CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN MCLEISH, DIRECTOR

# ABRASIVES

PRODUCTS OF CANADA
TECHNOLOGY AND APPLICATION

## Part II

# Corundum and Diamond

BY

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## INTRODUCTORY

In recognition of the importance of the abrasive industry, and the numerous inquiries concerning the uses, sources of supply, preparation and markets of the numerous minerals and materials included under the heading of Abrasives, the writer has made an investigation resulting in a series of bulletins embracing the subject in all its phases.

The following publications dealing with abrasives are issued as separate bulletins:—

Part I. Siliceous Abrasives: Sandstones, Quartz, Tripoli, Pumice, and Volcanic Dust.

Part II. Corundum and Diamond.

Part III. Garnet.

Part IV. Artificial Abrasives and Manufactured Abrasive Products and their Uses.

In the bulletin on Siliceous Abrasives will be found a general introductory and a table giving the varieties of natural abrasives, forms in which they are used and their principal uses, also a table showing the production of the various natural abrasives by countries between 1913 and 1923.

In this bulletin on Corundum a considerable amount of information has been summarized from reports by Dr. W. G. Miller and Dr. A. E. Barlow and brought up to date. An account of the emery industry and a few notes on abrasive diamonds are also included as well as a brief description of the principal deposits, production, and methods of treatment of the foreign materials.

# PART II

## CORUNDUM

Corundum, an oxide of aluminium, is, with the exception of diamond, the hardest mineral known.

### GENERAL HISTORY

It is only within the last century that corundum, in the form of grain, has been commercially used for abrasive purposes. However, it is believed that it was utilized, probably in the form of natural crystals, by the ancient Egyptians for carving hieroglyphics on their stone monuments.

In ancient times the only known use for corundum was as jewels, the gems, ruby and sapphire, being transparent forms of the purest corundum coloured either red or blue by certain other minerals. Much has been written by the early Greek and Roman writers concerning these gems which reveals an intimate knowledge of their physical properties, although they did not recognize them as different forms of the same mineral.

It was not until 1798 that the Hon. Charles Greville[1] described corundum as the crystallized form of the oxide of aluminium, and in 1805 Huay united the three forms, sapphire, corundum, and emery under the name of corundum.

Emery, which is a mixture of corundum and iron oxides, has been used as an abrasive for several centuries and is recorded as being first mined on the island of Naxos in the Grecian archipelago.

A little over a century ago true corundum was recognized in the United States from a sample found in the Laurens district, South Carolina[2], but it was not until after the discovery of emery at Chester, Massachusetts, by Dr. H. S. Lucas in 1864, that corundum mining for abrasive purposes was begun on the American continent.

### PHYSICAL AND CHEMICAL PROPERTIES

#### *Composition*

Corundum is the sesquioxide of aluminium ($Al_2O_3$) and has a theoretical composition of 52·9 per cent aluminium and 47·1 per cent oxygen, although it invariably contains small amounts of impurities such as silica, iron, lime, water, etc. (*See* Table I.) It is practically unaffected by even the strongest acids.

#### *Varieties of Corundum*

The mineral corundum is generally classified into three groups:—

(1) Sapphire or gem stone group which includes all the transparent varieties which are suitable for cutting and are recognized by name according to their colour, thus the red is ruby, blue is sapphire, yellow and green are sometimes called topaz and emeralds, though the last named is of entirely

[1] Phil. Trans. Roy. Soc., London, p. 403 (1798).
[2] Kunz: Gems and Precious Stones of North America, p. 42 (1892).

### *Colour and Lustre*

Corundum varies widely in colour, and shades from the intense blues and reds of the gems into the opaque dull hues through white, grey, pink, bluish to brown or bronze, depending on the impurities present and the state of decomposition. Often in an individual crystal the shading from the deeper colour in the centre to the lighter on the outside is not uncommon and is characteristic of the blue corundums of Dungannon township, Ontario. The most common colour is brown.

The lustre is adamantine to vitreous and in some cases pearly.

### *Crystalline Structure*

Corundum crystallizes in the rhombohedral division of the hexagonal system. In Canada it usually occurs as long, six-sided prisms that taper off towards either end from the centre, but it also occurs as short and stubby crystals assuming a barrel- or mallet-shaped outline. The light-coloured varieties generally occur as the latter form, whereas the brown or bronze crystals are more frequently long. The ends of the crystals are striated forming equilateral triangles, and the faces often show distinct cross-hatching. The common lamellar structure is due to twinning.

### *Fracture*

Although the gem varieties break with a conchoidal fracture, common corundum has a prominent basal cleavage that causes the crystals to break readily with smooth flat surfaces at right angles to the axis of elongation. It is believed, however, that these so-called cleavage planes are probably in reality parting planes along which the mineral undergoes certain chemical changes. This accounts for the pearly lustre on the faces of some specimens and for the bronze-like hue on others.

### *Hardness*

Next to diamond, corundum is the hardest mineral known, its value being 9 on Moh's scale. The hardness is, however, not uniform, even in the same varieties, thus, sapphire will scratch ruby, ruby will scratch the opaque corundum, and some variations exist among the latter varieties themselves. These variations appear to be mainly due to the state of purity of the mineral, particularly in the amount of contained water; the smaller the water content the harder is the mineral.

### *Specific Gravity*

Specific gravity of corundum varies from 4·10 to 3·93 depending on the amount of impurities present. The sapphire and ruby average 4·0, the former being slightly heavier. Some of the Canadian white or blue specimens are as high as 4·0, but the average is 3·95.

### *Optical Properties*

Corundum is next to diamond in permeability to passage of the Röntgen or X-rays, a characteristic which serves to distinguish the true gems from artificial stones, as well as from minerals such as garnet or coloured quartz. It has a high refractive index, but a low double refraction. In the gem varieties pleochroism is very strongly marked.

*Alteration of Corundum*

Although corundum is one of the most resistant of substances when subjected to weathering, it is believed that it undergoes decomposition and produces a number of other minerals.[1] However, the creation of parting planes such as are found in the Ontario corundums are apparently the result of the development of these films of softer aluminous minerals.[2] A very striking example of this occurs in the Blue Mountain corundum in Methuen township, where in every instance a pearly white muscovite mica in every gradation is found in the process of replacement of the corundum.

## USES OF CORUNDUM

### Production of Aluminium and Aluminium Alloys

On account of the high percentage of aluminium in corundum (theoretically 53 per cent) it has been suggested as a source of this metal. The material must, however, be pure corundum, and the expense of mining, concentration and grinding, as well as the competition from the comparatively cheap and softer aluminous minerals such as bauxite, has prevented its commercial use for this purpose. Previous to 1890, it was, however, sometimes used as a carrier of aluminium in the manufacture of copper- and iron-aluminium alloys.

### Gems

The use of the pure, transparent and highly coloured varieties of corundum for precious stones, such as ruby and sapphire, has been previously mentioned. Burma is the principal source of these stones.

### Watch Jewels

The small crystals of gem corundum that are too small for cutting into gem stones or do not possess the correct deep shades of colour are used as bearings for watches.

### Abrasive Qualities of Corundum

Practically the only use for the opaque forms of corundum is as an abrasive. The various qualifications of a good natural abrasive which have been discussed in the General Preface of the bulletin on Siliceous Abrasives apply to corundum. All corundums are, however, not equally effective for this purpose, and it would appear that since the hardest corundums are those which carry the least impurities and water of composition they would make the best abrasives. However, it is more the purity of the mineral, rather than the actual hardness which determines its abrasive qualities, since the purity has a significant bearing on the presence of the parting planes and their spacing. Thus the fewer the parting planes and the wider the lamellae between the polysynthetic twinnings, the greater will be the tendency for the mineral to crush into the requisite sharp and angular strips, rather than into flat pieces. A corundum that

[1] Genth, Dr. F. D.: "Corundum—Its Alterations and Associated Minerals"; Proc. Am. Phil. Soc., Phila., vol. XIII (1873); vol. XIV (1874); vol. XX (1882).
[2] Barlow, A. E.: Geol. Surv., Canada, Mem. 57, p. 132 (1915).

has proved to be excellently suitable for the manufacture of abrasive wheels, may not be so successful when used as a loose grain, since the physical properties requisite for an abrasive held in place are different from one which is used in the loose form.

Details of comparison and methods of testing various abrasives will be given under the heading of "Tests" in the bulletin "Artificial Abrasives."

As a rule the larger corundum crystals are better than the very small ones, for the former usually break up into small particles with the requisite sharp cutting edges, so that a rich deposit composed of very small crystals may be of less commercial value than a considerably poorer one, but which contains large crystals.

It is the general opinion of abrasive manufacturers who have used the various corundums from all over the world, that the clean Ontario material from Carlow and Raglan townships is the best. Little is, however, known of the blue and white corundums from Monteagle, Dungannon, and Methuen townships, which are purer and should be even better abrasives. (*See* Analyses, Table I.)

### FORMS IN WHICH CORUNDUM IS USED FOR ABRASIVE PURPOSES

The clean concentrates are graded into sizes (from 12 mesh to "Flour") required by the abrasive manufacturers, and are utilized by the trade in three forms:—

(a) *Grain Corundum*, as a loose grain for polishing rock specimens, gem polishing, and for glass grinding and bevelling, the largest consumption being in the latter trade.

(b) *Abrasive Paper or Cloth.* The various sizes of grain are fed on to glue-coated paper or cloth, which after drying is again coated with the abrasive. It is finally dried and cut up into the required shapes. This is employed in many kinds of metal work, by tanneries, leather, and wood workers.

(c) *Solid Forms*, such as wheels, sharpening stones, etc. The wheels consist essentially of two ingredients—the abrasive grain and the bond. There are four forms of these wheels, vitrified, silicate, elastic, and rubber.

The bond for the vitrified wheels consists of certain clays, feldspar, etc., and the mixture is baked in kilns at a high temperature for about two weeks. These are the most widely used and represent almost 90 per cent of the manufacture and require the purest corundum. The silicate bond is silicate of soda and the mixture is subjected to comparatively low heat for about two days. The process is specially suitable for making very large wheels. The elastic wheel bond is finely ground shellac and is subjected to a baking at low temperature for a short period. The rubber bond is selected crude rubber in sheets in which the grain is rolled and then vulcanized. The last two types of wheels are made very thin and are used for cutting and for grinding out narrow slots in metal.

A more detailed description of the processes of manufacture of these wheels will be found in the bulletin on Artificial Abrasives. At present, on the American continent, practically the only uses for natural corundum as an abrasive are to a small extent in vitrified wheels, and as loose grain in the optical trade for glass grinding.

During the last year (1924-25) a special aluminous abrasive has been made in the electric furnace, using natural corundum in the place of bauxite, since the former has almost double its percentage of alumina. This new product when made into wheels is said to be superior to the bauxite material for certain classes of grinding and is now made in several United States abrasive plants. This use for corundum is gaining favour, and it is believed that about 1,000 tons annually is the present rate of consumption. The corundum must be very pure and free as possible from titanium. The pure blue corundum from Dungannon township, Ontario,would be well suited (*see* Table I) provided the deposits are of sufficient size and the ore could be concentrated cheaply.

## WORLD'S OCCURRENCES OF CORUNDUM

Corundum is known to occur in about twenty kinds of rocks and in about thirty-five different countries throughout the world. Many of these occurrences are only of scientific interest, and the countries having deposits of commercial importance are, mainly, Canada, United States, Union of South Africa, India, Madagascar, and Russia; Greece and Turkey are the main sources of emery.

A detailed reference to the majority of the world's occurrences will be found in A. E. Barlow's report.[1]

The accompanying table (Table II) shows the world's production of corundum by countries since 1895.

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[1] Geol. Surv., Canada, Mem. 57, pp. 192–285 (1915).

## TABLE II

### World's Production of Corundum since 1895

(Short tons)

| Year | Canada[1] | | United States | | South Africa[2] | | | | Madagascar | | India | | Russia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Transvaal | | Namaqualand | | | | | | | |
| | tons | $ | tons | $ | tons | $ | tons | $ | tons | $ | tons | $ | tons | $ |
| 1895 | ... | ... | 385 | 59,900 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1896 | ... | ... | 250 | 35,000 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1897 | ... | ... | 293 | 19,810 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1898 | ... | ... | 786 | 63,630 | ... | ... | ... | ... | ... | ... | 425 | 7,220 | ... | ... |
| 1899 | ... | ... | 970 | 78,570 | ... | ... | ... | ... | ... | ... | 49 | 850 | ... | ... |
| 1900 | 3 | 300 | 830 | 58,100 | ... | ... | ... | ... | ... | ... | 77 | 1,120 | ... | ... |
| 1901 | 387 | 46,415 | ... | ... | ... | ... | ... | ... | ... | ... | 92 | 1,780 | ... | ... |
| 1902 | 768 | 84,465 | ... | ... | ... | ... | ... | ... | ... | ... | 31 | 540 | ... | ... |
| 1903 | 703 | 77,510 | ... | ... | ... | ... | ... | ... | ... | ... | 55 | 1,020 | ... | ... |
| 1904 | 993 | 109,545 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1905 | 1,644 | 149,153 | ... | ... | ... | ... | ... | ... | ... | ... | 59 | ... | ... | ... |
| 1906 | 2,274 | 204,973 | 500 | 25,000 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1907 | 1,892 | 177,922 | ... | ... | ... | ... | ... | ... | ... | ... | 31 | 540 | ... | ... |
| 1908 | 1,089 | 100,398 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1909 | 1,491 | 162,492 | ... | ... | ... | ... | ... | ... | ... | ... | 46 | 980 | ... | ... |
| 1910 | 1,870 | 198,680 | ... | ... | ... | ... | ... | ... | 12 | ... | 274 | 5,310 | ... | ... |
| 1911 | 1,472 | 161,873 | ... | ... | ... | ... | ... | ... | 165 | ... | 346 | 11,110 | ... | ... |
| 1912 | 1,960 | 239,091 | ... | ... | 111 | 3,200 | ... | ... | 545 | ... | 433 | 7,050 | ... | ... |
| 1913 | 1,177 | 137,036 | ... | ... | ... | ... | 13 | 630 | 2,209 | ... | 444 | 10,100 | ... | ... |
| 1914 | 548 | 72,176 | ... | ... | ... | ... | 12 | 700 | 611 | ... | 132 | 2,230 | ... | ... |
| 1915 | 262 | 33,138 | ... | ... | 67 | 2,280 | 1 | 50 | 360 | ... | 69 | 1,380 | ... | ... |
| 1916 | 67 | 10,307 | ... | ... | 753 | 37,700 | ... | ... | 1,005 | ... | 2,088 | 13,850 | ... | ... |
| 1917 | 188 | 32,153 | 820 | 67,461 | 2,623 | 64,800 | ... | ... | 813 | ... | 2,315 | 19,220 | ... | ... |
| 1918 | 137 | 26,112 | 365 | 38,100 | 3,829 | 128,250 | 47 | 2,540 | 196 | ... | 2,251 | 20,400 | ... | ... |
| 1919 | ... | ... | ... | ... | 138 | 4,450 | 50 | 2,750 | 893 | ... | 790 | 26,600 | ... | ... |
| 1920 | 196 | 24,547 | ... | ... | 245 | 6,280 | 15 | 740 | 573 | ... | 234 | 2,750 | 69 | ... |
| 1921 | 403 | 55,965 | ... | ... | 123 | 3,730 | ... | ... | 313 | ... | 71 | ... | 8 | ... |
| 1922 | ... | ... | ... | ... | 2,029 | 77,180 | ... | ... | 204 | ... | ... | ... | 2 | ... |
| 1923 | ... | ... | ... | ... | 2,787 | 112,340 | 13 | 420 | 463 | ... | ... | ... | ... | ... |
| 1924 | ... | ... | ... | ... | 1,495 | 53,120 | ... | ... | ... | ... | ... | ... | ... | ... |
| Total | 19,524 | 2,104,251 | 5,199 | 439,571 | 14,200 | 493,330 | 151 | 7,830 | 8,362 | ... | 10,312 | 134,050 | 79 | ... |

[1] Graded grain sold.

[2] Output in 1925.................... 1,818 tons valued at $64,293.
" 1926 (first four months) 1,660 " " 57,000.

## CANADA

### CANADIAN HISTORY

Corundum was first discovered in Canada on the farm of George Holliday, on concession IX, lot 2, North Burgess township, Ontario, when Dr. T. Sterry Hunt was making an examination of the rocks in this region.[1] The mineral which occurs in crystalline limestone attracted attention because of its great hardness and its transparent crystals with colours varying from rose to sapphire blue. Although the early Geological Survey reports give a detailed description of this discovery and possible uses of the mineral, it was apparently not followed up.

What is now the largest known deposit on the continent was discovered in 1876 on concession XVIII, lot 3, Raglan township, Renfrew county, Ontario, when the abundance of curious barrel-shaped crystals on Robillard mountain (now called Craigmont), attracted Mr. Henry Robillard's attention. Specimens were sent to a local expert who pronounced them to be phosphate or apatite, and eight years later the mining rights were applied for by Mr. John Fitzgerald. In 1886 Mr. H. R. Wood visited the deposit and also found small exposures of the same mineral in Carlow township. He appears to have informed Messrs. Robillard and Fitzgerald that their so-called phosphate mine was in reality a deposit of "emery stone"[2].

In 1896, W. F. Ferrier (at that time of the Geological Survey of Canada) recognized the presence of corundum in Carlow township and after the publication of his report[3] the value of the deposits began to be appreciated. Shortly after this, corundum was discovered in Methuen township, Peterborough county, about 45 miles southwest of the Carlow deposits, when Mr. George Bennett reported it from a mica mine on concession IX, lot 14.

A reconnaissance by the Geological Survey in 1897 showed that the belt of corundum-bearing rocks covered an area at least 16 miles long and was in one place 5 miles wide. By the end of the year the belt had been traced through seven different townships. Scientific prospecting was continued the next year with the result that a continuous series of corundum-bearing outcrops was traced for a distance of about 85 miles;[4] some years later the discovery of the mineral in Lutterworth township showed the main belt to be more than 100 miles in length.

During this period of investigation (1897-8) the late Dr. W. G. Miller who devoted considerable time and study to these corundum localities, shipped several tons of ore to Queen's University, Kingston, for analysis and experiments in concentration, and for making into corundum wheels.[5] Some of these wheels formed part of the Mineral Exhibit at the Paris International Exhibition of 1900, and also at the Glasgow Exhibition of 1901.

The extent and richness of these Ontario corundum occurrences prompted the Government to take steps to develop the industry, with the result that special regulations governing this territory under the leasehold system were drafted.[6]

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[1] Geol. Surv., Canada, Rept. of Prog. 1847–1848, p. 133; also 1863, p. 499.
[2] Barlow, A. E.: Geol. Surv., Canada, Mem. 57, p. 20 (1915).
[3] Geol. Surv., Canada. Pt. A, pp. 116–119 (1897).
[4] Miller, W. G.: Ont. Bureau of Mines Ann. Rept., vol. VII, pt. III, pp. 207-250 (1898).
[5] Op. cit., pp. 238–250; also 1899, pt. II, pp. 239–240.
[6] Ont. Bureau of Mines Ann. Rept., vol. VIII, pt. II, pp. 248–249 (1899).

*History of Operations*

In September 1899 a selected area of 1,400 acres was leased to Messrs. J. H. Shenstone and B. A. C. Craig on behalf of the Canada Corundum Company, who, in April 1900, was the first organization to start mining and milling operations for corundum in Canada. The village called Craigmont (named after the Vice-President) was built and the ore from Robillard mountain was concentrated in a 20-ton mill on the property.

In the following year the Imperial Corundum Company and also the Crown Corundum and Mica Company were organized and did a considerable amount of development work in Methuen township. In the same year (1901) organized prospecting revealed more deposits in the main belt in the vicinity of Palmer rapids on the Madawaska river, and the Corundum Refiners Ltd. was organized to develop them, but little work other than prospecting was carried out.

During 1902, Ferrier's original discovery in Carlow, now known as the Burgess mine, was taken up by the Ontario Corundum Company. At first the ore was hand-sorted and crushed and sent to the United States for concentration until the mill was completed in 1903. During this period the capacity of the Craigmont mill was increased to 200 tons per day. In 1904, the Burgess mill was destroyed by fire, but a larger mill using dry methods of concentration was erected before the end of the year.

The Imperial Corundum Company in 1905 mined ore from concession I, of Monteagle township, and shipped the hand-sorted ore to Springfield, Mass., for concentration. In the following year, the Burgess mine which had been operated by the Ontario Corundum Company was taken over by the Ashland Emery and Corundum Company, who also prospected several other nearby occurrences, but shipments were small and irregular. In the meantime the Canada Corundum Company (under the management of Mr. H. E. T. Haultain), who continued to be the world's largest shipper of grain corundum, located and prospected several new occurrences.

During 1908 the Craig mine closed down owing to over production and to the small demand for graded grain. In the following year the property was acquired by the Manufacturers Corundum Company which later absorbed the Burgess mine together with the other properties held by the Ashland company. The new company, with Dr. A. Brebner as Toronto manager and Mr. E. B. Clark as work's manager, continued production on a large scale at their various mines until the total destruction of the Craigmont mill by fire in February 1913. Changes were made in the Burgess mill and Craigmont ore was treated until the latter deposit was abandoned. The Burgess mine and mill were operated until 1917. Early in 1918 the Manufacturers Corundum Company dismantled the mill and shifted their activities to the various deposits in Raglan, Radcliffe, and Brudenell townships, erecting a 100-ton mill at Jewellville, in the vicinity of Palmer rapids, concession XVIII, lot 24, Raglan. Operations were confined to a number of scattered open-cuts from which the ore was hauled during the winter months to the Jewellville concentrator. In the fall of the same year operations ceased, since when no corundum has been mined in Canada. During the next year, however, the Corundum Limited leased the Manufacturers Corundum property at Craigmont and built a new 100-ton mill to treat the Craigmont tailings. From this source grain corundum was produced until the mill closed down in June 1921. Since this date no corundum has been produced in Canada.

## SUMMARY OF PROGRESS AND FUTURE OUTLOOK

Although the existence and value of Canadian corundum were not appreciated for many years, nevertheless, once mining operations were started in 1900, the industry made very substantial and rapid progress in spite of many disadvantages such as difficulties of transportation, of concentration, preparation for market as well as its introduction into the world's markets. When the market was established, Canadian corundum was regarded as a standard, and for fourteen years was the world's leading producer.

Almost from the beginning, the industry had a very serious competitor in the form of the artificial abrasives, first carborundum, the carbide of silicon, and later aluminous abrasives or artificial corundum. This increasing competition was the main cause of the steady decline in production from the peak year of 1906 until the final cessation of operations. During the last period when the old tailings were being treated the concentrates were naturally somewhat inferior to that of the freshly mined material, and tended to lower the high standard of Canadian corundum.

Natural corundum is to-day being shipped from various places (*see* Table II) throughout the world, the main producer being South Africa. There is still an appreciable demand as it is considered preferable for certain abrasive purposes. The majority of wheel manufacturers and other users who employ the natural corundum state that the pure Canadian material is the best. Although the present-day costs of operating some of the old Canadian deposits would be excessive, there are, nevertheless, several that are fairly close to transportation and water power.

The recent use for corundum in the manufacture of artificial abrasives has already been referred to and may be the means of stimulating the production of Canadian corundum.

## CANADIAN PRODUCTION

Corundum was first produced in Canada in 1900. No ore was mined after August 1918, but between 1919 and 1921 tailings from the Craigmont dump were treated by the Corundum Ltd. No corundum has since been produced in the Dominion.

The following table shows the yearly production:—

TABLE III

**Production of Corundum in Canada**

(Short tons)

| Year | Corundum ore treated | Grain graded | Per cent recovery | Shipments of grain corundum: Sold in Canada | Exported | Total shipments | Total value | Average price per pound |
|---|---|---|---|---|---|---|---|---|
| | tons | tons | | tons | tons | tons | $ | cents |
| 1900 | .......... | 60 | .......... | .......... | .......... | 3 | 300 | 5·00 |
| 1901 | 4,134 | 434 | 10·7 | 85 | 302 | 387 | 46,415 | 5·97 |
| 1902 | 7,996 | 805 | 10·1 | 106 | 662 | 768 | 84,465 | 5·49 |
| 1903 | (a) 8,877 | 839 | 9·5 | 85 | 618 | 703 | 77,510 | 5·51 |
| 1904 | 28,187 | 1,654 | 5·9 | 116 | 877 | 993 | 109,545 | 5·51 |
| 1905 | 23,571 | 1,681 | 7·1 | 140 | 1,504 | 1,644 | 149,153 | 4·48 |
| 1906 | 45,719 | 2,914 | 6·4 | 162 | 2,112 | 2,274 | 204,973 | 4·50 |
| 1907 | 60,532 | 2,682 | 4·4 | 164 | 1,728 | 1,892 | 177,922 | 4·70 |
| 1908 | 2,678 | 106 | 4·0 | 99 | 990 | 1,089 | 100,398 | 4·60 |
| 1909 | 35,894 | 1,579 | 4·4 | 129 | 1,362 | 1,491 | 162,492 | 5·45 |
| 1910 | 37,183 | 1,686 | 4·5 | 106 | 1,764 | 1,870 | 198,680 | 5·31 |
| 1911 | 41,975 | 1,641 | 3·9 | 92 | 1,380 | 1,472 | 161,873 | 5·50 |
| 1912 | 36,879 | 1,620 | 4·4 | 63 | 1,897 | 1,960 | 239,091 | 6·10 |
| 1913 | 12,290 | 763 | 6·2 | 23 | 1,154 | 1,177 | 137,036 | 5·82 |
| 1914 | 12,111 | 695 | 5·7 | 14 | 534 | 548 | 72,176 | 6·59 |
| 1915 | 1,724 | 116 | 6·7 | 21 | 240 | 262 | 33,138 | 6·33 |
| 1916 | 1,864 | 67 | 3·6 | 8 | 59 | 67 | 10,307 | 7·65 |
| 1917 | 4,659 | 188 | 4·0 | 16 | 172 | 188 | 32,153 | 8·55 |
| 1918 | 3,184 | 137 | 4·3 | 0 | 137 | 137 | 26,112 | 9·90 |
| 1919 | (b) 1,300 | 26 | 2·0 | | | | | |
| 1920 | (b) 13,025 | 322 | 2·5 | 20 | 176 | 196 | 24,547 | 6·25 |
| 1921 | (b) 11,256 | 407 | 3·6 | 0 | 403 | 403 | 55,965 | 6·94 |
| Total (ore) | 369,451 | 20,422 | .......... | 1,449 | 18,071 | 19,524 | 2,104,251 | .......... |
| " (tailings) | 25,581 | .......... | .......... | .......... | .......... | .......... | .......... | .......... |

(a) In addition to this amount which was milled in Canada, 267 tons of ore was mined and shipped to the United States.
(b) Tailings only.

## GENERAL DISTRIBUTION AND MODES OF OCCURRENCE OF CORUNDUM

Complete and detailed reports fully covering the geology, distribution, and occurrences of corundum in Canada have been compiled by W. G. Miller[1] and A. E. Barlow[2]. In the following pages will be found a general summary covering the distribution, occurrences, and accounts of the deposits that have been operated.

In Canada corundum is known to occur commercially only in southeastern Ontario. Other occurrences such as in the Sudbury district, Ontario, in British Columbia, and Quebec, appear to be only of scientific interest.

[1] Ont. Bureau Mines, Ann. Rept., Pt. III, pp. 207-250 (1898); also Pt. II, 206-214 (1899).
[2] Geol. Surv., Canada, Mem. 57 (1915).

The southeastern Ontario corundum-bearing zones are roughly divided into three belts:—

(1) Main or Northern belt.
(2) Methuen-Burleigh or Middle belt.
(3) Lanark-Frontenac or Southern belt.

The rocks comprising these belts in which corundum has been found are of four kinds, but in many instances one merges into the other.

(a) Syenites, (b) Syenite-pegmatite, (c) Nepheline-syenite, (d) Anorthosite.

## Main Belt

This is by far the largest of the three areas and from which the whole corundum output has been maintained, and consists mainly of nepheline or corundum syenites. The nepheline syenite is made up essentially of feldspars (usually albite), with nepheline, and biotite, hornblende, and occasionally pyroxene as the ferromagnesian minerals. Biotite is the most abundant of the latter minerals. (*See* Plate II). These syenites, however, show an extreme and rapid variation in composition.

It is of geological interest to note that the nepheline and associated alkaline syenites occur along the contacts of the Laurentian granite-gneisses and the Grenville crystalline limestones.

The Main belt is approximately 103 miles in length, with some interruptions, and with a maximum width of 6 miles. It runs in a northeast-southwest direction, the most westerly occurrence of corundum being on lot 12, concession IV, Lutterworth township. The belt passes through the townships of Glamorgan, Monmouth, Cardiff, Harcourt, Faraday, Dungannon, Carlow, Raglan, Radcliffe, Brudenell, and finally Algona and Sebastopol in the northeast. (*See* Figure 1). The greatest development of the corundum rocks is to the northeast, particularly in Carlow and Raglan, on either side of the boundary between these townships, being the Burgess and Craig mines from which practically the whole corundum output was obtained.

## The Middle Belt

The Middle belt which is about 25 miles to the south of the Main belt is a club-shaped area about 8 miles long and 1½ miles wide at the head, or northeast end, in Methuen township, and tapers down to about 200 yards at the southwest end at Stony lake in Burleigh township.

These rocks form a series of elevations known locally as the Blue mountains. The whole mass is composed of nepheline and alkaline syenites. The corundum which is bluish to greenish grey in colour occurs usually as rounded crystals surrounded by or embedded in mica. The mineral has been mined from coarse pegmatite dykes 1 to 4 feet wide.

## The Southern Belt

The Southern belt is approximately 65 miles east of the Middle belt and extends in a southwest-northeast direction for a distance of about 12 miles from the northeast corner of Hinchinbrooke township, Frontenac county, to South Sherbrooke in Lanark county. In places the band has a width of about 1 mile.

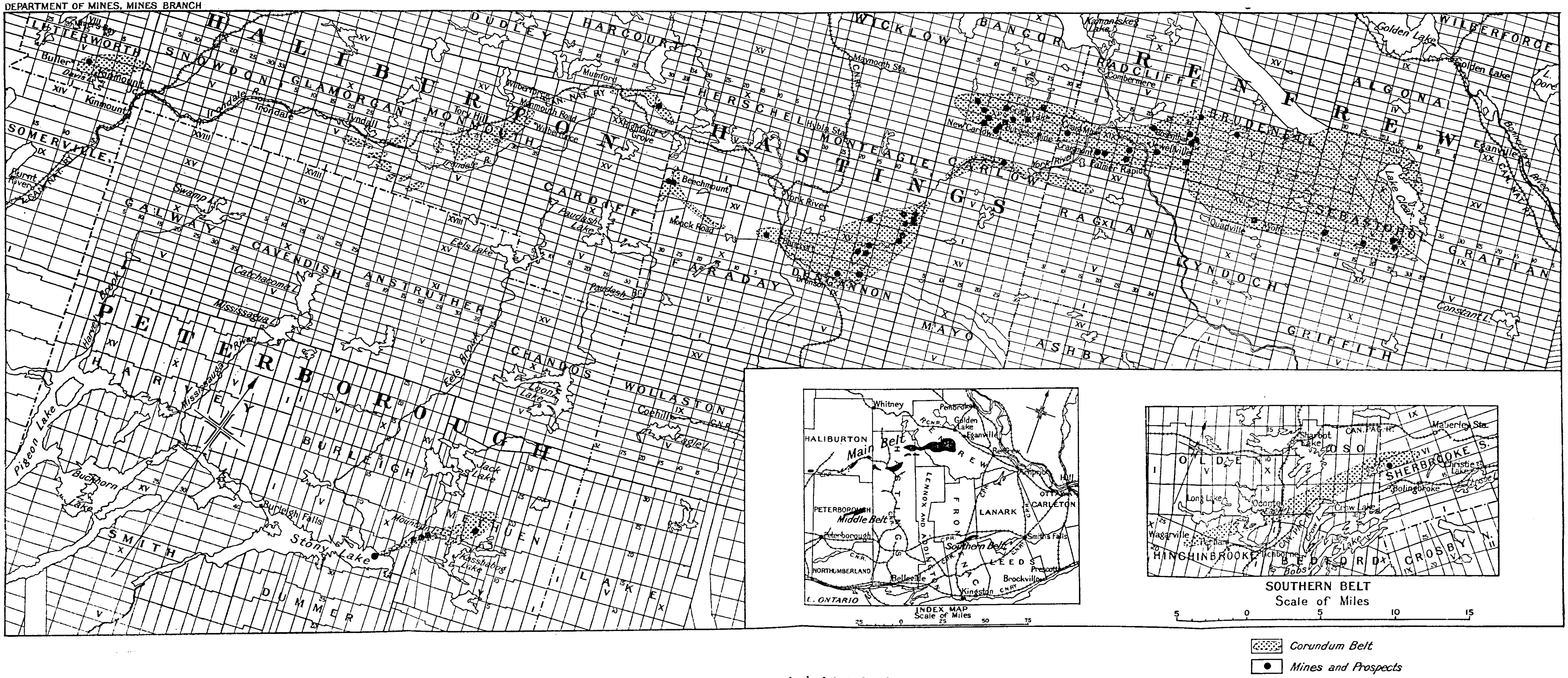


Figure 1. Corundum-bearing belts in Ontario

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The belt is largely made up of anorthosite, with some pegmatite syenite towards the southwest end. The corundum is light grey to almost white, some crystals exhibiting pinkish hues, and the individual crystals, which in some cases stand out in high relief on the weathered surfaces, are remarkably uniform in size. They average half an inch in diameter, and are tabular, but are shorter than those found in the Main belt.

No attempt appears to have been made to mine corundum from this belt, probably because of its low grade, as only in a few places does it exceed 5 per cent of the rock in which it occurs.

## CANADIAN OCCURRENCES

### Main Belt

#### Haliburton County

No work has been done on the southwestern end of this belt, and discoveries of corundum made so far appear to be of little economic value. Probably the best showing is about 5 miles west of Kinmount in Lutterworth township, where in places the corundum, associated with pearly mica and magnetite, would average about 10 per cent.

Following in a northeasterly direction there is an interruption in the succession of the nepheline syenite for about 20 miles, until it outcrops in Glamorgan, but no corundum has been found in this township. There are a number of exposures of the mineral in the syenites of Monmouth township as well as in the vicinity of Wilberforce village, Cardiff township, but all are of minor importance.

#### Hastings County

The nepheline syenite and the associated red alkali syenites are well exposed in the vicinity of Bancroft in the northeast corner of Faraday township, but very little corundum is seen.

*Dungannon Township*

Important deposits of corundum occur near York river, the most noteworthy being the blue-grey or white corundums in concession XI, lots 12 and 18; concession XIV, lot 14; and concession XVI, lots 4 and 5.

*Concession XIV, Lot 12.* East of York river there is an interesting occurrence of blue corundum in a white gneissic micaceous syenite, which is classified by Barlow[1] as dungannonite, a corundiferous andesine-anorthosite. The corundum occurs in two parallel bands each about 5 feet wide and separated by about 50 feet of foliated gneiss. The syenite is rich in corundum crystals of a semi-opaque pale blue colour. Some of these crystals are a rich transparent blue in the centre, but the colour fades away to a white or grey towards the edges. Every crystal examined was traversed by numerous fine fractures or parting planes. This is probably the nearest approach to the true gem sapphire that has been found in Canada, and it may be that in crushing the deep blue part of the best crystals, some small fragments of gem quality may be obtained. Owing to the extreme deformation of the central Ontario rocks the chances are against the occurrence of gem material of commercial size. However, owing to

[1] Geol. Surv., Canada, Mem. 57, pp. 80 and 83 (1915).

the great hardness of the blue corundum, some of the larger crystals may have withstood this alteration and shearing.[1] An excellent specimen from this locality was exhibited as a true sapphire at the Pan-American exhibition held at Buffalo, in 1901.

Only a few shots have been put into the deposits by way of preliminary prospecting.

*Monteagle Township*

Immediately to the north of the above, the nepheline anorthosites are in places highly corundiferous, the principal exposures being in lot 2, between concessions I and II. This is probably a northerly continuation of the dungannonite referred to above. The width of the belt here is about 400 yards. Samples taken over considerable areas, and concentrated in the Craigmont mill showed a recovery of about 6 per cent of corundum.

*Concessions I and II, Lots 2 and 3.* In 1906 the Canada Corundum Company did considerable prospecting and stripping in this locality on the east side of the York river, revealing some good deposits of the mineral.

*Concession I, Lot 13.* In 1906 the National Corundum Wheel Company of Buffalo, N.Y., did some development work in a coarse syenite pegmatite. The quarry is about 25 feet long with a 15-foot face. The hand-sorted ore was shipped to the United States for further treatment.

*Carlow Township*

Continuing in a northerly direction very little corundum is found until the high hills in the north of the township have been reached. There, numerous exposures occur between concessions XIII and XVI, and extend from lot 8 to beyond the eastern boundary. All these occurrences are in a coarse, red corundum syenite.

*Burgess Mine.* Mining was started in July 1902 on concession XIV, lot 14, by the Ontario Corundum Company. Operations were continued until 1905 when the property was taken over by the Ashland Emery and Corundum Company. Shipments were at first small and irregular, mainly owing to the depletion of the ore at the original location. Mining activities were transferred to a deposit on concession XVI, lots 15 and 16, north of Grady lake, about 2 miles to the north, from which a considerable tonnage was obtained for the next two years. In 1907 these deposits were also abandoned and ore was taken first from concession XII, lot 10, a haulage of 3 miles to the mill, and later from the deposit on John Armstrong's hill, concession XV, lot 10, about 1½ miles to the west.

Early in 1910 the Armstrong Corundum Company, Ltd., secured a lease on the Burgess plant, but after operating only two months it was taken over by the Manufacturers Corundum Company who was already operating the Craig mill and mine about 4 miles to the east. The crude concentrates from the Burgess mine were finished at the Craig mill.

In the main workings in the steep hill-side just to the north of the old mill the quarry is about 200 feet in length with a 50-foot face. The corundum, which is very pockety, occurs as large, brown or bronze crystals in coarse, micaceous, red pegmatite syenite. There is very little to be seen in place except at the north end of the workings near the contact of the syenite and banded gneiss.

[1] Ellsworth, H. V.: "Blue Corundum of the Bancroft Area"; Can. Min. Jour. (Oct. 10, 1924).

The nearest railway is at Barry's Bay station, 32 miles to the north. The ore and concentrates during the summer were hauled to a wharf on the York river and shipped by barge to the station.

There are many small prospects within a radius of about a mile, some of which show possibilities of being fairly rich in corundum, particularly those to the north and west.

### Renfrew County

#### *Raglan Township*

Adjacent to Carlow township, the Raglan corundum occurrences are the richest and most extensive in the region. The larger deposits follow very closely the boundary between concessions XVIII and XIX, starting with the Craigmont deposits on the west and crossing the York and Madawaska rivers to the Jewellville deposits east of the latter river.

##### CRAIG MINE

This is probably the largest corundum mine in the world. The workings are in the northwest of the township and cover about five lots, namely, lots, 2, 3, and 4 in concession XIX, and lots 3 and 4 in concession XVIII. Robillard mountain, on the southern slopes of which the workings are located, is in reality the eastern extension of the range of hills in which the corundum of northern Carlow township occurs. It is a conspicuous topographical feature and rises abruptly to a height of about 450 feet above the sand plains of York river immediately to the west. (*See* Plates II and III.)

*Occurrence and Nature of Ore.* The northern part of the Robillard mountain is composed of a banded and foliated reddish granite gneiss, intruded by many pegmatite dykes. This gneiss series, by a gradual decrease in its quartz content, appears to merge into the corundum-bearing series which overlies it and forms the summit and southern slope of the hill. The latter series is very complex and is composed of several types of rocks, which in many places gradually merge from one type into the other.

The following are some of the types of the Craig Mine corundum-bearing rocks, according to Barlow[1]:—

(1) *Craigmontite.* A pink, rather coarse-grained rock, rich in nepheline, but averages only 1 per cent corundum which occurs in the characteristic barrel-shaped crystals with their large axes often at right angles to the foliation.

(2) *Congressite.* Contains a high percentage of nepheline of a pale pink colour with an oily lustre. It is rather coarse grained and foliated, and the mica, when present, tends to segregate in little bunches. This rock is the main constituent of Congress bluff, or as it is locally called the "Klondike" quarries.

(3) *Raglanite.* A white or grey, high feldspathic variety of nepheline anorthosite containing about 4·5 per cent corundum.

(4) *Anorthosite.* A coarse, greenish grey rock often almost entirely composed of plagioclase feldspar and contains variable amounts of deep pink garnet, magnetite, and corundum.

[1] Op. cit., pp. 297-300.

(5) *Corundum Pegmatite.* This is almost entirely composed of deep red to pink feldspar and some quartz. It is representative of one of the final stages of crystallization of this highly aluminous magma. It contains the largest and most abundant crystals and masses of corundum and represents the richest ore. It occurs in dykes up to 18 feet in width.

*Operations at the Craig Mine.* The discovery and early history of the Craig mine have already been summarized under Canadian history. Work was first started in 1900 by the Canada Corundum Company and by the end of the year about 60 tons of clean, graded corundum was produced and the 20-ton mill was enlarged. The ore was obtained from large open-cuts in concession XVIII, lots 3 and 4. During the next three years over 15,000 tons of ore was mined and treated in this mill by means of which 10 per cent of the ore was recovered as graded corundum. Mining was continued from the same quarries as well as from the "Klondike" quarries on concession XIX, lot 2, about half a mile to the northwest.

A new 200-ton mill was completed early in 1904. A wet gravity process using Harz jigs and tables was employed by means of which about 10 to 12 tons of graded grain was produced daily (*see* description under Concentration).

Practically the whole of the world's record production of 1906 amounting to 2,914 tons of graded grain, valued at $262,448, is credited to the Craig mine. The company ceased operations in 1907 and in the following year the Craig mine and mill were operated by the Manufacturers Corundum Company. Most of the ore was at first obtained from the "Klondike" quarries. Operations were continued on a large scale until the mill was completely destroyed by fire in February 1913. A little ore appears to have been treated in the Burgess mill which had been previously acquired by the company, but the fire disaster marked the end of the mining operations at the Craig mine.

In 1918, the property was taken over by the Corundum Ltd., who built a small mill and treated about 25,000 tons of the old tailings, till they closed down in the summer of 1921.

*Mining Methods.* The ore was extracted by driving in a number of large open-cuts in the hill-side. A series of about 20 holes, 14 or 15 feet deep, were electrically fired and the blocks so obtained were further broken down by dynamite to suitable sizes for crushing. As the ore was not rich enough for straight milling, rough hand-sorting was resorted to in order to eliminate the waste and lowest grade, which resulted in about a 20 per cent mill feed. The ore was taken from the various quarry faces by teams to the nearest tramway and was then conveyed to the top of the mill building in 4-ton ore cars, each car being weighed before dumping into the storage bins (*see* "Concentration" for description of mill). There are over 20 pits and open-cuts in the hill-side, some of which are 500 to 700 feet long and up to 250 feet in width. (*See* Figure 2).

*Conclusions.* As a result of extensive quarrying and diamond drilling it would appear that the Robillard Mountain deposits of corundum are limited and also the mineral occurrences are comparatively shallow. Probably the best ore has been taken out, although some good ore is still to be seen in place. However, it is scattered and is likely to be both difficult and expensive to mine and concentrate.

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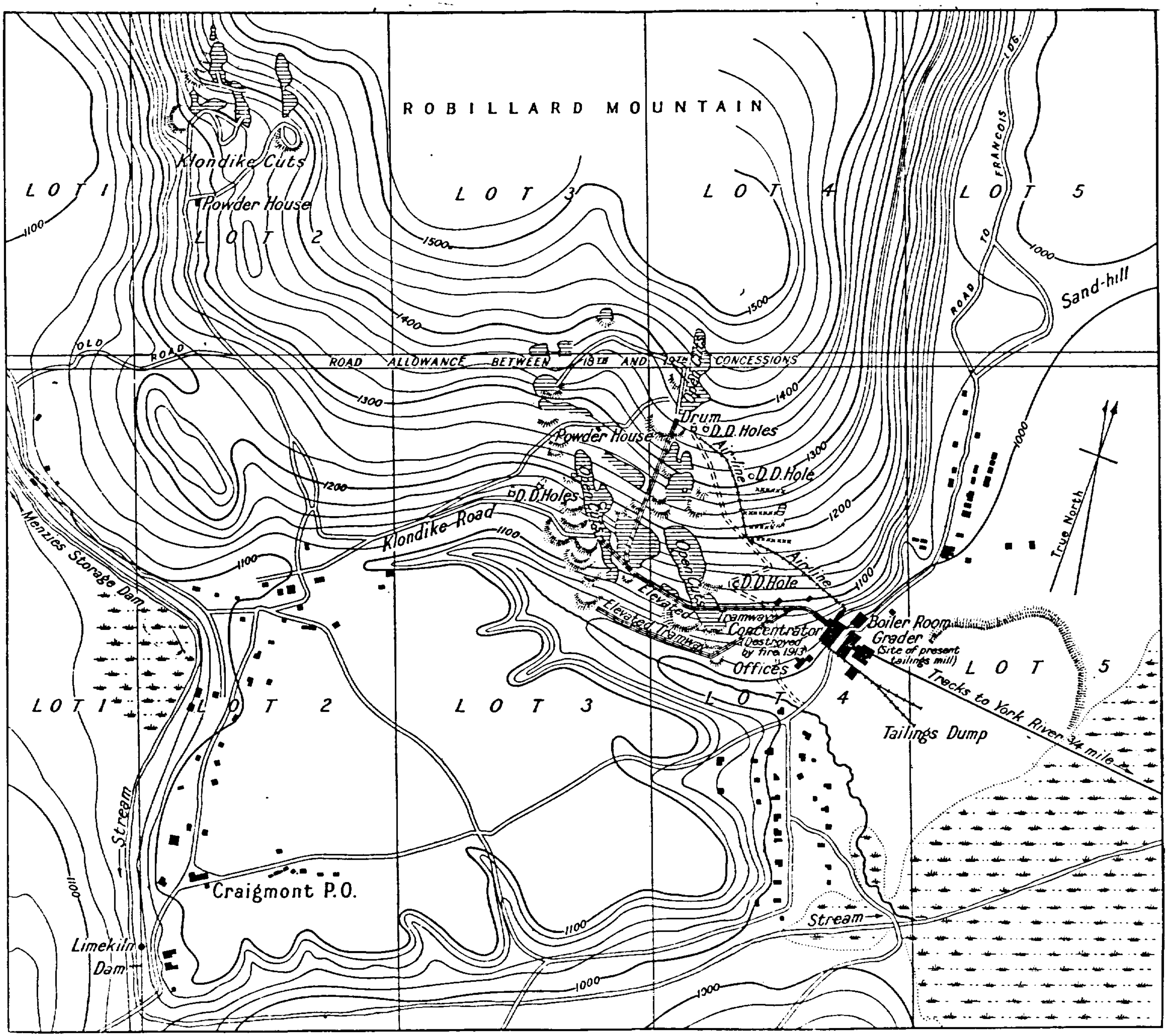


Scale: 1 inch = 800 feet.

Figure 2—The Craig corundum mine, Raglan township, Ontario (1912)

Immediately to the east of Robillard mountain, in the fork between the two rivers, outcrops of corundum have been found. The most promising being in Raglan township, concession XVII, lots 11 and 13, and 2 miles farther east on Indian hill, concessions XVII and XVIII, lot 19. The corundum in the latter is associated with garnet.

*Jewellville Mines.* East of the Madawaska river corundum occurs in numerous places in a coarse, pink syenite particularly along the boundary between concessions XVIII and XIX between lots 25 and 28. On lot 25, close to the road, the corundum occurs in small dykes in a white albitic phase of the syenite.

In 1901, the Corundum Refiners, Ltd., did a little preliminary prospecting but nothing was done until 1907 when the Canada Corundum Company, who was operating the Craig mine, did some more prospecting, made roads, and put up some buildings. In 1913, the Hamilton Corundum Company continued prospecting. It was not until the fall of 1915 that any serious work was undertaken on these deposits, when the Manufacturers Corundum Company, after doing considerable prospecting and some diamond drilling, dismantled the Burgess mill and installed the machinery in a 100-ton mill, on concession XVIII, lot 24, on the east bank of the Madawaska river. This mill used Wilfley tables and very high-grade concentrates are said to have been obtained.

During 1917 and 1918 about 8,000 tons was treated in the mill producing about 325 tons of graded grain. All operations ceased in August, 1918 which is the last date on which corundum was mined in Canada. The ore deposits appear to be small and shallow, and the work done consisted of a large number of scattered pits and open-cuts, mostly on the top of the hill. The majority of the ore was hauled to the mill during the winter months, a distance which varied from 1 to 4 miles.

Although the occurrences are small and scattered they are, nevertheless, numerous, and a recent (1924) examination of the workings on top of the hill showed the presence of a considerable amount of corundum in place in the sides as well as at the bottom of nearly every pit.

The deposits are close to water transportation to Barry's Bay station, 20 miles to the north, and only about 2 miles from Palmer rapids, which is capable of producing at least 1,000 h.p.

### *Radcliffe and Brudenell Townships*

Northeast of the Jewellville mines there are several corundum occurrences, the principal of which are shown on the accompanying map (Figure 1). On lot 34, concession VIII, Brudenell township, corundum crystals are associated with magnetite and thickly disseminated through a well-foliated nepheline syenite-gneiss, which crosses the road 2 miles south of Rockingham village, and has been traced across the strike for about 200 yards. In places owing to the quantity and close association of the magnetite, it resembles a coarse-grained emery. This occurrence is the nearest approach to emery so far found in Canada.

### *Lyndoch, Sebastopol, and Algona Townships*

Although nepheline and alkali syenites occur on the eastern end of the main corundum belt, there are only a few isolated occurrences of this mineral at present known, mainly in concession V, lots 24 and 25, and concession IV, lot 24 of Sebastopol township.

## Middle Belt

### **Peterborough County**

### *Methuen Township*

The nepheline and alkaline syenites strike in a northeast-southwesterly direction between concession VI and the western boundary of the township at lot 13, a distance of 5 miles, and thence as a narrow strip into Burleigh township for about 3 miles.

Mica had been mined in this region for some years before the corundum was recognized, as it was not identified until after attention was drawn to the existence of this mineral in Raglan and Carlow townships in the Northern belt.

The corundum occurs under conditions similar to those of the Main belt. The usually associated rocks are of three ages. The oldest of these is a dark gneiss, which is in many places cut through by different varieties of corundum-bearing syenites; both these are in places intruded by dykes of coarse quartz-bearing pegmatite. These syenites are a white or grey nepheline variety associated with a pink syenite. The latter rock, with amphibolite inclusions, forms a border along the northwestern side of the whole mass. It is along this border that the richest corundum and largest crystals occur.

The most easterly of the outcrops of corundum occurs in a coarse phase of the nepheline syenite on concession VII, lots 15 and 16, but are of minor importance.

*Concession VIII, Lots 14 and 15.* What is known as the Croft property was worked during 1901 by the Imperial Corundum Company. Dykes of pegmatite from 2 to 5 feet wide occur close to the contact of the dark gneiss and nepheline syenite in which several pits, up to 20 feet in depth, have been sunk close to the northwest end of Kasshabog lake. The corundum occurs with the muscovite mica, for which most of the mining was done, and although the company set aside about 10 tons of hand-picked corundum ore, apparently no shipments were made.

*Concessions IX and X, Lot 14, Bennett's Mine.* During 1901 the Crown Corundum and Mica Company did some work in the northwest corner of the above lot near the boundary between concessions IX and X. Nine or ten pits for white mica had previously been opened up in the coarse-grained syenite, and on the northwestern slope of the mountain several pits were sunk and three or four level entry cuts, each about 100 feet in length, had been driven, following coarse, pink syenite dykes of 1 to 4 feet in width. Nearly all these northerly workings particularly the most westerly cut, show the presence of a bluish corundum embedded in the muscovite. In many cases the corundum is not revealed until the mica books are broken open. The surface of the corundum crystals are frequently rounded due to their alteration into the mica. In other cases the corundum is splashed through the pink rock and is invariably completely fringed with a coating of pearly mica. In some instances also the presence of the corundum is somewhat deceptive as it occurs in small mica-like flakes of a bronze lustre on the weathered surfaces.

In places some of the syenite dykes contain probably up to 10 per cent corundum, but the average mining ore is decidedly less.

It was stated by local inhabitants that 150 tons of mica and corundum ore were shipped to the United States, but there is no official record of this.

On the Madill property, concession IX, lot 15, a little work has been done, where corundum, of a somewhat radiated structure, occurs surrounded by tough nodules containing masses of granular white feldspar and species of black mica. On the Miller property, concession IX, lot 13, on the south side of Little Mountain lake, most of the work was done for mica near the contact of a fine-grained syenite and the granite, but the percentage of corundum is small.

A detailed description of the geology and analysis of the rocks in this area will be found in the late Dr. W. G. Miller's report.[1]

#### *Burleigh Township*

A brown corundum exhibiting a bronze or pearly lustre occurs near the eastern boundary of the township on lot 7. The syenite ridge strikes due southwest till it reaches the shore of Stony lake, where the ridge is only 200 yards in width, and outcrops on some of the small islands, on one of which are bands of white and pink syenite, both containing small local segregations of corundum.

## SOUTHERN BELT

### Lanark County

#### *South Sherbrooke Township*

Corundum was first reported in the western part of concession VI by Mr. L. J. Gemmell of Perth, in 1898.

*Concession VI, Lots 12 to 1.* Corundum occurs in a grey compact rock consisting of basic plagioclase feldspar and some green hornblende, which has been determined as bytownite anorthosite. It lies wholly within concession VI, striking in a southwesterly direction parallel to and along the concession line from lot 12 into Oso township. The corundum occurs as thick tabular crystals of a pearl grey to white in colour, which are remarkably uniform in size, being about a half inch in diameter and up to one inch in length. The showings of corundum are pockety, but nowhere appear to exceed 5 per cent. The best outcrops were noted on M. J. Strong's farm, lots 7 and 8.

### Frontenac County

#### *Oso and Hinchinbrooke Townships*

The anorthosite belt crosses the western South Sherbrooke boundary; through Rock lake in Oso and thence southwesterly between Sharbot

[1] Ont. Bureau of Mines, Ann. Rept. vol. VIII, pt. II, pp. 206-214 (1899)

and Crow lakes, but no corundum has been recorded as occurring in place until the belt crosses the railway track about half a mile south of Oconto station. Characteristic boulders containing corundum have been found west of the track northeast of Eagle lake in Hinchinbrooke township as well as on the southwest end so that the belt probably runs through the southern edge of the lake.

*Concession VI, Lot 24.* Two wagon loads of corundum-bearing rock are said to have been shipped to Kingston in 1918 from Mr. Cornwall's farm about 4 miles west of Parham. The rock is a dark syenite pegmatite and is directly in the line of strike of the corundum belt. A recent examination of the pit, however, did not reveal the presence of corundum, but reddish brown feldspar and some garnet were noted.

Three or four occurrences of corundum were recently (1924) reported as occurring near Verona and near Godfrey, 10 or 12 miles to the south of the belt. An examination, however, showed the supposed corundum to be a brownish grey feldspar.

The only definite outcrops of corundum in place so far discovered are those at the northeast end of the belt in South Sherbrooke.

### Other Occurrences of Corundum in Canada

Belts of pink nepheline syenite striking north and south cross the French river and traverse Bigwood township on the southern boundary of the Sudbury district, Ontario. The widest part of the belt lies between concessions I to III and lots 10 and 11 and have been traced to a point 2 miles west of Rutter station on the Canadian Pacific railway. T. T. Quirke, who has recently examined this district, found specimens of bluish white corundum just north of the French river. The mineral is fringed with muscovite mica and is very similar to that already described as occurring in the Blue mountains of Methuen township, Peterborough county. No discoveries of commercial importance have been made.

Small fragments of a transparent green corundum have been found in the gold washings on the Pend d'Oreille river in the West Kootenay district, B.C. The only other recorded occurrence of corundum in Canada besides those already described in Ontario, is in the auriferous gravels south of the river St. Lawrence, Quebec.

## UNION OF SOUTH AFRICA

For the last three or four years South Africa has been the world's largest producer of corundum (*see* table of world's production). A small output has been intermittently obtained from the Steinkopp deposits in the vicinity of Port Nolloth in Namaqualand, but most of the corundum comes from the Zoutpansberg district in northern Transvaal and the Pietersburg district in eastern Transvaal.

Although these occurrences have been known for the last twenty years no mineral was produced until 1912, but the industry received great impetus during the war, the peak production of over 3,800 tons being reached in 1918.

The Transvaal deposits occupy a triangular-shaped stretch of country of about 2,000 square miles and are divided into two fairly distinct regions, i.e., the Plateau region from Pietersburg northwards to Louis Trichardt and the Low Country region reaching eastwards from the foot of the Drakensberg over the Olifants River mica fields.

In the Low Country the most productive areas are mainly east of Mica Siding; in the Plateau region they lie around Bandolierkop and Mara.

The most common corundum-bearing formations are gneissic and granitic rocks, in which occur a number of small patches of basic rocks such as serpentines, pyroxenites and peridotites, etc.

Corundum is mined in several forms: *Crystal Corundum* consists of loose crystals in shallow eluvial deposits or "paddocks" formed by the disintegration of corundiferous rocks. The bulk of the present output is in this form. *Boulder Corundum* is found as loose blocks composed of crystals cemented together in a matrix of partly altered feldspar. *Reef Corundum* occurs as a rule in vertical veins or dykes of a few feet wide that intrude the basic rocks. In the Plateau region these reefs are nearly always a white coarse-grained highly feldsphathic plumasite containing scattered crystals of greyish corundum. Plumasite is a white oligoclase alkali syenite and very closely resembles the raglanite or dungannonite which occurs at Craigmont and other deposits in Ontario, except that nepheline is absent in the Transvaal reefs. Mica is also usually present.

The payable reefs are said to contain 20 to 40 per cent corundum.[1]

The Zoutpansberg Grain Corundum Company is working one of the largest reefs which is about 3 miles west of Bandolierkop in the Turkaspost farm. Dykes of coarse, white plumasite, 12 feet wide, have been worked to a depth of over 60 feet.[2] The ore is concentrated and then graded into about fifteen different sizes (*see* flow-sheet Figure 6). The eluvial paddocks containing corundum are also worked. The methods of cleaning the corundum from this type of deposit will be found under the heading of "Concentration".

A detailed description of all the known Transvaal occurrences will be found in Dr. A. L. Hall's monograph,[3] also in a serial article by Dr. P. A. Wagner.[4]

## UNITED STATES

Corundum was first recognized in the United States a little over a century ago from a specimen submitted for identification from the Laurens district, South Carolina. Systematic mining for corundum, as distinguished from emery and the gem varieties, was first started at Corundum Hill, North Carolina, in 1871.

The mineral has been found in a great many localities throughout the Appalachian belt from Massachusetts to Alabama, but only a few deposits have been developed. The best deposits are found in Jackson, Macon, and Clay counties, North Carolina; and Rabun county, Georgia. Between 1900 and 1905 the corundum deposits of Gallatin county, Montana, were also worked to a small extent.

With the exception of a little activity during the latter part of the Great War, there has been no production in the United States since 1905, owing mainly to the keen competition from Canadian corundum and latterly from artificial abrasives.

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[1] Hall, A. L.: The South African Journal of Ind., p. 801 (Dec. 1924).
[2] Hall, A. L.: "Preparation of African Corundum": Abrasive Industry, pp. 190–193 (June 1923).
[3] Hall, A. L.: S. African Geol. Surv., Mem. 15, 225 pages (1920).
[4] Wagner, P. A.: South African Mining Journal and Eng. Rec., May 25, June 1, 8, and 22 (1918).

The Corundum Hill mine, Macon county, North Carolina, is situated about 8 miles northeast of Franklin on Cullasagee creek and is the largest corundum mine in the United States. The mineral occurs in a peridotite rock near its contact with gneiss. The deposit occurs as a blunt lens-shaped mass of dunite, about 1,200 feet long and about 450 feet wide, and covers an area of about 10 acres. A number of veins of high-grade corundum rock occurring in the dunite were worked by open-cuts and tunnels, but with one exception they all pinched out.[1] From the beginning of operations until 1900 the mine produced annually 200 to 300 tons of cleaned corundum. Several other mines in the immediate vicinity and in the same formation have also been worked for corundum.

The most important Jackson County deposits are in the extreme northeastern part, in the vicinity of Sapphire, where there are numerous outcrops of peridotite in which the corundum is associated with garnet.

All the Georgia corundum deposits occur in lime-soda feldspar veins intersecting basic magnesian rocks of the peridotite type, usually on a contact with mica schist in close proximity to hornblende gneiss. The Lucas mine at Laurel Creek, Rabun county, is one of the best-known corundum mines in the United States and was successfully operated between 1880 and 1893. Massive pieces of corundum weighing several hundreds of pounds were frequently encountered. The mineral occurs in an oval mass of altered peridotite about 2,000 feet long and 800 feet wide, and is enclosed in a foliated quartz-mica gneiss.

Several hundred tons of corundum were mined from the vicinity of Elk creek in the central part of Gallatin county, Montana, where the ore occurs in syenites and pegmatites.

## INDIA

India is the home of the gems, ruby and sapphire, and the famous Burmese mines have been worked steadily since the fifteenth century, the principal ruby mines being about 90 miles northeast of Mandalay.

Corundum has been produced annually from 1895 to 1920, since when production appears to have ceased. In the latter years the majority of the output was obtained from the Khasi and Jaintia hills of Assam, about 7,000 tons of picked ore having been recorded. The next largest production comes from Pipra in southern Rewah state in central India; a small annual output has been maintained from South Canara state of Madras. Corundum is also widely distributed throughout Mysore state, which was one of the earliest producers of the mineral; it continued a small but steady output up to 1916. The only other record of shipments was 80 tons of ore in 1918 from Hyderabad in the central Provinces.

In the majority of cases the Indian corundum occurs as isolated crystals throughout the country rocks. No workings exist of the kind that can ordinarily be described as mining and only the crudest and cheapest devices are employed for concentration.

The mineral is used locally to a considerable extent for the lapidary's needs and is a regular item of the trade in the bazaars of the larger cities.

Information concerning Indian corundum and gems may be obtained from references quoted in the bibliography.

[1] Pratt, J. H.: U.S. Geol. Surv. Bull. 269, pp. 117-119 (1906).

## MADAGASCAR

There has been a steady production of corundum from Madagascar since 1910. The mineral occurred originally in siliceous rocks, which have since been altered by climatic conditions into a soft decomposed material, forming the so-called "red earth", which covers a large part of the surface of the island, and sometimes attains a depth of 60 feet.[1]

The minerals in the original rocks, such as graphite, corundum, mica, etc., are usually found in place in the soft decomposed mass on the summits and flanks of the hills. In places where it has washed away the heavier minerals are found concentrated in the bottoms of the hills, and in places the corundum has been formed into round pebbles.

Typical deposits occur on the southwest of Ambositra in the bed of the small river Ifempina; also at Nevatana and Betafo. The mineral is usually of an opaque bluish colour. Black pyramidal crystals of corundum also occur in the basaltic tuffs of Diego-Suarez.

## RUSSIA

During the last few years a small amount of corundum has been exported from Russia. The mineral occurs in several localities, notably in the Urals, Archangel, and Kyschtym districts. The richest corundum-bearing rock is an anorthite-anorthosite corundum for which Josef Morozewicz has proposed the name "kyschtymite", from the district in which it occurs. In the same locality are dykes of corundum syenite, which is an admixture of corundum, feldspar, and biotite in stock-like segregations in granite.

The similarity of these rocks with those of Canada as well as many occurrences in India, are of interest; although nepheline occurs, the corundum, unlike that in Canada, is not found within the nepheline syenite.

# ORIGIN OF CORUNDUM

The origin of corundum has been discussed in great detail by a large number of authors. Many of the theories of origin are compared in the reports of A. E. Barlow,[2] Joseph Hyde Pratt,[3] A. L. Hall,[4] T. H. Holland,[5] and others.

A summary of the view of some of these authors with respect to the countries in which they are especially concerned is as follows:—

### *Canada*

According to A. E. Barlow:—

> The corundum was one of the first constituents to crystallize out from the molten magma while at the same time sufficient material remained in the more acid residual portions to form the large and important occurrences seen in the pegmatite dykes which mark the final stage in the process of solidification.

According to W. G. Miller:—

> It does not seem more necessary to attempt to explain the occurrence of corundum in syenite through the solution of pieces of highly aluminous rock, than it does to so explain the presence of free silica in granite, through the absorption of highly silicious rocks.[6]

[1] Kunz, G. F.: "Economic Minerals of Madagascar"; Eng. and Min. Jour., p. 14 (Jan. 1, 1921).
[2] Barlow, A. E.: Geol. Surv., Canada, Mem. 57, pp. 155-157 (1915).
[3] Pratt, J. H.: U.S. Geol. Surv., Bull. 269, pp. 81-82 (1906).
[4] Hall, A. L.: Geol. Surv. S. Africa, Mem. 15, pp. 187-200 (1920).
[5] Holland, T. H.: Econ. Geol. of India, 2nd Ed., pt. I, pp. 7-79 (1898).
[6] Ont. Bureau of Mines Ann. Rept., pt. II, pp. 213-226 (1898).

*United States*

According to J. H. Pratt:—

The corundum was held in solution in the molten mass of the peridotite when it was intruded into the country rock, and that as the mass began to cool, it was among the first minerals to separate. In these molten magmas, the more basic minerals, corundum and spinel, would be the first to separate and the separation would take place along the outer border of the mass, for there it would first cool.

Convection currents would then tend to bring into the outer zone a new supply of material carrying alumina, and when this zone was reached, crystallization would take place, and the alumina would be deposited as corundum.

*India*

According to T. H. Holland:—

The mineral seems to have crystallized in most cases as one of the earliest formed amongst the constituents of the rocks in which it occurs. There appears to be no *a priori* reason why corundum when occurring as a rock constituent should require any different explanation than that generally applied to the other simple oxides occurring in a precisely similar manner. The corundum occurs in the feldspar rock as a normal primary constituent.

*Russia*

According to Dr. Joseph Morozewicz,[1] who conducted an exhaustive series of experiments and studies:—

In certain supersaturated alumino-silicate magmas of soda, potash or lime, the whole of the excess of the alumina separates out as corundum if the presence of iron and magnesia is small and silica less than 6, but when high in magnesia, as spinel, and if high in the silica, as cordierite and other minerals.

The absence of corundum in the nepheline syenites of India and Russia is believed to be due to their containing too much iron and magnesia.

*South Africa*

According to A. L. Hall the origin of corundum in the Transvaal reefs is as follows:—

(a) The reefs originated as pegmatitic derivations of the granitic magma.

(b) While intrusive in the basic magnesian rocks, they became supersaturated in alumina, which caused this excess to separate as corundum, leaving the balance as feldspar (plumasite).

(c) Supersaturation came about through removal of silica, which converted the wall rock into talc along a "contact" zone; at the same time certain other constituents, e.g. potash, were supplied to form the micaceous veneer or "casing" of the reef.

(d) Subsequent magmatic changes—possibly under pneumatolytic conditions—changed the corundum-feldspar reef (plumasite) into a margarite-feldspar body—marundite.

As a result of careful study it appears there is a great similarity between the various corundum occurrences throughout the world. Although the various theories of origin are at times conflicting, there is, nevertheless, a general tendency to accept the Morozewicz theory. It appears to be universally accepted that in certain formations when silica is removed, the relative proportion of alumina is raised, and if this process goes on far enough the magma will become saturated with alumina (feldspar zone) and finally supersaturated, forming corundum. It is a note-

[1] Tschermaks Mineral and Petrog. Miltheil., vol. 18, pp. 1-90, 105-240 (1898); also review of same Jour. Geo., vol. 7, pp. 300-313 (1899).

worthy fact that free silica, such as quartz, is rarely, if ever, found in actual contact with corundum. In certain conditions corundum would be expected where the maximum loss of silica has occurred.

It was the artificial production of gems which led to research by the earlier chemists on the origin of corundum and some excellent results, were obtained in the manufacture of sapphires and rubies.[1] Further investigations led to the successful manufacture of artificial corundum, one of the most powerful of abrasives, now universally used under different trade names, which are classified as aluminous abrasives.

## CONCENTRATION OF CORUNDUM

### Experiments by the Kingston School of Mines

During 1897, after the discovery of corundum in Carlow township, exhaustive experiments to determine the most suitable means of concentration were carried out at the Kingston School of Mines by Prof. C. De-Kalb.[2]

The specific gravity of corundum, being about 4·0, is higher than most of the gangue minerals, which average 2·7, so that ordinary gravity methods of concentration may be employed. Magnetite is, however, invariably present and being heavier (specific gravity 5·0) than corundum, reports with it. However, most of it can be removed by magnetic separation.

#### *Crushing*

It was found that the degree of crushing is a very important matter as the proportion of the magnetite to corundum increases with the fineness of crushing. The corundum grain should be kept as large as possible, at the same time it is essential that the corundum be freed from the gangue. The gangue offers no peculiar difficulties, but the corundum, particularly the larger crystals, tends to break in the form of tabular plates, a factor that must be taken into consideration in selecting the screen meshes.

In the two series of tests carried out the ore was crushed in Blake jaw crushers to 1-inch mesh and then by rolls to $\frac{1}{4}$-inch in one case, and to $\frac{3}{8}$-inch in the other. It was found desirable to separate the coarse from the fines in the earliest stage and as often as possible.

#### *Tests*

Elaborate flow-sheets were tried out in which rolls, Harz eccentric jigs, Frue vanners, vertical line separators (an improved form of spitzlutte classifier), fixed buddles, driers, and Wetherill magnetic separators, were each employed many times during the successive stages of concentration. The graphic flow-sheet of test "B" showed finished corundum from about 40 different discharges.[3] Although the flow-sheets were too elaborate for practical use, nevertheless they clearly indicated the lines along which the concentration of the ore should follow.

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[1] Encyclopedie Chimique, vol. 2—L. Bourgeois, also Kunz, G. F.: New Artificial Rubies, Tr. New York Acad. Sci. (Oct. 4, 1886).

[2] Ont. Bureau of Mines Ann. Rept., vol. VII, pt. III, pp. 240-250 (1898).

[3] Op. cit., p. 239.

It was found that the jigs, both fine and coarse were very efficient, but the Frue vanners and buddles were not satisfactory. The Wetherill magnetic separator was proved to be of the highest value in removing the magnetite, and by varying the amperage, a good separation could be made between the various types of iron-bearing minerals.

Apparently the Wilfley table, which has since proved to be an essential part of a modern corundum mill was not tried out.

## Experiments by the Mines Branch, Ottawa

During December 1915 the Manufacturers Corundum Company sent to the Mines Branch, Ottawa, about 3 tons of corundum ore from the vicinity of Jewellville east of Madawaska river. A full detailed description of the tests will be found in the Summary Report for 1915.[1]

The ore which contained about 4 per cent corundum was first crushed in a jaw crusher to 1-inch mesh and then by rolls to $\frac{1}{2}$ inch. The product then passed through Ferraris screens in which a number of different openings from $\frac{1}{16}$ to $\frac{1}{8}$ inch were tried out. The oversizes in each case being reground to pass through the screen, were then graded in a Keedy sizer into 14 sizes from 6 to 86 mesh. In the preliminary test it was found that the corundum in the 6 and 8-mesh material had not been freed from the attached particles of gangue. Sizes 12 to 28 treated in a James jig did not give good recovery. Sizes 34 to 74 were satisfactorily treated on an Overstrom table. The table concentrates were then treated twice in an Ullrich magnetic separator.

In the final test all the first test products, with the exception of the above table concentrates, were mixed together and crushed to 24 mesh and were passed through a Keedy sizer giving 12 sizes from 28 to 200 mesh, each of which, except the 200 which was treated on a Deister slimer, was run over the Overstrom table. Each table concentrate was then fed to an Ullrich magnetic separator and returned again with poles closer together and using a maximum amperage of 10. The total recovery as concentrates was 2·8 per cent of the ore fed to the table.

### *Conclusions*

It was found necessary to crush the ore to at least 28 mesh in order to free the corundum from the gangue. Using very close sizing, the Overstrom table did good work especially on the 62 to 125-mesh material. The first pass of the table concentrates through the magnetic separator resulted in a clean tailing consisting of hornblende and pyrrhotite. The concentrates still containing a little hornblende and 2·25 per cent of iron pyrites were passed through a second time and a clean product was obtained. The tailings consisted of mica and a small amount of attached iron and corundum particles with the gangue.

[1] Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1915, pp. 90-99.

## Craigmont Concentrators

The original Craigmont 20-ton mill is described in the Ontario Bureau of Mines Report[1] from which the accompanying graphic flow-sheet has been derived. (Figure 3.)

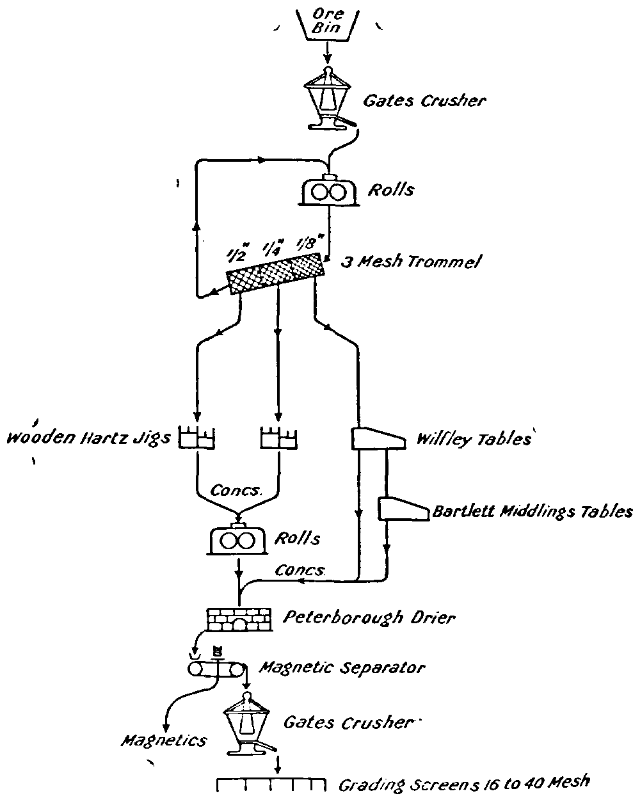



Figure 3. Flow-sheet of the original Craigmont 20-ton corundum mill

The large 200-ton plant was divided into three main buildings—the concentrator, grader, and power house. (Plate V.)

The power was obtained by 225 h.p. and 125 h.p. Corliss engines, and an auxiliary engine of 20 h.p. Wood fuel was used.

The graphic sketch of the flow-sheet of the large mill was compiled from the detailed description in W. G. Miller's[2] and A. E. Barlow's reports[3] and is self explanatory. (Figures 4 and 5.)

[1] Ont. Bureau of Mines Ann. Rept., vol. IX, p. 20 (1900).
[2] Miller, W. G.: Ont. Bureau of Mines Ann. Rept., 1904, p. 89.
[3] Barlow, A. E.: Geol. Surv., Canada, Mem. 57, pp. 301-308 (1915).

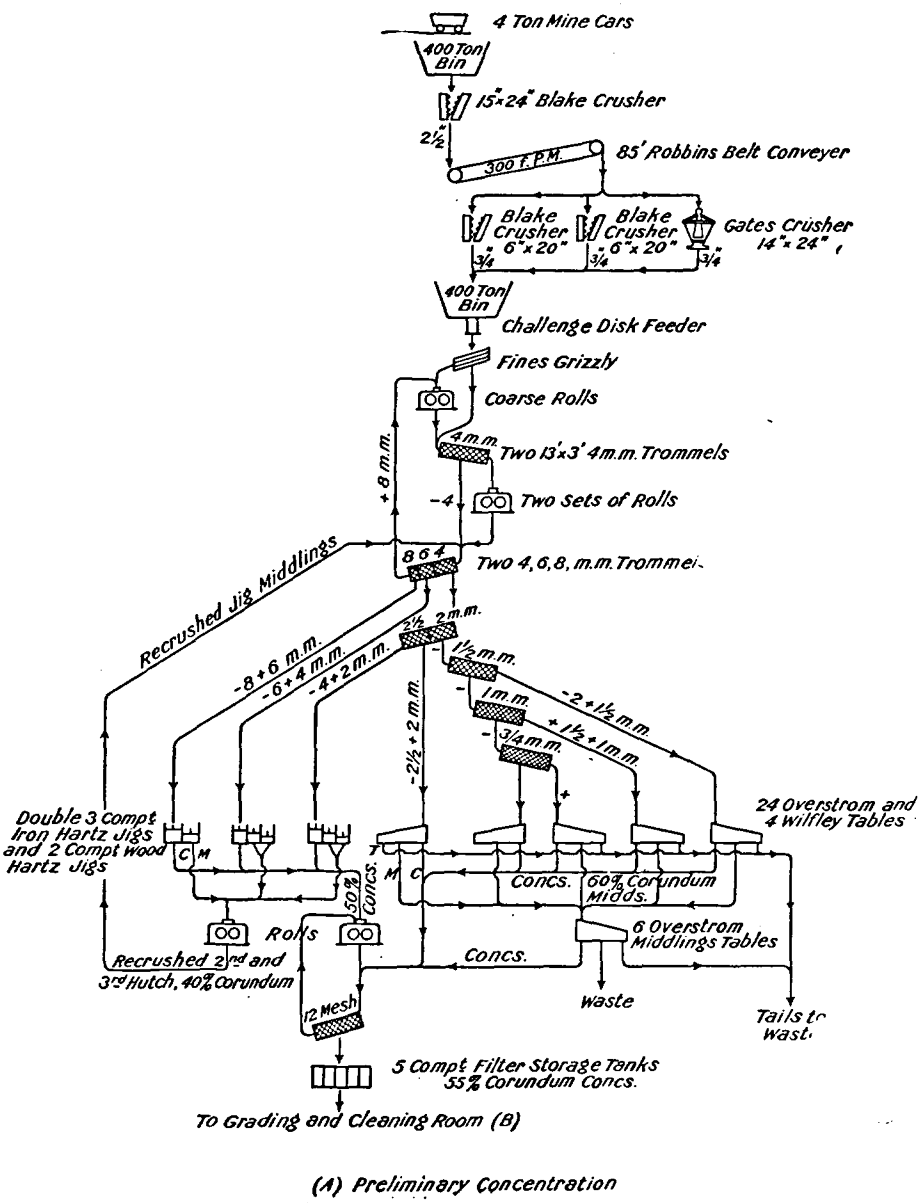
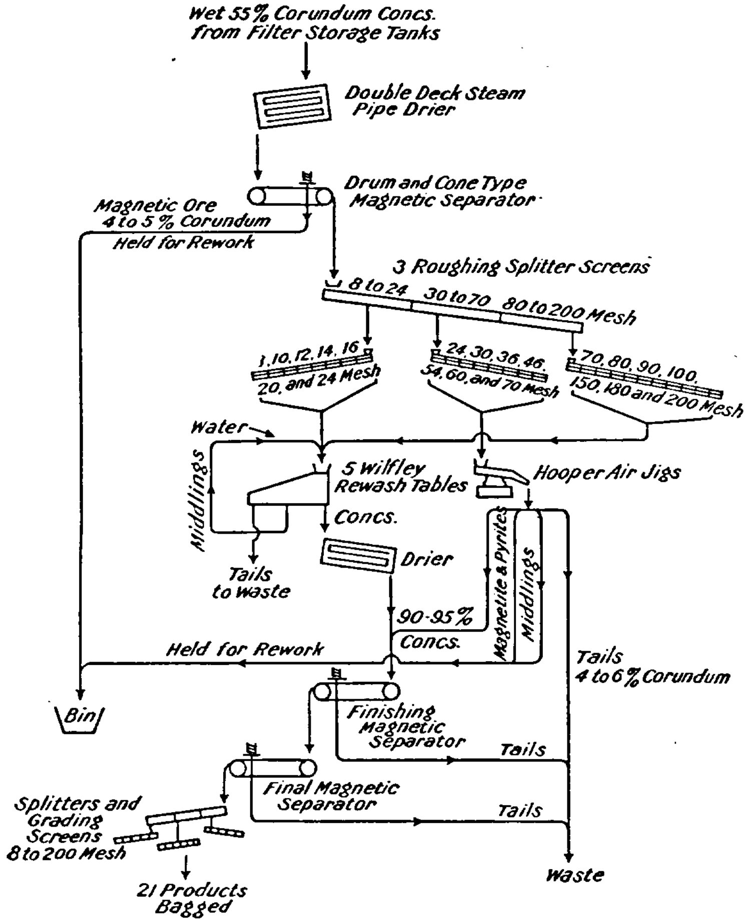



Figure 4. Flow-sheet of the Craigmont 200-ton corundum concentrator

*Grading and Recleaning*

The wet concentrates averaging 55 per cent corundum, and 12 to 15 per cent magnetic iron were dried over exhaust steam pipes and passed over two magnetic separators, one being the cone and the other the drum type. The magnetics containing 4 to 5 per cent corundum were re-treated and the non-magnetic concentrates were divided by rough splitters into three sizes, namely 8 to 24 mesh, 30 to 70 mesh, and 80 to 200 mesh. Each




*(B) Grading and Finishing Mill*

Figure 5. Flow-sheet of the Craigmont 200-ton corundum concentrator

of the three sizes was further sized into seven sizes and passed separately over Hooper air jigs. The jigs made four products, the heaviest, being mainly magnetite and pyrites, was re-treated together with the other magnetics. The next jig product was the clean 90 to 95 per cent corundum, the middlings were re-treated and the tails carrying 4 to 6 per cent corundum were sent to waste.

The coarse and fine sizes of the clean corundum were then treated on Wilfley tables, using a shorter stroke and quicker vibration for the fines. Four products were again made, namely, iron minerals, clean corundum, middlings, and tailings. The concentrates, after drying, joined the air jig concentrates, passed over a finishing magnetic separator and then over a final magnetic separator, leaving from 1 to 2½ per cent iron in the final concentrate. The concentrates were all re-graded by passing over a series of vibrating screens making 21 products of 8 to 200 mesh, which were bagged and sampled; the material containing the highest percentage of corundum was used for vitrified wheels.

The following shows the average percentage of corundum in the various end products:—

| | Per cent corundum |
|---|---|
| Ore fed to mill | 10½ |
| Jig concentrates | 50 |
| Jig partial concentrates | 40 |
| All jig tailings | 3 |
| All table tailings | 2 |
| Magnetic tailings, coarse | 7 |
| Magnetic tailings, fine | 3 |
| Average | 5 |
| Re-wash table tailings | 5 |
| Total mill tailings | 5 |

The corundum was cleaned to 90 or 95 per cent.

### *Corundum Ltd., 100-ton Tailings Mill*

This mill was constructed to treat some of the old Craigmont tailings dump which was estimated to contain 300,000 tons averaging about 5 per cent corundum.

The tailings were hauled by tram-cars to a 200-ton storage bin and elevated to a duplex Callow screen. The oversize, consisting of 16-mesh or coarser went to a 4- by 6-foot Hardinge conical ball mill. From the ball mill all fines passed through the classifiers to fourteen Wilfley tables and one Reid Deister table. The concentrates from the tables went to settling-tanks and from there to the driers and graders. The graders consisted of 1 splitter, 2 graders, 2 Hooper pneumatic air jigs, and a magnetic separator. The concentrates consisted of 18 grades ranging from 14 mesh to flour.

Power was supplied to the mill by two Fairbanks-Morse Diesel oil engines, one 75 h.p. and one 25 h.p. One 80 h.p. boiler furnished steam for heating and drying. Two water tanks were used for storing the water, one of 3,000-gallon capacity located in the upper part of the mill, and one of 4,000 gallons at an elevation of 30 feet above the mill; the latter supplied water to the classifiers.[1]

Wilfley tables were found to be the best. The grading machinery adopted was very similar to that used in the old mill.

Before the company ceased operations in June 1921, they had re-treated 25,580 tons of tailings from which 755 tons of graded grain were produced, a recovery of about 60 per cent of the corundum.

[1] Ont. Bureau of Mines Ann. Rept., vol. XXIX, pt. I, p. 110 (1920).

## Burgess Mill

In the original Burgess mill a 7-inch by 10-inch Blake crusher was at first installed, but it was afterwards found better to cob and hand-sort the ore. A product averaging 15 per cent corundum was obtained and shipped to the United States for further concentration. This practice was continued until a mill was erected at the mine. After operating a little over a year the mill was burnt down, but was immediately replaced by a larger one using dry methods of concentration.

This plant consisted of a steam drier, 5 Blake crushers, 2 impact crushers or pulverizers, 2 rolls, dividers, Noble magnetic separator, and 7 Hooper pneumatic jigs. Power was supplied by a 75 h.p. horizontal boiler. When this mill was burnt in 1913 extra machinery was added to the Burgess mill and a complex wet and dry process was used. However, the mill was not large enough and the process was not satisfactory. In 1916, the mill was dismantled and the machinery removed to Jewellville.

## Jewellville Mill

The Manufacturers Corundum Company in 1916 erected a 100-ton mill at Jewellville, near Palmer rapids, east of the Madawaska river. Wilfley tables were used and proved far more satisfactory than the dry process of the Burgess mill. After operating for about 1½ years the company closed down in August 1918, having treated about 8,000 tons of ore from which 325 tons of graded grain was produced.

## A MODERN SOUTH AFRICAN CORUNDUM MILL[1]

In the Transvaal Grain Corundum Company's mill at Bandolierkop in the Zoutpansberg district, Northern Transvaal, the ore, which is a coarse gravelly material mixed with earthy debris and larger blocks, is reduced to 2 inches by a 12-inch Robey crusher and then further crushed by five 1,500-pound stamps to 8 mesh. The product is lifted by a Frenier pump to a 20-mesh Callow screen. The oversize goes to a three-compartment Harz jig and the undersize to a spitzkasten table and then to two Wilfley tables, the slimes from which go to settling-tanks.

The product from the first hutch containing pure corundum is drained into settling-vats, dried, and passed over a magnetic separator and classifier. The middlings containing feldspar, etc., are returned to the stamps. The third hutch product goes to waste.

The jig and table concentrates are dried and passed over a magnetic separator. The cleaned product is then graded by passing over long vibrating screens into 15 different grades from 10 to 100 mesh; each grade is shipped in bags holding 112 pounds. (*See* flow-sheet Figure 6.)

[1] Hall, A. L.: Abrasive Industry, p. 190 (June 1923).

The daily output is 2½ to 3 tons of graded grain in 9 hours. The concentrates assay 95 to 96 per cent corundum.

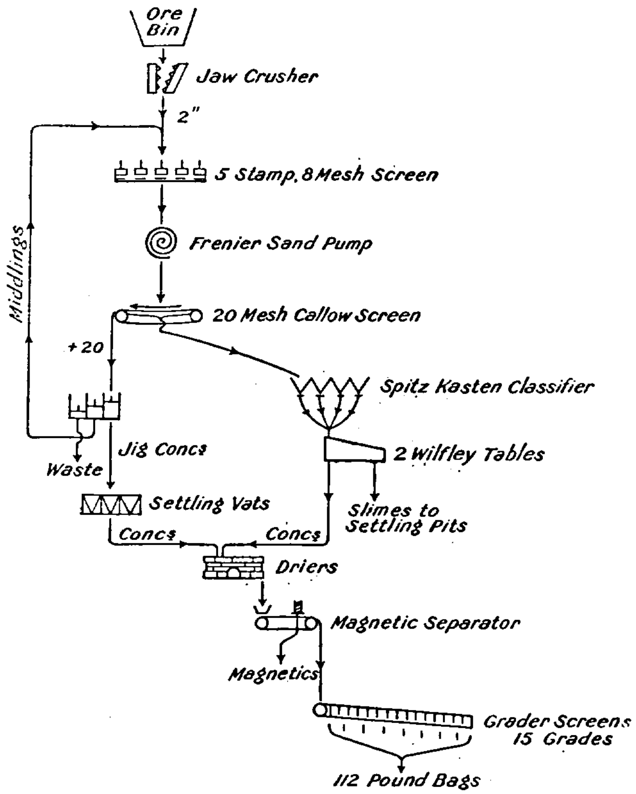



Figure 6. Flow-sheet of a modern corundum mill, Transvaal Grain Corundum Company, Zoutpansburg, Northern Transvaal, South Africa

## Concentration of Eluvial Corundum-Bearing Soil and Gravel

The South African corundum is very frequently found in the gravel of eluvial "paddocks" and concentration is performed by crude methods of hand-screening and washing. The corundiferous gravel or soil is thrown against an inclined stationary sieve of ½ to ¾-inch mesh. The oversize falls back and is washed in gravitating hand-sieves, where the corundum crystals, which concentrate in the centre, are picked out by hand, sun dried, and bagged. The undersize passes over a slightly inclined rocking sieve of ⅛-inch mesh. The undersize of this screen is rejected and the overs are washed in a simple hand-worked rotary pan with a radiating system of stirrers, whereby the heavy slimes containing the corundum are tapped off at intervals at the circumference by means of a sliding panel. The earth and light material travel to a sump in the centre. The corundum slimes are washed in a gravitating hand-sieve from which the concentrated corundum is picked from the centre, sun dried, and bagged either separately or mixed with the original coarse corundum. Sometimes when the corundum contains attached lumps of other minerals, barrel-cleaning is resorted to. A hollow cylindrical barrel, 2 feet long by 1 foot in diameter, is half filled with dry ore and rotated by hand at a suitable speed whereby the adhering lumps are knocked off. Final hand-screening and washing leaves clean crystals ready for drying and bagging.[1]

All the crude, South African corundum at present on the world's markets is prepared by the above method.

## ANALYSIS

### DETERMINATION OF PERCENTAGE OF CORUNDUM IN THE ORE

There are three different methods of determining the percentage of corundum in an ore or concentrate: (1) Hydrofluoric acid method; (2) Specific gravity method; (3) Separation by heavy solution. The last named method is only approximate.

### Hydrofluoric Acid Method

Hydrofluoric acid attacks corundum very slowly at temperatures up to 100° C. but more rapidly at higher temperatures. On the other hand it quickly disintegrates the minerals which accompany corundum.

A weighed ground sample (1 gramme) is ignited for 10 minutes in a platinum crucible and placed in a platinum evaporating dish. The sample is then moistened with about 5 c.c. of sulphuric acid and covered with about 10 c.c. of C.P. hydrofluoric acid and evaporated over a water bath until the sulphurous fumes appear and the rock is thoroughly decomposed and all the silica is evaporated from the solution which is then diluted. A little hydrochloric acid is added, if necessary, to bring sulphates into solution. The insoluble matter is then washed out on to a filter, washed, ignited and weighed as corundum.

To test the insoluble residue (or for an analysis of corundum itself) it is fused with sodium or potassium bisulphate and from the dissolved melt the alumina and other minerals are precipitated with ammonia. The lime and magnesia may then be determined.

For an accurate analysis allowances must be made for the grinding away of the mortar in which the sample is pulverized. This can be done by weighing the pestle and mortar before and after grinding, and distributing the loss over the weight of the sample being analysed. It is not necessary to grind very fine.

### Specific Gravity Method

This method is applicable to concentrates free from magnetite and other heavy minerals. For Canadian samples the calculation is made on the basis of a specific gravity of 4·0 for the corundum and 2·7 for the impurities (mostly feldspar) thus:—

$$\text{Corundum, per cent} = 100 \times \frac{C\,(S-F)}{S\,(C-F)} = \frac{400\,(S-2{\cdot}7)}{S \times 1{\cdot}3}$$

C = 4·0 = sp. gr. of corundum
F = 2·7 = " impurities
S = = " sample

[1] Hall, A. L.: Geol. Surv. S. Africa, Mem. 15, p. 166 (1920).

## Heavy Solution Method

In this method certain heavy solutions are used so that when stirred up in a separating funnel the lighter minerals in the finely crushed ore or concentrate will float, whereas the heavier will sink. When the solution is clear after settlement, the mineral at the bottom is extracted through the petcock, and is again subjected, if necessary, to a similar treatment in a still heavier solution.

The heavy solutions commonly used are potassium mercuric or barium mercuric chlorides, the former having a specific gravity of 3·15 and the latter 3·55. A very clean separation of the quartz and feldspar can be effected by this means, but some garnet, magnetite, etc., will report with the corundum, so that this method is only approximate. A further account of this method will be found in the bulletin on "Garnet".

## X-Ray Method

The purity of commercial samples of grain corundum can be determined by means of X-ray photographs, since the various minerals present can be distinguished from one another by means of their relative degree of translucency. All forms of corundum are practically transparent, and come next to diamond in Doelter's scale[1] and are not so impervious to the rays as are silicates such as feldspar, garnet, chlorite, mica, etc. This method, however, is of more value in distinguishing the gems ruby or sapphire from other minerals or artificial stones of similar appearance. Details of determinations by X-ray methods may be found in a recent article by Paul F. Kerr.[2]

[1] Neues Jahrbuch für Min., vol. II, p. 87 (1896).
[2] Determination of Ore Minerals by X-Ray Diffraction Patterns; Econ. Geol., pp. 1-34 (Jan. 1924).

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## EMERY

Emery is an intimate mixture of granular corundum and magnetite with some hematite. It takes its name from cape Emeri, on the island of Naxos in the Grecian archipelago, where it occurs in great abundance and from which it has been mined for several centuries.

### PHYSICAL AND CHEMICAL PROPERTIES

Mineralogically, emery has been regarded as either a mechanical admixture of corundum and magnetite or simply as a massive iron spinel-hercynite.[1]

It is a massive, nearly opaque, dark grey to blue-black, in some cases mottled, mineral. It has a specific gravity of 4, a hardness of about 8, breaks with a moderately regular fracture, and is always more or less magnetic. The appearance, hardness, composition and colour vary according to the locality in which it occurs. The hardness depends upon the amount of corundum contained and the emery may either be fine or coarse grained depending on the size of the corundum crystals present.

There are at least three recognized grades of emery: Grecian, Turkish, and American. Each one varies as to its chemical and physical properties.

#### *Abrasive Qualities and Uses*

The Grecian or Naxos emery contains the highest percentage of alumina (about 65 per cent). Since it does not undergo detrimental physical and chemical changes under heat, and the grains are very hard and sharp, this emery is suitable for the manufacture of grinding wheels.

The Turkish emery which comes from Asia Minor, contains about 25 per cent of iron oxide, and is slightly softer than the Naxos. The grains, unlike the Grecian, break down, or granulate under pressure, and constantly present new cutting edges. It is fairly tough so that it is the best suited for polishing purposes for which it is largely used in the form of loose grain, particularly in glass grinding and bevelling, or for the manufacture of emery paper or cloth, or in the setting up of polishing wheels. Since it undergoes changes under heat, it is seldom used for making grinding wheels.

The American emery, most of which comes from New York state and Virginia, contains about 45 per cent iron oxide and is the softest of the three. It is used on woods or for soft metal work.

#### *Types and Analyses of Emery*

Mineralogically, emery is divided into three varieties: (1) True emery, (2) Spinel emery, (3) Feldspathic emery.

(1) True emery is a mixture of corundum and magnetite, with or without hematite derived from the magnetite, such as the Grecian and Turkish emery, and is usually of a reddish black tint.

[1] Merrill, G. P.: Smithsonian Inst.—The Non-Metallic Minerals, p. 223 (1901).

(2) Spinel emery is a mixture of spinel (pleonaste-hercynite) corundum and magnetite. Corundum is present in variable proportions and is sometimes entirely lacking. It is usually a heavy, black, fine-grained aggregate with dark grey crystals of corundum appearing in the best varieties. The crystals are in many cases cracked and considerably altered to hydrous mica. This type is mined in New York and Virginia in the United States.

(3) Feldspathic emery is similar to the spinel but contains in addition from 30 to 50 per cent plagioclase. Pure magnetite often is found in streaks within this mass.

TABLE IV

**Analyses of Emery from Different Localities**

| Locality | Alumina | Silica | Magnetic iron oxide | Lime | Magnesia | Water | Total |
|---|---|---|---|---|---|---|---|
| Greece, Naxos........ | 62·64 | 4·90 | 31·41 | 0·45 | 0·06 | 1·04 | 100·50 |
| " " ........ | 68·53 | 3·10 | 24·10 | 0·86 | .......... | 4·72 | 101·31 |
| " " ........ | 57·69 | 6·36 | 30·87 | 0·89 | 0·20 | 3·99 | 100·00 |
| " Nicaria....... | 75·12 | 6·88 | 13·06 | 0·72 | .......... | 3·10 | 98·88 |
| Turkey, Kulah....... | 63·50 | 1·61 | 33·25 | 0·92 | .......... | 1·90 | 101·18 |
| " Gumuch...... | 60·10 | 1·80 | 33·20 | 0·48 | .......... | 5·62 | 101·20 |
| " Samos........ | (a) 70·10 | 4·00 | 22·21 | 0·62 | .......... | 2·10 | 99·03 |
| U.S.A., Virginia...... | 45·38 | 2·53 | 41·23 | 0·06 | 5·71 | 1·32 | 96·23 |
| " Chester....... | 50·02 | 3·25 | 44·11 | .......... | .......... | n.d. | 97·36 |
| " New York.... | (b) 59·22 | 0·84 | 30·68 | .......... | 3·54 | 2·70 | 96·98 |
| " " .... | 50·10 | 14·32 | 28·17 | 0·84 | 4·31 | n.d. | 97·74 |

(a) Also contains 3·72 per cent $TiO_2$ (ilmenite) and some of the alumina as spinel.
(b) Also contains 3·28 per cent $TiO_2$ (ilmenite) and some of the alumina as spinel.

## WORLD'S OCCURRENCES OF EMERY

### CANADA

Commercial emery has not been found in Canada, although certain corundum deposits east of Madawaska river, Ontario, are so intimately mixed with magnetite that they are practically a coarsely crystalline emery. A typical deposit occurs in lot 34, concession VII, Brudenell township, Renfrew county, where the mineral is thickly disseminated throughout a well-foliated nepheline-syenite-gneiss which has been traced across its line of strike for about 300 yards. No work has been done on the deposit.

### UNITED STATES

Emery has been mined from Chester, Massachusetts; Peekskill district, New York; and from Whittles, Virginia.

The annual production for the last two or three years has been between 2,000 and 3,000 tons. (*See* general Table B in bulletin on Siliceous Abrasives.)

#### Massachusetts

Emery was discovered in Hampden county at South Mountain near Chester in 1864 by Dr. H. S. Lucas, although 30 years previously the deposit had been unsuccessfully worked as an iron mine. Until recently, practically all the emery from the United States has been produced from this locality. The deposits are associated with a narrow band of amphibolite that extends almost continuously across the state. In the vicinity of Chester this band is about three quarters of a mile wide, and the emery deposits can be traced for about 5 miles. The deposits occur in the form of a vein in the eastern side of the band in close proximity to sericite schist. The emery is found in pockets from a few feet to 12 feet wide.

Six or seven mines were operated along this vein and large quantities of ore were extracted, but the mines have been abandoned for some time.

### New York

Emery deposits of the spinel variety occur east of Peekskill in Westchester county, and have been operated by various companies since 1883. The ore occurs on the border of an igneous complex composed of hornblende and olivine pyroxenite, termed the "Courtland" series. The emery occurs in a region in which mica schist inclusions are abundant, and is in sharply defined veins immediately associated with rocks containing sillimanite, cordierite, garnet, and quartz. A characteristic of these schist inclusions is the great abundance of biotite found around the ore in many places. The two chief mines are the Dalton and McCoy. They are worked by open-cut methods, some pits being over 80 feet deep. One of these mines is being worked by the Smith and Ellis Company.[1]

### Virginia

A spinel emery occurs to the west and south of Whittles, Pittsylvania county. Although the deposits were exploited many years ago for iron ore, they were not successfully worked for an abrasive until 1917 but up to the present have yielded a large quantity of good material.

There are two types of occurrence. (1) Schist ores in which thin bands of quartzite, interbedded with the schists in places, form one, and sometimes both, walls of the emery bodies. The rock is closely jointed and in many places pegmatitic. (2) Granite ores, or those enclosed in a decayed granite, which are in many cases cut by narrow, pegmatite dykes. The emery of both types are similar, being a heavy, black, fine-grained crystalline aggregate. Weathering has progressed to an advanced stage, so that in all the ore-deposits, the rocks are entirely decomposed, and owing to alteration of the schists into vari-coloured mottled clays, the surfaces of the emery bodies are often coated with a deep red clay.

The ore-bodies occur as irregularly-shaped lenticular masses of solid emery, the largest of which is about 130 feet long and 6 to 8 feet wide.

The method of mining the ore is based on the strongly-developed joint structure of the emery bodies. After removing the decomposed rocks, the emery blocks are dislodged by forcing iron bars into the joints; very little dynamite is used.

The emery is stated to be of good quality, but the chief drawback to the development of the deposits is the long distance from the emery-crushing mills in New York and Massachusetts.

[1] Peekskill District Emery Ore. Abrasive Industry, p. 65 (March 1924).

A full description of these Virginia deposits will be found in Thomas L. Watson's report.[1]

Information concerning the United States emery deposits will be found in the following:—

Williams, G. H.: Am. Jour. Sci., vol. 33 (1887).
Emerson, B. K.: U.S. Geol. Surv., Bull. 29 (1898).
Pratt, J. H.: U.S. Geol. Surv., Bull. 269 (1906).
Rogers, G. S.: N.Y. Acad. Sci. Anns., vol. 21 (1911).
Barlow, A. E.: Geol. Surv., Canada, Mem. 57, pp. 203–212, 222 (1915).
Steiger, G. and Watson, T. L.: "Emery, Pittsylvania Co., Va."; Jour. Wash. Acad. Sci., vol. 8, pp. 665, 676 (1919).
Shannon, E. V.: "The Chester Emery Mine"; Am. Mineralogist, pp. 69–72 (June 1919).
Ladoo, R. B.: "Emery"; U.S. Bur. of Mines (Jan. 1920).
Gordon, S. G.: Proc. Phila. Acad. Nat. Sci., pt. I (1921).
New York State Bull., p. 91 (1921).
"Emery Mining, Chester"; Abrasive Industry, p. 314 (Oct. 1922).
Watson, T. L.: "The Geology of the Virginia Emery Deposits"; Econ. Geol. vol. 18, pp. 53–76 (Jan. 1923).
"The Peekskill Dist. Emery Ore"; Abrasive Industry, p. 65 (March 1924).
"Non-Metallic Minerals"—"Corundum and Emery," pub. by McGraw-Hill Book Co., N.Y., pp. 164–66 (1925).
Gold, W. C.: "Emery"; Abrasive Industry, p. 57 (Feb. 1925).

## GREECE

Emery has been mined for several centuries from a number of islands in the Grecian archipelago, the largest and best-known deposits being found on the island of Naxos.

The mineral takes its name from cape Emeri, on Naxos, the largest of the Cyclades islands. It is usually found in large blocks, more or less mixed with the red soil of the island, in which form it occurs in such abundance, that until recently no attempt was made to mine it from the solid rock.

The island is principally made up of gneisses and schists, the latter consisting of mica schists alternating with crystalline limestones. The lenticular masses of emery varying in width from 15 to 150 feet and sometimes as much as 100 yards in length are closely associated with the limestone. The best Naxos emery is a dark grey colour, usually mottled with bluish specks or streaks of pure corundum, and is the hardest emery known. The best ore comes from Vothrie, 9 miles from the coast, on the northeast side of the island. Another important deposit is at Apiranthos, 7 miles inland, and the ore is shipped from the ports of Sulinos and Mutzoma. On the northern part of the island it is mined near Yasso.

Emery of a similar mottled appearance and quality, but presenting a lamellated structure occurs on the island of Nicaria, and a dark blue-coloured emery is found on the island of Samos, near the Asia Minor coast, but these deposits are not so extensive as those of Naxos. The mineral is sometimes also found embedded in white marble.

Emery was not extensively mined until 1870, about twenty years after the publication of Dr. J. Lawrence Smith's[2] memoirs on these deposits.

Mining operations are of the simplest character. The boulders or blocks containing the ore, when not too large, are transported in their natural condition to the sea-coast. The larger blocks are broken to a suitable size by means of hammers, sometimes with the assistance of heat and sudden cooling with water. Most of the present supply comes from the Liona and Mutzoma mines.

[1] The Geology of the Virginia Emery Deposits; Econ. Geol., pp. 53–76 (Jan.-Feb. 1923).

[2] Amer. Jour. Sci., 2nd Series, vol. VII (1849); vols. IX and X (1850); vol. XI (1851), and Scientific Researches, pp. 1–53 (1851).

Mining of emery is done under the supervision of the Greek Government, which has fixed certain prices on the Naxos emery at the mines, according to grade. There are six of these grades, i.e., first, second, and extra qualities, large and small, and the lumps are arranged in weight from 2 to 21 ounces for the three small grades and 21 ounces to 20 or 25 pounds for the three large.

The pre-war Greek production ranged from 8,000 to 13,000 tons annually, but has gradually increased since the war and is now over 20,000 tons. (*See* general Table B in bulletin on Siliceous Abrasives.)

## TURKEY (ASIA MINOR)

Emery is obtained in Asia Minor from the province of Aidin, which embraces almost the entire basins of the Sarabat and Mender rivers. Smyrna is the principal port and centre of trade for the surrounding districts and islands, and from which railways extend into the interior along the basins of the above rivers.

The greater part of the region is underlain by pure white or finely granular crystalline limestones which are interfoliated with chloritic and micaceous schists and gneisses. The emery deposits occur as pockets or lenticular masses in the limestones and vary from a few feet to 200 feet in width, and up to 300 feet in length.

Extensive deposits have been worked on the Gumuch-Dagh mountain in the vicinity of Ephesus and from the slopes of Ak Sivri in the Kulah district, which is about 100 miles southeast of Smyrna. The emery from the former locality is usually fine-grained, of a dark blue to purplish colour, and the interior of the masses is free from micaceous inclusions. The ore from the Kulah deposits is coarse grained and much darker in colour.

Usually the emery ore possesses numerous fractures or cleavage planes, so that it is easily broken into blocks of suitable size for handling. The main source of supply has been obtained from the loose emery or boulders embedded in a compact red clay, which occurs in shallow depressions in the limestone.

At the beginning of the war, the Abbotts' Emery Mines Ltd., the largest operator, installed a wire rope tramway system from their principal mines to a more accessible point near the coast, but the plant was seized and destroyed by the Turks. All of the nine or ten producing mines were closed during the war. The pre-war production amounted to 50,000 to 60,000 tons annually, but the production figures for recent years are not available.

Emery imported from Asia Minor is branded according to the seaports from which it is shipped, these being Smyrna, Kulluk, Syra, and Yoba Bay.

More detailed information concerning the Grecian and Turkish emery deposits may be obtained from the following:—

Merrill, G. P.: Smithsonian Inst., U.S.A. Nat. Mus., pp. 223-229 (1901).
Smith, J. Lawrence: Scientific Researches, pp. 1-53 (1851).
Thomae, W. F. A.: "Emery of Asia Minor"; Tr. Am. Inst. Min. Eng., vol. 28, pp. 208-225 (1898).
Haenig, A.: "Emery and the Emery Industry," London (1912).
Barlow, A. E.: "Corundum"; Geol. Surv., Canada, Mem. 57, pp. 236-38 (1915).
Abrasive Industry, p. 50 (Feb. 1924).
Plusch, H. A.: Eng. and Min. Jour. Press, pp. 339-340 (Aug. 30, 1924).
Ladoo, R. B.: U.S. Bur. of Mines, Bull. "Emery" (Jan. 1920).

### GERMANY (BAVARIA)

A small output of emery has been maintained annually from Bavaria, which has recently increased to about 400 tons.

## PREPARATION FOR MARKET

All the Grecian and Turkish emery is shipped in lumps ranging from the size of a marble to 25 pounds in weight. Formerly it was exported as ballast, but for the last twenty-five years it has been shipped as a regular cargo.

In the United States there are several emery-crushing and grading mills in which the crude ore is first crushed by jaw crushers and thence through a series of chilled rolls to $\frac{7}{8}$, $\frac{3}{8}$ and $\frac{3}{16}$-inch, then to finer sizes in ball mills. The mica is removed by allowing the coarse grain to fall down a chute; an uprushing current of air blows the mica to one side into a separate compartment. The emery then passes over a series of long trough, shaking screens, whereby the emery is carefully graded into about 30 different sizes. The oversizes are further reduced by means of small rolls, and return through the circuit.

In some plants the crude grain is washed with water in pans of the Chili mill type in which hardwood wheels revolve. This cleans off the adhering dirt, and the cleaned material is dried and graded. Although this washing process is more costly, a much purer and better cutting article is produced. The overflow from the washing pans which contain all the fines, flows through a series of long settling-troughs. The settled material is then shovelled out into drying ovens and this "flour" is further screened into three or four grades. The finest flour grades are made by drawing off the solutions at certain intervals of time, and drying the residue after finally settling.

The standard mesh sizes for emery are as follows: 6, 8, 10, 12, 14, 16, 20, 24, 30, 36, 40, 46, 54, 60, 70, 80, 90, 100, 120, 140, 150, 160, 180, 220, F, FF, FFF, FFFF. The first twelve sizes are termed "coarse grain," the next twelve "fine grain," and the last four "flour." In addition to these, there are still finer flours, produced by the decantation methods, which are principally used in optical work.

In the manufacture of emery paper or cloth, the largest size is No. 4 or 20 mesh and the following grading has been adopted:—

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grade.......... | 4 | 3½ | 3 | 2½ | 2 | 1½ | 1 | ½ | 0 | 2/0 | 3/0 | 4/0 |
| Mesh............ | 20 | 24 | 36 | 46 | 60 | 70 | 80 | 90 | 120 | 150 | 180 | 220 |

The finer grades of paper keep their designation of multiples of F.

## DIAMOND

Diamond, which is pure carbon, is the hardest known substance and is placed at 10 on Moh's scale, though the difference between diamond and corundum (9) is far greater than the difference between any two other minerals in the scale.

Diamond is found either as transparent colourless octahedral crystals or fragments from a microscopic size to specimens weighing over 3,000 carats, or as an opaque black to brown variety. The former variety is used as gems, but the latter is employed for abrasive or cutting purposes. Crystal diamond has a conchoidal fracture, but has a distinct cleavage parallel to one of the faces.

The two varieties of the opaque stones are *carbonado* (black "diamond" or "carbon") and *bort* ("bortz" or "boart"). Carbonado is compact, opaque and tough, usually black or dark brown, possesses no cleavage and breaks with a granular fracture. Bort is dark coloured, translucent to opaque, often with a radical or fibrous structure, and is found in crystals or fragments.

### USES AND PREPARATION

*Diamond dust* is produced either by utilizing the dust produced in the cutting and polishing of gem diamonds, or by crushing bort in a special mortar. The dust is graded by placing in high-grade olive oil and allowing it to stand for varying periods. The residues after pouring off the oil are classified as follows[1]:—

| Oil Settlement Time | Grade |
|---|---|
| Five minutes | No. 0 |
| Ten minutes | No. 1 |
| Thirty minutes | No. 2 |
| One hour | No. 3 |
| Two hours | No. 4 |
| Ten hours | No. 5 |
| Until oil clears | No. 6 |

The dust is used in the grinding and polishing of diamond and other gems, also in grinding operations where an extremely hard abrasive dust is required.

*Carbonado and bort* are used in the tips of drill bits for drilling rocks; in tools for truing abrasive wheels; as teeth in saws for cutting rock; in machine tools for turning hard rubber, fibre paper rolls, brass, bronze, etc.; in tools for glass-cutting.

The selection of the best size and type of diamonds for any particular use as well as the setting of the stones should be done by experts.

[1] Jacobs, F. B.: "Abrasives and Abrasive Wheels"; p. 31, pub. by N. W. Henley Publishing Co., New York (1919).

## OCCURRENCES AND PRODUCTION

Although no diamonds have actually been found in Canada, nevertheless in the glacial drifts to the south of lake Superior, particularly in Wisconsin, U.S., small diamonds up to a few carats in weight have been located. It is believed that they have been transported by ice during the Glacial period from the Laurentian plateau in the neighbourhood of Hudson bay so that their discovery in this region is possible.[1]

Microscopic diamonds were believed to have been discovered in the massive chromite in the vicinity of Black Lake, Megantic county, Quebec; in the chromite of Reaume township, north of Porcupine, Ontario; and associated with chromite in the altered peridotite in the Tulameen district, British Columbia.[2]

However, the existence of these diamonds never has been definitely confirmed.

About 80 per cent of the world's diamonds come from the Union of South Africa and the remainder mostly from Brazil, India, and Southwest Africa Protectorate.

Brazil is the main source of the abrasive diamond, carbonado, where it is found in the alluvial deposits in Western Minas Geraes and Bahia. In the latter they occur along the Paraquassu and the Pardo rivers. The stones average 6 carats, but some weighing as much as 3,000 carats have been found. Considerable quantities of "Black Jaeger" stones come from the South African fields.

Further reference to the mining, milling and production of diamond will be found in R. B. Ladoo's monograph which gives a bibliography[3] and in various articles in the "Abrasive Industry."[4]

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[1] Young, G. A.: Geol. and Econ. Minerals of Canada, Geol. Surv., Canada, Rept. 1085, pp. 18-83 (1909).

[2] References:—
Econ. Geol., vol. III, p. 525 (1908).
Johnston, R. A. A.: Geol. Surv. Canada, pp. 112, 262-263 (1911).
Camsell, C.: Econ. Geol., vol. VI, pp. 604-11 (1911).
Ont. Bureau of Mines Ann. Rept., vol. XXIII, p. 47 (1914).
Poitevin, E. and Graham, R. P. D.: Geol. Surv., Canada, Mus. Bull. 27, pp. 13-14 (Feb. 28, 1918).

[3] Ladoo, R. B.: Non-Metallic Minerals, pp. 181-185 (1925).

[4] Abrasive Industry—(1) Dessan, M. S.: "Industrial Diamonds," p. 8 (Jan. 1921). (2) Price, B. K.: "Diamond Cutting and Polishing," p. 331 (Oct. 1921). (3) "Diamond Sizes"; p. 18 (Jan. 1922). (4) Wade, F. B.: "Economical use of Bort Stones"; p. 69 (March 1922). (5) Conant, P.: "Diamonds used in Wheel Truing"; p. 168 (June 1922). (6) Van Moppes, M. L.: "Selection and Care of Diamonds"; p. 34 (Jan. 1923). (7) Smit, J. K.: "Preparing Carbon Stones for Use"; p. 37 (Feb. 1923). (8) Sansom, W. J.: "Industrial Diamond Nomenclature"; p. 49 (Feb. 1923). (9) Clarke, W. F.: "Choice of Wheel Truing Diamonds"; p. 57 (Feb. 1923). (10) Wagner, P. A.: "The Diamond Industry of Africa"; p. 227 (Aug. 1923). (11) Miller, H.: "Mounting Diamonds by Casting"; p. 1 (Jan. 1, 1924). (12) Wade, F. B.: "Hardness and Durability of Diamonds"; p. 35 (Feb. 1924); also "Industrial Diamonds"; pp. 93 and 106 (April 1924). (13) "Hints on Care of Diamonds"; p. 277 (Nov. 1924). (14) Dessan, M. S.: "Diamonds Perform Important Work"; p. 54 (Feb. 1925). (15) "Diamond Market is Summarized"; p. 151 (May 1925). Ball, S. H.: "Industrial Uses of Diamonds"; Eng. and Min. Jour. Press, pp. 847-50 (May 23, 1925).

PLATE II

*Photo by the late Dr. A. E. Barlow, Geological Survey.*

Nepheline syenite showing corundum crystals, Craigmont, Raglan township, Ontario

*Photo by the late Dr. A. E. Barlow, Geological Survey.*

General view of the Craig corundum mine, Raglan township, Ontario.
Looking east—Robillard mountain (1912)

*Photo by the late Dr. A. E. Barlow, Geological Survey.*

Corundum quarries at east end of Robillard mountain, Craigmont, Ontario. Looking north (1912)



*Photo by the late Dr. A. E. Barlow, Geological Survey, Ottawa.*

The corundum concentrator, Craigmont, Raglan township, Ontario, (1904). The mill on left was burned down in 1913, and the grading mill on right is the tailings concentrator

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