of localities in the vicinity of Hiawassee. Some of the corundum found has been of a ruby color and nearly transparent. See also Hog Creek mine.

Hog Creek mine.—This mine is 2 miles a little south of west of Hiawassee, Towns County, but it lacks development. The corundun is associated with peridotite, and is pink, blue, and white.

Laurel Creek mine.—In peridotite. (See p. 128.)

Monroe.—Four and a half miles from Monroe, Walton County, on the farm of Mr. George W. Breedlove, black corundum has been found associated with peridotite rocks. Some little prospecting has been done here within the formation and some near the contact.

Pine Mountain, Rabun County.—In peridotite. (See p. 128.)

Porter Springs.—One mile southeast of this place (in Lumpkin County) corundum has been found in an amphibolite, but not in quantity.

Powder Springs.—There is a considerable outcrop of peridotite in Cobb County, in the vicinity of Powder Springs, which offers a promising place for prospecting. A small vein has been opened on the W. B. Turner farm.

Rabun Gap.—Several pounds of corundum have been obtained from the Beavett mine; it occurs in a peridotite rock.

Teltonville.—One mile north of this town, in Forsyth County, surface specimens of corundum have been found which evidently originated in the quartz-schists of this region.

Stone mine.—This mine, which is in the same general formation as the Track Rock mine (see p. 130), is in Rabun County. Only a little development has been undertaken, and the prospect that the deposit may be valuable is not very favorable.

Thomaston.—Seven to 8 miles southwest of Thomaston, Upson County, considerable corundum has been found on the surface at the old Kelly farm. Some of the specimens of the corundum in the matrix indicate that it was derived from a mica-schist. The crystals are all flat and tabular, with basal plane very prominently developed, and they vary in thickness from an eighth to half an inch. They are usually bounded by the prism and the base with occasionally the unit rhombohedron. The basal plane is often pitted or etched with triangular indentations similar to those described as occurring on the North Carolina rubies (p. 103) and the Montana sapphires (p. 109).

Track Rock mine.—In peridotite. (See p. 130.)

West Point.—A short distance northeast of this town (in Troup County) corundum has been found sparingly in a narrow strip of peridotite. Apparently no large quantity is present.

IDAHO.

Orifino Creek.—(See p. 116.)

Pierce City.—Fragments and crystals of corundum have been found in the gravel deposits in the vicinity of Pierce City. (See p. 116.)

Rhodes Creek.—(See p. 116.)

MAINE.

Corundum has been found sparingly at Greenwood, Me.,[a] occurring in crystals in mica-schist and associated with beryl, zircon, and lepidolite.

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[a] Dana's Mineralogy, 6th ed., 1902, p. 213.

MARYLAND.

Corundum has been reported as occurring in the vicinity of Whitehall, Baltimore County, but no definite information can be obtained that any has been found here beyond a stray surface specimen.

MASSACHUSETTS.

Chester.—Emery in amphibolite. (See pp. 38, 92, 134.)

Huntington.—Emery in amphibolite. (See p. 137.)

Pelham.—Corundum in saxonite. (See p. 53.)

MONTANA.

American Bar.—The lowest bar on the Missouri River on which sapphires have been found. (See p. 106.)

Anceny mine.—In syenite. (See p. 133.)

Belgrade.—(See pp. 48, 133.)

Bozeman.—Fourteen miles southwest of this town corundum is found in syenite. (See p. 133.)

Cottonwood Creek.—In the gravels of this creek greenish-colored sapphires have been found. (See p. 111.)

Dana Bar.—A bar in the Missouri River, in the gravels of which sapphires have been found. (See p. 107.)

Eldorado Bar.—Sapphires in the gravel. (See p. 107.)

Emerald Bar.—The highest bar on the Missouri River in which sapphires have been found. (See p. 107.)

French Bar.—Sapphires have been found in a small dike of andesite. (See p. 107.)

Gallatin County.—Corundum in syenite. (See pp. 48, 133.)

Magpie Gulch.—Pale-greenish sapphires have been found in the gravel. (See p. 107.)

Metropolitan Bar.—Sapphires occur in the gravels. (See p. 108.)

Missouri River bars.—In the various bars along the Missouri River, 18 miles east and northeast of Helena, sapphires have been found in the gravel. (See p. 106.)

Norris.—(See p. 116.)

Rock Creek.—Sapphires of all colors are found in the gravel of this creek. (See p. 110.)

Ruby Bar.—Sapphires occur in an andesite dike. (See p. 44.)

Spokane Bar.—A bar of the Missouri River where the most mining has been done for sapphires that occur in the gravels. (See p. 107.)

Yogo Gulch.—Blue sapphires occur in a dike of monchiquite. (See p. 111.)

NEVADA.

Silver Peak.—Corundum has been reported from near this place.

NEW JERSEY.

Franklin Furnace.—A small pocket of corundum has been found here associated with dolomitic limestone.

Newton.—Blue and white corundum occurs in a whitish feldspar near the contact of the granitic rock and white limestone.

Vernon.—Small pockets of corundum in limestone, but not in great quantities. (See p. 60.)

NEW YORK.

Amity.—Blue and white corundum has been found in the limestone near Amity and Warwick, Orange County. Does not occur in large quantity.

Peekskill.—A short distance east of Peekskill emery is found in basic magnesian rocks in some quantity. (See p. 137.)

NORTH CAROLINA.

Acme mine.—This mine is located about three-quarters of a mile west of Statesville, Iredell County. The corundum occurs in crystals in an amphibolite.

Addie.—Crystals of corundum have been found sparingly associated with the peridotite rocks in the vicinity of Addie, Jackson County.

Asheville.—Near this town in garnetiferous gneiss. (See p. 51.)

Bad Creek mine.—Corundum associated with peridotite. (See p. 125.)

Bakersville.—Corundum crystals have been found sparingly in the gneiss at William Bowman's, three-fourths of a mile west of Bakersville, Mitchell County.

Behr mine.—This mine is near Elf post-office, on Shooting Creek, Clay County. Pink and white corundum have been found associated with peridotite rocks.

Belts bridge.—Crystals of black corundum occur in an amphibolite 8 miles northwest of Statesville, Iredell County, on the Hunter farm.

Betts gap.—Corundum in splendid grayish-white crystals that are translucent is found in the gneiss to the south of the gap in Jackson County. Garnet also occurs in the gneiss.

Blue Ridge properties.—Corundum occurs in gneiss. (See p. 122.)

Brockton mine.—Corundum occurs in the peridotite. (See p. 124.)

Buck Creek mine.—Also known as the Cullakeenee mine. Is in a peridotite formation. (See p. 120.)

Burnt Rock mine.—In a peridotite formation. (See p. 124.)

Caler Fork.—Ruby mine, the crystals being found in the gravels of the creek. (See p. 98.)

Caney Fork.—Two miles above the mouth of this creek, in Jackson County, corundum is found in the chlorite-schist in considerable quantity. At many points along this creek and its tributaries corundum has been found in the chlorite-schists and in gneiss near these schists, as at the mouth of and also 2 miles up Chastains Creek and on Shoal Creek Mountain, on the West Fork.

Carpenters Knob.—Along the ridge leading northwest from Carpenters Knob, near the border of Burke, Cleveland, and Catawba counties, corundum in grayish-blue tapering crystals is found associated with garnetiferous gneisses and schists.

Carter mine.—Corundum occurs in a peridotite formation associated with spinel. Considerable work was done here ten years ago, but since then the mine has been idle. This locality offers a somewhat promising prospect.

Celos Ridge.—Corundum crystals 2 to 3 inches long have been found sparingly in the decomposed gneiss on this ridge 8 miles southeast of Burnsville, Yancey County.

Chastains Creek.—See above, under Caney Fork.

Chunky Gal Mountain.—Corundum has been found in the bands of quartz-schists and gneiss of which the Chunky Gal Mountain is composed. Garnet is associated with the corundum, which forms a very small percentage of the rock. This occurrence is described on page 51.

Collins mine.—Pink corundum in cyanite occurs at this mine near Statesville, Iredell County.

Corundum Hill mine.—The corundum at this mine occurs in a peridotite. (See p. 117.)

Cowee Valley.—Ruby and red corundum, many specimens of which are transparent, are found in the alluvial deposits of this valley. (See description of ruby mine, pp. 98–103.)

Coweeta.—Pink corundum is found in a greenish cyanite at this place, in Macon County.

Cullakeenee mine.—Same as the Buck Creek mine.

Cullasagee mine.—This is the same as the Corundum Hill mine.

Democrat.—Corundum has been found, sparingly associated with the peridotite rocks, a little to the south of this place, in Buncombe County.

Egypt mine.—This mine is located in Yancey County, 10 miles west of Burnsville, and the corundum is in a peridotite. It is in crystalline masses and distinct crystals of a white color, often mottled with blue. This occurrence is interesting as being the only one where corundum has been found surrounded directly by dunite.

Elf.—Beautiful specimens of pink corundum are found in the green amphibolite. Occasionally there are blue pieces in this rock.

Ellijay Creek.—Corundum has been found at many points in the valley of this creek, associated with peridotite rocks. The more important of these are the Mincey, Haskett, and Higdon mines.

Fairview mine.—At this mine emery occurs in basic magnesian rocks. (See p. 139.)

Fishhawk Mountain.—At an elevation of 4,000 feet on the western slope of this mountain, on Hickory Knoll Creek, in Macon County, corundum has been found sparingly in a small outcrop of dunite.

Foster mine.—Near the summit of Chunky Gal Mountain, near the headwaters of the northern fork of Shooting Creek, in Clay County, corundum occurs in peridotite. (See p. 123.)

Gaston County.—Blue corundum, associated with mica and quartz, has been found at Chubbs, Crowders, and Kings mountains, in this county. Emery also has been found at Crowders Mountain.

Glenville.—Four miles north of this town, in Macon County, corundum occurs in chlorite-schist similar to that on Caney Fork.

Gray property.—Corundum in peridotite. (See p. 119.)

Grimshaw Gem mine.—Sapphires of various colors have been found at this mine in peridotite. It is near Montvale post-office, Jackson County. (See p. 104.)

Hampton mine.—Same as Mine Fork.

Haskett mine.—This is given under Ellijay Creek.

Herbert mine.—This mine is on Little Buck Creek, Clay County, and is in a long, narrow arm of peridotite extending out from the main mass of the Buck Creek peridotite formation. Some prospecting has been done here, and although corundum has been found, the main mass of it occurs in connection with the main mass of peridotite.

Higdon mine.—This mine was worked for a short time, and there is connected with it a mill for washing and cleaning the ore. (See Ellijay Creek, above.)

Isbel mine.—Corundum occurs sparingly in what may be a decomposed amphibolite. One of the largest washing and cleaning mills in the State is at this mine.

Kings Mountain.—See Gaston County.

Marshall.—Corundum has been found in large gray crystals half a mile north of the mouth of Big Ivy River and 3 miles above Marshall, Madison County, on the surface of a large amphibolite outcrop. It is on the property of Mr. G. C. Haynie, of Marshall.

McChristian place.—Emery of reddish-brown and grayish colors has been found at this place, which is 7 miles north of Friendship, Guilford County. The property lacks development. Surface specimens of corundum have also been found here.

Mincey mine.—The corundum at this mine is found in peridotite. (See p. 119.)

Mine Fork.—Emery, associated with staurolite. (See p. 140.)

Montvale.—At many of the peridotite formations in the vicinity of Montvale, Jackson County, corundum has been found. (See p. 104.)

Newfound Gap.—A little to the south of this gap, in Haywood County, red corundum has been found on the surface of a small mass of dunite.

Nona.—Corundum in distinct crystals has been found on the surface, in the vicinity of gneiss, at Nona, Macon County.

Owens Creek.—Crystals and grains of corundum have been found in bowlders of cyanite near the mouth of this creek, in Transylvania County.

Presley mine.—This mine is located 4 miles north of Canton, Haywood County. The corundum, of a blue and bluish-gray color, occurs in a pegmatitic dike.

Reed mine.—The corundum at this mine, which is 6 miles east of Franklin, Macon County, occurs in a saprolitic rock, and is in small prismatic crystals of a bluish color, some of which are nearly transparent.

Retreat.—Near Retreat post-office, in Haywood County, corundum has been found in limited quantity in small pegmatitic dikes in the gneiss.

Sapphire.—The mines in the vicinity of this town are described on page 123.

Sapphire mine.—The corundum occurs in peridotite. (See p. 125.)

Scaly Mountain.—The corundum occurs in quartz-schist. (See p. 122.)

Sheffield mine.—The corundum at this mine is in amphibole-schist. (See p. 119.)

Skeener Gap.—Emery is found here in a basic magnesian rock. (See p. 139.)

Shoups Ford.—At this place, in Burke County, corundum has been found associated with fibrolite.

Socrates mine.—One of the mines in the vicinity of Sapphire. Corundum occurs in peridotite. (See p. 125.)

Swannanoa Gap.—Float corundum has been found near an outcrop of peridotite.

Thumping Creek.—Corundum has been found in rough nodules and flat crystals in gneiss on the property of Curtis Ledford and C. C. Patterson, on this creek, Macon County.

Turkey Knob.—On the summit of this mountain, near the Macon-Jackson county line, corundum has been found sparingly in gneiss.

Waldroop mine.—Emery has been found in a basic magnesian rock. (See p. 139.)

Watauga mine.—Same as the Reed mine.

West Mills.—Red and ruby corundum have been found in the old gravel beds of the streams on the West farm, near West Mills, Macon County.

Whitewater mine.—The corundum is in peridotite. (See p. 125.)

Winston-Salem.—Near this place, in Forsyth County, emery has been found similar to that at the McChristian place.

Yellow Mountain.—The gneisses of this section carry a small percentage of corundum. (See p. 122.)

PENNSYLVANIA.

Blackhorse.—Slender grayish crystals of corundum have been found at this place, which is near Media, Delaware County. This has been found inclosed by feldspar.

Fremont.—Near this place, in West Nottingham Township, Chester County, corundum crystals have been found, surrounded by feldspar.

Mineral Hill.—Corundum crystals have been found at this place, which is near Media, in Middletown Township, Delaware County. They were surrounded by feldspar similar to that at Blackhorse.

Newlin.—See under Unionville.

Shimerville.—At this place, in Lehigh County, corundum crystals up to 8 inches in length and 4½ inches in diameter have been found loose in the soil.

Unionville.—In a large mass of serpentine rocks, 1 mile northeast of this village, corundum has been found. (See p. 132.)

Villagegreen.—Large crystals of corundum of a brownish color are found near this village, in Aston Township, Delaware County.

West Chester.—Corundum has been found in a serpentine of this township.

SOUTH CAROLINA.

Anderson County.—Corundum has been reported from this county, but none has been found in place.

Energy.—See York County.

Gaffney.—Corundum, usually of a gray color and in irregular masses up to 3 or 4 inches in diameter, has been found about 8 miles northwest of Gaffney, on the Island Ford road, near Maud post-office, on the Turner Phillips farm. It has not been found in situ, but in the gravels of a small stream and as loose fragments in the fields on the adjoining slopes. The fragments and what few crystals have been found are generally free from gangue, but some have been found with mica scales attached to them. It is not at all improbable that this corundum was derived from a mica-schist.

Laurens.—About 1¼ miles northeast of this town, in Laurens County, corundum has been found rather abundantly scattered over the surface. This surface corundum has been found for a number of miles to the southwest of this town. Although no corundum has been found in place, it was probably derived from a mica-schist, for the country rock in this section is largely a schist, and corundum crystals were found with portions of the mica-schist attached to them. The crystals are all rough, and vary from small ones to some that were over 3 inches long and 1 inch in diameter.

Oconee County.—Corundum has been found on the surface in this county, but none has been found in place.

York County.—In the northern part of this county, at Energy, near the North Carolina line, a black corundum has been found quite abundantly. (See p. 130.)

UTAH.

It is reported that a large deposit of corundum was found in this State in 1900, but no accurate information has been thus far obtained regarding location or quantity.

VIRGINIA.

Louisa County.—Deep blue crystals of corundum have been found in the soil in this county, but the exact locality is not known.

Pittsylvania County.—Emery. (See p. 140.)

Stuart.—Corundum has been found in a mica-schist near this place on Bull Mountain. (See p. 55.) No development of the occurrence has been made to determine the extent of the deposit or the percentage of corundum.

Whittles.—Emery. (See p. 140.)

ALASKA.

Copper River.—Asteriated corundum of gray and pink colors is said to occur in a locality on Copper River, Alaska.

DISTRIBUTION OF CORUNDUM IN FOREIGN COUNTRIES.

Until within the last few years there were no localities outside of the United States where corundum was mined for abrasive purposes, with the exception of the emery deposits of Turkey and of the Grecian Archipelago. This condition is now changed, and corundum has been mined in India and exported to the United States and to Europe. During 1901 the Canadian deposits of this mineral were commercially developed, the product going principally to Europe and the United States. This production has continued to increase each year since that time. Short descriptions are given below of those deposits that are of commercial importance.

CANADA.

The Canadian corundum deposits, which have been attracting considerable attention, are in the Province of Ontario. The corundum occurs as a primary constituent of syenite, pegmatite-syenite, and also of nepheline-syenite, and those rocks have been traced for over 50 miles across Renfrew, Hastings, and Haliburton counties, with smaller belts of the same rocks in Peterboro, Lanark, and Frontenac districts to the south, making a total distance of nearly 100 miles in which these rocks have been found.

The rock varies from a normal syenite to a nepheline-syenite, a mica-syenite, and a pegmatite-syenite. Corundum has been found in all four of these rocks, but it is more abundant in the normal syenite, which might well be classified as a corundum-syenite. These rocks, which occur as dikes cutting through the gneisses, are sometimes in large masses that appear to grade into granite. The dikes vary greatly in width, being usually a number of feet wide; a few have been observed, however, that were only a few inches wide and these were thickly studded with corundum crystals. Analyses of this rock from various parts of the occurrence show it to contain from 5 to 15 per cent of corundum.

The principal operator of these corundum deposits is the Canada Corundum Company (Limited), which owns deposits in the townships of Raglan, Radcliffe, Brudenell, Carlow, Monteagle, and Dungannon. This company's principal works are located at Craigmont, in the extreme northwestern part of Raglan Township, Renfrew County, about 8 miles southwest of Combermere, where a corundum mill, having a capacity of 15 tons of cleaned corundum a day, has been erected. The percentage of corundum in the commercial product is higher than in any corundum that has been put on the market for many years. When this corundum was first discovered in the normal syenite, the corundum on the surface showed a superficial alteration, which partially or wholly destroyed its abrasive value. As mining was carried deeper, however, this alteration was found to grow less and finally to disappear, so that the more recent tests of the commercial corundum from this mine show that it is giving very good satisfaction as an abrasive, and a very pure commercial corundum product is obtained. One of the chief difficulties encountered in cleaning this corundum was the elimination of the feldspar, but this difficulty has finally been overcome.

There are two other companies operating corundum deposits in this district. One, the Ontario Corundum Company, whose mine is situated at New Carlow, about 12 miles from Craigmont, has also erected a mill having a capacity of 4 tons of cleaned corundum per day. The other company is the Corundum Refiners (Limited), who own corundum deposits on Madawaska River, near Palmer Rapids, Renfrew County, and on York River, in Dungannon Township, near Bancroft, Hastings County. The location of the corundum-bearing rocks is indicated on the map (fig. 24).

Miller [a] has described specimens of corundum from Methuen Township, Peterboro County, that are entirely inclosed by mica. He says: "The corundum is often not observed in the mica until the latter is broken open, when it is found forming the center or core of

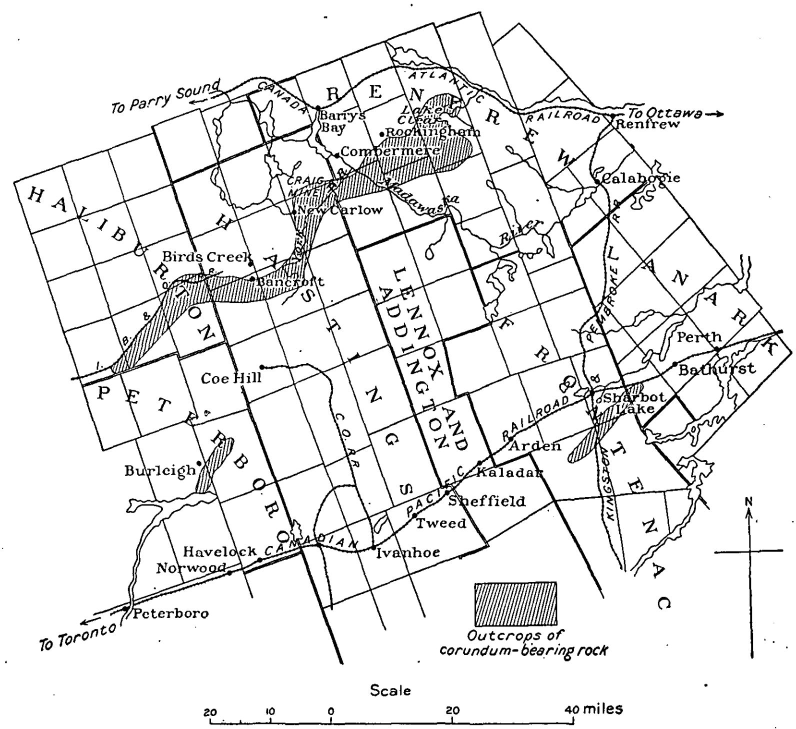

Fig. 24.—Map showing location of the corundum-bearing rocks of Ontario.

the mass. The rounded surfaces of the corundum and other characteristics lead to the belief that the masses of light-colored mica are secondary products after corundum." This very closely resembles specimens of corundum surrounded by muscovite mica that have been found in the Presley mine in Haywood County, N. C. (see p. 148), in which the muscovite is undoubtedly a secondary product after the corundum.

In the township of South Sherbrooke, Lanark County,[b] corundum has been found in a rock that is made up of a basic plagioclase feld-

[a] Rept. Bureau of Mines, Toronto, Ontario, vol. 8, pt. 2, 1899, p. 210.
[b] Loc. cit., p. 25.

spar and green hornblende, and has been called anorthosite by Miller. It is more basic in character than the typical varieties of this rock that have been described from other parts of Canada. The width of the belt of rock is nearly three-quarters of a mile and the corundum is found throughout the whole distance. It occurs in crystals of an almost uniform light-gray to white color that are usually about half an inch in diameter, the largest ones being 1¼ inches long.

AUSTRALIA.

In the central part of Queensland[a] there is an area of about 50 square miles where sapphires are found more or less abundantly in the old gravel and alluvial deposits. This was known as the Anakie sapphire fields, which are reached by the Central Railway, their station being Anakie, which is 26 miles from Emerald and 192 miles west of Rockhampton. The principal gravel deposits are along the banks of the Washpool, Retreat, Policeman, Serpentine, Tomahawk, and Central creeks. Sapphires have rarely been found in the streams themselves. Very few blue sapphires are found in these deposits, and the prevailing colors are various shades of green and yellow, the green stones being similar to those obtained from the Missouri River bars, described on page 109. Some of the Queensland stones are of bright green and yellow colors, making very handsome gems. The sapphires are often marked with hexagonal outlines, striations, etched figures similar to those described in the North Carolina rubies and Montana sapphires on pages 103 and 114.

The source of these sapphires is very probably the basaltic dikes which have been observed cutting the granitic rocks and in which some sapphires have been found.

INDIA.

The corundum deposits of India have been described by T. H. Holland.[b] He gives the Pararapatti area in the Salem district of the province of Upper Burma as one of the most promising for the mining of corundum for abrasive purposes. He describes the corundum as occurring in a matrix of deep flesh-colored feldspar which is in bands or lenticular masses, and has associated with it often a considerable proportion of sillimanite, rutile, opaque black and green spinel, and biotite. These masses, where they have been actually seen in the rock, are sometimes as much as 15 feet long and 8 feet in diameter. The feldspar rock is composed essentially of anorthite and hornblende, and in parts has a gneissoid structure, and these portions

[a] Dustan, B., Sapphire fields of Anakie: Special Report, Geol. Survey Queensland, 1902.

[b] Geology of India, pt. 3, Econ. Geol., and Rept. Bureau Mines, vol. 8, pt. 2, 1899, p. 230.

carry the corundum. The corundum varies from a deep purplish brown to a dark greenish gray, and is in irregular nodules varying from a quarter of an inch to an inch in diameter and in elongated barrel-shaped crystals sometimes an inch long.

There are two and perhaps more of these corundum-bearing bands that are parallel to each other; making the total known length of corundum-bearing rock over 24 miles. The percentage of corundum in the rock is very low, experiments that have been made on samples taken at different points on the band showing the presence of only 3.5 per cent.

Most of the outcrops of the bands of corundum rock have been found in connection with gneiss, and lie in lines that are roughly parallel to the strike of the gneiss. Some of them are, however, in close proximity to a nepheline-syenite.

Specimens of corundum sent by Dr. T. L. Walker from a district about 250 miles north of Calcutta and labeled "Pipra, South Rewah, India," are apparently similar to those described by Holland. The corundum is very fine grained in appearance and in nodules up to 2 or more inches long by 1 or more inches broad, with a pinkish to purplish-brown color. These nodules are partly or completely surrounded by a greenish mica, whose folia are small and rather brittle, and which has been referred by Mallet[a] to the euphyllite variety. In the mica there are small rough crystals of tourmaline. Just what the occurrence of this corundum is I do not know, but from the general appearance of the specimens it should make an ore from which the corundum could be readily separated and a very clean by-product obtained. If the corundum in the rock was 10 to 15 per cent of the quantity required to be removed in mining, this should make a very important and profitable corundum deposit.

In other specimens labeled "Salbanni," 4 miles east-southeast of Barampur, Manbhoorn district, India, there are blue crystals of corundum with a rough hexagonal prism embedded in a mass of interlocking bladed crystals of cyanite.

It is very probable that nearly all of the corundum deposits that are known in India are secondary minerals and the result of metamorphism. Professor Judd, in his paper on the Rubies of Burma and associated minerals,[b] says that all the corundum-bearing rocks in the districts of southern Asia appear to be gneisses which sometimes pass into schists and frequently contain masses of limestone and dolomite.

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[a] Mineral India, 1887, p. 130, and Dana's Mineralogy, 6th ed., 1892, p. 624.
[b] Trans. Royal Soc., London, 1896, p. 191.

BURMA, SIAM, AND CEYLON.

The finest sapphires that are known are found in Burma, Siam, and Ceylon, and have the rich, deep-blue color for which the oriental stone is noted. Sapphires of a rich, velvety blue, and some very good stones of a lighter color, have been obtained from Simla Pass, in the Himalaya Mountains.

In Ceylon, many varieties of corundum gems are found in the gravels of the streams and rivers of the Balangoda, Rakwana, and Ratnapura districts; but thus far none of the corundum gems have been found in place, and nothing definite is known as to their origin. Sapphires are much more common than the rubies. The stone for which the island is especially noted and which in some respects is peculiar to Ceylon is the star sapphire, or asteria. This stone, when cut en cabachon, exhibits a six-rayed star and in some instances a twelve-rayed star.[a]

TURKEY.

The Turkish emery is obtained from the province or vilayet of Aidin, in Asia Minor, which embraces nearly the entire basins of the rivers Sarabat and Mender. Smyrna is the principal town of the province, and is the center of trade for all the surrounding district and islands. The deposits that are now being worked are on the Gumush Dagh Mountain and on the slopes of Ak Sivri,[b] which is a mountain about 125 miles to the south. The former of these deposits is about 12 miles east of the ruins of Ephesus, and just north of the river Mender; the latter is in what J. Lawrence Smith[c] describes as the Kulah district, and it is much more inaccessible than the former. Emery has also been found in small quantities near Adula, a town about 12 or 15 miles east of Kulah, and also at Manser, about 24 miles north, and at Allahinan-Bourgs, about 20 miles south of Smyrna.

The occurrence of the emery at all these localities is very similar, it being embedded in a bluish, coarse-grained to compact marble or limestone, resting upon mica-slates, schists, and gneisses. It always occurs in the limestone or marble; not even a trace has as yet been found in the other rocks. It does not occur in a well-defined vein, but in pockets, scattered irregularly through the rock, that are sometimes 200 feet in length and 300 feet in width. The walls of these pockets are very irregular, as the limestone intrudes upon them and then recedes very suddenly.

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[a] Ceylon at St. Louis, 1904, p. 151.
[b] Trans. Am. Inst. Min. Eng., vol. 28, 1898, p. 206.
[c] Am. Jour. Sci., 2d ser., vol. 10, 1850, p. 357.

These emeries vary considerably in appearance. The Gumush Dagh is usually in fine grains and of a dark-blue to purplish color, and is similar to some varieties of magnetite. The interior of the masses of this emery are usually free from micaceous inclusions that are common to many emeries. The Kulah emery is coarser grained and much darker in color than the Gumush Dagh, and on its external surface it resembles sometimes the mineral chromite.

GRECIAN ARCHIPELAGO.

In a number of the islands of this archipelago emery has been found in considerable quantity. The most important of these localities is the island of Naxos, where the emery is found in large blocks more or less mixed with the red soil and also embedded in white marble. The deposits are located principally on the north and east sides of the island, the best ore being obtained from Vothrie, which is 9 miles from the coast. Another one of the better deposits on this island is at Apperonthos, which is 7 miles from the coast. In the southern part of the island the emery is found near Yasso. It occurs in such abundance on the island, in loose bowlders and in the soil, that there has been little need to mine it in the hard rock.

On the island of Nicaria emery has been found in quality equal to that from Naxos, but the quantity is not so great. A little was also found on the island of Samos. In all these islands the emery occurs in a limestone.

The Naxos emery is dark gray in color, with a mottled surface, and has small particles of a micaceous mineral disseminated through it. It often contains bluish particles of corundum that are readily recognized. Emery from the island of Nicaria sometimes presents a schistose or laminated structure, some of the specimens at times resembling certain gneisses. Its color is dark blue, and it is sometimes mottled like the Naxos emery. A compact variety is also found at this locality. There is in the schistose variety a considerable amount of micaceous mineral, which is readily observed. The emery from the island of Samos is of uniformly dark-blue color and is found in both coarse-grained and fine-grained varieties.

The mining of the emery is of the simplest character. Because of the great abundance of the ore that was found embedded in the soil and as loose bowlders it was many years before it was necessary to do much exploration of the rocks themselves. Blocks of ore, when not too large, are transported in their natural condition to the coast, but frequently they have to be broken, and when too large for this to be done with hammers they are heated for several hours, and then, on cooling, they usually yield to the blows of the hammer. Another method of breaking these large blocks is after heating to cool them suddenly with water.

The shipping point of the emery from all these localities is Smyrna, and, as it is usually taken as ballast, the cost of transportation is very low. Thus the actual cost of the emery laid down on the docks in a foreign port is about 1 cent per pound. This is one reason why there is such close competition between this emery and that of the United States.

OTHER LOCALITIES.

Corundum has been found sparingly at many other localities, but thus far it has not been found in quantity sufficient to make the occurrences of economic importance as a source of abrasive material.

The occurrence of sapphire corundum in Burma, Ceylon, and Siam has been mentioned on pages 98 and 155.

McMahon [a] has described sapphires from the Himalayas which were found in the southeast portion of the territories of the Maharaja of Kashmis, called Padar, on the borders of Zanskas. The corundum of blue and white colors occurs in a vein in crystalline rocks.

Lacroix, in a paper [b] on the metamorphic and eruptive rocks of Ariège, France, mentions the occurrence of corundum in the marbles of Mercus and Arignac. In a second paper [c] on acid inclusions in the volcanic rocks of the Auvergne, France, corundum is said to occur frequently in the granites and gneisses of this section. He has also described the occurrence of this mineral in the basalts, trachytes, and andesites in Haute-Loire, France.[d]

Salomon [e] has described the occurrence of corundum in phyllites, epidote-amphibolites, and mica-schists at Mount Aviólo, in the southern Alps. It occurs but sparingly in these rocks.

Heddle [f] has noted the occurrence of sapphire at Clashnaree Hill, in Clova, Aberdeenshire, Scotland. The mineral occurs sparingly with red andalusite in veins in a schistose rock.

Dana [g] mentions the occurrence of corundum near Canton, China; in Bohemia, near Petschau; at St. Gotthard, in dolomite; near Mozzo, in Piedmont, in white compact feldspar; and at Mudgee, New South Wales.

In the dune sands on the west coast of Holland, at Scheveningen, near The Hague, corundum has been found by Retgers [h] to be one of its constituents.

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[a] Mineral. Mag., vol. 7, 1886–87, p. 12.

[b] Bull. Serv. Carte géol. France, No. 11, vol. 2; and Am. Naturalist, Feb., 1891, pp. 138–139.

[c] Loc. cit.

[d] Bull. Soc. minéral., vol. 13, 1890, pp. 100–106.

[e] Jour. Deutsch. geol. Gesell., vol. 42, 1890, p. 450; and Am. Naturalist, 1891, pp. 571, 572.

[f] Mineral. Mag., vol. 9, 1890–91, p. 389.

[g] Mineralogy, 6th ed., 1892, p. 212.

[h] Recueil trav. chim. Pays-Bas, vol. 11, 1892, p. 169; and Am. Naturalist, 1893, p. 382.

Zirkel[a] mentions the occurrence of corundum as an accessory mineral in the amphibolites of northwestern Austrian Silesia; in the chlorite-schist of Nizhne-Issetsk, in the Urals; as a contact product of the diorites of Klausen, in Tyrol; in the andesite and tonalite of the Eifel; in a contact product of quartz-mica-diorite on quartz-phyllite in Val Moja, and similarly in the kersantite of Michaelstein, Harz; also in the graphite of Mühldorf, near Spitz, in lower Austria.

In describing the geology of the district around Pretoria, South Africa, Molengraaf[b] states that the oldest rocks of the region are granites and crystalline schists. Above these are another series of schist formations, comprising quartzites, clay slates, corundum schists, porphyroids, and chiastolite-schists that are cut by diabase dikes. He states that the corundum porphyroid resembles a feldspar porphyry, and that the corundum occurs in large individuals in a groundmass of quartz and chlorite. From the description given, there is a possibility that there is corundum in quantity in this district.

Pirsson[c] mentions the occurrence of corundum in small blue sapphires in the fresh basalt of Unkel on the Rhine and Steinheim, near Frankfort on the Main.

Morozewicz[d] has described the occurrences of corundum in Russia, the chief of which is in a rock composed essentially of anorthite and corundum, together with spinel and biotite. He claims that this is a new type of alumino-silicate rock and calls it "kyschtymite." Other rocks in the Urals that contain corundum are made up almost exclusively of this mineral and orthoclase; some of these are coarse grained, while others are fine. The coarse ones have been called corundum-pegmatite and the finer ones corundum-syenite. These rocks occur as dikes cutting through gneiss. It may be that when these corundum-bearing rocks of the Urals have been more specially examined as to their economic value they will be found to contain enough corundum to make them of importance as an ore of this mineral.

In many parts of the western Yunnan district, China, as in the prefecture of Shunning Fu, sapphire, ruby, and emerald corundum are said to occur.[e]

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[a] Lehrbuch der Petrographie, Leipsic, 1893, p. 461.

[b] Neues Jahrbuch für Mineral., vol. 9, 1894–95, pp. 174–291; and Am. Naturalist, 1895, p. 470.

[c] Am. Jour. Sci., 4th ser., vol. 4, 1897, p. 422.

[d] Tschermaks mineral. und pet. Mittheil., vol. 18, pt. 1; and Rept. Bureau of Mines, Toronto, vol. 8, pt. 2, 1899, p. 285.

[e] U. S. Cons. Repts., Jan. 1900, vol. 72, No. 232, p. 95; reprinted from Mesny's Chinese Miscellany, published at Shanghai, China.

TECHNOLOGY OF CORUNDUM.

METHODS OF MINING.

In considering the methods used in mining corundum it must be borne in mind that up to the past few years this mineral had only been obtained in quantity where it was associated with peridotite rocks. These rocks, as will be shown later, present certain difficulties which, if not overcome, will cause considerable delay and danger in mining. Where the corundum occurs in amphibolite, as at Chester, Mass., these difficulties are not so evident, and the mining operations can be carried on as in any metal mining. If the corundum occurs in gneiss, quartz-schist, or syenite, the ore can often be advantageously mined by means of open cuts, as at the Craig mine, Ontario, Canada. If the corundum-bearing portion of the rock is narrow it will be found more economical to mine by shafts, drifts, and crosscuts, as at the Montana deposits. As these latter occurrences of corundum offer no serious problems in mining, no description is given of their mining operations. As, however, corundum in peridotite does present certain difficulties to the miner these are treated briefly.

Nearly all of the peridotite formations in which the corundum deposits occur are bold outcrops on mountain sides and hilltops, having almost perfect natural drainage. At all the localities where there has been no mining the little prospecting has been usually by means of open cuts supplemented by tunnels. While at first mining by means of cuts may seem to be the most advantageous, it is soon found to be expensive. These cuts, or any other openings made over the surface of the peridotite, offer a much greater opportunity for surface water and frost to penetrate the mass of the rock formation. These rocks are more or less seamed or cracked, usually to the depth that alteration can extend, and thus they offer opportunities for the infiltration of water. As most of the alteration products of this peridotite formation are slippery, hydrous magnesium minerals, such as serpentine and talc, and as these are developed in the seams and cracks of the peridotite, anything that is done to disturb them will make them very liable to slip. At the Corundum Hill mine there are large masses of peridotite that have become loosened and have gradually slipped down and closed up some of the tunnels, and there is constant danger that fragments of the rock will fall into the cuts and some of the tunnels. At the Laurel Creek mine a mass of peridotite with soil, etc., nearly a 200-foot cube, has become loosened and slipped downward, effectually closing up the tunnel and shaft of the Big vein.

In mining corundum associated with peridotite rocks it is therefore advisable not to break the surface of the formation any more than is absolutely necessary and to do no work at all along the contact by means of open cuts, but to confine the mining to a system of tunnels and shafts. This method of mining will be found the cheapest in the end. Moreover, all the tunnels and shafts should be well timbered and the mine kept as thoroughly drained as possible.

A large amount of the material that must be handled is easily worked with pick and shovel, as it consists of the crystals and fragments of corundum in the zone of chlorite and vermiculite. In those veins in which the corundum is associated with feldspar, as at Laurel Creek and Buck Creek, and those in which there is considerable amphibole or enstatite, as at Corundum Hill, blasting is necessary.

If the mill is located some distance from the mine and if a line of sluice boxes can be built between the two, the more or less finely divided ore may be carried to the mill by means of these boxes. In this way the ore is partly cleaned by the time it reaches the mill. This is the method employed at the Corundum Hill mine.

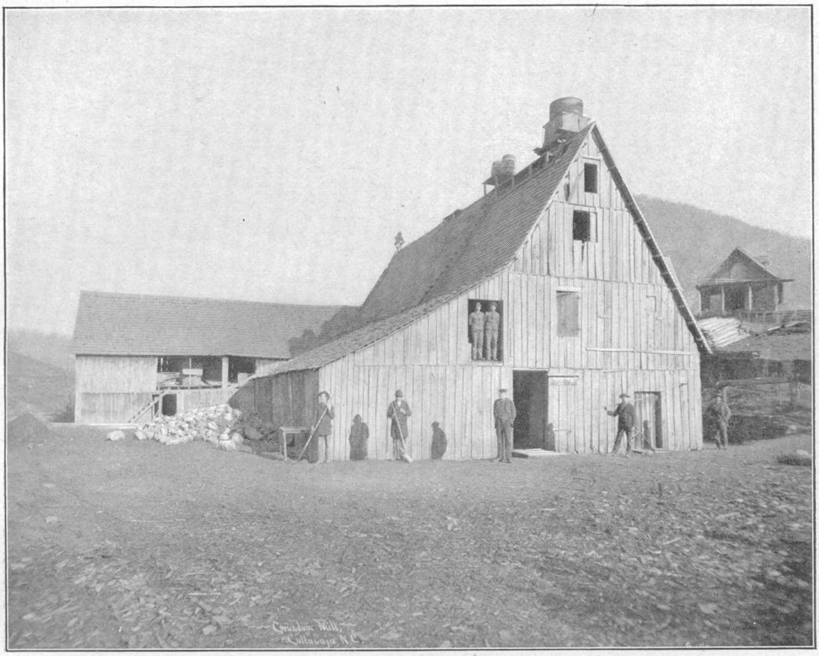
All of the gem corundum is mined by hydraulic methods similar to those used in sluicing placer gold, with the exception that the concentrates containing the sapphires are removed from the sluice boxes and further concentrated in a circular sieve either held in the hand or mounted; and by giving this sieve a certain circular motion the grains and crystals of corundum are collected in the center and at the bottom of the sieve. In accomplishing this separation it is necessary to screen the grains of the concentrates to nearly the same size before using the sieve. From the nearly pure sapphire concentrates the good stones are picked out by hand.

METHODS OF CLEANING.

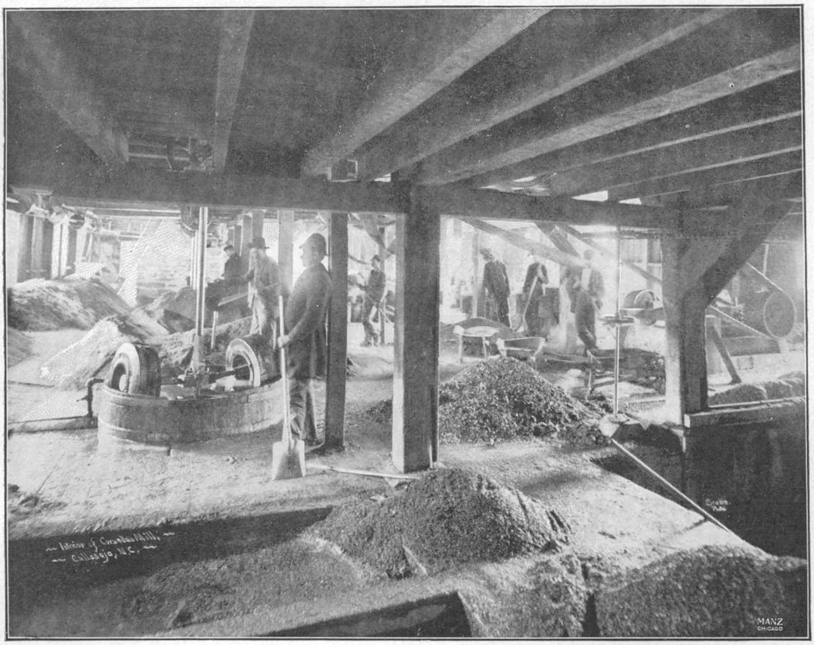
The difference between the commercial product and the ore as it comes from the mine is that the latter has been freed as far as possible of all impurities, so that the resulting product is or should be nearly pure corundum or emery.

Formerly there was but one method in use for cleaning corundum or emery ore, principally because the ore to be cleaned occurred either in peridotites or amphibolites; but now there are many differences to be noted in the various mills erected for the cleaning of corundum. This is due to the commercial sources of corundum being in syenites, etc., as well as in peridotites. It may be of interest to give a short description of the old method of treating the corundum ores, and of one which, with a few modifications, is applicable to corundum obtained from syenites.

The ore is crushed and sieved, and all that will not pass through a No. 12 screen is recrushed and passed between rollers until it is reduced to the desired size. Most of the impurities are then easily removed by conveying the crushed ore into boxes through which runs



A



B

CORUNDUM MILL AT CULLASAGEE, MACON COUNTY, N. C.

A, Exterior view; *B*, interior view.

a stream of water, so regulated that the corundum readily settles to the bottom of the trough and the lighter minerals are carried off. This washing process will remove only the impurities that are entirely separated from the particles of corundum, but there are usually some impurities attached to the particles or grains that have to be removed by another process. The product is therefore passed through a machine known as the screw or scouring machine, in which there is a coarse worm similar to the screw conveyer. This grinds out almost all of the impurities, and these are separated by again subjecting them to the washing process. The final impurities are separated from the particles of corundum by means of a machine called the "muller" or "chaser." (See Pl. XVIII, *B*.) The principle of this is to cause each grain of corundum to rub against another and thus wear away the adhering foreign substances. The machine consists of a shallow tub, in which are two heavy wooden rollers which move around its circumference. The freshly ground corundum on being thrown into these tubs is kept constantly stirred up by men with hoes or by plow-shaped iron blades in front of the wooden rollers, and is then pressed down by the rollers being passed over it. In this way the scouring motion is kept up between the grains. The impurities are thus gradually worn away and are carried off by a stream of water that flows continually through the tub. It usually requires from four to eight hours, according to the nature of the impurities that are attached to the corundum grains, to obtain a clean product.

There are two methods of drying this product, after it has been removed from the mullers and allowed to lie over night on inclined floors. By one method this product is conveyed by elevator belts to the second floor of the mill and dropped vertically for a distance of 20 to 30 feet down the stack of a furnace. At the bottom it strikes an inclined surface that is just above the flames of the furnace and slides down this surface into an iron box. By the other method the wet product is thrown in at the upper end of an iron cylinder, open at both ends, which revolves about a coil of steam pipes. One end of the cylinder is lower than the other, and the wet mass is alternately carried up by the revolving cylinder and dropped on the hot coil of pipes, and thus gradually worked toward the lower end, where it is caught in a hopper and conveyed by elevator belts to the sizing room. Here it is automatically screened to the various sizes.

In Pl. XVIII, *A* and *B*, are views of the exterior and the interior of the corundum mill at Cullasagee. In the foreground of *B* are the boxes in which the ore is first washed, and just beyond these are the mullers.

Only within the last few years has any attempt been made to improve the methods of concentrating and cleaning corundum.

There are now a number of companies that have installed complete concentrating mills, similar to those used in concentrating gold ores, but modified to suit corundum ore. While all are using jigs for the coarser sizes of the crushed ore, some are using Frue vanners and others Bartlett or Wilfley tables for the finer sizes. This method works very satisfactorily for concentrating the corundum, and if during the crushing and rolling of the ore the corundum is largely separated from the associated minerals a nearly cleaned product is obtained. Methods of separation similar to that last mentioned are being employed by the Canada Corundum Company on the ores from the Craig mine and by the Montana Corundum Company on the Gallatin County ores. Where, however, there are foreign minerals, especially mica, attached to the particles of corundum, it is necessary to adopt some process similar to that performed by the mullers in order to eliminate the foreign minerals.

Many other minerals that will be likely to remain with the corundum in the concentrates—as garnet, pyrite, etc.—can undoubtedly be separated by means of the Wetherill magnetic concentrator. Unless these minerals are unattached to the particles of corundum there will be a considerable loss of corundum by this method of separation.

USES OF CORUNDUM.

WATCH JEWELS.

Corundum is used for two general purposes, as gems and as an abrasive.

The varieties of corundum that are of value as gems have been described on page 22, and the many uses that are made of the cut stones in the jewelry trade are too well known to need more than a passing notice here. One use of the gem corundum that is perhaps worthy of notice is in supplying jewels for watches.

In a recent report by Mr. George F. Kunz,[a] it is stated that there are from 10,000,000 to 20,000,000 watch jewels sold annually. For this purpose corundum gems of all colors are used. Some of these are sapphires and rubies which are fine enough in quality to make gems, but of which only minute pieces are used. There are also used those corundum gems which are of such color as to have little or no value as jewels, such as very pale sapphires and the pink, greenish, and yellow corundums.

Many of the sapphires from Yogo Gulch, Fergus County, Mont., and the many colored corundum crystals from Granite County, Mont., which have but little value for cutting into jewels, are used for this

[a] Mineral Resources U. S. for 1903, U. S. Geol. Survey, 1904, p. 974.

purpose. The prices reported as having been received for these American gems are from $1 to $5 per ounce, and they represent at the present time an important factor in sapphire mining in the United States. In regard to the utilization of these stones, Mr. Kunz says:

In Switzerland most of the jewels are cut and sold in boxes of from 500 to 1,000 per box. Each stone has been given a rounded form and is pierced in the center, the drill hole being smaller by a minute quantity than the diameter of the axle which it is to hold. The bed of the stone in the watch is a small cylinder, apparently of brass, but in reality consisting of a soft-gold alloy. Before the stone is handed to the watchmaker it is put in a lathe, and by means of a tiny steel drill, covered with oil and diamond dust, the central opening is enlarged sufficiently to enable the steel axle or pin for which it is intended to fit into it accurately. The watchmaker first fixes the cylinder in the lathe, then picks up the stone with the moistened finger and inserts it in the cylinder while the latter is turning with the axis of the lathe. With a pointed tool the workman next presses against the edge of the revolving cylinder and thus forces the soft metal to cover and protect the sapphire or ruby to such an extent that it appears as if embedded in a metallic cushion. Next a drill is inserted in the metallic coat of the cylinder from the opposite side of the lathe, and a hole is drilled in this coat exactly of the same size as the hole in the stone itself. A great variety of forms have been made recently, not only for watches but for electric and other meters. The latter, as compared with watches, require a greater and more enduring life in the jewels, which, owing to the microscopic inclusions, either of softer minerals or of fluid cavities, is often shortened materially. Sapphires, rubies, and even diamonds are used with wonderful ingenuity, and with the increasing demand for hard bearings in the endless variety of electrical devices, in which the moving points revolve rapidly, there is much to be looked for in the way of new devices, and a greatly increased demand for jeweled bearings is probable.

CORUNDUM WHEELS.

Although an examination of a corundum property may show the existence of considerable quantity of the mineral, no mining should be undertaken until satisfactory tests have been made upon the corundum to prove that it has those properties that will make it of value as an abrasive.

The value of a corundum deposit as an ore for abrasive purposes depends upon that property of the mineral which enables it to retain a sharp edge, known as a cutting edge, when it is crushed to grains. All corundums do not have this property, and many that exhibit it in the first stage of the crushing do not show it in the finer fragments and grains. This is more apparent when the corundum has been made into a wheel, for when first used the wheel may do good work, especially if it is a coarse-grained wheel, but as it wears away the grains of corundum become rounded instead of breaking to a cutting edge. In estimating the value of a corundum deposit it is therefore very essential to determine the abrasive qualities of the corundum. Neither a chemical analysis nor a superficial examination of a corundum ore will determine its cutting qualities, and this can be obtained only by making the corundum into a wheel and testing it.

In estimating the value of an ore it is also necessary to determine to what degree of purity it can be cleaned or what percentage of the commercial product will be corundum, and also what will be the nature of the foreign minerals. A foreign mineral will always be softer than the corundum and will to a certain extent reduce its abrasive power. Beyond this the presence of a small amount of foreign mineral does not materially affect the value of the corundum for making a cement or chemical wheel, but is often the reason for discarding it in manufacturing a vitrified wheel on account of the low fusibility of the foreign substance. Garnet is perhaps the most objectionable mineral in a corundum ore, it being very difficult to separate it from the corundum, because the specific gravity of the two is nearly the same. Corundum containing even a little of the garnet can not be used in the manufacture of the vitrified wheel.

Both corundum and emery are used in the manufacture of abrasive materials, and these are on the market in three forms, as wheels and blocks of various shapes and sizes, as emery paper, and as grains or powder. The last two need no further explanation, but a description of the first is of importance.

The shapes of the corundum and emery wheels and bricks or stones are extremely varied, being adapted to all kinds of grinding. The principle of these wheels is the same at that of the rotary files; and as the points of a file become dull from using, so also do the grains or points of the emery and corundum in the wheel. In making a wheel it is necessary, therefore, to make it of such a temper or grade that when the grains become dull or rounded they will fall away or will be readily removed by a truing tool, and fresh, sharp grains will be exposed. The grade of a wheel depends upon the character of the work for which it is to be used, and the bonding material should be such that it will wear away a little faster than the corundum or emery, and thus always leave the sharp edges ready for cutting. The greatest economy is effected when the bond does not wear away until the grains of emery or corundum have become rounded or dulled, thus permitting the wheel to do its greatest amount of work.

Before leaving the factory all wheels should be thoroughly tested to a higher strain than that to which they are to be subjected in actual use; as the wheels have to be run at a very high velocity in order to secure the greatest efficiency, there is at times but little reserve strength, and a sudden blow will often cause them to fly to pieces.

To give an idea of the number of different wheels that the larger emery-wheel companies are prepared to make, I can not do better than to mention what I saw and what was told me at the works of the Norton Emery Wheel Company, at Worcester, Mass. The wheels are manufactured for the special work for which they are intended, and vary in shape, in bond, and in grain of corundum. The sizes of corundum that are used are Nos. 12, 14, 16, 20, 24, 30, 36, 40, 50, 54, 60, 70, 80, 90, 100, 120, 150, 160, 180, 200, and 6 grades of flour corundum. The bond has 26 degrees of hardness, represented by the letters of the alphabet, although a bond is seldom used softer than E or harder than M. There are 408 different sizes of circular wheels, so that the different grades of wheels possible are almost unlimited. (See figs. 25 and 26.)

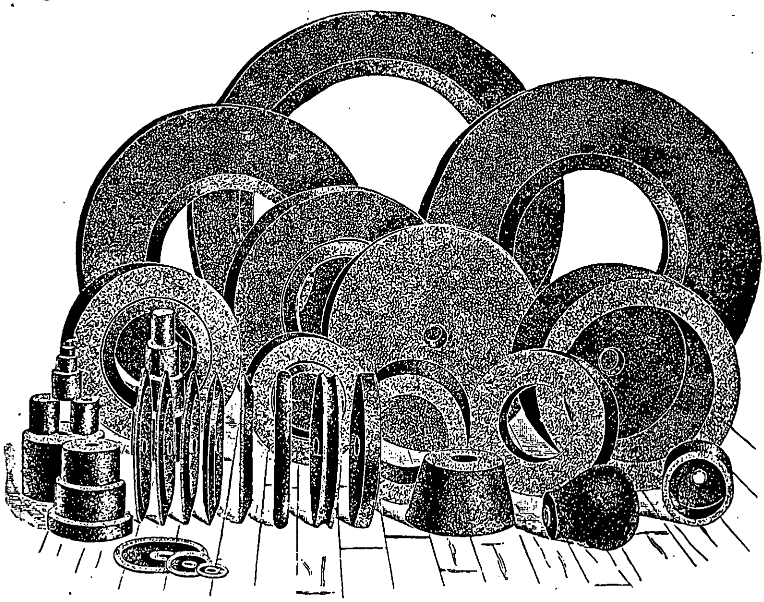


FIG. 25.—Emery and corundum wheels and stones adapted for all kinds of abrasive work.

There are three types of wheels known to the trade—vitrified, chemical, and cement—the names being derived from the process by which they are manufactured. In the manufacture of all, the corundum or emery used is in grains of uniform size, but varies with the grade of wheel that is to be made. The vitrified wheel is the most important and most generally used, although for some work one of the others is preferable, and for very large wheels the chemical is especially adapted.

VITRIFIED WHEEL.

In the manufacture of this wheel more care is necessary in the selection of the corundum, for in the vitrification of the bond foreign minerals containing water are very likely to cause the wheel to burst.

The corundum grains are mixed thoroughly in a paste of prepared clay and other binding materials, which is then poured into paper molds and set aside in a drying room until hard enough to be readily handled. When the molds are sufficiently dry they are subjected to a dressing or trimming process and shaped to approximate dimensions on a potter's wheel or a shaving machine, and are then further dried. The excess of mechanically included water having evaporated, they are then ready for the kilns. The kilns are cone shaped, and the inside measurements vary from 12 to 20 feet in height and from 10 to 18 feet in diameter. When the kiln is filled with the emery wheels the entrance is closed and sealed and the fires are started. The temperature is allowed to rise slowly until all the water

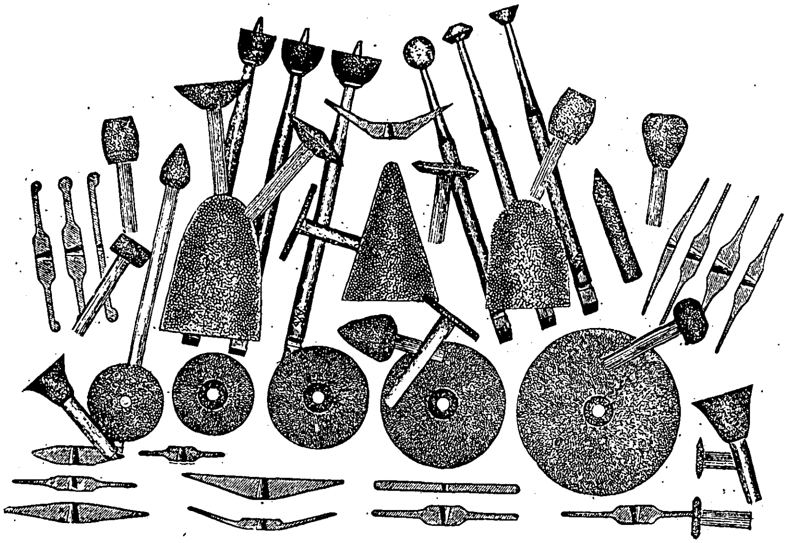


FIG. 26.—Dental points, wheels, etc., made of corundum.

of mechanical admixture and of crystallization in the foreign materials is driven off, when the temperature is raised to about 3,000°, or to a white heat, this heating process requiring several days. Where the foreign materials mixed with the corundum contain water of composition that is driven off only at a very high temperature the wheels are apt to be broken by this water coming off when the temperature of the kiln is raised to the fusing point of the clay. The clay and other binding materials fuse and form a porcelain setting for each fragment of corundum, which makes a very strong bond. The kilns are allowed to cool very slowly, several days being required for this. The kiln is then opened and the wheels are brought to a lathe, called the "truing machine," where they are turned to the exact dimensions desired, the hole is bushed to the exact size, and the wheel is then trued and balanced ready for shipping.

The heat necessary for the fusion in making the vitrified wheel apparently has no effect upon the corundum beyond a partial decolorization and the expulsion of the slight percentage of water in the corundum.

CHEMICAL WHEEL.

In the process of manufacturing this wheel, called the silicate process, silicate of soda is used as the binding material. The silicate is mixed with the emery or corundum and some drying material and tamped into molds. It is then subjected to an "oven" heat for twenty-four hours, after which it is removed and finished according to the method described above for the vitrified wheels after they are removed from the kilns. Wheels over 2,000 pounds in weight have been made by this process.

CEMENT WHEEL.

In the cement wheel, shellac, rubber, linseed oil, and other substances are used as the binding material. This makes a soft wheel that is well adapted for roll and surface grinding when made with shellac, and for saw gummers and thin wheels when made with oils.

OTHER USES.

An attempt has been made to use corundum as a source of aluminum, but on account of its refractoriness and the percentage of ferric oxide and silica that it often contains, and on account of the cost of the ore, this use has not been found feasible.

The late Mr. Alfred E. Hunt, of Pittsburg, Pa., made the following statement:[a]

> The real difficulty which we find in the use of corundum for this manufacture is the cost of the raw material as compared with that of native bauxites. In this item we include not only the price of the corundum as it has been offered to us, but also the expense of grinding it to an impalpable powder, which must be done before it can be used directly in the manufacture of aluminum, and the cost of preliminary chemical treatment for purification—which latter operation, however, is also required for bauxite.

Corundum has also been used as the source of the aluminum in the manufacture of aluminum-copper and aluminum-iron alloys. In the manufacture of these the corundum, without undergoing any previous treatment, was charged into an electric furnace with a mixture of carbon and copper or carbon and iron, according to whether aluminum bronze or ferro-aluminum was desired. Since 1890, however, when alumina began to be manufactured at a comparatively low price, this artificial oxide has been used in the place of the corundum.

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[a] Trans. Am. Inst. Min. Eng., vol. 28, 1898, p. 875.

SUGGESTIONS TO PROSPECTORS FOR CORUNDUM.

Many of the early discoveries of corundum were made as discoveries of many of the other minerals have been made—that is, by the accidental finding of fragments, which led to systematic search, resulting in many cases in the location of extended deposits. The presence of other minerals associated with corundum are important indications of its existence. Thus the presence of margarite at the old iron mine at Chester, Mass., was to Prof. A. T. Jackson, who was familiar with its occurrence, an indication that corundum would be found. His prediction was realized a short time later by the finding of the emery variety of corundum, and there subsequently followed the conversion of a profitless iron mine into an extensive and profitable emery mine. The finding of chlorite in connection with peridotite rocks has been the starting point for the location of a number of large corundum deposits.

To anyone who wishes to search for corundum it is suggested that he be thoroughly familiar with the mineral itself, as well as with its associates, for many instances could be cited where other minerals have been mistaken for it. Thus the mineral albite, one of the feldspars, is sometimes very similar in appearance to corundum, and has been mistaken for it, but the specific gravity and the hardness should at once distinguish it from corundum, albite being much lighter and softer. It is well in prospecting for corundum always to have a specimen of the pure mineral at hand with which to test the hardness of any material that may be supposed to be corundum. In testing the hardness of a mineral care should be taken that all decomposed and altered material be broken away and that the test be made on the pure unaltered material.

Where it is possible the prospector should visit either a corundum mine or a locality where prospecting has been done and corundum been found in place, and thus become acquainted with the rocks inclosing it and its general occurrence. As has been shown in the preceding pages, it is rare that any two localities are exact duplications of each other, even when they are close together, yet there are certain minerals that are to be found in the same type of rock at nearly all of those occurrences, and familiarity with these, even though but from one locality, will be of considerable value in the search for new localities.

Where the deposits of corundum are associated with the peridotites the mineral will be found chiefly near the contact of the peridotite with the gneiss or other country rock, and the deposits within the peridotite area will usually be small and in a short distance pinch out. Hence in prospecting over a peridotite area a careful, systematic search should be made along the line of contact. Corundum may often be observed first within the peridotite area, and, when this is the case, a larger deposit may very reasonably be expected to be found near the contact.

If, when examining a peridotite formation, no corundum is found along the contact of this rock with the gneiss or other country rocks, there is little or no need of searching in the midst of the formation, for it is only at the contact that any large deposit may be expected to be found. Again, if there are no fragments of corundum to be found at the lower borders of a peridotite formation and none can be obtained by panning the gravel of the streams flowing by them, there is but little probability that success will attend any further search. It should also be borne in mind that at all the peridotite localities examined no more than traces of corundum have been found where there is a quantity of chromite, and that, on the other hand, where there is much corundum there is a scarcity of chromite.

Where crystals and fragments of corundum are found in gravel beds or in the soil, they of course indicate the existence of corundum deposits at some distance from where they are found. On account of the stability of this mineral when exposed on the surface, it may have been transported long distances down the mountain slopes without showing any appreciable alteration and but little abrasion. When, however, it is associated with certain minerals, as fragments of chrysolite (olivine), chlorite, or talc, it is very probable that they have been transported but a short distance, for these minerals would have been almost entirely disintegrated and worn away before they could have been transported very far or exposed very long to surface influences. Where such fragments have been found, they should be followed up the valley or incline by which they could have most naturally reached their position. When following up these gravel deposits, whether they are in the actual or in the old beds of the streams, they should be tested at intervals by panning, until a point is reached beyond which no corundum is found in the gravel, and then the search should be carried on up the hillsides until the parent rock is located. If this rock is a peridotite, its contact with the other country rock should be carefully examined. Where there is considerable soil and decomposed surface materials, the contact can not always be at once located, and then ditches should be cut through the soil at right angles to the strike of the rock itself. When the contact has been found, the border zones of the minerals should be examined for corundum, a guide at this point being the chlorites and vermiculites that have always been observed surrounding corundum at the contact of a peridotite with a gneiss or other country rock.

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