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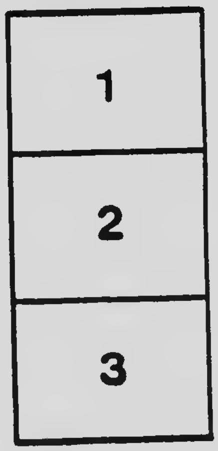
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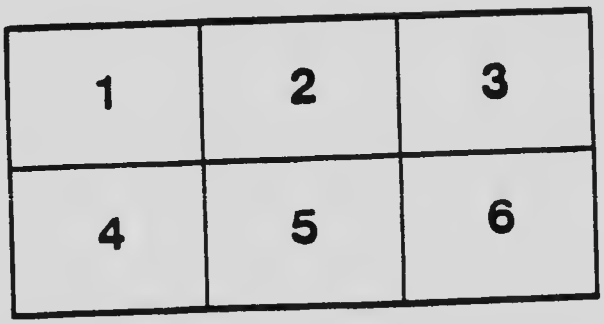
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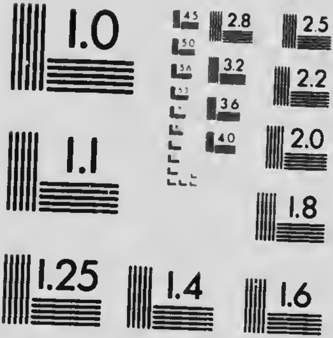


CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER, R. W. BROCK, DEPUTY MINISTER.

GEOLOGICAL SURVEY

MEMOIR 57

No. 50, GEOLOGICAL SERIES

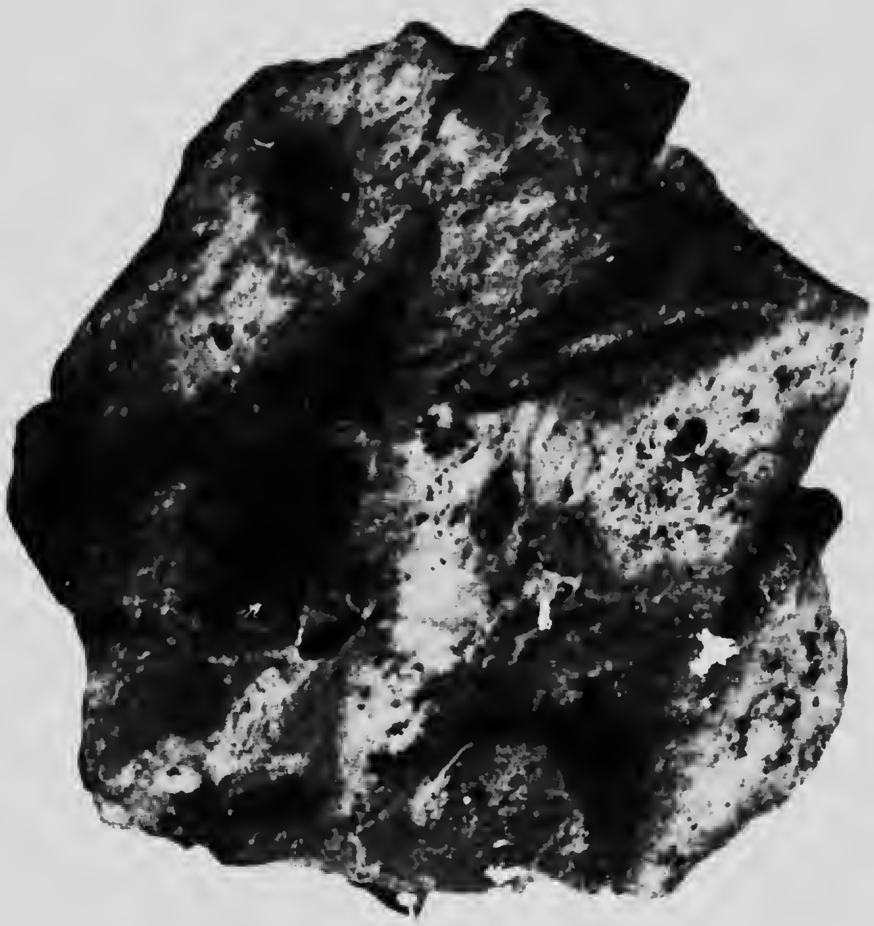
Corundum, Its Occurrence, Distribution, Exploitation, and Uses

BY

Alfred Ernest Barlow

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

No. 1022



CORUNDUM-SYENITE

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PREFACE.

The information contained in the following report was primarily intended to form a part of the chapter treating of economic geology in the memoir on the general geology of the Haliburton and Bancroft areas, Province of Ontario[1], which was published by the Geological Survey of Canada in 1910. As the investigation proceeded i was found expedient to extend the scope of the work not only on account of the economic importance of the corundum deposits themselves, but also by reason of the many new and interesting facts bearing directly on the origin and mode of occurrence of this mineral. The author has included only a very brief reference to the general geology of this portion of eastern Ontario where corundum has been found, which is a synopsis based upon the memoir already mentioned. A rather complete statement, however, is made of the geology and petrographical details of the nepheline and associated alkaline syenites with which the corundum deposits are directly associated. There have been very serious interruptions to the large amount of research work necessary to an adequate treatment of the subject, and it is a matter of sincere regret that such a very serious delay has marked the appearance of this final report. It is issued in the hope that it will dissipate many misconceptions and misunderstandings of this scientifically interesting and industrially valuable natural product.

[1]Memoir No. 6. "Geology of the Haliburton and Bancroft Areas, Province of Ontario" by Frank D. Adams and Alfred E. Barlow. Geol. Surv., Can. 1910.

Corundum, Its Occurrence, Distribution, Exploitation, and Uses.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The study of the natural history of corundum has for many years attracted a numerous band of investigators all eager to secure more precise and extended information regarding the origin and geological associations of this important mineral. The unusual fascination attaching to this study has, no doubt, arisen in large part at least from its two-fold value, for from the practical standpoint is presented a natural product which has for ages been highly prized for its wide industrial application, while from the point of view of science alumina has always commanded the attention of geologists as the third in importance of the constituents of the earth's crust. Silica, the most abundant member of the mineral species, forms more than half of the crust which is open to our inspection; aluminium is the third in order of importance of the elements, ranking next to oxygen and silicon in this regard. It is thus the most abundant of the metals entering into the composition of the lithosphere, being computed to form about 8 per cent; while iron, the fourth element, forms nearly 5 per cent of this rocky envelope. Aluminium's strong affinity for oxygen at once explains its absence in the native state, as also its prevalence as oxides and in silicates, fluorides, and various phosphates and sulphates. Aluminium is an essential constituent of all the important rocks with the exception of sandstones and limestones, and even these often contain this element as an impurity. It, is, therefore, [illegible]matic that nowhere can the free oxide exist in any such abundance as would be comparable to the vast quantities of aluminium stored up in various combinations in the earth's crust. Contrary, however, to the general belief even now sometimes expressed, corundum is by no means a rare mineral and has, moreover, a widespread distribution, recent explorations and examinations having revealed important areas of corundum bearing rocks in widely separated parts of the world. Lagorio in 1895 was the first investigator to call attention to the occurrence of corundum in igneous rocks of widely different type and composition, insisting strongly on the pyrogenesis of this mineral and its development as a primary crystallization from the same magma as the parent igneous rock with which it was associated. The publication of these conclusions was quickly corroborated by Morozewicz from an examination not only of the natural occurrences of corundum in the Ural mountains of Russia but also as a result of his brilliant synthetical experiments with artificial magmas. It was by this means satisfactorily and conclusively demonstrated that corundum crystallized as an independent primary oxide from igneous magmas supersaturated with alumina. At the same time the composition of the parent, or associated rock which contributed to its formation, was clearly indicated. The complete statement of this experimentation, and attendant studies covering a period of nearly six years, were not, however, published until early in 1889.

Quite independently of these observations, similar opinions had been expressed as a result of the studies of four investigators in three widely separated fields. Pirsson's pronouncement was made after a critical examination of the corundum crystals in the lamprophyre dyke of Yogo gulch, Montana. Holland's belief was expressed after a detailed study of the occurrences at Sivamalai, India; while the convincing evidence and simplicity of the Ontario occurrences of corundum left no room for doubt in the minds of Dr. Willet G. Miller, and the writer. While, however, Pirsson considered that the clay slates intersected by the Montana dyke had contributed the necessary excess of alumina to the lamprophyre magma, the other three observers were emphatic as Dr. Miller has so well expressed it that "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."

Previous to the appearance of these determinations, it was the generally accepted view that corundum owed its formation to a variety of causes not clearly understood nor readily explicable, such as contact action, the influence of so-called "mineralizing agents" or long continued metamorphism resulting in the breaking down of certain unstable minerals and the consequent development of corundum. Without attempting to deny that important concentrations of this mineral owe their origin and present position to these or similar agencies, it is the firm belief of the writer that all the deposits of corundum which are commercially valuable are not the product of secondary action but are primary crystallizations from igneous magmas containing an excess of alumina.

The corundiferous rocks of central Ontario are of syenitic, dioritic, and gabbroic type and appearance, the feldspathic constituent varying from microperthite through albite, oligoclase, and andesine to bytownite.

Scapolite and nepheline often accompany or replace the feldspars. These rocks are as a rule very poor in ferromagnesian constituents, while the prevailing scarcity or absence of quartz is noteworthy. The red feldspar rock or syenite (umptekose) and its pegmatitic equivalent (uralose) are the most highly corundiferous, and so constitute the most desirable "ore", but corundum is present and is sometimes in such abundance as to characterize certain of these syenites which are rich in nepheline (12–63 per cent) as also in some feldspathic varieties closely allied to plumasite, described by Lawson. In this respect the syenites of Ontario are, so far as known, unique; for although types containing nepheline occur as differentiated forms of the corundiferous rocks of Russia and India, no corundum has as yet been found directly associated with them. As a result of the detailed work accomplished, the Ontario occurrences of corundum stand unrivalled, not only by reason of the great areas covered by these highly aluminous rocks but also as regards the richness and unaltered character of the mineral secured.

It is worthy of remark in this connexion that the discovery of these economically valuable deposits of corundum was made by Mr. W. F. Ferrier, then on the staff of the Geological Survey of Canada. In the preliminary report addressed to Dr. George M. Dawson, then Director of this Department, he not only emphasized their commercial importance but ventured the prediction, since amply verified, that the original discovery (in Carlow township) is not an "isolated occurrence but that other deposits will be found in the Hastings district".

The growth of the corundum mining industry of Canada which was only made possible by and is a direct outcome of Ferrier's initial discovery, has been both steady and rapid. Starting in April, 1900, about 60 tons of graded grain corundum were produced, although only 3 tons of this were shipped. In the following year 444 tons were produced; in 1903 this production was nearly doubled when 806 tons of corundum were cleaned and graded. The maximum output was in 1906, when 2,914 tons were produced, but only 2,274 were sold valued at $204,973. In the following year there was a very much greater discrepancy between production and sales, due to the industrial depression prevailing in 1907, and of the total output of 2,682 tons credited to this year, 790 tons were left in stock in the warehouse. From 1909 to the present there has been a better balance preserved between production and shipments, so that in 1912 there was the large shipment of 1,960 tons of graded grain corundum valued at $239,091, being the largest amount received since the establishment of the industry. Of this large total in shipments, 1,928 tons valued at $205,819 were exported leaving only 32 tons to supply the home market. The total shipments of corundum made since the beginning of the industry until the end of 1913 have amounted in value to nearly $2,000,000.

EXPLANATION AND SCOPE OF PRESENT INVESTIGATION.

When Mr. W. E., afterwards (1856) Sir William Logan, of the Geological Survey of Canada, made an examination in

1844 of the region bordering the Ottawa river, he found great areas underlain by very ancient, foliated, crystalline rocks. These seemed to him, on further study, capable of subdivision into two conformable series, which he subsequently (1853) called the "Laurentian Series". This designation was proposed by the fact that these rocks constitute the bulk of the "Laurentide Mountains", a name suggested by F. X. Garneau, the historian of Quebec, for that great stretch of rocky country which forms the highlands to the north of the River and Gulf of St. Lawrence. This sharply defined series of elevations is not strictly a mountain range, but merely the steep margin of the great rocky plateau of the Canadian Shield.

Logan's lower or older group consisted exclusively of "Syenitic gneiss showing no end to the diversity of arrangement in which the minerals and the colours will be observed, but there is a never-failing constancy in respect to their parallelism. But this, though never absent, is sometimes obscure". These rocks were supposed by Logan to form a low anticlinal arch in the region extending from Mattawa river to the vicinity of Montreal river on Lake Timiskaming. The upper group is stated to crop out in the district south of Mattawa and Ottawa rivers and to be characterized "by the presence of important bands of limestone which have undergone extensive crystallization as a result of extreme metamorphism", while the different gneissic rocks which separate the various bands of limestone "differ in no way either in constituent quality or diversity of arrangement from the gneiss lower down".

Subsequently this lower gneiss was called the "Ottawa Series" while the upper group, differentiated in the first place solely on account of the presence of the limestones, was included under the name Middle Laurentian or "Grenville Series". He afterwards found in eastern Ontario a series of rocks which he considered in all probability to represent the Grenville series in a less altered state, and to this he gave the name of the "Hastings Series". The foliation of the gneisses was regarded by him as the survival of an almost obliterated bedding. The name Upper Laurentian was given to a terrane formed chiefly of anorthosites, which were afterwards shown to be of irruptive origin, and with which were classified by mistake certain gneisses and limestones identical in character with those included as the Grenville series, to which they clearly belong. For many years very little light was thrown upon the relations of the Grenville series and the Ottawa series or "Fundamental Gneiss" as it was frequently called. The relationship of the Grenville and Hastings series also remained a matter of uncertainty.

In 1885 Dr. Andrew C. Lawson showed the presence in the region northwest of Lake Superior, of great bodies of foliated granitic rocks forming the base of the geological column and the equivalent of the "Fundamental Gneiss" of Logan. This gneiss, as Lawson conclusively demonstrated, is intruded through the oldest sedimentary rocks (Keewatin Series) of that region in the form of great batholiths. This work marked an epoch in the interpretation of Pre-Cambrian geology not only in Canada but in all North America.

Then followed, in 1893, Adams' demonstration that Logan's "Upper Laurentian" did not exist as an independent geological series, the anorthosites, which were considered as constituting its main features, being in reality great intrusive masses. In a subsequent (1895) paper he showed that two distinct classes of rocks could be distinguished in the remaining portion of the Laurentian, the first being beyond all doubt igneous rocks and the second consisting of highly altered rocks of aqueous origin.

From the results of these investigations, it became evident that if a satisfactory knowledge of the origin, character, structure, and relations of the Laurentian succession in eastern Canada was to be obtained, it would be necessary to select some large area of these rocks and map it in much greater detail than had hitherto been attempted, the examinations in the field being supplemented by thorough petrographical study of the various rock types represented in the area. The area selected for such detailed study was that designated as Sheet No. 118 (Haliburton sheet) of the Ontario series of geological maps which are being issued by the Geological Survey of Canada. As will be seen by the accompanying sketch map, this district lies close to the margin of the great Northern Protaxis, north of Lake Ontario and to the east of Georgian bay.

Figure 1. Index showing the position of the Haliburton and Bancroft map areas in relation to Laurentian Highlands, etc.

Dr. Frank D. Adams, with whom the writer was subsequently associated, undertook for the Geological Survey a detailed geological study of this region, concerning the geological structure of which nothing was known at that time, but which, from its position, promised to yield valuable results if carefully studied. During the progress of this work it became evident, if the substantial results expected were to be realized, that the work should be extended to cover the district lying to the southeast of the Haliburton sheet. This was accordingly done and two maps were prepared; one, the Haliburton sheet, on a scale of 4 miles to 1 inch, and the other, embracing the southeastern portion of the Haliburton sheet and the district lying to the southeast, on a scale of 2 miles to 1 inch, which was designated as the Bancroft sheet. The Haliburton map-sheet embraces an area of 3,456 square miles; the Bancroft map-sheet 1,955 square miles; and the two map-sheets together cover 4,200 square miles. The field and accompanying laboratory work occupied a period of about eight years, the results being embodied in Memoir No. 6 issued by the Geological Survey of Canada in 1910.[1]

During the progress of these investigations, corundum was discovered within the area covered by these map-sheets. The conclusion reached as a result of the preliminary examination that these deposits would be economically valuable has since been amply justified by the establishment of the largest corundum mining industry in the world. The importance of the examination and study of these corundum deposits was also early in evidence, and the present memoir by the junior author of the first memoir is an attempt to give a comprehensive review of the whole subject both from an economic and a scientific point of view. The field work which formed the basis of the present thesis was carried on mainly in 1897, altnough a large amount of supplementary information was obtained during the progress of the work on the general geology of the whole area during the two succeeding seasons 1898-99. Early in July 1900, in company with Professor H. P. Cushing of the

[1]Adams and Barlow, Geol. Surv., Can., Geology of the Haliburton and Bancroft areas. Memoir No. 6, Pub. No. 1082, 1910.

Geological Survey of New York, some further geological examinations were made of the areas surrounding Craigmont, as also of certain lots in Monteagle and Dungannon townships near the York river. Professor Cushing was at that time engaged in a study of the Archæan rocks of certain sections of the Adirondack mountains. His visit to this district was for purposes of comparison and correlation. Since the completion of the geological work necessary for the larger memoir and accompanying maps, occasional short excursions have been made to the corundum bearing localities, and notably in November 1903 when Craigmont and the country bordering the York river between Foster rapids and Bronson landing were again examined and some further details secured affecting the mode of occurrence of corundum. In preparation for the visit of the International Geological Congress and in company with Dr. Frank D. Adams, some days were spent in 1912 in additional studies of these corundiferous rocks; while again in 1913 the whole of the month of June was occupied in field work considered necessary for the completion of the present report.

ACKNOWLEDGMENTS.

The acknowledgments of the writer for assistance are due to Mr. B. A. C. Craig, First Vice-President and General Manager of the Canada Corundum Company. It was in the main due to his determined and consistent efforts that the corundum mining industry was first established. No one unacquainted with the initial difficulties attending the birth of the industry can ever fully appreciate Mr. Craig's judicious and zealous conduct. He was the man for the place and the time. Mr. H. E. T. Haultain, the Manager of the Canada Corundum Company during the time of the visit of the Special Committee on the correlation of the Pre-Cambrian rocks in 1906, did all in his power to facilitate and expedite their important work and the various members expressed themselves as fully appreciative of his courteous and kindly treatment. To Mr. D. A. Brebner, the manager of the Manufacturers Corundum company, as well as to his representatives at Craigmont, Messrs. Clark and

Kelly, the writer is indebted for more than he can attempt to acknowledge. Much of the pleasure and profit of the visit of A2 Excursion of the International Geological Congress in 1913 were due to the untiring and well directed efforts of these gentlemen in conducting their visitors to view the interesting occurrences at Craigmont. Grateful acknowledgments are also due to many persons resident in the region for information and assistance during the progress of the field investigation.

LOCATION AND MEANS OF COMMUNICATION.

The corundum bearing areas are situated close to the edge of the great Canadian Shield of the Pre-Cambrian rocks, about midway between Ottawa and Toronto. They are in the midst of an old and partially settled district with numerous wagon roads, some of which are good while others can only be considered as passable. Craigmont (see Plate XXV) the centre of the corundum mining industry, is most easily reached from Barrys Bay, a station on the Ottawa and Parry Sound branch of the Grand Trunk railway, 109 miles west of Ottawa. Barrys Bay is nearly 12 miles north of Combermere, a small village on the Madawaska river about 7 miles north of Craigmont. A small steamer provides daily communication for passengers and mail between Barrys Bay and Combermere, and at certain intervals reaches Francois point on the York river, the deep water landing place about 2½ miles from Craigmont.

The Irondale, Bancroft, and Ottawa railway runs almost parallel with and usually in the vicinity of the southwestern extension of the main belt of the corundiferous syenites from Kinmount Junction (where it connects with the Lindsay-Haliburton branch of the Grand Trunk railway) to Bancroft, a distance of a little more than 54 miles. At Bancroft connexion is made with the Central Ontario railway for Trenton, on the main line of the Canadian Northern and Grand Trunk railways, the intervening distance between these stations being about 86 miles. Trenton is 110.5 miles east of Toronto on the Canadian Northern railway and 101.19 miles by way of the Grand Trunk railway. The Central Ontario railway crosses the

Toronto-Montreal line of the Canadian Pacific railway at Central Ontario Junction, 224.4 miles west of Montreal or 114 miles east of Toronto.

The Kingston and Pembroke railway affords access to the most southerly of the three belts of corundum bearing rocks, Olden station, between Sharbot Lake and Kingston, being located on this belt.

CHAPTER II.

EARLY HISTORY.

The original discovery and early recognition of the many valuable properties of the mineral corundum is shrouded in obscurity as its use long antedates the Christian era. Very little that is authentic can be related concerning the early history of this mineral, but many writers, in their speculations regarding the means used to produce the extreme delicacy and perfection seen in the carving of the hieroglyphics on the Egyptian monuments of granite and basalt, regard corundum, or emery, as the only abrasive adequate to produce these results. This view is all the more readily to be believed as some of the occurrences on the easily accessible islands of the Grecian Archipelago must have been known to the ancients.

The first authentic record of knowledge concerning this mineral is in regard to the precious or gem varieties. These gems, especially the ruby, were greatly sought after by all these ancient nations, not only for their own intrinsic beauty, but also for their supposed efficacy in healing and magic. The various forms of superstition attached to the possession of the gems have withstood in a remarkable degree the enlightenment of subsequent time, and the value is still enhanced by the belief that in some way their possession brings either good or evil fortune to the wearer. In the Bible we find repeated reference to both the ruby and sapphire,[1] and the earlier Greek and Roman writers, especially Aristotle, Theophrastus, and Pliny, not only make frequent mention of these gem stones, but also give such accurate descriptions of them as show an intimate knowledge of their peculiar physical properties.

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[1]Exod. XXIV, 10; XXVIII, 18; Ezek. 1, 26; X,1; XXVIII, 13. Rev. XXI, 19.

It is stated by Holland[1] that the Indian Empire can, with very good reason, be claimed as the home of this mineral, for not only are there numerous and important deposits of the common or "imperfect"[2] forms of corundum, but the finest specimens of the ruby or transparent red variety come from Burma, while the mines of Ceylon and Kashmir have furnished the best examples of the sapphire or blue variety.

The introduction of the gem material into England and Europe in the eighteenth century, mainly through the efforts of the East India company, at once attracted the attention of jewellers and lapidaries, who, ignorant of their mineralogical and chemical affinities, proposed names already in use, prefixing to these the term Oriental. Thus we obtained the Oriental Topaz, Oriental Ruby, Oriental Amethyst, Oriental Emerald, and Oriental Aquamarine.

The early crystallographer, Romé de Lisle, seems to have been the first to suggest the close relationship existing between the various forms of corundum, but it was not until 1798 that the Rt. Hon. Charles Greville[3] named and described as corundum the crystallized form of the oxide of aluminium, and in an appendix to the same paper the Count de Bournon dealt fully and satisfactorily with its crystallographic characters. Häuy was the first (in 1805) to formally unite the three subdivisions sapphire, corundum, and emery under the name (corundum), now generally accepted for the species.

The first known occurrence of corundum of economic importance as an abrasive was the emery found on the islands of the Grecian Archipelago. For several centuries the island of Naxos has furnished almost exclusively the emery used in the arts, the reason doubtless being that the material at this place was very uniform in quality and easily obtained. In addition emery is now known to occur on the islands of Nicaria and Samos. In 1847, Dr. J. Lawrence Smith, of Louisville,

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[1]Econ. Geol. India 2nd Ed. Pt. 1. Corundum, 1898, p.l.

[2]Phil. Trans. Roy. Soc. London 1802, p. 233.

[3]On the Corundum Stone from Asia, Phil. Trans. Roy. Soc. London, 1798, p. 403.

Ky., then in the employ of the Turkish government, made important discoveries of emery in Asia Minor and communicated his observations on its mode of occurrence and associations in a series of papers.[1]

HISTORY OF CORUNDUM IN AMERICA.

United States.

It will doubtless ever remain a matter of conjecture as to whether the aborigines of North America made use of corundum to trace out many of the curious hieroglyphics, which are even now so conspicuous on some exposed rock surfaces; but it is hardly conceivable that the sparkling brilliancy and colour of many of the loose or rolled fragments of the precious varieties of this mineral would fail to attract the savage love of finery. The first authentic record, however, of the presence of corundum in America dates back to the year 1819[2], when John Dickson, a teacher at Columbia, S.C., and former pupil of Prof. Benjamin Silliman, sen., sent him a lot of mineralogical and geological specimens, which he had collected on a tour through the Carolinas. Accompanying these came a letter, dated at Charleston, December 21, containing "Notices of mineralogy and geology of parts of South and North Carolina." With these specimens was included a very perfect hexagonal crystal of blue corundum, but which, curiously enough, was not named or alluded to in Mr. Dickson's letter. In answer to an inquiry as to the genuineness of the locality of this American corundum, a letter from Mr. Dickson, dated Charleston, March 9, 1821, says: "I think it was the Laurens District; at all events it was picked up by my own hands, if not in situ, in a place to which no geological or mineralogical specimens had ever been carried. I am sure it is American and Carolinian."[3] The locality from which

[1]Am. Jour. Sci. 2nd Series, Vol. VII, 1849, pp. 283-285; Vol. IX, 1850, p. 289; Vol X, 1850, pp. 354-369; and Vol. XI, 1851, pp. 53-66; Scientific Reasearches, 1851, pp. 1-53.

[2]Am. Journ. Sci. Vol. III, 1821, pp. 2-5.

[3]Am. Journ. Sci. Vol. III, 1821, pp. 229-230.

this corundum was obtained was subsequently found to be Andersonville, Laurens district, S.C., which later yielded a large amount of corundum.[1]

It was not, however, until the discovery of emery by Dr. H. S. Lucas, at Chester, Mass. on September 6, 1864, that active mining for this abrasive was established. Dr. Lucas had, earlier in the same year, predicted that emery would be found because of the recognition at this locality of margarite, a mineral which Dr. Smith had described as characteristic of the emery deposits of Asia Minor. Two years later distinct crystals of corundum were found in this same deposit.[2] The emery mine at Chester is still in active operation and one of the two producers of corundum in the United States. The discovery in 1849, and descriptions by Dr. J. L. Smith, of the Asia Minor occurrences, had stimulated, and to some extent directed American effort; and it was soon established that emery occurred, often in considerable deposits, at various places along the belt of crystalline rocks of the Appalachian region throughout nearly its whole length from Massachusetts to Alabama.

In 1870 Mr. Hiram Crisp found the first corundum which attracted attention in North Carolina as a possible field for mining at what has since been known as the Corundum Hill mine. The years 1870-71 witnessed an active prospecting for corundum in southwestern North Carolina, while about the same time approximately a thousand pounds of corundum, some masses of which weighed as much as 40 pounds, were obtained from the Corundum Hill property. Systematic mining at Corundum hill was, however, not begun until the latter part of 1871, when under the management of Col. Charles W. Jenks, the first real mining of corundum in America for abrasive purposes was inaugurated. In the spring of 1872 the Laurel Creek or Pine Mountain mine in Rabun county, Georgia, was also opened. These two mines, Laurel Creek and Corundum Hill, had contributed almost the whole of the corundum used in the United States, as well as in the world, until 1893, when mining was dis-

[1]Kunz. "Gems and Precious Stones of North America," 1892, p. 42.

[2]Am. Jour. Sc. 2nd Ser. Vol. XXXIX, 1865, pp. 87-90; Vol. XLII, 1866, p. 421.

continued at Laurel creek. Since then and until 1906 the Corundum Hill mine has been the chief producer of corundum. Since 1905 there has been no production of corundum in the United States, the magnitude and richness of the Ontario deposits, mined and milled for the first time in 1900, having gradually displaced the home material in the United States abrasive industry. Mining of the Montana corundum deposits was inaugurated in 1900, but this activity was discontinued after a few years. The occurrence of corundum in Plumas county, California, was prospected in 1901, but no deposit of economic importance was located.

Canada.

Corundum was first discovered in Canada in 1847, by Dr. T. Sterry Hunt of the Geological Survey.[1] In the summer of this year during an examination into the mineralogical character of the rocks along the Ottawa, he paid a visit to the farm of Mr. George Holliday, situated on lot 2, concession IX, of Burgess, for the purpose of securing additional information in regard to the mode of occurrence and extent of a deposit of copper pyrites, specimens of which had already been received and assayed in the laboratory of the Geological Survey. After mentioning that the chalcopyrite occurs in very small nests or strings in the crystalline limestone, he adds: "Among the masses of rock thrown out in blasting were some consisting of silvery mica with quartz, felspar or albite, and calc-spar, which contain imbedded masses of a delicate emerald-green and almost transparent pyroxene of rare beauty and crystals of a dark honey-yellow sphene. The mica is often aggregated in masses of small crystals, having a columnar arrangement; imbedded in this, and indeed disseminated throughout the rock, were a great number of small crystalline grains of transparent mineral, varying in colour from a light rose-red to a deep sapphire-blue. Their hardness, which is so great as to enable them to scratch readily the face of a crystal of topaz, shewed them to be nothing

[1]Ann. Rep. Geo. Surv., Can., 1847-48, pp. 133-134, also Geology of Canada, 1863, p. 499.

else than the very rare mineral corundum which from its colour is referable to the varieties known as the oriental ruby and sapphire. The grains obtained were very small, none indeed larger than a pepper-corn, but at the time I was on the spot they were not noticed, and the specimens were collected for the pyroxene, in only two or three of which I have since detected the corundum. It is probable that further examinations may develop larger and more available specimens of these rare and costly gems. It is in this crystalline limestone that they generally occur, and the corundum found in the State of New Jersey is in the same rock, and with similar mica. Those of the sands of Ceylon, which have supplied the market of the world with these gems, are derived from a similar crystalline limestone. I am indebted for this interesting fact to the courtesy of Major Lachlan, now of this city (Montreal), a gentlemen who spent many years of his life in India, and ever alive to the interests of natural science, made a fine collection of the minerals and other natural curiosities of Hindostan and Ceylon. Among these is a fragment of white crystalline limestone, containing small crystals of sapphire, with grains of chondrodite. The latter mineral, which is quite characteristic of these peculiar limestones, is very abundant throughout those of New York and New Jersey, and although I have not yet observed it in place in Canada, I have seen a specimen in the hands of Dr. Holmes of this city, which was taken from a boulder near Bytown,[1] and which contains crystals of spinel with chondrodite in limestone. The existence of the mineral corundum is also interesting from another consideration; it is this substance in a coarse massive form which constitutes the emery of the East Indies, so much valued as a material for cutting and polishing gems and articles of cutlery." The importance of this discovery was certainly not underrated by Dr. Hunt, as may be seen by the care with which he prepared the foregoing description, but pressure of other duties and especially the urgent necessity for extending as far as possible the geological reconnaissance of the whole country, no doubt contributed to the fact that these occurrences were not more fully examined at the time. No blame

[1]Now Ottawa the Capital of the Dominion of Canada.

can possibly be attached to Dr. Hunt or the other officers of the Geological Survey for this seeming neglect, for the detailed information given in this report was amply sufficient for the purposes of any qualified prospector.

As no specimens of this corundum were included in the collection of the Geological Museum of Ottawa, Dr. Miller decided to visit the locality mentioned by Dr. Hunt, in November 1397. It was then that he ascertained that the farm had passed into the possession of its present owner, Mr. Rathwell. Specimens of the mineral were found in the white crystalline limestone under the conditions described by Dr. Hunt, alongside of a lane and about 200 yards from the barn. The specimens obtained, all of small size, were of a light rose colour and on trial scratched topaz. In a footnote Dr. Miller explained that as the mineral spinel has a hardness equal to that of topaz and occurs in crystalline limestone under similar conditions, it would seem advisable that a careful examination, chemical and otherwise, be made of these specimens before their character is affirmed. Those collected are small and obtainable only near the surface and are, therefore, difficult of determination. One individual had a suspicious octahedral appearance, while a specimen which seemed to be impure was found to contain 74.5 per cent of alumina.[1] In these circumstances it is said that Dr. Miller is of opinion that both are present as they frequently are associated in the same rock mass.[2]

The presence of corundum in the northern part of the county of Hastings was really made known as the result of a visit made in October, 1896, by Mr. W. F. Ferrier, then lithologist to the Geological Survey of Canada. In the Summary Report for the year 1896[3] Mr. Ferrier relates the history of the discovery and the circumstances which occasioned his visit to that region. He writes: "One of the most interesting occurrences upon which I have to report is the recent discovery of corundum in Hastings County, Ontario. This came about in a somewhat unusual way. In 1893, I came into possession by purchase, of a number

[1]Ann. Rep. Bur. of Mines, Ont., 1898, 3rd Pt. p. 214.
[2]Jour. Can. Min. Inst. Vol. VII, 1904, p. 413.
[3]Summary Report Geo. Surv., Can., 1896., pp. 116-119.

of specimens collected by Mr. John Stewart, formerly of Ottawa, amongst them being a package labelled 'Pyroxene crystals south part of Carlow.' On examining these specimens some time ago I recognized them as corundum, and immediately took steps to ascertain, if possible, the precise locality from which they came. As you are aware I communicated the facts to you and was authorized in October to visit the township of Carlow, endeavour to locate this mineral, and determine the extent of the deposit. I was accompanied by Mr. Cole,[1] and after considerable difficulty found the mineral on lot 14, Con. XIV, of the Township of Carlow, Hastings County, Ontario."

It is now, however, stated on undoubted authority, that this was not the first intimation of the occurrence of corundum in the township of Carlow.

The largest known deposit of corundum in Ontario if not in the world, was discovered about the year 1876, on lot 3, concession XVIII of the township of Raglan in the county of Renfrew. The following interesting details of this event were furnished by Mr. Henry Robillard. Returning home from a cranberry marsh situated on the extensive flats which border what is now known as Campbell's marsh, an expansion of the York river, and climbing diagonally up and across Robillard mountain (Craigmont) with his daughter Annie, they stopped to rest at a point where the rock was "chock full of corundum." The curious crystals were aptly likened by Annie to cruet-bottle stoppers, and their abundance so attracted Mr. Robillard's attention that he collected some, and afterwards exhibited them to several local "mineral experts". One of these who had some previous experience of the apatite occurrences near Clear lake, pronounced them to be "phosphate". In 1884 Mr. John Fitzgerald, after certain agreements with Mr. Robillard, applied for the mineral rights on the property, including the several lots in concessions XVIII and XIX of Raglan.

In 1886 Mr. Herbert Ross Wood, a graduate in Natural Science of Toronto University, went north to examine into the reported occurrence of various minerals of economic importance.

[1]Arthur A. Cole, now Mining Engineer Timiskaming and Northern Ontario railway, Cobalt, Ont.

Incidentally he appears to have visited the Carlow locality. In answer to an inquiry as to any information he may have gained regarding the occurrence of corundum in Carlow, he writes: Rockwood Asylum, Kingston, February 1901. "So far as I can recall the discovery of corundum, it was in the year 1886 or 1887. There is only a small exposure in Carlow the working deposits being in Raglan, near Combermere, and at other points. I was collecting mineral specimens and crystals near Armstrong's and came upon it unexpectedly. It exhibits a roughly crystalline character at that place and is associated with magnetite in feldspathic rock. I believe I was the first discoverer of that exposure, but was followed by others who found the large workable deposits above mentioned." It is not quite certain whether Mr. Wood was the expert who about this time informed Messrs. Robillard and Fitzgerald that their so-called apatite mine was in reality a deposit of "emery stone". The value of these finds, however, does not appear to have been appreciated by the original discoverers, as nothing further was heard of them until after Mr. Ferrier's return from Hastings. One of Mr. Armstrong's sons states that he, personally, conducted Mr. Ferrier to the spot where the crystals occurred. Although it is thus evident that the nature of the mineral was known some years before Mr. Ferrier's visit, there can be no doubt that the true value and extent of the deposit would have remained practically unknown but for his report of its mode of occurrence and his emphasis of its economic importance. Following the publication of Mr. Ferrier's report, the attention of Messrs. Robillard and Fitzgerald was again directed to the interesting crystals found on their Raglan property, which is about 5 miles to the east of the Carlow locality. These, as has been stated, had been determined as apatite or "phosphate". Mr. Ferrier's description, and the knowledge that these crystals were approximately on the same range of hills, confirmed the belief that the supposed apatite was in reality corundum. This likewise coincided with the opinion of the "expert", expressed some years before; although at the time no great reliance was placed on the accuracy of his diagnosis. Immediately on Mr. Ferrier's return to Ottawa, (October 23, 1896), Dr. George

M. Dawson, the Director of the Geological Survey, communicated to the Ontario Bureau of Mines this discovery of corundum in Carlow township, at the same time placing at the disposal of this provincial department for publication the preliminary report submitted to him by Mr. Ferrier.

Following shortly on this discovery and as a direct result of it, came the news that Mr. George Bennett had found corundum at a so-called mica mine on lot 14, concession IX, of the township of Methuen in Peterborough county, about 45 miles to the southwest of the Carlow occurrence.

In the following summer (1897) the belt of corundum-bearing rocks was delimited for a distance of about 16 miles from the original discovery on lot 14, concession XIV, of Carlow township to the eastern boundary of the Haliburton map-sheet (Sheet No. 118, Ontario Series of Geological Maps). Mr. Joseph Keele, who was at that time assistant to the writer, was handed specimens of corundum which were reported as occurring about a mile north of Quadville P.O. Assuming this discovery as authentic,. the belt of corundum-bearing rocks was described as fully 5 miles in width [illegible] place.[1] In September of the same year, accompanied [illegible]e Dr. R. W. Ells and Messrs. James White and Joseph K[illegible]ough geological reconnaissance was made of the region between Quadville P.O. and Clear lake, a distance of about 12 miles. Dr. Ells also examined a small area northeast of Clear lake. As a result of this preliminary examination, it was stated in the preliminary report that "the assumption at present seems reasonable that corundum will be found if careful and systematic prospecting is undertaken in the northern portion of Lyndoch, the southern part of Brudenell, and the middle concessions of Sebastopol.[2] The work undertaken by the writer was of necessity limited to that portion of the corundum belt embraced by the geological map-sheets, then in course of preparation. The great area included in the Haliburton and Bancroft map-sheet to be surveyed and examined, and the great complexity of the Archæan problems to be studied, no doubt, influenced the Director of the Geological Survey in

[1]Summary Rep. Geo. Surv., Can., 1897, p. 53.
[2]Summary Rep. Geo. Surv., Can., 1897, p. 52.

the first place to communicate to the Ontario Bureau of Mines not only the importance of this discovery of corundum, but the probability of its economic importance. This final report has been greatly retarded for numerous reasons, which it is not necessary here to enumerate, but very full interim reports dealing especially with the ecomonics of this mineral have appeared from time to time, and in these the origin, mode of occurrence, and distribution of corundum in this region have been adequately discussed.[1]

The Director of the Bureau of Mines of Ontario being convinced of the great importance of the discovery of corundum, and the probability of the early establishment in this region of an extensive mining industry, deputed Mr. Willet G. Miller, then professor of geology at the School of Mining, Kingston, Ontario (now Provincial Geologist of Ontario), to carry out the necessary investigations. Much interest had been evinced by the discovery of this mineral by manufacturers of emery wheels and others so that it seemed advisable that a careful examination should be made at once of the Carlow deposit in order to obtain more information, especially from an economic point of view. Moreover it was considered that a determination of the character of the deposit would materially assist in the intended search for other occurrences of the mineral in the district. Professor Miller's instructions, therefore, called for an examination of the corundum bearing rocks. and to search for other deposits of the mineral in the district as well as to make careful notes on deposits of other minerals of economic importance which might be met with in the field. In this work Professor Miller had the able and zealous assistance of Messrs. R. T. Hodgson and W. C. Rogers, then students at the Kingston School of Mining. Early in July in company with Mr. N. T. Armstrong, of New Carlow, Professor Miller spent a few days

[1]Summary Repts. Geol., Surv., Can., 1896 pp. 9, 53, 116-119; 1897 pp. 48-56 with map, 127-128; 1898 p. 110; 1899 pp. 130-131; 1900 pp. 127-128; 1901 p. 150; 1903 pp. 132-133; 1904 pp. 132-133; Also Reps. Div. Mineral Statistics and Mines, Geological Survey; and Mineral Production of Canada, Mines Branch, Dept. Mines, Canada (See Bibliography) Trans. Roy. Soc. Can. 3rd Series Vol II, Sect IV, pp. 1-76; Memoir No. 6, Geol. Surv., Can., pp 1-419.

in the study of the original locality where corundum had been discovered, as also two other deposits of the mineral in this vicinity. Later in the season, from August 2 until October 15, Professor Miller, having closely studied the mode of occurrence of the corundum, spent most of the time in prospecting for the mineral in the northern part of the county of Hastings, and the southern part of the adjoining county of Renfrew. As a result outcrops of corundiferous rocks were found in seven different townships covering a distance of about 30 miles.

Although the letter of transmittal from the Commissioner of Crown Lands of Ontario, addressed to the Lieutenant Governor, presenting the Sixth Annual Report of the Ontario Bureau of Mines for the year 1896, bears the date of April 7, 1897, it contains a short account of the field work accomplished by Professor Miller between the latter part of June and the end of August, 1897.

Accompanying this interim report, Mr. Archibald Blue, then Director of the Bureau, also included Mr. Ferrier's preliminary report communicated by Dr. Dawson. In conclusion Mr. Blue writes: "Meantime it may be stated that the mineral rights in these lands over which the corundum is found to extend, have been withdrawn from sale pending the completion of Mr. Miller's report."[1] The complete report covering the whole of this investigation is contained in the Seventh Annual Report of the Bureau of Mines.[2] In the following year (1898) this detailed and scientific prospecting was continued with the same assistance. As a result of the work of both the Bureau of Mines and the Geological Survey, a somewhat narrow and sinuous strip of country, having a general northeasterly strike, was outlined, extending from the township of Glamorgan to the township of South Algona, in which corundum has been found at intervals. Throughout this distance of about 83 miles, the corundum-bearing rocks are represented by very frequent exposures, constituting an almost continuous series of outcrops. Later, in the summer of 1905, corundum was found on lot 12, concession IV, of the township of Lutterworth, by Mr. Tett, assistant

[1]Ann. Rep. Bur. of Mines, Ont. 1896, p. 66.
[2]Ann. Rep. Bur. of Mines, Ont. 1898, 3rd Pt. pp. 207-250.

to Mr. W. A. Johnston, of the Geological Survey of Canada.[1] This gives a further extension to the main corundum belt, making a total distance of about 103 miles. Very similar rocks were found to outcrop in the township of Methuen, Peterborough county, extending thence through a corner of the township of Burleigh to Stony Lake, a distance of over 8 miles.[2] Still a third belt, which so far as examined by Professor Miller is known to have a length of nearly 12 miles, runs from the western part of the township of South Sherbrooke in Lanark county, through the township of Oso and southwestward into Olden and Hinchinbrooke township, in Frontenac county.[3]

It was fully recognized, however, that the geological and mineralogical associations of the Ontario corundum were so different from the Georgia and North Carolina occurrences of this mineral, that resort must be made to a much more elaborate scheme of concentration in order to obtain a clean and high grade product. Acting in this belief Professor Miller in November 1897 shipped several tons to Kingston where the necessary experimentation was carried out under the superintendence of Professor Courtenay De Kalb. The details of these mill tests, as also the analyses of corundum and corundum bearing rock by Dr. W. L. Goodwin, accompany Professor Miller's report.[4] Later an additional quantity of corundum bearing rock was treated under the direction of Mr. Reginald Instant in the mill of the Kingston School of Mining.[5]

These tests were further supplemented by trials of wheels made from corundum. The Prescott Emery Wheel company of Prescott, Ont., the Hart Emery Wheel company, Hamilton, Ont., and the Northern Emery Wheel company, Worcester, Mass., U.S.A., to whom material was sent, manufactured a number

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[1]Summary Rep. Geol. Surv., Can. 1905, pp. 93-94.

[2]Trans. Roy. Soc. Can. 3rd Series, 1908, Vol. II, Sec. IV, pp. 49-58; Memoir No. 6, Geol. Surv., Can., 1910, pp. 291-305; Bur. of Mines, Ont. Vol. VIII, 2nd Pt., 1899, pp. 206-214.

[3]Am. Geol. Vol. XXIV, November 1899, pp. 276-282; Ann. Rep. Bur. of Mines, Ont. 1899, Vol. VIII, 2nd Pt., pp. 225-230.

[4]Ann. Rep. Bur. of Mines, Ont. Vol. VII, 3rd Pt, 1898, pp. 238-250.

[5]Ann. Rep. Bur. of Mines, Ont. Vol. VIII, 2nd Pt. 1899, pp. 239-240.

of wheels, some of pure corundum, and others of mixed corundum and emery, the wheels varying in size from 1½ inches to 14 inches in diameter. These formed an important and comprehensive portion of the abrasive materials section of the Canadian Mineral Exhibit at the Paris International Exhibition of 1900 and also of the Glasgow exhibition in 1901.

The great extent and comparative richness of the Ontario corundum deposits prompted the government of that province to take such action as seemed best calculated to develop the deposits and also to establish a home industry. Regulations were accordingly drafted under which the mineral rights in lands lying within the known areas of corundum-bearing rocks were withdrawn from sale, so that their acquisition for mining purposes could only be obtained under the leasehold system. An Order-in-Council was adopted on July 4, 1898, embodying a series of provisions having such a purpose in view, it being stated that the Commissioner of Crown Lands may receive tenders for mining lands and mining rights in the explored belt to the 15th day of September, 1898.

Only one substantial tender was received under the terms of the proposed regulations, but an agreement upon all details was not reached until September 15, 1899.[1] The contract was entered into with the Commissioner of Crown Lands by Messrs. Joseph H. Shenstone and B. A. C. Craig, of Toronto, on behalf of the Canada Corundum company.[1] A partial agreement, however, was made on September 15, 1898, with these same gentlemen, together with Mr. Lloyd Harris, of Brantford, that they should explore the corundum belt and select corundum-bearing lands from it, not to exceed 2,000 acres. Mr. Thomas Hodgson, who had been Professor Miller's assistant in the two previous years, and Mr. M. B. Baker, of Kingston, were engaged to do the necessary prospecting for the location of workable deposits of corundum. By September, 1899, a total area of 1,400 acres had been chosen and these lands were leased on September 15 to the Canada Corundum company, who were organized to carry on mining and milling operations.[2]

[1]Ann. Rep. Bur. of Mines, Ont. Vol. VIII, 2nd Pt., 1899, pp. 248-249.

[2]Journal Canadian Mining Inst. Vol. VII, 1904, p. 414.

The Canada Corundum company was, therefore, the first in the field, and in addition to the mining areas leased from the Government, purchased other lands from private owners. These included certain lots having deposits of corundum situated in Raglan, Radcliffe, Brudenell, Carlow, Monteagle, and Dungannon townships. Briefly stated, the agreement between the Ontario Government and the Canada Corundum company, granted to the latter the exclusive right to make the first selection of corundum deposits throughout the Ontario corundum-bearing area, on lands whose mineral rights were still vested in the Crown. The company, as their part of the covenant, agreed to the expenditure of $100,000 on certain specified conditions in the development of these mining lands and the establishment of a corundum industry. The agreement also entailed an obligation on the company's part to conduct certain experiments affecting the use of corundum especially as an ore of aluminium.

Active mining development work was inaugurated in April, 1900, under the supervision of Mr. Thomas Hodgson. The village and post-office were called "Craigmont" in appreciation of the services of Mr. B. A. C. Craig, the first Vice-President and General Manager of the company, to whose optimism and insistence the world is indebted for the establishment of its greatest natural corundum industry. An old sawmill, with a small water power, on a creek flowing near the base of Robillard mountain (see Plate XXV), on which the corundum deposits are situated, was almost entirely remodelled, and concentrating machinery with a crushing capacity of about 20 tons of corundum bearing rock daily, was installed. This mill is about 7 miles from the village of Combermere on the Madawaska river. At first water power alone was used, but in a very short time this was supplemented by a 25 horse-power steam engine. Mining or quarrying operations (for the corundum rock was obtained by means of a series of large open-cuts or excavations), were undertaken on lots 3 and 4, concession XVIII, of Raglan, and later were extended into the same lots with addition of lot 2 in concession XIX, of the same township. The equipment of the mill which is located close to the line between lots 1 and 2, concession XVIII, was mainly designed for experimental purposes, following

Professor De Kalb's experimentation at the Kingston School of Mining, but on a much larger scale. It anticipated the construction of a much larger mill when the various problems attending the concentration of the corundum would be more thoroughly understood. Before the end of the year (1900) about 60 tons of cleaned, graded corundum were produced, but of this amount only 3 tons were sold.

In 1901, the Imperial Corundum company, as also the Crown Corundum and Mica company, both of Toronto, Ontario, were organized and the same year did a considerable amount of development work, the former on lot 14 and part of lot 15, concession VIII, and the latter on lot 14, concession IX, of the township of Methuen, in Peterborough county.

It was the irony of fate that despite the somewhat unusual imposed conditions affecting the lease by the Ontario Government of lands in the belt of corundum bearing rocks, all mining activity, even that contemplated, was on lots which were deeded to the original settlers, inclusive of the mineral rights, many years before.

In the spring of 1901, Mr. John Donnelly of Kingston, convinced that other deposits of corundum might be found which had not been selected by the Canada Corundum company, who had been accorded special permission by the Ontario Government to make the first selection of corundum-bearing lands, engaged Messrs. M. B. Baker and A. Longwell to prospect for occurrences of corundum, which gave promise of development as mines.[1] These gentlemen after a search of about six weeks, selected the corundum deposits situated on lots 27 and 28, concession XIX, of Raglan township, in the county of Renfrew. Besides the advantageous situation of these occurrences on the side of a big hill, it is located within a short distance (2.5 miles) of Palmer rapids on the Madawaska river, a water power which with a head of 17 feet has a minimum capacity of 980 horsepower.[2] A company known as the "Corundum Refiners Limited" was organized under the management of Mr. P. Kirkegaard, formerly of the Deloro Gold Mines, to develop this property.

[1]Jour. Can. Min. Inst. Vol. VIII, 1904, pp. 410-421.

[2]Commission of Conservation "Water Powers of Canada" 1911, p. 142.

Plans were also made for the erection of a large mill at Palmer rapids, but up to the present time, with the exception of some stripping and other preliminary mining development work, little or nothing has been done.

In July 1902, the Ontario Corundum company, with offices at Ottawa and Boston, commenced corundum mining operations at the locality where corundum was originally discovered by Ferrier (lot 14, concession XIV of Carlow township) now known as Burgess Mines. A Blake crusher, 7×10 inches, was installed to crush the corundum-bearing rock, but it was afterwards found better to cob the ore into large lumps, this hand sorting resulting in a product which would average about 15 per cent of corundum. This practice was continued until the latter part of 1903, the high grade cobbed product being shipped to the United States for further concentration.

At the end of 1902, the new mill (see Plate XXVIII) for this company was completed, and high grade, grain corundum was then produced and shipped. The practice adopted was that in use in the corundum mills of North Carolina and Georgia, the crushed rock going to [illegible] to separate the corundum from the micaceous and decomposition products associated with it. The fines were thus washed away and only the coarser material, after being dried and sized, was concentrated. The large mill for the Canada Corundum company was started in January 1903, and about a year was required to build and equip it. It had a capacity of about 200 tons per day of corundum rock with a production of between 10 and 12 tons of graded grain corundum daily. In this same year a detailed contour survey of the southern side of Robillard mountain was made by Mr. John A. Baker, the whole of this slope being denuded of trees. This enabled an accurate mapping of the various outcrops of corundum-bearing rocks, noting any peculiarities of composition, and especially of the presence and relative abundance of corundum. This mining geological work was done by Mr. Alex. Longwell. In the spring of 1904 the mill of the Ontario Corundum company was destroyed by fire, but before the end of the year another and larger mill was designed and constructed in which the principle of concentration by dry methods was adopted.

The Armstrong property (lot 14, concession XIV, Carlow) was operated as a quarry for corundum by the Ontario Corundum company until June 1, 1905.

The Imperial Corundum Wheel company, with head office at Buffalo, N. Y., did some preliminary mining development work on lot 13, concession I, of Monteagle township. The material secured was sorted by hand and the high grade product thus obtained was shipped to Springfield where it was further concentrated.

The Ashland Emery and Corundum company were the successors of the Ontario Corundum company, beginning operations on January 1, 1906. During this year they prospected several locations for corundum in the vicinity of their mill at Burgess Mines, especially at John Armstrong's hill, on lot 10, concession XV of Carlow. In view of this and the difficulties attending transport, shipments were small and irregular.

During 1906 the Canada Corundum company, under the managership of Mr. H. E. T. Haultain, did considerable prospecting and some stripping on certain lots in the first and second concessions of the township of Monteagle on the southeast side of the York river. Most of the production for 1906, which amounted to 2,914 tons of grain corundum, valued at $262,448, must be credited to the Canada Corundum company. Both the Canada Corundum company and the Ashland Emery and C[illegible]um company were operating in 1907, the former company pr[illegible]ng a considerable tonnage, while at the same time endeavouring to sell the large amount which they had in stock in their warehouses. The latter company in this interval was prospecting besides making some mill runs. A few shipments were made, but mining operations were conducted on a small scale. About the beginning of the year 1908, the Canada Corundum company ceased operations owing to over-production and the small demand of the market for graded grain corundum. Throughout the year the company was busy trying to sell this great surplus product.

In 1909 the Manufacturers Corundum company acquired the mines and mills of the Canada Corundum company, and also in the following year the concentrating plant and the properties of the Ashland Emery and Corundum company. Mr. D. A. Brebner, with headquarters at Toronto, is manager, with Mr. E. B. Clark as assistant manager at Craigmont. In addition to the corundum quarries at Craigmont, a considerable tonnage has been secured from the corundum deposits immediately north of Grady lake, on lots 14 and 15, concession XVI, and at present from lot 10, concession XV, of Carlow township (John Armstrong's hill). Until the total destruction by fire in February 1913, the operations of the Manufacturers Corundum company and the consequent production have both been maintained on a large scale, but the burning of their mill will bring about a serious curtailment in their activity, as under the most favourable conditions the capacity of this mill at Burgess mine cannot be made to exceed 3 tons daily of graded cleaned corundum, operated at its maximum capacity. Furthermore there must be an undue loss, resulting from the crowding of the material and the imperfection of the method in use which is a combination of the wet and dry process.

The corundum industry of Canada, as represented by the operations of the companies, an epitome of whose history has just been related, has made very substantial progress in spite of very many disadvantages. Most of these difficulties were in a manner inherent and peculiar to the product sought to be exploited. Perhaps the most serious disability from which the industry at first suffered, related to its concentration and preparation for market, but closely related adverse conditions affected the selling of the refined article when brought to the high standard aimed at and reached. Almost from its inception it had a worthy competitor in carborundum and a little later alundum, and both of these artificial abrasives have in many fields successfully challenged the superiority of the natural substance. In spite, however, of this very serious competition there is a steady and a very insistent demand for corundum, which may be regarded and with good reason, as preferable to all other abrasives in certain classes of work. In spite of the very substantial assistance from a practical point of view of the Ontario Bureau of Mines, which in the first place not only directed and controlled the prospecting for corundum, and the concentration of corundum-bearing rock, but helped by their expressed faith in the industry, in the final financial arrangements, the industry had a very small beginning, although its subsequent growth was both rapid and steady. As discovered and first described, the mode of occurrence and geological association of corundum in Hastings were believed to be unique, and it soon became evident that the problems attending its concentration were not only in many respects novel, but likely to prove very complex before corundum of the purity desired could be produced.

Transportation, at first sight apparently simple and inexpensive, proved on experience to be unduly costly and for the most part inadequate. The local labour supply was small and irregular, many of the men employed being unaccustomed and averse to continuous work, and recourse was had to the most trivial domestic demands to secure immunity from steady employment. For many years after the beginning of operations there were frequent changes in the direct management, the mine superintendent alone being allowed to remain until the present time, despite the fact that, either as managers or superintendents some of them had already gained a world-wide experience in concentration methods. The publicity and selling departments also shared in these initial and to some extent unusual difficulties. At first the main objective of those in charge of this department was to supplant emery as an abrasive, ignoring the fact that certain peculiarities in the physical character and composition of emery recommended its use in wheel manufacture, notwithstanding the very manifest superiority of Ontario corundum both as regards purity and abrasive efficiency. Each, although in many respect rivals, as abrasives have certain spheres of usefulness, which may not be invaded by the other. Those in control of the corundum industry neglected altogether to so extend their operations as to engage in the manufacture of the various products requiring the use of corundum, contenting themselves with the less lucrative production of graded grain corundum However, owing to the unbounded optimism and energy of those in control, especially Mr. B. A. C. Craig, and later Mr. D. A. Brebner, the various difficulties were gradually overcome and the industry firmly established. The various grades of corundum produced are now accepted as standard by the numerous wheelmakers and others engaged in the use of corundum as an abrasive. The degree of purity guaranteed is very closely maintained, while until the recent (February 13, 1913) total destruction of the big mill at Craigmont, the trade were sure of obtaining a steady and abundant supply of a very uniform product.

Almost coincident with this fire disaster, although more slowly realized, came the conviction that the corundum deposits of Craigmont (Robillard mountain) which were at first thought to be inexhaustible, had reached a stage when it was both difficult and expensive to obtain a sufficient supply of the desirable quality of ore. The decision that such ore is by no means abundant on this hill has been reached by reason of rather extensive drilling and tunnelling operations, combined with the knowledge gained in the operation of the large excavations or quarries. There is, however, a considerable supply of good corundum ore in the deposits north and west of the Burgess Mines in Carlow township. Other deposits of corundum which are regarded as of commercial grade and size, occur in the vicinity of Palmer rapids, in the northeastern part of Raglan township. These likewise have the advantage of convenient location to existing means of transportation. Deposits of corundum of very distinct promise occur in Brudenell township and in the northwest corner of Faraday township. The mill tests of the material secured from the Monteagle and Dungannon localities in the vicinity of the York river, are said to have been disappointing. Transportation will again largely determine the scene of future operations. Competition of artificial abrasive has no doubt lessened the demand and price for natural corundum, but in spite of these there is always a ready demand for the natural product, especially in times of industrial activity. The future of the industry, although uncertain, is by no means without hope.

PREVIOUS WORK.

The first geological examination of the region in which corundum has been found, was made by the late Alexander

Murray, of the Geological Survey of Canada, in 1853. Ascending the Bonnechere river, from Chats lake, an expansion of the Ottawa river, he made a survey (part of which was instrumental) of the canoe route from Round lake, by way of the Little Madawaska river, and across the height of land to Barrys bay (of Kaminiskeg lake). He continued his micrometer traverse across Kaminiskeg lake down the Madawaska river to its intersection with the southwest branch of York river, which he ascended, passing through Baptiste lake to Papineau lake. From this point he crossed country by a chain of lakes, including Fishtail, Miskwabi, Long, Drag, and Kushog lakes. He then portaged from the southwest end of Kushog lake to Gull river, descending this stream through Gull and Mud Turtle lakes to Balsam lake, which was then on the outskirts of civilization. His geological notes are somewhat meagre and confined to brief general descriptions of the rocky outcrops encountered along the shores of the lakes and rivers he traversed. Most of these geological notes are included on the large scale maps which accompanied this report.[1] He designates the nepheline and associated alkaline syenite as "mica slate" and quartzite, while hornblendic varieties of the latter are included as "hornblende rock". It is hardly necessary to add that he did not notice corundrum for his examination was much too hurried to permit of its recognition.

In 1865 Mr. Thomas Macfarlane visited the Hastings district, but his examinations were confined to the area south of Tudor township.[2] In the following year Mr. Henry G. Vennor made a geological reconnaissance of the southern portion of the Hastings district, continuing the general geological section on the Hastings road as far north as the crossing of the York river in Dungannon township.[3] The discovery of gold in Madoc and Marmora townships in 1866, directed attention to the mining possibilities of this region, while at the same time it was believed that large deposits of iron and lead existed. With the exception,

[1]Ann. Rep. Geo. Surv., Can. 1853-56. Also Atlas accompanying this eport.

[2]Ann. Rep. Geo. Surv., Can. 1866, pp. 92-111.

[3]Ann. Rep. Geo. Surv., Can. 1866-69, pp. 143-171.

however, of isolated reports on occurrences of certain economic minerals, chiefly iron and gold, and the reports already cited, the whole of the area embraced in the Haliburton and Bancroft map sheets was geologically considered a "terra incognita" until 1893, when Dr. Adams agreed to undertake a geological reconnaissance of this part of eastern Ontario for the Geological Survey.

The occurrence of nepheline syenite in this region was first recognized in 1893, attention having been directed to its probable existence by a specimen of sodalite which was sent to the museum of the Geological Survey at Ottawa, from the township of Dungannon, in the spring of this year.

On visiting the locality from which this sodalite was obtained the mineral was found to occur in the form of veins, streaks, or patches, traversing a large area of nepheline syenite associated with the very ancient Laurentian crystallines. A brief description of the occurrence of this somewhat unusual rock was furnished by Dr. F. D. Adams, in a paper which appeared in 1894, while analyses of the sodalite and certain other associated minerals were published at the same time by Dr. B. J. Harrington[1].

The discovery of corundum in the alkali pegmatite on lot 14, concession XIV, of the township of Carlow, was made by Mr. W. F. Ferrier, then lithologist of the Geological Survey of Canada, in 1896.[2] The direct result of this discovery and the subsequent description and delimitation of the corundum bearing rocks by the Geological Survey and the Bureau of Mines, was the establishment of a corundum mining industry, whose progress up to the present time has already been described in this report. The exploitation of the sodalite and marble in the vicinity of Bancroft, was also made possible by the geological investigations initiated by the Geological Survey.

[1]Ame. Journ. Sc. Vol. XLVIII, July, 1894;
Ann. Rep. Geol. Surv., Can. Vol. VI, 1892-93, p. 5 J.
[2]Summ. Rep. Geol. Surv., Can. 1896, pp. 116-119.

CHAPTER III.

SUMMARY AND CONCLUSIONS.

(1) The corundiferous rocks of eastern Ontario are of syenitic, dioritic, and gabbroic type and appearance, the feldspathic constituent varying from microperthite, through albite, oligoclase, and andesine to bytownite. Nepheline and scapolite often accompany or replace the feldspars.

(2) The nepheline and related alkaline syenites with which the principal occurrences of corundum are associated, show an extreme and rapid variation in composition. Too much emphasis can hardly be given to this fact, for it is believed that no other class of rocks show an equally great diversity of types within such short distances. At the one extreme are the contemporaneous dykes or veins of pegmatite made up of an almost equal proportion of feldspar and quartz, although such inordinate acid types are by no means common, and the normal phase is a rock composed almost wholly of feldspar, chiefly a microperthite prevailingly albitic. These coarsely granular apophyses intersect medium textured alkaline syenite of reddish, greyish, or whitish colours, rich in soda. These differentiate into corundum syenites and corundum pegmatites, as also into nepheline syenites and nepheline rocks which by an increase in the ferromagnesian minerals show a gradual though distinct passage to essexites and even to more basic varieties probably ijolites.

As a result of the prevailing abundance of soda in the magma from which these rocks have solidified, there are several varieties of the nepheline syenites which are extremely rich in nepheline and which in the absence of any feldspathic constituent, constitute types closely allied to "urtite" described by Ramsay from Finland. Instead of ægirine, which is the prevailing ferromagnesian mineral in the European representative, a very basic hornblende to which Dr. Harrington, after examination gave the name of "hastingsite," occurs. Dr. Adams who has published a detailed description of this new rock type has proposed the name "monmouthite" from the township of Monmouth, where the original or type specimen was collected. A somewhat similar though less extreme differentiation of an alkali-rich magma has been described by Teall from the district around Lake Borolan in the northwest of Scotland. He thus describes the occurrence "We have in the plutonic complex of Lake Borolan a connected group of rocks formed by the consolidation of alkaline magmas rich in soda . . . . the evidence available suggests that the quartz syenites shade into the quartzless syenites and these again into the nepheline syenites."[1]

(3) All of these various rocks in the corundum bearing syenitic complex are differentiation products of one highly aluminous magma, representing one phase of plutonic activity. They belong to one petrographical province and represent a single geological unit.

(4) These syenitic rocks differ from most occurrences of these rocks which have been described in other parts of the world in that they do not possess the usual massive granitoid character of these ordinary intrusives, but on the contrary exhibit a very distinct and often pronounced foliation in close concordance with the same structure developed in the neighbouring granite-gneisses usually classified as Laurentian. The arrangement of the component minerals with their longer axes in the same direction, produces this foliation, while their variation in amount from band to band serves to emphasize it. The foliation is not such as would be produced by the direct crushing of an originally massive rock. Cataclastic structures are very seldom seen and the rock rarely, if ever shows any pronounced evidence of pressure. In these circumstances it is believed that the banded structure so universally observable in these rocks, was imparted to the whole mass while still in a molten, or, at most only partially consolidated condition. It is, therefore, considered as essentially a normal and original structure.

(5) These rocks are as a rule very poor in iron-magnesia constituents and differ from the great majority of the occurrences

[1]Geo. Mag. Dept. 1900, p. 390.

of similar rocks in that the augite, which is usually present, is replaced by biotite (lepidomelane) or hornblende (sometimes hastingsite) or both. Augite is occasionally observed but is always in very subordinate amount. In this respect these syenites resemble the Indian occurrences as well as those near Miask in Russia, in which biotite is also the predominant dark coloured mineral. The prevailing absence or scarcity of quartz or free silica is especially noteworthy, but although quartz and corundum are commonly considered to be mutually exclusive, specimens have been found at Craigmont in which small quantities of both minerals are present in close proximity to one another.

(6) All phases of this magma were in certain localities supersaturated with alumina which when the magma was low in MgO and FeO, crystallized out as corundum.

(7) The simplicity and at the same time completeness of the Ontario occurrences of corundum, combined with the fresh and unaltered character of the associated minerals, at once removed all doubt of the pyrogenesis of this mineral, showing clearly its development as a primary constituent from a highly aluminous silicate magma, as one of the first products of its crystallization. The chemical analyses give remarkable emphasis to the fact that these natural occurrences of corundum conform very closely to the laws formulated by Morozewicz from his observations of the behaviour of the cooling of magmas artificially produced. This law, in brief, recites that the development of corundum in any pure alumino-silicate magma is dependent on the ratio of the alumina to the sum of the other bases. With the knowledge of this fact, therefore, we can predict with the utmost confidence the saturation point for alumina for any such magma. This law received a severe test in the case of one of the rocks (Craigmontite) found at Craigmont, where an excess of alumina, as shown by analysis, indicated the presence of corundum. The thin sections examined under the microscope failed to show any trace of this mineral; but separation of the powdered rock by means of the Thoulet heavy solution at once revealed the occurrence of very minute crystals of corundum. Corundum, therefore, although an accidental constituent in these syenitic and gabbroic rocks is, nevertheless, frequently

so abundant as to characterize the containing rock, and we accordingly have corundum syenites, corundum pegmatites, etc. For instance the specimen of the red corundum pegmatite, chosen for analysis as a representative occurrence at Craigmont contains 34.14 per cent of corundum. In this respect it is almost identical with the similar type present at the Russian locality which on analysis furnished 34.62 per cent of corundum. Moreover a comparison of the analyses of the two rocks from these widely separated localities, shows their almost identical chemical composition. Both differ from the Indian representative whose microperthite is made up largely of orthoclase, while in the Canadian and Russian microperthite, albite is the predominant constituent of this composite feldspar. The corundum bearing rock from Dungannon (dungannonite) closely allied to Lawson's plumasite from California, contains 13.24 per cent of corundum, 72 per cent of andesine, and 3 per cent of nepheline; the remaining 12 per cent being made up of scapolite, biotite, muscovite, magnetite, and calcite.

In addition the results of concentrating operations at the Craigmont mill covering a period of two years in the earlier part of milling operations, showed a saving of 10.41 per cent of corundum.

(8) The frequent occurrence and at times abundance of corundum in the nepheline syenites of Ontario is, so far as known, unique; for although similar rocks occur as differentiated facies of the corundum syenites in India and Russia, no corundum has as yet been found immediately associated with them. It is confidently believed, however, by those who have studied the Canadian occurrences, that more careful prospecting will result in the finding of corundum in the nepheline syenites of both these countries.

It is worthy of remark that at Craigmont, small crystals of corundum amounting to half a per cent of the whole rock mass, have been found in a rock to which the name craigmontite has been applied, composed of 63.18 per cent of nepheline, 29.66 per cent of oligoclase, and 4.39 per cent of muscovite, the remaining 2 per cent being made up of calcite, biotite, and magnetite. Another closely related type occurring at the same place and interfoliated with it (raglanite) has 4.5 per cent of corundum, 70 per cent of oligoclase, 12 per cent of nepheline, and 10 per cent of muscovite, the other minor constituents being calcite, biotite, and titaniferous magnetite.

(9) The rarer or accidental minerals include calcite, muscovite, apatite, garnet, magnetite (always titaniferous), sodalite, cancrinite, zircon, sphene, tourmaline, gahnite or zinc spinel, graphite, molybdenite, chrysoberyl, pyrite, chalcopyrite, pyrrhotite, galena, eucolite, and eudialyte.

(10) Extended outcrops of these nepheline syenites very frequently show very coarsely crystalline or pegmatitic developments of the rock. On the York branch of the Madawaska river close to the bridge crossing on the snow road leading east from Bancroft, the rock contains individuals of nepheline, 2½ feet in diameter, while still larger masses are obtainable on lot 30, concession VI, of the township of Glamorgan. These pegmatitic developments in some cases have the form of dykes cutting the normal nepheline syenite, while in other instances they occur in very coarse grained, ill-defined masses in the finer grained rock analogous to the more familiar developments of granite-pegmatite in similar circumstances.

(11) The corundum-bearing rocks occur as three distinct bands, the longest of which with some rather important interruptions, is about 103 miles in a northeast and a southwest direction, with a maximum width of nearly 6 miles. The others with a similar strike are 8 and 12 miles long respectively. The distances intervening between these bands across the strike are approximately 25 miles and 50 miles, making the total distance between the two most distant bands about 75 miles.

(12) In agreement with the facts these occurrences are considered as the most extensive developments of corundum bearing rocks known. They form part of the Pre-Cambrian complex of the great Canadian Shield or North American Protaxis, and constitute a marginal facies of the batholiths of Laurentian granite-gneisses, where these intrude the crystalline limestones of the Grenville series.

(13) This almost universal occurrence of the nepheline and associated alkaline syenites, along the margin of the granite

batholiths, where these are in contact with the limestones, is a very striking and noteworthy feature. When the actual junction of the two rocks is exposed, large individuals of nepheline, biotite, and other of the constituents of the syenites are developed in the coarsely crystalline limestone, while the detached or "stoped" fragments of the limestone, both large and small, may be found scattered through the syenite, being especially abundant and large in the immediate neighbourhood of the line of contact. Receding from the line of junction these limestone fragments become gradually reduced in size and some distance away, survive as separated, usually irregularly rounded grains of calcite, often enclosed in single individuals of perfectly fresh nepheline, hornblende, or other minerals of the nepheline syenite, or lying between these with the form of the latter impressed upon them on every side.

(14) The occurrence of graphite is perhaps noteworthy, although the mineral is not, so far as observed, a frequent or abundant constituent. It has, however, been noticed in the coarse phase of the nepheline syenite to the east of the bridge over the York river, on the Snow or Mississippi road. It occurs very pure in small, rounded, shot-like forms, consisting of very minute scales of the mineral arranged in a radiating or plumose manner. In certain portions of the rock at this locality, it is rather abundantly distributed, Graphite has also been noticed by Holland as occurring in a certain variety of the nepheline syenite of Sivamalai in India, where it constitutes 0.58 per cent of considerable masses of the rock.

CHAPTER IV.

GENERAL PHYSICAL FEATURES OF REGION.

The general character of the region in which these corundum deposits have been found, may perhaps be best described as that of an uneven or undulating rocky plateau with a gentle slope to the south (see Plate II). It forms a portion of the southern margin of the great Canadian Shield which stretches with almost unbroken continuity to the borders of the Arctic ocean. In common with other Pre-Cambrian areas it is decidedly rough and rocky and thus in large part unsuited for agriculture. The scattered farming population, confined for the most part to those districts underlaid by the limestones, eke out a scanty and somewhat precarious subsistence. It is pre-eminently adapted for grazing purposes when sufficiently cleared, although great stretches, especially in the northern portion, still remain as forest lands. In physiographic character it is thus in marked contrast to the country underlain by the Ordovician limestones to the south and east, which is prevailingly flat, well cleared, and the site of numerous and extensive fertile farms. The area occupied by these Pre-Cambrian crystallines, represents a very ancient peneplain, which emergi[illegible]y from beneath the overlying mantle of Palæozoic rocks, shows a gradual though quite appreciable uplift to the north, the gradients which have been calculated varying from 6 to 8 feet per mile, until a maximum of about 1,500 feet above sea-level is attained near the northern limit of the Haliburton map-sheet. The hill features are of low accentuation, the highest rarely exceeding 500 feet in altitude above the general level of the intervening valleys. These elevations and their complementary depressions give a decidedly rolling character to the surface of the country. These inequalities of surface outline are, however, not observable when the landscape is viewed from any of the higher points, the horizon being bounded in all directions by a uniformly flat sky-line, or at most only slightly interrupted by an occasional low monadnock. One of the most striking characteristics of this plain is the presence of a large number of lakes, both large and small, which are scattered over the surface. These lakes are in themselves noteworthy not only for their many intricacies of shore-line, but also because of the abundance of the islands which interrupt the continuity of their surface. At first sight these lakes are seemingly governed by no law in regard to their development and distribution, but a closer examination reveals the intimate interdependence of outline and structure. This intimate relationship between the topography and the composition and attitude of the surrounding strata is perhaps nowhere better exemplified. Most of the depressions occupied by these beautiful stretches of fresh water are true rock basins, directly dependent for their present configuration on the processes of rock decay and erosion of their softer portions. The distribution and present extent of many of these lakes have also been largely determined by the irregular disposition of the drift material. A glance at the geological maps which accompany the memoir on the general geology of the district, will show the remarkable influence which the strike and the character of the rock underlying the area has had upon the positions of the lakes as well as on the courses of the connecting discharging channels. In the southern portion of the area these follow very closely the trend of the bands of the Grenville limestones, while in the granitic portion to the north they constitute a delicately etched pattern, in the surfaces of the granite gneisses, conformable for the most part to the strike of the foliation.

In the area embraced by the Haliburton and Bancroft map-sheets (4,200 square miles) there are about 525 of these lakes, ranging in size from comparatively large expanses with an area of 20 square miles or even more, to small ponds which cover a superficies of only a few acres. These lakes with their connecting channels and streams, which are often small, rocky, and shallow, form a wonderful series of routes by means of which it is possible to traverse the region by canoe in almost any direction without making portages of any great length.

The district is drained by several important and well known rivers. Much of the northern and central part of the region discharges the surplus of its surface water through the Madawaska river and its southwestern branch now known as the York river, into Chats lake, an expansion of the Ottawa river at Arnprior. The headwaters of the Mississippi river, which also reaches the Ottawa, within about 3 miles of the Madawaska, also drain certain of the lakes in the eastern part of the area, while the lakes in the southern and southwestern portions have their outlet in a number of small streams which unite in the Burnt river and ultimately reach Lake Ontario through the River Trent. The drainage of the district in the northwestern part of the Haliburton map-sheet is through the Muskoka river and into Georgian bay of Lake Huron. It will thus be seen that a large tract of country in the central part of the sheet is in the highlands of central Ontario.

CHAPTER V.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The several geological systems and formations represented in this portion of central Ontario may be tabulated, as follows in descending order:—

Quaternary.....	Post-Glacial or Modern........	....Sands, gravels, and stratified clays.
	Glacial or Pleistocene....	Boulder clay, etc. (*Great unconformity.*)
Palæozoic......	Ordovician.........	Black River formation. Lowville formation. (*Great unconformity.*)
Pre-Cambrian ..	Laurentian.........	Red and grey gneiss and amphibolite. Nepheline and alkaline syenites and related rocks; anorthosites (often corundum bearing.) (*Intrusive contact.*)
	Irruptive..........	Gabbro and diorite. (*Intrusive contact.*)
	Grenville series.....	Limestone, paragneiss, amphibolite, quartzite.

The district in which corundum has been found is a very typical Archæan or Pre-Cambrian area, although presenting a much greater variety of rock types than has so far been described from any similar tract of country of equal extent. The flat lying Ordovician strata which survive as evidence of the transgression of the Palæozoic sea from the south, outcrop in various patches in the townships of Lake, Methuen, Burleigh, and Harvey, near the southern and southwestern portions of the region, included within the limits of the Bancroft map-sheet. To the south of Stony lake, the northern portions of Dummer and Smith townships are underlaid by these sedimentaries belonging to the main body of the Ordovician formations, which beneath the drift stretches with practically unbroken continuity to the shores of Lake Ontario. To the north and east of the main corundum belt, small and thin patches of Utica shale resting upon still more extensive outcrops of Trenton and Black River limestone, occur, which are extensions in this direction of the Ottawa River basin of Palæozoic strata.

An inspection of the geological map will show that this Pre-Cambrian region is characterized by a diversified series of altered sedimentary rocks, among which limestones predominate. To the south of the main belt of corundiferous rocks, these limestones with their associated paragneisses, quartzites, and amphibolites form wide and continuous bands covering great stretches of country with comparatively small and infrequent masses of igneous intrusions. Toward the north, however, granitic invasions become much more abundant and extensive, disturbing, penetrating, and altering the sedimentary material. This progressive metamorphism and disturbance by the Laurentian granites and gneisses is characteristic and widespread. The limit of such disintegration and dissociation of originally continuous sedimentary formation is reached when over hundreds of square miles the rock is a veritable breccia made up of shreds and patches of the intruded sedimentaries, enclosed by the intrusive granite. These isolated and scattered fragments have, moreover, undergone such extensive metamorphism and recrystallization that their recognition is extremely difficult and often impossible.

The type of structure assumed by these granite intrusions is that of a batholith. This structure is well shown on the geological map of the area, the invading granites and granite gneisses occurring in vast, irregularly oval or rounded masses, which arch up and penetrate the neighbouring sedimentaries.

The post-Glacial deposits of sands, gravels, and stratified clays with some alluvium found in the valleys and flats between the hills are the complementary or modified portions of the underlying boulder clay or till from which they have in large part been derived. Over the greater portion of the area the drift material is comparatively thin, so that while it forms the soil of the country, the underlying rock in the form of smoothed and striated "roches moutonnées" protrudes through it at frequent intervals. On the higher levels the drift is unstratified, and filled with boulders, while accumulations of boulders and other unassorted loose material of morainic or drumlin formation are by no means rare. The nature and succession of these old Pre-Cambrian crystallines as developed in this region, is very different from that which obtains in the district to the northwest of Lake Superior, or in the area surrounding Lake Timiskaming and the north shore of Lake Huron. Up to the present time the Grenville series has nowhere been found in contact with the Huronian or Keewatin, and any attempt at correlation must be a matter of conjecture and opinion. The paragneisses greatly resemble, if they are not identical with, similar foliated and schistose rocks found in the Coutchiching series of Lawson, as also the Pontiac-schists of Wilson, but neither of these groups of strata has associations of crystalline limestones. It seems a reasonable assumption, however, and one most in accord with our observed facts and information, that the Grenville series is closely related in age with the Coutchiching series, and is thus an older formation than the Huronian.

LAURENTIAN.

Under this designation are included certain granites and granite-gneisses (see Plate III) with numerous inclusions of amphibolite, which in assembled form occur as batholiths, disturbing, penetrating, and altering the associated sedimentaries. Of the same age and of similar origin are certain nepheline and alkali syenites, often foliated (see Plate VI) which occur for the most part as peripheral phases of certain portions of the Laurentian, usually in association with the Grenville crystalline limestones. These syenitic rocks will be given separate and more adequate treatment by reason of the fact that it is in association with these rocks that the corundum deposits have been developed.

The great area underlain by the Laurentian (2,596 square miles of the total area of 4,200 square miles included in the Haliburton and Bancroft geological maps, or nearly 62 per cent), is rather monotonous, owing to the great similarity of its rocks and rock structure. The prevalent type is granite-gneiss, or granite of varying shades of red and grey colours, with inclusions of amphibolite, dark in colour and of basic composition.

These batholiths have a general trend in a direction about N. 30° E., which is also the direction in which the area is folded. They occur isolated or in linear series so arranged that a very small amount of additional erosion, by removing the intervening cover, would evidently convert the series into a single, long, narrow batholith.

Within the batholiths themselves the strike of the foliation follows sweeping curves, which are usually closed and centred about a certain spot in the area where the foliation becomes so nearly horizontal that its direction and even its existence, where the surface is level, becomes difficult to recognize. From these central areas of flat-lying gneiss, the dip of the gneiss (where it can be determined) is usually found to be outward in all directions. The batholiths are, therefore, undoubtedly formed by an uprising of the granite magma from below, and these foci indicate the axis of the greatest upward movement. These centres are not all areas of more rapid uplift. On the contrary the gneissic foliation in some cases dips inward in all directions towards the centre, thus marking them as places where the uprise of the magma was impeded, that is to say, places where the overlying strata have sagged down into the granite magma.

If this district presents the basement of a former mountain range, now planed down, the direction of this mountain range was about N. 30° E., or, in a general way, parallel to the course of the valley of the St. Lawrence river.

The movements in the granite to which reference has been made, did not take place solely while the rock was in the form of an uncrystallized or glassy magma. They continued as the rock cooled and while it was filled with abundant products of crystallization, the movement being brought to a close only by the complete solidification of the rock. Evidence of protoclastic structures can, therefore, be seen throughout all the areas coloured as granite or granite-gneiss on the map, except in the case of a few small bodies of granite apparently of more recent age. This protoclastic structure is marked by the presence of more or less lenticular, broken fragments of large individuals of the feldspar, in a fluidally-arranged mosaic of smaller allotriomorphic feldspar grains with quartz strings and a few biotite flakes. This fluidal arrangement, which constitutes the foliation of these rocks, is seen in every stage of development, there being an imperceptible gradation from the perfectly massive forms occasionally seen, through the more or less gneissic varieties, to thinly foliated gneisses. It is impossible to separate the several varieties. They constitute progressive developments of one and the same structure, and are different phases of one and the same rock mass.

The granite-gneiss, which is undoubtedly of igneous origin, is very uniform in its mineralogical composition, and differs distinctly from the sedimentary gneisses (paragneisses) of the area. It is medium to rather fine in grain, and composed almost entirely of quartz and feldspar, the latter preponderating. Biotite is present in very subordinate amount. The rock in the southern batholiths occasionally contains a little hornblende. While the feldspar is always reddish in colour, a large proportion of it is really an acid oligoclase. The rock would ordinarily be classed as an albite-granite or granite-gneiss, and although the soda feldspar preponderates, should be so classed since it resembles a granite in every respect.

Agreeably with the analyses undertaken, quartz varies from 27.72 to 37.68 per cent; microcline and orthoclase from

18.35 to 25.58 per cent; oligoclase from 34.34 to 47.72 per cent; biotite or hornblende or both, 0.90 to 4.49 per cent. The grey gneiss sometimes has a reddish tinge, but usually varies from light grey to darker grey according to the relative proportions of the ferromagnesian constituents present. As a general rule it weathers more readily than the red gneiss. It differs essentially from the red gneiss in the larger content of plagioclase, the lower of quartz, and, in general, the larger of the coloured constituents.

Dark inclusions are present throughout the granite gneiss almost everywhere in the area (see Plate IV). These are often very abundant, and consist of amphibolite or closely allied rocks. In some places on account of their abundance and angular character, the granite presents the appearance of a breccia. These fragments, while usually more or less angular, have sometimes been softened and drawn out in the direction of the movement of the gneiss, so as to impart to the rock a streaked or banded appearance. In other places the inclusions have been so completely permeated by the granite magma that they are utterly disintegrated. Every stage of passage from the sharply angular inclusions to the final products of disintegration can be traced in many places, although in most cases the inclusions are well marked and sharply defined against the enclosing gneiss. At many points, throughout the red granite gneiss of the batholiths, moreover, streaks of grey gneiss are found. It is estimated that, taking the granite gneiss of the whole area examined, the amphibolite inclusions represent about 10 per cent of its volume and this grey gneiss another 10 per cent.

The origin of these amphibolite inclusions and of the masses of grey gneiss, is not only a question of much interest, but one of considerable importance to the true understanding of the geological processes which have been at work in this region. As is well known, similar inclusions of dark basic rocks of the nature of amphibolite are found in very many occurrences of granite, especially those of Pre-Cambrian age, in various parts of the world, and they have been the subject of much investigation and widespread discussion. By many geologists they have been considered to be basic differentiation products from the acid magma, while others have looked upon them as fragments of foreign rocks caught up by the granite.[1] In the region at present under discussion there are three ways in which it would be possible to consider them as having originated.

(1) As the basic differentiation products (Germ Ausscheidungen) from the granite magma.

(2) As portion of the rock forming the walls or roof of the batholith, which had fallen into the granite magma and had partaken of its subsequent movements.

(3) As fragments of intrusive masses, dykes, stocks, etc.

A careful study of all parts of the area has failed to furnish any evidence that the first is the true explanation anywhere. There is positive proof that the second is the correct and only explanation of the inclusions in several parts of the area, and it is an explanation not opposed to the facts in any part of the area. The inclusions in some places, more especially in the great northern granite gneiss areas, may have originated in part as set forth in the third explanation. The form of the inclusions sometimes suggests this, but the movements in the granite have been so great, and the inclusions have been so torn to pieces, that it has been impossible to decide whether any of them have been derived from the source indicated under this head.

GABBRO AND DIORITE.

These rocks differ from the amphibolites in that they are massive and usually coarse grained. They also differ in their

[1]C. H. Smith, jun. "Report on the Crystalline Rocks of the St. Lawrence county," N.Y. State Mus. 49th Ann. Rep. 1895, Vol. II (1898) p. 490. The black inclusions in the granite gneisses of the Adirondacks are considered to be broken masses of an older rock caught up by the granite gneiss when the latter was still in a molten condition. B. Frosterus, 'Bergbyggnaden i Sydostra Finland', Bull. Comm. Geo. Finl. Vol. II, No. 13 (1902) p. 157, considers that the amphibolites which are characteristic associates of the granite gneiss of Southern Finland, are probably for the most part altered dyke-rocks. Some of them still show a gabbro-like structure, which, if the granite be supposed to represent the original sub-crust in a softened or remelted condition, cut through this crust and were connected with basic affusives at the surface: these masses, having been torn to pieces by the subsequent movements of the softened granite, now appearing as scattered fragments.

mode of occurrence as great basic intrusions. While some of these intrusions are rather uniform in character, others display a very marked differentiation and present many petrographical varieties within a single intruded mass.

Many of them, in addition to pyroxene, a basic plagioclase and iron ore, hold a large amount of hornblende and may be described as gabbro-diorites, for the character of the hornblende frequently suggests its derivation from augite under the action of metamorphic agencies.

GRENVILLE SERIES.

This formation has been separated from the Laurentian, with which it is sometimes included, because of its difference in age, and origin.

In common with other Pre-Cambrian areas in the St. Lawrence region, this district is characterized by the presence of enormous bodies of limestone and dolomite. In this respect it is in marked contrast with other Pre-Cambrian areas, especially that to the northwest of Lake Superior, as also the country which has been mapped in northern Ontario. Indeed it may be safely stated that the Grenville series presents by far the thickest development of Pre-Cambrian limestones in North America, at the same time including one of the most extensive series of Pre-Cambrian sediments on this continent.

Not only has the Grenville series an enormous thickness, but it also has a great superficial extent, being exposed over an area of 83,000 square miles in eastern Canada and New York state. It may be here stated that the "Hastings series", a designation applied by Logan to certain rocks of the Madoc district, has proved, as Logan conjectured, to have no independent existence, but to be merely the less metamorphosed portion of the Grenville series, seen in the southern part of the Bancroft area.

Limestone.

The prevalence of calcareous strata in the Pre-Cambrian of this region, is especially true of the southern, and to a less extent, of the northeastern portions, while in contradistinction the country covered by the northwest corner of the Haliburton map-sheet, contains no limestones recognizable as such.

In their more altered form, these limestones are identical with those described by Logan and Hunt under the name of Laurentian limestones. Throughout the area and especially in the neighbourhood of the belts of corundum bearing rocks, these limestones have been very thoroughly metamorphosed, and rendered crystalline and impure by the secondary development in them of certain silicates. Forty-two mineral species have thus far been recognized among these impure and secondary products, due to the direct action of the magmatic waters accompanying the intrusion of Laurentian granite batholiths. In certain cases autoclastic action has been very pronounced, with the production in certain localities of very handsome coloured marble breccias, which are now being extensively exploited to the south of Bancroft. The purer forms of these crystalline limestones are white in colour, but shades of deep salmon, pale pink, yellow, and green are also commonly met with. Limestone predominates over dolomite, while magnesite has not yet been recognized.

The evidence is conclusive that these limestones or marbles were originally fine-grained limestones of a bluish grey colour, similar to those seen in later formations, but which, as a result of metamorphism, have been altered to their present highly crystalline condition.

Paragneiss.

These rocks differ distinctly in appearance from the foliated granite-gneisses already described as constituting the batholithic intrusions. They are fine in grain and show no protoclastic or catalastic structure, the original material having been completely recrystallized. They have, therefore, an allotriomorphic structure with a tendency for certain of the constituent minerals to be elongated in the direction of the original bedding. While quartz, feldspar, and biotite are among the constituents present, the mica is usually more abundant than in the granite-gneisses.

In addition to these, garnet, sillimanite, graphite, and pyrite are very frequently present, the oxidation of the last mineral giving rise to a prevailingly rusty colour on the weathered surface. These gneisses occur in well defined beds, and are usually found intimately associated with the limestones. They resemble in many respects the hornstones which are found in granite contact-zones, but are rather more coarsely crystalline than is usual in this class of rocks.

Amphibolites.

Intimately associated with these sedimentary gneisses and the limestones on the one hand, and with the gabbros and diorites on the other, is another class of rocks which is grouped under the name of amphibolite. While many varieties of these rocks occur in the area, differing considerably one from the other in appearance, they have in common a dark colour and a basic composition. Quartz, one of the commonest constituents in the gneisses, is absent, or is present only in very small amount; while hornblende and feldspar, the latter chiefly plagioclase, are the main constituents of the rock. Pyroxene and biotite often replace the hornblende in part.

These rocks underlie large areas, as represented on the Bancroft sheet. They also occur as interbedded layers so intimately associated with certain developments of the limestones that these limestone-amphibolite occurrences have been mapped separately. In places the sedimentary gneisses also fade away into occurrences of amphibolite when traced along the strike. Masses of amphibolite also abound as inclusions throughout the granite of the batholiths. These amphibolites are not peculiar to this area, but occur abundantly everywhere in the Laurentian. They have always proved to be one of the chief difficulties in the way of a correct understanding of the geology of this system, seeing that it has been impossible to do more than indulge in conjectures concerning their origin. The same difficulty has been encountered in the case of these and allied rocks occurring elsewhere, as, for instance, the trap-granulites of the Saxon Granulitgebirge or the amphibolites of the crystalline complex of certain portions of the Alps, the origin of which remained in doubt, while that of the rocks wherewith they were associated has been definitely determined.

Two of the more common varieties of these amphibolites are represented by special designations on the map. One of these, which has been termed "Feather-amphibolite", always occurs in thin bands interstratified with limestone, and derives its name from the curious feather-like development displayed by large skeleton crystals of hornblende or pyroxene which appear on the plane of stratification of the rock, to which they give a striking appearance when it is split along this direction. The other variety of amphibolite, which also frequently occurs as heavy bands in the limestones, is of a finely granular character without very distinct foliation. On weathered surfaces it presents a uniformly, minutely speckled appearance, owing to the intimate admixture of the minute grains of hornblende and feldspar. On this account, during the prosecution of the field work, this variety was designated as "the pepper and salt amphibolite", and in the legend of the Bancroft sheet it is designated as granular amphibolite.

Still other varieties differ from this granular amphibolite, in being somewhat coarser in grain or less regular in composition.

As the result of a very careful examination, it has been possible to prove conclusively that in this area the amphibolites have originated in three entirely different ways, the resulting rocks, although of such diverse origin, often being identical in appearance and composition. This remarkable convergence of type, whereby rocks of widely different origin come to assume identity of character, explains the difficulty which has been experienced up to the present time in arriving at a satisfactory conclusion concerning their genetic relations.

(*a*) Some of these amphibolites result from the metamorphism and recrystallization of sediments. To this class belong the feather amphibolites above described, which usually occur in thin bands alternating with crystalline limestone, and are evidently of like origin. They represent siliceous or dolomitic laminæ in the calcareous deposit. In many cases the bands of crystalline limestone become thinner and less abundant, and the composite rock passes gradually over into a body of pure feather-amphibolite. Whether the granular amphibolite, which is also found alternating with bands of limestone, very frequently and over wide areas, is in some cases of similar origin, it has not been possible up to the present time to decide.

(*b*) Certain granular amphibolites represent altered igneous intrusions, for they are found in the form of dykes, cutting across the stratified white crystalline limestone on the shores of Jack lake in the township of Methuen. The limestones here dip at a low angle to the south, and are excellently exposed in low cliffs about the lake. The typical granular amphibolite can be seen rising above the surface of the water in the form of vertical dykes 1 to 2 feet wide, which cut directly across the stratification of the limestone. These can frequently be seen to have been diverted along certain bedding planes and torn apart by movements in these planes, the limestone-strata having experienced somewhat extensive movements along their bedding-planes during their upheaval. The dykes, after following the bedding-planes for a certain distance, once more cut vertically across them and so reached the surface. Such dykes when seen on limited exposures of the bedded surface of the limestone, especially in contorted districts, would usually present the appearance of interstratified masses of amphibolite.

This amphibolite has the regular allotriomorphic structure of a completely recrystallized rock, and differs from any of the normal igneous rocks. Under the microscope it is identical with an amphibolite described by Dr. Teall, which was developed by the alteration of a diabase dyke where crossed by a line of shearing. In the case of these Canadian dykes, however, the amphibolite is not confined to that portion which has been clearly subjected to movement, but forms the whole mass of the dyke.

(*c*) Amphibolites which are identical in physical character and in composition with those described under (*b*) are also produced by the metamorphic action exerted by the granite-batholiths on the limestones through which they cut. This is a remarkable fact, and one which at first sight seems scarcely credible. It is, however, a change which has undoubtedly taken place on a large scale.[1]

In addition to the amphibolites which have originated in the three ways above mentioned, it is highly probable, judging from their character and mode of occurrence, that the amphibolite bands associated with the large gabbro and diorite masses—as for instance, that running in a northeasterly and southwesterly direction through the township of Wollaston, and that extending from the southeastern corner of the township of Cardiff, into Anstruther—represent highly altered basic volcanic ashes and lava-flows, connected with vents represented by the gabbro-stocks. The latter of these amphibolite bands presents a great variation from place to place in the character of the constituent rock. While in some places it is well banded, elsewhere it is streaked or presents an appearance strongly resembling flow-structure, with lighter coloured lath-like forms highly suggestive of feldspar phenocrysts thickly scattered through it. Yet elsewhere, the appearance suggests an original amygdaloidal structure. The rock, however, is so completely recrystallized, that a microscopic examination does not yield any conclusive evidence concerning its original character.

Quartzite.

Quartzite is not common in this area, the most extensive exposures occurring as a band crossing the township of Monmouth. It is found interstratified with crystalline limestones and rusty weathering gneisses of sedimentary origin. There is every reason to believe that these quartzites represent, in most cases at least, altered sandy sediments.

[1]On the origin of the Amphibolites of the Laurentian Area of Canada; Jour. of Geol. Vol. XVII: 1909. Memoir No. 6, Geol. Surv., Can., 1910, pp. 98-115.

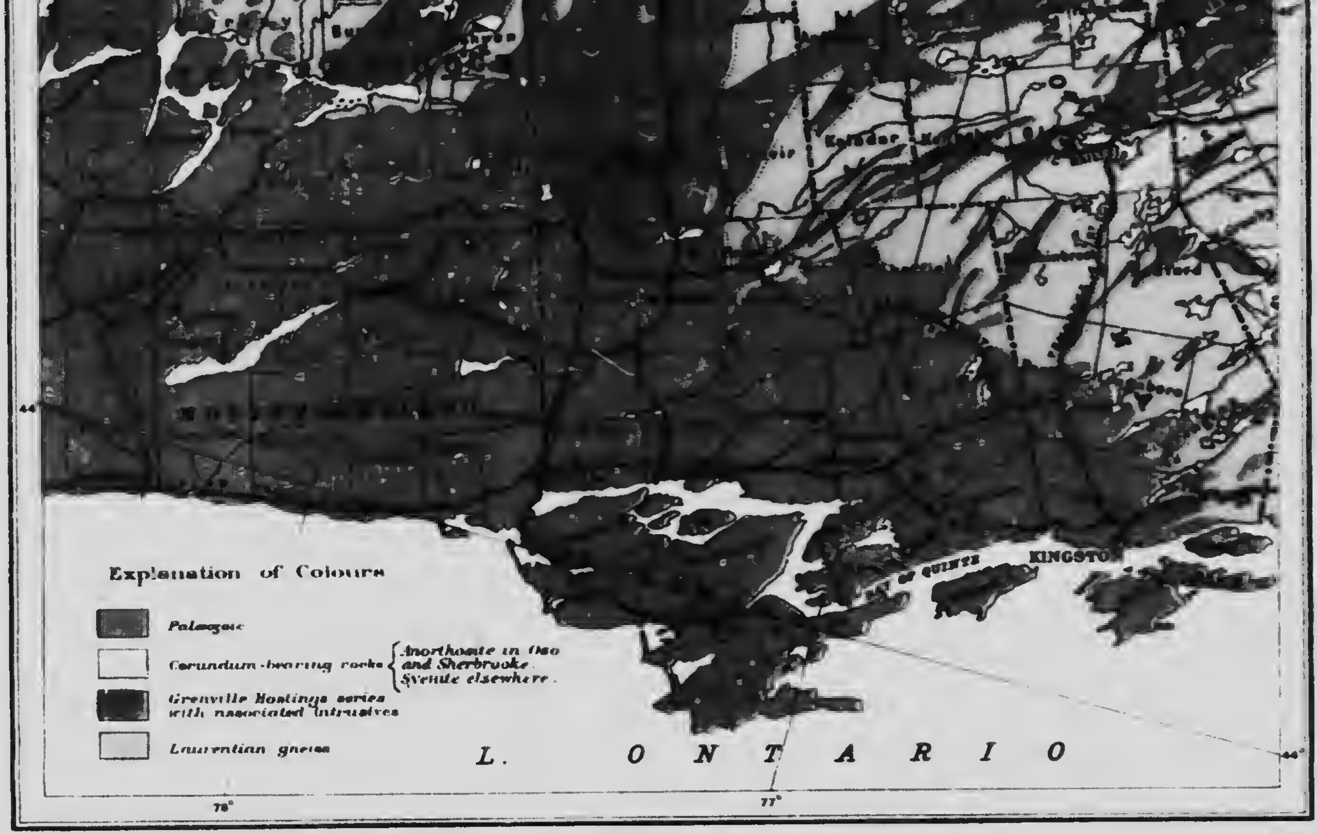
CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER,
R. W. BROCK, DIRECTOR

1909.



No 1023

Geological Map
OF
CENTRAL ONTARIO
showing the position
of the several belts of
CORUNDUM-BEARING ROCKS
To accompany Report by
FRANK D. ADAMS and ALFRED E. BARLOW

Scale of Miles

CHAPTER VI.

THE NEPHELINE AND ASSOCIATED ALKALI SYENITES (INCLUDING CORUNDUM-BEARING ANORTHOSITES).

GENERAL STATEMENT.

The corundum-bearing syenites and anorthosites appear to be included in three belts.

1. Main or Northern Belt.
2. Methuen-Burleigh or Middle Belt.
3 Lanark-Frontenac or Southern Belt.

DISTRIBUTION.

All the occurrences of nepheline syenite and associated corundum-bearing rocks, comprised in what has been called the main or northern belt, are confined to a comparatively narrow stretch of country which has a general northeasterly course, as shown on the accompanying map. The most westerly occurrence discovered is that in the township of Lutterworth, where a corundum-bearing syenite has been found on lot 12, concession IV, of this township. The next occurrences are those which are situated in the townships of Glamorgan and Monmouth, in which townships some twenty separate areas of the rock have been mapped and studied. The largest and in many respects the most noteworthy of these is a wide belt of nepheline syenite which surrounds an occurrence of granite intervening between this rock and the limestone which forms the country rock of the central portion of the township of Monmouth. Here the nepheline syenite and the granite are clearly seen to be differentiation products of a common magma. The other occurrences of these townships are smaller and lie for the most part in the limestone.

Going to the east from the township of Monmouth a narrow band of nepheline syenite can be traced across the corner of the township of Cardiff into concession II of Harcourt, beyond which, in the northeast corner of Cardiff, occurrences of the closely related white alkali syenite have been noted by Dr. Miller at Leafield.

Beyond this, in the northwest corner of the township of Faraday, what appears to be a continuous belt of nepheline syenite, accompanied sometimes by the closely related red alkali syenite, extends in a southeasterly direction for a distance of about 3½ miles, crossing the Monck road on lot 26, between concessions A and B. Near this place there is a gradual change in the strike of the rock, the band curving around and running in a direction a little north of east, as far as lot 16 of concession A. It is impossible to trace its further extension eastward, as occasional outcrops only were found protruding through the deep covering of drift. It seems, however, entirely reasonable to assume that the several exposures found, belong to one continuous belt, for as the village of Bancroft is approached there is a very marked increase in the area over which these syenite rocks are distributed. At its intersection with the Hastings road at the village of Bancroft, between the townships of Dungannon and Faraday, the nepheline syenite measures over half a mile across its strike, which is here nearly east and west. East of Bancroft (see Plate V) these syenite rocks increase very rapidly in volume, attaining their maximum development in the vicinity of Bronson, where extended and often nearly continuous outcrops may be found for a distance of over 2½ miles in a north and south direction, underlying most of the area between concessions XI and XIV as far as the York river.

Along the valley of the York river and extending in a general direction a little east of north from the bridge over the York river in concession XI of Dungannon to the mouth of Papineau creek in the township of Carlow, there are a large number of lenticular masses of nepheline syenite and alkali syenite intruded along the strike of the crystalline limestones and amphibolites. Time did not permit of a sufficiently detailed examination of this valley to accurately outline all such masses,

EXPLANATION OF PLATE V.

Hills of nepheline syenite, 2 miles east of Bancroft, Dungannon township.
(See page 58.)

Hills of Nepheline Syenite, two miles east of Bancroft, Dungannon township.

even if this were possible with so heavy an accumulation of drift as is here found. The position, however, of certain of these occurrences as well as their strike is convincing that they are much more continuous and extensive than shown on the Bancroft map-sheet.

A little to the east of Papineau creek, nepheline syenite is met with on both sides of the river, while farther down the river a little north of Foster rapids, an extremely basic nepheline rock occurs. Still farther to the east Dr. Miller mentions nepheline syenite outcropping on a ridge in concession IX, of Carlow about 1½ miles northwest of Campbell's bridge on the York river.

No very detailed examination was made of the area between Carlow and Brudenell, but corundum syenites occur in concessions XVIII and XIX of Raglan and in concession II of Radcliffe, close to Palmer rapids on the Madawaska river, while nepheline syenite has been found on lot 25 of concession XIX of Raglan.

All these last mentioned occurrences in Raglan and Radcliffe belong to another and parallel band of these syenite rocks, which, starting from about lot 6, in the township of Carlow, extends eastward through the two northern concessions of Raglan, having been traced a short distance east of the Madawaska river near Palmer rapids. The occurrences of nepheline syenite and the closely related red syenite in concessions V and VII of the eastern part of the township of Brudenell, with their northwest and southeast strike, occupy an intermediate position between these and the Algona and Sebastopol occurrences in the east. Extending eastward from these discoveries in the eastern part of Brudenell and the western lots of Radcliffe and Raglan. a very wide belt of these syenitic rocks (sometimes over 6 miles in width) covers the northern concessions of Lyndoch, and the southern concessions of Brudenell. Still farther eastward they cover nearly the whole of the township of Sebastopol and extend across Clear lake into the southern part of South Algona. The Palæozoic rocks and drift deposits of the Ottawa River basin here intervene, but it is probable that these rocks will be found to extend into the Province of Quebec, if search is made for them.

From the township of Lutterworth where, as already mentioned, the most westerly development of these rocks is found, the occurrences of syenite are confined to a narrow and somewhat sinuous belt of country, having a general northeasterly strike as far as the township of South Algona. This represents a distance of about 103 miles. Within this belt from the township of Glamorgan northeast of the Ottawa river, over a distance of about 83 miles, the nepheline syenites and their associated rocks are represented by very frequent exposures, constituting an almost continuous development.

The Methuen-Burleigh belt of corundiferous syenites extends from lot 21, concession V, of the township of Methuen on the northeast to lot 3, concession XI, of the township of Burleigh at the southwest end. In this direction it is concealed by the waters of Stony lake although exposures have been found by Dr. Miller on one of the small islands. The area underlain by these rocks is of club shape with a general direction of north-northeast and south-southwest. The wide part of this mass is toward the northeast and measures more than 1½ miles across, while toward the southwest end the handle of the club is only 200 yards wide in some places. The total length is, therefore, little more than 8½ miles.

The Lanark-Frontenac band extends so far as examined in a northeast and southwest direction for a distance of about 12 miles, reaching from the northeast corner of the township of Hinchinbrooke, across the southeast corner of Oso township, Frontenac county, and into the township of South Sherbrooke in Lanark county. This belt is largely made up of anorthosite, but toward the southwest end corundum has been found in the more usual syenite pegmatite. In some places this band has a breadth of nearly one mile.

GEOLOGICAL RELATIONS OF CORUNDUM SYENITES AND ANORTHOSITES.

The region in which the corundum-bearing syenites and anorthosites occur is underlain by the Laurentian system of

Logan. According to Logan, this system was composed of the Fundamental Gneiss, with an overlying series of very ancient sediments consisting chiefly of limestones, and which subsequently came to be known as the Grenville series. Logan considered both series to be of sedimentary origin, the well defined bedding of the upper series being in the Fundamental Gneiss, replaced by a gneissic structure which he regarded as representing an almost obliterated bedding. The contact of these two series in the area which he examined in detail, lying north of Grenville, situated about halfway between the cities of Montreal and Ottawa, is of such a character as to lead some support to this old Wernerian view.

A careful examination of the very large areas in which the relations of these two series has since been closely studied, shows, however, that in all cases the so-called Fundamental Gneiss breaks up through the overlying Grenville series, the contact being of an intrusive character, so that over wide stretches of country in the province of Quebec and in eastern Ontario the "Laurentian system" is composed of a great series of sedimentary rocks chiefly limestone, invaded and intensely altered by enormous intrusions of the Fundamental Gneiss. To the northwest of Lake Superior and in the Cobalt region, a similar relationship obtains, the oldest stratified series, the Keewatin Series, having been invaded by the Laurentian or Fundamental Gneiss. In fact, the same anomalous condition has been found in all parts of the world where these ancient crystallines have been studied. There is no floor to the sedimentary series, no basement of granitic or other rocks on which the oldest sediments of the geological column repose and from which they have been derived, but, instead, the oldest sedimentary series float on enormous intrusions of granite, which break up through them in every direction.

In this region the limestones, with their associated sedimentary gneisses and amphibolites (Grenville series) are of great extent and thickness.

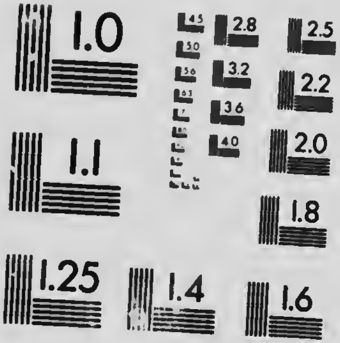
The nepheline and their associated alkali syenites are found either along the actual junction of the granite and the limestone, or in the limestone itself near the granite contact. There is only a single exception to this in the area under discussion, namely, the nepheline syenite mass in the township of Methuen, which occurs between a great granite intrusion and a body of amphibolite, containing a few small bands of limestone.

These nepheline rocks are of the same age as the general complex in which they occur. They are intruded into the crystalline limestones and associated sedimentary rocks of the Grenville series, while at several points where examination is possible, they pass gradually into the Laurentian gneiss. In certain localities, however, dykes of syenite cut the Laurentian gneiss. A careful study of the whole area shows that the nepheline syenite and its associated alkali syenites represent a peripheral differentiation phase of the granite (Laurentian gneiss) and that the syenite dykes which intrude the Laurentian gneiss are differentiated material of the same magma corresponding to the more usual granite pegmatite representing the last product of the crystallization of an ordinary granite magma.[1]

[1]The comparative rarity of the alkaline rocks in contrast with the widespread occurrences of those of subalkaline type, has been generally assumed by both geologists and petrographers. Recently, however, Daly has furnished a definite quantitative statement based on careful compilation and consideration of existing information, that alkaline rocks constitute less than one per cent of all igneous rocks. Such a statement, while no doubt of value, is rather premature and manifestly based on insufficient data. Alkaline rocks are by no means easy of recognition especially in the necessary hurry of the reconnaissance geological surveys which have mostly been made of the great stretches of our old Pre-Cambrian crystallines. It is the opinion of many Pre-Cambrian geologists who have given the matter serious attention, that rocks of alkaline type cover extensive areas even in tracts of country which have been subjected to rather close geological scrutiny. While the intimate and widespread association of limestone with alkaline rocks cannot be of accidental occurrence, the influence of the presence of such calcareous sediments in determining the alkaline character of the neighbouring intrusives is by no means obvious as Daly's conclusions would seem to imply. It is, moreover, a matter of great surprise that although the alkaline rocks of the Bancroft area show very extensive incorporation of the neighbouring crystalline limestones, yet there is comparatively little evidence of any real digestion and assimilation of this calcareous material. In fact the evidence available seems to accord with Smyth's suggestion that the magma from which these rocks have solidified contained within itself, the agents of differentiation. The magma should be regarded as ultimately derived from the more usual

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Explanation of Plate VI.

Nepheline syenite showing regional foliation near York River bridge, lot 13, concession XII, Dungannon township. (See pages 47. 63, 67, 72.)

Nepheline Syenite showing regional foliation near York River bridge.
Lot 13, Con. XII Dungannon township

GENERAL PETROGRAPHICAL CHARACTER.

It would far exceed the scope of the present report to describe in detail the exact composition of these syenites at the many localities where they are exposed, for their extreme and rapid variation in composition is one of the most noteworthy features of their development. In fact, too much emphasis can hardly be given to this feature, for no other rocks show an equally great diversity of types within such short distances. It is quite possible to obtain hand specimens from the same exposure, and even from contiguous bands, which exhibit such a wide difference in their mineralogical composition as to be classed as separate and distinct types of rock. All these, however, are differentiation products of one highly alkaline and aluminous magma, representing one phase of plutonic activity. Although belonging to one petrographical province, for convenience of description they may be considered as divisible into six groups, although it must be understood that no arbitrary lines exist in nature between these respective subdivisions.

(*a*) Nepheline syenite.
(*b*) Monmouthite, craigmontite, and congressite.
(*c*) Nepheline-syenite-pegmatite.
(*d*) Anorthosite.
(*e*) Red alkali syenite.
(*f*) Syenite pegmatite.

(*a*) *Nepheline Syenite.*

The rock (see Plate VI) is made up essentially of plagioclase usually albite but sometimes also oligoclase and andesine, with nepheline and biotite (often lepidomelane), hornblende, or pyroxene as the ferromagnesian minerals. Of these dark coloured constituents, biotite is the most abundant and prevalent,

and abundant subalkaline magma, the relatively high content of the rarer elements in the resulting rock masses and their pronounced differentiation being largely effected by the presence of certain mineralizers using this term in its broader and more recent sense. (Bull. Geol. Soc. Amer. XXI, 1910, pp. 87-118; Am. Jour. Sc., Vol. XXXVI, 1913, pp. 33-46.)

although hornblende is also of common occurrence, and may replace or occur in conjunction with the biotite. Pyroxene is noteworthy by reason of its scarcity, although it has been recognized by Dr. Adams in certain phases of this rock outcropping in Monmouth, Glamorgan, and Methuen townships. Orthoclase, microcline, and microperthite are occasionally present as accessory constituents. The term syenite as applied to occurrences of these rocks in eastern Ontario is somewhat of a misnomer for plagioclase is always the prevalent and often the only feldspathic constituent. Dr. Adams[1] in his paper announcing the discovery of these occurrences in the townships of Dungannon and Faraday, made reference to this as follows: "If the distinctive character of the nepheline syenite named 'Litchfieldite' by Bayley, be the replacement of the orthoclase by albite, this rock is a more typical Litchfieldite than that from the original locality. The propriety of defining nepheline syenite as a rock composed essentially of nepheline and alkali feldspar, is rendered evident, as otherwise it would be necessary to classify this rock as a theralite from typical specimens of which it would differ greatly in composition."[2]

(*b*) *Monmouthite, Craigmontite, and Congressite.*

The nepheline syenite exhibits the extremes of variation in the relative proportion of its constituent minerals, passing by a decrease in the amount of plagioclase into rocks composed exclusively of nepheline and ferromagnesian minerals, and of these into varieties made up almost exclusively of nepheline such as monmouthite (see Plate VIII) congressite, and craigmon-

[1]American Journal of Science, Vol. XLVIII, 1894, p. 15.

[2]Dr. P. D. Quensel has proposed the name "Canadite" for this type of rock, thus indicating the country where they were first described and where they have their greatest areal development. He defined this variety of nepheline syenite as consisting of "nepheline and albite or a highly sodic plagioclase as principal felsic constituents. The abundant mafic minerals contain a certain amount of normative lime-feldspar which is not present in the rock leaving the modal feldspar free or all but free from calcium." ("The alkaline Rocks of Almunge" by Percy Quensel, Geol. Inst. of Upsala, Vol. XII, p. 177.)

tite, or into very basic varieties composed almost wholly of iron-magnesia constituents and approaching ijolite and jacupirangite in composition. Calcite is almost invariably present in rocks belonging to these two groups, while scapolite often replaces either the feldspar or nepheline.

(c) *Nepheline-Syenite-Pegmatite.*

Intimately associated with the rocks included in these two groups (a and b), and forming an integral part of the same igneous complex are certain abnormally coarse phases, which are their pegmatitic equivalents. These may occur as parallel or intercalated bands (see Plate X) or they may cut across the foliation of the rock in dyke-like masses. The contact of these pegmatites with the parent or normal plutonic rock is sometimes quite sharp, especially in the case of those which intersect the foliation. They usually, however, present a rather abrupt, though quite perceptible transition into the ordinary, medium grained type. Nepheline-syenite-pegmatite is usually composed almost wholly of nepheline and plagioclase often in very coarse individuals, localities near the York river and in Glamorgan township having furnished the collection with masses of nepheline from 2 to 3 feet in diameter. Sodalite is often present and muscovite, biotite, and occasionally hornblende, apatite, magnetite, and zircon occur in comparatively large crystals.

(d) *Anorthosite.*

The pale greyish or whitish feldspathic differentiate of the nepheline syenite has usually a composition very closely analogous to anorthosite. Albite, oligoclase, andesine, and bytownite anorthosites have all been recognized. Most of these are included in the group of the white alkali syenites. The variety to which the name plumasite (after Lawson) has been applied and as it occurs at Craigmont is a rock made up almost wholly of oligoclase with very subordiate amounts of biotite and sometimes nepheline and with varying quantities of corundum, this mineral sometimes forming as high as 15 per cent of the whole mass. Dungannonite is in reality an andesine anorthosite with corundum (type specimens contained 13.24 per cent of corundum). A pale greenish grey rock with corundum and garnet, at Craigmont, contains a plagioclase intermediate in composition between oligoclase and andesine. The anorthosite with which the corundum is usually associated in the Lanark-Frontenac belt is a bytownite anorthosite made up almost wholly of bytownite and hornblende.

(e) *Red Alkali Syenite.*

This rock is at once distinguished from the anorthosite or white alkali syenite as it has usually been termed, by its pinkish or greyish colour. Like the anorthosite it contains plagioclase usually, at least, albite, as the predominant feldspar, but orthoclase and microcline are always present and are relatively much more abundant than in the paler coloured rock. Occasionally a little nepheline occurs, and its alteration to pinkish or reddish gieseckite, deepens the reddish colour of the rock. Magnetite in small crystals and irregularly bounded grains is usually present and characteristic. Biotite is the iron magnesian mineral represented and is as a general rule present in very subordinate amount. Occasionally this mica is absent and some bands are thus made up almost wholly of feldspar. Quartz is characteristically scarce if not entirely unrepresented. In certain instances, however, these highly feldspathic representatives which on first inspection appear to contain no quartz, are shown both by the microscope and analysis to contain a certain proportion of this mineral.

(f) *Syenite Pegmatite.*

This rock, which is the pegmatitic form of the normal red alkali syenite, is differentiated solely by its relatively coarser texture. As developed at the various localities where corundum has been found, it is made up almost wholly of microperthite, the albite being more abundant than the orthoclase in this composite feldspar. Sometimes very large individuals of biotite and hornblende are present, but such masses of basic material are by no means common. Very large crystals of muscovite as well as smaller individuals are also by no means unusual. This rock is the matrix of the richest corundum ore, and sometimes portions of contemporaneous dykes of corundum-syenite pegmatite will contain as much as 75 per cent of this mineral. Corundum crystals are comparatively large in this rock but are very often irregular in outline. Some of the individuals obtained weighed more than 30 pounds each. Occasionally quartz occurs in the same specimen with corundum, but such anomalies are rare. With the addition of quartz the rock passes over into a quartz or granite pegmatite and some dykes were found which were made up of feldspar and quartz in about equal proportions. These intersect the quartzless or syenite pegmatite and are the latest differentiation products of the whole igneous complex.

General Remarks.

The rocks of these several groups pass into one another by imperceptible gradations. The magmas of all four types were in places supersaturated with alumina, this excess crystallizing out as free alumina in the form of corundum. In those varieties of nepheline syenite which are unusually rich in nepheline as craigmontite, the corundum is only developed when the iron magnesia minerals do not occur in any appreciable amount.

These various rocks, while sometimes quite massive, possessing a true hypidiomorphic granular structure, usually have a more or less perfect foliated structure which in many places presents an actual schistose development, the strike of which conforms to that of the adjacent country rock (see Plate VI). The foliation has all the characters of an original structure. They vary in texture from medium to coarse grained, while the pegmatitic phases sometimes present nepheline and plagioclase individuals as much as a yard in diameter.

The rock is, as a rule, remarkably fresh and unaltered. Evidences of pressure even in the most pronouncedly foliated or schistose varieties are extremely rare. In occasional instances, however, some of the feldspar show strain shadows and curved or slightly dislocated twinning lamellæ. Sections of the rock comprising the narrow part of the band, crossing the Monck road in Faraday township, show quite pronounced granulation and cataclastic structure.

The relations of the constituent minerals, especially the feldspathoid species, do not indicate the same regular and definite order of succession which is seen in most of the rocks which have crystallized from a molten magma. In general, however, it may be stated that after the crystallization of such minerals as apatite, zircon, sphene, corundum, and magnetite, individuals of which usually possess rather good crystal outlines, the hornblende and biotite were formed. Both of these last mentioned minerals, and especially the hornblende, exhibit many sharp and distinct crystallographic boundaries. Plagioclase came next in order, while the remaining interspaces were filled either with the potash feldspars when present, or with nepheline. So far as the texture of the rock is concerned, in the great majority of instances nepheline apparently plays the same part as quartz in an ordinary granite. Garnet, which is a very frequent and often abundant accessory constituent, is distinctly later than all of these constituents. Sodalite and cancrinite are also distinctly later, filling cracks and fissures.

On the other hand many grave exceptions to this general order of crystallization have been noticed, such as the inclusion of rounded individuals of nepheline and microcline in the plagioclase, and of plagioclase and nepheline in the hornblende. Again, albite is frequently found forming poikilitic intergrowths with hornblende, such included individuals of albite often having direct connexion and more or less distinct optical continuity with certain mantles or borders which sometimes surround the hornblende, separating individuals of this mineral from the other constituents of the rock. There is, moreover, undoubted evidence of very pronounced magmatic corrosion, due apparently to progressive changes in the physical constitution and composition of the magma.

The shells or mantles of muscovite which often enclose the individuals of corundum are distinctly and clearly attributable

EXPLANATION OF PLATE VII.

Nepheline syenite (× 55 diam.), lot 32, concession VI, Glamorgan township. The section shows two grains of calcite, one lying between the biotite and nepheline and the other (at the edge of the slide) enclosed in microcline. All the minerals are absolutely fresh and show no trace of decomposition products. (See pages 69, 111.)

Corundum enclosed in muscovite. From red alkali syenite just west of Blue mountain, Methuen township (×50 diam. between crossed nicols.) (See pages 107, 132.)

Nepheline Sy[illegible] diam Lot 32. Con VI
To[illegible] Glam[illegible]gan
Biotite, [illegible] and Nepheline

The section shows two [illegible] of Calcite, one [illegible] between [illegible] Biotite and Nepheline and the other [illegible] the edge of the slide [illegible] the Microcline. All the minerals are absolutely fresh and show [illegible] of decomposition products

[illegible]
From [illegible] east [illegible]
[illegible]

to the increased acidity and hydration of the magma in its later stages.

The nepheline syenites and the associated alkali syenites occur almost invariably on the borders of the granite batholiths where these cut through crystalline limestone. When the actual contact of the two rocks is well exposed, large individuals of nepheline, biotite, and other constituents of the syenite can be seen to have developed in the limestone all along the margin of the nepheline syenite body, while masses of the limestone, great and small, can be found scattered through the nepheline syenite along the contact (see Plate IX). These masses, furthermore, were evidently in process of replacement by the magma, the various constituents of the nepheline syenite growing into them (see Plate VII). They thus become gradually reduced in size, and now survive merely as separate, irregularly rounded grains of calcite often enclosed in single individuals of perfectly fresh nepheline, hornblende, or other minerals of the nepheline syenite, or lying between these, with the form of the latter impressed upon them on every side.

Every stage of the passage from the solid limestone to the separate calcite grains enclosed in the constituent minerals of the nepheline syenite can be distinctly traced, while the latter is at the same time fresh and free from decomposition products. The phenomenon is well seen in the railway cutting on the outskirts of the village of Bancroft. In some cases an additional proof of the derivation of the calcite from the adjacent limestone is afforded by the fact that the calcite grains enclosed in the nepheline syenite show the twisting and the strain shadows to be observed in the constituent individuals of the invaded limestone, while the minerais of the nepheline syenite which enclosed them are absolutely free from all signs of pressure. The calcite in the syenites is, therefore, undoubtedly foreign to the magma and represents inclusions of the surrounding limestones. In the case of the only important body of nepheline syenites which does not have limestone as a wall rock, namely the occurrence in the township of Methuen, calcite is very rarely found in the rock, and when it does occur, it is in very small amount, while the mode of its occurrence is entirely different from that above described and is such as to indicate that the mineral is probably secondary or a later infiltration.

The presence of calcite has been noted in other occurrences of nepheline syenite. These are like those of the area at present under discussion, associated with ancient metamorphic rocks, but the calcite in them is believed to be primary by the investigators who have studied them. The occurrences in question are the nepheline syenites of the Sivamalai series of India[1] and that of the Island of Alno[2] in Sweden. A similar association has been noted in the occurrences at Kussa in the Ural mountains[3] and in the nepheline rocks of the Kaiserstuhl in Baden[4].

Concerning the calcite in the Indian occurrences, Holland says: "The calcite occurs in granular crystals with apparently as much right as any of the others to be considered a primary constituent. The crystals form isolated granules, and there are no signs of secondary decomposition......the low silica percentage in this group of rock removes the chief theoretical difficulty to its crystallization from a molten magma as a normal constituent of an igneous rock." The Alno rock contains large masses of crystalline limestone as well as scattered granules of calcite and micropegmatite intergrowths of calcite with nepheline, ægerine, or feldspar, and Högbom believes that the limestone has been fused in the magma without decomposition and was, during the process of solidification, crystallized out of the magma in precisely the same way as the other minerals. In neither of these cases does limestone now occur in the immediate vicinity of the syenite, but it may, especially in the

[1]Holland T. H. The Sivamalai Series of Elaeolite Syenite and Corundum Syenites in the Coimbatore District, Madras Presidency—Mem. Geol. Survey of India, Vol. XXX, part 3, 1901, p. 197.

[2]Högbom, A. G. Ueber das Nephelinsyenitgebiet auf der Insel Alno. Geol. Foren i. Stockholm Förh. Bd. 17, Heft 2, 1895 s. 118. Also abstract in Min. Mag. Vol. XI (1897) p. 250, and Rosenbusch Mikr. Phys. (1896) pp. 169 and 171.

[3]Arzruni A. Die Mineralgruben bei Kussa and Miass—(in the Livret—Guide for the Ural Excursion of the International Congress of Geologists, St. Petersburg Meeting 1900.)

[4]Graeff—Zur. Geologie des Kaiserstuhlgebriges—Mitt. der Bad. Geol. Landesanst. Bd. II, 1892.

latter case, have sunk down into it from overlying beds, since removed by erosion.

This is also considered by Graeff to be the true explanation of the origin of the limestone inclusions in the Kaiserstuhl occurrence. Of the crystalline limestone associated with the Kussa nepheline syenite, Arzruni says that its "austreten unaufgeklart geblieben ist."

DETAILED STATEMENT.

(*a*) NEPHELINE SYENITE.

The term syenite usually applied to developments of these old crystallines in central Ontario is open to serious criticism, for orthoclase is very rarely if ever the predominant feldspar present. On the contrary, plagioclase, ranging in composition from albite to bytownite, is always more abundantly represented, often to the exclusion of the potash feldspars. This is especially true of the several varieties of the so-called nepheline syenite, as also in a less degree of its more immediate differentiate, the white or grey alkaline syenite or albite anorthosite, while in the usual types of the red syenite, orthoclase, microcline, and microperthite together often fail to equal in amount the soda feldspar present.

As a rule the ferromagnesian minerals are subordinate in amount and extended outcrops are made up largely of feldspar and nepheline. Quite frequently, however, certain folia or bands, as also large exposures, show a relative abundance of these dark coloured constituents. Biotite is the usual and often the only bisilicate mineral represented. Common hornblende, and sometimes the variety now known as hastingsite, often replaces and sometimes accompanies the dark mica. Pyroxene, sometimes acmite, is rarely present, but occasionally it replaces both the biotite and hornblende. The prevailing accessory minerals are scapolite, calcite, muscovite, garnet, pyrite, magnetite, apatite, zircon, sodalite, cancrinite, and corundum (see Plates XIV, XV). A detailed statement of the mode of occurrence of these minerals will be found in the section treating of the mineralogy.

The nepheline syenite is rarely of massive or granitoid type, usually possessing a pronounced foliated (see Plate VI) and occasionally schistose structure. It varies in texture from medium to coarsely granular, the coarser or pegmatitic phases sometimes exhibiting almost pure nepheline individuals a yard or more in diameter with correspondingly coarse plagioclase.

The nepheline is more susceptible to weathering processes than the plagioclase and, as a consequence, occupies well marked depressions or pits with smoothly rounded surfaces of a pale greyish colour. The plagioclase, on the contrary, stands out with prominent angular relief, usually of a chalk-white colour (see Plates VIII, IX). The nepheline is present in very variable quantity, in some extreme cases completely replacing the feldspar, while, at other times, only occasional individuals can be distinguished. Very frequently, owing to incipient decomposition, the nepheline has a pale pinkish and in more advanced cases a deep reddish colour. The following are analyses of these nepheline syenites found in the Haliburton-Bancroft district. (Memoir No. 6, Geol. Surv., Can., 1910.)

	A	B	C	D	E
SiO_2	59·68	51·58	44·00	43·67	42·72
TiO_2	none	0·35	0·75	0·78	0·38
Al_2O_3	23·48	19·40	23·31	20·91	25·08
Fe_2O_3	0·59	4·26	2·37	3·54	2·00
FeO	0·37	5·25	7·43	8·01	4·36
MnO	none	0·20	0·22	0·05	0·16
CaO	0·26	3·64	4·86	7·37	6·92
MgO	0·21	0·49	0·25	1·46	0·97
K_2O	4·68	4·23	3·09	2·25	2·69
Na_2O	9·52	7·49	10·65	6·73	11·02
P_2O_5	none	0·15	0·33	0·11	0·19
CO_2	0·04	1·53	0·98	2·37	2·99
H_2O	0·66	1·02	1·45	2·52	0·88
	99·49	99·59	100·06‡	99·77	100·36

‡With trace of BaO, 01·01 of SO_3, 0·08 of Cl, and 0·28 of FeS_2.

A. Nepheline syenite, lot 13-14, concession IX, Methuen township, Ontario. Analysis by N. N. Evans. Described by F. D. Adams. Contains in percentages orthoclase 16.12; albite 54.70; nepheline 18.18; muscovite 7.95; biotite 1.27; magnetite 0.93. (Miaskose.)

B. Nepheline syenite, lot 16, concession IX, Monmouth township, Ontario. Analysis by M. F. Connor. Described by F. D. Adams. Contains in percentages, orthoclase 4.45; albite 52.08; nepheline 8.05; biotite 29.61; iron ore 0.73; apatite 0.34; calcite 3.45. (Essexose.)

C. Nepheline syenite, lot 32, concession III, Glamorgan township, Ontario. Analysis by M. F. Connor. Described by F. D. Adams. Contains nepheline, hornblende (hastingsite), some albite and calcite. (Lujavrose.)

D. Nepheline syenite, lot 11, concession VIII, Monmouth township, Ontario. Analysis by N. N. Evans. Described by F. D. Adams. Contains in percentages, orthoclase 2.78; albite 23.94; nepheline and kaolin 26.23; hornblende 39.75; apatite 0.34; calcite 5.50. (Essexose.)

E. Nepheline syenite, lot 11, concession VIII, Monmouth township, Ontario. Analysis by N. N. Evans. Described by F. D. Adams. Contains in percentages, albite 19.39; nepheline 50.57; pyroxene 18.35; garnet 1.45; iron ore 1.86; apatite 0.34; calcite 6.80. (Vulturose.)

(*b*) MONMOUTHITE, CRAIGMONTITE, AND CONGRESSITE.

The nepheline syenites exhibit great variations in the relative proportion of their constituent minerals, at one extreme passing by a decrease in the amount of feldspar into rocks composed almost wholly of nepheline. Several varieties of these nepheline-rich rocks have been described to which the names monmouthite, craigmontite, and congressite have been applied. These rocks are allied to urtite but contain a relatively small amount of ferromagnesian minerals. The following are analyses:—

	A	B	C	D
SiO_2	39·74	45·28	48·38	41·53
TiO_2	0·13	.....	Trace	0·22
Al_2O_3	30·59	27·37	30·54	30·36
Fe_2O_3	0·44	3·53	0·40	2·46
FeO	2·19	0·49	0·06	1·64
MnO	0·03	0·19	Trace	0·03
CaO	5·75	5·47	1·87	0·88
MgO	0·60	0·33	0·19	0·37
K_2O	3·88	3·51	3·70	5·15
Na_2O	13·25	17·29	13·94	14·30
P_2O_5	(A)	.....	Trace	0·07
CO_2	2·17	.....	0·62	0·80
H_2O	1·00	0·40	0·50	1·01
	99·86 (x)	99 61	100·20 (x)	99·55 (x)

(A) SO_3 trace, ClO ·02, SO.07. (x) New type.

A. Nepheline rock (monmouthite), lot 10, concession VIII, Monmouth township, Ontario. Analysis by M. F. Connor. Described by F. D. Adams. Contains in percentages, albite 1.83; nepheline 72.20; sodalite 0.28; cancrinite 5.14; hornblende (hastingsite) 15.09; hematite 0.50; calcite 3.12; pyrite 0.14; excess of alumina = corundum ? 1.20. (Monmouthose.)

B. Nepheline rock (urtite), Kola peninsula, Finland. Analysis by N. Sahlbom; described by W. Ramsay.[1] Contains in percentages, nepheline 85.7; pyroxene mostly ægirite 12.0; apatite 2.0. (Urtose.)

C. Nepheline rock (craigmontite), "The Klondyke," Craigmont, Ontario. Analysis by M. F. Connor. Described by A. E. Barlow. Contains in percentages, oligoclase 29.66; nepheline 63.18; muscovite 4.39: calcite 1.42; corundum 0.50; biotite 0.50; magnetite 0.10. (Craigmontose.)

D. Nepheline rock (congressite), "The Klondyke," Craigmont, Ontario. Analysis by M. F. Connor. Described by F. D. Adams. Contains nepheline about 75 per cent; plagioclase about

[1] Geol. Fören. Förhandl., Vol. XVIII, 1896, p. 463.

Explanation of Plate VIII.

Monmouthite, lot 11, concession VIII, Monmouth township. Nepheline with subordinate albite (white) and hastingsite (black). $\times \frac{1}{2}$. (See pages 64, 72, 75, 92.)

Monmouthite. Township of Monmouth, Lot 11, Concession VII.
Nepheline with subordinate Albite (white) and Hastingsite (black).

5 per cent; sodalite 2.22; muscovite 6.55; biotite 3.36; apatite 0.34; magnetite (titaniferous) 4.17; pyrite 0.36; calcite 1.80.

The exposures which are representative of monmouthite occur on lot 10, concession VIII of Monmouth, but extended outcrops of very closely related rock types occur elsewhere throughout the district and especially in the vicinity of the York river (see Plate VIII). This rock is, as a rule, coarse in grain and with a rude though distinct foliation. At the type locality it occurs in bands 6 or more feet in width. On the weathered surface there is a marked contrast between the nepheline with its smoothed, depressed grey surface and the accessory chalk white albite and black hornblende which stand out in sharp relief. Monmouthite is made up very largely, at least, by nepheline and hornblende of a variety allied to hastingsite. Albite, cancrinite, and calcite are the principal accessory constituents, while sodalite, apatite, sphene, biotite, pyrite, and magnetite are often present although always in very small quantities.

Congressite is the product of differentiation at Craigmont in which nepheline is most abundant. It is closely allied to craigmontite but contains more nepheline, biotite, and magnetite and much less plagioclase. Owing to the relative abundance of biotite and magnetite, it is darker in colour than craigmontite. It has a pale salmon pink colour, owing to the predominant nepheline which has undergone incipient decomposition. The parallel segregation of the biotite and magnetite, and even the white plagioclase in narrow streaks and bands, give the rock a faint though decided foliation.

Craigmontite is another nepheline-rich rock which occurs at the same locality. It is often interfoliated with congressite, raglanite (nepheline-oligoclase-anorthosite), and plumasite (oligoclase-anorthosite). It differs from congressite mainly by reason of the almost total absence of biotite and the relatively greater abundance of oligoclase. Craigmontite is a very beautiful pale pinkish rock, due to the prevalence of the slightly decomposed nepheline, with streaks and patches of white oligoclase. Under the microscope it is made up almost wholly of nepheline and oligoclase with a very little muscovite, a smaller amount of calcite, and a still less quantity of biotite, corundum, and magnetite. It was selected as representative of a nepheline-rich rock which was apparently saturated with alumina. Craigmontite, congressite, raglanite, and plumasite are intimate associates, usually interfoliated with one another in the same rock mass at "The Klondyke" openings for corundum near the west end of Robillard mountain at Craigmont. Plumasite and raglanite are essentially the corundum bearing types or "ore" at this place. Corundum occurs sparingly in craigmontite but seldom, if ever, in the congressite. In craigmontite (see Plate XIII) the corundum crystals are more plentiful in those bands which are richer in oligoclase, and very often embedded in the nepheline the corundum individuals have a mantle or corona of oligoclase or muscovite surrounding them. Sodalite of a beautiful pale bluish colour is abundant in the nepheline as irregular streaks and patches in both congressite and craigmontite.

(*c*) NEPHELINE-SYENITE-PEGMATITE.

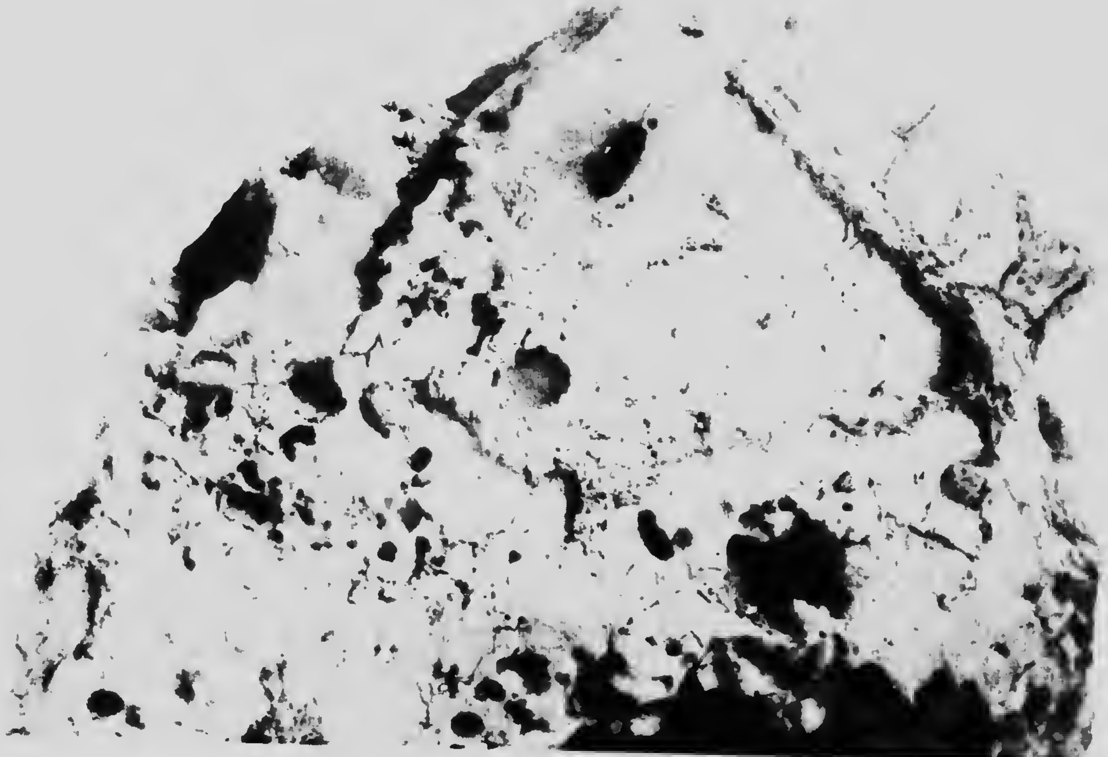
This abnormally coarse representative of the nepheline rocks of the preceding groups, occurs in the form of dykes, either as interfoliated masses (see Plate X) or intersecting the foliation at various angles. Perhaps the most coarsely crystalline type is that exposed by blasting on lot 30, concession IV, of the township of Glamorgan. The rock consists essentially of nepheline and albite with occasional individuals or small masses of calcite (see Plate IX). Biotite is present in very small amounts and over large surfaces is absent. A black hornblende and pyrrhotite are very sparingly represented. Some of the individuals of nepheline are over a yard in diameter. Small irregular masses of blue sodalite are present in the nepheline.

(*d*) ANORTHOSITE.

In most of the reports and descriptions previously issued it has been usual to refer to the more acid varieties of these rocks as the white or grey alkali syenite.

Explanation of Plate IX.

Nepheline syenite pegmatite, lot 30, concession IV, Glamorgan township. Nepheline and albite (standing out on weathered surface). The cavities in the surface of the nepheline are caused by inclusions of calcite which have weathered out, × ⅔. (See pages 69, 72, 76, 92.)



Nepheline Syenite Pegmatite. Township of Glamorgan, Lot 30, Concession IV.
Nephelite with Albite (standing out on weathered surface). The cavities in the surface of the Nepheline are caused by inclusions of calcite which have weathered out. x $^{2}/_{3}$

EXPLANATION OF PLATE X.

Dyke of nepheline-syenite-pegmatite cutting nepheline syenite parallel to the foliation. Lot 25, concession XIV, Dungannon township. (See pages 65, 76.)

Dike of Nepheline-Syenite-Pegmatite cutting Nepheline Syenite parallel to the foliation.
Lot 25, Con. XIV., Dungannon township

The rock consists essentially of plagioclase and passes on one hand into the nepheline syenite of the ordinary type, and on the other hand into the reddish variety of alkali syenite. It may, therefore, be regarded as a rock of intermediate type marking a transition between the two, although rather more closely related to the former. The constituent minerals are for the most part identical with those present in the nepheline syenite. Sodalite and cancrinite are absent. The plagioclase present varies somewhat in different occurrences, albite, oligoclase, andesine, and bytownite having been found. As in the case of the nepheline syenite, separate occurrences of the rock seem to be characterized by the pressure of one variety of plagioclase to the almost complete exclusion of another. Plagioclase often makes up from 75 to 95 per cent of the whole rock, the other constituents being biotite, hornblende, muscovite, calcite, magnetite, and occasionally corundum, scapolite, and nepheline. Some extreme phases of this rock are made up almost entirely of plagioclase with little or no ferromagnesian minerals. When such rocks contain an excess of alumina which has crystallized out as corundum, they are very closely related to, and sometimes identical with, the rock plumasite described by Lawson.[1]

All the albite anorthosites which have been described from this region contain an appreciable quantity of the potash feldspars as well as nepheline and are, therefore, included as nepheline syenites. The following are analyses of the anorthosites chosen as representatives of the several types. For purposes of comparison analyses of "plumasite" and "kyschtymite" are included.

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[1]Bull. Geol. Dept. of the University of California, Vol. III, No. 8, pp. 219-229.

	A	B	C	D	E	F	G	H	I
Corundum	4·45	16·00	13·24						
Corundum and spinel.					47·51		59·51		
SiO_2.......	55·45	51·80	49·56	47·32	22·52	43·17	16·80	41·49	42·33
TiO_2.......	0·30	.....	.....	.....	.....	.....	.....	.....	.....
Al_2O_3......	21·65	19·39	30·46	30·36	16·31	31·26	13·89	34·31	32·78
Fe_2O_3.....	0·81	.....	0·93	1·35	2·20	4·21	0·76	1·88	3·05
FeO.......	0·49	.....	1·42	1·55	.....	.....	.....	.....	.....
MnO......	0·01	.....	.....	.....	.....	.....	.....	.....	.....
CaO......	3·65	4·54	5·89	15·45	6·64	12·73	7·26	17·68	15·20
MgO......	0·13	.....	0·97	2·44	1·34	2·57	0·61	1·51	2·04
K_2O.......	1·62	.....	1·23	0·66	0·58	1·11	0·13	0·32	0·72
Na_2O......	9·31	6·82	4·95	1·88	1·00	1·92	0·38	0·94	1·43
P_2O_5......	0·01	.....	.....	.....	.....	.....	.....	.....	.....
CO_2.......	0·88	.....	0·17	0·58	.....	.....	.....	.....	.....
H_2O.......	1·64	1·45	0·84	0·10	1·58	3·03	0·76	1·87	2·45
	100·40	100·00	99·66	101·69	99·68	100·00	100·10	100·00	100·00

A. Oligoclase-nepheline-anorthosite (raglanite), "The Klondyke", Craigmont, Ontario. Analysis by M. F. Connor. Described by A. E. Barlow. Contains in percentages, oligoclase 69.10; nepheline 12.00; corundum (by trial) 4.45 with subordinate amounts of calcite, muscovite, biotite, magnetite, and apatite. (Raglanose.)

B. Oligoclase - corundum - anorthosite (plumasite), Spanish Peak, Plumas county, California, U.S.A. Analysis by J. Newfield. Described by A. C. Lawson. Contains in percentages, oligoclase 84; corundum 16.

C. Andesine-anorthosite (dungannonite), lot 12, concession XIV, Dungannon township, Ontario. Analysis by N. N. Evans. Described by A. E. Barlow. It contains in percentages, andesine (Ab_3An_2) 72.00; nepheline 3.00; scapolite 2.00; corundum (by trial) 13.24; biotite 5.00; muscovite 3.00; magnetite 1.39; calcite 0.37. (Dungannonose.)

D. Bytownite-anorthosite. South Sherbrooke township, Ontario. Analysis by William Lawson. Described by W. G. Miller (Am. Geol. Vol. XXIV, Nov. 1899, pp. 276-282).

Consists largely of bytownite (Ab_1An_4) together with some common green hornblende (pargasite) and a little corundum?

E, F, G, H, I. Corundum-anorthite-anorthosite. Kyschtym (on the river Borsawka), Russia. Analysis by J. Morozewicz. Described by J. Morozewicz. The chief constituents of the rock are corundum and anorthite with some spinel and biotite. Apatite and zircon are accessory constituents, while secondary minerals are muscovite, chlorite, kaolin, and chromic iron ore.

E. Contains between 51 and 52 per cent of corundum and spinel, about 38 per cent of anorthite (Ab_1An_6), and 10 per cent of biotite and other minor constituents. There is between 3 and 4 per cent of spinel present Deducting the corundum from E and recalculating to a basis of 100, the result under F is obtained.

G. This is an analysis of a similar type of rock from the same locality containing more spinel and less biotite. The anorthite is more basic in composition, corresponding very closely with that represented by the symbol An. The composition of the rock shows from 40-50 per cent of corundum with spinel; anorthite (An) 36-38 per cent; biotite and other constituents 4-10 per cent. Leaving out of consideration the corundum and spinel under G and recalculating to a basis of 100, the result under H is obtained.

I. Under this heading is furnished the mean of the two analyses omitting the corundum and spinel. This would, doubtless, represent very closely the mean composition of the rock mass at this place with which the corundum is associated.

The rock, raglanite, which derives its name from the township in which it was first found, is a white or grey corundiferous nepheline anorthosite or nepheline plumasite. The type specimens were collected in the corundum quarries ("The Klondyke") near the west end of Robillard mountain at Craigmont. It also occurs near the farther end of the tunnel. It occurs in masses and bands often interfoliated with craigmontite, congressite, and plumasite and is one of the "ores" of corundum at this locality. The mode or actual mineralogical composition of the rock is somewhat different from the norm as calculated from the analysis, the difference relating . y to the grouping of the feldspar molecules and the modal presence of micas. It is composed of nearly 70 per cent of oligoclase, 12 per cent of nepheline, and 4.45 per cent of corundum, with small amounts of muscovite, biotite, calcite (1.98), titaniferous magnetite (1.31), and apatite.

Another type of anorthosite has recently been recognized in some of the less important quarries near the centre of the hill at Craigmont. It is a coarsely granular rock of greyish or greenish grey colour. It is composed essentially and almost wholly of a plagioclase feldspar, having a composition intermediate between oligoclase and andesine. It also contains a variable quantity of deep pink garnet, magnetite, and corundum. The microscope reveals the presence of subordinate amounts of muscovite, biotite, scapolite, and a dark green spinel (gahnite). A closely related rock, of pale greenish colour and granular texture, is made up almost exclusively of scapolite whose specific gravity (2.67) shows that it is of intermediate composition in the scapolite group. It occurs as various folia or bands with the ordinary corundum syenite and also in wider bands or masses, together with titaniferous magnetite.

Dungannonite is the name proposed for ` corundiferous andesine-anorthosite with accessory nepheline which occurs on the east side of the York river in the townships of Dungannon (lot 12, concessio V) and Monteagle (lot 2, concession II). At both these localities considerable mining development work has been accomplished.

The typical dungannonite contains nepheline only in small amount and as an accessory constituent. Associated with it in the same series of exposures, however, there are differentiation phases of the magma which are rich in nepheline, the nepheline syenite thus resulting having as its essential constituents nepheline, plagioclase, and biotite. This rock in places contains dark basic patches which are rich in hornblende, as well as others of a yellowish colour which contain an abundance of scapolite. The whole series has a well-defined foliation striking N. 25° E.

The dungannonite under the microscope is seen to be made up largely of plagioclase having the composition of andesine.

Next to this feldspar, corundum is the most important mineral constituent. Scapolite is also present, usually in subordinate amount, the larger individuals occupying the interspaces between the feldspars. Biotite is present in small amount, while muscovite occurs both intergrown with the biotite and as mantles of variable width surrounding the corundum individuals. This muscovite is regarded as a primary constituent formed at a time immediately preceding the complete solidification of the magma. Occasional grains or imperfect crystals of magnetite, with a small amount of calcite, complete the list of minerals found in the thin sections of this rock. The corundum is often very abundant. Some of the individuals show a nearly perfect crystallographic development, but the mineral as a general rule occurs as imperfect crystals or as irregular grains. It frequently shows very distinctly the parting planes parallel to the faces of the rhombohedron and the base. The colour varies even within the same individuals; the mineral has usually a distinct and often pronounced sapphire blue colour, but the corundum is sometimes white or brown in colour. The individuals of corundum frequently have a distinct corona of muscovite surrounding them, although this is not invariably present. The corundum is by no means uniformly distributed through the rock. A large portion of the rock is completely free from this mineral, while other areas, rather ill-defined in shape, contain a very high percentage of it. In outcrops exposed to the weather the corundum becomes very conspicuous, weathering out as it does in pronounced relief from the surface of the rock. In some places characteristic barrel-shaped hexagonal crystals, several inches in length, may be seen on these weathered surfaces. In the freshly broken rock, on the other hand, the corundum is detected only with difficulty, unless it assumes the usual bluish colour which enables it to be readily distinguished from the other constituent minerals of the rock.

In the exposures these rocks are seen to be cut through in various directions by dykes of fresh red pegmatite composed chiefly of red feldspar (orthoclase), microperthite, and quartz, with a little hornblende. In some places imperfect crystals of this last-named mineral can be found which measure from 4 to 6 inches in diameter. These dykes are evidently differentiation forms of a red syenite, which occurs in considerable volume immediately to the south of these exposures, and which is a somewhat quartzose type of the normal red variety of alkali syenite (umptekite).

Bytownite-anorthosite is the prevalent and characteristic rock of the Lanark-Frontenac Corundum Belt, although at the southwest end this rock is replaced by the corundum-pegmatite. On weathered surfaces the rock is grey or at times somewhat purplish in colour and varies in texture from medium to coarsely granular. The microscope shows that the most abundant constituent is bytownite which, on analysis, is agreeable in composition with that represented by the formula Ab_1An_4. Black hornblende, which is of a deep green colour in transmitted light, and sometimes corundum, accompany the basic plagioclase. The largest crystals observed in the rock have a length of about 1.25 inches but are thick and tubular in habit. The majority of the crystals have a diameter of about half an inch and are strikingly uniform in size, there being scarcely any of the mineral in small grains. The colour of the corundum is white or light grey, sometimes light pink or flesh coloured. It is distributed across the whole breadth of the bands of anorthosite and the richer portions average probably about 5 per cent. The crystals stand well out on the weathered surface of the rock and are often attached to it by a very small part of their under surface. The following are analyses:—

	A	B	C	D	E	F	G	H
SiO_2	46·24	46·54	47·32	47·40	48·12	48·03	41·40	39·58
TiO_2	......	......	......	......	......	......	......	Tr.
Al_2O_3	29·85	30·73	30·36	30·45	34·54	33·43	15·39	14·91
Fe_2O_3	1·30	3·23	1·35	0·80	0·36	......	7·01	4·01
FeO	2·12	1·18	1·55	......	......	......	7·17	10·67
MnO	Tr.	......	......	......	......	......	Tr.	Tr.
CaO	16·24	15·45	15·45	14·24	16·30	16·28	12·53	11·76
MgO	2·41	1·35	2·44	0·87	Tr.	......	10·31	13·06
K_2O	0·18	0·52	0·66	0·38	0·15	......	1·56	0·62
Na_2O	1·98	1·36	1·88	2·82	1·91	2·26	3·58	2·87
CO_2	1·03	......	0·58	......	......	......	......	......
H_2O	......	0·04	0·10	2·00	none	......	0·81	2·79
	101·35	100·40	101·69	98·96	101·38	100·00	99·76	100·27

A. Anorthite-anorthosite. Seine river, western Ontario. Analysis by William Lawson. Described by A. P. Coleman. Contains about 90 per cent anorthite with small quantities of chlorite, zoisite, epidote, and calcite.[1]

B. Anorthite-hornblende rock from Konschekowskoi Kamen, Urals, Russia. Analysis quoted by Zirkel. Contains in percentages anorthite 90; hornblende 10.

C. Bytownite-anorthosite. South Sherbrooke, Ontario. Analysis by William Lawson. Described by W. G. Miller (Am. Geol. Vol. XXIV, Nov. 1899). Composed principally of bytownite (Ab_1An_4) with some dark green common hornblende and a very little corundum?

D. Bytownite-ano[illegible]te, from near Ottawa (formerly Bytown). Analy[illegible]d description by T. Sterry Hunt.[2] A greenish white granular variety of anorthosite from a boulder near Ottawa, having a density of 2.73. This is a portion of the specimen upon which Dr. Thomson founded the feldspar species named by him "bytownite".[3]

E. Bytownite from the anorthosite. South Sherbrooke, Ontario. Analysis by William Lawson. Described by W. G. Miller (Ann. Rep. Bur. of Mines, Ont. Vol. VII, 1899, p. 227). The bytownite has the composition represented by Ab_1An_4. A careful comparison with the analysis F, which is the theoretical composition of bytownite, shows a close agreement in the silica, lime, and alkalis. The proportion of alumina is, however, over one per cent higher than that of the theoretical percentage. This may be due to the presence of a small amount of corundum embedded in the feldspar in a very fine state of division. The microscope shows the feldspar to contain numerous crystallite-like inclusions. Some of these may be corundum.

F. Bytownite, Ab_1An_4, theoretical percentage given by Zirkel.

G. Hornblende from the anorthosite. South Sherbrooke, Ont. Analysis by William Lawson. Described by W. G.

[1]Ann. Rep. Bur. of Mines, Ont., 1895, p. 100.

[2]Geol. of Canada, 1863, p. 479.

[3]Min. 1. 372, 1836. Ottawa before being named as the seat of government was called "Bytown."

Miller. It is a typical variety of what is called common hornblende.

H. Hornblende from hornblende-gabbro, quoted by Rosenbusch.

(*e*) RED ALKALI SYENITE (UMPTEKITE).

Associated with the anorthosites as well as with the nepheline rocks, and passing into these sometimes by an abrupt though usually by a gradual transition, are certain highly feldspathic rocks, often occurring as very extensive independent masses which are distinguished in the field mainly by their reddish colour and the marked scarcity or entire absence of quartz. They differ from the anorthosites in that orthoclase, microcline, and microperthite are quite abundant. Plagioclase, usually at least albite, is also very plentiful, sometimes equalling in amount if not exceeding the potash feldspars. A comparatively large area representative of this variety of syenite occurs intimately associated with the nepheline syenite near the York river and is referred to in the first published descriptions as "a reddish biotite granite resembling aplite in appearance."[1] This rock is exposed on both sides of the York river, extending from concessions XI to XV. Nepheline syenite occurs on both sides of this batholith, and if the outcrops of this rock sould be traced and found continuous would doubtless form an association closely analogous to that described by Dr. Adams as occurring in the township of Monmouth. The rock is essentially a quartz mica syenite made up almost wholly of orthoclase, microcline, albite, quartz, biotite, and in places hornblende. The biotite is in very small and exceedingly irregular or ragged scales, with strongly marked pleochroism and absorption. This brownish biotite has a distinct greenish tinge. The various cracks and fissures are filled with reddish brown iron oxide, which also stains the orthoclase and microcline.

Sometimes the ferromagnesian constituents are absent and the rock is made up wholly of feldspar. It is then often referred to as "feldspar rock." Often magnetite seems to re-

[1] Am. Jour. Sc. Vol. XLVIII, 1894, p. 11.

place the dark coloured constituents and a rock composed of feldspar and magnetite results.

The rock is younger than the nepheline syenite which it sometimes intersects, and decidedly later than the surrounding crystalline limestone. Its intimate association with the nepheline rocks, however, strongly suggests that both are the products of the differentiation of a single magma.

A similar type of rock prevails along the southern slope of the hill at Craigmont in Raglan township. This reddish or pinkish rock frequently contains bands of a dark coloured, highly micaceous or hornblendic rock which may represent deformed and altered dykes of basic composition. In places masses and patches of almost pure hornblende occur.

Another important occurrence of this red syenite is in the township of Monmouth where in association with the nepheline syenite it extends in a direction about N. 30° E. from concession VII to concession XIV, a distance of about 6 miles. The nepheline syenite forms a border to this mass varying from an eighth to half a mile in width. It is of varying shades of red, usually pale red or pink, this tint becoming lighter on exposure. In places it has a distinctly foliated structure. Quartz is never abundant, although toward the northeast it is present in considerable amount. The rock is composed (lot 26, concession XII, Monmouth) of albite, microcline, orthoclase, microperthite, quartz, hornblende, biotite, sphene, apatite, and magnetite. Albite and microperthite together are double the amount of orthoclase and microcline. Quartz is about equal in amount to the potash feldspar. The dark coloured constituents have a frayed or irregular outline. Two varieties of hornblende are present, one green and the other blue in colour. Biotite is only sparingly represented. The syenitic phase differs from the granitic type in that no quartz is noticeable in thin section and also in the absence of hornblende. The feldspar is for the most part microperthite. It contains a little biotite, muscovite, and calcite. This syenitic type passes imperceptibly into the nepheline syenite by the disappearance of the quartz with the concomitant increase of albite at the expense of the potash feldspars.

This transition is very well illustrated by the exposures on lot 26, concession XII, of Monmouth, the intermediate phase having a faint reddish tinge with a little nepheline and occasional small crystals of corundum. Magnetite in rather large grains is disseminated through the rock. It has a distinct foliation due to the approximately parallel alignment of the abundant biotite. Examined with the microscope it consists of albite, orthoclase, microcline, and a little microperthite with nepheline, biotite, calcite, magnetite, and apatite. The albite in comparison with the potash feldspars is present in the proportion of about 18:1.

The reddish syenite in the township of Methuen has also a pale reddish or pinkish colour and is rather fine and even in grain. The iron-magnesia constituents, which are very subordinate in amount, occur in the form of very small dash-like streaks, their parallel disposition marking the foliation of the rock. It is chiefly confined to the sides of the Blue Mountain massif, although not continuously developed about it. The rock first appears as streaks in the white nepheline syenite (albite-nepheline-anorthosite) and is traversed by the pegmatitic veins or dykes which have been worked for corundum. Farther west the red syenite replaces the paler coloured rock. Under the microscope the red syenite is composed essentially of albite and nepheline. The twinning of the microcline is very fine and some untwinned grains are apparently orthoclase. The other minerals are biotite, magnetite, pyrite, calcite, and quartz. These occur usually in close proximity to one another and form the dash-like streaks to which allusion has already been made. Magnetite often has a rude crystalline outli... All of these minerals occur in small quantity. The quartz and also the calcite are not present in all the thin sections examined. They are rather intimately associated in the form of rather large irregular grains. The rock has the "mosaic" or "pavement" structure so characteristic of metamorphic rocks.

The reddish colour is apparently due to very minute reddish inclusions which occur in both feldspars, while even the nepheline is decomposed to a reddish gieseckite-like aggregate.

These red syenites, together with their pegmatitic equivalents, are pre-eminently the corundum bearing rocks throughout the district. The analyses undertaken were of material selected so far as possible free from corundum. They are, therefore, representative of the rock which has resulted from the crystallization of the alumina saturated magma.

The following are the analyses of the red syenite:—

	A	B	C	D	E	F
Corundum..					18·55	
SiO_2........	..65·89	64·15	58·44	56·05	52·34	64·65
TiO_2........	none	....	....	0·47	....	....
Al_2O_3.......	19·73	19·04	20·79	17·02	16·05	19·83
Fe_2O_3.......	2·03	1·02	0·58	9·10	0·45	0·56
FeO........	0·75	0·93	3·85	4·20	....	....
MnO.......	Trace	0·16	....	0·08	....	....
CaO........	0·46	1·37	2·24	0·72	0·20	0·25
MgO.......	0·27	0·37	0·43	0·12	0·16	0·19
K_2O........	3·95	7·10	9·83	5·12	6·58	8·14
Na_2O.......	6·59	5·37	2·85	6·10	4·77	5·89
P_2O_5........	none	0·10	....	0·04	....	....
CO_2........	0·44	0·70	....	....	....	....
H_2O........	0·34	0·27	1·36	0·36	0·40	0·49
	100·45	100·38	100·37	99·38	99·50	100·00

A. Red alkali-syenite. Methuen township, Ontario. Analysis by N. Norton Evans. Described by Frank D. Adams. Contains in percentages, albite 57.76; orthoclase 23.35; quartz 11.22; corundum 3.77; magnetite 2.32; biotite 0.70; pyrite 0.48. (Miaskose.)

B. Red alkali-syenite. Monmouth township, Ontario. Analysis by N. Norton Evans. Described by Frank D. Adams. Contains in percentages, albite 47.26; orthoclase 37.25; quartz 4.20; muscovite 4.78; biotite 3.93; magnetite 1.39; calcite 1.60; apatite 0.27. (Phlegrose.)

C. Corundum syenite. Tenna Hena, near Kandy, Ceylon. Analysis and description by A. K. Coomára Swamy. Contains in percentages, orthoclase 64.2; oligoclase 23.5; biotite 4.7; corundum and other heavy minerals (chiefly garnet, spinel, and zircon) 7.6.

D. Red alkali-syenite. Craigmont, Ontario. Analysis by M. F. Connor. Described by A. E. Barlow. Contains in percentages, albite 54.97; orthoclase 30.02; titaniferous magnetite 13.21; corundum 0.20; with a little biotite and still less apatite.

E. Corundum syenite. Nikolskaja Ssopka, Urals, Russia. Analysis and description by J. Morozewicz. Contains mainly microperthite and corundum (18.55 per cent), together with a very little biotite.

F. Omitting the corundum and recalculating the analysis under E to a basis of 100. This is the crystalline representative of the magma saturated with alumina.

CORUNDUM PEGMATITE.

Corundum pegmatite (see Plates XVI, XVII, XVIII, XIX) is the rock which contains the largest and most abundant crystals and masses of corundum and thus is the richest "ore" which has been quarried or mined at Craigmont. This rock occurs in the form of dykes, which sometimes attain a width of 18 feet. Sometimes these dykes cut across the banding or foliation of the series, but usually run parallel with these structures. There is often a distinct and perfect gradation between this coarse-grained phase and the normal type of syenite, which also contains corundum, although in less abundance and in smaller individuals. The rock is made up almost entirely of a deep, flesh-red to very pale salmon pink feldspar, which in thin section under the microscope is seen to be an irregular intergrowth of orthoclase and albite, the latter, as indicated by the analysis, being the more abundant. Associated with this microperthite as accessory constituents, locally and usually in small amount, are biotite, muscovite, scapolite, calcite, magnetite, hematite (micaceous iron ore), molybdenite, pyrite, pyrrhotite, chalcopyrite, chrysoberyl, spinel, and quartz. Although quartz and corundum are commonly supposed to be mutually exclusive, specimens have been found containing these two minerals in small amount.

This syenite pegmatite is representative of the final stages in the crystallization of this highly aluminous magma.

The following are analyses of corundum pegmatites and the accompanying microperthite:—

	A	B	C	D	E	F
Corundum	34·62	35·40	....	....	....	....
SiO_2	40·53	40·06	62·30	62·71	63·43	63·26
Al_2O_3	13·62	13·65	20·93	21·37	20·78	21·87
Fe_2O_3	0·19	0·35	0·29	0·55	0·29	0·22
FeO	0·04	....	0·06	....	....	....
CaO	0·67	0·30	1·02	0·47	1·00	0·21
MgO	....	0·15	....	0·23	0·07	....
K_2O	5·92	5·20	9·10	8·14	8·00	3·09
Na_2O	3·40	3·71	5·23	5·81	5·20	10·25
H_2O	1·01	0·46	1·07	0·72	1·00	0·78
	100·00	99·28	100·00	100·00	99·79	99·68

A. Corundum-pegmatite. Craigmont, Ontario. Analysis by M. F. Connor. Description by A. E. Barlow. Made up almost altogether of microperthite and corundum. (Uralose.)

B. Corundum-pegmatite. Nikolsaja Ssopkka, Urals, Russia. Analysis and description by J. Morozewicz. Composed chiefly of microperthite and corundum. (Uralose.) (Tschermak's Min. und Petr. Mittheil. XVIII, 1898, p. 219).

C. Analysis A, neglecting the corundum and recalculating to a basis of 100.

D. Analysis B, omitting the corundum and recalculating to a basis of 100.

E. Microperthite of corundum pegmatite, Craigmont, Ontario. Analysis by M. F. Connor.

F. Microperthite of corundum pegmatite from Sivamalai, India. (Mem. Geol. Surv. Ind., Vol. XXX, Part 3, 1901, p. 202).

An examination of these analyses will show at a glance the remarkable similarity in chemical composition of these corundum-bearing rocks, occurring at such widely separated localities as Canada and Russia. The specimens of the Canadian and Russian occurrences are practically identical. No analysis of the corundum syenite from India is available. The analysis of the feldspar from the Indian rock is very closely analogous in composition to that of the other syenites free from corundum, the only substantial difference being in the relative amounts of soda and potash present. Taking into consideration the molecular values of soda and potash, the ratio of the soda to the potash in the Indian feldspar is 5 : 1, while in the Canadian and Russian occurrences the soda is only slightly in excess, and in the separated feldspar is practically the same.

EXPLANATION OF PLATE XI.

Crystals of nepheline and albite from miarolitic cavity in nepheline syenite, lot 25, concession XIV, Dungannon township. Block measures 26 inches in length. (See pages 91, 97.)

Crystals of Nepheline and Albite from Miarolitic cavity in Nepheline Syenite. Lot 25, Con. XIV, Dungannon township.
(Block measures 26 inches in length.)

CHAPTER VII.

MINERALOGY OF THE SYENITES AND ANORTHOSITES.

The following minerals have been found in the nepheline and associated alkali syenites and anorthosites:—

Nepheline	Quartz	Eucolite
Sodalite	Corundum	Eudialyte
Cancrinite	Calcite	Molybdenite
Feldspar	Garnet	Apatite
Scapolite	Zircon	Magnetite
Biotite	Sphene	Pyrite
Hornblende	Tourmaline	Pyrrhotite
Hastingsite	Fluorite	Chalcopyrite
Pyroxene	Spinel	Graphite
Muscovite	Chrysoberyl	

NEPHELINE.

As a rule the mineral (see Plate XI) is quite fresh and glassy, breaking with a sub-conchoidal or uneven fracture. The freshly broken fragments are often distinguishable with difficulty from the plagioclase. It varies from almost colourless to white or very pale grey. Often it possesses a beautiful pale salmon pink colour, which on inspection is seen to accompany an incipient decomposition of the mineral. A progressive increase in this alteration is characterized by a gradual deepening of the tint until a bright brick red colour is assumed, representing the extreme stages in the decomposition and hydration of this mineral. The resultant products in the primary stage are chiefly minute scales of muscovite, with very brilliant double refraction, the process extending from certain cracks, and from the margin of the individual or forming "halos" around certain inclusions.

Some of the individuals are more or less turbid and opaque as a result of decomposition. In the more highly coloured phases of the mineral an aggregate resembling gieseckite in composition and appearance is produced, giving rise to very brilliant aggregate polarization.

It is usually comparatively free from inclusions, although sometimes hornblende, biotite, calcite, and even feldspars occur enclosed. The hardness of the nepheline occurring at York river according to Dr. Harrington[1] is nearly 6. The specific gravity at 17° C. = 2.625 as determined with the bottle and 2.618 by suspension with a hair. Before the blowpipe it fused quietly at about 3.5 to a colourless slightly vesicular glass. An analysis of this nepheline by Dr. Harrington gave the following results (under I). For comparison an analysis of the yellow variety of nepheline of Coimbatore, Madras, India, is given under II.[2]

	I	II
SiO_2	43·51	43·35
Al_2O_3	33·78	34·32
Fe_2O_3	0·15	1·02
CaO	0·16	0·82
MgO	tr.	.....
K_2O	5·40	5·52
Na_2O	16·94	14·62
Loss on ignition	0·40	0·75
	100·34	100·40

The appearance of the nepheline on the weathered outcrops of the nepheline syenite is noteworthy (see Plates VIII, IX). When surfaces of the rock, which have been exposed to the action of the atmosphere, are examined, each grain or individual of nepheline will be found to be represented by a depression. At

[1]Amer. Jour. Sc. Vol. XLVIII (1894) p. 17.
[2]Mem. Geol. Surv. Ind., Vol. XXX. Part III, 1901, p. 187.

the bottom of this the nepheline grain can be seen with a smooth rounded surface, as if it had been partially dissolved away, the feldspar and iron magnesia constituents standing up above it on all sides. The surface of the nepheline is coated with a mere film of decomposition products and is of a faint bluish grey colour, the feldspar weathering chalk white, and on breaking the rock open the nepheline appears to be perfectly fresh. Evidently the nepheline is destroyed much more readily by the weather than the other constituents of the rock, and the alteration products are of such a character that they are at once removed, leaving the surface of the mineral fresh and hard. This peculiar method of weathering makes it possible to determine the presence or absence of nepheline in any specimen of the syenite from a careful inspection of the weathered surface of the rock alone. In fact, its presence can be quite as certainly determined in this way as by means of chemical tests or a microscopical examination. This simple method has furthermore the advantage that it can be applied to large areas of rock surface.

SODALITE.

This mineral was observed at a large number of widely separated localities along the great belt of these syenite rocks in the townships of Glamorgan, Faraday, Dungannon, Monteagle, Raglan, Brudenell, and as far as Clear lake near the northeast end of the belt. It usually occurs in ill-defined irregular masses and patches, of comparatively small size, in the nepheline syenite, especially in those portions which are unusually rich in nepheline. It is also developed along and in the immediate vicinity of certain cracks and fissures in the nepheline, with no sharp line of division between the two minerals, the bluish colour gradually fading in passing outward to the white or pale greyish nepheline. In thin sections under the microscope it is seen to occur in irregular strings or vein-like forms cutting across and among the other constituents. In certain portions of the area it occurs in very large masses, notably on lot 25, concession XIV, of Dungannon. The presence of the sodalite at this locality has been proved over a length of some 250 feet with a width of from 40 to 50 feet, and it is stated to be even more extensive than the present developments have shown. Sufficient quarrying has, however, been done to prove this occurrence to be of distinct economic importance, as it is quite possible to secure blocks of sodalite weighing several tons. In 1906 a shipment was made of 130 tons of what was considered suitable material, to be used in the decoration of the residence of Sir Ernest Cassell, in Park Lane, Hyde Park, London, England. This property has been known as the "Princess Quarries" (see Plate XII). Other exposures showing large masses of beautifully coloured sodalite also occur on lots 25 and 29, concession XIII, of Dungannon. At the first mentioned locality, preliminary development work consisting of stripping and some blasting has shown the presence of several large patches of the sodalite. At Craigmont in Raglan township and on lot 34, concession V, of the township of Brudenell, patches of deep blue sodalite occur in a nepheline syenite made up in addition to this sodalite of a beautiful pale salmon nepheline and grey plagioclase, the association producing a rock which has a very pleasing effect. The colour in this mineral varies from a very dark cobalt blue to very pale bluish, the colour fading rapidly when exposed to the action of the weather. It is susceptible of a high polish and is eminently suitable for inside decorative work. It is often associated with more or less magnetite and biotite, and displays veinlets of reddish and whitish feldspar which was shown on analysis by Dr. Harrington to be orthoclase. A sample in the museum of the Geological Survey shows a crystal of hastingsite several inches in length and perfectly terminated, completely enclosed in the sodalite Most of the material is compact with a multitude of very fine cracks which may be due to the shocks of blasting. The specimen selected by Dr. Harrington for analysis showed distinct dodecahedral cleavage and vitreous lustre. It was translucent and often sub-transparent in ordinarily thin fragments, and its hardness was about 5.5. Heated in a closed tube the sodalite became perfectly white, while before the blow-pipe it fused easily with intumescence to a colourless glass. Under I is given an analysis of the sodalite from lot 25, concession XIV, of Dungannon, by

Dr. B. J. Harrington.[1] Under II an analysis of sodalite from Dungannon by L. McI. Leigher and G. J. Volckenning.[2]

III. Analysis of sodalite from Montreal by Dr. B. J. Harrington.[3]

IV. Analysis of sodalite from Ice river, B.C., by Dr. B. J. Harrington.[3]

V. Analysis of sodalite from near Kishengarh in Rajputana, India.[4]

	I	II	III	IV	V
SiO_2	36·58	37·34	37·52	37·50	38·055
Al_2O_3	31·05	31·25	31·38	31·82	31·30
FeO	0·20	.....	.....	.....	......
Na_2O	24·81	25·01	25·16	25·55	24·77
K_2O	0·79	0·74	0·78	0·27	......
CaO	.....	0·38	0·35	.....	0·001
Cl	6·88	6·79	6·91	7·12	7·18
SO_3	0·12	.....	.....	.....	Trace.
H_2O	0·27	.....	.....	.....	......
Insoluble	0·80	.....	.....	.....	......
	101·50	101·51	102·10	102·26	101·306
Deducting O = Cl	1·55				1·61[illegible]
Specific gravity =	2·295	2·303	2·20	2·293	2·2[illegible]

CANCRINITE.

This mineral was first detected in Canada by Dr. Harrington in the nepheline syenites of Mount Royal and Beloeil, in the province of Quebec.[5] In the nepheline syenites of Ontario, it usually can only be distinguished by the assistance of the microscope. It occurs in irregular grains or rude radial aggregates, whose outlines are dependent on the surrounding minerals.

[1]Amer. Jour. Sc. Vol. XLVIII, 1894, pp. 17 and 18.
[2]Am. Jour. Sc. Vol. XLIX, 1895, pp. 465-66.
[3]Trans. Roy. Soc. Can. Vol. 4, Sect. III, 1886, p. 81.
[4]Rec. Geol. Surv. Ind. Vol. XXXI, Part 1, Jan. 1904, pp. 43-44.
[5]Trans. Roy. Soc. Can. Vol. I, Sect. III, 1882-83, p. 81.

It is usually at least in immediate association with the nepheline and sometimes forms a narrow border more or less completely surrounding the individuals of this mineral, thus between crossed nicols it appears as a brilliant edging about nepheline or hornblende and calcite inclusions in the nepheline, the small prismatic individuals of cancrinite being arranged with their longer axes at right angles to the contact or to the direction of the crack or cleavage. Cancrinite also occurs in fissures or cleavage planes in the nepheline. In these circumstances at least, it has the appearance of being an alteration product of the nepheline. Under the microscope it is transparent, colourless, and altogether free from inclusions or alteration products. In convergent light it is shown to be uniaxial and negative. It also shows a slight but distinct dispersion of the bisectrices, giving a brownish and a bluish tint on either side of the position of maximum extinction. When separated by Thoulet heavy solution, it was found to have a specific gravity between 2.44 and 2.48. The amount of cancrinite present in these nepheline rocks varies very considerably. It is especially abundant in those specimens which are rich in nepheline. In the specimen of monmouthite described by Dr. Adams, 5.14 per cent was found by analysis. In other specimens more was noticed although in no case is this mineral abundant. Cancrinite was noticed in considerable amount in the nepheline syenite where it crosses the Monck road in Faraday township, and is also found in the nepheline syenite about 2 miles east of Bancroft. On lots 25, concessions XIII and XIV, of Dungannon, the cancrinite was found in small irregular masses with rather ill defined boundaries, and so intimately associated with the nepheline as to be separable only with extreme difficulty. The cancrinite is translucent, of a pale citron-yellow colour, gradually fading on exposure to the weather. It has a subvitreous and somewhat greasy lustre. It is undoubtedly an alteration product of the nepheline, the cleavage planes, in contiguous masses or areas, being common to both minerals, while boundaries between the two are rarely, if ever, sharp or distinct.[1]

[1]Can. Rec. Sc. Vol. VII, No. 4, 1896-7.

FELDSPAR.

Plagioclase varying in composition from albite through oligoclase and andesine to bytownite, is the prevailing feldspar in all of these rocks. Albite, with a small percentage of lime, seems to be the most common variety (see Plate XI). The specific gravity of the albite near York river is 2.6207 and 2.625, while in a separation of the rock from lot 25, concession XIV, of Dungannon, it was found to be not greater than 2.623. The specific gravity of the fresh oligoclase from the syenite was about 2.64, although some of it which had undergone partial alteration was considerably lighter. The andesine which is the feldspathic constituent of the nepheline syenite from lot 12, concession XIV, of Dungannon, was determined by heavy solution on fine fragments to be 2.668.

A noteworthy feature in connexion with the development of the feldspar, is the frequent occurrence of a thin mantle of plagioclase (albite) more or less completely surrounding individuals and even aggregates of hornblende and separating these from the surrounding and more abundant nepheline. It has also been noticed as a border surrounding calcite and between this mineral and the nepheline. This bordering zone of plagioclase is rather variable in width, but shows very marked optical continuity over long distances, in this respect also being in close agreement with similar feldspathic material which occurs filling up the various inequalities in the hornblende individuals formed as a result of this mineral's imperfect crystallographic development—and also with inclusions of feldspar in the midst of the hornblende. In some respects this phenomenon resembles certain "reaction rims," and it is thus explained by Holland.[1] This curious occurrence is well illustrated in certain of the hornblendic varieties of the syenite exposed at the dam at Bancroft and at Egan chute on the York river. The larger crystals of corundum occurring in the nepheline rich variety of the syenite at Craigmont are also frequently surrounded by a zone of plagioclase, separating the former mineral from the nepheline.

[1]Mem. Geol. Surv. Ind., Vol. XXX, part 3, 1901, pp. 190-191.

Microcline is rather unusual in the nepheline syenite and much of it presents a somewhat indefinite and distorted mesh which is not distinctive. Much of the microperthite has the very fine and interrupted twinning lamellæ characteristic of anorthoclase with which it is probably identical. Most of what has been considered to be orthoclase also shows quite a perceptible intergrowth of other feldspars, the potash feldspar being, however, predominant.

The following are analyses of the various feldspars:—

	A	B	C	D	E	F	G	H
SiO_2....	63·00	63·43	63·26	61·36	57·15	58·11	48·12	48·03
Al_2O_3....	18·93	20·78	21·87	22·97	26·74	26·62	34·54	33·43
Fe_2O_3....	0·59	0·29	0·22	......	......	......	0·36	......
FeO....	......	......	......	......	0·25	......	......	......
CaO....	0·08	1·00	0·21	5·38	6·66	8·34	16·30	16·28
MgO....	0·09	0·07	......	......	0·59	......	Tr.	......
MnO....	......	......	......	......	Tr.	......	......	......
K_2O....	12·08	8·00	3·09	......	0·38	......	0·15	......
Na_2O....	3·67	5·20	10·25	8·08	6·83	6·93	1·91	2·26
H_2O....	1·00	1·00	0·78	1·72	0·90	......	none	......
Totals...	99·44	99·79	99·68	99·51	99·50	100·00	101·38	100·00
Sp. Gr...	2·555		2·594	2·633	2·668	2·680	2·731	2·735

A. A white and reddish mineral which was proved on analysis by Dr. Harrington to be orthoclase, fills certain little cracks traversing the sodalite on lot 25, concession XIV, of Dungannon. It is mostly dull, but in places shows cleavage surfaces with a pearly lustre. The reddish portions probably owe their colour to the decomposition of pyrite, occasional grains of which still remain. (Am. Jour. Sc., Vol. XLVIII, July, 1894, p. 18).

B. Microperthite separated from corundum pegmatite, Craigmont, Ontario. Analysis by M. F. Connor.

C. Microperthite from corundum syenite, of Sivamalai, India, described and analysed by T. H. Holland. (Mem. Geol. Surv. Ind. Vol. XXX, Part 3, 1901, p. 202).

The microperthite consists of intimately intergrown orthoclase and albite with a small quantity of secondary muscovite and kaolin.

An examination of these analyses will show at a glance the remarkable similarity in chemical composition of these microperthites from such widely separated localities as Canada and India. Taking into consideration the molecular values of soda and potash, the ratio of the soda to the potash in the Indian mineral is as 5:1, while in the Canadian occurrences the soda and potash are practically the same.

D. Oligoclase separated from plumasite, near Spanish Peak, Plumas county, California. Analysis by J. Newfield. Described by A. C. Lawson (Bull. Dept. Geol. Univ. of Cal. Vol. III, No. 8, pp. 226, April, 1903.) Calculated to a water free basis, the molecular ratios correspond to those of an oligoclase of the formula Ab_5An_2 with 2.7 per cent of silica to spare.

E. Andesine separated by Thoulet heavy solution from dungannonite, lot 12, concession XIV, Dungannon township, Ontario. Analysis by M. F. Connor. Described by A. E. Barlow. The material was somewhat impure owing mainly to the admixture of a small amount of biotite. This accounts for the iron, potash, and magnesia found in the analysis. Neglecting these the composition corresponds rather closely to that of an andesine with the formula Ab_3An_2, with 0.96 per cent too little of silica and 1.68 per cent too little of lime. The specific gravity for such a mixture should be 2.68, while that of the andesine separated from the rock was 2.668, this slight decrease in weight being, no doubt, due to the unusually low lime. For purposes of comparison, the theoretical composition of andesine corresponding with the generally accepted formula for this species of plagioclase made up of a mixture of albite and anorthite in the ratio of 3:2, is given under F.

F. Theoretical composition of andesine Ab_3An_2, according to Zirkel.

G. Bytownite from corundum-bearing anorthosite, South Sherbrooke, Ontario. Analysis by William Lawson. Described by W. G. Miller.

H. Theoretical composition of bytownite Ab_1An_4. (Zirkel, Lehrb. d. Petrographie, p. 221.)

It will be noticed that there is a remarkably close agreement between the theoretical composition of the bytownite (Ab_1An_4) as regards the percentages of silica, lime, and alkalis and that of the basic plagioclase from South Sherbrooke. The proportion of alumina is, however, one per cent higher than that of the theoretical percentages. This may be due to minute crystallites of corundum in the feldspar, although they were not positively dentified by Dr. Miller.

SCAPOLITE.

Scapolite is a frequent and often abundant constituent of both the nepheline and alkaline syenites. At Craigmont especially it forms considerable rock masses as well, replacing a large part of the feldspar in some of the bands of the gneissic syenites. It occurs in clear colourless, sometimes polygonal grains which meet the accompanying nepheline and feldspar grains with a perfectly sharp outline with little or no suggestion that the mineral is the result of alteration or weathering. Sometimes it occurs in irregular individuals, growing through the feldspar, and associated in some cases with calcite and epidote. It is uniaxial and possesses a high double refraction, showing the characteristic cleavage with parallel extinction. The double refraction is much stronger than in the nepheline and feldspars, the interference colours seen in the thin sections being red, blue, and yellow. In this it resembles cancrinite, from which it can generally be distinguished by its habit, the cancrinite usually filling in cracks and the small interspaces left after the crystallization of the other constituents. At Craigmont large masses and interfoliated often thick bands of a pale greenish granular rock are made up almost exclusively of scapolite. The mineral has a specific gravity of 2.67 showing it to be of intermediate composition in the scapolite group. Associated with this scapolite are small bands of titaniferous magnetite. A scapolite which occurs in large amount in lot 11, concession VIII, of Monmouth, in rock made up of nepheline, albite, brown hornblende, and a little biotite, shows good prismatic cleavages and is usually quite fresh. It has a specific gravity of 2.711 showing that it is near the meionite end of the scapolite group.

BIOTITE.

This is the chief iron-magnesia constituent of these rocks, but it is usually present in subordinate amount. It occurs in the usual small scales and plates, some of which exhibit good crystal boundaries. The hand specimens show an almost black mica which has usually a distinctly greenish colour in transmitted light. The thin sections under the microscope have a very strong pleochroism from pale greenish yellow to very deep almost opaque greenish brown. Basal sections are distinctly biaxial, but with a very small axial angle. In some of the coarser phases of the rock, as well as occupying certain miarolitic cavities, as in the northwest corner of Faraday some of these biotite crystals are very large and well formed.

The following are analyses of biotite:—

	A	B	C
SiO_2	31·48	34·52	32·09
TiO_2	2·50	2·70	....
Al_2O_3	17·23	13·22	18·52
Fe_2O_3	5·85	7·80	19·49
FeO	27·96	22·27	14·10
(Co, Ni) O	......	0·30	..
MnO	1·61	0·41	1·42
CaO	1·33	.....	.....
MgO	2·99	5·82	1·01
K_2O	4·17	8·59	8·12
Na_2O	1·68	0·16	1·55
Li_2O	0·00	0·04	...
Water (combined)	3·94	4·39	4·62
Fl	0·00	0·34	.....
	100·74	100·56	100·92
Sp. Gr.	3·25		

A. The deep brown or black lepidomelane (a variety of biotite) separated from the nepheline syenite (essexose), lot 16, concession IX, Monmouth township, Ontario. Analysis by J. E. Egleson. Described by F. D. Adams. This was isolated from the rock by means of a Wetheral Electro-magnetic separator and further purified by the use of Thoulet heavy solution .

B. Lepidomelane, Port Henry. Analysis by Clarke and Schneider. (Am. Jour. Sc. 40, 410, 1890.)

C. Lepidomelane, Litchfield, Me. Analysis by Riggs. (Am. Jour. Sc. 31, 268, 1886.)

HORNBLENDE.

Although less common than the biotite, this mineral often is the prevailing ferromagnesian constituent.

Dr. Adams in his first description of the Dungannon occurrences, made mention of the fact that two distinct varieties of hornblende, both green in colour, could often be distinguished in the same hand specimens, and this has been found to be true of outcrops in the southwestern and northeastern extensions of the band. The individuals are, as a rule, much larger than those of the biotite and present a nearer approach to perfection of crystallographic outline. The prismatic cleavages at angles of about 124 degrees are often well seen. The first variety has a large axial angle, with strong pleochroism in tints varying from pale yellow to deep green. Before the blowpipe it fuses with intumescence to a black glass, giving at the same time a strong soda flame. This variety probably contains a considerable quantity of soda, but approaches common hornblende in composition.

The second variety, the type specimen of which was obtained from a series of exposures about 2 miles to the east of the village of Bancroft in Dungannon township, has a small axial angle with a high extinction angle and a much stronger pleochroism in the bluish tints suggestive of arfvedsonite. The mineral occurs in hypidiomorphic grains which show the usual hornblende cleavages.

HASTINGSITE.

The name "hastingsite" was suggested by Adams and Harrington for this remarkable basic variety of hornblende, thus connecting it with the region where it occurs.[1]

Hastingsite, as seen in thin sections of the nepheline syenite, is characterized by a very strong pleochroism. Basal sections are yellowish green for light vibrating along the shorter diagonal of the rhomb, and deep bluish green, or nearly opaque, if the section is at all thick, for light vibrating parallel to the longer diagonal; prismatic sections similarly are deep bluish green to opaque for light vibrating along the cleavage and pale yellowish green for light vibrating perpendicular thereto, while at the same time they are distinguished by an unusually large extinction angle, the maximum value observed being about 30 degrees. Occasional fragments are seen which have only a very slight pleochroism (i.e., sections apparently perpendicular to the acute bisectrix) and when these are examined in convergent light they exhibit a nearly uniaxial figure, the angle between the optic axes being so small that the hyperbolic brushes about them have united to form an apparent black cross. The figure, however, is obviously biaxial, being coloured red in one pair of opposite quadrants, transverse to the cleavage cracks, and bluish green in the other; but owing to the deep colour and the weak birefringence of the mineral, it is usually difficult to decide as to which of these directions is the line joining the optic axes. Usually in hornblende the axial plane lies in the plane of symmetry, but in the case of hastingsite, an examination of specially prepared sections showed that the axial plane is transverse to the plane of symmetry of the mineral. The optic axial angle could not be measured, but by comparison with biotite it was estimated to be in the neighbourhood of 16 degrees for green light; for red light it is less, the dispersion being strong in the sense $\rho < \upsilon$ and there may even be a crossing of the optic axial plane for these colours,

[1]Am. Jour. Sc. 3rd Ser. Vol. XLVIII, 1894, p. 13; 4th Ser. Vol. I, 1896, pp. 210-217; Can. Rec. Sc. Vol. VII, 1896-97, pp. 77-87; Trans. Roy. Soc. Can. 1908, 3rd Ser., Vol. II, Sect. IV, pp. 20-22; Mem. No. 6. Geol. Surv., Can., 1910, pp. 243-246; Am. Jour. Sc. 4th Ser. Vol. XXVIII, 1909, pp. 540-543.

since the interference figure observed in yellow light approaches very nearly to the uniaxial cross. Considered with reference to the crystallographic axes, the pleochroism is like that usually met with in amphiboles; but since in the case of hastingsite the plane of the optic axes lies across the plane of symmetry instead of along it, we have **b** > **c** > **a**, **b** and **c** being nearly equal. An approximate determination of the refractive index, by immersing fragments in a mixture of methyline iodite and naphthalene monobromide, gave a value of 1·69. The birefringence is weak and negative.

The foregoing description has been furnished by Mr. R. P. D. Graham of McGill University, w. undertook a detailed optical examination at the request of Dr. F. D. Adams.[1]

The following are analyses of hornblende. The analysis under A is of hastingsite, while under F is included the analysis of the common hornblende occurring in the corundum anorthosite of South Sherbrooke, described by Dr. W. G. Miller.

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[1]The indefiniteness in our conception and interpretation of the amphiboles is indicated in the researches and conclusions of Scharizer (Neves Jahrb. für Min. 1884, II p. 143); Penfield and Stanley (Am. Jour. Sc., 4 Ser. Vol. 23, 1907, p. 23); Murgoci (Bull. Dept. Geol. Univ. Cal. Vol. 4, No. 15, p. 384) and Allen and Clement (Am. Jour. Sc. 4th Ser. Vol. 26, 1908, p. 101). Dr. Percy Quensel after consideration of a certain number of hornblendes which are strikingly similar in chemical composition but which show a wide divergence in their optical properties concludes that nere is "no essential difference between hastingsite and the arfedsonitic hornblende or the green and brown alkaline hornblendes. They seem rather to form links in a series." Pending a fuller acquaintance with the subject he defines hastingsite as a hornblende with small axial angle, with probably an indefinite position of the axial plane, with low birefringence and with strong axial dispersion. Murgoci's definition for the proposed new type of hornblende ("laneite") is practically identical, but the name hastingsite has priority. Chemically such hornblendes are distinguished by low alumina about 10 per cent, a nearly equal amount of Fe_2O_3, 20-25 per cent of the FeO, about 10 per cent of CaO, and relatively low alkalis. (Bull. Geol. Inst. of Upsala Vol. XII, 1914, pp. 145-152.)

	A	B	C	D	E	F	G	H
SiO_2....	34·181	36·86	39·167	39·66	39·62	41·40	40·02	37·49
TiO_2....	1·527	1·04	....	0·89	0·19	...	.....	0·86
Al_2O_3....	11·517	12·10	14·370	14·83	14·92	15·39	15·55	10·81
Fe_2O_3....	12·621	7·41	12·423	12·37	10·28	7·01	3·44	7·52
FeO.....	21·979	23·35	5·856	1·97	7·67	7·17	8·60	25·14
MnO....	0·629	0·77	1·505	.....	0·24	trace	.....	0·95
CaO.....	9·867	10·59	11·183	12·47	12·65	12·53	12·21	9·77
MgO....	1·353	1·90	10·521	14·25	11·32	10·31	14·37	1·34
K_2O....	2·286	3·20	2·013	1·25	2·18	1·56	2·13	1·91
Na_2O....	3·290	1·20	2·478	2·47	1·12	3·58	2·40	2·06
H_2O.....	0·348	1·30	0·396	.....	0·48	0·81	1·81	2·01
F.......	......	0·27	......	......	.....	.....	.....	.....
	99·601	99·99	99·912	100·43	100·67	99·76	100·53	99·86
Sp. Gr.	3·433	.....	3·33	.....	3·266	3·18	.....	.....

A. Hastingsite near Bancroft, Ontario. Analysis by B. J. Harrington (Amer. Jour. Sc. 4 ser. vol. I, 1896, p. 213).

B. Hornblende (hudsonite), Cornwall, New York. Analysis by J. L. Nelson (Am. Jour. Sc. 4th ser. Vol. XV, 1903, p. 227).

C. Pargasite (hornblende), Island of Jan Mayen. Analysis by Scharizer (N. J. f. M. 1884, 2 p. 143).

D. Pargasite (hornblende), Bohemia. Analysis by Schmidt, (Min. Mitth 4, 23, 1881.)

E. Pargasite (hornblende), Stenzelberg. Analysis by Rammelsberg (Pogg. Ann. 1858 CIII 454.)

F. Pargasite (hornblende), South Sherbrooke, Ontario. Analysis by William Lawson (Am. Geol. Vol. XXIV, 1899, p. 282.)

G. Pargasite (hornblende), lot 11, concession VIII, Bathurst township, Ontario. Analysis by B. J. Harrington (Ann. Rep. Geol. Surv., Can., 1873-74, p. 201.)

H. Hastingsite, seglinge, Almunge, Sweden. Analysis by R. Mauzelius. Described by Percy Quensel. "The Alkaline Rocks of Almunge" Bull. Geol. Inst. of Upsala, Vol. XII, 1914, pp. 145-152.

PYROXENE.

This mineral, which is usually the chief iron magnesia constituent elsewhere in rocks of this class, is almost wholly replaced by biotite or hornblende in the Ontario occurrences. There are, however, exceptions to this prevailing scarcity of pyroxene and Dr. Adams has described a nepheline albite rock (vulturose) from lot 11, concession VIII, of the township of Monmouth, which contains 18.35 per cent of this mineral. The pyroxene in this rock is of a very deep green colour, with distinct pleochroism. It is evidently very rich in iron and holds rounded inclusions of calcite and nepheline. It is sometines surrounded by a border of garnet; a paler-coloured pyroxene occurs as an accessory constituent with nepheline, albite, hornblende, and garnet on the southern part of lot 32, concession III, of Glamorgan. Pyroxene also occurs in the nepheline syenite forming the summit of the ridge on the southern part of lot 17, concession VIII, of Methuen. Here, with the exception of a few crystals of magnetite, it is the only dark constituent of the rock, but occurs in very small amount. It is bright green in colour, distinctly pleochroic with a small axial angle, and is probably acmite.

MUSCOVITE.

The mineral has a pearly white, pale yellowish, or occasionally a pale lavender tint. Under the microscope the thin sections show no pleochroism, and [illegible]y a very slight difference in absorption, but with very strong negative double refraction. This mineral seems to occ[illegible] [illegible] [illegible]nite and distinct forms. In the first place, it occurs in comparatively small individuals, somewhat similar in dimens[illegible] habit to the biotite, which is the usual and more abunda[illegible] [illegible]n this mode of development it is often intergrown with the biotite. As large individuals, together with nepheline [illegible] [illegible]stitutes a pegmatitic phase of the nephe[illegible] [illegible] concession I, of Monteagle township, on th[illegible]rk[illegible].

In the second place, muscovite occ[illegible] [illegible] larger plates and aggregates, in more or less intimate association with corundum, in those types of the syenite which have consolidated from a magma supersaturated with alumina (see Plates VII, XX, XXI). It is, therefore, present in greater abundance, and more characteristic of these somewhat unusual types of the nepheline syenite, which mainly by the almost complete failure of the ferromagnesian minerals, favoured the separation of the excess of alumina in the form of corundum. The mineral under these conditions of association has always been described and regarded as secondary, resulting from the alteration of the corundum. The supporters of such a view argued that every gradation in the process of this alteration may be seen, from those occurrences in which comparatively pure crystals of corundum are penetrated or coated with thin films or scales of the mica, to others in which the whole of the original corundum crystal has been replaced by muscovite. On the other hand, the peculiar conditions which attended and contributed to the replacement have never been satisfactorily explained. Both minerals are developed side by side in perfectly fresh and unaltered rocks, the surrounding constituent minerals having undergone little or no perceptible change. Moreover, it is well known that corundum is one of the most unalterable of substances when subjected to ordinary processes of atmospheric decay, this fact receiving the strongest support from the Ontario occurrences. The critical and extended studies of these Ontario deposits of corundum, both in the field and in thin sections under the microscope, is amply convincing that this apparent alteration is closely connected with some phases of pneumatolytic or vein action, which immediately preceded the complete solidification of the enclosing rock from the molten magma. The extreme phases of such alteration are best seen in the pegmatitic or coarser varieties of the syenite, although examples are not lacking in the more normal grained portions of these rocks. Indeed it seems to belong to the same class as that which gives rise to the corona or reaction rims which so frequently surround some of the earlier formed minerals in many plutonic rocks.

The alteration in the case of the Ontario corundum is always to muscovite, and this mineral may chemically be considered as made up of orthoclase, corundum, and water. Morozewicz has shown experimentally that a magma such as that which gives rise to a soda-syenite has the power to dissolve alumina, and on cooling to separate out any excess completely. The conditions laid down by what is known as Morozewicz's law are completely fulfilled by the corundum-bearing syenites and anorthosites of Ontario. In all magmas, those of acidic composition especially, water is believed to be present in considerable amount. As the corundum separated out the magma would tend to approach more nearly to the composition of a mass of fused feldspar, together with a certain amount of water. At this stage, and on account of some condition, or change of conditions, this residual magma attacked the corundum and more or less redissolved it, the hydrous feldspathic magma, together with the alumina from the dissolved corundum, making muscovite, which crystallized around or replaced the corundum, according to the following formula:—

$K_2O,\ Al_2O_3,\ 6SiO_2$ (=orthoclase) $+ 2Al_2O3$(=corundum)$+$ $2H_2O = K_2O,\ 2H_2O,\ 3Al_2O_3,\ 6SiO_2$ (=muscovite).

This would likewise explain the marked prevalence of this alteration in the pegmatitic facies of the syenite, for it is in these residual differentiated portions of the magma that water plays such an important part in the process of crystallization.

QUARTZ.

Quartz is conspicuous by its scarcity or absence in most of the outcrops of rocks with which corundum is associated. The red alkali syenites show a distinct transition into rocks which contain quartz in appreciable amount and are, therefore, to be classed as granites. The pegmatites occurring in intimate association with the syenites and anorthosites at Craigmont and in Carlow township, show every gradation from a pure feldspar rock with microperthite often as the sole constituent to representatives of these coarse phases in which quartz makes up about 50 per cent of the whole mass. In the normal medium grained red alkali syenite, quartz is present in considerable amount; sometimes as much as 12 per cent has been noted.

EXPLANATION OF PLATE XVII.

Crystal of corundum in syenite pegmatite. The syenite pegmatite or feldspar matrix fills in the basal cracks. Craigmont, Raglan township, Ontario, (See pages 88, 109, 128.)

Crystal of Corundum in Syenite Pegmatite.
The Syenite Pegmatite or Feldspar Matrix
Fills in the Basal Cracks.

O. E. Prudhomme, Del.

Craigmont, Raglan Township, Ontario.

Explanation of Plate XIX.

Crystal of corundum (measures 7 × 2½ inches) showing muscovite developed along basal parting planes. Craigmont, Raglan township, Ontario (See pages 88, 109, 128.)

Crystal of Corundum, measures 7 x 2½ inches, showing Muscovite developed along basal parting plane
Craigmont, Raglan township, Ontario

Quartz and corundum although for the most part mutually exclusive are sometimes present in the same rock mass. Almost every igneous eruption or complex is accompanied by quartz veins, which are the end product of the segregative consolidation.

CORUNDUM.

The crystals (see Plates XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI) when normally developed, are usually six-sided prisms, which are sometimes terminated by a six-sided pyramid, and not infrequently by the basal plane. Many of the crystals, especially those occurring in the nepheline syenite, have a tolerably sharp and perfect outline, frequently showing a tapering to either extremity, thus producing the very characteristic barrel-shaped outline. The pyramidal and prismatic faces are very often more or less deeply striated or grooved horizontally. The basal planes or truncated ends of the crystals are frequently striated in three directions, forming equilateral triangles, corresponding with the less perfect rhombohedral partings or pseudo-cleavages. The crystals vary greatly in size, the largest noticed in the nepheline syenite being about 8 inches in length by 2 inches in diameter. Such crystals are comparatively rare, the usual size being about 2 or 3 inches, and from that shading down into those of microscopic dimensions. Some of the larger crystals, as well as the very small ones, are usually inclined to have an irregular or imperfect outline. The corundum is in many instances somewhat brittle, breaking with an uneven or conchoidal fracture, but when in large masses it is exceedingly tough. The lustre is in general vitreous, but in the translucent light green variety noticed in Brudenell township the lustre is somewhat pearly. The colour of the corundum in the nepheline syenite is, in general, of varying shades of blue to white. It is sometimes of a distinct red-rose colour. Many of the crystals, especially those present in the nepheline syenite exposures in the vicinity of York river, show an irregular or cloud-like arrangement of the colouring material, shading off from deep azure blue through pale blue to colourless. Occasionally crystals exhibit a very decided and beautiful zonal arrangement. The hardness of the mineral is 9, or second only to that of the diamond. The specific gravity of the blue corundum from dungannonite ranged from 39.3 to 4.01, with an average of 3.95.

A microscopical examination of the thin sections of this rock show that, in addition to the larger and more perfect crystals which are visible to the naked eye, there are innumerable small, usually exceedingly irregular individuals distributed through the rock, which would add greatly to the richness of the product derived from concentration.

Corundum under the microscope has a high index of refraction, but a low double refraction, and in good thin sections the interference colours do not exceed red of the first order. Such sections are, however, difficult to obtain on account of the relatively much greater hardness of corundum than the surrounding minerals. These latter may be thin enough, while the corundum grains, as may be seen in sections from which the cover glass has been removed are in considerable relief, the result of their resistance to the grinding operations. As a consequence, therefore, the corundum is given a higher double refraction than it actually possesses. Most thin sections, therefore, of this mineral, show very brilliant chromatic polarization between crossed nicols. The pronounced relief, the dark borders of total reflection, the rough surfaces, and the parting planes or pseudo-cleavages (see Plate XX) are very strongly marked with negative double refraction.

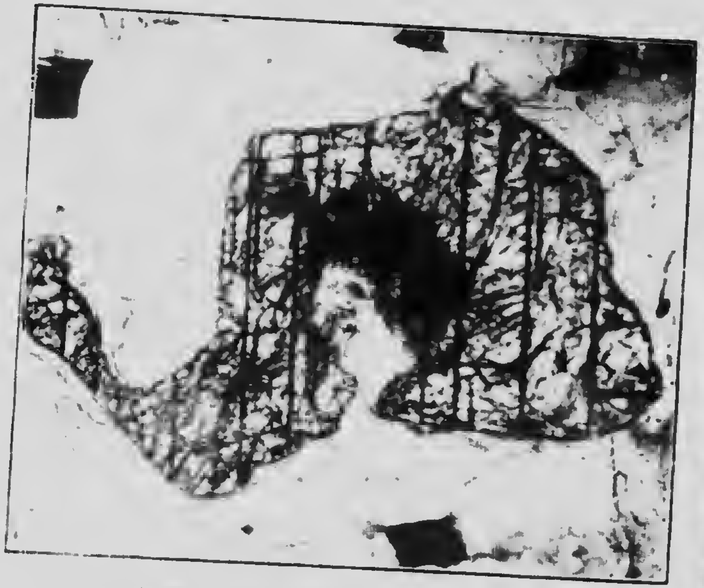
The following are analyses of corundum:—

	A	B	C	D	E	F	G
SiO_2..........	none	none	1·77	0·90	1·45	.....	0·07 (av.)
Al_2O_3 (diff.)....	96·90	95·58	94·58	98·79	95·51	96·26	97·27
Fe_2O_3+FeO....	0·76	2·10	0·69	0·75	0·88	0·36	0·32
CaO..........	0·46	0·48	0·44	Trace	und.	.....	.....
MgO..........	1·00	1·00	.....	.....	.....	.....	.....
H_2O..........	0·88	0·84	2·51	0·78	0·74	1·93	.....
	100·00	100·00	99·99				

EXPLANATION OF PLATE XX.

Corundum, showing planes of parting, with andesine, biotite, and muscovite (×40 diam.) Lot 12, concession XV, Dungannon township. (See pages 110, 132.)

Corundum with muscovite, biotite, and plagioclase. (×40 diam.) Lot 2, concession II, Monteagle township. (See page 107.)



Explanation of Plate XXI.

Corundum in muscovite. Blue mountain, Methuen township, Ontario.
(See pages 107, 109, 132.)

Ontario.

CORUNDUM IN MUSCOVITE
(BLUE MOUNTAIN, METHUEN TOWNSHIP, ONTARIO)
CORUNDUM IS OFTEN SURROUNDED BY A "CORONA" OR MANTLE OF MUSCOVITE.

O. E. PRUDHOMME, DEL

A. Blue corundum from dungannonite, lot 12, concession XIV, Dungannon township, Ontario. Analysis by M. F. Connor.
B. Brown corundum from corundum pegmatite, Craigmont, Ontario. Analysis by M. F. Connor.
C. Corundum from Acworth, Georgia, U.S.A.[1]
D. Corundum from Macon county, North Carolina, U.S.A.[1]
E. Corundum from Laurel creek, Georgia, U.S.A.[1]
F. Corundum from Craigmont, Ontario. Analysis by W. L. Goodwin.[2]
G. Corundum from Craigmont, Ontario. Analysis by J. W. Wells.[2]

CALCITE.

This mineral is almost invariably present, and is especially abundant in those exposures which are in immediate contact with crystalline limestone. Its unexpected presence in such a rock has already been fully explained, and the interpretation that this mineral is distinctly foreign to the magma, and derived from the neighbouring limestones, is in direct agreement with all the phenomena observed. Its mode of occurrence is entirely different from that of a secondary constituent, being found in comparatively large, well defined, usually rounded grains, sometimes completely enclosed by the other constituents, or in other cases lying between them (see Plate VII). The line of separation is quite sharp and distinct, with no hint of decomposition in any of the surrounding minerals. The individual grains show the usual perfect rhombohedral cleavages, often with well marked twinning lamellæ. Comparatively large individuals occur in the pegmatitic phases, as noticed in the exposures east of the bridge over the York river, on the Mississippi road in Dungannon township.

GARNET.

This mineral is of common occurrence, and is occasionally so abundant, especially at certain exposures near the York

[1]Trans. Am. Inst. Min. Eng. Vol. XXIX, 1900, p. 248.
[2]Ann. Rep. Bur. of Min. Ont. Vol. VII, 1898, pp. 238-239.

river, in the northern part of Dungannon, as to characterize the rock. In the hand specimen it exhibits a dark reddish brown colour. In thin sections it is, of course, much paler in tint, assuming a deep brownish tint, fading to yellowish toward the interior of the larger grains. It shows the usual high index of refraction and consequent very pronounced relief. It is quite isotropic. The individuals, and especially the larger grains, usually possess a very jagged outline, with irregular arms and intricate indentations, with very abundant inclusions of most if not all of the other constituent minerals. In some instances it exhibits well developed crystallographic boundaries. It is especially abundant in those varieties of the syenite which contain hornblende and pyroxene, as the ferromagnesian minerals, and is for the most part developed in immediate association with these minerals. It resembles a garnet found in small amount in the nepheline syenite of the Corporation Quarry at Montreal, and also the melanite in the nepheline syenite of Alnö.[1]

A chemical analysis by Dr. B. J. Harrington afforded the results under A, showing the garnet to be a titaniferous andradite.[2] For comparison, analyses of two other similar garnets are quoted under B and C.

	A	B	C
SiO_2..............	36·604	36·63	35·84
TiO_2.	1·078	.....	1·04
Al_2O_3..............	9·771	9·97	6·24
Fe_2O_3..............	15·996	13·45	23·12
FeO..............	3·852	2·28	.....
MnO..............	1·301	0·63	.....
CaO..............	29·306	35·90	32·72
MgO..............	1·384	0·28	1·04
Loss on ignition ...	0·285	0·16	.....
	99·577	99·20	100·00
Sp. Gr............	3·739		

[1]Geol. Fören. i. Stockholm, Förh, 1895, p. 144.

[2]Can. Rec. Sc. Vol. VI, 1894-95, pp. 480-481; also Vol. VII, 1896-97, pp. 87-88.; Am. Jour. Sc. Vol. I, 1896, p. 217.

Andradite (titaniferous) near Bancroft, Ont. Analysis by B. J. Harrington (Am. Jour. Sc. March 1896, p. 217.)

Andradite Stokö. Analysis by Lindström (Zt. Kr. 16, 160, 1890.)

Andradite (titaniferous) Frascati (Dmr. L'Institut Dec. 1876.)

ZIRCON.

This mineral is quite commonly noticeable in thin sections under the microscope, but it is usually a comparatively rare accessory constituent. The microscopic representatives are rather short prismatic forms and as a rule somewhat rounded. The index of refraction and the double refraction are very high giving characteristic pronounced relief and brilliant red and green interference colours between crossed nicols. In some of the coarser phases of the rock, noticeably at the York river in Dungannon township and at Craigmont in Raglan township, crystals are not uncommon which would measure from a quarter to half an inch in length. One short stout crystal at present in the museum of the Geological Survey at Ottawa, measures an inch in length by three-quarters of an inch across. Other crystals of zircon, dark reddish brown in colour, over an inch in diameter and each consisting of a double tetragonal pyramid are also found in pegmatitic dykes of the nepheline syenite, consisting of albite, nepheline, biotite, and apatite, in lot 32, concession III, of Glamorgan. The crystals always show sharply angular and definite crystalline outline. Some of these crystals were sent from the Glamorgan locality by Dr. Adams to the mineralogical laboratory of the Sheffield Scientific School for crystallographic measurement and description. Mr. J. H. Pratt, to whom they were entrusted, gives full details of his examination from which the following is taken[1]: "The crystals occur embedded in the usual manner in the rock, from which they can readily be separated in an almost perfect condition. They show two quite different habits, one, in which by the development of two opposite pairs of the pyramidal faces, together with a pair of the prisms of the second order, the crystal becomes columnar

[1]Amer. Jour. Sc. Vol. XLVIII, 1894, p. 215.

in this direction, and mimics a hexagonal prism of the second order terminated by rhombohedral faces. In the second habit the pyramidal faces are strongly developed, while the prism faces are short or lacking altogether." Both these habits are represented by good specimens in the Geological Survey Museum. The comparatively large individual already mentioned belongs to the second habit.

SPHENE (TITANITE).

This mineral is also represented, although by no means abundant, and, so far as observed, in microscopic crystals only. It is often in characteristic wedge-shaped though somewhat rounded forms, but also occurs in irregular grains. It is more abundant in the hornblendic varieties, where it is often quite an important accessory constituent. The index of refraction is high, and as a consequence the individuals show very pronounced marginal reflection and rough surface. The double refraction is quite strong in some sections. It sometimes has a comparatively strong yellowish brown colour, with quite a perceptible pleochroism.

TOURMALINE.

This mineral was only noticed occasionally, and in small amount. It occurs in the characteristic crystals, which are black in colour. It was noticed in the dungannonite on lot 12, concession XIV, of Dungannon, and lot 4, concession I, of Monteagle.

FLUORITE.

This mineral is occasionally noticed in purplish grains, but it is one of the rarer of the accessory minerals.

SPINEL (GAHNITE).

A dark green spinel, evidently closely allied if not identical with gahnite or automolite (Zn Al_2O_4), has only occasionally been noticed in connexion with the corundiferous rocks, although it is more abundant in the red alkali syenite. It has, however, been distinguished in thin sections of the nepheline-rich variety occurring on lot 33, concession VII, of Brudenell, as also at Craigmont, where it occurs in irregular, dark green isotropic octahedral crystals and grains. Crystals of this mineral were first found by W. F. Ferrier (first recorded occurrence in Canada) lining cavities in a dark brown massive corundum on lot 2, concession XVIII, Raglan (Craigmont). The form of the crystals is that of the octahedron with the interfacial edges replaced by the dodecahedron. They are blackish green by reflected and green-blue-green by transmitted light. They are translucent on the edges and have a vitreous lustre.

CHRYSOBERYL.

This mineral has been found occasionally at Craigmont in yellowish grains and crystals.

EUCOLITE, EUDIALYTE.

A mineral with the characters of eucolite and eudialyte, occurs rather abundantly in the hornblendic variety of the nepheline syenite at Egan chute, on the York river, as well as at another locality a little lower down the same stream. It occurs with a yellow colour, usually with incomplete crystallographic boundaries. It is intimately associated with hornblende and garnet, frequently enclosed in the former, and with an appearance altogether suggesting the latter mineral. It has, however, quite a distinct though apparently low double refraction, but a high index of refraction, with decided relief, a rough surface, and parallel extinction. It is distinguished from the garnet by a decided difference in colour, the garnet being brownish or reddish brown in thin sections, while the eucolite is pale yellowish. Treated with the heavy solution, eucolite falls with the hornblende and garnet, and can only be separated with the greatest difficulty from these minerals. By magnetic separation several times repeated fairly pure material is obtained, but hardly pure enough for purposes of chemical analysis. It is likely that further and more careful research in this region would show larger and more abundant individuals of this mineral.

MOLYBDENITE.

This mineral is occasionally represented, and occurs usually in small plates and scales, and occasionally in crystals. It presents no unusual features worthy of description in the present instance. Two localities where it may be found without any great difficulty, are lots 25, concessions XIII and XIV, of Dungannon. Large specimens may also be obtained from certain of the openings in the corundum syenite at Craigmont.

APATITE.

This mineral is a very common constituent of the nepheline syenite, but it is usually present as a very subordinate accessory constituent, and in very small, often microscopic crystals. In such cases it rarely possesses sharp crystallographic outline, but occurs as comparatively short stout prisms, often doubly terminated, but these planes are either disguised or obliterated by rounding, the result, doubtless, of magmatic resorption. In some localities in Dungannon, especially on lot 25 of concession XIV, and in association with the iron on lot 30, concession XIII, comparatively large crystals of apatite may be obtained (see Plate XXII), while in the northwest corner of Faraday well defined prisms, terminated at one end with the planes of two pyramids, have been noticed.

MAGNETITE.

This mineral has a very general distribution throughout the whole mass of the nepheline and alkaline syenites and anorthosites although its complete and unexpected absence from occasional outcrops, representing even the more basic phases of the rock, is noteworthy. It is usually present, how-

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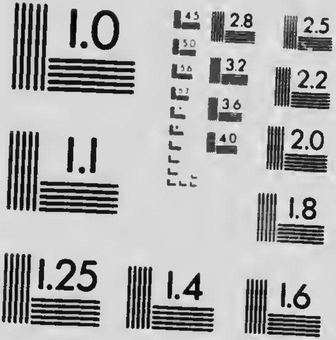

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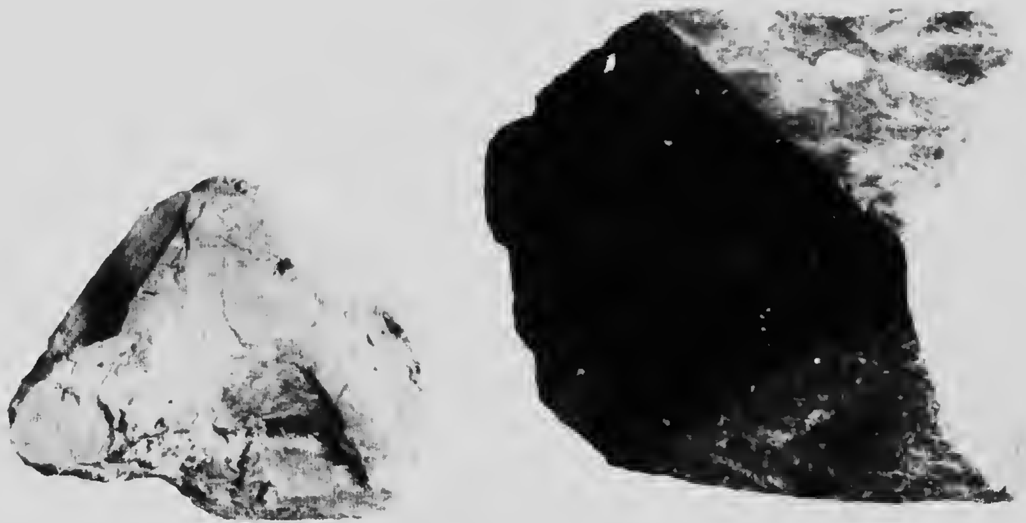
EXPLANATION OF PLATE XXII.

Curved crystal of apatite in nepheline syenite with calcite. Lot 25, concession XIV, Dungannon township. (See page 116.)

Curved Crystal of Apatite in Nepheline Syenite with Calcite
Lot 25. Con. XIV. Dungannon township

Explanation of Plate XXIII.

Crystals of magnetite from nepheline syenite. (Larger crystal weighs 7¼ pounds). Lot 30, concession XV, Faraday township. (See page 117.)



Crystals of Magnetite from Nepheline Syenite. Lot 30, Con. XV. Faraday township.
Larger crystal weighs $7\frac{1}{4}$ lbs.

ever, and certainly is one of the more important of the accessory constituents. Individuals in thin sections under the microscope often show fairly good crystalline form, but the grains are usually somewhat rounded and irregular in outline. In many places the magnetite differentiates out from the rest of the rock, and forms large and important masses of this mineral, much of which is free from any other admixture. Attempts have sometimes been made to work some of these masses in the hope that they would ultimately become producing mines. At one locality, on lot 30, concession XIII, of Dungannon, considerable development work, consisting chiefly of stripping and blasting, has revealed the presence of considerable bodies of very pure magnetite, which, however, judging from analogous occurrences accompanying the red syenite, and which have been analysed, would in all probability contain titanium. The mineral here has a very perfect octahedral parting. In certain localities in Dungannon, and especially in the northwest corner of Faraday, perfect octahedrons of magnetite can be occasionally secured, weighing several pounds (see Plate XXIII). An analysis of the magnetite, by M. F. Connor, from the corundum pegmatite of Craigmont, is included under I. Under II is the theoretical composition of magnetite.

	I	II
Silica and silicates	1·40	......
Fe_2O_3	65·04	69·00
FeO	30·60	31·00
TiO_2	2·50	....
H_2O	0·57	....
	100·11	100·00

PYRITE, PYRRHOTITE, AND CHALCOPYRITE.

All three of these sulphides have been noticed as constituents of the syenites. The pyrite is the most common. Under the microscope it is occasionally present in small defined cubes, but usually it occurs in rounded or irregular grains. The reddish brown stains so frequent in some exposures of the rock are due to the presence of this mineral in a more or less oxidized condition.

GRAPHITE.

This mineral is not, so far as observed, a frequent or abundant constituent, but it has been noticed in the coarse phase of the nepheline syenite exposed to the east of the York river, in Dungannon township. It occurs very pure, in small rounded shot-like forms, consisting of minute scales of this mineral arranged in a radiating or plumose manner. In certain portions of the rock at this locality graphite in this form is quite abundantly distributed. It has been noticed as an important and characteristic mineral in a certain variety of the nepheline syenite of Sivamalai, in India, described by Holland, where it constitutes 0.58 per cent of considerable masses of the rock.[1]

Holland explains its presence in this rock as due to its crystallization from fusion, and regards it as a primary constituent and older than the feldspar. This conclusion is also satisfactory as applied to its presence in the nepheline syenite pegmatite near the York river north of the Mississippi road.

[1]Mem. Geol. Surv. Ind. Vol. XXX, part 3, pp. 174 and 175.

CHAPTER VIII.

NOMENCLATURE, AND PHYSICAL AND CHEMICAL PROPERTIES OF CORUNDUM.

NOMENCLATURE.

The name corundum is only a modified form of the Sanskrit word "Korund". Woodward first in 1714 and again in 1728, refers to this mineral as corivindum or corivendum, doubtless derived from "Kurivinda" of the Hindu Puranas, a term used for a ruby of the second grade.[1] A great number of synonymous terms have been given to the different varieties of corundum, relating chiefly to differences of colour, hardness, purity, and structure. This multiplicity and consequent confusion in names arose in large part from a lack of knowledge of the true properties of the substances named or described. Many of these varieties were regarded by those who named them as distinct mineral species. The Greek sapphiros was not the sapphire but the lapis lazuli, as appears from the descriptions given by Theophrastus and Pliny. The blue sapphire is the hyacinthus of the Greeks and Pliny. The ruby was probably included in the anthrax of Theophrastus and the carbunculus and lychnis of Pliny. It is unnecessary to give a detailed list of the names applied to the different varieties of corundum, as reference may be made in this connexion to Dana's System of Mineralogy, Chester's Dictionary of the Names of Minerals, and also the Catalogue of Minerals and Synonyms by Egleston.

It is stated by Holland[2] that the Indian Empire can, with very good reason, be claimed as the home of this mineral, for not only are there numerous and extensive deposits of the com-

[1] Fossils of all kinds digested into a method suitable to their mutual relations and affinity. London, 1728.

[2] Econ. Geol. India, 2nd Ed. Pt. 1, Corundum, 1898, p. 1.

mon or "imperfect"[1] forms of corundum, but the finest specimens of the ruby or transparent red variety come from Burma, while the mines of Kashmir and Ceylon have furnished the best examples of the sapphire or blue variety.

The introduction of the gem material into England and Europe in the eighteenth century, mainly through the efforts of the East India company, at once attracted the attention of jewellers and lapidaries who, ignorant of their mineralogical and chemical affinities, proposed names already in use, prefixing to these the term Oriental. Thus we obtained the Oriental Topaz, Oriental Ruby, Oriental Amethyst, Oriental Emerald, and Oriental Aquamarine.

The early crystallographer, Romé de Lisle, seems to have been the first to suggest the close relationship existing between the various forms of corundum; but it was not until 1798 that the Rt. Hon. Charles Greville[2] named and described as corundum the crystallized form of the oxide of aluminium, and in an appendix to the same paper the Count de Bournon dealt fully and satisfactorily with its crystallographic characters. Häuy was the first (in 1805) to formally unite the three subdivisions under the name now generally accepted for the species.

VARIETIES OF CORUNDUM.

There are three divisions of corundum now known and recognized in the arts, which until early in the last century were regarded as distinct mineral species. It is now well understood that these occurrences are merely varieties of the same mineral, differing only in purity, state of crystallization, or structure: (1) sapphire; (2) corundum; (3) emery.

(1) *Sapphire* includes those transparent or translucent varieties, which possess good colour and are, therefore, suitable for use as gems. It has been customary to distinguish such material by colour. Thus the red is the oriental or true ruby; the blue is the sapphire; the yellow is the oriental topaz; the green is the oriental emerald; and the purple the oriental ame-

[1]Phil. Trans. Roy. Soc. London, 1802, p. 233.

[2]On the Corundum Stone from Asia, Phil. Trans. Roy. Soc. Lon. 1798, p. 403.

thyst. The star sapphire (asteria) is a variety showing a six-rayed star when viewed in the direction of the vertical axis of the crystal. The blue sapphire of Ceylon was called Salamstein by Werner. Barklyite is a more or less opaque magenta-coloured sapphire or ruby from Victoria, Australia. It was so named by Liversidge.[1] Chlorsapphire is a deep green variety occurring in bombs of a sanidine-gneiss included in an old trachyte-tuff at Königswinter on the Rhine.

(2) Corundum embraces those varieties having dull colour and not transparent, the colours being white, greyish, greenish, light bluish, or brownish.

The original adamantine spar from India has a dark greyish smoky brown (hair-brown) tint, but greenish or bluish by transmitted light, when translucent. The Armenian stone is supposed by King to have been corundum rather than emery.

(3) Emery is an intimate mixture of granular corundum, and magnetite or hematite, the first mentioned iron ore prevailing. It is of greyish black or black colour, sometimes mottled. Sometimes it contains an abundance of iron spinel or hercynite or pleonaste; tourmaline, chloritoid, muscovite, margarite, and calcite are other impurities, but these are relatively unimportant. The best Naxos emery has a dark grey colour with a mottled or streaked character, due to disseminated pure corundum. The emery from Samos is uniformly of a dark blue colour, while that from Nicaria is very similar in appearance to that from Naxos, often presenting a lamellar structure. The mixture of corundum and magnetite is usually so intimate that no separation is commercially possible. There are gradations in the texture of emery from what is uniformly fine-grained to varieties in which the corundum is in distinct crystals. Occasionally the iron spinel is so abundant that the emery passes over into a kind which is called spinel emery. It is softer, and thus less efficient as an abrasive than corundum emery.

The bulk of the material found in central Ontario is included under the second division, but some of the finer coloured translucent crystals found in the corundum anorthosite of the vicinity of the York river seem to encourage the hope that material fit

[1] Min. N. S. W. 1888, p. 198.

for gem purposes will yet be found. In the concentrating process an intimate mixture of magnetite and corundum is produced, which may be classified as emery.

COMPOSITION.

The theoretical composition of corundum is a sesquioxide of aluminium Al_2O_3 (oxygen 47·1, aluminium 52·9), but in nearly every instance analyses have shown the presence of small percentages of other constituents, mainly silica, water, iron oxide, and lime. Some varieties of corundum contain very little ferric oxide or silica, while in others 3 or 4 per cent of these constituents may be present. With the exception of the purest forms of the gem varieties all forms of corundum contain water, sometimes as much as 3 per cent.

In the following tables some analyses are given of the Canadian and foreign corundums. The first table includes analyses by Dr. J. Lawrence Smith.[1]

	Effective hardness	Spec. grav.	Water	Alumina	Mag. oxide of iron	Lime	Silica	Manganese.	Totals
Sapphire of India......	100	4·06	....	97·51	1·89	....	0·80	....	100·20
Ruby of India........	90	....	....	97·32	1·09	....	1·21	....	99·62
Corundum,									
Asia Minor	77	3·88	1·60	92·39	1·67	1·12	2·05	....	98·83
Nicaria....	65	3·92	0·68	87·52	7·50	0·82	2·01	trace	98·53
Asia.......	60	3·60	1·66	86·62	8·21	0·70	3·85	....	101·04
India......	58	3·89	2·86	93·12	0·91	1·02	0·96	....	98·87
Asia.......	57	3·80	3·74	87·32	3·12	1·00	2·61	....	97·79
India......	55	3·91	3·10	84·56	7·06	1·20	4·00	0·25	100·17

[1]Am. Jour. Sci. 2nd Series, Vol. XI, 1851, p. 54.

	Sp. Gr.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	H_2O	Insoluble	Totals	Analyst
Corundum, Dungannon.........	3·95	none	96·90	0·76	0·46	1·00	0·88	....	100·00	Connor
" Craigmont...........	3·95	none	95·58	2·10	0.48	1·00	0·84	....	100·00	Connor
" "	....	0·87	95·64	0·80	....	....	1·22	....	98·52	Goodwin
" Carlow..............	....	....	96·92	....	....	....	2·43	1·36	100·71	Lehmann
" "	....	....	96·26	0·36	..	....	1·93	....	98·55	Goodwin
" "	....	....	97·27	0·32	....	....	....	....	.....	Wells
Sapphire, Ceylon..............	....	....	99·33	0·92	....	....	....	....	100·25	Pfeil
Ruby, Burma..................	....	....	99·50	0·81	....	....	....	....	100·31	"
Ruby, Siam...................	....	....	99·42	0·92	....	....	....	....	100·34	"
Corundum, Perak [1]Malay peninsula	3·75–3·90	0·15	97·10	....	0·50	Tr.	2·41	....	100·16	....
Sapphire, Mudgee district, N.S.W.	3·59	....	98·57	2·25	0·45	....	....	....	101·27	Thomson
Ruby, Two Mile Flat, N.S.W.....	3·59	....	97·90	1·39	0·52	0·63	....	....	100·44	"

[1]Analysis by Dr. A. M. Thomson, Sydney University, of small slightly barrel-shaped hexagonal crystals, ¼ inch long and $\frac{1}{20}$ inch wide; opaque, peculiar lavender colour with a few dark blue spots.

The following is a list of analyses of corundum published by W. H. Emerson, of the Georgia School of Technology[1]:—

	Alumina	Mag. oxide of iron	Silica	Loss on ignition	Calcium oxide
Acworth, Georgia........	94·58	0·69	1·77	2·51	0·44
Iredell, N.C.	und.	1·97	0·69	0·45	und.
Macon co., N.C.	98·79	0·75	0·90	0·78	Trace
Sapphire mine, N.C......	und.	1·60	1·68	0·52	und.
Laurel Creek, Ga........	95·51	0·88	1·45	0·74	und.

A red to grey specimen of corundum from Shimerville, Lehigh county, Penna., was analysed by Edgar F. Smith with the following results:[2] alumina 85·75 per cent, ferric oxide 4·26 per cent, titanic oxide 2·74 per cent, silica 3·28 per cent, lime 1·99 per cent, water 1·37 per cent, magnesia trace.

The following list of analyses of emery accompanies Dr. J. Lawrence Smith's account of his investigations into the geology and mineralogy of the Asia Minor occurrences of this material:—

Analyses of Emery from Asia Minor and the Grecian Archipelago.[3]

Locality	Effective hardness	Spec. grav.	Water	Alumina	Mag. oxide of iron	Lime	Silica	Totals
Kulah...	57	4·28	1·90	63·50	33·25	0·92	1·61	101·18
Samos...	56	3·98	2·10	70·10	22·21	0·62	4·00	99·03
Nicaria..	56	3·75	2·53	71·06	20·32	1·40	4·12	99·43
Kulah...	53	4·02	2·36	63·00	30·12	0·50	2·36	98·34
Gumuch.	47	3·82	3·11	77·82	8·62	1·80	8·13	99·48
Naxos...	46	3·75	4·72	68·53	24·10	0·86	3·10	101·31
Nicaria..	46	3·74	3·10	75·12	13·06	0·72	6·88	98·88
Naxos...	44	3·87	5·47	69·46	19·08	2·81	2·41	99·23
Gumuch.	42	4·31	5·62	60·10	33·20	0·48	1·80	101·20
Kulah...	40	3·89	2·00	61·05	27·15	1·30	9·63	101·13

[1]Trans. Amer. Inst. Min. Eng. Vol. XXIX, 1900, p. 248.

[2]Am. Chem. Jour. Vol. V, p. 272.

[3]Amer. Jour. Sci. 2nd. Series Vol. X, 1850, p. 366.

Analyses of Emery from Chester, Mass., U. S. A.[1]

Effective hardness	Alumina	Mag. oxide of iron	Silica
33	44·01	50·21	3·13
40	50·02	44·11	3·25
39	51·92	42·25	5·46
45	74·22	19·31	5·48
..	84·02	9·63	4·81

The following are analyses and mineral contents of emery from Asia Minor by Tschermak:—

	SiO_2	B_2O_3	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	Ign.	Total	Sp.gr.
Renidi..	5·45	0·88	56·52	34·65	0·43	0·90	0·60	0·40	0·42	100·25	3·72
Kremno	5·64	1·15	57·67	33·36	0·83	0·43	?	0·31	0·70	100·09	3·98

TiO_2 was detected in both and CO_2 in the emery from Renidi.

	Corundum	Magnetite	Tourmaline	Chloritoid	Muscovite	Margarite	Calcite
Renidi....	50·00	33·00	9·00	4·00	3·00	....	1·00
Kremno..	52·40	32·10	11·50	....	2·00	2·00	....

The following relate to the composition of Grecian and Turkish emery (Jagnaux, Bull. Soc. Min. Paris 1884, 7, 161):—

	Corundum	SiO_2	Magnetite	Fe_2O_3	Total
Naxos........	64·20	2·00	26·80	6·9	99·90
Tyrus........	55·80	7·20	17·50	19·5	100·00
Symrna.......	56·10	7·00	11·00	25·9	100·00

[1]Amer. Jour. Sci., 2nd Series, Vol. XLII, p. 89.

DETERMINATION OF CORUNDUM IN AN ORE.

Most of these analyses of the corundum, especially of Canadian corundum, were conducted with material which was pure, for the most part, crystalline corundum. Sometimes commercial analyses of corundum are made to include the alumina, contained in aluminous minerals, which may accompany the corundum as impurities. In these circumstances a high content of alumina does not necessarily imply that the material is rich in corundum.

Pratt[1] in his account of the "Progress of the Corundum and Emery Industry during 1901," mentions the following method of determining the percentage of corundum in an ore, as used by Pratt and Boltwood of New Haven, Conn., which has thus far proved satisfactory. "The material is crushed in an iron mortar to pass through a 14-mesh sieve, and sampled; two grams of the sample are taken and treated with concentrated hydrochloric acid on the water bath for two hours. The residue is then filtered off, dried, and fused one-half hour with six grams of sodium carbonate mixture (two parts Na_2CO_3, one part K_2CO_3) in a platinum crucible over an ordinary Bunsen burner. The fused mass is extracted with hot water and the solution decanted through a filter. The residue is treated with a large excess of dilute hydrochloric acid, and this solution is decanted through the same filter. The filter paper is dried and ignited in a platinum dish, the residue from treatment with hydrochloric acid is added to the dish, and the whole is treated with an excess of concentrated hydrofluoric acid. The excess of hydrofluoric acid is removed by evaporation on the water bath, and the residue is treated with hot water and finally transferred to an ashless filter paper, which with its contents is dried, transferred to a weighed platinum crucible, ignited, cooled, and weighed. The increase in weight (residue) is calculated as pure corundum.

The following method is recommended by Mr. M. F. Connor of the Geological Survey of Canada, than whom perhaps no

[1]Mineral Industry Vol. X, 1891, p. 18, Corundum and the Peridotites of Western North Carolina N. C. Geol. Surv. Vol. I, 1905, p. 177.

one has had more successful experience in the analysis of these corundiferous rocks.

The method used for the determination of the percentage of corundum in these rocks is as follows. After first pulverizing the sample by the use of a hard faced steel hammer (say 3 pound hammer) on a hardened steel surface of plate 5 inches × 5 inches × 1 inch, and then grinding to a fine powder in a small agate mortar, the sample is weighed (1 gramme), and ignited for ten minutes in a platinum crucible, and placed in a platinum evaporating dish (say 200 c.c.). Water is added, also about 10 c.c. of hydrofluoric acid c.p. and 5 c.c. of sulphuric acid; place on the water bath and evaporate until the rock is thoroughly decomposed, and all silica evaporated from the solution, dilute, add a little hydrochloric acid if necessary to bring sulphates into solution; digest, filter, wash, and ignite; weigh as corundum. After some little practice the operator can judge as to the solution of the rock being thorough, etc. Fine grinding of the sample is required, although not too fine. In an accurate analysis, it must be remembered that the corundum wears the agate in the process of grinding, and the silica thus worn from the mortar and pestle becomes incorporated with the rock sample. This can be accurately allowed for by weighing the little mortar and pestle before and after the operation of grinding and distributing the loss over the total number of grammes of sample ground in the mortar.

Potassium bisulphate is required for the solution of corundum if it is found necessary to analyse the corundum itself.

In the estimation of the corundum there is a slight attack of the corundum by the hydrofluoric and sulphuric acids. This is best determined by the operator himself by taking selected, pure crystals of corundum, and making an analysis of the material before and after treatment (bearing in mind as above mentioned, correction for silica taken up from the agate mortar).

In the analysis of the corundum itself, two acetate separations with an ammonia precipitation to separate any alumina from the filtrates will give good results. The lime and magnesia may then be determined. If it suits the purpose for which the analysis is made, the alumina may be approximately determined by subtraction of water, iron, oxide, lime, magnesia, and silica percentages from 100 and thus avoiding a long washing of the extremely bulky alumina precipitate.

Another means of determining the purity of commercial samples of grain corundum is by means of Röntgen X Ray photographs. Doelter[1] has shown that ruby, spinel, and garnet, can be distinguished from one another by means of their relative degree of translucency. Thus the ruby and other forms of corundum are practically transparent (Degree 2 of Doelter); spinel is barely translucent (Degree 5), and the garnet nearly opaque (Degree 7), when treated with the X Rays. Miller[2] has made some X Ray photographs illustrative of the transparency of grains of corundum. For contrast he introduces an X Ray photograph of so-called grains of ruby corundum from the southern United States, which must be grains of garnet, as they are almost opaque.

CRYSTALLINE STRUCTURE.

Corundum crystallizes in the rhombohedral division of the hexagonal system. The crystals, when normally developed, are usually six-sided prisms, which are sometimes terminated by a six-sided pyramid, and occasionally by the basal plane. Many of the crystals found in Ontario, especially in the nepheline syenite, have a tolerably sharp and perfect outline, frequently showing a tapering to either extremity, thus producing the very characteristic barrel-shaped outline. The pyramidal and prismatic faces are very often more or less deeply striated or grooved horizontally. The basal planes or truncated ends of the crystals are frequently striated in the directions forming equilateral triangles, corresponding with the less perfect rhombohedral partings or pseudo-cleavages, or divided into sections by lines radiating from the centre (see Plates XVII, XVIII, XIX).

Some of the crystals in the red syenite exhibit a tabular habit, which was considered by Lagorio[3] a characteristic feature

[1]Neues Jährbuch für Min. etc. 1896, Vol. II, p. 87.

[2]Ann. Rep. Bur. Mines, Ont. Vol. VIII, 1899, p. 217.

[3]Prof. A. Lagorio "Pyrogener Korund dessem Verbreitung and Herkunft," Zeit für Kryst. Band. XXIV, pp. 285-296, 1895.

of pyrogenetic corundum. Many individuals, especially the smaller grains noticed in the thin section under the microscope, show an extremely irregular outline with a border more or less continuous, and of varying width, of the pale-coloured and brilliantly polarizing muscovite. These rough exteriors are due, no doubt, in large part at least, to magmatic resorption, while the micaceous borders have been produced by the action of the magma as already explained. When the crystals are large they are usually rough and imperfect. Interpenetration twins are rare, but polysynthetic twinning is very common, parallel to the rhombohedron and giving rise to the frequent lamellar structure, as well as pseudo-cleavage. "Perfect" corundum, as the sapphire and other transparent gem material is often called, breaks with a conchoidal fracture like that of quartz, showing little or no signs of cleavage planes. But the darker coloured varieties of the Ontario corundum show a tendency to break in three series of directions, which are parallel to certain crystal planes. Thus there is a very marked tendency to split parallel to the basal plane, sometimes also parallel to the faces of the rhombohedron and less frequently and more imperfectly parallel to the faces of the hexagonal prism. Prof. Judd[1] has shown that these are in reality parting planes that are not due to true cleavage but that these directions, which are gliding or twinning planes, become also "solution planes", along and in the vicinity of which the mineral undergoes certain chemical changes. This is the cause of the pearly lustre seen most frequently in the light coloured varieties, as also the distinct, bronze-like, metallic lustre characteristic of the so-called cleavage planes. The mechanical stresses to which the containing rocks have been subjected have, no doubt, aided largely in the production and accentuation of these planes, and contributed to the fact that Ontario occurrences are of the "imperfect", or common form of corundum rather than the "perfect" and much more valuable gem varieties.

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[1]Mineralogical Magazine, Vol. XI, p. 49, 1895, also Trans. Roy. Soc. Lond. Vol. 187, p. 226.

FRACTURE.

Unaltered or "perfect" corundum, especially the gem varieties of this mineral, show little or no development of the parting planes or pseudo-cleavage, breaking with a hackly or conchoidal fracture. This irregularity in fracture is a very desirable quality in corundum, as it not only gives assistance to the binder, but in wearing away constantly presents good cutting as well as durable edges to the component grains.

HARDNESS.

The exceptional hardness of corundum is the quality which, in the main, determines its value as an abrasive. Next to the diamond—which is 10 on Mohs' scale—it is the hardest mineral known. It has long been recognized, however, that the several varieties, and even individual specimens of the same variety, show a considerable diversity in this respect, dependent in the main, it is believed, on the state of purity of the mineral, chiefly in regard to the amount of contained water. Thus the blue sapphire will scratch the ruby, and this in turn will mark the ordinary forms of the mineral.

SPECIFIC GRAVITY.

The specific gravity of corundum varies from 3.95 to 4.10; sapphire and ruby being, in general, about 4. The average density of selected, clear, finely coloured gems from Burma, according to Professor Judd, was found to be 4.03. Most of the associated red corundums of Burma, however, have a considerably lower density; and one showing marked alteration was found to be as low as 3.74. Of sixteen different specimens of sapphire examined by Count de Bournon, the average specific gravity was 4.016; of twenty specimens of ruby 3.977; and of thirty-three specimens of common corundum 3.931. The specific gravity of corundum from Canada, lot 3, concession XVIII, of Raglan township, varies according to Mr. Instant, from 3.945 to 3.976. Other specific gravities conducted on carefully selected material from the same locality range from 3.92 to 4.02, with an average of 3.95. The blue corundum occurring on lot 12, concession XIV, of Dungannon township, range from 3.93 to 4.01 with an average of 3.95. This high specific gravity is a very important characteristic for it is this superior density over the associated minerals (except magnetite) that is made use of to effect concentration from the Ontario occurrences.

LUSTRE AND COLOUR.

The lustre of corundum is adamantine to vitreous; but in the translucent light greenish variety from Brudenell township the lustre is somewhat pearly. In a great many instances the surfaces revealed by the basal parting showed a distinct bronze-like metallic lustre, resembling very much in this particular that of the cleavage planes of bronzite.

The several varieties of corundum differ greatly in colour, even in individual crystals or masses. The commoner forms, as might be expected, exhibit similar colours to the gem varieties; but advance in decomposition has produced the more or less dull tones usually noticed. The colour of the corundum in the red syenite is, in general, brownish, deep greenish, or greyish. In the nepheline and other allied syenites it is blue, white, pale greenish, yellow, and occasionally rose red.

Frequently the colour is not uniform, but patches of grey, brown, and green, blend into each other. Many of the crystals, especially those present in the nepheline syenite exposures in the vicinity of the York river, show an irregular or cloud-like arrangement of the colour material, shading off from deep azure blue, through pale blue, to colourless. Occasionally crystals exhibit a very decided and beautiful zonal arrangement; Pleochroism and asterism, sometimes characteristic of the gem varieties, are not common in the Ontario specimens.

OPTICAL PROPERTIES.

Pleochroism is very strongly marked in the deep coloured varieties of corundum, especially rubies and sapphires. The action of the Röntgen or X Rays with corundum gems is a means of distinguishing them not only from other minerals, which resemble them, but also from artificial stones. Doelter has arranged minerals according to their permeability to the passage of the X Rays. The diamond allows the rays to pass through it the most readily. Corundum is next in order and the free passage of these rays through sapphire and ruby serves to distinguish these gems from spinel garnet and other gem minerals which they sometimes resemble. Corundum is uniaxial and negative. It has a high index of refraction, but a low double refraction and in good thin sections the interference colours do not exceed red of the first order.

Good thin sections are, however, rare on account of the relatively much greater hardness of corundum than the surrounding minerals. These latter may be thin enough, while the corundum grains, as may be seen in sections from which the cover glass has been removed, are in considerable relief, the result of their resistance to the grinding operations. As a consequence, therefore, the corundum is given a higher double refraction, as well as index of refraction, than it actually possesses. Most thin sections, therefore, of this mineral show brilliant chromatic polarization between crossed nicols.

The double refraction is only about 0·008 to 0·009 or about the same as quartz.

ALTERATION OF CORUNDUM.

Most of the Ontario corundum is practically pure especially for all purposes for which this mineral is commercially valuable. The loss of transparency, however, and the creation of parting planes or pseudo-cleavages are clearly the result of the development of other and allied aluminous minerals, constituting for the most part only an incipient replacement of the more desirable corundum by thin films of these softer and less valuable compounds. The most abundant mineral in intimate association with the corundum in Ontario is a very beautiful and pure pearly white muscovite (see Plates VII, XX, XXI) and every gradation in the process of the replacement of the corundum by this mineral may be seen from those occurrences in which the comparatively pure crystals are penetrated or coated with thin films, or scales, of this mineral to others in which the whole individual has been replaced by the muscovite. The circumstances under which this replacement, or seeming alteration, takes place have not been satisfactorily explained. These peculiar conditions are, moreover, often present in comparatively fresh and unaltered rocks, where the surrounding constituents have undergone little or no perceptible change. In addition it is well known that corundum is one of the most unalterable of substances, when subjected to ordinary processes of weathering and this fact receives the strongest support from the Ontario occurrences.

It would seem, however, that in most cases, at least, the minerals associated with the corundum, and described as alteration or decomposition products of this mineral, are in reality true independent species, owing their development to the same process, or series of processes, as the corundum itself. It is believed that in the earlier investigations of the origin of corundum undue prominence was given to the chemical side of the question, while the association or larger field relations of the various occurrences were almost entirely ignored.

Full details regarding the alteration products of corundum are considered by Dr. F. A. Genth in a series of papers communicated to certain scientific journals.[1] With the assistance of various salts dissolved in circulating waters, he urged that the decomposition of corundum may be so modified as to produce a considerable number of other minerals, concluding that these have all been formed by epigenetic processes. The list includes gibbsite, spinel, tourmaline, cyanite, fibrolite, andalusite, pyrophyllite, muscovite, paragonite, chloritoid, margarite, zoisite, various vermiculites and chlorites, and even the associated feldspars. Although not positive about the derivation of feldspar from corundum, he asserts that "there are cases where

[1]Corundum, "Its Alterations and Associated Minerals." Con. Lab. Univ. Penna. No. 1, 1873, Proc. Am. Phil. Soc. Phila. Vol. XIII, 1873, pp. 361-406; Vol. XIV, 1874, pp. 216-218· Vol. XX, 1882, pp. 381-404; Am. Jour. Sc. 3rd Series, Vol. VI, pp. 461-462.

feldspar has been formed from corundum and it is very probable that many may have thus been formed but at the same time a portion of the alumina recrystallized as corundum, which we then find embedded in the feldspathic matrix."

Chatard[1] in summarizing his conclusions in relation to the origin of the corundum at Corundum Hill, N.C., states that "it is difficult to resist the conclusion that the chlorite now found with the vermiculite is not the residue of a process which has converted the rest into vermiculite." Further on he also mentions that "both damourite and margarite are found enveloping corundum, the outlines of the mass closely imitating the form of the enclosed crystal, so as to be easily mistaken for a true pseudomorph, and yet both of these minerals occur with corundum in such a manner that it is hardly possible to conceive that they are derived from it.

The same may be said of the associated lime-soda feldspars which, in general, present all the appearance of a gangue and not of an alteration product."

It has been stated with emphasis that corundum is one of the most refractory of minerals, suffering little or no decomposition in the presence of ordinary atmospheric waters. Insoluble even in the strongest acids, it is not altogether unattacked by them. Thugutt[2] found that corundum suffered appreciable hydration with water heated to about 230 degrees. After treatment in this manner for 336 hours, the product showed the presence of 5.14 per cent of combined water. Even at 100 degrees in an open vessel some water was taken up. Prolonged treatment with $K_2Si_2O_5$ converted it into a substance having the composition of orthoclase, while sodium silicate produced a compound resembling analcite. By water alone corundum may be transformed into diaspore (H AlO_2) which is one of its frequent associates.

It is, therefore, conceivable that although some of the minerals associated with corundum are doubtless secondary, they are not necessarily due to the direct transformation of corundum. The envelopment of one mineral by another does not necessarily

[1]Bull. 42 U.S. G.S. 1888, pp. 62-63.
[2]Mineralchemische Studien, Dorpat 1891, p. 104.

establish the derivation of the second mineral from the first. Hunt[1] in commenting on the results of Genth's researches on corundum and its associated minerals is very emphatic that all the phenomena described are nothing more than examples of association and envelopment.

There can be no reasonable doubt that such changes are not the result of any process of weathering. On the other hand the evidence available, from a critical and extended examination of the Ontario deposits, points to the conclusion that the apparent alteration is closely connected with some phases of pneumatolytic or vein action accompanying the solidification of the enclosing rock from the molten magma. The extreme phases of such alteration are best seen in the pegmatitic or coarser varieties of the syenites, although examples are not lacking in the finer-grained portions of this rock. Indeed it seems to belong to the same class as that which gives rise to the "corona" or "reaction rims", which so frequently surround some of the earlier formed minerals in many plutonic rocks. Thus Williams,[2] in the hypersthene-gabbro of the Baltimore district, mentions that both the hypersthene and diallage are surrounded by a double rim of hornblende, interposed between the pyroxene and the feldspar, and due to a reaction between them. The inner zone of the rim is of fibrous, the outer of compact hornblende. They are apparently the beginning of a process by which the pyroxene is eventually wholly transformed into the green hornblende. Adams[3] noticed in the norite of the Lake St. John region, that a double rim, or border, of hypersthene and hornblende intervenes between the plagioclase and olivine. The former minerals have an intermediate composition between that of olivine and plagioclase, so that there is a progressive increase in lime and decrease in magnesia in the composition of the several minerals in going from the olivine to the plagioclase. Williams explains that these rims are produced before

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[1]Proc. Nat. Hist. Soc. Boston, Vol. XVI, 1873, pp. 332-335.

[2]Am. Jour. Sci. XLIII, pp. 515-518 (1892); Jour. of Geol. Vol. 1, pp. 702-710. (1893).

[3]Can. Rec. Sci. (1891) p. 357, Zirkel Lehr. der Pet. Band 1, p. 360; Harker Petrology for Students, p. 74.

the complete solidification of the rock from the molten magma. The alteration in the case of the Ontario corundum is always to muscovite, and this mineral may be considered chemically as orthoclase + corundum + water. Morozewicz has shown that a magma, such as that which on cooling gives rise to a soda-syenite, has the power to dissolve alumina, and on cooling to separate it out completely. In all these acid magmas water is believed to be present in considerable amount. This water is, in addition, in many minerals, believed to play the part of a base, replacing K_2O or Na_2O, as in the micas. The presence of this water, together with an excess of Al_2O_3 in the magma would, in these circumstances, tend to prevent any production of sillimanite along with the corundum. As the corundum separated out and the water of the magma was partially dissipated, the latter would tend to approach more nearly to the composition of a mass of fused feldspar plus a less amount of water. At this stage, and on account of some condition or change of conditions, this residual magma attacked the corundum and partially re-dissolved it, the hydrous feldspathic magma, together with the Al_2O_3 from the dissolved corundum, making muscovite, which crystallized around the corundum, according to the following formula: K_2O, Al_2O_3, 6 SiO_2 = orthoclase + 2 Al_2O_3 = corundum + 2 H_2O = K_2O, 2 H_2O, 3 Al_2O_3, 6 SiO_2 = muscovite.

This would likewise explain the marked prevalence of this alteration in the pegmatitic facies of the syenites, for it is in these residual differentiated portions of the magma that water plays such an important part in the process of crystallization.

CHAPTER IX.

THE ABRASIVE EFFICIENCY OF CORUNDUM.

The fact that corundums from different localities exhibited, within certain limits, considerable diversity in their relative degrees of hardness was well known and definitely stated by all of the earlier investigators into the properties of this mineral. The reasons stated for such discrepancies were in general agreement and believed to be directly traceable to the presence of certain impurities, chiefly hygroscopic moisture. Dr. Smith, in his examination of the emery of Asia Minor, was impressed by the fact that although the relative degree of hardness in a mineralogical sense was not a very difficult matter to determine; still the possession of this information conveyed no very adequate idea of the grinding properties of the substance. In every instance where close attention was given to the rubbing of the emery against any hard substance, such as agate or glass, it was noticed that it was only when projecting points of corundum were encountered that the grinding or scratching results were adequate and substantially the same, while contact with the intervening spaces occupied by the more impure intermixed material produced little or no effect. The knowledge, therefore, of the relative hardness, according to Mohs' scale, was of no great practical importance. The same principle was found to govern, though in a less degree, occurrences of corundum. It has, therefore, been concluded that although the abrasive power of any mineral is dependent primarily on its hardness, the possession of certain other peculiar qualities is essential before such material can be regarded as of the first rank for grinding purposes. These qualities relate chiefly to certain properties of cohesion, determined mainly by the absence of planes of pseudo-cleavage or parting, the possession in a strong degree of toughness and the power of disintegration under pressure into "shotty" fragments rather than into long, flat, or plane-bounded pieces.

The popular idea that all corundums are nearly, if not quite, equally effective for all purposes for which abrasives are used has never received any support whatever from the experience of wheel manufacturers and others who daily employ such material in their business. The possession of this information by such interested parties has, at last, brought about the conviction that the adoption of some recognized and uniform standard is imperative before the abrasive industry can be established on a proper economic basis, and thus prevent much of the wholesale misrepresentation and adulteration so long and openly practised. The establishment of reliable tests would, at least within certain limits, determine the comparative efficiency and, therefore, relative value of any abrasive which may be offered on the market. Dr. Smith devised a simple, yet within reasonable limits, a very effective method of determining the "effective hardness" of emery corundum. Fragments of the material to be tested are placed in a diamond mortar and crushed with two or three sharp blows of a hammer. This is thrown into a sieve (having about 400 holes to the square centimetre). The portion passing through this screen is collected and the larger fragments returned to the diamond mortar to be again crushed in the manner described. These operations are repeated until a sufficient quantity (about a gramme) is obtained. The object of this peculiar and slow method of crushing is to avoid the production of an undue proportion of fine dust or "flour". To test the abrasive efficiency of the mineral thus pulverized, a circular piece of glass, about 4 inches in diameter, and a small agate mortar were used. The glass is first weighed in a delicate balance and placed on a piece of glazed paper. The fine material is then applied, little by little, rubbing it against the glass with the bottom of the agate mortar. This grinding operation is continued until the abrasive is reduced to an impalpable powder which has little or no effect on the glass. The glass is then weighed and the loss noted, the latter being considered a measure of the effective hardness. Glass and agate were chosen only after certain detailed experiments, using two surfaces of agate, two pieces of glass, or metal and glass in combination with one another. The agates were found to be too hard, and the emery was crushed with very little abrasive effect. The other substances mentioned were found on the other hand not to crush the emery sufficiently, making the experiments too tedious and long. Glass and agate gave, on the whole, by far the best results, the portion of the glass abraded in a reasonable time being sufficient for weighing purposes and thus more capable of accurate comparison. The results obtained by Dr. Smith are included in the table of the composition of the different corundums and emeries examined by him (see page 124).

Probably the most comprehensive series of experiments in regard to the abrasive efficiency of corundum were those undertaken at the suggestion of Dr. David T. Day, of the United States Geological Survey, by Prof. W. H. Emerson of the Georgia School of Technology, Atlanta, Ga.[1] These investigations were prompted by the discovery of corundum of markedly inferior quality for manufacturing purposes at Acworth, Ga. The specimen was received at the Geological Survey of Georgia in the summer of 1894 with the request that it be analysed to ascertain whether this inferiority was due to some peculiarity of composition. In general appearance it resembled other corundum, although rather easily scratched with a knife, while at the same time it abraded agate easily. The analysis already given (see page 124). showed nothing unusual beyond a rather excessive water content (2.51 per cent), the amount commonly present in southern corundum varying from 0.3 per cent to about 1 per cent. The opinion that an undue amount of water impairs the hardness of corundum has been successively held by all observers ever since the appearance of the celebrated memoir on this mineral by the Count de Bournon in 1802. Moreover, Dr. Smith, as a result of his tests in 1850 in regard to the "effective hardness" of corundum, has concluded that "other things equal those containing the least water are the hardest."

The experiments, therefore, undertaken by Prof. Emerson were to ascertain more definitely, if possible, whether any relation could be traced between the amount of water and the ab-

[1]Am. Inst. Min. Eng., Vol. XXIX, 1900, pp. 230-248.

rasive efficiency. Twelve samples, in all, were submitted to the tests, and these varied in total water contents from 0.36 per cent to 2.89 per cent, the latter being the specimen from Acworth, Georgia. With one exception, of which the locality was unknown, the samples were obtained from well-known deposits in Georgia and North Carolina. The material to be tried was first carefully freed from decomposition products or gangue, then pulverized in a diamond mortar and screened through an 80-mesh sieve, in the same manner as advised by Dr. Smith, until enough of the pulverized material had passed through the sieve for the purposes of the test. This powder was freed from iron by very dilute nitric acid. Of the original sample, 0.7 of a gramme was weighed and divided roughly into four equal parts. Each part was ground for twenty minutes on a weighed glass plate with the bottom of a small agate mortar. The plate was then washed and weighed, and its loss in weight divided by the weight of the corundum was taken as the effective hardness. It was found impracticable to pulverize the mineral until it ceased to abrade the glass. Repetition of the test with the same corundum occasionally varied as much as 10 per cent. As a result of these experiments it is concluded that while there is some relation between the amount of water and the effective hardness, it is not intimate enough to permit the estimation of one from the other, though it would appear from Dr. Smith's results and those of Prof. Emerson, that where water is very high—say over 2 per cent—the effective hardness is likely to be very low. Trials of corundums deprived of their water by heating tended to prove that "heating to a high temperature slightly increases the effective hardness."

The value, therefore, of Dr. Smith's method was not seriously doubted for many years, but lately such men as T. Dunkin Paret and Dr. H. S. Lucas, recognized authorities on the subject, have stated their conviction that although the Smith test unquestionably gives the relative values of corundum when used in loose or grain form, it is practically valueless in predicting the true efficiency of such material when moulded into wheels.

The publication by Mr. Paret[1] of these views induced Prof. Emerson to continue his experiments, as he was fully impressed

[1]Jour. Frank. Inst., Nos. 5 and 6, 1894.

with the fact that in fixed corundum "the force is applied in an entirely different way, and the relation between the resistance to stresses so differently applied may not be the same in different corundums." Small cylinders of various corundums were made by using a No. 16 paper shell as a mould. The grain corundum used was obtained by passing the pulverized material through an 80-mesh and catching on a 100-mesh screen. The materials of the cement used were water glass and a strong solution of mixed chlorides of calcium, magnesium, and iron. The abrasometer employed consisted essentially of a soft steel plate fitted with a small box fitted to the top of the rotating spindle of a centrifugal machine so that it was horizontal. The test piece was pressed upon the surface of the plate by means of an adjustable arm with a weight of 3.25 pounds and the plate rotated with a speed of 300 revolutions to the minute. The test piece was moved at frequent intervals to allow of the grinding of the whole surface of the plate. It is to be regretted that the results obtained were not so conclusive as might have been expected, and three reasons are cited for the discrepancies noted: (1) thinning of the plate; (2) change in the plate from exterior to interior, possibly due to cooling after rolling or cold rolling; (3) the actual physical effect of "cold work" upon the plate modifying its properties.

As a result of these tests, however, it appears that the efficiency of corundum is not connected—at least not closely—with the composition and also that Smith's test is valueless, as a means of determining the efficiency of corundum when applied in a fixed state instead of a powder.

It is, therefore, apparent that the method of testing any abrasive must be determined by the manner in which it is intended to be used. The different manner in which corundum is employed may be summarized as follows: (1) loose; as grain corundum of the various degrees of texture. (At the Craig mine of the Manufacturers Corundum Co., 18 grades are manufactured, varying in texture from 12-200.) (2) As a cloth or paper. (3) As solid wheels.

The simplest, and yet for all practicable purposes the most reliable method of testing the efficiency of material to be used in either of the two first mentioned shapes has already been fully described as advised by Smith and Emerson.

One convenient method, which with certain modifications is employed for testing corundum wheels, and which with some necessary pirecautons gives fairly accurate and concordant results, is as follows: an iron piece of suitable length and say $\frac{3}{8} \times 1$ inch in area, is held perpendicular to the face of the wheel between guide rolls, and a uniform degree of pressure obtained by the use of a weighted lever arm or rest. The number of revolutions of the wheel required to cut into the iron to a depth say of one-half an inch, multiplied by its diameter in feet gives the number of running feet or miles which forms the basis of comparison.

Another methodconsists in the employment of what may be called an abrasometer, consisting of an abrasion block of known hardness and suitable shape. This is held against the corundum wheel with a constant pressure, the wheel being rotated at a given rate of speed. By a determination of the exact weight of the abrasion block and wheel before and after the test, a standard of comparison is secured which may be compared relatively with a number of the other wheels of similar dimensions, or of some standard pattern previously tested in the same manner. The loss in the weight of the wheel is usually neglected as too insignificant.

A very interesting series of tests from a commercial point of view was carried out some years ago by Mr. C. N. Jenks of Asheville, N.C.,[1] under special conditions aiming to secure the utmost degree of uniformity and completeness in results, so as to permit of accurate and definite comparison. The wheels to be submitted for competition were to be of the same size (12 inches in diameter and $1\frac{1}{2}$ inches face); similar grain or number of mesh, and each number was to constitute a series of tests. The wheels were also to be made by the same formula and thus possess a like degree of hardness, and were to be mixed, moulded, and handled by the same workmen, under the same supervision. Each lathe was to carry two wheels on the same spindle, thus securing uniformity in speed during the trial, while the feed

[1]Min. Industry, Vol. IV, 1895, pp. 16-17.

and pressure were automatic. The speed varied from 1,200 to 2,500 revolutions per minute and the pressure from $5\frac{1}{4}$ pounds upward, as seemed desirable to secure the best results. The metals employed were Jessop tool steel in bars $1\frac{1}{2} \times 1\frac{1}{2}$ inches, and cast iron in bars 1 inch square. As a result, Mr. Jenks gives the following list in the order of efficiency of abrasives when made into cement wheels: diamond; North Carolina corundum (Jackson county); North Carolina and Georgia corundum (standard) Chester (Mass.) corundum (emery); Turkish emery (best); Bengal, or so-called India corundum and a few other foreign emeries; Naxos emery; Peekskill (N.Y.) emery-garnet, best North Carolina occurring in chlorite matrix; carborundum; preparations of crushed and chemically prepared steel grains; best flint, quartz crystal, and ordinary garnet; common quartz, flint, buhr stones, sand, etc.

The advantage of securing some reliable series of comparative tests, which would enable a more accurate judgment to be reached in regard to the relative value of the Ontario corundum, was brought to the attention of the Director of the Bureau of Mines of Ontario soon after the deposits in this province had been proved to be of economic importance. A quantity of grain corundum, obtained from the original locality in Carlow township (lot 14, concession XIV), milled and graded in the laboratory of the Kingston School of Mines, was submitted to the Hart Emery Wheel company of Hamilton, Ontario, for a test of its abrasive qualities.[1] The trials were conducted on wheels 12 inches in diameter, and from $\frac{3}{4}$ to 1 inch in thickness. The wheels were placed on opposite ends of the same arbour, one made of the Hastings (Ontario), corundum being placed on one end, the other being occupied by discs made of North Carolina corundum or carborundum. The speed was 1,700 revolutions per minute, and the abrasive blocks used were composed: (1) brass; (2) cast iron; (3) wrought iron; and (4) cast steel. These trial bars were about 1 inch by $\frac{1}{2}$ inch in size. The company under date of March 2, 1899, report to the Director having made 23 comparative tests. Four of these tests described as made with Hastings "Special" are not included, as no statement is

[1]Ann. Rep. Bureau of Mines, Ont., Vol. VIII, 2nd part, pp. 238-239.

made by the company as to what is meant by the material thus designated. In the comparative test on brass of Ontario corundum and North Carolina corundum the former showed an excess of one-half ounce ground in 3 hours. The two comparative tests on brass between the Ontario corundum and carborundum show some large discrepancies which need explanation before they can be accepted. The evidence available, however, was largely in favour of carborundum. Four tests were made with the cast iron on wheels made of the Ontario and North Carolina corundum respectively. In the longer of these tests, lasting three hours, the Hastings corundum showed the net amount ground of 8¾ ounces, while the North Carolina corundum showed only 3½ ounces ground in the same time. An analysis of these tests shows that the North Carolina wheels, although cutting with greater rapidity than the Ontario corundum, have a tendency to "glaze" or become more or less "greasy," thus requiring frequent dressing, while, on the other hand the Ontario corundum has the very valuable property of the grains disintegrating in such a manner as to constantly present new cutting edges to the material to be abraded (see Plate XXIV). In a comparative test between Ontario corundum and carborundum on cast iron, lasting an hour, the net amount ground was the same in both cases (2¾ ounces). In the comparative tests between the Ontario and North Carolina corundum on wrought iron on the one hand, and again between Ontario corundum and carborundum on the other, the results are certainly very unsatisfactory and far from uniform, so that they need not be considered as proving anything in favour of, or against, the Ontario corundum.

In the two comparative tests between wheels of Ontario corundum and North Carolina corundum, made on cast steel and maintained for 1 hour and 2 hours respectively, the result was, in the first instance, identical (3 ounces), while in the second instance the net amount ground by the Ontario corundum was 4½ ounces to 3½ ounces ground by the North Carolina wheel. In the comparative test between wheels made of Ontario corundum and those made of carborundum, on cast steel, and maintained for a total period of eight hours, the former showed the net amount ground to be 19 ounces, while the latter showed only 5¼ ounces, being an excess of 13¾ ounces, or 262 per cent. In addition the Ontario corundum showed very rapid abrasion all through the test, thus proving conclusively the vast superiority of wheels made from Ontario corundum for sharpening tools and all implements made of steel.

Tests of this kind almost always show a similar and in some cases wider variation in results, so that no particular abrasive or class of abrasives can be claimed as universally more efficient than all others. Careful consideration of the kind of work to be done is always necessary, but for the general purposes of abrasion it may be said that corundum will be found the most satisfactory.

The superiority of Ontario corundum for all abrasive purposes is now acknowledged by all who have made use of this material, and if ordinary precautions are taken to secure a uniform product approximating as closely as possible to 95 per cent of pure corundum, there can be no doubt of its replacing much at least of the other abrasive substances now in use. So far none of the blue and white corundum occurring in the large deposits situated in the townships of Monteagle and Dungannon have been cleaned and graded into grain corundum, and it is expected that this evidently very pure corundum will make a still more efficient abrasive than the justly celebrated Craig mine crystal corundum.

The late Richard P. Rothwell thus concludes his article on "The Testing and Relative Efficiency of Abrasives"[1]: "The rapidity of grinding and the consequent economy of work of an abrasive or abrasive compound, other things being equal, is proportional to the hardness of the abrasive and to its facility of so disintegrating that new cutting edges are continually presented to the surface to be abraded. Other elements to be considered are high speed under pressure, heat, chemical changes, and the retention by the wheel of impurities contained therein through disintegration. These factors determine the durability and efficiency of any abrasive agent, and especially its continuous and rapid cutting abilities, which are the real measure of its value."

[1] Min. Ind. Vol. IV, 1895, pp. 15-18.

CHAPTER X.

USES OF CORUNDUM.

Corundum is the richest ore of aluminium, and from time to time mention is made of its proposed use for the production of this metal. Various difficulties have up to the present operated against its employment in this particular. The real difficulty consists in the fact that corundum is far more valuable as an abrading agent than as a source of aluminium, and this condition of affairs will doubtless continue as long as there are the sufficient supplies of the softer hydrated oxides such as bauxite. Besides there is the additional expense of grinding the corundum after concentration, into an impalpable powder to permit of its easy solution in the bath. In the concentration of the Ontario corundum, repeated and earnest attempts were made by the use of various refinements of treatment to produce a grade of sufficient purity to meet the requirements of the aluminium makers. Prof. de Kalb succeeded in these experiments in obtaining a product which contained over 99 per cent pure corundum with 0.4 per cent silica and 0.39 per cent ferric oxide. Grains of corundum selected from such high grade concentrates with the assistance of a lens to ensure freedom from adherent silicates showed 0.07 per cent silica and 0.36 per cent ferric oxide, the original ore containing about 5 per cent of magnetite. Canadian corundum according to the analysis available contains from 0.32 to 2.10 per cent ferric oxide. Wells found from 0.05 to 0.09 per cent of silica in the corundum from Carlow township, while Connor reports the complete absence of silica from the corundum of Craigmont and Dungannon. Goodwin detected 0.87[1] per cent of silica in the corundum examined by him from Craigmont.

[1]As shown by Connor, much of the silica at least in these circumstances may have been obtained during the grinding of samples in agate mortars. Experiments showed that about 0.3 per cent is introduced from abrasion of the sample powder in ordinary rock (silicate) samples. Corundum-bearing

The standard required by the aluminium manufacturers is stated to be not more than 0·10 per cent silica, and not more than 0·05 per cent ferric oxide. If, therefore, this present high standard is maintained by the manufacturers, even the richest concentrate of our corundum will have to undergo considerable further purification before it can enter into competition with similarly refined bauxite. Such further refinement is, no doubt, quite possible by a further reduction in the grain of the corundum concentrate, but under present conditions there appears to be but little hope of the early use of corundum for the manufacture of aluminium.

Corundum has also been used as a source of the aluminium in the manufacture of aluminium-copper and aluminium-iron alloys. In the production of these, the corundum, without special previous treatment, was charged into an electric furnace with a mixture of carbon and copper, or copper and iron, according to whether aluminium, bronze, or ferro-aluminium was wanted. Since the year 1890, however, this practice has not been followed, and the artificial oxide made at a comparatively low cost and regarded as more suitable for this purpose, has taken its place.

The comparatively limited market for corundum as an abrasive, and the danger of over production was in the earlier years a source of anxiety to manufacturers of this material, and repeated inquiries and experiments were made with the object of extending its use. In the granting of certain concessions and special privileges by the Ontario Government to the Canada Corundum company, one of the stipulations agreed upon by both parties was to the effect that the company was to undertake to expend $1,000 per year for three years for the purpose of making a series of experiments to discover some method or methods for the production of materials of commercial value from corundum-bearing rock, other than grain corundum, special attention to be given to the production of the metal aluminium. Some experiments with this latter object in view

rocks showed the presence of from 1.00 to 3.50 per cent of silica obtained in this way. M. F. Connor. "Some notes on Rock Analysis" Congress Geol. Int. 12th Session, Canada 1913, 6 pages.

have certainly been made, making use not only of the corundum but also of the associated alumina-rich silicate-nepheline. The exact nature and progress of such experiments are by the terms of the agreement, of a confidential nature between the Canada Corundum company, and the Ontario Government, although it was stipulated that a report covering such research work was to be presented to the proper authorities on the first of July in each year. The only interim report which has so far appeared is that furnished by Mr. B. A. C. Craig, who concludes[1]. "The production of aluminium from corundum is something that will take not only money but painstaking and long continued research."

The main use of corundum, up to the present time, is as an abrasive; and the qualities or properties which contribute to its efficiency as such have already been discussed at some length. It may, however, be mentioned in this connexion that the value of a corundum deposit for abrasive purposes is dependent not alone on its extent or comparative richness, but the mineral itself must possess, above all things, that peculiar property of disintegration when under pressure or in operation with the production of irregularly-rounded grains presenting frequent sharply cutting edges. The possession of this peculiar and valuable quality must in some degree characterize even the most minute fragments obtained by crushing; and its existence in any marked degree marks such corundum as of specially superior quality. It has also been noticed in some instances that this feature may obtain in the larger sizes of the grain corundum, while in the finer material, the property is of such infrequent occurrence as to mark the product as of decidedly inferior quality. The possession, moreover, of this property in any marked degree is particularly insisted upon for all purposes of wheel manufacture. It is of the utmost importance that before any large development work is undertaken in connexion with any corundum proposition that suitable and exhaustive tests should be undertaken to determine fully, not only the abrasive qualities of the material in a loose state but its suitability for manufacturing purposes.

[1]Ann. Rep. Bur. of Mines, Ont. 1904, pp. 19-20. Trans. Am. Inst. Min. Eng. Vol. XXVIII, 1898, p. 875.

This can only be done by the actual moulding and use of the different kinds of wheels. In addition, the presence and character of the various impurities and minerals, which are usually associated with and often to a large extent detract from the quality of the corundum, must be fully ascertained. The impurities present are always much softer than the corundum, and their presence in quantity very seriously affects its abrasive qualities. When the various impurities are determined, proper methods must be devised for their more or less complete elimination. Some deposits, or portions of deposits, contain an over-abundance of the heavier silicates, such as scapolite and labradorite; in other places there is rather a plentiful admixture of bisilicate material, such as hornblende, biotite, or muscovite, while again the presence in abnormal quantity of such heavy minerals as magnetite, spinel, and apatite, renders more difficult and expensive the process of concentrating the corundum. On the other hand where the matrix enclosing the corundum is almost wholly made up of the lighter feldspars, such as orthoclase and microperthite, the resultant product is relatively much purer and more suitable for abrasive purposes, the comparatively wide difference in the specific gravity of the corundum and the associated feldspar permitting, and even favouring, the production of a very clean concentrate. In addition to the presence of products which detract from the effective hardness of the corundum, there are certain other minerals, such as garnet, whose occurrence in any deposit of corundum is especially injurious; for not only is this mineral extremely difficult to remove by any of the ordinary processes of concentration in general use, but its presence, even in very small quantities, in corundum concentrates, forbids the use of such material in the manufacture of the vitrified wheel.

Corundum for abrasive purposes may be used under the following general conditions:—

(*a*) In loose form, as grain corundum, in the usual grades or sizes.

(*b*) Mixed with glue and other forms of soft cements as a coating for cloths, paper, etc.

(*c*) As wheels, and also in blocks of various sizes and shapes.

Grain corundum is classified according to the number of holes in the screen, or sieve, through which it passes, and the ordinary article of commerce varies in texture from the coarse-grained material which passes through a screen with 12 meshes to the inch, to the finer sizes which pass through a sieve having as many as 200 holes to the inch. In addition, the latter is usually divided into five or six sizes of superfine or flour corundum. These last mentioned finest sizes are obtained by washing in water and collecting all sediments which form after certain intervals of time, varying from 10 seconds up to 60 minutes usually. The finer material, of course, remains longer in suspension than the coarser, and deposition is often retarded, and the sizing made more perfect, by the addition of some material like gum arabic to the water. In addition, the large quantity of dust which always collects on the various beams and projecting ledges in the mills is also collected and sold for various purposes of lapidary work. At the Craigmont mill of the Manufacturers Corundum company the following sizes of grain corundum are manufactured: Nos. 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 200.

The use of corundum mixed with glue to form a coating for paper, cloth, and wood is so well known as to deserve only a passing notice in this connexion.

The sizes and shapes of the corundum wheels and blocks are extremely varied, and determined altogether by the character of the work they are to be called upon to perform. The principle of these wheels is identical with that of a rotary file, and a corundum wheel has sometimes been aptly described as a file whose cutting points never grow dull. The latter statement must evidently be limited in some degree, for the dulling of a corundum wheel through use is an acknowledged fact. By a judicious selection of the material of the bond or cement with which the grain corundum is mixed and by which it is held together, a certain temper or hardness is produced, the bond wearing away a little faster than the corundum, thus leaving exposed the broken and sharp edges of the latter which are always ready for cutting. The corundum wheel, therefore, is so designed that despite its constant use it will retain its cutting or abrasive efficiency until fully 90 per cent of its original weight has been lost, while a file is practically useless before it has lost 5 per cent of its weight. According to Holland[1] it has been estimated that to remove one pound of iron with a file costs 2s. 6d., while the same amount of work can be done by an emery wheel in about one-eighth of the time and at one-seventh the cost. Compared with grindstones, in grinding tools, experiments by some English firms show that the cost of the emery wheel is about one-fifth and the time only one-half of that required by the use of the old grindstone, and, at the same time, the danger of bursting during rapid revolution, which is such a common accident with the latter tool, has been practically abolished.

There are three general types of wheels which are known to the trade by names which have been suggested by their method of manufacture. These are:—

(1) The Vitrified Wheel.
(2) The Chemical Wheel.
(3) The Cement Wheel.

In the manufacture of all of these the size of the grain corundum used in each individual wheel should be uniform, varying, of course, with the grade. The vitrified wheel is the one which is in most general use, but for certain varieties of work one made by either of the other processes is preferred. The chemical process is especially adapted for the manufacture of the very large wheels. Pratt[2] mentions that the Norton Emery Wheel company of Worcester, Mass., makes 408 different sizes of circular wheels, so that the grades required for the different sorts of work are almost unlimited. These wheels are usually manufactured for any special line of work for which they may be required, and vary accordingly in shape, bond, and in size of grain.

The sizes of the grain corundum in use at these works in the manufacture of these wheels are Nos. 12, 14, 16, 20, 24, 30, 36, 40, 50, 54, 60, 70, 80, 90, 100, 120, 150, 160, 180, 200, and six grades of flour corundum. The bond, or cement material, has 26 de-

[1]Econ. Geol. India, Part 1, Corundum (2nd Ed. Revised) 1898, p. 55.

[2]Bull. No. 180, U.S. G.S., 1901, p. 76.

grees of hardness, represented by the letters of the alphabet, although a bond is seldom used softer than "E" or harder than "M."

THE VITRIFIED WHEEL.

Greater care is required in the manufacture of this type of wheel than any other, and the material used must be of extreme purity. Any impurities, especially those containing a undue amount of water, are apt to cause the wheel to burst during the vitrification of the bond. The grain corundum of the required size is mixed with about half its weight of clay and other fluxes, with sufficient water to make a stiff paste. This mixture is then pressed into paper moulds and set aside in properly devised drying rooms until hard enough to be handled without danger of injury. The wheels are then roughly trimmed to the requisite size and shape and are again laid aside for further drying. In this way the excess of moisture being driven off, the wheels are ready for the kilns. These latter are cone-shaped ovens, with measurements varying in some instances from 12 to 20 feet in height and 10 to 18 feet in diameter. The wheels once inside, the entrance is closed and the firing commenced. The heat is applied very gradually to permit of the slow expulsion both of the water remaining in the clay and a portion of that contained in the corundum itself, as well as of the associated impurities. The temperature is then again raised to a white heat or about 3,000 degrees Fahrenheit, this heating process requiring several days. This is the critical stage, for at this time, when the temperature of the kiln is raised to the fusing point of the clay, and a large amount of water driven off, the wheels are apt to break. The fusion of the clay or cement produces a porcelain-like matrix in which the different grains of corundum are firmly embedded. The kilns are then allowed to cool slowly, several days being necessary for this operation. While the kilns are opened all of the wheels which have survived the firing ordeal without rupture are "trued" on a lathe to the exact dimensions and after careful balancing are ready for shipment. Two to four weeks are generally required for the manufacture of wheels by this process. The corundum seems to gain in hardness as a result of the application of this intense heat, with a slight loss in the specific gravity. With the exception of a slight discoloration or lightening in colour, and a faint, though appreciable, difference in the development of the planes of parting, the corundum is unaffected during this process.

THE CHEMICAL WHEEL.

This wheel is also called the "Silicate" wheel, because silicate of soda is used as the binding material in this process. The silicate is thoroughly mixed with the corundum and some drying material, and pressed into moulds. It is then subjected to an "oven" heat for twenty-four hours, when it is removed and finished in the same way as the vitrified wheel. Some wheels have been made by this process that were over 2,000 pounds in weight.

THE CEMENT WHEEL.

In this process, shellac, rubber, linseed oil, and other substances are used as the cementing material or bond. This makes a soft wheel which is well adapted for certain purposes. One form of this type of wheel ("Sterne" wheel) is made by cementing the corundum by means of camplicon, or so-called oxid[illegible] linseed oil, mixed with shellac, or asphalt, and sulphur. Th[illegible] or base, of the black wheel is India rubber, while the [illegible]els are cemented mainly by shellac. Some wheels have oxychloride of magnesium as the cementing material. The celebrated "Tanite" wheel has some sort of a so-called solution of leather for its cement, but the exact nature of this material, as well as its process of manufacture, is a trade secret.

The corundum-sane, or lapidaries' wheel, as used in India, is composed of about two-thirds of finely crushed corundum, cemented with one-third of lac-resin. The powdered corundum is heated in an earthern vessel, and when sufficiently hot, the resin is added in successive portions, with constant stirring of the melting mass. The mixture is placed upon a slab of stone, kneaded, rolled, and re-heated several times, until the mass is perfectly homogeneous. It is then laid upon a stone table previously covered with fine corundum powder, and flattened into the form of a wheel by an iron rolling pin. The central hole is made by a heated metal rod and the wheel finally polished with corundum on an iron plate. Different grades are made according to the work for which they are intended.[1]

The American Emery Wheel Works of Providence, Rhode Island, who are interested in and large users of Canadian corundum, produce the following sizes: 10, 12, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150. In addition to these numbers what is known as "flour" is sometimes used. This is marked F, FF, FFF, FFFF, and SF, according to the fineness. The grades or degrees of hardness of the wheel are 18 in number for wheels manufactured by the vitrified process. G denotes the very soft wheel, while Z is extra hard. Wheels made by the silicate process are denoted by numerals from one-half up to 7 and are of thirteen grades. A similar method prevails in designating wheels made by the elastic process, but each numeral has the letter E affixed to it. Each letter or numeral indicates one degree harder than the preceding letter or numeral. All wheels are carefully compared with standards kept at the factory. The list of wheels furnished by this company shows a variation in their diameter up to 60 inches and up to 4 inches thick. A wheel 60 inches in diameter and 4 inches thick weighs 944 pounds. Wheels made by the vitrified process constitute about 90 per cent of their total manufacture. The elastic wheel is valuable for work requiring very thin wheels as they are made as thin as one-sixteenth of an inch and up to 8 inches in diameter, and one-eighth of an inch up to 12 inches. They are also made in all sizes up to 36 inches. They are well suited for work requiring a fine finish and are the only wheels suitable for grinding aluminium.

[1]Econ. Geol. India, Part 1, Corundum, 1898, p. 56.

CHAPTER XI.

ORIGIN AND MODE OF OCCURRENCE OF CORUNDUM.

It would seem indisputable that a proper understanding of the exact geological relations and association of any mineral is necessary, not only for purposes of definite and precise correlation and comparison often of widely separated occurrences, but is also, doubtless, one of the most valued criteria in forming a just estimate as to the extent and possible economic importance of any deposit. The commercial value of such accurate, technical knowledge, especially in the initial stages of the development of any mining proposition, is, of late, receiving very wide recognition at the hands of careful investors and especially the larger mining corporations. At such time the advice of a competent geologist is often invaluable in advising or directing the necessary exploration, while in other cases it will often prevent useless expenditure in opening up what are manifestly unimportant or minor occurrences. The necessity of a thorough geological training is now fully appreciated by the mining departments of our universities, and the later curricula show a more just appreciation of the importance of the various problems which come within the scope of what is now known as applied geology.

The need of such precise information was perhaps at no time more distinctly felt than when the occurrence of corundum in Ontario was first recorded by Ferrier in 1896. A careful study of existing literature on the subject seemed convincing that no known deposits were comparable to these, either in origin, environment, or extent. It is true that critical, and in some respects exhaustive studies of much interest and value had been undertaken and successfully carried out by many very capable and zealous investigators, in regard to special occurrences of this mineral, but the aggregate of such information was neither sufficient nor of a character to enable any one to pronounce with any degree of authority as to the origin and associations of corundum. The problem was primarily attacked almost wholly from the chemical standpoint, and any statements in regard to the field relations of the enclosing rock masses are either conspicuous by their absence or so vague and unsatisfactory as to be almost misleading. The results, therefore, while highly gratifying and instructive to the chemist and mineralogist, added very little to our knowledge of those seemingly intricate and inexplicable processes to which corundum owes its production in the vast laboratory of nature.

As pointed out by Lawson[1] "Even in the latest text books (previous to 1903) corundiferous igneous rocks are not discussed." In Iddings' translation of Rosenbusch's "Mikroskopische Physiographie," 1900, it is asserted that "corundum never occurs as an essential constituent of rocks with the exception of emery, which together with iron oxides forms independent bodies in the crystalline schists. It appears only as an accessory constituent in granite, gneisses, granular limestones and dolomites and is constantly accompanied by spinel, rutile and sillimanite." In Rosenbusch's "Elemente der Gesteinlehre," 1898, no corundum-bearing rocks are specially recognized. Zirkel[2] thus mentioned the mode of occurrence of corundum as a rock constituent: "Corundum in small fine grained aggregates is the chief constituent of emery. Otherwise it occurs only occasionally as an accessory in granites, gneisses, granular limestones and dolomites, in the amphibolite, of northwestern Silesia, in the chlorite-schist of Nischne-Issetsk in the Urals, in the graphite from Mühldorf near Spitz in Lower Austria; as blue sapphire in several basalts, where it is perhaps originally a remnant of molten inclusion, often with spinel rutile and sillimanite. Worthy of note is the occurrence as a contact product of the diorite of Klausen in the Tyrol. It is also observed as altered foreign inclusions or as real accessory masses in certain eruptive rocks

[1]Bull. Dept. Geol. Univ. Lab. III, No. 8, pp. 219-220. Plumasite, An oligoclase—corundum rock near Spanish Peak, California, Berkeley, April, 1903.

[2]F. Zirkel Lehrbuch der Petrographie, Part I, p. 416. Leipsic, 1893.

often with cordierite, spinel and andalusite. As inclusions in the andesitic lavas of the Eifel and similarly in tonalite. Besides it occurs scattered through a quartz-phyllite occurring as a contact product with quartz-mica-diorite in Val-Moja. Similarly in the Kersantite dyke of Michaelstein in the Hartz."

It is not surprising that the genesis and mode of occurrence of corundum should have remained so long a matter of speculation and doubt, for it must be remembered that for many years aft r the first discovery of this mineral in America all the more important or workable deposits were situated within the unglaciated area of the southeastern United States. The various hypotheses advanced to account for its presence in certain localities and under special conditions, were in most cases without sufficient foundation to justify their acceptance or application. These first examinations and studies were necessarily undertaken in localities where the products of subaërial decay had accumulated for untold centuries. Much of the underlying rock was thus effectually concealed from view, while such outcrops as did occur, were in most instances so metamorphosed, that very little could be ascertained with regard to their original structure and composition. Many of the component minerals were themselves evidently the product of secondary action. Moreover, the vast accumulation of loose surface material often very effectually concealed the true relations and structure of the underlying rock.

The idea that the various masses of dunite or peridotite which recur at frequent intervals throughout the entire Appalachian belt, are in some way intimately connected with the development of deposits of corundum, has been the theory advanced by successive writers who have given consideration to this subject. It was, of course, known to many of these observers and occasional mentior made of the fact that important bodies of this mineral did occur, which had no visible connexion with any contiguous mass of dunite, but the existence of such deposits was considered as very exceptional and in no way invalidating the testimony of the more usual occurrences. Besides, diligent search of the area surrounding bodies of corundum which exhibited such unusual conditions of geological association sometines showed the presence of this characteristic basic magnesian rock, and the location of any such mass within a radius of several miles was at once accepted as abundant testimony, of their direct connexion, possibly at some distance beneath the earths surface. All of the writers on these Appalachian occurrences of corundum have repeatedly emphasized the importance of outlining the boundaries of such dunite (or chrysolite) masses as one of the most important aids to prospecting for corundum. It was universally agreed that all new discoveries of this mineral, especially those likely to be of economic importance, would in the light of past experience be found at the junction between these basic magnesian rocks and the associated gneisses.

In 1872[1] C. U. Shepard described at some length the occurrences of corundum and chrysolite of North Carolina and Georgia giving the sequence of what he calls the "strata". Although assuming the sedimentary origin of the associated rocks he suggests no theory to account for the presence of corundum.

The late Dr. F. A. Genth, who was one of the earliest investigators, devoted several years of his life to the chemical examination of corundum, its alterations and associated minerals.[2] He touches very lightly and generally on the subject of the origin of corundum in the following words. "That at the great period when the chromiferous chrysolite beds (partly subsequently altered into serpentine, etc.) were deposited, a large quantity of alumina was separated which formed beds of corundum." The true significance of the associated feldspar (chiefly oligoclase, andesine, or albite) is entirely overlooked, these being included with other associated minerals as the products of the alteration of the corundum. In this respect he writes: "There are cases where feldspars have been formed from corundum, and it is very probable that many have thus been formed, but at the same time a portion of the alumina recrystallized as corundum which we find in the feldspathic matrix."

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[1]Am. Jour. Sc. 3rd Ser. Vol. IV, 1872 pp. 109-114; 175-180.

[2]"Corundum its Alterations and Associated Minerals," Contrib. from Lab. Univ. of Penna. No. 1, 1873, Proc. Am. Phil. Soc. Vol. XIII, 1873, pp. 361-406 (Review), Am. Jour. Sc. 3rd Series, Vol. XV, 1873, pp. 461-462.

Explaining the presence of corundum crystals embedded in chlorite, Dr. Genth writes that they "appear to have been formed after a great portion of the original corundum has changed into chlorite, as if there had been an excess of alumina ready for combination, which, not finding a supply of the requisite amount of silicic acid and bases, had again crystallized as corundum."

The general accuracy and value of Dr. Genth's research work from a chemical point of view, can hardly be questioned, but some of the conclusions reached disregard almost entirely any testimony afforded by the broader field relations of the mineral. Thus the several dykes or veins of corundum are regarded as beds, while the associated dunite, which all the later writers regard as of igneous origin, is described by Dr. Genth as the direct result of aqueous deposition.

Dr. T. Sterry Hunt[1] in commenting on the work says: "Dr. Genth unlike his predecessors taking his departure from corundum and from various facts in the association and envelopment of minerals found accompanying it, is led to conclude that these have been formed by epigenesis spinel, tourmaline, fibrolite, cyanite, paragonite and other micas, chlorite and probably various feldspar. According to him great beds of micaceous and chloritic schists have resulted from the transformation of corundum and even the beds of bauxite which abound in certain Tertiary deposits were once corundum or emery from which they have been derived by a retrograde movement." Dr. Hunt, who had the advantage of personal interviews with Dr. Genth as well as of the examination of his type specimens, concludes that "all of the phenomena in question are nothing more than examples of association and envelopment, precisely analogous to beryl and tourmaline in the granite veins of the White Mountains".

T. M. Chatard,[2] also in criticism of Dr. Genth's conclusions, mentions that "the lime soda feldspars in general present all

[1]"On Dr. Genth's Researches of Corundum and its Associated Minerals," Proc. Nat. Hist. Soc. Boston, Vol. XVI, 1873, pp. 332-335.

[2]"Gneiss, Dunite Contacts of Corundum Hill, North Carolina, in relation to the Origin of Corundum." Bull. No. 42, U.S.G.S., 1887, pp. 62-63.

the appearance of a gangue and not of an alteration product." He also states that "both damourite and margarite are found enveloping corundum, the outlines of the mass closely imitating the form of the enclosed crystal, so as to be easily mistaken for a true pseudomorph, and yet both of these minerals occur with corundum in such a way that it is hardly possible to conceive that they are derived from it". The true significance of these micaceous associates is explained in the description of the Ontario occurrences of corundum.

J. Lawrence Smith[1] in describing occurrences of corundum with peridotite in North Carolina and Georgia, states that "in common with the emery deposits of Asia Minor, the masses of corundum give evidence of having been formed by a process of segregation by the exercise of homogeneous and chemical attractions."

C. D. Smith in 1875 points out certain facts that led to his belief in the igneous origin of the dunite. Affecting the occurrence of corundum in veins of chlorite, he states that "the chlorite seems to have been first crystallized; and then the alumina of which the corundum is composed was evidently in a state of solution and must have permeated the chlorite either in thermal waters or steam."[2]

A. A. Julien in his paper on the "Dunyte Beds of North Carolina"[3] regards the corundum as in all cases a secondary or alteration product, explaining the various alteration products as caused by the introduction of a solution of soda and alumina into the fissures during the period of metamorphism and alteration. The peridotites were also described as of sedimentary origin.

M. E. Wadsworth mentions in his "Olivine Rocks of North Carolina"[4] that corundum is looked upon as a secondary mineral and not as Dr. Genth maintained as the primary mineral from which many minerals were formed.

[1] Am. Jour. Sc. 2nd Ser. Vol. X, 1850, p. 354; 3rd Ser. Vol. XV, 1873, pp. 180-186.

[2] "Corundum and its Associated Rocks" Rep. Geol. Survey. N.C., 1875, Appendix D. pp. 91-97.

[3] Proc. Nat. Hist. Soc. Boston, Vol. XXII, 1882, pp 141-149.

[4] Science Vol. III, 1884, pp. 486-487.

T. M. Chatard in a bulletin entitled "The Gneiss Dunyte Contacts of Corundum Hill, North Carolina, in relation to the Origin of Corundum,"[1] furnished a detailed study from a chemical standpoint of certain specimens collected as illustrative of a cross section of the contact between the peridotite and the gneiss. As a result of the series of chemical analyses he indicates that there is a progressive increase of magnesia as the peridotite is approached with a corresponding decrease in the amount of alumina. He divides the material secured into three series or groups, aluminium silicates, aluminium magnesium silicates, and magnesium silicates. The order and mode of occurrence of these groups are in accord both from a chemical point of view and in the field. The corundum is regarded as an accessory mineral, which is sometimes absent, and when present, in very variable amount. It represents a certain balance between the magnesium and aluminium silicates which have produced the chlorite and vermiculite. In a summary statement Chatard writes: "Whether the solution of soda and alumina must be heated in order to effect the production of these minerals is a question to which at present no definite answer can be given . . . . We must therefore conclude that the gneiss can furnish an alkaline solution of alumina and the dunyte a solution of magnesia without the production of heat and perhaps without its acid."

Francis P. King in "A Preliminary Report on the Corundum Deposits of Georgia,"[2] describes the geological relations of the occurrence of this mineral in this state, mentioning that the deposits occur in veins intersecting the peridotites and their alterations. Four types of these veins are enumerated; but they only differ slightly in the proportion or character of some of the mineral constituents, while all have a close genetic relationship and agree in their common pegmatitic origin. The prevalence of the lime-soda feldspars and the absence or scarcity of quartz, are to be remarked, and their general character closely

[1]Bull. U.S.G.S. No. 42, 1887, pp. 45-63.

[2]Bulletin No. 2, Geol. Surv. Georgia, 1894, pp. 75; 106-107.

resembles many of the pegmatitic occurrences in Ontario, in which corundum has been found.

As regards the origin of corundum he maintains that the study is still in its infancy. "Scientists are not yet prepared to offer more than hypotheses and only a few of these have sufficient foundation to justify second thought. Conservation in conclusion based on the few facts at our command is therefore most necessary." With this introduction expressive of the prevailing uncertainty in this regard he writes on the next page.

"Corundum, therefore, seems to be essentially an accessory mineral, its presence being occasioned by an excess of aluminium present in the rock masses, chrysolite, gneiss and hornblende gneiss. Alterations of these yield respectively, magnesium silicates, alkaline salts, and ferro-silicates, which together with the carbonic acid of the percolating waters, would dissolve the combined aluminium, and on re-crystallization, produce all the minerals mentioned as associates of corundum, and in case of an excess of aluminium, the aluminium oxide corundum."

Joseph Volney Lewis[1] in his report on "Corundum and the Basic Magnesian Rocks of Western North Carolina" points out that "thus far all that is known of the extent and value of our corundum deposits has been derived from experience; that is to say from active prospecting and mining." He mentions with appreciation the work of Chatard, Julien Shepard, Genth, and others but declares that "no attempt has been made to cover the whole field; consequently the various theories that have been advanced in regard to the origin of corundum and its associated rocks, have left entirely out of consideration much evidence which only a careful survey of the whole area could furnish. I can scarcely hope by the work in hand to furnish a final or even a very satisfactory answer to the question of origin; for such problems in areas of great disturbance and so thoroughly metamorphosed as the one under consideration do not readily yield clear results."

Professor John W. Judd writes as follows regarding the origin

[1]Bulletin No. 11, Geol. Surv. North Carolina, 1896, p. 10.

of the rubies of Burma:[1] "Pyroxene gneisses abound with an unstable basic feldspar (labradorite or anorthite) which is easily converted by the action of minute quantities of hydrochloric acid under pressure into a scapolite; the scapolite in turn breaking up into various hydrated aluminium silicates and calci' . . . . While the limestones are being formed from basic feldspar, the aluminium silicates taking up water may also be attracted by sulphuric, hydrochloric, boric or hydrofluoric acid acting at moderate temperatures, and the salts of aluminium thus formed are easily decomposed; the aluminium oxide either hydrated (diaspore, gibbsite, bauxite, etc.) being set free, or under certain conditions of temperature and pressure, the anhydrous oxide itself being formed. The slowly liberated oxide may assume the crystalline form, and thus give rise to corundum. That the crystallization of the aluminium oxide took place under great pressure, and probably at moderate temperatures, is indicated by the circumstance that the crystals include not only cavities containing supersaturated solution of chlorides, sulphates, etc., but also, in some cases, liquid carbon dioxide, which remains liquid at all ordinary temperatures below the critical temperature for that gas."

All of the foregoing theories, however, were advanced prior to or without knowledge or proper recognition of the results achieved by a number of brilliant investigators regarding the development of corundum especially in magmas artifically prepared, as also relating to the igneous origin of certain ore deposits.

The adaptation and development of the microscope as a means of precise mineralogical research has led to the establishment of the science of petrology. Petrologists have within the last twenty years, especially, shown an extraordinary activity forming a bond of union between the mineralogists and geologists. The influence of petrology on mineralogy has been abundantly exemplified in the issue of monographs on mineralogy in which treatment is given affecting the broader relationships

[1]The Rubies of Burma and Associated Minerals: Their Mode of Occurrence, Origin, and Metamorphosis. A Contribution to the History of Corundum by C. Barrington Brown and Prof. J. W. Judd. Phil. Trans. of the Roy. Soc. London, Vol. 187 (1896). A. pp. 218; 225-226.

of minerals, especially as regards origin, consanguinity, and mode of occurrence. In addition as relating to geology, one of the most significant developments in petrology has been the formulation of the hypothesis known as magmatic differentiation. This doctrine or phenomenon which bears so intimately on the genesis of igneous rocks and their component minerals, may be briefly described as the division or differentiation of a viscous or molten magma or fused mass of rock into chemically and mineralogically diverse parts, which on cooling yield correspondingly diverse types of rock.

With increased perfection of methods of petrologic research and in the light of these discoveries it is not surprising that among the most interesting of the problems successfully attacked, was the origin of corundum, or the crystallized oxide of aluminium. As already related, previous to the elaborate studies and experimental work of Vogt,[1] Lagorio, and Morozewicz relating to the formation of minerals in molten magmas, it was the current belief that the generation of uncombined alumina was the result of some unusual or secondary causes not clearly understood, and, therefore, not readily explicable. In 1895, Professor A. Lagorio[2] strongly insisted on the pyrogenesis of corundum, and pointed out its known occurrence in igneous rocks of widely different type and composition, such as granite, pegmatite, trachyte, andesite, basalt, nephelinite, and peridotite. Its free crystallization from an igneous magma was entirely similar to that of the other commoner oxides.

About the same time Josef Morozewicz of Warsaw[3] was induced to undertake experiments in regard to the development of corundum and other allied minerals in artificial magmas, because in seeking to produce certain types of rocks, he obtained some crystalline masses which were extremely rich in corundum and spinel. He separated these minerals and analysed them as also the remainder of the material or matrix in which they were

[1]Zeit. für. Prak. Geol. Nos. 1, 4, 7, 1893.

[2]"Pyrogener Korund, dessen Verbreitung und Herkunft." Zeit. für. Kryst. Vol. XXIV (1895), pp. 285-296.

[3]"Ueber die Kunstliche Darstellung von Spinell und Korund aus Silicatschmelzen" Zeit. für Kryst. Vol. XXIV (1895), p. 281.

embedded. He found that this "mother liquor" or menstrum has the molecular ratio characteristic of the feldspar group. He, therefore, concluded that when alumina is present in excess of that ratio it is liable to crystallize out in the form of corundum or corundum and spinel alone, the amount of the latter mineral being dependent on the amount of magnesia present.

On this side of the Atlantic very little attention was given at first to these results, for the conviction that corundum owed its production to a variety of unusual causes was so deep rooted owing to the researches of Julien, Genth, Chatard, and others that it was not until the discovery and description of the Ontario occurrences and the publication of Pratt's paper "On the Origin of the Corundum associated with the Peridotites of North Carolina"[1] that definite attention was drawn to the matter.

Referring to the relation of certain corundum crystals occurring in a basic lamprophyre dyke at Yogo gulch, Montana, consisting mainly of biotite and pyroxene, Prof. L. V. Pirsson says[2] "The clear-cut form of the crystals and their general distribution, shows that they had crystallized out of the magma with as much certainty as the well formed phenocrysts of feldspar in a porphyry betray their origin." He explains the presence of the mineral by supposing that the original magma dissolved portions of the clay slates of the district, thus forming local areas in the magma very rich in alumina, which on cooling, would allow of the separation of crystals of corundum.

Prof. W. G. Miller[3], after a careful examination of the Ontario deposits, came to the conclusion that the corundum occurred as an original constituent of the syenite and says, "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."

The writer of the present report in his first description of

[1]Am. Journ. Sc. 4th Series, Vol. VI, 1898, pp. 49-65.

[2]"On the Corundum bearing rock from Yogo Gulch, Montana," Am. Journ. Sc. 4th Series, Vol. IV (1897), p. 42-3.

[3]Ann. Report. Bureau of Mines, Ont. Vol. VII, 1898, pp. 213 and 226.

the Ontario occurrences writes:[1] "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."

Thomas Holland[2] gives very detailed description of the occurrences of corundum in India. Amongst the most interesting and satisfactory are the descriptions of the deposits in the Coimbatore district, Madras presidency. At this place the corundum occurs in a coarse grained pink syenite, made up essentially of microperthite (orthoclase and albite) and corundum. The accessory minerals are biotite, muscovite, apatite (deep blue), zircon, zinc spinel (automolite), and a sulphur yellow platy form of chrysoberyl. The finer grained rock often contains a red garnet, magnetite, and black spinelloids. Quartz is generally absent, and when present, is in extremely small quantities. The corundum is in large, tabular six-sided crystals, sometimes measuring half an inch across. The pegmatitic facies of this rock carries crystals of corundum, sometimes over 6 inches across. The rocks occurring at this place may be enumerated as follows:—

(*a*). A highly alkaline division comparatively rich in ferromagnesian silicates, giving rise to the various forms of nepheline syenites.

(*b*). A division supersaturated with alumina and poor in the ferromagnesian protoxides, forming the corundiferous feldspar rocks with chrysoberyl.

(*c*). A division approximately intermediate between (a) and (b) including the laurivikites, and

(*d*). The siliceous end products, probably forming the associated acid pegmatites carrying aquamarine (beryl) and quartz veins.

The whole of these rocks are regarded as genetic relatives, formed by the differentiation of a highly aluminous and alkaline magma. The petrologically different types belong to a pet-

[1]Summary Report, Geol. Surv. of Can. for 1897, p. 52.

[2]Econ. Geo. India 2nd Ed. Part 1, Corundum, 1897. Mem. Geol. Surv. Ind. Vol. XXX, Part 3, pp. 169-220 (1901).

rographical province, which so far as known, is of Archæan age. It must be noted that unlike the Ontario outcrops, no corundum has yet been found in the nepheline syenite.

Holland also mentions the occurrences which he thinks are of corundum in an anorthite (indianite) rock from the Salem district in Madras, which is famous for being the material used by the Count de Bournon for his memoir on corundum. This and a similar rock from Ceylon, have been made the subject of a microscopic study by Lacroix,[1] who has pointed out the occurrence in this rock in addition to anorthite of hornblende, ga[illegible] scapolite, pyroxene, epidote, and a new mineral to which he has given the name fouqueite and which he regards as a dimorphous form of zoisite. The Ceylon rock contains besides, sphene and calcite. In addition Holland states that the sapphires of Kashmir are developed in a pegmatite in which in addition to the quartz, feldspar, and smaller quantities of dark coloured mica, there occur well developed crystals of tourmaline, light green euclase, minute red garnets, and crystals of sapphire. This pegmatite cuts a dark schistose gneiss, containing white feldspar and much black mica, having portions crowded with deep red and brown garnets.

Thomas H. Holland[2] writing of the origin of the Indian corundum states: "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 constituen[t] should require any different explanation than that generally applied to the other simple oxides occurring in a precisely similar manner." This view was further emphasized by Holland after his more critical and extended study of the corundum occurrences in the syenites of the Coimbatore district, Madras presidency, for he states:[3] "The corundum occurs in the feldspar rock as a normal primary constituent, the crystals being idiomorphic in

[1]"Contributions à l'étude des gneiss à pyroxene et des roches à wernerite." Bull. Soc. Fr. Min., 1889, pp. 282-348; Rec. Geol. Surv. Ind., Vol. XXIV, Part III, p. 155 (1891).

[2]Economic Geology of India, 2nd Ed. Part I, Corundum, 1897, pp. 7-79.

[3]Mem. Geol. Surv. Ind. Vol. XXX, Part 3, p. 205.

outline and embedded in the feldspathic material without a recognizable 'court' or peripheral alteration."

There is thus a very striking similarity in the composition and age of the corundum rocks of India and Ontario, and this analogy has been further emphasized by the later work of Holland and Walker of the Geological Survey of India.

J. H. Pratt[1] in his summary of occurrences of corundum in the United States says: "The theory advanced in this paper is that the corundum was held in solution in the molten mass of the peridotite when it was intruded into the country rock, and that 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".

It would indeed seem singular if corundum was differentiated from the peridotite magma, that some occurrences of it should not be noticed in the main body of this plutonic mass. Both Pratt[2] and Lewis mention that only one instance has been recorded of a crystal of corundum being found in dunite (Egypt mine, Yancey county, N.C.) without accompanying alteration products. This would indeed seem singular if Pratt's theory were correct, for minerals which occur as differentiation products along the borders of igneous plutonic rocks, can generally be distinguished in the midst of the igneous mass.

It is to be regretted that both Pratt's and Lewis' descriptions, evidently prepared with great care, are lacking in many very essential details, and this with very good reason as has already been pointed out. Any comment or criticism on the results must take these facts into consideration. The rocks of this southern Appalachian crystalline belt are very similar to those in central Ontario. Sillimanite and quartzose gneisses abound

[1]Bull. No. 269 U.S.G.S. 1906, pp. 81-82.

[2]Bull. No. 269, U.S.G.S. 1906, p. 33, Bull. 11, N.C.G.S. 1896, p. 60.

which are evidently of sedimentary origin, and these are interfoliated with and sometimes intruded by other gneisses of both acidic and basic composition. Many of these latter are undoubtedly of igneous origin, and some of them—as in Ontario—just as certainly belong to the alkaline type of the alumina rich series. Hitherto no detailed petrographical or chemical examination has been made of many of them, and this is very necessary before they can be compared with the Ontario outcrops. It is very doubtful if it will ever be possible to separate these gneisses by mapping, but it seems reasonable to suppose that detailed work will add very materially to our knowledge regarding their chemical and mineralogical composition, as well as their true affinities and relations.

Holland[1] criticizes these conclusions in regard to the development of corundum in the peridotite of North Carolina, and points out that Morozewicz's experiments, far from giving support to any such view clearly point out: "that the formation of corundum is independent of the basicity of the magma, whilst when magnesia is present, corundum is formed only when there is more than enough alumina present to use up the magnesia as spinel".

J. J. H. Teall[2] in his paper on "The Natural History of Cordierite and its Associates" is also very sceptical in regard to Pratt's theory, although leaving it still an open question. He likewise quotes Morozewicz in his support, who found in his experiments with basic magmas, containing magnesia, that silicates of magnesia were rare or absent in those masses which contained corundum. Almost the whole of the magnesia combined with alumina to form spinel, and it was only when there was a deficiency of magnesia, that corundum was produced. Moreover, in magmas with an excess of silica over that necessary to form feldspar, cordierite was produced. How then, Teall asks, can alumina crystallize out of a highly magnesian silicate magma? Why are not spinel and cordierite formed instead?

Teall suggests an experiment as to the solubility of alumina

[1]Zeit. für Kryst. XXIV, 1895, pp. 281-285; Mem. Geol. Surv. Ind. Vol. XXX. Pt. 3, 1901, pp. 209-210.

[2]Proc. Geol. Assoc. Vol. XVI, Part 2, 1899, p. 72.

in a dunite or peridotite magma which should then separate out as corundum if Pratt's contention is to be upheld. Lawson[1] also commenting on Pratt's description says: "The important occurrences of corundum associated with the peridotite in the Appalachian belt described by Pratt, appear to be concentration products on the contacts of the peridotite, and may therefore be secondary rather than pyrogenic."

The presence of corundum in syenite occurring on a high foothill between the Gallatin and Madison rivers in Gallatin county, Montana, described by Pratt[2], is most suggestive of similar deposits in Ontario, India, and Russia. The normal facies of the rock has a somewhat gneissoid structure, with finely divided corundum occurring in fine grains and crystals embedded in a matrix composed essentially of orthoclase and biotite. In the pegmatitic facies the largest crystals of corundum vary from a fraction of an inch to 8 inches in length, and some have been found that weighed as much as 2 pounds each. They are fairly well developed in the prismatic zone. The corundum varies in colour from bluish grey to almost colourless. The percentage of corundum is large; some of the smaller seams are almost pure corundum, and in the larger ones the percentage varies from 10 to 70 per cent. The full width of the corundum bearing syenite is from 8 to 10 feet, and it will average from 5 to 10 per cent of corundum.

In Russia, Morozewicz has described a corundum-bearing anorthite rock made up essentially of corundum and anorthite, together with spinel and biotite. Apatite and zircon occur as accessory minerals. Muscovite, chlorite, kaolin, and chromic iron ore also occur as secondary products. The primary constituents have crystallized out in the following order from the original magma, zircon, spinel, corundum, anorthite, and biotite. This rock for which the name "kyschtymit"[3] is proposed by Morozewicz, occurs as stocks and very large dykes associated with granite and serpentine in the vicinity of the river Borsowka,

[1]Bull. Geol. Dept. Univ. Cal. Vol. III, No. 8, p. 221.

[2]Bull. No. 269, U.S.G.S. 1906, pp. 48 and 133.

[3](Called for the district "Kyschtym") in which it occurs in the Ural mountains.

south of Ekaterinburg in the Ural mountains. This rock varies from medium to fine-grained in texture and through the greyish groundmass are developed long hexagonal or small pyramidal crystals of corundum. This anorthite matrix although the first described among the occurrences of corundum and one which has attracted most attention, is doubtless one of the rarer associations. It has, however, been noticed in India and also in Ontario; but in all three places the rock has evidently a much more limited distribution than the corundiferous syenites and more acid anorthosites.

Besides the anorthite rock, Morozewicz has described other types of corundum-bearing rocks, which are more acid in composition, and which resemble very closely the similar types described recently from Montana, India, and Ontario. These are especially acidic feldspar rocks, and he refers to them as corundum-pegmatite and corundum-syenite. The feldspar is almost always microperthite, made up of orthoclase and albite, sometimes occurring in Carlsbad twins. This contains long embedded hexagonal crystals of bluish corundum, some of which are about 4 inches long by nearly half an inch in width. Besides the corundum, this feldspathic matrix contains small crystals of rutile and short needlelike forms of apatite and zircon. The secondary products of decomposition are kaolin and limonite. Some small black opaque glistening prisms of an unknown mineral are embedded in both the orthoclase and the corundum.

The corundum syenite is made up essentially of corundum, orthoclase, and biotite, occurring in segregations in granite; some varieties are rich in biotite, while others are poor in this bisilicate material. In the former, the corundum is in broad dark plates, while in the latter the corundum occurs in short prismatic crystals of a bluish colour. The corundum is regarded as playing the role of quartz in an ordinary granite.

No corundum has as yet been discovered in the nepheline syenite (miascite), but as this rock occurs in the same igneous complex, and is regarded by Morozewicz as genetically related to the prevailing corundiferous rock, it is reasonable to suppose that this mineral may yet be distinguished with the nepheline syenite.

Morozewicz regards the greater part of the known igneous rocks as being the products of the alumino-silicate magmas, and with these components as a basis he subdivides such rocks into two groups, which he names respectively A and B.

Group "A."

(1) Magmas supersaturated with alumina, as corundum-syenite.
(2) Magmas saturated with alumina, as syenite.
(Magmas not saturated with alumina, as gabbro.

Group "B."

(1) Magmas supersaturated with silica, as granite.
(2) Magmas saturated with silica, as syenite.
(3) Magmas not saturated with silica, as nepheline-syenite.

It would no doubt be unwise in the present state of our knowledge to be dogmatic or to assert that corundum must in all cases be regarded as a primary constituent of certain igneous rocks. It is quite conceivable and even probable that some occurrences of corundum are secondary, but the work of recent years has shown the existence of large bodies of highly aluminous rocks of syenitic and gabbroic type in which corundum is an essential and very important constituent. These occurrences are not confined to one locality, but have been recognized and rather fully described in Russia, India, California, Montana, Colorado, and Ontario. It is known that rocks of similar composition are present and doubtless cover very considerable areas in the Appalachian belt.

In addition to occurrences of corundum which must be regarded as direct and primary products of both natural and artificial alumina silicate magmas, this mineral is also present as one of the products of contact metamorphism around certain plutonic masses. It also occurs as a constituent of inclusions in certain plutonic rocks, dykes, and some volcanic rocks, including both lavas and agglomerates. In view of the proved pyrogenic origin of corundum, it seems reasonably certain that many at least of these migratory occurrences of corundum should also be regarded as the products of the crystallization of magmas.

The results of the brilliant synthetical experiments and studies of Dr. Josef Morozewicz, although not published until 1899, really anticipated the foregoing conclusions reached by the examination of natural occurrences of corundum. These researches, covering a period of nearly six years, and which were conducted by means of a Siemens furnace in a glass factory at Warsaw, afford a very complete and satisfactory explanation of the conditions attending the development of corundum in feldspathic or syenitic magmas. By means of these trials, he not only demonstrated the pyrogenesis of corundum, but indicated clearly the peculiarities in composition of the enclosing parent plutonic rock which contributed to its formation.[1]

The simplicity and at the same time completeness of the Canadian occurrences of corundum, combined with the fresh and unaltered character of the associated minerals, at once removed all doubts as to the pyrogenic and primary character of the mineral. All of the chemical analyses undertaken give remarkable emphasis to the fact that the natural occurrences of corundum conform very closely to the law formulated by Morozewicz from his observations of the behaviour of the cooling of magmas artificially reproduced.

Morozewicz has shown by direct experiment that in supersaturated alumino-silicate magmas, whose general composition is RO, m Al_2O_3, n SiO_2 (where $R = K_2$, Na_2 or Ca, and $n \geq 2$), the whole of the excess of alumina separates out—(1) as corundum, if no considerable amount of [illegible] is present; and if n is less than 6. (2) As sillimanite and corundum; if n is greater than 6. (3) When the magma is rich in magnesia, as spinel or spinel and corundum; if n is less than 6. (4) As cordierite, or cordierite with one or more of the other minerals, if n is greater than 6. The absence of corundum in the nepheline syenites of India is explained by Holland as due to the fact that

[1] "Experimentelle Untersuchungen über die Bildung der Minerale im Magma." Tschermak's Min. und Pet. Mitth. Bd. XVIII, H. 12 and 3. pp. 1-90, 105-240; 8 plates, 1898. Review by T. A. Jaggar, jun., Journ. of Geol. Vol. VII, 1899, pp. 300-313.

these rocks, as shown by analysis, contain too much MgO and FeO; and he refers to the abundance of iron magnesia in the nepheline syenite and the scarcity of such minerals in the corundum syenite as amply accounting for the abundance of free alumina in the latter and its absence in the former. A similar low content of iron and magnesia is noticeable in the Canadian corundum syenites, and, together with the high percentage of alumina in the magma, explains the development of corundum in them.

Agreeably with the analyses the following are the molecular ratios in the corundum bearing rocks from Canada. For purposes of comparison similar ratios are quoted for the corundum syenites and pegmatites from Russia and India.

	$CaO + K_2O + Na_2O$	Al_2O_3	SiO_2
Corundum pegmatite .... =	1	1	5·2 = Ontario
Corundum pegmatite ...... =	1	1	5·3 = India
Corundum pegmatite ...... =	1	1·1	5·5 = Russia
Corundum syenite .... =	1	1	5·7 = Canada
Corundum syenite .... =	1	1·1	5·9 = Russia
Plumasite .... = (Oligoclase-anorthosite)	1	1	4·5 = California
Raglanite .... = (Oligoclase-anorthosite)	1	1	4·3 = Canada
Dungannonite .... = (Andesine-anorthosite)	1	1	4·2 = Canada
Craigmontite .... =	1	1	2·8 = Canada
Anorthosite .... = (Bytownite anorthosite)	1	1	2·6 = Canada
Kyschtymite .... = (Anorthite anorthosite)	1	1	2·15 = Russia.

The ratio of the molecular values of $K_2O : Na_2O$ varies from 1:4 to 1:8 in the corundum-bearing anorthosites. In the Russian and Canadian corundum pegmatites the ratio of the potash to the soda is substantially as 1:1. In the corundum syenite from Canada the ratio of $K_2O : Na_2O$ is 1:2. No analyses of the corundum pegmatite and syenite from India are available, but the analysis of the separated feldspar, which is at least very closely analogous in composition to that of the rock with the corundum deducted, shows a ratio in molecular values of potash to soda as 1:5. The ratio of Al_2O_3 to the sum of the other bases CaO, Na_2O, K_2O is either 1:1 or only a little in excess of this proportion. As magmas for the solution of alumina and its complete separation on crystallization as corundum, they are, therefore, in perfect conformity with Morozewicz's law as already explained. Of the alkalis, soda as a rule predominates, thus lending assistance in the solution of the alumina. There is usually an excess of ferrous iron and magnesia, above what has been thought permissible (0:5) by Morozewicz's law, but these amounts have been necessary to assist in the formation of the comparatively small quantities of biotite and magnetite present in the rock. It might, therefore, be expected that with the excess of ferrous iron and magnesia, spinel would be formed in addition to the corundum, but this mineral is by no means abundant in association with Canadian corundum. It is not unlikely, therefore, as Holland points out, that Morozewicz's law does not represent the whole truth, for magnetite occurs locally in the corundiferous rocks in quantities sufficiently large to represent more than 0·5 per cent of FeO. With the presence of Fe_2O_3, magnetite is formed rather than hercynite (FeO, Al_2O_3). Holland mentions having frequently found the two minerals associated, the magnetite being included in the hercynite, indicating that FeO, Fe_2O_3 forms before FeO, Al_2O_3. It is only locally, however, that magnetite is abundant in the corundum syenite. An average analysis shows less than 0·5 per cent of FeO.

The formation of corundum (under experimental conditions at least) according to Morozewicz, is not dependent on the basicity of the magma, but on the ratio of the aluminium to the sum of the other bases, so that the saturation point of alumina for any pure alumino-silicate magma can be predicted with a very close approximation to the truth. In a pure anorthite magma the minimum limit for alumina is about 36.5 per cent, in nepheline about 32 per cent, in bytownite 33 per cent, in labradorite 27.30 per cent, microperthite 19.22 per cent, albite about 19 5 per cent. Attention should be directed to the fact that ... molecular value of the soda should be greater than that ... h for he found that although alumina is readily ... molten soda alumino-silicate, it is insoluble in potash ... ate, while the introduction of soda into the latter ... increases its solubility which is, of course, an essential preliminary to its subsequent separation as corundum. Holland finds ... analysis that the feldspar near Sivamalai, India, is ... orthoclase. As this feldspar mixture ... principal mass of the rock, it satisfies as a magma the con... shown by Morozewicz, and would become saturated b... quantity of alumina than the magma containing ... From this consideration alone one would expect to find less corundum in the nepheline syenite than in the feldspar rock, if both had similar opportunities of saturation with alumina. In addition, moreover, the conditions as regards the presence of ferrous iron and magnesia are exceeded in the case of the prevalent type of nepheline syenite at Sivamalai. The presence of considerable quantities of ferromagnesian minerals in the nepheline syenite and the remarkable freedom from these compounds of the associated corundum syenite, would thus alone account for the separation of free alumina in the latter case, and its absence from the nepheline syenite.

Similar excuses for the absence of corundum could doubtless be furnished from the Russian occurrences of nepheline syenite, but in both instances it may be predicted with some degree of confidence, that more extended exploration will yet reveal the presence of this mineral in both countries in the rock more intimately connected with the nepheline syenite than the red alkaline syenite. The discovery of the first occurrences of corundum in the nepheline syenite at the original locality in Raglan township was really accidental, for attention was first directed to these outcrops on account of the presence in the rocks of the beautiful and attractive sodalite. Previous to this discovery the detailed examination of the whole field was strengthening the impression that all these syenites had very intimate genetic relationship and the discovery of corundum under similar conditions in the several types, added a further and very strong proof of the accuracy of this conclusion. Extended and careful search in other localities soon led to the recognition of this mineral in the nepheline syenites of other localities in Ontario, which had previously been examined in much detail, but without this object of special search. In short the outcome of these examinations has led to the conclusion that the occurrence of nepheline syenite is very strong presumptive evidence of the presence of corundum in its immediate vicinity. It may be pointed out that the marked tendency to differentiation and as a consequence, the great diversity in composition of nepheline rocks, is now well known, so that it is believed that in some outcrops or portions of outcrops of such rocks in India and Russia, the mineral will yet be found in rock types which agree more closely in composition with the law formulated by Morozewicz.

CHAPTER XII.

DISTRIBUTION OF CORUNDUM.

The oxide of aluminium either in its gem variety as sapphire and ruby, or as abrasive material in the form of corundum and emery, has a world wide distribution. Its occurrence and associations have occasioned a most voluminous literature in a great many different languages, much of which is very difficult of access. The following summarized statement of the distribution of this very interesting and economically valuable mineral is, therefore, necessarily incomplete, but it is believed to include most of the known occurrences of corundum especially those which are of economic importance. A glance over the list of countries included is at once convincing that contrary to the general accepted idea, the mineral corundum is almost universally and in some countries generously distributed.

CANADA.

In addition to the ruby and sapphire found by Dr. T. Sterry Hunt in 1847 in the crystalline limestone of North Burgess in Lanark county[1] and whose geological associations have already been described (see page 16) corundum also occurs in certain alluvial deposits in both the province of Quebec and British Columbia. In Quebec, corundum has been found in the heavier portions of the auriferous gravels obtained by washing, in the region to the south of the River St. Lawrence. These concentrates are found to contain an abundance of magnetite, hematite, both specular and compact, chromite, and ilmenite, with occasional grains of garnet, rutile, and more rarely zircon and corundum.[2] A small rolled fragment not exceeding 7mm. in its greatest diameter,

[1]Ann. Rep. Geol. Surv., Can., 1847-48, pp. 133-134; Geol. of Canada, 1863, p. 499.

[2]Ann. Rep. Geol. Surv., Can., 1863-66, p. 213.

of a transparent, light celandine green variety of corundum which was found by Mr. R. A. A. Johnston to have a specific gravity at 15.5 C. of 3.957 was received from Mr. F. Fletcher P.L.S., through Mr. R. G. McConnell of the Geological Survey of Canada. Mr. Fletcher stated that this specimen had been obtained in washing for gold on the Pend d'Oreille river which flows into the Columbia river in the West Kootenay district of British Columbia.[1] With the exception of these two widely separated occurrences, all the corundum so far discovered in Canada has been confined to the three belts of corundum bearing rocks which have already been mentioned.

These three belts, for such they may for convenience of description and correlation be considered, are situated in the central part of southeastern Ontario. The origin, mode of occurrence, and geological association of the corundum in these belts have already been discussed and the following are only some brief and general notes relating mainly to the distribution of the corundum. These belts of corundum bearing syenites and anorthosites may be named as follows:—

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

The distribution and areal development of these belts have already been described (Chapter VI) and, therefore, only very brief descriptions are here necessary.

(1) MAIN OR NORTHERN BELT.

All the occurrences of corundum in this belt are confined to a comparatively small strip of country extending in a general northeasterly direction from the township of Lutterworth (Haliburton county) through North Hastings to the township of South Algona in Renfrew county. The total length of the band is about 100 miles. With the exception of a rather important interruption between the outcrops of the Lutterworth syenite and those of related type in the township of Glamorgan there is no very serious break in the continuity of the belt.

[1]Ann. Rep. Geol. Surv., Can., Vol. IX, 1896, part R, p. 15.

Haliburton County.

LUTTERWORTH. Corundum was found on lot 12, concession IV, of the township of Lutterworth, by Mr. Tett, assistant to W. A. Johnston of the Geological Survey of Canada, in 1905. The corundum bearing rock is a pink syenite cutting the gneissic granite of the district, and occupies an irregularly shaped area of thirty or forty acres; throughout a considerable part of which corundum was found in more or less abundance.

A small hill over which the road from Kinmount to Norland passes is especially rich in this mineral and a considerable part of it would probably assay 10 per cent of corundum. Associated with the corundum is a small amount of pearly mica and magnetite. This occurrence of corundum may prove valuable; it is easily accessible being only about 5 miles from Kinmount on the Haliburton branch of the Grand Trunk railway.[1]

GLAMORGAN. The next occurrences of the syenites with which corundum is usually associated are in the southwest corner of Glamorgan township. There is thus an interruption in the succession of these rocks of about 20 miles between the Lutterworth outcrops and those of Glamorgan. The Glamorgan nepheline syenites are remarkable by reason of the occurrence of enormously coarse-grained phases constituting the nepheline-syenite pegmatites. No corundum has yet been found in any of the outcrops of these syenites in this township. The occurrence of little strings of muscovite of the form and character usually associated with and often enveloping corundum in other parts of the district was noticed by Dr. Adams on lot 35, concession I, of Glamorgan, although no corundum was observed. At this place there are large exposures of syenite containing only a small amount of nepheline, and this mineral when present is represented by a yellowish alteration product (gieseckite). The rock is reddish or greyish in colour consisting essentially of two felds-pars, one grey and the other pink in colour. These together with a little biotite and occasionally magnetite seem to be the only minerals present. The rock has a banded appearance and in places holds large segregations sometimes as much as 2 feet

[1]Summ. Rep. Geol. Surv., Can., 1905, pp. 93 and 94.

in diameter of a very coarsely crystalline black mica, the individual plates of mica are several inches in diameter[1].

MONMOUTH. The outcrops of nepheline and alkaline syenites in the township of Monmouth are among the most extensive and noteworthy in the whole district. Full details of their petrography and geological reaction have already appeared[2] (see page 57). These masses may be considered as an extension in a northeasterly direction to the Glamorgan exposures. Corundum has been found in a number of places in this township, but these occurrences have apparently no economic significance. On lot 26, concession XII, of Monmouth, small crystals of corundum were noticed in one or two places. This rock (see Plate XIV) containing the mineral is the albitic phase or white alkali syenite (albite anorthosite) which marks the transition between the granite or quartzose syenite and the nepheline syenite. It is usually rather coarse in grain and dark in colour showing on weathered surfaces a little nepheline. There are also, as is often the case in this variety, rather large disseminated grains of magnetite. The rock has a distinct foliation due chiefly to the approximately parallel arrangement of the biotite of which a large amount is present. The thin sections examined show the rock to be composed mainly of albite, orthoclase, microcline, and a little microperthite with nepheline, biotite, and calcite; magnetite and apatite are greatly subordinate in amount. The albite in comparison with the potash feldspar is present in the proportion of about 18:1. Corundum has also been noticed in rock of similar mineralogical composition on lot 15, concession VIII; lot 28, concession XIII; and also at the fork of the road a little west of Hotspur post-office.

CARDIFF. To the southwest as well as to the northeast of Wilberforce and in both the townships of Monmouth and Cardiff the position of the syenite band is occupied largely by drift for a distance of nearly 4 miles. Corundum has only been found in one place in this township by Dr. Miller. He mentions that large angular boulders of the white syenite with brown

[1]Mem. No. 6, Geol. Surv., Can., 1910, p. 287.

[2]Trans. Roy. Soc. Can. 3rd Ser. Vol. II, Sect. IV, 1908, pp. 29-44; Mem. No. 6, Geol. Surv., Can., 1910, pp. 256-283.

corundum were found northwest of Leafield post-office, lot 24, concession XXII, and a careful search discovered the corundum "in situ" in the syenite about half a mile east on lot 26, concession XXII, of Cardiff.[1]

Hastings County.

FARADAY. Nepheline syenite and the associated red alkali syenite are well exposed in the northwestern corner of the township of Faraday. It is very evidently a continuation in this direction of the outcrops of syenite found to the east of Leafield post-office in Cardiff which have already been mentioned, but its continuity or otherwise in the intervening space has not been traced. From the northwest corner of Faraday, however, it is believed to be continuous with the rest of the belt, as exposed in the vicinity of Bancroft and beyond to the east, although concealed by drift in places. The exposures of these rocks in the northwest corner of Faraday are remarkable for their coarsely crystalline texture in certain places with the development of surprisingly large and perfect crystals of magnetite, apatite, and mica in some cases in miarolitic cavities. Corundum has also been found and in certain places is a rather important constituent of the syenite forming considerable exposures of the so-called red corundum syenite. The corundum syenite outcrops are believed to be in the vicinity of lots 31 to 33 close to the boundary between concessions XV and XVI of Faraday township. Corundum is also mentioned as occurring in syenite about half a mile west of Bancroft but it is only sparingly present.[2]

DUNGANNON. The township of Dungannon adjoins Faraday to the east and is noteworthy from a geological standpoint as containing the largest areal development of nepheline and alkaline syenites in the whole of this region. It was the discovery of sodalite in the nepheline syenite of this township which first directed attention to the occurrences of these rocks. Besides the sodalite quarries (Princess quarries, see Plate XII) which have been developed to a certain extent these rocks also contain

[1]Ann. Rep. Bur of Mines, Ont., Vol. VIII, 1899, p. 216.
[2]Ann. Rep. Bur. of Mines, Ont., Vol. VIII, 1899, p. 217.

segregations of magnetite near the southern border of the syenite mass in the vicinity of Bancroft which have also received some attention as a possible source of iron ore. In addition the disturbing influence consequent on the intrusion of the syenite batholith and the widespread effect of the metamorphism due chiefly to the heated magmatic waters which accompanied this igneous invasion has produced a series of clouded white and coloured marbles and breccias which are probably not surpassed by any similar occurrences in the world. Important deposits of corundum have also been found, one of these being situated near the centre of lot 18, concession XI, of Dungannon. Dr. Miller who found this deposit writes "Some of the mineral is light bluish grey, almost white, and it occurs in large sized pieces. The percentage of the mineral over the small surface examined here compares favourably with that seen in the deposits in other parts of the district". Corundum of a pale bluish grey or white colour is also found near Egan chute on both sides of the York river. Over some of the surfaces the mineral is present in large amounts. Corundum also occurs on lot 14, concession XIV, of Dungannon, these exposures being noteworthy as having afforded the specimens from which the descriptions of the new rock type dungannonite (a corundiferous andesine-anorthosite with accessory nepheline) have been furnished. In addition corundum was found by Hodgson and Baker on lots 4 and 5, concession XVI, of Dungannon.

MONTEAGLE. The occurrences of nepheline anorthosites which are in places highly corundiferous, in the township of Monteagle are in the first and second concessions extending from lot 4, concession I, to lot 2, concession II. The principal exposures are on lot 2 near the boundary between concessions I and II. The corundum-bearing rock here is also dungannonite or andesine anorthosite. It is doubtless an extension in this direction of the band of similar rocks occurring on lots 4 and 5, in concession XVI, of Dungannon, which in turn would probably be traceable without serious interruption to the exposures of corundum bearing rock near Egan chute on the York river if the overlying drift material permitted. The width of the belt in Monteagle is about 1,100 feet, while it is traceable without any serious break in a north and south direction for nearly a mile. The rocks are distinctly gneissic and often schistose. As exposed at this locality they show a very great variation in mineralogical composition and neighbouring exposures as well as contiguous bands are alternately rich in biotite, hornblende, feldspar, or nepheline. The bands or masses in which the corundum is abundant are usually highly feldspathic and contain relatively smaller quantities of both nepheline and biotite. In the immediate vicinity, however, of these highly corundiferous portions, certain varieties made up almost wholly of nepheline occur. Some of the outcrops and especially those near the landing on the York river contain a large quantity of hornblende. Trials of the corundum bearing syenite conducted at the Craigmont mill are said to have shown a recovery of about 6 per cent of corundum over considerable areas of the rock surface.

At the southern end of the exposures a dyke of nepheline-syenite-pegmatite crosses the ridge which is made up of nepheline and some individuals of muscovite with small patches of sodalite. Corundum also occurs on the west side of the York river notably on lot 13, concession 1, of Monteagle, where it has been mined. The mineral occurs rather sparingly disseminated in a syenite pegmatite dyke made up of coarsely crystalline flesh red feldspar, biotite, and hornblende. In 1906 the National Corundum Wheel company of Buffalo, N.Y., did some development work on this deposit opening a quarry 25 feet long, 20 feet wide, with a face about 15 feet high. The corundum bearing rock was hand sorted and the best ore shipped to the United States for further treatment.

CARLOW. With the exception of an occurrence of corundum found by Dr. Miller in the nepheline syenite near the boundary between concessions X and XI about half a mile southeast of the east end of Foster lake, all the deposits in the township of Carlow are confined to a series of comparatively high hills which cover most of the northern part of this township from concession XIII to concession XVI, and which extend from lot 14 to the eastern boundary. In addition corundum has been found on some comparatively low lying ridges which protrude through the sandy drift as far west as lots 8 and 10, concession XV, and lots

10 and 11 in concession XIV. All of these occurrences of corundum are in the red corundum syenite and especially in the coarser phases, the corundum pegmatite. The various lots on which the corundum has been found as a result of the careful prospecting work done by Dr. Miller and his assistants are shown on the map which accompanied his report in 1898[1]. Mining work in the southern portion of lot 14, concession XIV (where corundum was first discovered by Ferrier in 1896), was started by the Ontario Corundum company in July, 1902. This place is now known as Burgess Mines. This company continued mining corundum at this locality until June 1, 1905. Subsequently in January, 1906, the Ashland Emery and Corundum company took over the mine and mill, which had been erected, securing most of their corundum from certain deposits north of Grady lake (lots 15 and 16, concession XVI). This company was in turn succeeded in 1909 by the Manufacturers Corundum company, which were already operating at Craigmont. Since the destruction by fire of their mill at Craigmont in February, 1912, the company have confined both the mining and milling operations to Burgess Mines. Most of the ore being used at present comes from John Armstrong's hill on lot 10, concession XV, of Carlow township.

Renfrew County.

RAGLAN. The corundum deposits in this township are the most varied as affecting their mode of occurrence and geological relations as well as the richest and most extensive in the region. Robillard mountain at Craigmont is in reality the eastern extension of the range of hills on which corundum has been found in the northern part of Carlow. These hills with important breaks at the York and Madawaska rivers extend a considerable distance farther to the east. The corundum deposits at Craigmont have already been described and mention need only be made in this connexion that the larger deposits follow very closely the boundary between concessions XVIII and XIX. Crossing the York and Madawaska rivers the corundum deposits

[1]Ann. Rep. Ont. Bur. of Mines (facing page 207).

so far discovered are also confined to a comparatively narrow strip in the vicinity of this same concession line as far east as the boundary. Three occurrences have, however, been found in the northern part of certain lots in concession XVII. Corundum has also been developed in the red syenite and pegmatite in this township and only very small outcrops of the nepheline syenite have been found in this township to the east of the York river. On lot 19, concession XVIII, corundum is associated with garnet which is very unusual in Ontario. Considerable prospecting work has been done on lot 29 concession XIX, of Raglan township, by a company known as the Corundum Refiners Limited.[1]

RADCLIFFE. Dr. Miller found several occurrences of corundum in the township of Radcliffe, lot 31, concession II, and lot 21, concession I, as well as smaller outcrops on one or two lots immediately to the east. On lot 31, concession II, the mineral occurs throughout a width of 12 to 15 feet in a pink somewhat laminated rock. On lot 21, concession I, the corundum is associated with garnet.[2]

BRUDENELL. Corundum has been found in large and very important deposits on lot 34, concession VII, and on lot 34, concession V. It also occurs on lot 24, concession VI. On lot 34, concession VII, of Brudenell, the corundum crystals are thickly disseminated through a well foliated nepheline syenite-gneiss which in association with the red syenite-gneiss crosses the road nearly 2 miles south of the village of Rockingham. The two varieties of rocks are interfoliated with a strike of northwest and southeast.

The corundum was noticed at intervals in comparatively small crystals, but more thickly and evenly distributed than usual for a distance of about an eighth of a mile across the strike

[1]Ann. Rep. Bur. of Mines, Ont. Vol. VII, 1898, p. 221; Vol. VIII, 1899, pp. 222-223.

[2]Ann. Rep. Bur. of Mines, Ont. Vol. VII, 1898, pp. 221-223; Vol. VIII, 1899, pp. 223-224.

of the foliation, although it was not so abundant in the red syenite. A comparatively large amount of magnetite is present in intimate association with the corundum. Some of the smaller light coloured crystals and grains of corundum are completely embedded in the magnetite and the whole occurrence is strongly suggestive of a coarsely crystalline emery.

On lot 34, concession V, of Brudenell, the corundum occurs often in large irregular barrel-shaped crystals and masses embedded chiefly in nepheline syenite, as well as in the red alkali syenite which is also represented at this locality. At one place a rather sharp contact was seen between the nepheline syenite and the red alkali syenite, the larger crystals of corundum being developed in the nepheline syenite close to the line of junction (see Plate XIV). The strike of the foliation of these rocks is nearly northwest and southeast. The corundum is generally of a brownish colour, but some of the smaller crystals embedded in the albitic phase of the syenite are light greenish, yellowish, and greyish to almost white or colourless, while occasional individuals have a distinct rose red colour.[1]

LYNDOCH. Syenitic rocks cover most of the three northern concessions (XIV-XVI) of Lyndoch, but corundum has only been found in the grey albitic variety of nepheline syenite on lot 13, concession XIV.[2]

SEBASTOPOL AND ALGONA. Both nepheline and the alkaline syenites cover a large part of the township of Sebastopol and extend thence across Clear lake into the southern portion of the township of South Algona. Corundum has been found by Dr. Miller on lot 16, concession IV, and lot 24, concession V, Sebastopol. It also occurs in places in concession VI, between lots 23 and 25, Sebastopol.

The nepheline syenites in concession I, of South Algona, are remarkable for their large masses and crystals of nepheline and magnetite. No corundum in place was found, but boulders were located which had not travelled any great distance.[3]

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[1]Summ. Rep. Geol. Survey, Can., 1897, pp. 51, 54-55.
[2]Ann. Rep. Bur. of Mines, Ont., Vol. VII, 1898, p. 223.
[3]Ann. Rep. Bur. of Mines, Ont., Vol. VIII, 1899, p. 224.

(2) METHUEN-BURLEIGH OR MIDDLE BELT.

Peterborough County.

METHUEN AND BURLEIGH. The corundum bearing rocks in the county of Peterborough, which have usually been referred to as the Methuen-Burleigh or Middle Corundum Belt, are confined to a club-shaped mass trending in a north-northeast and south-southwest direction and extending from the western side of concession V (lots 20 and 21) of the township of Methuen to Stony lake in the western part of Burleigh township (lot 3, concession XI). The total length of this inlier as outlined by Dr. Adams on the Bancroft map-sheet is nearly 8½ miles, while its greatest width at the big end of the club toward the northeast end is nearly 1¾ miles. The tapering handle of the club toward the southwest end as it passes through Burleigh township is only about 200 yards across, while at its extreme end on an island just off the west shore of Stony lake it is scarcely 75 yards in width. This alkaline massif is intrusive into certain amphibolites and basic gneissic rocks with subordinate bands of crystalline limestone included in the Grenville series, at the same time showing an apparent and doubtless real transition into the associated granites and granite-gneisses usually classified as Laurentian. These rocks form a series of elevations known locally as the Blue mountains, which rise in general to a height of 200 feet above Kasshabog lake, although toward the northeast end some of the elevations have an altitude of 300 feet above this sheet of water. The whole mass is composed of nepheline and alkaline syenites with their respective pegmatitic equivalents. Toward the centre of the northeastern portion where these rocks have their greatest areal development the rock is massive and granitoid in structure, but on either side a certain parallelism has been developed which is rather indistinct in places by reason of the paucity or failure of the dark coloured constituents. In addition, in many places a streaked appearance obtains owing either to differences in texture or the relative abundance of certain of the mineral constituents.

The rock as viewed with the microscope is as a rule a very fresh or unaltered admixture mainly of albite, microcline, and nepheline with biotite or hornblende (hastingsite) or both, and in rare instances pyroxene (probably acmite). The albite is very typical of this species with a specific gravity of nearly 2.60. It is always largely in excess of the microcline usually from two to four times as much. Muscovite is a very frequent and sometimes abundant constituent associated with the biotite. Accessory constituents are garnet (titaniferous andradite), scapolite, zircon, and spinel, but these are only occasionally present and then in very small amounts. The finer grained type of this rock, with less than the usual amount of nepheline was selected for the chemical analysis (see page 72). Under the microscope it is chiefly composed of albite with a considerable amount of microcline and nepheline. Muscovite and magnetite are the only other minerals seen in the thin section. Agreeably with the analysis the mineralogical composition in percentages is as follows: albite 54.70; microcline 16.12; nepheline 18.18; muscovite 7.95; biotite 1.27; magnetite 0.93. Associated with this white or grey nepheline syenite is a pink or pale reddish syenite, the prevailing colour being imparted to the rock by an abundance of very minute reddish inclusions in both the microcline and albite, while any nepheline present is as a rule altered to a gieseckite-like product which also has a decided reddish tinge This red syenite forms a border along the northwestern side of this whole rock mass from lot 21 in Methuen to Stony lake; it also forms a fringe along the southern margin on lots 14, 15, and 16 of Methuen. Under the microscope the specimen selected for analysis (see page 87) showed this rock to be made up in percentages of microcline and orthoclase 23.35; albite 57.76; quartz 11.22; the other minerals also present in much smaller amounts are biotite, magnetite, pyrite, and calcite. The analysis shows in addition 3.77 per cent of corundum which was not found in any of the thin sections examined. Near the boundary between Burleigh and Methuen (about lot 7, concession XII, of Burleigh) this red syenite holds corundum in large amount. The thin section shows the rock to be composed of albite which is present largely in excess of microcline and orthoclase, biotite, muscovite, and corundum. Biotite is only sparingly represented but there is a very considerable proportion of muscovite. The corundum occurs in individuals which are as a rule about half an inch in length, which are especially abundant in certain more or less parallel streaks. The thin sections show the corundum often rounded or corroded embedded in muscovite. The significance of this intimate association has already been explained (see page 107) so that strictly speaking the muscovite is an envelope or corona surrounding the corundum, and not an alteration product of the corundum. Both the nepheline syenite and the red alkali syenite frequently exhibit coarse-grained streaks or dyke-like forms which are their pegmatitic equivalents. Mining operations have been conducted on some of these dyke-like masses which often occur as apophyses into the surrounding basic gneisses and amphibolites. This mining activity was at first directed to securing the mica (muscovite) which is often a very abundant constituent, sometimes occurring in plates several inches in diameter. Subsequently corundum was found often so completely enclosed in the muscovite that it was not discovered until the muscovite crystal was split apart revealing an irregularly rounded core of corundum. Usually the corundum is of a bluish colour, the depth of shade often varying in the same individuals. Some of it is of a greenish grey colour often changing to blue in the centre of the crystal. The colour is very suggestive of sapphire and some specimens show a distinct approach to gem material, but as a rule the mineral is either opaque or at best translucent. Corundum is found sporadically developed from near the boundary between lots 16 and 17, concessions VI and VII, in Methuen, to the small island in Stony lake near the western mainland. The coarse corundum pegmatites mined for corundum in Methuen vary in width usually from 1 to 4 feet. The corundum is usually in rounded individuals each having an irregular, though smooth surface resembling that which might have been produced by solution. It is almost invariably surrounded by muscovite, both minerals being quite fresh and sharply separated from one another. It has been mined on lot 15, concession VIII, of Methuen, by the Imperial Corundum company and on lot 14, concession IX, by the Crown Corundum and Mica company.[1]

(3) LANARK-FRONTENAC OR SOUTHERN BELT.

Lanark and Frontenac Counties.

SOUTH SHERBROOKE, OSO, AND HINCHINBROOKE. The Lanark-Frontenac or Southern Belt of corundum-bearing rocks is characterized by the presence of bytownite-anorthosite, although corundum-pegmatite has been found apparently as an extension of these outcrops some miles to the southwest in the township of Hinchinbrooke. The writer has not had the advantage of a personal examination of this portion of Ontario and the following information in regard to the occurrences of corundum are a synopsis from Dr. Miller's report.[2]

In the township of South Sherbrooke, Lanark county, the corundum belt is confined to concession VI, in which it has been traced from lot 12 to lot 1 where it meets the boundary of Oso township in Frontenac county. The band extends into Oso township which adjoins South Sherbrooke to the southwest with the same strike (N.45°E.) and a width of about three-quarters of a mile. The largest crystals of corundum, which are short and of a more tabular habit than those found in the counties of Hastings and Renfrew, have a length of about 1¼ inches. Most of the corundum individuals are remarkably uniform in size, with a diameter of nearly half an inch and there is scarcely any of the mineral in small grains. The colour of the mineral is in general light grey to almost white, sometimes pale pink or flesh coloured. It is distributed across the whole breadth of the band, but in no place examined was the proportion present greater than 5 per cent.

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[1]Trans. Roy. Soc. Can. 3rd ser. Vol. II, 1908, Section IV, pp. 49-58; Memoir No. 6 Geol. Surv., Can., 1910 (Publication No. 1082), pp. 291-305; Ann. Rep. Bur. of Mines, Ont., Vol. VII, 1898, pp. 227-228; Vol. VIII, 1899, pp. 206-212.

[2]Ann. Rep. Ont. Bur. of Mines, 1899, pp. 225-228; Am. Geol. Vol. XXIV, Nov. 1899, pp. 276-282.

The crystals are usually in high relief on weathered surfaces. At the boundary to the township of South Sherbrooke, the corundum anorthosite enters the township of Oso near the northern end of Rock lake. This is about lots 9 and 10, concessions VII and VIII. From this point, judging mainly by the position of the boulders carrying corundum, the belt trends in a southwest direction about midway between Sharbot lake and the northern end of Crow bay (Bobb lake). The corundum band is not so well defined in Oso township although corundum was found in place at two or three places and a considerable portion of the rock formation resembled that found farther east. The belt crosses the Kingston and Pembroke railway a short distance south of Olden station. Immediately east of the railway crystalline limestone is found in association. Many boulders carrying corundum were noticed at the end of the railway, the rock composing them having a bluish or purplish shade of colour which serves to differentiate them from other boulders of basic rocks which accompany them. West of the railway the belt trends toward the north end of Eagle lake of which the greater part is in the northeast corner of the township of Hinchinbrooke. A boulder carrying corundum was found at the roadside about one mile north of Parham village. As none of the rock was found in place north of Eagle lake the band must either pass through the lake or to the south of it. Possibly it may be in place on some of the islands, but Dr. Miller had no time to examine further. He predicts, however, that the belt will be found to continue to the southwest of Eagle lake.

UNITED STATES OF AMERICA.

Corundum has been found at a great many localities throughout the Appalachian belt from Massachusetts to Alabama.

In spite of this somewhat lavish arrangement, the deposits are by no means numerous which show the mineral in large quantity, and only a very few have either been developed as mines or offered evidence that they are of economic importance. Most of the corundum mined in the United States has been from deposits in North Carolina and Georgia, although between 1900 and 1905 the corundum deposits of Montana were being developed and some of their product placed upon the market. The emery deposits of Chester, Mass., have been operated with more or less continuity from 1864 to the present time, while similar occurrences of the same material in Peekskill, New York, have been worked since 1889. The mining of corundum in the United States was discontinued in 1905 owing no doubt to the keen competition of Canadian corundum and carborundum. With the exception of a few localities in California, Montana, Colorado, and Idaho, most of which are relatively unimportant, all occurrences of corundum are confined to the Eastern States, mainly at least in the Appalachian region. The sapphire variety has been mined very extensively in Montana and to a limited extent in North Carolina, while Georgia has furnished some pink to ruby red corundum which makes very handsome mineral specimens. It is unnecessary, however, to make more than passing mention of these occurrences in connexion with this report and for further particulars reference may be had to various publications.[1]

NORTH CAROLINA.

The southwestern counties of the state of North Carolina[2] show the greatest areal development of peridotite rocks in the whole of the Appalachian belt and the corundum deposits are also the most numerous and extensive. Corundum occurs in Clay, Macon, Jackson, Haywood, Transylvania, Buncombe, Madison, Yancey, and Mitchell counties along the belt of these basic magnesian rocks. East of the Blue Ridge it has been located in Cleveland, Burke, Gaston, Alexander, Iredell, and Guilford counties.

Corundum Hill mine in Macon county, which is probably the most important corundum deposit in the United States,

[1]Amer. Jour. Sc. 4th Ser. Vol. VIII, 1899, pp. 370-379; Id. Vol. IV, 1897, pp. 421-424; Twentieth Ann. Rep. U.S.G.S. Part III, 1898-99, pp. 552-556; Min. Mag. Vol. IX, 1891, pp. 395-396; Bull. No. 269 U.S.G.S., 1906, pp. 97-116; Geol. Surv. North Carolina Vol. I, pp. 186-190.

[2]Geol. Surv. North Carolina Vol. 1, 1905, pp. 239-267; Bull. No. 269 U.S.G.S. 1096 pp. 28-38; 79-81; 116-127; 139-140.

was discovered in 1870 and mining commenced about a year later under the direction of Col. C. W. Jenks. It is located about 8 miles southeast of Franklin, the county seat, on the northeast side of Culsagee creek, a tributary of the Little Tennessee river. The corundum occurs here in the so-called "veins" in peridotite rock, especially near its junction with gneiss and mica schist. A number of veins have been worked within the dunite, but with one exception they all pinched out. A small quantity of garnet is occasionally found associated with the corundum. The peridotite, which is of the dunite variety, occurs in an irregular oval shaped mass the longer diameter running in a northeast and southwest direction. It is about 1,200 feet long and averages between 400 and 500 feet wide, covering an area of about 10 acres. The hill is about 350 feet high or 500 feet above the level of Culsagee creek. Most of the mining has been done on the southeast side of the peridotite outcrop on what has been called the "Big Vein". It was first developed as open-cuts but later by tunnels. A cut has been made nearly the whole distance along the southeast boundary of the dunite mass, following the contour of the hill, in turn intersecting either the peridotite or the gneiss or following the line of junction between these two rocks. As mined at first the finer corundum was neglected and only gem material, cabinet specimens, and the larger blocks and crystals were marketed.

About 100 tons were mined, which was fully 90 per cent corundum. Corundum has been proved to occur almost continuously a distance of 1,280 feet along the southeastern boundary of the dunite formation. The Stanfield mine at the northeast end has encountered a "vein" of corundum 8–10 feet wide. The Zeb Jones mine on the northeast side of the dunite formation had in July, 1899, exposed a vein of ore 25 feet in depth, 2–5 feet wide, and 50 feet in length, which would average about 50 per cent of corundum. Since the beginning of operations until 1900 this mine has each year furnished an average of 200 to 300 tons of cleaned corundum. The water of Culsagee creek is used for washing and cleaning the corundum at the mill which is located at Culsagee, the post-office about 1½ miles from the mine. A line of sluice boxes connects the mine with the mill and the finer grained material is readily carried in these boxes. The more massive corundum is hauled to the mill, the road being practically down grade all the way. The mine is owned by the International Emery and Corundum company, of New York, who also own the Buck Creek mine in Clay county and the Laurel Creek mine at Pine mountain in Georgia. The Mincey mine is about 2 miles northeast of the Corundum Hill mine near Ellijay post-office. The main work consists of a large open-cut, as well as a shaft and tunnel in the midst of the dunite formation. Nearer the contact between the dunite and gneiss another cut was made in which corundum was found. About 150 tons of a peculiar bronze coloured corundum, locally known as pearl corundum, was obtained from this deposit by the Hampden Emery and Corundum company.

The Moses mine not far removed was also worked by the same company, but both of these mines have been closed down since 1894.

At the Sheffield mine in Cowee township about 7 miles northeast of Franklin, oval shaped nodules up to an inch in diameter of pure corundum occur in an amphibolite. The percentage of corundum in the rock is too low to permit of its profitable extraction in the small mill which was erected to clean the saprolitic ore.

At the Reed or Watauga mine about 6½ miles east of Franklin on the road to Dillsboro, corundum has been found in a dyke of saprolitic rock which is probably a weathered amphibolite cutting hornblende-gneiss. On the opposite side of Watauga creek corundum has been found in a number of places in the gneiss. The corundum in the saprolitic rock is in prismatic crystals varying in size from that of a grain of buckwheat to individuals nearly half an inch in diameter. The corundum is of a pale bluish colour, and some crystals are semi-transparent to transparent. A small mill erected at this place with a daily capacity of three tons, could not be profitably supplied with ore.

The Buck Creek or Cullakeenee mine is about 21 miles a little north of east of Hayesville, the county seat of Clay county. The nearest point on the Murphy branch of the Southern railway is 18 miles over a good road.

These deposits of corundum are associated with the longest mass of peridotite known in the Appalachian region. This outcrop of basic magnesian rocks is club-shaped, lying in a west-northwest direction, with a length of a little over 1½ miles and a maximum width at the east end of a little over half a mile. Very little systematic mining has been done, most of the work being of the nature of open-cuts and pits for prospecting. The principle work has been done near the east end of the peridotite mass near its contact with the gneiss. The vein is stated by Pratt to be different from most of the veins in the peridotite rocks, consisting essentially of plagioclase feldspar and hornblende[1]. Amphibolite intervening between the peridotite and gneiss contains corundum quite abundantly of a delicate pink to ruby red colour. This property is owned by the International Corundum and Emery company of New York.

The Herbert mine owned by the North Carolina Corundum company is situated near the northwest end of the Buck Creek peridotite area. Corundum has been found in a number of veins with seams from 3 to 6 inches wide of almost pure massive corundum. The holding company has equipped a mill for cleaning and preparing the corundum for market, and has graded a road a distance of 18 miles to the nearest railway station.

The Isbel mine at the base of the southern slopes of Chunky Gal mountain was formerly known as the Shooting Creek mine. It is at the headwaters of Shooting creek on the Macon-Clay county road. Both the amphibolite dyke in which the corundum occurs and the surrounding rocks are so badly decomposed that only included masses of the original rock remain. The largest and best equipped corundum mill in the state owned by the Isbel Corundum company of New York has been built at this mine, although a large open-cut and some tunnelling afford no evidence of a commercial deposit of corundum being developed.

The Behr mine is at Elf post-office on Shooting creek, 5 miles east of Hayesville, the capital of Clay county. The nearest shipping point on the railway is 25 miles. It was first opened by Dr. H. S. Lucas in 1880, a steam cleaning plant erected, and

[1]Bull. No. 269 U.S.G.S. 1906, p. 120.

considerable prospecting done. Several carloads of cleaned corundum ore were shipped, but in 1890 the mine was closed down.

Under the caption "Blue Ridge corundum tracts" Pratt includes certain bands of corundum bearing rocks which have sometimes been traced for a distance of over 2 miles. These have been found in the southeastern part of Clay county, North Carolina, and in Rabun and Towns counties which adjoin this to the southwest in the State of Georgia. These bands of highly crystalline rocks vary in composition from a normal gneiss to a quartz-biotite schist in which there is no feldspar. Some bands or portions are rich in garnet, while others are entirely free from this mineral and the rock is essentially a pure white quartzite. In general the strike is northeast and southwest and the dip is to the northwest at an angle of 20 degrees to 30 degrees. These distinctly interlaminated rocks are intersected by dykes often of very coarse pegmatite, some of which are parallel to their schistose structure. Portions or bands of these schists varying from a foot or two to 12 or even 18 feet are corundiferous. The amount of corundum present is never very large, usually averaging not more than 2 to 3 per cent. Assays of material from deposits on the Foster tract in Georgia averaged about 5 per cent, but there is more garnet associated with this ore than at any other place. Scaly Mountain ore showed usually less than 5 per cent although some specimens yielded 12 per cent.

The corundum occurs for the most part in small particles and fragments that have no definite shape and are of a grey, white, and bluish white colours to almost colourless. It is also present in prismatic forms which sometimes attain a length of 2½ inches with a width of half an inch. Pratt regards these schists as the result of the metamorphism of original sandstones and shales, the latter being rich in alumina, possibly in the form of bauxite.

The Corundum Mining and Manufacturing company of Philadelphia was organized in 1900 to develop the Scaly Mountain and Foster tracts. A great deal of money was spent in preliminary mining work, and in the erection of a crushing and cleaning plant. The abundance of garnet and the difficulty of separating this mineral from the corundum, as well as the small percentage of corundum obtained in the concentrate soon brought about the abandonment of the enterprise.

The most important corundum deposits in Jackson county are in the extreme southeastern portion in the vicinity of Sapphire, extending thence into Transylvania county which adjoins it. There are in this section of country about 30 outcrops of peridotite extending in a northeast and southwest direction. None of these masses are large but corundum has been found more or less intimately associated with many of them. At the Burnt Rock mine, as also at the Brockton mine (5 miles and 1½ miles respectively northeast of Sapphire) all the mining done has been within the peridotite. From 10,000 to 12,000 pounds of corundum free from garnet have been mined at each locality. The corundum at the Burnt Rock mine is in white crystals and knotty nodules, while that from the Brockton mine is in dull grey crystals. The little work done at the Sapphire mine shows a considerable quantity of white and grey corundum speckled blue, very similar in appearance to that found at the Whitewater mine 6 miles south. The Socrates mine about a mile south of Sapphire shows small knotty nodules of corundum in a bold outcrop of peridotite. A border vein was discovered, but little work was done to develop it.

The Bad Creek mine, nearly 1½ miles almost south of Sapphire, has had more development work carried on than any other deposit in this area. The mining accomplished has been almost entirely on a border vein which has been exposed for a distance of 150 feet and to a depth at one place of 60 feet. Some of the corundum is associated with garnet and hornblende and is thus undesirable to the manufacture of vitrified wheels owing to the difficulty of obtaining a clean product. Other corundum is found in a matrix of biotite and can readily be separated from this mineral. The vein has an average width of nearly 9 feet and will carry 15 to 20 per cent of corundum. During the summer of 1903, Mr. Walter G. Chandler made certain trials of these sapphire corundum localities concluding that with the exception of the Bad Creek mine these deposits are not commercially valuable.

It is of interest that the first corundum found in North Carolina, a large dark blue cleavable mass of this mineral, was picked up on the surface in 1847, about 3 miles below Marshall in Madison county.

The Carter mine is situated in the southeastern corner of Madison county, very close to the boundary between this and Buncombe county. The corundum secured, probably from an interior vein, enclosed by chlorite and vermiculite, is in masses of pink, white, and blue colours intimately associated with greenish black spinel and feldspar. Corundum was found in this place in 1880 by Dr. C. D. Smith. Regular mining began in 1886, a steam crushing and cleaning plant and about 20 tons of cleaned corundum were shipped from Marshall. Mining and milling operations only continued for about six months.

The Egypt mine in Yancey county, 10 miles west of Burnsville, is interesting as being the only occurrence where corundum has been found directly embedded in and surrounded by dunite. The crystals and crystalline masses are of a white colour often mottled with blue.

Other occurrences of corundum in North Carolina are enumerated and briefly described by J. H. Pratt and J. V. Lewis.[1]

GEORGIA.

Corundum deposits have been found in this state accompanying scattered masses of peridotite which extend across it in a northeast and southwest direction. They are considered as lying in a narrow belt whose width as it enters Georgia from North Carolina is limited to the area between the Laurel Creek corundum mine, Rabun county, and Brasstown Creek valley, in Towns county. This represents a width in an east and west direction of about 40 miles. The belt is supposed to narrow down and enter Alabama from Troup county.

In this region corundum has been found in Rabun, Towns, Union, Lumpkin, Habersham, Hall, Cobb, Paulding, Douglas, Carroll, Heard, and Troup counties. It is also found in Walton

[1]Bull. No. 269 U.S.G.S. 1906, pp. 145-149, Geol. Surv. North Carolina, Vol. I, 1905, pp. 239-267.

county somewhat off this general direction. All the corundum deposits thus far observed in Georgia are stated by Francis P. King to occur in basic magnesian rocks whose general type is peridotite.[1] A matter of note is the constant presence of hornblende gneiss either on one or other side of the masses. Gneiss or mica schist seems always to surround the peridotite, the hornblende-gneiss apparently never coming in close contact with the peridotite.

The corundum occurs in veins intersecting the peridotite and its alteration phases. These veins vary in form from those which have approximately parallel walls, usually inclined and descending to unknown depths to simply lenticular pockets. In width they have been found from 1 to 12 feet.

Four types of these veins are recognized and described by King:

1.—Lime-soda feldspar, with quartz and phlogopite; also with vermiculites instead of phlogopite.

2. —Lime-soda feldspar, with actinolite.

3.—A coarse-grained aggregate of lime-soda feldspar and a black hornblende. Margarite is sometimes present in place of the feldspar.

4.—A massive vein made up of a light grass green amphibole (smaragdite) lime-soda feldspar and a little chromite.

All these types have walls of compact scaly chlorite which quite frequently contains corundum. The first type is the most common and scattered through it, in "bunches" or "pockets", occur the various coloured varieties of corundum. The second type is apparently rare, with only scattered small irregular pieces of corundum enclosed usually in margarite. The third type is more common than the second and is of a distinctly hard massive pegmatitic character with comparatively unaltered feldspar and hornblende in about equal proportion: grey, greyish blue, and slightly pink corundums are evenly distributed through the rock in irregular grains varying from the size of a pea to pieces several inches in diameter. The fourth type is rare and occurs at only one locality in Georgia. The rock is

[1]Bull. No. 2, Geol. Surv. Georgia, 1894, pp. 74-76.

made up of fine blades of smaragdite of a beautiful light grass green shade, feldspar, and small grains of pink or ruby red corundum. Specimens of this rock are strikingly beautiful in mineral cabinets and are highly prized.

A few small crystals of ruby colour but somewhat cloudy have been found at Hog creek, but Georgia corundum is essentially of the non-transparent or "imperfect" variety. In colour it is usually pink, grey, or blue, all these colours often occurring in the same specimen. Shades of red and light to dark blue are common. White corundum is rare and shades of yellow and brown have not been noticed. Georgia corundum is often found in crystals generally six-sided prisms with or without pyramidal terminations. More highly modified forms have been found at the Laurel Creek mine. Massive pieces weighing several hundreds of pounds have frequently been obtained at the Laurel Creek mine. Georgia corundum is well known and has established an enviable reputation for its excellence and uniformity. The Laurel Creek mine, locally known as the "Lucas mine", is perhaps the most famous corundum mine in the United States, having furnished ore from which an exceptionally good commercial corundum was obtained.

It was discovered in the early seventies by an Englishman named Thompson. Colonel Jenks worked it intermittently during 1873 and 1874; but the deposit was considered so poor that work was discontinued. In 1880 it was worked by local men for asbestos, who in ignorance discarded certain hard and heavy rocks which were afterwards found to be corundum. Dr. H. S. Lucas of Chester, Mass., purchased the property for the Hampden Emery company, of Massachusetts. It was mined with eminent success from 1880 to 1893 when the tunnels and shaft of the big vein (at this point averaging about 8 feet in width) were destroyed by a rock slide. Mining has not since been resumed.

The peridotite at the Laurel Creek mine is an irregular ovoid mass; the longer diameter of which has a direction a little east of north being nearly 2,000 feet, and the maximum width about 800 feet. The peridotite is a somewhat serpentinized dunite and replaced in the southern hill partly by its altered derivative anthophyllite. This basic magnesian rock is enclosed on all sides by a well foliated quartzo-micaceous gneiss, the strike of this parallel structure curving around in close agreement with the outlines of the dunite mass. The hornblende gneiss on the east side does not come in immediate contact with peridotite. Most of the mining operations have been carried on in the vicinity of the boundary between the gneiss and the dunite. The workings which are extensive consist at the southern end of an open-cut which reaches a depth of 200 feet at the lower end.

The lower end of this cut intersected the southern extension of the "Big Vein" which has been followed for a distance of over 300 feet. This big vein has been worked by an inclined shaft 116 feet in depth with tunnels aggregating over 300 feet in length. Dr. Chatard described this occurrence as alike in the occurrence of corundum to that at Corundum Hill mine, "the vein of vermiculite containing masses of corundum, sparingly mixed with chlorite and vermiculite and frequently of great size, several having been obtained of at least 5,000 lbs. in weight". King commenting on this description says that, "the corundum is not confined to vermiculite and chlorite but is abundant in the lime-soda feldspar. The testimony of the miners in this respect was corroborated by the presence at the mill of several tons of feldspar, thickly studded with corundum. A stamp mill and other machinery for crushing and cleaning the corundum was installed, the corundum and its matrix being transferred to the mills by means of a tramway.

The Track Rock mine is located on the south side of Track Rock gap in the northeastern part of Union county, Georgia. The peridotite is altered and now composed chiefly of fine blades of actinolite, small granules of chrysolite, and an abundance of magnetite.

The sequence of formations as furnished by the foreman of the mine, Captain R. J. Cook, to Mr. Francis P. King of the Geological Survey of Georgia, is decidedly instructive. In the 198 feet of measured section, four corundum bearing bands were encountered. The rock composing these bands is described by Mr. King[1] after careful inspection of the specimens obtained,

[1]Geol. Surv. Georgia, Bull. No. 2 Atlanta, Ga., 1894, pp. 93-94.

"an extremely disintegrated light green material, consisting mainly of kaolinized feldspar with a smaller proportion of light green actinolite. These bands differed only in the relative proportion of the corundum. Together they aggregate a total of 66 feet. One band 24 feet wide is stated to be rich in corundum. Another band 40 feet in width is described as made up of lime soda feldspar with mica but no trace of quartz. There is very little if any suggestion of peridotite or its altered derivatives in the whole section of 198 feet." Pratt's description which purports to be based on King's diagnosis is altogether misleading[1]

Details of other occurrences of corundum in Georgia are embodied in, "A Preliminary Report on the Corundum Deposits of Georgia" by Francis P. King, Assistant Geologist.[2] It is one of the best contributions to the history and mode of occurrence of Appalachian corundum which has yet appeared.

MASSACHUSETTS.

Corundum has been found near Pelham, Mass.,[3] in a zone of biotite which intervenes between an acid gneiss and a basic hartzburgite (or saxonite) made up of a very fresh mixture of olivine and enstatite. This basic mass is lenticular in outline, measuring about 200 feet long and 40 feet wide. The band of bronze coloured biotite is usually from 4 to 8 inches in width, but occasionally is 4 feet wide. In this wider portion corundum of a greyish colour mottled with blue has been found. Dark green hornblende and paler coloured actinolite are the other mineral accompaniments. The corundum is by no means abundant. This mantle, chiefly of biotite, is doubtless a contact metamorphic product as also the enclosed corundum.

The emery deposits of Chester, Massachusetts, have been made the subject of an elaborate description by Professor B. K. Emerson in his monograph on the "Geology of Old Hampshire County, Mass., comprising Franklin, Hampshire, and

[1]Bulletin No. 269 U.S.G.S., 1906, p. 130.

[2]Geol. Surv. Georgia, Bull. No. 2, Atlanta, Ga. 1894.

[3]Mon. U.S.G.S. Vol. XXIX, 1898; Bull. No. 269 U.S.G.S. 1906, pp. 53-54.

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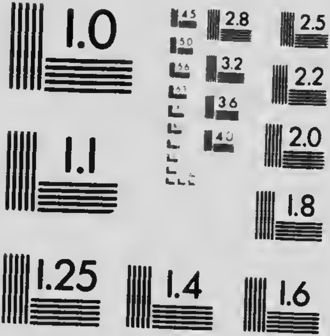

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Hampden counties."[1] The band of amphibolite with which these emery deposits are associated, extends almost continuously across the state, conformable with the enclosing "Rowe" and "Savoy" schists. Its width will only average a few rods but in the vicinity of Chester it is three-quarters of a mile wide. It is in this wider part that the emery deposits are found. The emery occurs on the eastern side of this band of amphibolite and is separated from the sericite schists by a band of amphibolite, sometimes serpentinized, varying in width from an inch up to 18 feet. The emery deposits can be followed for a distance of nearly 5 miles, the disconnected deposits being traceable by means of continuous streaks of chlorite. The vein varies in width from a few feet up to 12 feet, the average width being about 6 feet. The ore varies from an almost pure magnetite to an intimate admixture of magnetite and corundum. Sometimes the corundum has crystallized out in blue and white crystals and in masses a pound or two in weight. Professor Emerson regards this amphibolite as an altered sedimentary rock and accounts for the presence of the emery deposits as follows: "That the emery-magnetite vein was originally a deposit of limonite which was formed by the replacement of limestone and into which alumina was carried by infiltrating solutions and deposited as allophane and gibbsite".[2] Pratt on the contrary is inclined to the belief and supports it to a considerable degree, that the amphibolite is of igneous origin and that the magnetite and the emery were the first minerals to separate out from this basic magma.[3]

The emery at Chester was discovered by Dr. H. S. Lucas in September, 1864, when mining began. Six mines have been operated known as the Wright, Melvin, Old, Macia, Sackett, and Snow mines. Until recently most of the emery produced in the United States was mined in the vicinity of Chester, but now the greatest production comes from Peekskill.

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[1]Mon. U.S.G.S. Vol. XXIX, 1898, 790 pp.; "The Chester Emery Bed," pp. 117-147.

[2]Mon. U.S.G.S. Vol. XXIX, 1898, p. 145.

[3]Bulletin No. 269 U.S.G.S. 1906, p. 92.

Blue and white, pink and reddish corundum have occasionally been found in crystalline limestone associated with spinel and rutile near Amity and Warwick in Orange county. Although scientifically interesting these occurrences have no economic significance.[1]

The emery deposits occurring a short distance east of Peekskill in Westchester county are at present, by reason of their production, the most important in the United States. The following description has been summarized from the latest contribution treating of these deposits and their geological association by Mr. G. Sherburne Rogers of Columbia University, New York.[2]

The Cortlandt series is a small but remarkably complete igneous complex lying to the south and east of Peekskill about 35 miles north of New York city. It was so named by Dana, who was the first geologist to give it serious attention because its boundaries were apparently in close agreement with those of Cortlandt township, the most northwesterly subdivision of Westchester county in the State of New York.

From an historical standpoint the interesting note is made that the emery was first recognized by Henry Hudson.[3] W. W. Mather in 1843 and Herman Credner in 1865 made the earliest attempts at the identification of these rocks. The evolution of Dana's ideas, especially as regards the origin of this complex, may be studied in a series of three papers contributed between the years 1880 to 1884. In the first he describes the series as "a mass of old sediments worked over by great pressure and heat"; this he modifies in 1881 by the statement that they may have been originally volcanic ashes. Finally, in 1884, in all

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[1]Dana, System of Mineralogy, 1909, p, 213; J. F. Kemp and Arthur Hollick "The Granite at Mts. Adam and Eve, Warwick, Orange Co., N.Y., and its Contact Phenomena" Ann. New York Ac. Soc. Vol. VII, 1893, p. 638.

[2]Ann. New York Ac. Sc. Vol. XXI, 1911, pp. 11-86.

[3]"The Third Voyage of Master Henry Hudson," New York Hist. Soc. Colln. I, 143, 1809.

frankness abandoning his previous pronouncements, he asserted his belief that the basic members must at least be considered[1] of igneous origin. Dana called Williams' attention to this area, and to the great variation in the rock types encountered. As a result Williams undertook and completed a petrographic study which although incomplete as regards details of distribution and extent of the rock types described and his failure to discover the acid extreme of the series, is a scholarly investigation.[2] In the first of a series of papers Williams describes the more basic members of the series furnishing a very complete petrographic description of the hornblende peridotite. His second paper deals with the norites, furnishing details of the mineralogical composition not only of the norite proper but the hornblende norite, mica norite, angite norite, and finally pyroxenite. In this paper he makes the statement that he considers the emery as a segregation in the norite. His third paper treats of the composition of the gabbros and diorites, mentioning that the gabbro is a rare rock, a hybrid formed by the action of the norite magma on the adjoining limestone. He furnishes an elaborate subdivision of the various types of diorites distinguished by the presence and relative abundance of brown and green hornblende, mica, hypersthene, and quartz. Later he discussed the "Contact metamorphism in the adjoining mica schist and limestone by the rocks of the Cortlandt series." In this paper the statement appears that the emery may be referred with certainty to contact action on pre-existent material, apparently abandoning his former position that it was due to magmatic segregation.

James F. Kemp in 1888[3] describes the Rosetown extension of the series, an area about three-quarters of a mile in extent about a mile west of Stony point. It is prevailingly diorite, surrounded by gneiss and enclosing a small patch of marble. It also contains emery similar to that found in the principal area. The Connecticut extension of the series, consisting of

[1]Amer. Journn. Sc. 3rd Ser. Vo[illegible]X, 1880, p. 194; Id. Vol. XXII, 1881, p. 103; Id. Vol. XXVIII, 1884, [illegible].

[2]Am. Journ. Sc. 3rd Ser. Vol. XXXI, 1886, p. 26; Idem. Vol. XXXIII, 1887, 135, 191; Id. XXXV, 1888, p. 438; Idem. XXXVI, 1888, p. 254.

[3]Am. Journ. Sc. 3rd Ser. Vol. XXXVI, 1888, p. 247.

two patches in the vicinity of Prospect hill in the township of Litchfield, have been described by Wm. H. Hobbs.[1] The larger of these two patches covers an area of about 40 square miles. The smaller area is apparently similar to the Rosetown mass earlier described by Kemp. The larger mass differs from the main area in the abundance of a more basic plagioclase, the absence of emery, and the presence of chalcopyrite and pyrrhotite locally known as "nickel mines." The latest contribution to this interesting series is a very complete and satisfactory statement of the "Geology of the Cortlandt Series and its Emery Deposits" submitted by G. Sherburne Rogers[2] in partial fulfillment of the requirements for the degree of doctor of philosophy in the Faculty of Pure Science of Columbia University. While Dana considered mainly the genesis of the series and Williams treated of their aggregation as a series of petrographic types, Rogers divides the differentiates into various broad types, directly proportionate from a geological standpoint to their areal importance.

The Cortlandt series is regarded as an igneous complex whose geological correlation cannot be definitely stated. It is at least later than Pre-Cambrian and is probably late Palæozoic. In this igneous complex pyroxenite including hornblende and olivine pyroxenite are the most important of the whole series as together they cover about one-fourth of the whole area. This pyroxenite differentiates into peridotite simply by an increase of the olivine present. This latter mineral sometimes constitutes about three-fifths of the whole rock mass. The variety named by Williams "Cortlandtite" is made up of olivine and hornblende. Hornblendite is not common being known to occur in only four small areas.

Biotite augite norite (hyperite) is the most important of all the norites and from its central position it gives the impression of being the fundamental norite. The other two important members of the norite family are biotite norite and hornblende

[1]Festschrift zum siebzigsten Geburtstage von Harry Rosenbusch Stuttgart, 1906, p. 25.

[2]Cont. Geol. Dept. Columbia University, Vol. XXI, No. 4; Ann. New York Ac. Sc. Vol. XXI, pp. 11-86, Plates III-IV and map, May 15, 1911.

norite. Other representatives, such as norite proper, quartz norite, augite norite, biotite hornblende norite, and olivine augite norite are relatively unimportant. The granite member of the series covers an area of about 3¾ square miles. Syenite is a member whose areal importance is small and ill-defined. Sodalite syenite is one of the most interesting of the rock types discovered and described. It occupies a very small space at only one locality. The diorites are well developed in the western part of the district. The gabbro may be regarded as intermediate between the diorite and syenite, but unlike the diorite it is really unimportant. Dykes are fairly common throughout the district and are usually small. They include pegmatite, aplite, dacite-porphyry, various types of basic lamprophyres, hornblendite, and serpentine (peridotite).

The emery is divided by Rogers into three varieties: (1), pure emery; (2), spinel emery; (3), feldspathic emery.

(1) Pure emery which has a peculiar reddish black tint is rare. Corundum which is the chief constituent can only be distinguished with the assistance of the microscope. The small square grains of this mineral contain abundant inclusions probably ilmenite. Magnetite constitutes about one-third of the substance, spinel is rare, while biotite has only been noticed in small amounts.

(2) Spinel emery is a heavy black fine-grained aggregate with dark grey crystals of corundum appearing in the best varieties. Sometimes the corundum is pink and sometimes blue. In thin section under the microscope it is seen to consist of an aggregate of pleonaste, corundum, and magnetite. The pleonaste constitutes the bulk of the rock occurring in rich green grains of irregular shape, isotropic, high index of refraction, and with very fine parallel rod-like inclusions of magnetite. Corundum is present in variable proportion and it may be lacking entirely. The grains which occasionally reach an inch in size exhibit a prismatic shape and apparently always crystallize before the spinel. They are always strongly cracked and considerably altered to a hydrous mica. The magnetite usually in small grains seems to have crystallized at the same time as the corundum.

The following analyses (I, II), are of the pleonaste chemically separated from the magnetite and ilmenite by Rogers, while under III is an analysis by Wolle (Am. Jour. Sc. 48, 1860, 350), specific gravity 3·58.

	I	II	III
Al_2O_3..............	64·86	65·19	60·79
Fe_2O_3	.....	....	5·26
FeO...............	21·78	20·78	21·74
MgO..............	13·36	14·03	12·84
	100·00	100·00	100·63

(3) Feldspathic emery resembles the spinel variety and a considerable amount of plagioclase may be present without being noticeable to the unaided eye. Pure magnetite may occur in streaks in this variety which was formerly mined for iron. From one-third to one-half of the whole mass may be a basic plagioclase. Corundum usually colourless in medium sized crystals is generally associated with the more basic minerals. In certain localities the corundum is deep bluish green in colour resembling glaucophane, strongly pleochroic E light greenish yellow and O dark greenish blue. Spinel and magnetite are abundant; sillimanite and fibrolite are also often present.

The following are analyses of the three varieties of emery just described by G. S. Rogers: I, pure emery, Dalton mine; II, spinel emery (high grade) Buckbee mine; III, feldspathic emery, Salt hill.

	I	II	III
SiO_2	0·84[1]	1·93[1]	40·60
Al_2O_3	59·22	68·14	13·72
Fe_2O_3	16·66	1·43	13·75
FeO	14·02	16·25	20·11
MgO	3·54	10·02	8·59
CaO	trace	trace	0·08
Na_2O	trace	trace	0·56
K_2O	trace	trace	0·52
H_2O+	2·65	1·15	0·85
H_2O-	0·05	0·12	0·07
TiO_2	3·28	1·41	1·43
P_2O_5	trace	trace	trace
S	0·06	0·05	0·07
Cr_2O_3	trace	0·04	0·06
MnO	0·06	trace	0·10
	100·38	100·54	100·51

[1]Probably derived in considerable part from the agate mortar.

Agreeably with these analyses, the mineralogical composition of these three varieties of emery is as under.

	I	II	III
Quartz	0·	1·90	3·90
Orthoclase	...		2·80
Albite	.....	.....	4·70
Anorthite	.....	.....	3·90
Spinel	21·10	.....	61·30
Corundum	45·20	75·00	0·90
Magnetite	2[illegible]·10	19·50	19·70
Ilmenite	6·20	2·10	2·60
		2·60	

As remarked by Rogers "From the composition of the Cortlandt emery it is evidently a low grade ore. The presence of spinel, sillimanite, garnet, feldspar, quartz, etc., greatly lowers its cutting efficiency and materially affects its toughness. It is suitable for the manufacture of emery wheels by the vitrified process"; and for the many purposes where extreme hardness is not required the abundant presence of spinel furnishes a product which is a convenient intermediary between true emery and garnet.

In brief, as affecting the mode of occurrence it may be stated that:

(1) The emery usually occurs in a region in which mica schist inclusions are abundant and often within a hundred feet or so of such an inclusion; the largest deposits (McCoy and Dalton mines) are within 1,000 feet of the border of the Cortlandt series.

(2) The ore is always in sharply defined veins, pockets, or lenses, but its constituents often occur disseminated through the rocks immediately adjacent.

(3) The ore is immediately associated with abnormal rocks, containing sillimanite, cordierite, garnet, quartz, or allanite which are found nowhere else in the area except around certain schist inclusions; or more rarely it adjoins rocks which are normal except for the spinel scattered through them. There is often a great abundance of biotite around the ore which is often characteristic of these inclusions.

(4) These rocks often exhibit evidences of shearing, faulting, and cracking which is rare in other parts of the district, except around schist inclusions.

Rogers discusses at considerable length the origin of the emery, weighing the evidence presented in support either of magmatic differentiation or through absorption of sedimentary material. While it is possible that the corundum and magnetite have separated out of the magma as an original pyrogenic constituent he strongly inclines to the view that the more detailed work would seem to indicate that it is due to the absorption of sedimentary xenoliths. This would give rise to a magma supersaturated with respect to iron and alumina from which emery would separate out according to the laws formulated by Morozewicz. This view is supported by its frequent, though somewhat remote association with visible inclusions of schist;

by its accompaniment of exactly the same suite of minerals as those developed in the borders of the district and in certain inclusions whose relations are unmistakable, and by its frequent occurrence banded with quartz sometimes contorted and resembling exactly a black quartz schist. This view is in rather close agreement with Williams' later conception of the origin of this emery. As quoted by Rogers, he says:[1] "The isolated inclusion (metamorphosed schist inclusions) of spinel and corundum are almost identical with the more extensive deposits of the same character occurring near the southern border of the norite region farther to the east and described at length in a former paper. Their origin in both cases is without doubt essentially the same."

Emery has been mined in this district since 1889 and many thousands of tons have been removed for use as an abrasive. Previously to this attempts had been made to mine this as an iron, but on account of its high contact of alumina it clogged the furnace and the undertaking was abandoned. At present work is being carried on in the Dalton pits, at the McCoy mine, and in the southeastern area. The Tanite Emery company of Stroudsburg, Penna., have operated the McCoy mine under lease for many years. The Keystone Emery company of Frankport, Penna., have worked the Buckbee and Dalton mines. The deposits vary greatly in size and all are worked by open-cut methods. At the McCoy mine the largest pit is about 75 feet long, 40 feet wide, and 80 feet deep. The emery is all shipped in lump form to the abrasive manufacturers who crush and prepare it for use. The competition of Naxos and Turkish emery is keenly felt and the industry seems to be steadily declining. In 1908 the actual amount reported by the producers was 690 short tons valued at $8,860; in 1909, 892 short tons valued at $10,870; in 1910 it was 978 short tons v[illegible] at $11,736, and in 1911, 769 short tons of the value of $8,81[illegible].

MONTANA.

The only deposits of corundum of any commercial importance west of the Appalachian mountains are those of Montana.

[1] Am. Jour. Sc. 3rd Ser. Vol. XXXIII, 1887, pp. 194-199.

These are situated in the central part of Gallatin county, near Salesville and about 23 miles south of Belgrade on the Northern Pacific railway. Both corundum syenite and corundum pegmatite are described as present in this locality and the occurrences seem closely analogous in geological association with similar deposits described from Canada, India, and Russia. The corundum syenite is the prevalent type and has a gneissoid structure in which the corundum is present in fine grains and small crystals. The syenite is very largely feldspathic (orthoclase chiefly) with a smaller quantity of biotite. The corundum pegmatite is as its name implies coarsely crystalline and almost altogether made up of feldspar with prisms of corundum varying in size from a fraction of an inch up to 8 inches in length. Some individual crystals have been found weighing from 1½ to 2 pounds each. The corundum is not always evenly distributed but is sometimes concentrated into seams or patches sometimes nearly 3 feet in width. Some smaller seams are almost pure corundum and in the larger occurrences the mineral varies from 10 to 70 per cent. The full width of the corundum syenite is from 8 to 10 feet which will average from 5 to 10 per cent of corundum. Three companies have operated in the Montana corundum field. The Bozeman Corundum company have developed their property about 14 miles southwest of Bozeman by means of shafts and drifts. The corundum bearing rock sometimes attains a width of 3 feet. About 5 miles west of the Montana Corundum Company's property, the Ancens corundum mine has shown by development a considerable quantity [illegible] corundum. The largest and most important company, however, is the Montana Corundum company. By means of [illegible]s, tunnels, crosscuts, and pits they have shown a rather permanent band of corundum rock for over 1,000 feet. This property has been thoroughly equipped for mining, cleaning, an[illegible] pre-paring the corundum for the market. Before 1[illegible] [illegible]any produced about 325 tons of corundum. During [illegible] 1903, about 25 tons were cleaned but none was mark[illegible]g to adverse freight rates. Later in the year a more favourable freight rate was secured to Chicago and in July [illegible]03, this company was producing at the rate of 800 to 1,000 tons per year. No further information seems to be available and apparently nothing has been done at these mines since 1903[1].

Sapphire corundum occurs at a considerable number of localities in Montana. The blue sapphires, found in a dyke of monchiquite at Yogo gulch in Fergus county[2] have been mined extensively. Although the colour is not as dark as the highly prized Ceylon and Siam gem material they are said to show a brilliancy and richness not equalled by the Oriental representatives. Sapphire corundum has also been found in dykes of mica-augite andesite at Ruby Bar near Eldorado Bar on the Missouri river 12 miles northeast of Helena, Montana; also at French Bar nearly 12 miles due east of Helena.[3]

The sapphires which occur in the bars of the Missouri river from 12 to 18 miles east and northeast from Helena, Montana, have doubtless been derived from the decomposition and erosion of these and doubtless other similar dykes which have not yet been found. These sapphires were first found by placer gold miners and were described by Dr. J. Lawrence Smith in 1873.[4] It was not, however, until 1891 that actual mining operations were inaugurated. Near Norris, Madison county, Montana, Mr. A. W. Tanner reports the finding of considerable gem corundum in his concentrates from placer gold mining, one piece showing red and green colours and weighing 8 ounces, while a fragment of ruby corundum weighed 588½ carats.[5]

Rubies of rich red colour have been found in the gravels of the upper waters of Rock creek, Granite county, and in less amount in the gravels of Cottonwood creek in Deerlodge county. They are found with other corundums and a very small per-

[1]Bull. 269, U.S.G.S. 1906, pp. 48, 133; Min. Res. U.S. 1902, pp. 885,886; 1903, p. 1006; Min. Industry, Vol. XI, 1902, pp. 18-19.

[2]Am. Jour. Sc. 4th Ser. Vol. IV, 1897, pp. 421-424; 20th Ann. Rep. U.S. G.S. 1898-99, pp. 454-460 also 552-556; Bull. 269 U.S.G.S. 1906, pp. 46-47; 106-116.

[3]Min. Mag. London, Vol. IX, 1891, pp. 395-396; Am. Jour. Sc. 4th Ser. Vol. IV, 1897, pp. 417-420; Bull. 269 U.S.G.S. 1906, pp. 44-46.

[4]Am. Jour. Sc. 3rd Ser. Vol. VI, 1873, pp. 180-186.

[5]Min. Res. U.S.G.S. 1903, p. 1007.

centage of the corundum found is of value as gems. The majority of the gems found are pale green, yellow, pink, and from bluish white to colourless.

ALABAMA.

Between Dudleyville and Perry Mills in Talapoosa county and also in the vicinity of Hanover in Coosa county corundum has been found.[1]

COLORADO.

A very unusual mode of occurrence of corundum has been described by J. H. Pratt[2] and later by George J. Finlay, of Colorado Springs, Colo.[3] The corundum is present in an acid pegmatite dyke, associated with dumortierite and sillimanite, all seemingly original mineral constituents. Corundum was first noticed in the dyke by Mr. Eugene Weston of Canyon City.

The vein of pegmatite is on the ridge between the Rocky Mountain Boy and Joker mineral claims on Grape creek, 7 miles southwest of Canyon City, in Fremont county, the nearest station on the Denver and Rio Grande railway. The dyke is from 40 to 80 feet wide. It stands vertically in the epidotic schist striking N.46° E. The corundum bearing portion is stated by Pratt to have a maximum width of 3 feet and to be traceable for 3,000 feet. Along the south wall where the corundum occurs most abundantly and against the schist are stains of malachite. The country rock is an epidote schist, dark in colour and fine-grained in texture. The microscope shows an apple-green hornblende as the most abundant constituent. Quartz is in small grains, the feldspar is deeply kaolinized with muscovite as an alteration product; epidote and magnetite are abundant. Dark biotitic granite appears in extensive mass which is a portion of the complex of the northern end of Wet mountains, on which Ordovician

[1]Am. Phil. Soc. Vol. XIII, 1873, pp. 370-403; Rep. Geol. Surv. Alabama 1875, p. 85; Am. Phil. Soc. Vol. XX, 1882, p. 386.

[2]Bull. No. 269 U.S.G.S. 1906, p. 49.

[3]Jour. Geol. Vol. 15, 1907, pp. 479-484.

and later Palæozoic rocks rest unconformably. This biotite granite is made up of microcline, acid plagioclase, quartz, biotite, zircon, apatite, magnetite, and secondary hematite.

Hand specimens show glassy quartz in grains an eighth of an inch across as the most abundant mineral. The corundum seems to favour association with this quartz. White sugary plagioclase and more rarely pink microcline are present. Biotite and muscovite are both present, the former being the more abundant, and some of the individuals are half an inch in diameter. Corundum appears as a local constituent of the vein in hexagonal crystals which are often half an inch in diameter. The mineral is glassy and of a clear blue colour, but not good enough to be of gem quality. Basal parting is prominent.

Under the microscope quartz with minute needles of rutile is as abundant as the feldspars taken together. Microcline and acid plagioclase, probably albite, are the feldspathic representatives. Muscovite is unusually prominent. The corundum is usually clear with included negative crystals of hematite. Basal parting is well developed. Dumortierite[1] which can only be detected under the microscope occurs in very perfectly pointed prisms, 1 mm. in length by 0.03 mm. in width of a faint blue colour. Large more massively columnar aggregates are very strongly pleochroic from faint blue to bright smalt blue. Bundles of radiating needles of sillimanite are occasionally seen, while zircon occurs rarely. Secondary hematite is at times conspicuous.

Finlay expresses in very strong terms his conviction that the pegmatite dyke owes its present position to igneous injection and near the igneous end of the pegmatite series. "It would appear that the acid magma was in places uncommonly rich in alumina and that the excess of the Al_2O_3 over that required to satisfy the alkalies and lime for the formation of feldspar crystallized as the oxide corundum." The corundum has the same indigenous aspect as the other constituents of the rock. It is difficult to reconcile its distribution in the rock with the assumption that the alumina needed for it was gained by the working over in the magma of included portions of the wall rock.

[1]Named for the palæontologist Eugène Dumortier; a basic aluminium silicate, probably $Al_8Si_3O_{18}$.

At the Calumet iron mines in Chaffee county, corundum crystals have been found in mica schists at their contact with intrusive dykes of diorite. Mr. R. C. Hills, geologist to the Colorado Fuel and Iron company, wrote to J. H. Pratt that this band of rock from 6 inches to 2 feet thick has been followed for 500 feet with an average corundum content of 40 per cent.[1]

Mr. F. A. Maxwell of Georgetown, Clear Creek county, reports the finding of corundum at Saxon mountain near that place.[2]

CONNECTICUT.

The discovery of corundum in this state dates back to 1822 when on the information obtained from Mr. John B. Brace, both Edward Hitchcock and Parker Cleaveland[3] described a mass of cyanite found at Litchfield which was reputed to weigh 1,500 pounds. This cyanite was "associated with talc, sulphuret or iron and corundum." The corundum was of a dark greyish blue colour, both massive and in six-sided prisms embedded in the cyanite. Shepard[4] described bright blue star sapphire in cyanite at W. Farms near Litchfield. It also occurs at Washington and Newton in cyanite.[5] Small sapphire crystals entirely enveloped in fibrolite are reported by both Shepard and Genth as occurring at the Yantic falls near Norwich.[6] Emerson[7] describes the occurrence of corundum in mica schist with essonite at Barkhamsted. It is in dark blue masses with occasional patches of a pistachio-green colour. Through these masses are scattered microscopic prisms of cyanite and penetrated in all directions by a carbonaceous substance which is considered to have been introduced in a tarry condition and

[1]Bull. No. 269, U.S.G.S. 1906, p. 141.

[2]Ming. and Sc. Press, September, 1903, Min. Res. U.S. 1903, p. 1007.

[3]Am. Jour. Sc. 1st Series, Vol. VI, 1823, p. 219; Cleaveland's Mineralogy and Geology, Boston, 1822.

[4]Minerals of Connecticut, Rep. Geol. Surv. Conn., 1837, p. 64.

[5]Am. Phil. Soc., 1873, p. 381.

[6]Am. Jour. Sc. 3rd Ser., Vol. IV, 1872, p. 180.
Am. Phil. Soc. 1882, p. 390.

[7]Am. Jour. Sc. 3rd Series, Vol. XIV, 1902, pp. 234-236.

has been inspissated in place. The mica schist holding the corundum also contains cyanite, while in the associated fibrolite-gneiss are found the garnets, coated with graphite of the same origin as already described.

DELAWARE.

Corundum has only been found in small quantity near Chandlers Hollow in Newcastle county close to the Pennsylvania boundary.

IDAHO.

Mr. Victor C. Heikes in connexion with the black sand investigation at Portland, Oregon, found semi-transparent to translucent corundum of various shades of blue and green.

The occurrence of gem sapphire in Idaho was announced by Dr. Robert N. Bell in 1907. The sapphire was first found in the concentrates from the Rock Flat placer gold mine, near Meadows post-office in Washington county. Their possible gem value being recognized they were sent for inspection to Dr. Kunz. The general formation according to Dr. Bell is gneiss and the corundum crystals which include some of excellent gem quality seem to be derived from a wide dyke of basaltic clay formation with a peculiar spheroidal structure. The gem stones were found associated with pyrope garnets at an old placer pit. Some are bronzelike, while others have an opalescent silky sheen. Some stones of a beautiful cornflower blue when cut are from one-half a carat to a carat in size. Some brilliant pink stones were 1½ carats in weight after cutting, but nothing as yet of a true ruby colour.[1]

INDIANA.

Attention was called by Dr. O. G. Farrington of the Field Columbian Museum of Chicago to the prospecting for sapphire in placer gravels by R. L. Royce of Martinsville. He reports

[1]Min. World, April 6, 1907, p. 449; Min. Res. U.S., 1906, p. 1231.

this mineral found in the auriferous glacial drift of Morgan county. Nearly all the sapphires found have a bronze colour with a marked sheen or chatoyancy due to minute regularly arranged inclusions. One gem cut en cabochon from such material gave a very fine cat's-eye effect with a brownish to reddish flash. Mr. Royce calls it oriental girasol, a name which may be used with a certain degree of appropriateness.[1]

MAINE.

Corundum has been found at Greenwood in Oxford county near West Paris Station on the Grand Trunk railway. It is associated here with beryl, zircon, and lepidolite.[2]

NEW JERSEY.

About 1828 a specimen of sapphire corundum was found at Franklin Furnace in a loose piece of feldspar. A few years later this variety of corundum was found partly surrounded by a carbonate in feldspar in Newton township about 6 miles from Franklin Furnace. W. P. Blake in 1832[3] described red sapphire as occurring in crystalline limestone in Vernon township, Sussex county. Choice specimens were ruby red in colour, others of various shades of purple, but none were transparent. Dana[4] reports the occurrence at Newton of blue crystals of corundum in granular limestone with grass green hornblende, mica, and tourmaline. At Vernon, near the state line, red crystals often several inches long occur.

NEVADA.

Hoffmann[5] mentions corundum occurring in fragments near Silver Peak.

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[1]Min. Res. U.S. 1908, Part II, p. 838.

[2]Dana System of Mineralogy; 1909, p. 213.

[3]Amer. Jour. Sc. 1st Ser. Vol. XXI, 1832, p. 319; Id. 2nd Ser. Vol. XIII, 1852, p. 116.

[4]System of Mineralogy, 1909, p. 213.

[5]Mineralogy of Nevada.

PENNSYLVANIA.[1]

Large crystals of brown corundum have been found in Aston township, near Village Green, Delaware county. At Blackhorse and Mineral hill near Media in the same county corundum has been found embedded in feldspar. A similar association is characteristic of the corundum found near Fremont in West Nottingham township, Chester county. At Shimerville in Lehigh county corundum crystals measuring 8 by 4½ inches have been found loose in the soil. Corundum has been found in a serpentine in West Chester township.

Corundum has been found much more abundantly near Unionville in Newlin township, Chester county. It is associated with a mass of serpentine, about a mile in length by 800 feet in width. The corundum is in crystals, occasionally 4 inches in length, and masses of which weighed 4,000 pounds.

SOUTH CAROLINA.

Corundum is found in Laurens, Anderson, Cherokee, Oconee, York, and Spartanburg counties. Although very little work has been done to make known the corundum deposits in this state it is noted as having furnished the first corundum crystals recognized as such in America. These were said to have come from the Laurens district and Kunz mentions[2] definitely that they were obtained at Andersonville, a small village in Anderson county, near the Georgia state boundary and about 10 miles west of Anderson on the Southern railway.

Corundum usually of a grey colour and in irregular masses up to 3 or 4 inches in diameter has been found about 8 miles from Gaffney in Cherokee county near Maud post-office which is close to the North Carolina state boundary. The fragments have been found loose in the fields as also in the gravels of a small stream. About 1¼ miles northeast of Laurens in Laurens county rough crystals of corundum, some of which are 3 inches

[1]Dana's System of Mineralogy 1909, p. 213; Bull. No. 269 U.S.G.S. 1906, pp. 131-132, 149.

[2]Gems and Precious Stones of North America, 1892, p. 42.

in length have been found scattered over the surfaces for a number of miles to the southwest of this town.

In the northeastern part of York county and not far from the North Carolina state boundary, corundum has been found in a belt of rocks about 200 to 300 yards wide, along the western slope of Nannies mountain. This locality is on the property of Alexander Rickard, about 12 miles northeast of Yorkville which is a town on the Southern railway at its junction with the Carolina and Northwestern railway. The country rock is a much decomposed light grey biotite granite. The corundum, embedded in muscovite, forms irregular masses of a black colour varying from small grains to several inches in diameter, usually with well developed parting planes. Corundum is also scattered abundantly over the fields, some masses of which weighed several pounds. Many tons of these loose fragments have been collected and shipped. At the so-called Rickard mine, at the north end of the mountain a shaft 35 feet deep has been sunk besides some drifts, but work has been suspended. A little to the west of Nannies mountain about 1½ miles from the Rickard mine some prospecting was done for corundum but without substantial results.[1]

SOUTH DAKOTA.

Corundum is reported as having been found with cassiterite in the Black hills.[2]

VIRGINIA.

Deep blue crystals of corundum have been found in the soil in Louisa county, but the exact locality is not known. Corundum associated with andalusite, cyanite, chloritoid, and mica has been fo[illegible]n the mica-schist of Bull mountain about 2 miles from [illegible]t in Patrick county. The mica-schist, somewhat gneissic and garnetiferous, is intruded by granite. The corundum is colourless to white and greyish white and occurs

[1]Bull. U.S.A. No. 269, pp. 48, 130-131, 149-150.

[2]Groth's Zeitschr, 38, 695.

as rough crystals up to one inch in length. It is also in microscopic grains enclosed in the associated minerals. It is readily separated and cleaned and is well adapted for wheel manufacture by the vitrified process.

Emery occurs about 1¾ miles south of Whittles, a station on the Southern railway, in Pittsylvania county. The associated rocks are apparently decomposed amphibolites or pyroxenites.[1]

CALIFORNIA.

A very interesting occurrence of corundum has recently been described by Dr. Andrew C. Lawson of Berkeley.[2] The locality is at Spanish Peak in Plumas county, California, about 1½ miles northwest of Meadow Valley post-office. The corundum bearing rock occurs at an elevation of about 4,100 feet, near the line of fault to which the bold eastern scarp of Spanish Peak owes its origin and about 2 miles due east of the summit. The first specimens of corundum were found as "float" by Mr. J. A. Edman of the Diadem mine in a gulc between some of the minor ridges which form the lower flanks of the mountain and by him traced to their source.

Dr. Lawson relates that he became interested in the discovery through seeing a fragment of the rock in the lapidary shop of Mr. Kinrade of San Francisco. He secured this specimen and immediately communicated with Mr. Edman, who subsequently conducted him to the locality where it had been found. Although the credit of the original discovery, therefore, belongs to Mr. Edman, it was Dr. Lawson's privilege to furnish a very complete and satisfactory statement as to its character and mode of occurrence, without which it would be impossible to form any just appreciation either of its importance or relationship to other known deposits of this mineral.

The corundiferous rock occurs in the form of a white feldspathic dyke cutting a hornblende peridotite which has been rather fully described by H. W. Turner of the U. S. Geological

[1]Bull. No. 269, U.S.G.S. 1906, pp. 140,150.

[2]Bull. Dept. of Geol. Univ. California, Vol. 3, No. 8, pp. 219-229.

Survey.[1] Referring to the geology of the Sierra Nevada he describes this peridotite as an immense dyke, which in the northern end of the range in Sierra and Plumas counties has a width of more than 3 miles where it is crossed by the middle fork of the Feather river. Outcrops of this rock 1½ miles west of Spanish Ranch post-office are stated by him to be a fine-grained purplish and green rock, evidently in part serpentine. Under the microscope, the structure is coarsely granular and made up largely of olivine showing the usual alteration, in different stages, to serpentine with the development of black streaks of magnetite in aggregates of minute grains. A colourless amphibole, accompanying the fibrous serpentine, was, by subsequently more detailed chemical and microscopical examination, shown to be in part a monoclinic amphibole, probably edenite and an orthorhombic variety probably gedrite.

Lawson writes that the representative of this rock found in association with the corundum-bearing dyke "may be found both in a fairly fresh condition and also largely serpentinized. The fresh rock has a well marked but rude schistosity; on fractures transverse to this schistosity it is of a dull greenish grey colour and compact texture, relieved by long narrow blades of a light-coloured, cleavable mineral and showing irregular partings in the plane of schistosity. On the cleavage surfaces, the rock presents a silver-grey spangled appearance as a ground mass with numerous cleavage blades of the same light coloured material. These blades lie with their axes of elongation rudely parallel to the schistosity but in all orientations in that plane." Under the microscope it is seen to be made up of two primary minerals. The more abundant of these is olivine, forming a mosaic of rather angular or occasionally sub-rounded anhedrons. The olivine shows for the most part incipient alteration along irregular cracks to serpentine and occasionally this decomposition has proceeded so far that patches of serpentine have resulted. Lying in this mosaic are elongated prisms of a colourless monoclinic amphibole, which in Lawson's opinion is undoubtedly the same referred to by Turner as partly edenite

[1]14th Ann. Rep. U.S.G.S. Part II, 1892-93, pp. 476-477; also 17th Ann. Rep. U.S.G.S. Part I, 1895-96, p. 577, and Bidwell Bar Folio 1898.

and partly gedrite. This mineral makes up about 20 per cent of the rock. The only other mineral is magnetite which is secondary occurring in shreds in the serpentine.

Turner regards the amphibole in the rock described by him as an alteration product, but in the specimens examined by Lawson it is primary for it occurs in part undergrown with the olivine. Its idiomorphic character is in contrast with the irregular shaped olivine, showing that for the most part it antedated the latter in its crystallization. Altered representatives of the rock show mainly serpentine with some residual olivines and pseudomorphs of the amphibole. There is also more secondary magnetite with a notable amount of calcite or dolomite. The rock may thus be referred to in its fresh condition as an amphibole-peridotite.

The corundiferous dyke, being composed chiefly of feldspar and white in colour is in marked contrast to the darker mass which it cuts. The dyke is about 15 feet in width and the only three exposures which protrude through the soil and disintegrated peridotite do not extend for more than 125 feet along the strike, which is north-northwest or transverse to the axis of the ridge. At the pit made by Mr. Edman the rock is a coarse granular aggregate of white feldspar in which are embedded crystals of corundum. The feldspar is only slightly decomposed and the symmetrical extinction angles of the fine albite lamellæ are those characteristic of oligoclase. The specific gravity shows an average of 2.633, while the analysis shows it to be an oligoclase of the formula Ab_5An_2 with 2.7 per cent of silica to spare. The corundum is of a pale violet blue colour, and often occurs in well defined crystal forms with sharp hexagonal cross sections, varying in size from a few millimetres to over 5 centimetres in length. The faces are rough, and there is but one habit represented, that of an acute rhombohedron without prismatic faces. The specific gravity of the corundum varies from 3.9 to 4.2 with an average of about 4.0. The fracture surfaces of the corundum show not uncommonly scaly films of a pearly micaceous mineral which has been identified as margarite. Throughout the feldspathic part of the rock along the minor breaks and dislocations occurs a greenish secondary mineral with a waxy lustre whose general characters agree rather closely with a light coloured chlorite. The specific gravity of the rock is 2·789. Knowing this and also the specific gravity of the oligoclase and the corundum, the proportion was found to be oligoclase 83.64 per cent, corundum 16.38 per cent. The bulk analysis of the rock would, therefore, be as under I. Under II is an analysis of the oligoclase by Newfield. Under III is given the molecular ratios calculated to a water free basis. Under IV is an analysis by Blasdale of the peridotite, while under V the calculated mineralogical composition of the peridotite is given.

	I	II	III	IV	V		
SiO_2	51·80	61·36	1·045	41·49	Olivine	44·97	%
Al_2O_3.......	35·39	22·39	0·230	2·22	Serpentine	33·12	"
Fe_2O_3.......	....	....	..	1·07	Magnetite	1·39	"
FeO	....	....	...	7·11	Amphibole	19·60	"
MgO.......	....	.....	.....	39·63			
CaO........	4·54	5·38	0·098	1·89			
Na_2O	6·82	8·08	0·134	.....			
H_2O........	1·45	1·72		5·56			
	100·00	99·51		98·97			

The dyke is far from uniform from a petrographical standpoint. At an exposure 100 feet northwest of the pit where the corundum was obtained, the dyke has an exposed width of 15 feet. About two-thirds of the dyke are made up of the very coarse textured white feldspar, but without corundum. A greenish grey monoclinic amphibole with fibrous radial habit occurs in occasional nests. The remaining third of the dyke, apparently the chilled selvage, is much finer grained and porphyritic, also wholly white feldspar. The other exposure 25 feet to the southeast of the pit is also fine grained and porphyritic, the phenocrysts being optically determined as andesine. No corundum occurs in this facies of the dyke. For convenience of reference, Dr. Lawson has proposed the name of plumasite from the name of the county in which it occurs, defining it as a rock resulting from the consolidation of a magma having the composition of a medium acid plagioclase with an excess of alumina, the amount of such excess being immaterial.

Pratt[1] referring to his examination of specimens of the corundum-bearing rock, serpentine and peridotite, sent to him by Mr. Edman, and after a consideration of Lawson's descriptions, finds that this oligoclase-corundum rock is similar to the zone of corundum and oligoclase feldspar, which is believed to have separated from the peridotite magma at Buck Creek, Clay county, N. C. A careful consideration, however, of Lawson's and Turner's petrographical descriptions is convincing that this rock cannot be considered as a differentiate of the peridotite magma. According to both these authorities rocks of essentially similar type have an extensive development as dykes throughout the Sierra Nevada, those examined by Turner being mainly composed of albite and thus classified by him as albitites under the soda syenites. Some of these, however, are rich in quartz while others are quite devoid of this mineral, so that although having a distinct consanguinity they would fall into a number of petrographically different classes. As has already been pointed out, the true significance of the associated feldspars in the corundum deposits of the southern Appalachians has been almost entirely overlooked by the writers on this subject. Genth, King, Lewis, and others who have described these occurrences mention the fact of the presence of "many feldspars," the several species recognized being albite, oligoclase, and andesine; but while some regard them as the gangue material of the corundum and as such a purely accidental association, others raise the question as to whether such feldspars are in part at least an alteration product of the corundum, due to the longer continuance of the same secondary action to which the corundum itself owes its development. In Ontario rocks of essentially similar type occur not only as dykes, but as independent masses covering many square miles of country. They are at least closely related if not identical with dykes seen by the writer in North Carolina,

[1]Bull. No. 269 U.S.G.S. p. 44.

some of which are being mined for kaolin. Quartz when present is only in very subordinate amount, and is for the most part conspicuous by its absence. The experimental researches of Morozewicz have shown that magmas from which such rocks have solidified are capable of dissolving large quantities of alumina, the whole of such excess above that required by the alumino-silicates crystallizing out as corundum on solidification. The presence of this excess of alumina is regarded as due to local differentiation of the magma, for it is well known that all these alkaline types show very pronounced and rapid variation from point to point. In Ontario where these rocks are so extensively and typically developed, they have no genetic connexion with peridotite masses for such do not exist in their neighbourhood. Rocks precisely similar to the "plumasite" described by Lawson are very commonly represented in Ontario both in the form of dykes and batholiths, the prevailing feldspars so far recognized being mainly albite, but sometimes oligoclase and andesine. Such rocks show differentiation on the one hand into nepheline-anorthosites and on the other to more acid types of syenite (umptekite), in which orthoclase and microperthite accompany the plagioclases. Locally all three phases of these rocks and their several varieties show the local development of corundum as a primary constituent, sometimes in such abundance as to form an ore of this mineral.

ALASKA.

Asteriated corundum of grey and red colours is reported as occurring on the Copper river[1] in the Juneau Indian Reservation.

MEXICO.

Sapphire and ruby of value as precious stones have never been reported as occurring in Mexico, but among a number of rolled pebbles of jasper, agate, and chalcedony from Mexico that were found near San Geronimo, Oaxaca, not far from the

[1]Bull. 269 U.S.G.S. 1906, p. 150.

Isthmus of Tehuantepec, and which were brought to Dr. Kunz of New York by Dr. Knight Neftel, was a rolled pebble of sapphire. It was translucent, mottled blue and yellowish white, and was without crystalline form. It had a specific gr. ity of 3.9. Ruby is said to occur in Durango and also in Seconi but it may have been mistaken for garnet.[1]

COLOMBIA.

Rubies and sapphires about the size of a pea are found in the black (magnetite) sands of the Quebradas between the rivers Sombrerillos and Mayo.[2] In black limestone from Muso, emery with calcite and parisite is present.[3]

BRAZIL.

Bright blue corundum occurs in lenticular masses associated with brown mica, rutile, and tourmaline in a mica-schist in the Serra de Itaqui northwest of Sao Joao in Sao Paulo. The corundum constitutes 71 per cent of these masses.

Common corundum is especially abundant in the granite of Xiririca in the valley of the Ribeira. Small pyramidal crystals, in part of a beautiful sapphire blue and some as large as 1.5 mm. across, are found in the gold bearing sand, the latter made up chiefly of fragments of phyllite and quartz, on the Ribeira a few kilometres from the mouth of the little stream Pedro Cubas. In the diamond sands of the Rio Sapucahy in the northern part of Sao Paulo, sapphire pebbles are found as large as 1 c.m. in diameter; also in the sands of the little streams of Canôas and Santa Barbara and their tributaries.[4] In Minas Geraes white tabular crystals are occasionally found in the diamond sands at Diamantina. Large white, dark grey to black fragments and bronze-like adamantine spar, up to 1 c.m. in diameter, accompany

[1] "Gems and Precious Stones of North America" 1892, p. 276.
[2] "Reiss und Stübel, Groth's Zeitschr, 35, 301.
[3] B. Lewy, Am. Jour. Sc. 14, 1852, p. 274.
[4] Hussak Bol. Comm. Geogr. e. Geol. Sao Paulo, 1890, No. 7, 35,40, 12. Groth's Zeitschr. 21, 407.

the diamonds in the sands of the Rio Paraguassu as also at Bandeira de Mello. At San Isabel corundum is present but rare: at Camassari it is abundant in white, bright red, and sky blue rounded fragments.[1] In the sands of Salobro it occurs colourless, greyish, and red grains.[2]

GREENLAND.

In the Godhavn district grains of corundum occur in plagioclase at Uifak. In Godthaab at Avisisarfik it occurs in irregular particles with anthophyllite and biotite. The so-called emery of Fiskernaesset is sapphirine. In Frederikshaab emery is doubtfully reported from Arsuk Storö; corundum in granite at Kipisako. It is mentioned as occurring also in granite at Cape Hvidtfeld.[3]

RUSSIA.

Ramsay has described corundum from the Kola peninsula in the province of Archangel, Russia. At Umptek nepheline syenite differentiates into a syenite which is free from nepheline to which the name umptekite has been given. On the east side ot this intrusive mass, sillimanite gneiss occurs in contact with it, the umptekite sending out apophyses, many of which are in the nature of interfoliated sheets or dykes of all dimensions. This "lit par lit" injection is often minute and intricate. This gneiss in addition to sillimanite contains zoisite, garnet, spinel corundum, and magnetite.[4]

In the Ural mountains about 62 miles north of Jekaterinburg on the right bank of the Embarka in a deposit east of Bysowa dark red non-transparent crystals some as large as 2.5 c.m.

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[1]Hussak Tschermak's Mitth., N.F. 18, 343, 350, 357, 359.

[2]Gorceix, Comp. Rend. 1884, 98, 1446; Bull. Soc. Min. Paris, 1884, 7, 214.

[3]Boggild Min. Greenland 1905, p. 93
Hintze, Handbuch der Mineralogie 1908, p. 1776.

[4]Fennia, Helsingfors, Vol. II, 1894, pp. 2, 77, 97.

across occur in a vein of kaolin in a highly metamorphosed garnetiferous enstatite-amphibolite with epidote.[1]

In a deposit near the village of Kaltaschi about 50 miles north of Jekaterinburg rubies and sapphires occur in dolomite as also in alluvium.[2]

Near the village of Palkina from 9 to 12 miles west and northwest of Jekaterinburg small but beautiful transparent crystals of ruby are occasionally found in association with microcline and garnet.[3] At the Kornilowsk ruby mine in the granite area about 5.5 miles from Mursinka numerous but small grains and occasionally crystals of corundum of greyish white, yellow pink, dark blue, brown, or carmine red colours.[4] Blue semi-transparent crystals of corundum up to 1.5 c.m. long occur in chlorite schist at Kossoibrod south of Jekaterinburg. Emery also occurs finely disseminated through chlorite schist at Mramorskoi.[5]

In the district of Kyschtym, white, grey, and light to dark blue corundum occurs in large pieces and aggregates sometimes several pounds in weight.[6] G. Rose found sharply bounded pyramidal crystals from 1 to 1½ inches in length in the gold gravels of the Barsowka in blocks of barsowite (anorthite). In colour these crystals are light blue to beautiful dark sapphire blue.[7] Kokscharow mentions that in 1823 von Fuchs found such crystals and named them soimonite after Senator Soimonow.[8] In the same gravels leaf-like forms of bluish grey adamantine spar with bronze-like lustre are found.[9]

[1]Jereméjew, Russ. Min. Gest. 1893, 30, 478; Russ. Berg-Jour. 1894, 326; Groth's Zeitschr, 25,573; 26,517; Karnojitsky Russ. Min. Gest, 1896, 34, 1. Groth's Zeitschr, 30, 316.

[2]Karnojitsky, Groth's Zeitschr, 30, 317.

[3]Karnojitsky, Groth's Zeitschr, 30, 314.

[4]Zerrenner, Berg-u-Hüttenm. Ztg. 1866, 25, 129; N. Jahrb. 1866, 727.

[5]Rose, Reise, 1837, 1. 256, 151, 248.

[6]Karpinsky Russ. Min. Gest. 1902, 39, 58; Groth's Zeitschr 37, 493.

[7]Rose, Reise, 1842, 2, 152, 466.

[8]Kokscharow, Mat. Min. Russ. 1853, 1, 30; 1854, 2, 80.

[9]Sillem, N. Jahrb., 1851, 330, 404; 1852, 527 Hintze Handb. d. Min. 1908, pp. 1757-1758.

The richest corundum bearing rock from Russia which at the same time has attracted most attention, is the anorthite-anorthosite corundum rock for which Josef Morozewicz proposed the name "kyschtymite."[1] This rock occurs in stocks and very large dykes on the river Barsowka in the Kyschtym district. To the northeast it is bounded by serpentine and on the opposite side by granite or granite-gneiss. It is medium to fine grained in texture, sometimes with a gneissoid structure. The chief constituents of the rock are anorthite varying in composition from Ab, An_6 to An, and corundum together with spinel and biotite. Apatite and zircon occur as accessory minerals, while the secondary constituents noticed are muscovite, kaolin, and chromite. The order of crystallization from earlier to later is as follows: zircon, spinel, corundum, anorthite, biotite. The corundum occurs both in hexagonal crystals and in small pyramidal forms, scattered through a grey groundmass. The following are analyses of kyschtymite or as it may be better termed corundum-anorthite-anorthosite.

	I	II	III	IV	V
Corundum and spinel	.....	.....	59·51	.....	.....
Corundum	47·51	.....	.....	.....	.....
SiO_2	22·52	43·17	16·80	41·49	42·33
Al_2O_3	16·31	31·26	13·89	34·31	32·78
Fe_2O_3	2·20	4·21	0·76	1·88	3·05
CaO	6·64	12·73	7·26	17·68	15·20
MgO	1·34	2·57	0·61	1·51	2·04
K_2O	0·58	1·11	0·13	0·32	0·72
Na_2O	1·00	1·92	0·38	0·94	1·43
H_2O	1·58	3·03	0·76	1·87	2·45
	99·68	100·00	100·10	100·00	100·00

I. Kyschtymite—contains about 38 per cent of anorthite (Ab_1An_6), 10 per cent of biotite, and between 51 and 52 per

[1] Tschermak's Mitth. N.F. 18, 206, 215.

cent of corundum and spinel together. There is thus between 3 and 4 per cent of spinel in the specimen analysed.

II. Neglecting the corundum in I and recalculating to a basis of 100 we get the result under II.

III. This is an analysis of a similar type of rock from the same locality containing more spinel and less biotite. The anorthite is also more basic in composition corresponding very closely to the formula An. In percentages the mineralogical composition is as follows: corundum 40-50 with spinel; anorthite 36-38; biotite and other constituents 4-10.

IV. Omitting the corundum and spinel and recalculating to a basis of 100 we get the results under IV.

V. This is the mean of the analyses of the two specimens, neglecting both the corundum and spinel and recalculating to a basis of 100. It doubtless represents very closely the mean composition of the rock mass at this place with which the corundum is associated.

In the vicinity of the Barsowka and the Kyschtymite outcrops at Nikolskaja Ssopka as well as near the village of Sseljankina Morozewicz has also described a "corundum syenite"[1] which is a granular admixture of corundum, potash feldspar, and biotite, in stock-like segregations (anhäufungen) in granite. The corundum seen at the first locality was in short flat greyish individuals from 1 to 5 c.m. thick. Corundum has also been found nearly 5 miles from Selankina, in the Ilmen mountains, and about 12 miles north of Miask, in greenish and bluish grey elongated, also beautiful transparent sapphire blue crystals from 2 to 3 inches in length, in a rock made up of white feldspar and pale yellowish mica.[2] Some of the syenite is rich in biotite and in this phase of the syenite the corundum occurs in broad dark grey platy forms. In the almost pure feldspar rock the corundum is almost invariably in short prismatic crystals. The "corundum pegmatite", also so named by Josef Morozewicz, is a coarse-grained dyke rock cutting the granites and granite gneisses of the Ilmen mountains.[3] The feldspar is almost wholly a yellowish mi-

[1]Tschermak's Mitth. N.F. 18, 217.
[2]G. Rose, Reise, 1842, 2. 76, 466.
[3]Tschermak's Mitth. N.F. 18, 82, 215.

croperthite, made up of an intimate undergrowth of orthoclase and albite. Besides corundum, it contains embedded in its mass small needle-like crystals of rutile, apatite, and zircon. Kaolin and limonite are secondary decomposition products.

The corundum is in bluish hexagonal crystals, some of which attain a length of nearly 4 inches with a width of about half an inch. The smaller crystals noticed have a length of about 1 to 1.5 mm. and a thickness of 0.5 mm. These smaller individuals often have pyramidal terminations.

Sustchinsky[1] mentions a similar corundum pegmatite from a corundum deposit about 2 miles southwest of Lake Tatkul between the villages of Turgojak and Togusowa north of Miask. The corundum is of a blue colour and occurs in pyramidal forms some of which are 3 inches in length. Other pyramids are more stunted in their growth.

Carmine to pale rose red crystals of corundum are reported as occurring at Taschkent, perhaps from the Tian-Schan mou. tains.[2]

The following are chemical analyses of corundum syenites and corundum pegmatites from Canada, Russia, and India. A glance at these analyses is amply convincing of the close analogy in chemical composition of these widely separated occurrences.

—	I	II	III	Ia	IIa	IIIa	IV	V
Corundum...	34·62	35·40	18·55	.....	.....	.....	....	.....
SiO_2........	40·53	40·06	52·34	62·30	62·71	64·65	63·43	63·26
Al_2O_3........	13·62	13·65	16·05	20·93	21·37	19·83	20·78	21·87
Fe_2O_3........	0·19	0·35	0·45	0·29	0·55	0·56	0·29	0·22
FeO.........	0·04	.....	......	0·06	.....	.....	....	.....
CaO.........	0·67	0·30	0·20	1·02	0·47	0·25	1·00	0·21
MgO........	.....	0·15	0·16	.....	0·23	0·19	0·07	.....
K_2O.........	5·92	5·20	6·58	9·10	8·14	8·14	8·00	3·09
Na_2O........	3·40	3·71	4·77	5·23	5·81	5·89	5·20	10·25
H_2O.........	1·01	0·46	0·40	1·07	0·72	0·49	1·00	0·78
	100·00	99·28	99·50	100·00	100·00	100·00	99·79	99·68

[1]Soc. Imp. Nat. St. Petersb. 1900, 29, 21; Groths Zeitschr. 36, 178.

[2]Hintze (Handb. d. Min. p. 1761) says that the source of this corundum may be from the ruby mines at Schignan on the Oxus river in Badakschan which have been known from the early centuries (see also p. 1759).

Under I is an analysis of the corundum-pegmatite from Craigmont, Ontario, Canada, with the results adjusted to a basis of 100. The analyses of the corundum-pegmatite and corundum-syenite from Nikolskaja Ssopka in the Urals, Russia, are included under II and III (Tschermak's Min. and Pet. Mittheil., XVIII, 1898, p. 219). Under I (a) is given the analysis of I, omitting the corundum and adjusting it to a basis of 100. Under II (a) and III (a) are similarly included analyses of II and III, in which the corundum is neglected and the remaining constituents recalculated to a basis of 100. Under IV is an analysis of the separated microperthite from the corundum-pegmatite of Craigmont, Ont. Under V is an analysis of a similar feldspar of the corundum-pegmatite from Sivamalai, India.

GREECE.

At a number of islands in the Grecian Archipelago emery has been mined from the earliest times.[1] The largest and best known deposits are those situated on the Island of Naxos. The best comes from Wothri (Bothris) 9 miles from the shore and is shipped from Sulionos. Other good deposits are at Apiranthos 7 miles from the shore and the emery is shipped from a small port called Mutzoma. These are in the northern or eastern part of the island. In the southern part of the island of Naxos it is found near Yasso. The principal port of shipment, however, is now Syra on a neighbouring island. The emery is found in huge blocks usually in the red soil. It occurs in such abundance in these loose boulders and blocks that until very recently it has not been found necessary to mine it from the solid rock. It occurs in numerous lenticular masses, varying in width from 15 to 150 feet, and sometimes as much as a kilometer in length in a crystalline often saccharoidal limestone surrounded by micaceous schists and gneisses. It is thought to have originated from the influence of massive dykes of pegmatite which in turn are related to intrusions of granite. The best Naxos emery is of a dark grey colour, usually mottled with bluish specks

[1] "Ueber den Smirgel von Naxos" Tschermak's Min. und Pet. Mitth. Band XIV; 1895, pp. 311-342.

or streaks which are easily recognized as pure corundum. It usually has a platy or schistose structure, although occasionally massive. It is chiefly a very intimate admixture of corundum and magnetite; the powder even when examined under the microscope shows the separate existence of the two minerals which appear to be inseparable. The decomposition products usually present are red and brown iron ore, as also margarite, which is often disseminated through it in small scaly particles.

Other accompanying minerals which, however, can rarely be detected without the assistance of the microscope, are tourmaline, muscovite, chloritoid, diaspore quartz, and sillimanite. Less abundantly, disthene, staurolite, biotite, rutile, spinel, vesuvianite, and pyrite are found. The corundum is usually in rounded grains averaging about half a millimetre across; also in small crystals embedded in the iron ore. The bluish coloration is irregularly distributed through the individuals of corundum and zonal structure , . as also inclusions, especially of magnetite and rutile.

Emery is less abundant on the Island of Nicaria, but it is of similar quality to that from Naxos and possesses the same mottled appearance besides presenting a lamellated structure. The emery found on the Island of Samos is of a dark blue colour, also in loose nodular masses. The emery occurring on the islands of Heraklia and Sikinos to the south and southwest of Naxos is similar in character but is more finely granulated and associated with more finely crystalline limestones. The mining of this emery is still carried on in rather crude fashion. Notwithstanding the immense quantity that has been carried off, little of what might be called mining has been undertaken. The blocks of ore when not too large are transported to the coast. The larger blocks are broken to suitable size by the aid of sledge hammers, sometimes with the assistance of heat and sudden cooling with water. An analysis by the Naxos Union afforded the following composition:

Al_2O_3 57.69; Fe_2O_3 30.87; SiO_2 6.36; CaO 0.89; MgO 0.20; MnO trace; H_2O 3.99.

TURKEY (ASIA MINOR).

Turkish emery is obtained from the village or province of Aidin in Asia Minor. Smyrna is the principal city and business centre for this province and the islands adjacent to the coast. From this city two lines of railway extend into the interior along the valleys of the Sarabat (Hermus) and the Mender (Meander) rivers. The region is one of contrast, topographically, hills of rugged outline from 3,000 to 7,000 feet in altitude bounding and separating the broad and flat fertile valleys. The country rises inland until at the headwaters of the Mender the valleys are 3,000 feet above the sea. The hills are covered with a scanty and scattered growth of low prickly shrubs interspersed with pine and oak trees. In startling contrast to these uncultivated rough slopes, the valleys are often veritable gardens with a luxuriant growth of fig, olive, orange, and pomegranate trees.

Geologically the greater part of the region is underlaid by crystalline limestone often pure white and saccharoidal, at other times compact and finely granular. The less altered varieties are bluish in colour. These limestones are interfoliated with chloritic and micaceous schists and gneisses. In general the strike is nearly east and west, although locally there is a considerable departure from this prevailing direction. The dip is as a rule steep; south of Aidin it is in a southerly direction, while to the north of this town the angle of inclination of the rocks is in an opposite direction.

Farther north again at Odemish they dip south, indicating that there is considerable folding in the series. In several places belts of serpentine occur interfoliated with the schists and crystalline limestone which represented altered intrusive basic olivine rocks. Around the Bay of Smyrna are extensive areas of trachytic lavas and tuffs. Overlying the older crystallines are gently dipping sandstones and chalky limestones of Tertiary age filled with characteristic fossils.

The emery deposits of Asia Minor were made the subject of several extensive memoirs by Dr. J. Lawrence Smith about the years 1849-51.[1] Later these interesting deposits have received additional attention from W. F. A. Thomae of London, England,[2] K. E. Weiss,[3] A. Haenig,[4] and Simmersbach.[5]

It was not, however, until twenty years after Dr. Smith made his first investigations in 1849 that much attention was directed to the exploitation of this emery as a serious competitor to the Naxos deposits. The openings are most numerous in the belts of limestone near Tireh and the Gumuch Dagh. Many of these deposits are no longer economically workable, while others have not been touched.

The chief supplies come from the slopes of the Gumuch Dagh and farther from Ak Sivri. The former is about 12 miles southeast of the ruins of the ancient city of Ephesus (Ayasaluk) and just north of the Mender river. The latter is much more remote, about 100 miles southeast of Smyrna. Emery has also been found in the soil at Kulah on the river Hermes not far from the ancient city of Philadelphia; near Adula west of Kulah; at Manser north from Smyrna. In the vicinity of Smyrna deposits are mentioned at Baltizik, Azizich, Coshunar, and Kulluk. The deposits are of two kinds (1) rock emery or emery occurring "in situ" or in its original rock or host, and (2) emery drift or detritus resulting from the weathering of deposits of rock emery.

The rock emery occurs in pockets or lenticular masses in the crystalline limestone. They vary in width from a few feet up to a maximum of 200 feet, while the longest are not more than about 300 feet. They are generally worked to a depth of from 10 to 50 feet, although very often the deposit itself is deeper. Elongated deposits varying from 5 to 6 feet wide rise boldly at the surface and many run for a distance of 300 feet. The walls of the deposits are abrupt though irreg-

[1]Am. Jour. Sc. 2nd Series, Vol. VII (1849) pp. 283-285; Vol. IX, 1850, p. 289; Vol. X, 1850, p. 354, and Vol. XI, 1851, p. 53. Scientific Researches 1851, pp. 1-53.

[2]"Emery, Chrome-ore, and other Minerals in the Villayet of Aidin, Asia Minor" Trans. Am. Inst. Min. Eng. Vol. 28, 1898, pp. 208-225.

[3]Zeit. für Prak. Geol. 1901, pp. 252-253.

[4]Emery and the Emery Industry, London, 1912.

[5]Zeit. Berg. Hütten-u-Salienw, 1904, 52, 515; Groth's Zeitschr 12, 635.

ular. The emery itself is an intimate admixture chiefly of corundum and magnetite with a certain quantity sometimes abundant of certain silicates chiefly margarite, chlorite, and chloritoid. Sometimes these undesirable impurities are in veins or bands traversing the emery in various directions. A marked feature and one favourable to economical mining is the tendency of the emery ore to break into blocks of irregular, though suitable size for handling. When these regular fractures or cleavages are absent or ill-developed resort is still had to "fire setting."

Loose emery or emery detritus has so far been the main source of supply. Such emery is in the form of more or less rounded fragments or "boulders" embedded in a compact clay coloured in many cases a bright red owing to the oxidation of the iron in the ore. These often occupy depressions in the limestone, usually shallow but occasionally 20 feet in depth. Sometimes their source is in the immediate vicinity, while at other times no trace of the original deposits can be found.

Rock emery is quarried or mined by means of tunnels opening into big caves, the roofs of which are supported by big pillars. It is picked over and the desirable ore is loaded usually on camels carrying 4 to 5 hundredweight each, to the nearest port or railway sometimes over 20 miles distant. The royalty is about 13 shillings per ton, which amounts on the best ore to 17 per cent and on the low grade ore to 26 per cent on the value at the port of shipment, which is indeed a heavy tax. The chief shipping port is Smyrna.

GERMANY.

In the basin of the Rhine at various localities in the Siebengebirge and in the Eifel district sapphire corundum has been described by various observers as occurring in silicate inclusions in the basalt, in the bombs of certain andesitic tuffs associated with cordierite, sanidine, biotite, sillimanite, magnetite, and spinel.[1] The chlorsapphire is a deep green sapphire corundum occurring in bombs of a sanidine-gneiss enclosed in an ancient trachytic lava at Königswinter. Zirkel[2] mentioned the occur-

[1]Laspeyres, Verh. Naturhist Ver. Rheinl. Bonn. 1900, 460.
[2]Lehrbuch der Petrographie, 1893, p. 461.

rence of corundum in the andesite and tonalite of the Eifel district. Pirsson[1] also mentions the occurrence of small blue sapphires in the fresh basalt of Unkel on the Rhine and Steinheim near Frankfort-on-the-Main. The trachytes, andesites, and basalts of Siebengebirge as described by Dannenburg[2] contain in addition to corundum, spinel, magnetite, sillimanite, numerous inclusions of sandstone, schist, and granulite. G. Leonhard had as far back as 1842 recognized sapphire in the lava from Niedermendig and Mayen.

The hornblende-andesites of Bocksberg and Rengersfeld in the Eifel district described by Vogelsang[3] are not homogeneous in character. They contain masses which sometimes have the aspect of included fragments or streaks which differ in character from the rest of the rock. These portions of the rock are made up of cordierite, andalusite, sillimanite, feldspar, biotite, pleonaste, bluish crystals of corundum, rutile, quartz, garnet, zircon, and magnetite. These masses vary in size, being sometimes nearly 2 inches in diameter, while certain streaks are sometimes nearly 5 inches in length.

Vogelsang is inclined to the view that these inclusions have been derived from the crystalline schists. A significant fact, relating especially to the origin of the emery at Peekskill, New York, is the occurrence of spinel in the andesite immediately surrounding the inclusions. It is stated that some of these minerals at least owe their origin and presence to the chemical change in the magma consequent on the solution of a certain amount of the material in the inclusion.[4] The volcano of the Laacher See, like that of Vesuvius, is remarkable for the number and variety of the ejected blocks contained in the agglomerates. They include fragments of crystalline foliated rocks of which cordierite-gneiss is the most abundant. Some of these blocks show very little alteration as a result of heat and the cordierite

[1]Am. Jour. Sc. 4th Ser, Vol. IV, 1897, p. 422.

[2]Tschermak's Min. und. Petro. Mittheil. Vol. 14, 1894, p. 17.

[3]"Beiträge zur Kenntniss der Trachyt—und Basalt—gesteine der hohen Eifel," zeit. d. deut. geol. Gesell. B. XLII, 1890, p. 25.

[4]J.J.H. Teall "The Natural History of Cordierite and its Associates Prov. Geologists Assocn. Vol. XVI, Part 2, 1899, p. 67.

is clear, only faintly pleochroic, and contains inclusions of spinel and corundum. In the altered blocks the cordierite is strongly pleochroic and mostly free from sillimanite. It is also surrounded by glass and contains secondary glass inclusions. The biotite in such rocks has often been fused to a glass from which spinel has separated. In the more altered forms, the original minerals have entirely disappeared and the newly formed cordierite is in a matrix of brown glass.

In Baden, corundum occurs northerly from Schenkenzell as bluish grains about the size of a pea in sericitic segregations in a granite-porphyry.[1] Beautiful blue small columns of sapphire have been noticed at Horberig in the Kaisertuhl.[2]

In Bavaria the emery at Wildenreuth is in a quartzose and garnetiferous hornblende schist;[3] corundum also occurs in hornblende gneiss at Albersreith near Vohenstrauss.[4]

In Hesse sapphire was noticed in the basalt of the Calvarienberg at Fulda.[5]

At Michaelstein in the Harz mountains corundum occurs in a kersantite dyke which is intrusive into clay slates with subordinate limestone, quartzite, and hornstone of lower Devonian age.[6] The kersantite which is dark grey to almost black in colour is made up of numerous phenocrysts of biotite and occasionally of feldspar embedded in a fine-grained groundmass. Enstatite and cordierite are recognizable under the microscope and the latter mineral is in well defined hexagonal prisms, seemingly authigenic and formed from the magma. It is crowded with minerals which seem entirely foreign to the rock, including feldspar, garnet, sillimanite, cyanite, quartz, biotite, rutile, spinel, apatite, staurolite, hypersthene, calcite, magnetite, anatase, and titaniferous iron-mica. These apparently extraneous minerals occur either singly or in aggregates, the latter varying

[1] Groth's Zeitschr, 29, 157.

[2] Rosenbusch Physiog. 1905, 1, b. 39.

[3] Rumpf. N. Jahrb. 1856, 559; Oebbeke, nutzb. Min. Ind.-Ausst. Nurnb. 1906, 34.

[4] Bruhns, Nutzb. Min. 1906, 685

[5] Sandberger, N. Jahrb. 1890, 1, 100.

[6] Max Koch "Die Kersantit des Unterharzes" Sahrh d. preass. geol. handesanst 1886, p. 44.

in size from those of microscopic dimensions to others equal in size to that of a walnut or sometimes larger. In some portions more than half the dyke is made up of these inclusions.

Corundum also occurs in this kersantite in small crystals up to 0.5 m.m. in aggregates of spinel, rutile, and staurolite, as well as in irregular grains in fibrous sillimanite. These minerals according to Teall[1] undoubtedly owe their origin to the chemical change in the magma owing to a certain amount of digestion and assimilation of the material of the numerous inclusions.

In Saxony bluish grey occasionally red corundum in small crystals and grains has been found in gravel near Hinter-hermsdorf. On the Ochsenkopf at Brockau near Schwarzenberg deep bluish grey granular masses with "beilstein" meneghinite and talc in a glistening quartz-phyllite. Similarly it occurs as phenocrysts in the magnetite of Mittelberg near Waldheim.[2]

One of the most interesting occurrences of corundum in Germany is that described by Professor Dr. Ernst Kalkowsky[3] from the granulites of Saxony.

The so-called corundum granulite is in lenticular masses 4 metres in width within the prevailing sillimanite granulite. Although the whole lens-shaped mass of corundum granulite is sharply bounded and is thus a petrographical unit it is divisible into certain varieties which are readily recognizable, although transitional phases are also present. A general description recognizes the whole mass as essentially a quartz-free medium-grained admixture of albitic feldspar with prismatine (or kornerupine)[4] in columns of good size, garnets about the size of a

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[1]Proc. Geologists' Association. Vol. XVI, part 2, 1899, pp. 66-67.

[2]Frenzel, Min. Lex. 1874, 177.

[3]"Der Korund granulite von Waldheim in Sachsen" "Isis" Jahrgang 1907, Heft 2, pp. 47-65.

[4]The analyses of this rare and imperfectly known mineral show it to have a composition in close agreement with the formula $Mg Al_2SiO_6$ first described in 1884 as Kornerupine by J. Lorenzen from material obtained in Fiskernäs, Greenland, where it occurs with green amphibole, sapphirine, and a light brown magnesia mica, also gedrite and occasionally cordierite (iolite). Named after the Danish geologist Kornerup—Prismatine was so named by A. Sauer in 1886 after an analysis of the Waldheim mineral. Ussing calls attention to the similarity of the two independently described minerals.

hazel-nut and a characteristic tourmaline. In certain instanc a lime feldspar is represented an' there is a facies of the roc which contains a certain amoun. of quartz. In general th corundum has the clear violet colour characteristic of the orienta amethyst. It has distinct though weak pleochroism, high inde of refraction, and low double refraction. It is uniaxial, an negative and sometimes shows certain optical anomalies. Rutil is sometimes present as inclusions in the corundum, occasionally tourmaline, and very rarely feldspar. In the larger individuals these inclusions are arranged towards the centre. In addition to minerals which are usually met with in the granulite Kalkowsky mentions zircon, abundant rutile and sillimanite, small amounts of disthene, and in certain differentiated portions andalusite.

The t variety of the corundum granulite is designated by Kalkowsky as the "prismatine granulite poor in corundum." It is white in colour and fine to medium grained in texture with disseminated small dark brown tourmalines some of which approach a size of 2 mm. The presence of biotite is dependent on the absence of tourmaline. The garnet crystals noticed are from 3 to 4 mm. across and sometimes more than 1 c.m. thick. The whole rock is filled with prismatine chiefly in radial aggregates. Some large columnar forms occur in certain more highly feldspathic portions of the rock. The small anu infrequent particles of corundum are readily missed if special search is not made for them. There is a definite passage from this phase of the corundum granulite into the second form which is called the "granular granulite rich in corundum." This rock is rather variable in colour, usually reddish but sometimes greyish. The corundum which is abundant occurs as bright bluish grey specks sprinkled through the rock. Foliation is indistinct, but becomes more apparent by increase of biotite or tourmaline. Tourmaline and biotite seem to be mutually repellant, while there is also an antagonism between the tourmaline biotite and prismatine. Garnet is very sparingly present. In the third variety which is known as the "biotite rich corundum granulite" the prevalence of the mica gives the rock a pale violet tinge. In spite of the abundance of the small plates of biotite the foliation of the rock is not very decided. No tourmaline is present but in certain portions garnet and prismatine. Corundum is not recognizable without the assistance of the microscope and is sometimes with difficulty distinguishable from the sillimanite which is present in small masses of minute whitish grains. In the "reddish schistone corundum granulite" the corundum is not only abundant but in larger crystals which can be seen with the unaided eye. On the broken surface of a hand specimen 20 or even more tabular crystals may be counted. These are conspicuous by reason of their brilliantly shining cleavage surfaces. They are irregularly distributed, usually associated with the larger individuals of prismatine. The rock contains very little tourmaline, and garnet is very rarely represented. On the contrary sillimanite and rutile are abundant. The fifth phase of the granulite is described as the "white granulite rich in quartz and poor in corundum." The corundum is present in small greyish grains 3 to 7 to a square centimetre. When richer in corundum they are 10 to 12 grains in a square centimetre. Kalkowsky asks, "Why should free alumina occur in such intimate assocation with free silica? Why is not this surplus alumina used in the formation of feldspar or to form sillimanite?" He considers the corundum granulite as an unusual rock, but its structure, immediate associations, and banded character are those of a true granite.

The ore bearing rock of the nickel deposits near Sohland on the Spree near Bautzen, Saxony, discovered in 1900, is in the form of dykes cutting the country rock, the so-called Lausitzer granite. The principal ore bearing dyke is from 30 to 60 feet wide and has been traced for more than half a mile. It is most largely developed as "proterobase," a fine to medium-grained rock consisting chiefly of plagioclase, augite, brown hornblende, and brown mica. The chief accessory minerals are a colourless pyroxene, magnetite, ilmenite, apatite, zircon, and rutile as well as secondary hornblende, talc, chlorite, and serpentine. In part it takes the form of a biotite diabase which is finer grained and occurs as irregular modules within the proterobase. Brown hornblende is absent, but otherwise it rather resembles the proterobase into which there is a gradual transition. The basic segregations are of two varieties, one not found "in situ" is characterized by countless octahedra of a green transparent spinel and a few grains of corundum. The other variety which is found in the ore body is made up largely of aggregates of sillimanite and contains numerous spinel and sapphire crystals. The sapphire is in tabular forms up to 0.7 mm. broad.[1]

Von Foullon[2] has found corundum in a quartz porphyry from Teiplitz. In an insoluble residue obtained from treating this rock with hydrofluoric and sulphuric acids he obtained small grains of corundum.

In Silesia small grains of pale coloured red and blue corundum have been found in the gold bearing gravels at Goldberg.[3] Small rounded individuals of this mineral have also been found in pegmatite at Rabenstein near Wolfshau.[4] Andreas and König[5] describe an extremely basic facies of saussuritic hornblende gabbro at Frankenstein in which masses and streaks of magnetite, sillimanite, and tabular crystals of colourless corundum occur in large allotriomorphic masses of plagioclase. This is comparable to the occurrence of nodules and masses of spinel and corundum in coarse irregular feldspars in the somewhat amphibolized gabbro in Veltlin described by Linck.[6] (Compare emery of Cortlandt Series, Peekskill, New York.)

AUSTRIA-HUNGARY.

Bohemia. On the Iserweise small pebbles of sapphire up to a gramme in weight are only found rarely.[7] Sapphire and ruby in grains up to 1 cm. across and larger pyramidal crystals as much as 5 mm. in diameter, of blue, greenish, whitish, and pale

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[1]Beck "Die Nickelerz lagerstäate von Sohland a.d. Spree, und thre Gesteine" Zeitschr., a.d. geol. Gesell, 1903, 55, 311; Jour. Can. Min. Inst. Vol. IX, 1906, p. 254.

[2]Verhandl. geol. Reichsanstalt, Wien, No. 8, 1888, p. 178; Am. Nat. 1889, p. 524.

[3]G. Rose, bei Roth, Erläut, Karte, 1867, 385.

[4]Von Milch, N. Jahbr. 1899, Beil-Bd. 12; 237.

[5]Abhandl. Senck. Gesell. Frankfurt, 1888, p. 62; Bull. 269 U.S.G.S. 1906, p. 63.

[6]Sitzungsber. K. preuss. Akad. Wiss. zu Berlin, Vol. 6, 1893, p. 47

[7]Leonhard, top. Min. 1843, 451; Zepharovich, Lex. 1859, 227; 1873, 171.

red colour are found in the concentrates of Podsedlitz and Triblitz.[1] Near Petschau in pale reddish grains it occurs in association with cyanite and quartz. Corundum is also present in association with hercynite at Natschetin near Ronsperg.[2] In gold bearing sands near Bergreichenstein rolled pebbles and rounded crystals of corundum are found. Near Pisek rose to hyacinth red grains and fragments are found in the sands of the Votawa.

Moravia. Near Kerchmislau corundum has been noticed in deep blue grains in talc schist. At Nedwieditz small grains and crystals of light blue corundum are disseminated through crystalline limestone.[3] Near Mährisch-Schönberg crystals of corundum of greyish white to yellow colours slightly transparent and up to 12 mm. long and 6 mm. wide are embedded in granular plagioclase associated with cyanite.[4] At Pokojowic near Okrisko greyish, occasionally blue crystals of corundum are found embedded in a coarse-grained vein of potash feldspar in gneiss.[5]

Austrian Silesia. In the northwestern corner of Austrian Silesia near Jauernig an occurrence of corundum has been described by F. von Camerlander in olivine-gabbro associated with amphibolite. The corundum is in whitish or blue grains sometimes as large as a hazel nut. It is optically biaxial.[6]

Hungary. Near Szob blue crystals of corundum as much as 0.3 mm. across occur in inclusions of cordierite gneiss in andesite, also in very small crystals in hornblende andesite near Deva, at Nagyag, at Szarazpatak near Sztolna and at Gyalu. Corundum also occurs near Ajnacsko up to 7 mm. long and 1.5 to 2 mm. thick, of a greyish blue colour in basalt.[7]

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[1]Oehmichen, Zeitschr. pr. Geol. 1900, 5.

[2]Kalkowsky, Zeitschr. d. geol. Ges. 1881, 33, 536.

[3]Zepharovich, Lex. 1859, 227.

[4]Oborny, Jahrb. geol. Reichsanst 1°65. 15 Verh, 14; Zepharovich, Lex. 1873, 171.

[5]Barvir, Groth's Zeitschr. 25, 432.

[6]Verh. geol. Reichsanst, Wien 1886, 356; Zepharovich Lex. 1893, 142.

[7]Szadeczky, Földt. Köslöny 1895, 25, 229; 1899, 29, 296; Groth's Zeitschr. 27, 99; 34, 709.

Siebenbürgen. Small pebbles of sapphire have been noticed in the gold-bearing sands of Olahpian.[1]

Austria. In lower Austria Wichmann described corundum as embedded in graphite of Muhldorf near Spitz. It is in columns or spindle forms up to 2.5 c.m. long, of reddish to bluish more rarely greyish cloudy crystals. It also occurs in blocks of pegmatite at Felling, in crystals as much as an inch in length, of bluish, greenish grey, and violet colours.[2]

Tyrol. Corundum in dull crystals up to 1.5 cm. long occurs in granular dolomite at the foot of the Karl Weissen.[3] At Monzoni according to Doelter it is associated with spinel in a red granitic dyke rock.[4] On the Cima d'Asta corundum has been found in a hornstone phyllite at the Canale San Bovo and lower down in the valley Calamento.[5] Teller and von John found corundum associated with tourmaline, spinel, ilmenite, rutile, and biotite on the borders of the quartz-mica-diorites that intrude the gneisses and schists at Klausen. The corundum is in colourless or bluish crystals of microscopic dimensions, the tourmaline alone being visible to the naked eye.

SWITZERLAND.

At Tessin[6] on the Campo Longo corundum occurs in dolomite with diaspore, pyrite, rutile, to[illegible]aline, and mica. For the most part it is pale red, also bl[illegible]n grey or colourless, transparent to translucent. Prism[illegible] ividuals are clear and as much as 10 cm. long. Red a[illegible] blue corundum occurs at St. Gotthard in dolomite.[7]

ITALY.

Sapphire and ruby are mentioned as occurring with zircon in Venice in the sands of Lonedo. A very interesting account

[1]Zepharovich Lex. 1859, 227.

[2]Verh. geol. Reichsanst Wien 1884, 150; Groth's Zeitschr. 10, 429. Zepharovich Lex. 1859, 227; 1893, 141; Sigmund, Niederöst Min. 1903, 10.

[3]Weinschenk, Tscherm. Mitth. N.F. 22, 77; Zeiske, 23, 100.

[4]Sitzb. Ak. Wiss. Wien, 1903, 112, 169; Groth's Zeitschr. 41, 508.

[5]Salomon, Tscherm Mitth. N.F. 17, 200, 204, 206.

[6]Kenngot, Min. Schw. 1866, p. 145.

[7]Dana System of Mineralogy p. 212.

is given of the occurrence of corundum and its associated minerals on the Italian slopes of Adamello in Lombardy at Monte Aviolo by Salomon.[1] The mountain mass of which Monte Adamello is the highest peak (11,681 feet) forms part of the southern portion of the Eastern Alps.

It consists of a central mass of tonalite or quartz-diorite, surrounded by sedimentary rocks of various ages, many of which show evidences of contact metamorphism. The rocks concerning which the investigation was made comprise part of a zone extending along the western edge of the intrusion and have been traced for a distance of nearly 9 miles. They are a part of the older metamorphosed sedimentaries which have been further altered by the tonalite. The most characteristic rock of the inner belt is made up of from 50-70 per cent of cordierite associated with biotite, andalusite, sillimanite, quartz, titaniferous iron ore, and in certain cases, plagioclase, orthoclase, garnet, spinel, and corundum. Inclusions of the cordierite phyllite or hornstone have been caught up and embedded in the tonalite. Some portions of this hornstone are rich in corundum.

Corundum also occurs in mica-schist on Monte Muffeto near Bovegno in the province of Brescia.[2] Corundum is present with hercynite at Le Prese.[3]

Piedmont. In the province of Novara it has been found in a contact-hornstone near Baveno.[4] In the district of Biella, especially near Mosso Santa Maria it occurs in dykes of altered white oligoclase which Lacroix has identified with Lawson's plumasite.[5] In the province of Turin according to Jervis, near Lemie toward the Cima del Morosso there is grey corundum in feldspar; near Locana and Castellamonte corundum is in erratic blocks. Near Gressoney-la-Trinité grey corundum with quartz also occurs.[6]

[1] "Geologische und petrographische Studien am Monte Aviolo" Zeit d. deut. geol. Gesell. B. XLII, 1890, p. 450.

[2] Jervis, Tesori sotterr. Ital. 1873 I. 281.

[3] Linck, Sitzber. Ak. Wiss, Berlin, Feb. 1893.

[4] Salomon Tscherm. Mitth. N.F. 17. 266.

[5] Bull. Soc. Min. Paris, 1903, 26, 149.

[6] Hintze Handb. d. Min. 1907, p. 1755.

PORTUGAL.

Leonhard[1] states that corundum occurs in Portugal in the vicinity of Lisbon.

SPAIN.

The southeast coast of Spain in Andalusia in the province of Almeria, from Cabo di Gata to the neighbourhood of Cartagena, a distance of about 100 miles, has a fringe of volcanic rocks belonging to the upper Miocene or early Pliocene periods. The volcanic rock is a mica-andesite, containing porphyritic individuals of a basic plagioclase, biotite, rhombic pyroxene, and hornblende in a glassy base. Cordierite inclusions sometimes as large as a hazel nut and sharply defined idiomorphic and authigenic crystals are present in this andesitic lava. In intimate association with the cordierite are feldspar and quartz with abundant spinel corundum and andulasite.[2] In the province of Malaga at Ronda corundum occurs with mica mixed as emery; also in the sands on the coast near Marbella. In Estramadura at Canchal de la Muela in the province of Caceres this mineral also has been found, while rounded crystals of corundum may be picked up in Galicia in the sands of the Sil.[3]

FRANCE.

In the Hautes-Pyrénées near Cauterets corundum occurs in tabular crystals in leptynolite.[4] Grey pyramidal crystals of corundum have been detected in a dyke of grey pegmatite in granite between Pouzac and Ordizan.[5] Lacroix has described corundum in microscopic blue grains with spinel as one of the constituents of the crystalline limestones interfoliated with

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[1]Top. Min. 1843, 450.

[2]Osann, "Ueber den Cordierit-führenden Andesit vom Hoyazo" Zeitschr. d. geol. Ges. 1888, 40, 701; 1891, 43, 334.

[3]Tenne-Calderon, Min. Iber. 1902, 88.

[4]Lacroix, Min. Fr., 1901, 3, 245.

[5]Frossard, Bull. Soc. Min. Paris, 1891, 14, 77.

gneiss at Arignac in Ariège. The other associated minerals chiefly noticed are humite, brucite, amphibole, phlogophite, scapolite, sphene, rutile, and zircon.[1] Dark blue corundum is associated with red andalusite in a mica schist at the Col des Cadènes in the "Massif" of Pic St. Barthélemy.[2] In the department of Haute-Garonne in the gedrite at Gèdres and at Lac de Caillaouas in the valley of the Louron, blue grains of corundum are intermixed with green spinel.[3] Lacroix[4] described the occurrences of corundum in the trachytes, andesites, and basalts of the volcanic district of the Auvergne mountains in the "Plateau Central". The corundum is associated with zircon, diaspore, sillimanite, and other related species. The rocks contain many acid inclusions that have been more or less dissolved and incorporated in the magma. In Cantal, the trachyte at Menet has inclusions of sanidinite which are rich in corundum crystals up to 5 mm. across of bluish, milk-white, and spotted bluish colours. In the department of the Haute-Loire this mineral is by no means rare in the basaltic tuffs and breccias as also in the river sands.

At Le Croustet and the volcano Le Coupet and many other places in the region it occurs in basalts or enclosed within the tuffs and breccias. The crystals which are bluish and sometimes as large as 3 cm. across are almost invariably rounded as though corroded by the basalt magma. They are seldom sharply defined with glistening faces.

At the Puy-de-Dôme dark blue prismatic crystals 2 mm. long have been found in a granite inclusion containing nephelinite of the Puy de Saint-Sandoux (or du Barnaire).[5] In Brittany in the department of Loire Inférieure large pyramidal crystals of dark blue star sapphire with rough surfaces from 12 to 14 mm. in diameter have been found in a field at La Mercredière on the road to La Haie-Fouassière.[6]

[1] Bull. Soc. Min. Paris, 1889, 12, 519; Am. Nat. 1891, pp. 138-139.
[2] Lacroix Min. Fr. 3, 241.
[3] Lacroix Min. Fr. 3, 246.
[4] Min. Fr. 3, 243, 241; Bull. Soc. Min. Paris, 1891, 14, 316.
[5] Lacroix, Bull. Soc. Min. Paris, 1894, 17, 46; Min. Fr. 3, 242.
[6] Lacroix, Bull. Soc. Min. Paris, 8, 440; Min. Fr. 3, 241.

An inclusion of leptynolite occurring in the granite of Pont Paul near Morlaix[1] in the department of Finisterre has been described, some of the layers of which this rock is composed containing abundant sapphire blue tabular forms of corundum up to 1.7 mm. in diameter associated with biotite, magnetite, pleonaste, andalusite, staurolite, quartz, and pyrite.

ENGLAND.

Corundum has been found in a felsite (granite) which is intrusive in clay slates at Dartmoor near South Brent in Devonshire. It is most abundant near the contact of the felsite with the clay slates and is, therefore, regarded by Busz, who has described the occurrence, as a contact product. The mineral is in minute tabular colourless crystals (0.02–0.03 mm.) sometimes showing hexagonal outline. Busz explains the presence of corundum in these conditions by the fact that portions of the slates were dissolved by the granite magma which thus became locally supersaturated with alumina and on cooling this excess of alumina crystallized as corundum. Corundum also occurs as rolled fragments in the Avon river.[2] In Essex it occurs in the Red Crag at Beaumont,[3] while in Cumberland bluish grey crystals of corundum are present in nacrite at Carrock Fells.[4]

IRELAND.

Small blue pebbles of corundum occur in the bed of a stream which flows from the Croghan Kinshela mountains in the county of Wicklow.

SCOTLAND.

Blue crystals of corundum have been found in red andalusite on Clashnaree hill at Clova, Aberdeenshire.[5]

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[1]Barrois Bull. Soc. Géol. France, Vol. XIV, 1886, p. 888.

[2]Professor Busz. "On the Occurrence of Corundum produced by Contact Metamorphism." Geol. Mag. 3, 1896, 492; Brit. Assocn. 1896, 807.

[3]Lomas, Quar. Jour. Geol. Soc., 1900, 56, 738.

[4]Greg and Lettsom, Min. Brit., 1858, 135.

[5]Heddle, Min. Soc. Lon. 1891, 9, 389; Min. Scotl. 1901, 1, 88.

Cordierite bearing rocks often containing sillimanite, spinel, and in certain localities at least, corundum, have been recognized at many points in the Eastern Highlands in the counties of Aberdeen, Banff, and Forfar. One specimen obtained by Hinxman from the top of the Buck of Cabrach shows "a massive dark bluish rock spangled with small flakes of white mica. It possesses a somewhat spotted appearance in consequence of the presence of individuals or aggregates of cordierite. The colourless constituents, cordierite, andalusite, white mica, microcline, and quartz make up the main mass of the rock. The dark minerals are magnetite and biotite, but the latter is very feebly represented." A specimen from the railway cutting southeast of Little Arnage is "a compound rock due to the superposition of igneous upon metamorphic material. The igneous portion is represented by more or less idiomorphic oligoclase, biotite, orthoclase, and quartz; the metamorphic portion by cordierite, quartz, biotite, sillimanite, iron ores, and a green spinel. The rock into which the granitic magma was intruded is now represented by somewhat ill-defined shreds, patches, and streaks in a paste of igneous origin." Other specimens submitted by Barrow and Kynaston have since been examined. One of Barrow's specimens, collected in the Glen Muich area, is composed of cordierite, sillimanite, quartz, biotite, iron ores, green spinel, and probably a little feldspar. It contained a very high percentage of alumina (32.4). Barrow regarded the rock as produced by the general thermo-metamorphism associated with the intrusion of the earlier granitic material. Kynaston's specimens were collected from the vicinity of the Ben Cruachan granite and are regarded by him as normal contact products resulting from the intrusion of this granite. They are of medium grain, dark bluish grey, rather massive rocks made up of cordierite, andalusite, alkali feldspar, oligoclase, biotite, pyrite, and a green spinel. Quartz is sometimes but not always present. The presence of a colourless grain in one

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NOTE. Hintze (Handb. d. Min. p. 1757) makes a footnote that emery is said to occur in the Island of Jersey, at Maldron in Cornwall, and at the foot of one of the Mourne mountains in County Down. The corundum from Auchindoir, in Aberdeen is red tourmaline.

of the thin sections prepared from a specimen from the neighbourhood f Ben Cruachan led to a further investigation. The coarse pov der from the rock was allowed to be digested by hydrofluoric acid for several days, when an examination of the residue revealed the presence of corundum, pyrite, spinel, and a few crystals of rutile, which last mentioned mineral had escaped detection in the slide.

The corundum in this rock occurs c 1 crvst ls and irregular grains. The crystals are combinations of the hexagonal prism, the primitive rhombohedron, and the basal plane. They are sometimes flat and sometimes prismatic.[1]

SWEDEN.

Corundum occurs in Lapland in the Baron mine at Gellivare-Mamberg in both magnetite and hematite with syenite. It usually occurs in small grains and crystals, but in some of the coarsely crystalline phases of both the magnetite and the hematite the corundum is in larger individuals up to one centimetre in diameter. In the earlier description of this occurrence (1803) it was stated to occur in hematite with feldspar apatite and mica.[2] Sillimanite gneiss is exposed in several small rocky knobs.

FINLAND.

Translucent pyramidal crystals of corundum have been recorded in Lojo at Ammänkallio (Maila) in limestone.[3]

GERMAN EAST AFRICA.

Corundum has been obtained from Mulale, west of Kisitwi. The specimens noticed are sometimes 3 cm. in length, rose to flesh red in colour, and either opaque or only slightly translucent.

[1]J. J. H. Teall, Proc. Geologist's Assocn. Vol. XVI, Part 2, 1899, pp. 63-64.

[2]Leonhard, top. Min, 1843, 322; Erdmann, Min. 1853, 228; Stutzer, N. Jahrb. 1907, B.B. 24, 637; Högbom, "The Gellivare Iron Mountain" Intern. Geol. Cong. Sweden, 1910, Guide Bk. 4, p. 25, 32; Geol. Foren i. Stockholm Förhandl. Bd. 32, Häft 3, Mars, 1910.

[3]Wiik, Mineralsaml, Helsingfors, 1887, 15.

The corundum is loose and occasionally it is found intergrown with rutile.[1]

SOUTH AFRICA.

In Swaziland in immediate association with cassiterite, corundum has been noticed both in the rock and in alluvial deposits. It occurs in individuals showing twinning striations, sometimes partly altered to diaspore.[2] Molengraaf in a description of the geology of the gold fields in the vicinity of Pretoria, mentions that the oldest rocks are granites, sericite, and actinolite schists and amphibolites. Superimposed on these are quartzites, clay slates, corundum schists, and porphyroids, and chiastolite schists intruded by dykes of diabase. The corundum porphyroid resembles a feldspar porphyry with large crystals of biotite and corundum in a groundmass of quartz and chlorite. According to S. M. Tweddill, curator of the Museum of the Transvaal Geological Survey, a ruby-bearing rock has been discovered at Leydsdorp. The essential constituents of the rock are a ferromagnesian mineral and a granular ruby coloured corundum. The occurrence of this ruby bearing rock in Northern Transvaal with the discovery of fairly large pebbles of ruby still farther north point to the probability of the gem being found in some amount.

A new discovery of corundum was made toward the end of 1911 on the upper ridges of the watershed 7 or 8 miles from Oliphant river. The deposits according to J. Broad Roberts are associated with a mica belt and occur in a variety of forms. One is an irregular vein of feldspar and quartz about 4 feet wide in which sapphires are found. The foot-wall is a calcareous tuff, the hanging-wall a talcose and micaceous decomposed schist. At two other points lenses of granular corundum were discovered associated with cyanite and fuchsite.[3]

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[1]Spencer Min. Soc. London, 1905, 14, 181.

[2]Molengraaf Trans. Geol. Soc. S. Africa, 1898, 4, 141; Groth's Zeit. 32, 301; Zeit. für Prak. Geol. 1900, 147; Prior Min. Soc. London, 1898, 12, 96.

[3]Minerals of the Murchison Range, Transvaal, Mica and Corundum Deposits, South African Min. Jour. June 29, 1912, p. 655.

In the matrix of the diamond at Jagersfontein, small irregular grains of corundum occur which are strongly pleochroic and exhibit twinning lamellations. The mineral is of a deep indigo blue, bright violet, and greyish colours. It is biaxial and was at first diagnosed as cordierite.[1]

In German Southwest Africa deep blue crystals of corundum are found embedded in a crystalline limestone at the Ussab gold mine.[2]

MADAGASCAR.

Corundum has been found in the alluvial deposits of Mevatanana, Ambositra, and Betafo, mostly dark blue in colour, also colourless and in red and green shades. In the basaltic tuffs of the vicinity of Diégo-Suarez black pyramidal crystals are accompanied by ferropicotite. At Betsiriry bluish or greyish crystals of corundum are associated with muscovite. Prof. Lacroix writes that "In Madagascar the gems that accompany the gold are chiefly corundums, garnets (chiefly of the almandine variety showing a wide range of colour from dark red to a pretty rose) occasionally some chrysoberyl, some spinel, and topaz. One of the most typical of the alluvial deposits he visited was that to the southwest of Ambositra in the bed of the small river Ifèmpina. In addition to some gold, many crystals of corundum much rolled are obtained. In fact the corundum crystals of this alluvia[l dep]osit are at times converted into absolutely round pebbles although they have only been removed a few kilometres from their source. Most of the corundum is opaque, but some individuals are transparent. Some of the uncoloured corundum with a perfect limpidity has been found which weighs as much as 500 grammes. The rubies and sapphire which accompany this colourless corundum are in much smaller individuals. "In order to find the deposits rich in rubies and especially in sapphires you must climb towards the north on the volcanic massif of Ankaratra where are worked some basaltic alluvia containing debris of granitic extraction, the original source of corundums

[1]Knop Oberrhein, geol. Ver. 1889, 20; 1890, 21; Groth's Zeitschr. 20, 300.
[2]Gürich N. Jahrb. 1890, 1, 106.

and zircons which accompany them." Professor Lacroix in a foot-note states that "by their properties and their kind of deposition these stones are identical with those of Velay especially near Le Puy and Le Coupet in France".[1]

INDIA.

The corundum deposits of the Indian Empire are still among the most extensive and important in the world, for they include not only the common variety of this mineral but also the most highly prized specimens of the gem variety. The deposits situated in the Madras Presidency furnished the material used by the Count de Bournon in preparing his famous memoir on the several varieties of this mineral.[2] The following provinces and native states also contain this mineral in more o less abundance: Afghanistan, Assam, Bengal, Burma, Central Provinces, Hyderabad, Kashmir, Madras, Mysore, Punjab, Rewah, and Travancore.

The occurrences in Afghanistan are situated at Jagdalak, 32 miles east of Kabul, and at Gandamak, about 20 miles from Jagdalak. They consist of rubies, which at Jagdalak are contained in a crystalline, micaceous limestone (cipollino), very similar in character to the parent rock of the celebrated Burmese rubies. These limestones are considered by Griesbach[3] to be unquest... ..bly sedimentary, metamorphosed by the numerous intrusions of granite which ramify amongst them.

In Assam a finely granular, massive, light grey corundum occurs at the village of Nongryniew in the Khasi hills, two days journey northwest of Nongstoin, the capital of a petty Khasi state. No detailed information is available regarding the mode of occurrence of this rock.

The mineral is found in blocks weighing several tons and in smaller fragments is piled up and used by the villagers as grindstones.[4] The localities are difficult of access for the exploitation of the mineral on a large scale.

[1]Min Fr. 1901, 3, 247, 245, 242; Smithsonian Report, 1912, pp. 380-381.
[2]Phil. Trans. Roy. Soc. Lon., Vol. 92, p. 233 (1802).
[3]Rec. Geol. Surv. India. Vol. XX, pp. 24 and 97 (1887).
[4]Rec. Geol. Surv. India, Vol. XII, p. 172 (1879).
Sketch of the Mineral Resources of India, 1908, pp. 47 and 48.

In the Mandbhum district in Bengal, a valuable deposit of blue corundum associated with cyanite was discovered in 1895 by Dr. H. Warth, of the Geological Survey of India, in a vein, in a road-cutting near the village of Salbanni, 4 miles east-southeast of Balarampur, Bengal-Nagpur railway.[1] The vein is about 3 feet thick and is traceable at intervals for 6 miles. The cyanite, corundum, and damourite lie in a coarse-grained quartz rock, in which are large quantities of black tourmaline and which has been penetrated by numerous veins of graphic granite. The deep blue, often variegated and zoned, corundums vary in size from minute granules to crystals three pounds in weight, with nearly always fairly sharp prismatic outline. These are embedded irregularly in large bladed or platy crystals of pale blue cyanite from which they are often separated by a thin layer of pearly damourite. Genth,[2] explaining a very similar mode of occurrence in Patrick county, Virginia, states that the cyanite and associated minerals (cyanite, mica andalusite, etc.) are derived from the alteration of the corundum. Holland[3] arguing from the evidence presented by the associations of this Bengal deposit regards the corundum as "the earliest formed mineral in the rock, whilst it subsequently became enveloped by the cyanite which has been partially changed to mica by the introduction of potash and silica, ... the excess of simple base was first separated and was followed by the formation of a compound of the remainder of that base with silica".

Burma has ever since about the end of the fifteenth century been famous in Europe for its rubies. From the time of Tavernier[4] various descriptions of these celebrated deposits have appeared. Upper Burma has long been known to be the source of the magnificent red corundum ("pigeon's-blood ruby") and also of the red spinels (Balas ruby) and of the pink tourmaline (rubellite) a gem which, by the Chinese, is prized even more highly

[1]Econ. Geol. of India, 2nd Ed. Part 1, Corundum, pp. 16 and 21 (1898).
[2]Am. Journ. Sc. 3rd Series, Vol. XXXIX, 1890, p. 47.
[3]Econ. Geol. of India, 2nd Ed. Part 1, Corundum, p. 17, 1898.
[4]Tavernier's "Travels in India" Translated from the original French edition of 1676 by V. Ball, London, 1899, pp. 99.

than the true ruby. Europeans, however, regard the true or oriental ruby as not only more precious than any of the accompanying minerals but as the most valuable of all gems, as the best coloured specimens bring far higher prices per carat than diamonds of the first water. The ruby mines of Burma appear to have been worked from very early times, the Burmese being said to have acquired them from the Shans about 1630, but they were regarded as royal property, and very jealously guarded from Europeans. Until, therefore, the country was conquered and became part of the British Empire in 1886, very little was known concerning the mode of occurrence of the corundum and associated minerals. In 1887 the Secretary of State for India determined to send out an agent to make independent inquiries concerning the value of the mines and to make suitable recommendations in regard to their working. Mr. C. Barrington Brown was selected for this work and every facility was afforded him by the different authorities during the progress of his investigations. His preliminary report was presented to the Indian Government on June 15, 1888, but the fuller description was deferred until such time as the specimens collected could be fully examined. A joint paper was prepared for the Royal Society by Mr. C. B. Brown and Prof. John W. Judd[1] entitled "The Rubies of Burma and Associated Minerals; their Mode of Occurrence, Origin, and Metamorphoses. A Contribution to the History of Corundum." This memorable paper was received on February 6, and read before the Society in London on March 7, 1895. Mr. Brown is responsible for those sections dealing with the geographical distribution, physical features, geological structure, and economics, while Prof. Judd has prepared the introduction and furnished all details of the mineralogy and petrology of the corundum and associated minerals as well as of the enclosing rocks. The ruby-bearing rocks extend over a large portion of Upper Burma on the eastern side of the Irrawaddy and from thence in the Shan states. They are officially stated to cover an area of 45 square miles and with some of the smaller outlying districts this would be increased to 66 square miles. The principal centres are Mainglon state, Mogok area, Nanyetseik, and Sagyin.

[1]Phil. Trans. Roy. Soc. Lon. Vol. 187, pp. 151-228 (1896).

Valuable rubies are reported to have been found in the river-gravels near Namseka village in Mainglôn state (Northern Shan states), but Dr. Fritz Noetling who was sent to examine into these occurrences found a large excavation in gravels with spinels, tourmalines, etc., but obtained no rubies. He suggests, however, that if the report be reliable they may have been brought by the Mogôk stream from the ruby-mines area.[1]

The principal ruby mines of Burma are situated in the hilly district about 90 miles north-northeast of Mandalay. The rubies are found in (1) crystalline limestone, (2) hill-wash, (3) alluvium. The mines are situated along the outcrops of the crystalline limestone which is an integral part of the gneissic rocks of this area and which Mr. Brown first showed is the parent rock of the ruby. The gneisses, of which there are a great variety, are divided by Prof. Judd into three great divisions according to their relative acidity and these again into minor subdivisions dependent on their mineralogical composition. The rocks forming the great bulk of the foliated masses of the district are of intermediate composition mainly biotite-gneisses, granulites, or schists. With these, rocks of both acid and basic composition are interfoliated. The basic rocks with their intimately associated crystalline limestones are of the greatest interest in this regard for it is in connexion with these rocks that the rubies and spinels are found. These rocks contain in addition to a lime-feldspar (anorthite, bytownite, or labradorite) several varieties of pyroxene (diopside, sahlite, and hypersthene) which may be replaced by hornblende or biotite and in many cases a considerable quantity of scapolite, wollastonite, and calcite. The crystalline limestones are most intimately connected with these basic pyroxene and scapolite rocks, and are believed by Prof. Judd to have resulted from their alteration.

He states[2] that "between these gneissic rocks containing numerous crystals of calcite and dolomite and rocks consisting mainly of these minerals with the various constituents of the basic gneisses—augite, enstatite, scapolite, phlogopite, etc.—scattered through them, we find every gradation. The idea that

[1]Rec. Geol. Surv. India. Vol. XXIV, 1891, p. 119.

[2]Phil. Trans. Roy. Soc. Lon. Vol. 187, Part A, 1896, p. 205.

great beds of crystalline limestone intercalated in a series of foliated rocks must necessarily have resulted from the metamorphism of calcareous strata of organic origin, finds no support from the characters presented by the rocks of Burma."

The general conclusions concerning the origin of the rubies of Burma to which Prof. Judd has been led by his studies are as follows: pyroxene-gneisses abound with an unstable feldspar (labradorite or anorthite) which is easily converted by the action of minute quantities of hydrochloric acid under pressure into a scapolite, the scapolite in turn breaking up into various hydrated aluminium silicates and calcite. In some cases, however, the basic silicate may be converted directly, by carbonic or other acids, into a mass of hydrated silicates, quartz, and calcite. While the limestones are being formed from basic feldspars, the aluminium silicates taking up water may also be attacked by sulphuric, hydrochloric, boric, or hydrofluoric acid acting at moderate temperatures, and the salts of aluminium thus formed are easily decomposed; the aluminium oxide either hydrated (diaspore, gibbsite, beauxite, etc.), being set free, or under certain conditions of temperature and pressure the anhydrous oxide itself being formed. The slowly liberated oxide may assume the crystalline form and thus give rise to corundum.

The mining carried on, however, is almost exclusively in the "hill-wash" and alluvium. The hill-wash is the detrital material not sufficiently removed from its source to permit of perfect sorting of the clays from sands. The richest portions of this hill-wash are the sands and gravels mixed with a dark reddish brown earthy clay, resulting from the disintegration of the crystalline limestone. Eliminating the clay and fine sand by washing, the remaining portion is found to be composed of quartz, gneiss, pegmatite, schorl, spinel, garnet, ruby, and sometimes sapphire.

Clays, gravels, and sand form alluvial deposits in the larger valleys. In the upper part of the Mogok valley this alluvium consists of a brown sandy loam resting upon coarse gravel, beneath which is a mixture of clay, gravel, and sand with rounded fragments of gneiss. The sand grains consist principally of quartz, gneiss, pegmatite, spinel, garnet, tourmaline, and ruby.

The lowest portions of the sand and gravel contain varyi quantities of garnets and rubies.

So far no rubies have been found in situ in the crystalli limestone of Nanyetseik in the Bhamo district, although t rocks are identical with those in the Ruby-mines district. D Warth, however, obtained rubies and sapphires by washing t alluvium in this area at different points over an area of 1 square miles.

The rubies found at Sagyin[1] occur both in the comparativel solid crystalline limestone as well as the so-called "vein stuff" or decomposed material filling the clefts and interstices in thi limestone. These cavities vary from a few inches to 4 or 5 feet in width. This "vein stuff" consists of a red earthy matrix in which are embedded the numerous minerals derived from the weathering of the limestone. The limestone itself varies from a pure white rock, in which the calcite individuals sometimes measure from 3 to 4 inches across, to a bluish grey crystalline mass. The accessory minerals include phlogopite, chondrodite, biotite, augite, scapolite, pyrrhotite, graphite, orthoclase, spinel (chiefly purple in colour), and ruby. The limestone forms the topmost member of a series of rocks made up in addition of gneiss and conglomerate in descending order. The conglomerate is composed of pebbles of limestones, gneiss, and pyroxene-granulite in a calcareous matrix. The gneiss is hornblendic. Both the limestone and the "vein stuff" have been worked for rubies. The softer and more decomposed portions of the limestone are washed in flat baskets by a process resembling that of "panning." The heavier material consisting of pieces of rock, quartz, tourmaline, spinel, and ruby, is then carefully searched for the last mentioned mineral. Barrington Brown obtained in one of the old workings a specimen of limestone with pale pink crystals of ruby with pyrite and purplish to blue crystals of sapphire. The necessary blasting operations in the quarrying of the limestones and the harder parts of the "vein stuff" results in the destruction of a number of rubies. Most of the rubies found in Sagyin "stone tract" are small and violet

[1]Yule's Mission to the Court of Ava p. 326 (1858) also Econ. Geol. of India, Part I, 1898 pp. 31-33.

in tint, although valuable finds have been reported. The mines at Sagyin have been worked for many years and King Mindoon is said to have obtained 30,000 rupees worth of rubies from an old working formerly called the "Royal Loo."

In the Central Provinces[1] rubies were formerly obtained near Wairagarh, in the Chanda district, but the mines have long since been abandoned. Sapphires are also said to occur in the neighbourhood of Paluncha in the Upper Godavari district. Red, yellow, and white corundum and emery, some individuals of which are almost fit for gems, are reported to occur at several places in Hyderabad,[2] but no regular mining is carried on in the Nizam's dominions. Occasional crystals are collected and sold by the inhabitants in the bazaars to lapidaries and armourers for abrasive purposes.

The existence of sapphires in considerable quantities in some part of the northwest Himalayas became known in India through specimens brought into Simla by traders from Lahol.[3] The diggings are situated in a small upland valley near the village of Soonjam in the district of Padar. They are confined to a narrow patch of debris about 33 yards wide along the northern edge of the valley. The sapphires appear to have been originally derived from the high cliffs forming the northern side of the valley as blocks of granite crowded with crystals of corundum, mostly with a bluish tinge, were found on the northern side of this ridge. The ridge itself is made up of a coarse schistose gneiss, containing white feldspar and much black mica, having portions crowded with deep red and brown garnets. This gneiss is intercalated with a coarsely crystalline siliceous limestone and large masses of anthophyllite. The gneiss is traversed by numerous veins of coarse-grained granite (pegmatite) in which besides the quartz, feldspar, and smaller quantities of dark coloured mica, there

[1]Central Provinces Gazeteer pp. 138 and 506 (1870).
[2]Madras Journ. Lit. Sci. Vol. XVI, p. 506 (1851).
[3]Rec. Geol. Surv. Ind. Vol. XV, p. 138 (1882).
Rec. Geol. Surv. Ind. Vol. XXIII, Part II, pp. 59-69 (1890).
Am. Jour. Sc. 3rd Series, Vol. XXVI, pp. 339 (1883).
Rec. Geol. Surv. Ind. Vol. XV, p. 141 (1882).
Econ. Geol. of India, 2nd Ed. Part I, Corundum pp. 16 and 34-35.
Rec. Geol. Surv. India, Vol. XXXII, part I, p. 109 (1905).

occur well developed crystals of tourmaline, light green euclase, cyanite, minute red garnets, and crystals of sapphire. Large stones have been obtained from this area, one of which measured 5 inches in length and 3 inches in breadth, well coloured in the central portions. Of late years, however, only small sapphires have been obtained. Sapphires of considerable value were formerly obtained in the Zanskar range in Kashmir state, but the mines are said to be exhausted and returns for recent work are not available.

The occurrences of corundum in the Presidency of Madras are of especial interest as being the earliest known and the source of the material used by the Count de Bournon in the preparation of his famous memoir.[1]

Corundum is now known to occur in the following districts in Madras: Anantapur, Coimbatore, Kristna and Godavari, North Arcot, Salem, and South Kanara.

From the Anantapur district specimens of a sea-green corundum associated with white feldspar and mica were brought to the Indian Geological Survey Office, said to come from the vicinity of Punighi in the Hindupur taluk. These specimens were obtained from pits 6 or 7 feet deep and it was stated large quantities had been shipped to England (1880). The specimens in the Geological Museum of Calcutta like the Mysore corundum are in contact with a mixture of magnetite and green spinel (hercynite-pleonaste). Corundum is also reported as occurring in several parts of the Madaksira, Dharmavaram, Kalyandrug, and Anantapur taluks.

In the Coimbatore district corundum has been found at or in the neighbourhood of the following places:—

(1) Selangapalaiyam.
(2) Gopichettipalaiyam.
(3) Karutapalaiyam.

Corundum is also reported from Padyur, Shigrispalaiyam, Kandyankovil, and Kangyam, where it occurs as large idiomorphic crystals several inches across in oligoclase.

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[1]Phil. Trans. Roy. Soc. Lon. Vol. 92, p. 233 (1802), also Abs. Phil. Trans. Vol. 1, pp. 82-87 (1800-1830).

Corundum has not been found in place either at Selangapalaiyam or Gopichettipalaiyam, but it occurs in fairly large quantity as irregular rolled lumps scattered over the fields. It is picked up by women during the rains and taken to Madras.

The occurrences of corundum at Sivamalai near the village of Karutapalaiyam in the Dharapuram taluk, Coimbatore district, are perhaps the most interesting from a Canadian point of view, as they present a geological environment very closely analogous to the deposits of this mineral in central Ontario.

Holland has lately[1] made a detailed examination and study of this mode of occurrence and the fortunate circumstance of his being at once an experienced field geologist as well as petrographer gives additional weight to his conclusions. It is the most complete and satisfactory explanation of all the Indian deposits. The rocks associated with and containing the corundum at this place are very similar to those in central Ontario, and the conclusions reached with regard to its origin are substantially identical with that mentioned by the present author. In a previous chapter of this report, the several rock types associated with the corundum are briefly described, but mention may be made of the feldspar rock or corundum syenite, which contains the corundum. This rock occurs in intimate association with an elaeolite-syenite and augite syenite, and is regarded by Holland as a genetic relative of both, due to differentiation of the magma. The rock occurs in two degrees of texture, a medium-grained or granulitic form traversed by its own coarse-grained pegmatite. These agree closely in composition both being composed largely of feldspar which in the granulitic form is microperthite and in the coarse type is an irregular growth of albite and orthoclase. The finer-grained form often contains a red garnet, black spinelloids, besides tabular six-sided crystals of corundum larger than any of the other constituents and sometimes measuring half an inch across. The feldspar in the coarse-grained variety is a complicated intergrowth of more than one species in which a well twinned albite

[1]Rec. Geol. Surv. Ind. Vol. XXIX (1896) p. 47.
Mem. Geol. Surv. India, Vol. XXX, Part 3, pp. 169-220 (1901).
Econ. Geol. of India, 2nd Ed. Part 1, pp. 37-38 (1898)

and orthoclase are prominent forms. This carries crystals of dark or light greenish grey corundum measuring sometimes 6 inches across. In this rock several other accessory minerals occur like biotite, muscovite, deep blue apatite, zircon, zinc-spinel (automolite), and a sulphur-yellow platy form of chrysoberyl. Quartz is generally absent and when present is in extremely small quantities and can only be regarded as an accidental and local accessory, being altogether difficult to find. No corundum has yet been found in the nepheline syenite. Briefly stated Holland regards the corundum as a normal primary constituent and like the enclosing rock of igneous origin.

In 1895 the mining of corundum near Sivamalai was quite an active industry. A number of irregular holes and a few trenches were dug. One trench noticed was 15 yards long, 2 yards wide, and 20 feet deep, while another at right angles to this and following the junction of the corundum and nepheline syenites was 15 yards long, 2 yards wide, and 20 feet deep. The largest and most productive working was close to the village of Karutapalaiyam. Some of the crystals obtained here were 6–8 inches across. Mr. Middlemiss of the Geological Survey, who visited this place, considered it to be the most promising amongst those he had seen in the Coimbatore district.

In the Salem district[1] corundum deposits are reported as occurring at the following places:—

(1) Sittampundi, Namakkal taluk.
(2) Paparapatti, Dharmapuri taluk.
(3) Rengopuram, Dharmapuri taluk.
(4) Road from Dharmapuri to Morappur.
(5) Royakotta, Hosur taluk.

In the Namakkal taluk, the productive area lies from half a mile to a mile south of Sittampundi village, covering an area measuring 2 miles in length by from 100 to 1000 yards in width. The association of minerals is very strikingly like those described in the original paper by the Count de Bournon, and stated to be obtained from the Carnatic.[2]

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[1]Rec. Geol. Surv. India, Vol. XXX (1897) p. 118, also Econ. Geol. India, 2nd Ed. Part I, Corundum (1898) pp. 39-40.

[2]Phil. Trans. Roy. Soc. Lon. (1802) p. 233.

The rock containing the corundum is a gneiss of a pale silvery or pearly grey colour, consisting chiefly of anorthite (indianite) and hornblende, with garnet and small quantities of chondrodite? (probably fouqueite). The foliation is produced by the parallel arrangement of the elongated prisms of hornblende, and emphasized by the alternation of bands relatively richer in this bisilicate material. The corundum occurs in irregular lumps, rarely showing prismatic and pyramidal faces, the lumps averaging from a quarter of an inch to an inch in diameter. The corundum is of a pale, greenish grey, rarely flesh colour, and occurs sparsely distributed through these bands and portions of the gneiss which are relatively richer in anorthite. Nearly all the individuals of corundum are surrounded by a shell of calcite varying from one-fourth to an eighth of an inch thick. It occurs not only embedded in the rock but is found scattered all over the area to the south of Sittampundi.

Besides the common forms of corundum there are sometimes minute fragments of red corundum which locally pass into ruby. Most of these, however, are not transparent but dull and opaque. The presence of minute pieces of fairly translucent red colour lends support to the report that rubies of value were formerly obtained from these rocks. These red corundums are contained in the more hornblendic portions of the gneiss surrounded by a shell of anorthite partly converted to calcite.

The Paparapatti corundum area lies about 10 miles west-northwest of the village of Dharmapuri in the taluk of the same name. These occurrences are especially noteworthy, as this is one of the few localities in India in which attempts have been made to mine the mineral for use as an abrasive.

The actual matrix of the corundum in this area is lenticular masses of a flesh coloured orthoclase, finely crystalline and showing under the microscope a fine microperthitic or cryptoperthitic intergrowth of possibly plagioclase. These feldspathic lenticles occur in a pyroxene granulite which has been penetrated by veins of very coarse red granite or pegmatite and closer textured purplish granite as well as by dykes of a dark compact trap. In size these lenticles are sometimes as much as 15 feet long and 8 feet wide, and are distributed along a band not far from the junction of the pyroxene granulites (Charnockite Series) with a rock similar to the foliated biotite-granite so largely developed in the Hosur and Krishnagiri taluks.

The corundum is a deep purplish brown or sometimes dark greenish grey colour and occurs in hexagonal crystals with a great number of variously inclined and imperfectly developed pyramidal faces, thus giving the prisms an elongated barrel or spindle-shape. In size they vary from individuals which are only microscopically visible to crystals several inches in length and as much as an inch in diameter. With the larger crystals of corundum in the feldspathic lenticle are much smaller individuals of the same mineral, with sillimanite (fibrolite) rutile, transparent green and opaque black spinelloids, and biotite, which last mentioned mineral is especially abundant near the periphery of each lenticle. Each of the longer crystals of corundum is surrounded by a shell or court of pure feldspar, generally flesh-coloured, but sometimes, white, having a width or thickness of from an eighth to a quarter of an inch. This shell differs from the rest of the lenticle in the complete absence of the minute corundums, sillimanite and most of the other accessory minerals which usually occur. Corundum has been found under precisely similar geological conditions in the Hosur taluk to the north as also along the same line to the south; thus making the corundum-bearing band over 24 miles long. This, together with the fact that the mineral occurs in two and probably more parallel bands, makes the Paparapatti area a decidedly promising one.

To test the prospects of successful mining in this area Mr. C. S. Middlemiss of the Geological Survey of India, carried out certain preliminary mining development work on a lenticle measuring 13×8×9 feet near the village of Errantali, 2½ miles from Palakod.[1] It was found that 722 hundredweights of matrix rock yielded 2,845 pounds or nearly 3.5 per cent of pure corundum. As, however, the whole of the work was performed by manual labour it would be useless as well as unfair to institute any comparison as regards the cost of these operations with corundum obtained by crushing and washing by machinery, as is always the

[1]Rec. Geol. Surv. India, Vol. XXX p. 118.

case where the actual mining and concentrating of this mineral is carried out on any commercial scale.

Corundum occurs near Pennagaram, 2 miles from Rengopuram village in the Dharmapuri taluk. It is present as short hexagonal though very much rounded and corroded prisms of a greenish grey colour. Two pits sunk into the country rock at this place, which consists of alternate layers of feldspathic rock and hornblende gneiss, show no corundum and no satisfactory explanation was given for such mining operations. The mineral, however, occurs abundantly in the surface debris overlying the edges of the mine.

On the road from Dharmapuri to Morrapur, and near the 6th milestone, corundum has been found at one locality, the enclosing rock and mode of occurrence being entirely similar to those of the Paparapatti area. At another place the few fragments found were of a dark grey corundum set in a very fine-grained rock, resembling a phyllite or schist.

In the Hosur taluk new corundum localities were found, the mineral occurring in rock resembling thos of the Paparapatti and Palakod areas in the Dharmapuri taluk. These occur along a north and south line about one mile east of Royakotta, extending for several miles farther south.

Specimens of corundum obtained from Kemmar village, Uppinangadi taluk, South Kanara district, are on exhibition in the Madras Museum, and although nothing is known as to their geological associations, it is probable that they are a continuation in a north-northwest direction of the corundum deposits of Mysore, as corundum has been found along this line for 30 miles. Corundum is also reported to occur at Bandar, Kadicar, Hirebandady, Ellenir, and Malekai in the same taluk. The occurrence of corundum in Mysore was first noticed by Newbold[1] who described the mines of Golhushully, in the division of Noogyhully, and Kulkairi, in the division of Chinrayapatam, 98 miles west of Bangalore. The mineral was mined by means of shallow pits, and occurs with schorl in a bed of talcose schist, associated with mica schist, gneiss, and protogine (? pegmatite). These mines

[1]Capt. J. T. Newbold, Madras Journ. Lit. Sc. Vol. XI, 1840, p. 46. Journ. Roy. Ass. Soc. Vol. VII, pp. 219, 224, 1842.

are stated to have been opened about the year 1830. Corundum is very widely distributed throughout the state of Mysore, its occurrence being reported from all districts except that of Shimoga. The material collected is of a reddish colour and occurs for the most part as loose surface stones. The corundum occurrences of the Hunsur taluk were cursorily examined by Holland[1] in 1892 and are stated by him to be associated with graphitic schists, feldspar rocks, amphibolites, and fibrolite rock.

The masses of corundum adjoin a great intrusion of basic and ultra-basic rocks of a remarkable nature. Olivine rocks are associated with others made up almost entirely of granular hypersthene, magnetic iron ore, and hercynite. This association of corundum is very similar to the emery deposits of the Cortlandt norites described by the late Prof. G. H. Williams[2] as also near Ronsperg on the eastern edge of the Bohemian forest.[3]

Under the microscope, according to Prof. J. W. Judd, the corundum rock is seen to be made up of nearly colourless corundum, almost all of which exhibits the secondary twinning planes parallel to the faces of the primitive rhombohedron. In very thin sections the grey colour of the mass is seen to be due to numerous dark-coloured inclusions, arranged parallel to the twinning planes and like them probably of secondary origin. The other minerals present in the rock are diaspore and other alteration products of corundum, and a biotite with the usual high pleochroism and absorption.[4]

Numerous other localities in South Mysore are mentioned by Holland on the strength of information received from Dr. J. W. Evans, Director of the Mysore Geological Department, but no detailed description of the associations are yet available.[5]

Mr. Calvert[6] is said to have found sapphires, rubies, and other gems in Kulu in Punjab but confirmation is lacking from official sources.

[1]Econ. Geol. Ind. 2nd. Ed. Part 1, Corundum 1898, pp. 12 and 44-45.
[2]Am. Journ. Sc. 3rd Ser. Vol. XXXIII, 1887, p. 194.
[3]Kalkowsky, Zeit. d. deutsch. geol. gesell. Vol. XXXIII, 1881, p. 537.
[4]Min. Mag. Vol. XI, 1895, pp. 59-60.
[5]Econ. Geol. Ind. 2nd Ed. Part I, Corundum, 1898, pp. 45-49.
[6]Kulu, its beauties, etc. (1873), pp. 54 and 92.

The first mention of the Rewah corundum deposit is by Dr. Francis Hamilton,[1] who although unable to visit the locality mentions that there was apparently a considerable trade in the mineral in 1814. Capt. W. S. Sherwill[2] states that in 1845 owing to a superstition the mines were only worked one day in each year when enough corundum was obtained to supply the merchants who carried the mineral away on bullocks and supplied the greater part of Western India.

According to Mr. F. R. Mallet[3] who examined the deposit in 1872-73, the corundum rock occurs in a small hill between Pipra and Kădopáni, about a mile east of the rive. Rehr, the rocks here striking irregularly about east-northeast and west-northwest. The thickness of the mass could not be accurately determined owing to the quantity of debris lying about. Mr. Mallet, however, estimated the breadth of the outcrop, where thickest, to be 90 feet, and the mass is nearly vertical, and it was traced for about half a mile. The other rocks with which this great mass of corundum-rock seems to be interfoliated are as follows:—

a. White quartz-schist.

b. Hornblende-rock passing into jade, a few yards thick.

c. White tremolitic quartz-schist (fibrous).

d. White and green jade, containing some purple corundum "euphyllite" and schorl (*c* and *d* are about equal in thickness to *b*).

e. Bed of corundum-rock several yards thick, reddish sometimes purplish, or grey, with "euphyllite" schorl and diaspore in the cracks.

f. Porphyritic gneiss with hornblende-rock, junction not exposed.

Although no indication was found that the 90 feet of rock was not composed entirely of corundum, it may nevertheless contain some subordinate bands of other rocks.

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[1]Edin. Phil Jour. Vol. 11 (1802), p. 305.

[2]Jour. As. Soc. Beng. Vol. XV, Proc. p. XV (1845).

[3]Records of the Geol. Surv. India Vol. V, p. 20, and Vol. VI, p. 43, also Man. of Geol. of India, Mineralogy p. 48, also Min. Mag. Vol. XI, pp. 57-59, also Econ. Geol. Ind. 2nd Ed. Part 1. Corundum (1898) pp. 49-51.

The corundum-rock is described by Mr. Mallet as containing in its cracks larger crystals of corundum, with green mica ("euphyllite"), black tourmaline, and kyanite in radiating aggregates of a reddish colour.

This rock has a beautiful purple tint, and a specific gravity varying from 3.84 to 3.88. The least dense varieties are those in which a large quantity of mica and other secondary minerals have been developed. Under the microscope it is seen to be almost made up of prismatic crystals and grains of corundum, which occasionally show the secondary parting (gliding-planes) following the primitive rhombohedron. The accessory minerals present are rutile, picotite (chrome-spinel)—of dark coffee-brown colour and isotropic—diaspore, and the green mica ("euphyllite" or "fuchsite").

The corundum is as a rule purple in colour, of a tint well known in the so-called oriental amethyst. Usually, however, the colour and pleochroism are not strong when the mineral is examined in tolerably thin sections. In one very interesting specimen, however, given to me by Mr. Mallet, a remarkable phenomenon is exhibited. There are groups of intensely coloured and highly pleochroic corundum scattered about in the midst of the pale coloured mineral. That this highly coloured material is simply corundum is shown by the fact that the crystals with intense pleochroism have the same refraction, double-refraction, and extinction as those which are nearly colourless; and cases may be found in which one part of a prism is deeply coloured and pleochroic, while the other part is almost colourless. Occasional grains of sapphire occur, in which the colour given with the ordinary ray is blue, and with the extraordinary ray pale straw-yellow. In the deep purple variety O is a rich purple, E very faint yellow. The groups of highly coloured corundum appear to be generally portions of crystalline masses which extinguish simultaneously, and the rock has thus a "micro-poikilitic" structure.

The surface of the hill is covered with blocks some of which are not less than two or three tons in weight and the supply is practically inexhaustible. The merchants at the time of Mr. Mallet's visit paid about 18 shillings a ton for the mineral.

Dr. Balfour mentions that corundum in limestone from the Travancore state was exhibited at the Madras exhibition,[1] while Dr. W. King states that red, blue, and yellow sapphires occur in the sands of the Travancore coast.[2]

In most cases the corundum of India is scattered as isolated crystals through the rock and only the most economical devices for its separation can make mining remunerative. Here where the use of corundum has been known for many generations the requirements of the country have been met by a few comparatively rich deposits, but it is doubtful if these are worth working for export in the face of the competition from Europe and America, or will even stand against the importation of cheap abrasives. There is still and for many years has been a certain trade in Indian corundum, but the returns for production are manifestly incomplete. No workings exist of the kind that could ordinarily be described as mining, but attempts have been made to increase the scale of operations at Palakod and Paparapatti in the Salem district near Hosur in Mysore and in South Rewah. In 1898 the figures showed a production of [illegible]503 hundredweights, but the output never approached this figure in any subsequent year.

Corundum is widely distributed throughout the Mysore state and the annual production in Mysore has been estimated as follows:—

1898,	2,937 cwt.	valued at	£698
1899,	879	" "	£171
1900,	1,386	" "	£225
1901,	1,634	" "	£357
1902,	574	" "	£108
1903,	995	" "	£205

Much of the corundum which is a regular item of trade in the bazaars of cities like Delhi, Agra, and Jaipur, where the Indian lapidary still flourishes, is collected in a casual way by agriculturists and cowherds who dispose of it through the village bania to the larger dealers of the great cities. Sapphires of considerable value were formerly obtained in Zanskar, Kashmir

[1] Selections from Records Madras Gov. Vol. XXXIX, p. 94

[2] Rec. Geol. Ind. Vol. XV (1882), p. 89.

state, but the mines are said to be exhausted and returns for recent work are not available. Occasionally the normal blue sapphire and the rarer green, yellow, and white varieties are found in the ruby-bearing gravels in Burma.[1]

CEYLON.

Corundum is abundant in the gem-bearing gravels of Ceylon. Varieties of corundum include the most important gem stones, ruby and sapphire. These are found in the same gravel beds together with lower grades of corundum, spinel zircon, tourmaline, beryl, and topaz. Most of these minerals are supposed to have come from the intrusive granite rocks of the Balangoda group, but tourmaline alone has actually been found in a granite matrix on the island. The hills and ridges are so covered with jungle that it is almost impossible to trace the sources of the minerals brought down by the streams. Ceylon rubies are never the true red of the Burman although often more brilliant and hence are less valuable.

The only mention of the occurrence of corundum "in situ" in Ceylon is by A. K. Coomaraswamy, the Director of the Mineral Survey of Ceylon.[2] Crystals of corundum were found in the surface soil on a piece of land known as Tenna Hena, and situated east of Kandy, and three-quarters of a mile northeast of Talatnoya bridge. A small excavation had been made and a few pounds of corundum extracted and sold for use as emery before Mr. Coomaraswamy's visit to the spot. All the rock exposed was decomposed and crumbled in the fingers, being in a condition resembling sand. He made an excavation to the depth of 30 feet without finding any solid rock. The occurrence is of considerable interest, although as the author remarks, not very satisfactory in itself. The corundum bearing rock is a decomposed feldspathic rock made up mainly of orthoclase, microperthite, plagioclase (oligoclase), biotite, corundum, and small quantities of garnet, green spinel, and zircon. No quartz

[1]Rec. Geol. Surv. Ind. Vol. XXXII, Part 1 (1905) p. 105. Sketch of the Mineral Resources of India, 1908, pp. 46-48.

[2]Geol. Mag. Vol. X, 1903, pp. 348-350.

could be detected. The minerals were present in the following proportions:—

Orthoclase......	64 2 per cent.
Oligoclase........................	23.5 per cent.
Biotite............................	4.7 per cent.
Heavy minerals, chiefly corundum.....	7 6 per cent.

The result of the chemical analysis of the rock is given under I. Omitting the water and recalculating the remainder to 100, we obtain the results under II, while under III are the molecular ratios.

	I	II	III
SiO_2..............	58·44	59·02	0·983
Al_2O_3..............	20·79	21·00	
Fe_2O_3..............	0·58	0·59	0·210
FeO	3·85	3·89	0·065
MgO.	0·43	0·43	
CaO..............	2·24	2·26	
Na_2O..............	2·85	2·88	0·192
K_2O	9·83	9·93	
H_2O	1·36	..	
	100·37	100·00	

The analysis as above shows a small excess of alumina above what is required for the feldspar and biotite, which might be expected to have crystallized as corundum.

The author remarks that the presence of corundum has more likely resulted from a local variation in the constitution of the consolidating magma than that the magma should have absorbed some rock rich in alumina of which no trace remains here or elsewhere.

SIAM.

Burma may be considered as the home of the ruby, for the finest specimens of the "pigeons's-blood" ruby have so far been obtained from the mines of this country, while Siam must be credited with the honour of having produced the most beautiful "cornflower blue" sapphires. At the present day, sapphire from Siam is considered as the type in comparison with which the Burmese stones are generally too dark, those from Ceylon too light, while those from Kashmir and Australia are as a rule too milky or too dark. The prevailing colour of the more desirable gems from Montana is a bright blue, varying from a light tint which is the prevailing shade to a dark blue, while a very few approach the true cornflower blue assumed by the Siam representatives especially, and sometimes also by the sapphires from Ceylon. Most beautiful sapphires are obtained especially at Battambong southeast of Bangkok, where they occur in association with small rubies which are biaxial. These are obtained from the mine known as the Bo Pie Rin in the valley of the Phelin where they occur in a somewhat arenaceous clay, in most instances about 2 feet below the surface. The numerous sapphire gems found are of a most beautiful blue colour with a distinct velvet sheen or lustre; some specimens are of a very deep blue constituting the "cornflower" or "tincture" blue variety. The rubies from Siam are usually of a very dark red colour, often with a tinge of brown, much resembling garnet. They are considered usually as of a lower grade than the Burmese although many individual specimens of ruby from the mines in the provinces of Chantabun and Krat are of exceedingly good quality. These mines in the neighbourhood of the provincial capital of Chantabun are not far removed from the coast of the Gulf of Siam. The higher mountains inland are made up of a greyish granite, while the lower foothills are of limestone. As in Burma, although so far it has not been proved, these limestones may have been the original host or matrix of the sapphire, but hitherto they have only been found in washings. In the vicinity of this city dark bottle green to bluish violet transparent gem material, the so-called oriental emerald, has been found in certain of the diggings, having a specific gravity of 3.933. In the Province of Krat the ruby mines are in two groups about 30 miles distant from one another. The sapphire deposits at Bo Navong, southeast of Chantabun and about halfway from Krat are in yellowish or brownish clays overlaid by sand. At the immediate contact between the clay and the sand, both rubies and sapphires have been found. The openings to secure this gem material are from 2 to 4 feet deep. Northeast of the Navong mine are the deposits known as Bo Tschanna, where the ruby bearing sands are from half a foot to 2 feet in depth. Rubies are more abundant in these deposits than sapphires. In 1906, 3,000 miners were working these deposits.[1] It is the prevalent opinion that these sapphires have been carried by river action from the mountains of Kao-Sam-Nam. In the district of Moung (Muang) between the provinces of Chantabun and Krat and in front of the great mountain ranges, the poorer ground for gem material is covered by a sandy or clayey mass. This appears to be the product of the subaërial decay of the underlying rock which is a basalt or trap rock, while the stream sands and gravels are made up of fragments of trap, pebbles of white quartz, rubies (specific gravity 3.979), sapphire (specific gravity 3.974), opaque corundum, quartz crystals, zircon, and abundant ilmenite.[2] The best known gem mine in the south of Siam is the Pailink sapphire mine which in 1906 employed about 4,000 workmen.

PERSIA.

Emery has been found near Deschenet in the vicinity of Nirîz in Eastern Fars.[3]

MALAY PENINSULA.

In the Malay peninsula in the Kinta district at Perak near Ipohe corundum occurs in association with cassiterite in alluvial sands, in rolled masses some of which weigh as much as

[1]Min. Jour. London, Dec. 22, 1906.

[2]H. Louis, Min. Soc. London, 1893, 10, 267; H. Warrington Smyth, "Five Years in Siam," 1891 to 1896, 2 Vols. London, John Murray, 1898. J. Crawford, "Geological Observations made on a voyage from Bengal to Siam and Cochin China"—Geol. Soc. Trans. 2nd Ser. Vol. 1, 824, p. 407; Edin. New. Phil. Jour. 1827, p. 366; Carl Hintze Handbuch der Mineralogie, 1908, pp. 1766-1767.

[3]Houtum Schindler, Jahrb. geol. Reichsanst, 1881, 31, 178.

9 pounds. The corundum is pale blue to bluish green in colour and is said to be harder than that from Ceylon although the specific gravity is only from 3.75 to 3.90. It contains 2.41 per cent of water and 97.10 per cent of alumina.[1]

THIBET AND CHINA.

Thibet and China have furnished specimens of adamantine spar. Leonhard notices beautiful crystals of corundum in a mixture of feldspar, mica, and sillimanite from Canton or Kwang-tschufu in the province of Kwangtung.[2] In the western part of Yunnan district, sapphire, ruby, and emerald corundum are reported to occur.[3]

JAPAN.

Beautiful blue hexagonal tabular forms, as well as greyish columnar crystals are found in the province of Mino in the tin alluvial deposits of Takayama and Hirukawa.[4] Sapphire is also reported from Tadachi, Nishi-chikumagori in Shinano, while rubies come from Kiura, and Onogori in Bungo.[5]

BORNEO.

Ruby and sapphire corundum are reported as occurring in Borneo. They are found in small pieces associated with gold in the beds of mountain streams tributary to the Pâsir river in the sultanry of that name. It is noteworthy that the associated gold occurs only in the lower portions of these little rivers and is in wire-like and "toothed" (crystalline) forms, a fact indicative of a near source. It also occurs as a characteristic accompaniment of diamonds, in southeastern Borneo in rolled fragments,

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[1]Penrose. Jour. Geol. 1903, 11, 135.
[2]Leonhard top. Min. 1843, 323.
[3]Mesny's Chinese Miscellany, Shanghai, China.
[4]Wada-Ogawa. Min. Jap. 1904, 52; Jimbo Min. Jap. 1899, 232.
[5]"Outlines of the Geology of Japan" Part III, Economic Geology, 1902, 235, 184.

sometimes as large as a man's fist. It is usually blue in colour but has also been noticed in greyish and brownish shades. It is the "bator timahan" of the natives.[1]

PHILIPPINE ISLANDS.

Roy C. Hopping of the Department of Mines of the Philippine Islands Exhibit at St. Louis, quoting from an article by H. D. McCaskey, chief of the Mining Bureau, published in the Official Gazette for May, 1904, writes, "Some very small rubies are reported as having been found in the headwaters of the streams flowing into the ocean near Mambulao and Paracale." Paracale is the centre of the best known gold field.[2]

AUSTRALIA.

SOUTH AUSTRALIA. According to Brown, sapphire occurs in the Macdonell ranges perhaps at Echunga; also at Mount Crawford.[3] In a bulletin issued by the South Australian government in 1911 entitled "The Occurrence of Uranium (Radioactive) Ores and other Rare Metals and Minerals in South Australia" there is a description of occurrences of corundum near Mount Painter, 4 miles west of Mount Painter and 2 miles east of Mount Pitts. The corundum occurs in a mica-schist in the form of scattered crystals, irregular lumps, and small grains. It occurs in various colours, blue, white, greenish, and mottled, and is associated with minute red crystals chiefly rutile which occur both in the corundum and in the matrix. The width across the strike of the rock formation in which corundum is visible is about 5 chains. The average content of corundum in certain places is estimated at 10 to 25 per cent. Another occurrence of corundum is about a mile west of Mount Pitts. The corundum has been cleaned and concentrated and the product

[1]Fr. W. Voit Berg-und Hüttenm Zeit, Nos. 38 and 39, 1902, pp. 445-449; Min. Res. U.S.A. 1902, p. 834. Gascuel, Zeitschr. pr. Geol. 1902, 161.
[2]Min. Res. U.S.A., 1903, p. 971.
[3]Cat. South Aust. Min., 1893, 14, 27.

has been found to be suitable for abrasive purposes as well as for wheel manufacture.[1]

QUEENSLAND. The famous sapphire fields of Anakie are situated toward the central part of Queensland, the railway station of Anakie on the Central Queensland line being 192 miles west of Rockhampton. Anakie station with an elevation of 815 feet above the sea is situated to the south and west of the sapphire deposits which cover an area of a little over 50 square miles. Black Peak or Knob is the highest elevation but its exact altitude has not been determined. Mount Leura, 2000 feet high, is perhaps the most prominent landmark, although Mount Hoy (1860 feet) approaches it in this respect. Numerous other peaks for the most part isolated are scattered over the country, owing much of their prominence to a capping of basalt, the remnants of a once continuous lava flow, which covered the granite and other underlying formations. The whole of this region is drained by the tributaries of the Nogoa river of which Theresa creek is the principal affluent. It is in the vicinity of the smaller branches of Theresa creek that the principal deposits of sapphire are found including principally Central, Tomahawk, Retreat, Argyle, and Sheep Station creeks.

Sapphires were discovered in the Anakie district in April, 1876, by John Evans, a gold prospector, but it was not until 1881 that development was started in the Evans freehold block. In 1891, adjoining territory was opened up, and the Oriental Sapphire company started operations in 1892. In 1900 the Withersfield Sapphire Syndicate was also formed. The first report dealing with this area was by Dr. R. L. Jack in 1892.[2]

In 1902, Mr. B. Dunstan, Assistant Government Geologist, published an extended report dealing not only with geological and mineralogical associations of these interesting deposits but containing all essential details affecting the history of the discovery and the topography of the adjacent area. Adequate descriptions are furnished of the various sapphire fields situated in the vicinity

[1]Bull. Imp. Inst. London, Vol. X, No. 1, April 1912, p. 170.

[2]Report on the Sapphire Deposits and Gold and Silver Mines near Withersfield. Geol. Surv. Queensland, Brisbane, 1892.

of the several creeks, accompanied by an account of the methods of treating the "sapphire washdirt."[1]

An examination of the geological map which accompanies the reports is at once convincing that granite and especially a closely related syenite is the oldest and most extensive rock formation; gneisses, schists, and slates rest against the granites and there seems to be a gradual change in these rocks from one to the other. Intrusive rocks are of both acid and basic facies. The acidic rocks, represented mainly by pegmatite, feldspar-porphyry, and felsite are very abundant and traverse the granites and gneisses in all directions. The basic rocks are either a massive hornblende rock or diorite. Outcrops of epidote-garnet rocks probably represent alteration of limestones in contact with the granite. A very great hiatus appears between these rocks and what are known as the Drummond Beds, a series of shales, sandstone, and conglomerates. At or near the junction with the granite these rocks are highly inclined (sometimes 60 degrees to 70 degrees), but elsewhere they seemed to be horizontal. Although no fossils have been found in these sedimentary rocks they are regarded as probably of Permo-Carboniferous age. Again there is a great interval in the geological record and the only evidence remaining of any intervening formation is the presence of certain boulders of a hard flinty quartzite locally known as "billy", which are often included in Tertiary and recent alluvial deposits. Basalt is found at a great number of places, but there are no very extensive areas overlaid by what must once have been a rather continuous flow. Denudation has removed the great part of it leaving only a capping on the tops of the hills and mountains.

The sapphire deposits are nearly all confined[1] to the granite country. The deposits are rarely found in the beds of the present streams, but generally at higher levels on the sides or at the bases of the low hills and roughly parallel with the creeks in most places. No sapphires have been found in the recent

[1] "The Sapphire Fields of Anakie" 26 pp. 12 plates, 2 maps, Geol. Sur. Queensland, Brisbane, 22 Jany. 1902; also Lionel C. Ball, "The Sapphire Fields of Central Queensland," Queensland Govt. Min. Jour., March 15, 1905, pp. 112-117 with illustrations.

debris of the streams. The presence of zircons and the absence of sapphires in alluvial deposits covered by basalt may be taken as an indication that the sapphires have been deposited at a time later than that at which the basalt flow took place. On certain of the creeks boulders of basalt invariably occur with the sapphires. Pleonaste is a very common inclusion in the basalt but not in forms which would suggest their authigenesis. If they have been formed from the magma they must have been solid while the basalt was still molten for they have suffered much from magmatic corrosion. A pale blue sapphire having a thick black scaly coating on one side together with an abundance of pleonaste was found on the summit of Mount Hoy over 500 feet above the highest alluvial sapphire deposits. It had probably weathered out of the basalt together with the pleonaste with which it was found. At Mount Leura a piece of bronze black corundum was discovered partly exposed on a large face of basalt. This was the only corundum found "in situ" by Dunstan. To the miners, however, such occurrences were not unfamiliar and reference was made to the mineral as "bronze pleonaste." A small parcel of stones collected by a prospector from the summit of Black Peak was found to comprise, pleonaste, ilmenite, hornblende, and two small angular pieces of corundum. In seeking to explain the source of the corundum, Dunstan remarks: "What happened in the early stages of the history of the sapphire is purely speculative. Possibly the basalt has disturbed some of the metamorphic or granitoid rocks at a depth from the surface containing sapphires and in being erupted has caught up portions of these rocks and with them the sapphires."

In the different workings the thickness of the sapphire wash varies considerably, in some places being only a few inches deep while in others it amounts to several feet. In the western part of the district the waste is of enormous thickness, possibly 50 feet or even more. The boulders and pebbles include several varieties of "billy" red and brown jasper, basalt, hornblende rock, [illegible]e, sandstone, quartz, and diorite; while the smaller pebbles include fibrous hornblende, magnesite, tourmaline, topaz, pleonaste, rock crystal, and several varieties of chalcedony.

More intimately associated with the sapphires are corundum, ilmenite, pyrope garnet, amethyst, zircon in several shades of colour, and some fine hyacinths.

The hexagonal pyramid with its modifications is common, but the prism is comparatively rare. The simple barrel-shaped form was observed. Very acute rhombohedrons with terminal basal planes occur; also pyramids with curved faces. The hardness is variable and lapidaries have repeatedly stated that it is frequently greater than 9 (Moh's scale). Determinations of the specific gravity of blue, yellow, and green sapphires and also of large pieces of corundum showed a variation ranging from 4.009 to 4.050, no specimens being below 4. The blue varieties are characteristic of the deposits in the eastern part of the field (Retreat and Policemans creek), while the green stones are the more usual in the western deposits (Tomahawk and Central creeks). The parti-coloured stones are common in all the deposits, while the yellow stones are rare. The shades of blue range from a very light to a very dark blue, but the much prized "cornflower blue" has not been found. The green shades vary from pale green to a deep olive green. The light green stones with just a perceptible golden tinge are very beautiful. Some fine specimens have been found of both canary and orange yellow shades. Ruby is rare although occasionally found, as also stones of a purple colour. The fine bright green and yellow shades when cut make very beautiful gems and are characteristic of this field. The beginning of operations was on a very small scale, but in 1901 there was "a permanent population of about 200 individuals in the field and an average of 100 miners at work at the several deposits. Up to 1902 it is estimated that £10,000 was the value received by the miners for the sapphires secured to that date. The output of sapphires for 1904 was estimated at 14,100 ounces at 15 shillings per ounce, and there was consequently much discontent felt at the low price received. In 1905 the average price paid was from 15 shillings to £1. In 1906 and 1907 £1, 4s. per ounce was paid. The value of the sapphire production in 1906 was £18,000 and 1907 £40,100.[1] In 1908 the production of sapphire for gem

[1]Min. Jour. London, Feb. 22 and March 14, 1908.

and mechanical purposes from Anakie was valued at £15,200, the production of gem sapphire alone being estimated in value at £11,800. In 1909 the production was estimated to be worth £23,116.[1]

NEW SOUTH WALES. The New South Wales sapphires in common with those from other parts of Australia are usually rather dark in colour; they are, however, found from perfectly colourless and transparent through varying shades of blue and green to a dark and almost opaque blue. Parti-coloured sapphires are also occasionally found while the asteria sapphire, showing a six-rayed star in reflected light, are by no means uncommon. The usual forms met with are double pyramids sometimes in combination with the basal plane. Prismatic forms are less common. Although they have not been found in situ, in certain individuals the sharp and unworn edges seem to indicate that their source has not been far removed from their present position. Sapphires are almost invariably encountered by the placer gold miners. Sapphire corundum is widely distributed over the New England district as at Bingera, Murchison county; near Inverell, Rose valley, Swanbrook, Vegetable creek, Scrubby gully, Mole Tableland, Glen Elgin, Dundee, Ben Lomond, Manns river, and Newstead in Gough county, with tin, adamantine spar, zircon, topaz, and bismuthite; in Copes creek and Tingha Hardinge county; Oban, Clarke county; Nundle creek and Peel river, Parry county; Gwydir river; in Sandon county on the Wollombi river and at Uralla; on the Namoi river; on the Abercrombie river; blue and green sapphires, with pleonaste, zircon, and gold near Mount Werong, Georgiana county; on the Cudgegong river, Phillip county; at Two-Mile Flat, Bells river, and Pinks creek, Roxburgh county, with white topaz, almandine garnet, epidote, spinel, chrysoberyl, chrysolite, and hyacinth; at Tumberumba, Winyard county, with tinstone, gold, diamond, emerald, and other minerals; in the Shoalhaven river, St. Vincent county; Snowy river, Wallace county; also with other gems, in the Wingecarribee river, at Berrima, Mittagong, and Puddledock.

[1]Ann. Rep. Under Secretary of Mines, Queensland, 1909.

Blue and green sapphires are found with gold zircon and other gems on Native Dog creek, an eastern branch of Sewells creek, Oberon district. Small prismatic sapphires have been found in the Severn river, Furrucabad creek, and Glen Elgin.

Ruby is more rare than the blue or other sapphire gems. It has, however, been found on the Cudgegong river between Eumbi and Bimbijong with sapphire, chrysolite, hyacinth, and amethyst; as also in Mullens and Lawsons creeks in the county of Phillip. It has been found at Tumberumba, Winyard county. It is not common at Mudgee and only in individuals of small size. It occurs in a small creek about 2 miles from the head of Hunter river, as well as in the Peel river; also at Bald hill, Tumberumba, with diamonds and other gems. A specimen of barklyite (magenta coloured, more or less opaque variety) from Two-Mile Flat had a specific gravity of 3.7382. The brown variety of corundum or adamantine spar has been found at Two-Mile Flat, Hardinge county; Uralla, Sandon county; Bingera, Murchison county; and Inverell in Gough county. When cut and polished "en cabochon" this forms a handsome ring stone. Specific gravity at 17°C. 4.0306. The rolled pebbles of corundum from the diamond drift on the Cudgegong river were found by Dr. A. M. Thomson to have a specific gravity of only 3.21 to 3.44, but with a hardness of 9 as usual. Corundum is said to occur in basalt with olivine at Bald hill, Hill End, County of Wellington.[1] Green corundum occurs in gem sands from Duckmaloi creek near Oberon.[2]

VICTORIA. Sapphire sometimes in fragments as large as a walnut, as also barred-shaped crystals, varying from yellow to deep blue in colour, are often obtained from the gold bearing alluvial sands at Beechworth. At this place the bright amethystine and greyish to bluish grey asteriated sapphire is also found. At Daylesford, large individuals, as well as hexagonal tabular forms, sometimes over an inch across, occur. Corundum may be collected at Vaughan in the Blue mountain: also at Upper Yarra where the so-called "oriental smaragdite" occurs which

[1]Archibald Liversidge, "Minerals of New South Wales" 1882, pp. 133-134; 1888, pp. 196-198; Jour. Roy. Soc. N.S.W. 1895, 29, 216.

[2]Card, Rec. Geol. Sur. N.S.W. 1895, 4, 130.

resembles green chrysoberyl. Small magenta coloured rubies occur at Mount Eliza; at Inglewood. In the drift material of Blue mountain and Beechworth hair brown adamantine spar occurs with parting plains and opalescent sheen in irregular masses and lumps sometimes as much as a pound in weight It also occurs in opaque yellow (resembling quartz), greyish brown, also purplish red or magenta colours at Reids creek, Woolshed, Sebastopol, and Sheep creek in the Beechworth district. Some black corundum in fragments large as a bean has been found, seldom showing any crystal faces or planes of parting. The hardness is also often greater than 9. The composition is as follows: Al_2O_3 67.37; SiO_2 5.35; Fe_2O_3 28.04; MgO 0.30; H_2O 0.61; total 101.67.[1] Beautifully coloured ruby as also yellow and green sapphire are found in the vicinity of Pakenham, which were apparently, according to Ulrich, derived from a doleritic basalt.[2]

TASMANIA.

Sapphire and corundum are by no means rare in Tasmania. They vary in colour to a great extent being found in almost all shades of blue, dull green, purple, and yellow and from translucent to opaque Occasionally they are varicoloured with shades of blue to yellow and colourless. The star sapphire has also been found, but really fine gem material is rare, and although some very good specimens have been secured, such are so uncommon as to be of no commercial importance. Corundum is found in the alluvial deposits of the northeast coast in association with tin, the usual colours are brown, yellow, green, blue, and red. The principal localities are Mount Cameron, Thomas Plains, Weld river, Main creek, Moorina, Branxholm, Blyth river, and Boat harbour near Table cape. It is also found on the northeast coast at Shekleton with zircon and quartz.[3]

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[1]Selwyn and Ulrich Min. Victoria, 1866, 67.
[2]Ulrich Contrib. Min. Victoria, 1870, 14.
[3]Petterd. Min. Tasmania, 1896, p. 30; Min. Rev. U.S.A. 1904, pp. 950-951.

NEW ZEALAND.

Corundum has been found in the gold fields on Back creek near Rimu in blocks with margarite. The colours represented in these aggregates are rose to carmine and deep purplish blue.[1]

[1]G.H.F. Ulrich Min. Soc. Lon. 1893, 10, 217.

CHAPTER XIII.

ARTIFICIAL CORUNDUM.

Crystalline alumina in the form of corundum has been produced very successfully by various methods, and the material thus obtained has been of many forms and colours. The artificial production of gem corundum was the first and principal incentive for these attempts. Many of these processes, however, have no equivalent in nature They may be roughly grouped as follows: (1) The crystallization of alumina held in solution in various molten fluxes, such as borax, carbonate of soda, potassium bichromate, etc. (2) By decomposing aluminium chloride or fluoride by water at high temperatures. This method may shed some light on the formation of corundum in metamorphic rocks or as a product of contact metamorphism. (3) The thermal decomposition of alumino-silicates; Vernadsky obtained sillimanite and corundum by fusing muscovite. (4) Crystallization from artificial alumino-silicate magmas. (5) By direct fusion of bauxite or amorphous alumina

It would far exceed the scope of the present report to describe even very briefly all of these processes and a selection will be made of some of those which seem of economic or geologic interest. The various methods employed have, moreover, already been well and fully summarized by Fouqué and Lévy, Bourgeois, and by Morozewicz.[1]

P. Hautefeuille and A. Perrey[2] give a description of the formation of hexagonal plates of corundum by dissolving alumina in melted nepheline. Upon cooling the greater part of the vitreous paste crystallized out as corundum; with leucite, a

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[1]Synthèse des minéraux et des roches, Paris, 1882; Reproduction artificielle des minéraux, Frémy Encyclopédie Chimique, Vol. 2, Appendix 1; Min. pet. Mitth. Vol. 18, 1898, p. 23.

[2]Bull. Soc. Min. France, Vol. XIII, 1890, p. 147; Am. Nat. Nov. 1890, p. 1076.

similar result was obtained; but an artificial potassium nepheline gave no similar reaction The development of corundum in the nepheline-rich rocks of central Ontario is much more readily understood in the light of these experiments.

W. Bruhns[1] obtained small hexagonal crystals of corundum with pyramidal terminations by heating alumina for ten hours to a temperature of 300 degrees in a platinum tube with water containing a trace of ammonium fluoride. At 250 degrees no crystallization took place. Similar experiments produced hematite, quartz, tridymite, and ilmenite. Such results seem to strengthen the current belief that compounds of fluorine accompanying volcanic exhalations assist in the formation of these minerals under natural conditions.

G. Friedel[2] heated amorphous alumina from 450 degrees–500 degrees with a solution of soda in a closed tube when corundum and diaspore ($HAlO_2$) were both produced. At 530 degrees to 535 degrees corundum alone formed, while at 400 degrees only diaspore was developed. If the alumina contained a little silica crystals of quartz appeared. When the soda contains a small amount of aluminium and calcium carbonates crystals of calcite accompany the corundum. By a similar reaction between ferric hydroxide and soda solution the same experiments obtained crystals of hematite. The artificial production of rubies is described in detail with many coloured plates by Frémy in Synthèse du Rubis (Paris, 1891).[3] In the most successful method the alumina with more or less potash was heated to a very high temperature in an earthen crucible with barium fluoride and potassium bichromate for colouring purposes. The ruby corundum obtained was well crystallized, clear and of a brilliant colour.

From a scientific standpoint the results of the elaborate series of experiments on the synthesis of certain minerals and

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[1]Neues Jahrb. für Min. Vol. II, 1889, p. 62; Am. Nat. July, 1890, p. 671.

[2]Bull. Soc. Min. Franc. Vol. XIV, 1891, pp. 7-8.

[3]See also A. Verneuil. "Mémoire sur la reproduction artificielle du rubis par fusion" Ann. Chim. et de Physique 1904 Ser. 8. Vol. III, pp. 20-48. Reprinted separate pagination, Paris, Gauthier, Villar, 1904, pp. 1-30: Min. Mag. 15, 153, 1908.

rocks carried on by Dr. Josef Morozewicz are by far the most interesting as well as the most instructive. This 'Experimental Investigation of the Formation of Minerals in an Igneous Magma'[1] occupied from the end of the year 1891 to the beginning of the year 1897 although the results were not published until early in 1899. This synthetic production of corundum really anticipated the main conclusions reached in regard to the origin of corundum by the examination of the natural occurrences of this mineral, at the same time throwing a flood of light on the crystallization of igneous magmas. In addition to obtaining thirty-four distinct minerals, Morozewicz succeeded in producing the following rocks: liparite, basalt obsidian, enstatite-basalt, magma-basalt, augitite, melilite-basalt, hauynophyre, hauyn-basalt, cordierite andesite, spinel-basalt, feldspar basalt, nepheline basalt, corundum bearing nepheline basalt, corundum nephelinite, and a coarse trachytic corundum-bearing anorthite-nepheline substance.

This brilliant work marks a distinct epoch in experimental geology and being conducted on a much larger scale and with a closer imitation of natural conditions is of more value to practical geology than even the exhaustive experiments of Fouqué and Lévy published in Paris in 1882.[2] In the case of the work carried on by Fouqué and Lévy the fusions were made in small crucibles of platinum in the Fourquignon furnace, the resultant products being subjected to detailed microscopical examination. Morozewicz made use of much larger vessels composed of fire-clay for melting purposes, the crystallization being accomplished in smaller ones of 150°C.C. capacity. These were placed in a corner of a large Siemens furnace in a glass factory at Warsaw, the furnace being heated by a blast of mixed carbon monoxide and air, the temperature varying from 500° to 1,600°C. Different conditions of temperature were secured by simply changing the position of the crucible in the furnace, thus permitting its gradual cooling. Crystallization lasted commonly from one to three weeks; but in some cases this was prolonged to a period

[1]Tschermak's mineral und petrog. Mittheil. Vol. XVIII, 1898, pp. 1-90; 105-240; Review of same Journ. Geol. Vol. VII, 1899, pp. 300-313.

[2]Synthése des Minéraux et des Roches, Paris, 1882.

of even two and a half months. Some experiments were conducted with crucibles carrying over a hundred pounds of molten material. The products after cooling were subjected to a very complete chemical investigation in addition to their examination under the microscope, while some of the mixtures were so coarse as to admit of the separation of the component minerals. One of the results of especial interest in the present circumstances relates to the genesis of corundum and its faithful companions spinel, sillimanite, and cordierite (iolite). The experiments enabled the promulgation of Morozewicz's law relating to the development of these minerals in an alumino-silicate magma which has done so much to assist us in the study and proper understanding of the natural history of this interesting group of minerals.

Artificial corundum is also produced from the waste matter alumino-thermic processes. Such corundum is especially hard when the raw material is obtained from the chromium process, as it contains traces of that element.

Artificial corundum has been made as follows: 100 parts of pulverized and fused borax, 100 parts of aluminium dust, and 125 parts of flowers of sulphur are mixed in a crucible and calcined with a mixture made up of magnesium and barium dioxide. When cold, the product is treated with dilute ammonia; the aluminium hydroxide formed by the decomposition of the aluminium sulphide is eliminated by means of hydrochloric acid. A residue is obtained which contains globules of aluminium, brown flakes of boron, and a white crystalline powder of corundum. After removing the metallic globules, the boron is dissolved in nitric acid leaving the pure corundum behind.[1]

A very interesting method of producing artificial corundum consists in the reduction of certain metallic oxides with the assistance of powdered metallic aluminium. Dr. G. Döllner of Rixdorf has patented a process in Germany to make fused or sintered corundum by this process. Powdered aluminium is intimately mixed with oxides, peroxides, or other metallic oxygen compounds in a refractory crucible. A characteristic feature of such a mixture is that when it is ignited by suitable means

[1]A. Haenig "Emery and the Emery Industry," London, 1912, p. 34.

it reacts endothermally owing to the extremely high combustion temperature of aluminium, causing the formation of aluminium, accompanied by a separation of the metals whose oxides, peroxides, or other oxygen compounds were used. This reaction is, of course, dependent on the strong affinity of aluminium for oxygen. The aluminium oxide is completely fused[1] and solidifies on cooling to a mass which is characterized by extreme hardness. Oxides of the heavy metals are specially adapted for this process. For instance, a mixture of chromium oxide and aluminium furnishes both alumina and chromium which on cooling separate into two layers, an upper layer of corundum or aluminium oxide and a lower one of metallic chromium. Metals such as titanium, tungsten, vanadium, molybdenum, etc., which were either very difficult or impossible of reduction can now be obtained by this process with comparative ease and at very small cost.

The corundum obtained by this process is said to be so hard as to scratch emery and may replace diamonds for certain technical purposes. The material is also reported eminently adapted for drill crowns. It may be crushed and moulded in the usual manner with or without a binding medium. The corundum obtained varies in colour and is dependent to a large extent on the metallic oxide used. Thus with oxide of chromium it is ruby red, with nickel oxide it is blue, with titanium oxide it is brown, and with manganese oxide it is yellow or greenish yellow.

Some mention should also be made of a process which has been patented in Germany by F. Hasslacher, Frankfort-on-Main, for converting native emery into an anhydrous, iron-free corundum. As has been mentioned, emery is a mixture of corundum with certain iron oxides, chiefly magnetite. Some emery contains as much as 35 per cent of iron oxide. This is an impurity which certainly adds nothing to the abrasive efficiency although its presence is considered very helpful for some of the purposes for which emery is used.

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[1] Corundum is fusible at 2250°C according to H. Moissan, Comptes Rendus, vol. 115, 1892, p. 1034. W. Hempel says fusible at 1880 degrees.

The native emery is mixed with a certain quantity of charcoal or powdered coke determined by the percentage of iron oxide present. Emery containing 25 per cent iron oxide requires between 4 and 5 per cent of carbon. The mixture is then exposed to the arc of an alternating current in an electric furnace which when the requisite temperature is reached fuses, the iron oxide being reduced by the carbon to metallic iron which meets and runs together usually in lumps. Emery also contains a certain proportion of combined water, sometimes as high as 5 per cent, the presence of which causes considerable trouble in the baking of the manufactured emery discs at high temperatures. This water is driven off and an anhydrous corundum which is also free from iron results. The deposited iron contains some alumina and this when crushed is separated by means of an electro magnet. The resultant corundum is crystalline, nearly colourless, but occasionally dull ruby red, or blue with a lustre like quartz; sometimes beautiful deep blue more or less transparent crystals of sapphire are found in small cavities in the mass. A suitable and low priced product for this process is afforded by the emery dust powder from the emery mills.

From an economic standpoint the most satisfactory method which has been devised for the manufacture of artificial corundum is a process which consists essentially of subjecting beauxite to an intense heat in an electric furnace. This process, which was developed about 1900, follows a suggestion made by Dr. T. S. Hunt of the Geological Survey of Canada in 1861[1] in a paper "On the Origin of Some Magnesian and Aluminous Rocks." Describing the occurrence of bauxite at Beaux (or Baux) near Arles in France he stated that "by an intense heat this substance is converted into crystalline corundum resembling emery in physical character." This artificial abrasive known now as alundum was first marketed in 1904 when 3,612,000 pounds valued at $252,480 were produced by the Norton Emery Wheel company at their plant at Niagara Falls, New York. Bauxite occurs either in rounded grains or as earthy or clayey material. It varies in colour from white through greyish or yellowish to brown and even red, the depth of shade being de-

[1]Am. Jour. Sc. 2nd Ser. Vol. XXXII, 1861, p. 288.

pendent on the amount of iron present. Bauxite is a form of hydrated alumina. The formula usually employed as expressive of the analyses is Al_2O_3, 2 H_2O (alumina 73.9, water 26.1) but some of the analyses indicate Al_2O_3, H_2O like diaspore. Other analyses give the formula Al_2O_3, 3 H_2O. Analyses of bauxite from Wilkinson county, Georgia, gave Edgar Everhart as follows: Al_2O_3, 41.97-61·77; F_2O_3, 0.96-18.24; SiO_2, 0.90-17.50; H_2O, 16.83-32.44; TiO_2. 1.84-3.65; moisture 0.35-2.79. Most of the bauxite comes from Arkansas, the principal deposits being in Saline and Pulaski counties. According to the Mineral Industry, Arkansas produced 150,000 tons of bauxite in 1912, while Georgia contributed 30,000 tons. In Arkansas three grades of bauxite are produced. The highest grade as free as possible from iron but containing from 6-7 per cent of silica is shipped and used in the manufacture of alundum. Another grade carrying less than 2 per cent of iron is used for aluminium salts, while the more ferriferous ore is used for making metallic alumimium. An analysis of washed and calcined bauxite from Arkansas afforded S. R. Stone the following results:[1] Al_2O_3, 87.30; Fe_2O_3, 1.43; SiO_2, 6.40; TiO_2, 3.99; H_2O, 0.88.

The bauxite intended for the manufacture of alundum is specially selected and only the highest grade as free as possible from iron, is used. Before it is ready for the electric furnace it is thoroughly washed, dried, and heated or calcined, which not only drives off the moisture but also the water of composition so that the product which is actually given to the electric furnace is an anhydrous oxide of aluminium.

The rotary calciner 60 feet long is heated by two gas producers. It is continuously in action and will calcine 40 tons of bauxite per day. The furnaces are conically shaped pots which stand on cars, 4 feet in diameter and 5 feet high, and are heated by two vertical carbon electrodes, 4×12 inches in cross section, which are gradually raised as the molten material fills the furnace. Each furnace uses several hundred horse-power and the total consumption in the furnace room amounts, it is said, to 2,000 electric horse-power. The heat generated in the furnace is stated as from 5,000° to 6,000°F, more than sufficient to

[1]Min. and Eng. World Vol. XXXVII, Aug. 24, 1912, p. 342.

fuse the bauxite which recrystalizes as corundum. Some bauxite is used as a lining for the furnaces, which in addition have a water cooled shell. The ingot or "pig" as it is taken from the furnaces has an outer layer of nearly unaltered bauxite and weighs from 2½ to 3 tons. A portion of the artificial corundum or alundum is well crystallized in hexagonal forms which are very similar to those obtained in the reduction of the metallic oxides as already described. During the fusion the small amount of iron present in the original bauxite is reduced. This iron, containing from 5 to 12 per cent of silicon, is sold to the steel manufacturers. After fusion is complete, the furnace is wheeled to a position under an electric crane which removes the solidified "pig," and places it on the cooling floor. When cool enough to handle, the whole mass is broken up and fed to a crusher whence it passes through a reel which removes all the fine dust. This fine material is returned to the furnace for re-fusion. The product is passed over a sorting belt and material which is unsuitable is then removed. The resultant product in lumps about the size of a man's fist is sent to the company's works at Worcester, Mass., where it is crushed and graded before it is ready for use in the manufacture of alundum wheels.

Alundum was first used as an abrasive in the manufacture of alundum wheels, in competition with wheels made from natural corundum. Later its employment was extended to the making of alundum sharpening stones and also in grain form. Abrasive wheels made from this artificial substance are finding an increased use in the cut glass and lens making industries. Since 1910 it has been quite extensively used in the manufacture of refractory products, especially laboratory ware such as combustion boats, ignition and filter crucibles, extraction thimbles, filter dishes, muffles, tubes, and cores. The melting point of alundum is 2050C. and that of the manufactured bonded article only slightly lower. It is stated in the Mineral Industry that crucibles made of bonded alundum have been used repeatedly without injury for melting pure platinum. Experiments made with alundum bricks for furnace linings where high temperatures are encountered, have only met with moderate success as the cost of alundum is necessarily appreciably higher than other standard refractory substances.[1]

The production of alundum, which was first started in 1904, has now (1912) reached the extraordinary figure of 13,266,486 pounds valued at $795,989 a year.

[1] L. E. Saunders, Trans. Am. Electrochem. Soc. Vol. XXI, p. 333.

CHAPTER XIV

MINING AND MILLING OF CORUNDUM.

Corundum or the crystallized oxide of aluminium is the most important mineral from an economic standpoint, which occurs in the area included by the Haliburton and Bancroft map-sheets in eastern Ontario. It is sporadically developed along the three belts of syenites and anorthosites whose areal distributions has already been described. In the northeastern part of the region covered by the Bancroft map-sheet there are a great many deposits of this mineral, but only those at Craigmont in Raglan township and Burgess Mines in Carlow township have been developed and mined to any extent. Other occurrences of corundum of promise are known in Lutterworth, Faraday, Dungannon, Monteagle, and Brudenell townships, but not enough work has been done on them to enable an intelligent judgment to be formed as to their real extent and economic importance.

BURGESS MINES.

The scene of mining and milling operations at present is at Burgess Mines on lot 14, concession XIV, of the township of Carlow. This is the location where corundum was first discovered by Ferrier in 1896, "where a range of very high prominent hills ends somewhat abruptly in [illegible] cliff or precipice, composed chiefly of coarse flesh red pegmatite, cutting a dark reddish or brownish gneissic rock which on examination under the microscope proves to be a hornblende granite gneiss." This deposit is now exhausted and present mining is carried on at John Armstrong's hill about $1\frac{1}{4}$ miles west of Burgess Mines.

The following description of the equipment is taken from the fourteenth report of the Ontario Bureau of Mines:

"The two main buildings are the boiler-house and mill. In the former, a 125 h.p. boiler is installed to do all the drying by steam as well as to run the plant. The plant comprises five Blake crushers, one 9 by 15 inches, two 7 by 10 inches, and two [illegible] by 10 inches; two 'lightning' (impact) crushers or pulverizers; two rolls; dividers; magnetic separator—the Noble, seven Hooper pneumatic jigs; a dryer; a 75 h.p. horizontal engine; and electric lighting plant. The ore is dried immediately on arrival from the mine."

CRAIGMONT.

The most extensive mining for corundum has, however, been at Craigmont in Raglan township, but owing chiefly to the destruction of the mill at this place in February, 1913, all operations at this place have been suspended, some of the buildings even having been removed to Burgess Mines. Both geologically and from an industrial standpoint these occurrences of corundum merit a special and detailed description.

Geology of the Vicinity of Craigmont.

Craigmont (formerly Robillard mountain—see Plates XXV, XXVI, and XXVII) is a well marked topographical feature rising abruptly from Campbell's marsh and extending as far west as the post road between Combermere and Fort Stewart. It covers most of the first four lots in concessions XVIII and XIX, Raglan township, the line between these two concessions running along the southern slope of the mountain. The highest point is about 420 feet above the sand plain to the south, or 1,520 feet above mean sea-level.

The northern portion of the "mountain" is composed of the reddish granite-gneiss of the Laurentian batholith so prevalent throughout the region. This gneiss is well banded as well as very distinctly foliated and contains the usual amphibolite inclusions, for the most part elongated in the direction of the strike. This granite gneiss is intruded by many dykes and masses of granite pegmatite, often with very marked "augen," probably a protoclastic structure, induced in the rock mass during the later stages of its consolidation. The granite gneiss contains quartz, while the granite pegmatite is often quite rich in this mineral.

The gneissic granite series to the north of the hill, by a gradual decrease in quartz, seems to merge into the corundum-bearing series which overlies it and which forms the summit and southern slope of the hill. The corundum-bearing series is a complex of diverse though closely related rock types, differentiation products of one highly alkaline and aluminous magma and representing one phase of plutonic activity. These different rock types usually occur in irregularly sinuous, rather ill-defined bands, the gradual transition from one type to another being a distinctive characteristic of their occurrence. They are usually foliated, the strike being N.75° E. with a dip to the south at an angle of 10 degrees to 12 degrees. These rocks are intersected by dykes and masses of syenite pegmatite, which are very frequently parallel to the foliation, merging into the normal or finer grained types. Superimposed upon this corundiferous series and represented by small and infrequent outcrops protruding through the sand plain to the south of the hill are the crystalline limestones of the Grenville series. As elsewhere through the region, the nepheline-bearing rocks are intermediate in position between the crystalline limestones and the granite-gneiss batholith. The following types have been selected as the most important representatives of this igneous complex, although it must be understood that no sharp line exists in nature between these several varieties.

(1) *Craigmontite* This variety is very rich in nepheline and contains a very small proportion of corundum, usually less than one per cent. The rock is prevailingly pinkish in colour, owing to incipient alteration of the nepheline, and is rather coarse in grain. Under the microscope it is seen to be composed of nepheline, oligoclase, muscovite, biotite, calcite, magnetite, and corundum. The corundum (as also in raglanite) occurs in well defined crystals, often with characteristic, barrel-shaped outline, and so disposed in the rock that their longer axes are often at right angles to the foliation. Smaller individuals viewed with the microscope are often irregular shaped, owing to magmatic corrosion, usually surrounded by a corona or mantle of muscovite

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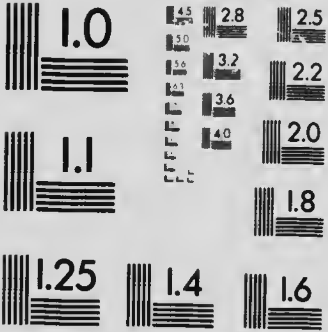

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(2) *Congressite.* This rock represents the product of differentiation in which nepheline is most abundant. It is allied to monmouthite and urtite but is richer in alkalies belonging to the 9th order of the persalanes in the quantitative classification. The rock appears as great exposures in that part of the Craigmont hill known as Congress bluff ("The Klondyke Quarries", see Plate XXVI). It is rather coarse in grain and usually possesses a more or less marked foliation, as in the case of the other members of the series. It is pale pink in colour owing to the large amount of nepheline which it contains, this mineral having a pink colour and a distinct oily lustre. In places, however, the rock displays little white bands or streaks of plagioclase. Sodalite when present occurs enclosed in the nepheline in the form of small grains which are bright blue in colour, while the other constituents occur as little flakes or grains, distributed through the rock serving to mark the foliation. The mica in some cases displays a tendency to segregate into little bunches.

(3) *Raglanite.* This is a white or grey corundiferous nepheline anorthosite chosen as representative of the more highly feldspathic variety of the nepheline syenite of Craigmont. Since that time quarrying operations have exposed still more highly feldspathic phases, which may be referred to as plumasite a name originally proposed by Dr. Andrew C. Lawson (Bull. Dept. Geol. of California, Vol. III, No. 8, pp. 219–229). The rock is composed of about 69 per cent of oligoclase, 12 per cent of nepheline, and 4.45 per cent of corundum, with subordinate amounts of muscovite, biotite, magnetite, calcite, and apatite.

(4) *Plumasite.* This is an oligoclase anorthosite made up almost exclusively of white oligoclase with a variable amount of corundum. Muscovite, biotite, and scapolite are sometimes present as accessory constituents. Plumasite is closely allied to raglanite and dungannonite.

(5) *Umptekite.* This rock is the red or pink alkali-syenite and differs from plumasite chiefly by reason of the fact that a considerable quantity of potash feldspar is present. Usually it is distinctly foliated, the structure being marked by minute scales of biotite. Umptekite is, perhaps, the most abundant

representative of this alkali series at Craigmont. Its approximate mineralogical composition is of orthoclase and microcline (30 per cent) albite (55 per cent), magnetite with a little biotite and corundum. Some specimens contain small amounts of hornblende or pyroxene as accessory constituents replacing the biotite.

(6) *Anorthosite.* Another anorthosite is a coarsely granular rock of greyish or greenish-grey colour. It is composed, essentially, and sometimes almost wholly, of a plagioclase feldspar, having a composition intermediate between oligoclase and andesine. Most of the exposures, moreover, contain a variable quantity of deep pink garnet, magnetite, and corundum. Under the microscope the thin sections show the presence of subordinate amounts of muscovite, biotite, scapolite, and a deep green spinel.

(7) *Scapolite Rock.* Some of the quarries show the presence of a pale greenish granular rock made up almost exclusively of scapolite. The mineral has a specific gravity of 2.67, showing that it is of intermediate composition in the scapolite series. Associated with this scapolite are small bands of magnetite.

(8) *Amphibolite.* Amphibolite occurs intimately associated with the other members of the corundiferous series chiefly as dark greenish bands, analogous to similar inclusions in the granite gneiss batholith. Some bands are highly micaceous, while others are composed almost altogether of hornblende. In some cases they are apparently deformed and altered basic dykes.

(9) *Corundum Pegmatite.* This is the rock which contains the largest and most abundant crystals and masses of corundum at Craigmont and thus is the richest "ore" which has been quarried or mined. This rock occurs in the form of dykes, which sometimes attain a width of 18 feet. Sometimes these dykes cut across the banding or foliation of the series, but usually run parallel with these structures. There is often a distinct and perfect gradation between this coarse-grained phase and the normal type of syenite, which also contains corundum, although in less abundance and in smaller individuals. The rock is made up almost entirely of a deep, fresh-red to very pale salmon pink feldspar, which in thin section under the microscope is seen to be an irregular intergrowth of orthoclase and

albite, the latter, as indicated by the analysis, being the more abundant. Associated with this microperthite as accessory constituents, locally and usually in small amount, are biotite, muscovite, scapolite, calcite, magnetite, hematite (micaceous iron ore), molybdenite, pyrite, pyrrhotite, chalcopyrite, chrysoberyl, spinel, and quartz. Although quartz and corundum are commonly supposed to be mutually exclusive, specimens have been found containing these two minerals in small amount.

This syenite pegmatite is representative of one of the final stages of the crystallization of this highly aluminous magma. Pegmatite dykes with a variable but usually small quantity of quartz are the latest intrusions in this igneous complex.

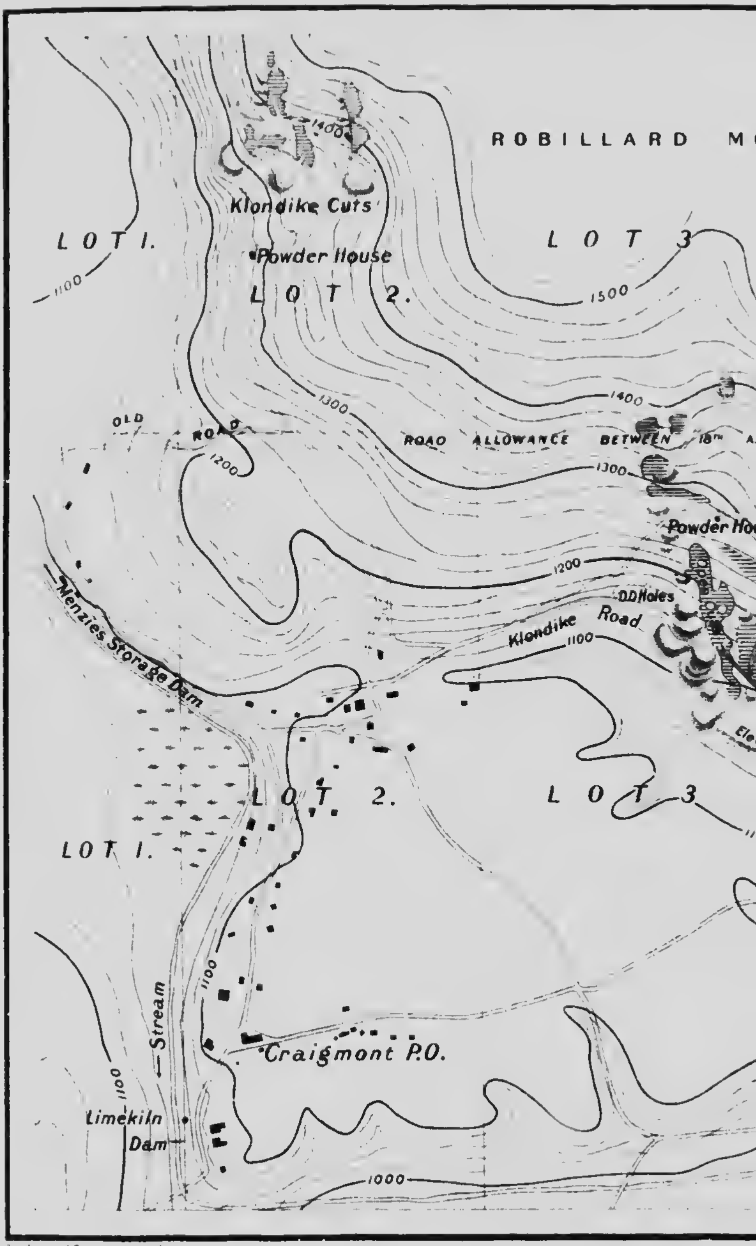
Mining at Craigmont.

On the property of the Manufacturers Corundum company at Craigmont, the mining (see Plate XXVII) is done in the usual way, by means of air drills and dynamite. The holes are drilled 14 and 15 feet deep, and a series of as many as twenty holes are sometimes fired off by means of the electric battery. A large quantity in big pieces is thrown down, and they are block-holed and bull-dosed with dynamite down to suitable sizes for handling by the cullers, as it is very necessary to cull or select the ore. The percentage of corundum does not run high enough to allow of milling all the ore coming from the mine, without sorting out the low grade, as the lowest grade of ore fed to the mill requires to be higher than the amount which is lost in the tailings; it is also necessary to prevent as much as possible large pieces of magnetite, iron pyrites, or hornblende, from going to the mill, as they are difficult to remove when concentrating to 95 per cent.

In the very fine fissures, thin splashes of molybdenite are found, but this ore does not occur in any quantity, enough for samples only.

The drilling of the corundum-bearing rock, either by hand or by rock drills, is not difficult; but requires special experience in the sharpening of the drills.

From the open quarries on the face of the hill, the ore is brought down in stoneboats and trucks by teams to the tramway,



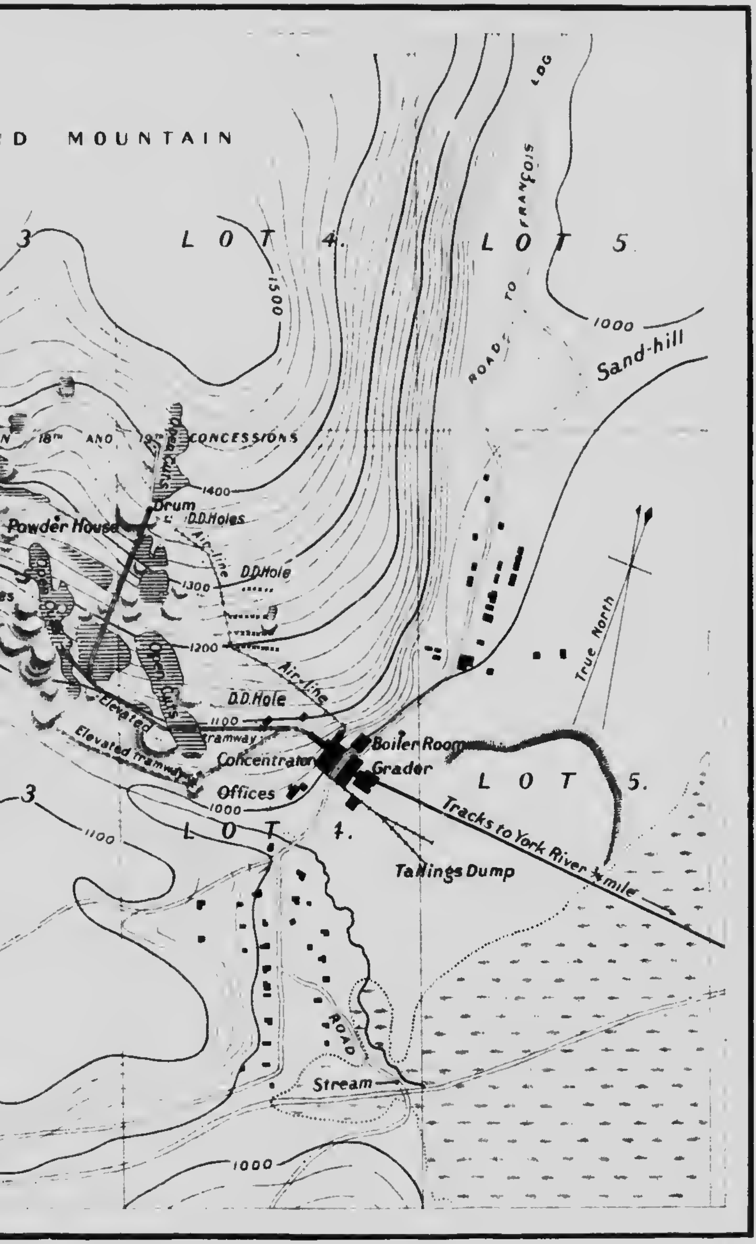
Geological Survey, Canada

Craig Mine, Raglan To

Feet

Metres

To accompany Memoir by A. E. Barlow



1473

...aglan Township, Ontario.

Feet

Metres

where it is loaded on to cars, carrying 3 to 4 tons. The cars run on a tramway into the top of the mill; before entering the mill the car load is weighed and an exact tally kept of the number of tons which go into the mill every day (in wet weather, an allowance is made for the moisture in the ore). The cars are drawn by horses, and can handle 150 tons in 10 hours.

MILL. The mill (see Plate XXVIII) is situated at the east end of the southern face of the hill on which the corundum ore is quarried. The tramway, already mentioned, comes from the weighing machine and enters at the top of the mill; the cars are of the flat-top type and tip on both sides into the bin below. The bin is square and flat bottomed, with a capacity of 400 tons. The chute for feeding the crusher is near the centre of the bottom of the bin, and comes out to the ore-crusher; and alongside this chute a man stands and feeds the crusher, which is of the Farrell type of Blake crusher, 15 inches by 24 inches, running at 250 revolutions per minute, and crushing down to 2½ inches. The ore, after being crushed, drops to a Robbins conveyor belt, 18 inches wide and 85 feet long, travelling at a speed of 300 feet per minute, with 20 per cent of an elevation to the delivery end.

The stream of ore coming from the conveyor belt is divided into three, and fed by short chutes into three smaller crushers, two of them being the Farrell type of Blake crushers, 6 inches by 20 inches, and one a Gates gyratory type A crusher. These three crushers reduce the ore to three-quarter inch and less, and drop it to another large bin underneath, of 400 tons capacity.

From the underside, at the face of the bin, the ore is fed into coarse rolls by means of a Challenge feeder, the ore dropping from the disc of the feeder into the screen chute and straight into the rolls; the screen taking out all fines allows the rolls to do better work. The Challenge feeder formerly stood below the centre of the ore bin, and the ore was carried to the rolls by a belt conveyor; but this was discarded, owing to the amount of ore spilled and to permit of the attendant's getting to the back part of the rolls so as to tighten the springs.

The ore, after passing through the coarse rolls, drops down, and is divided between two trommels, 13 feet long and 3 feet in diameter, running at 20 revolutions per minute, sloping 1 inch to the foot, the screens having 4 millimetre holes. The undersize passes downward into the vertical elevator and the oversize passes to two sets of rolls and then into the same elevator. The elevator is an india rubber belt with buckets bolted on (the bucket being 18 inches long, 6 inches wide, and 6 inches deep), running at 350 feet per minute. All the crushed ore is raised by this elevator in the form of a watery pulp to the top of the mill, where it is divided into two sets of five trommels in each set. Each trommel, 3 feet in diameter and 13 feet long, making 20 revolutions per minute, and with a slope of 1 inch to the foot, is driven by a sheave pulley and rope drive on the oversize end.

The pulp enters the two coarse trommels, the first 6 feet being covered with screen perforated with 4 millimetre holes, 4 feet with 6 millimetre holes, and 1½ feet with 8 millimetre holes. All pulp passing through the 4 millimetre holes goes to the next trommel, that passing the 6 millimetre holes goes downward to two sets of double three compartment iron Hartz jigs; and that passing through the 8 millimetre holes passes downward through wooden spouting lined with steel plate to a set of double two-compartment wooden Hartz jigs. The oversize, from these two trommels, goes downward to the roll floor, and, being re-crushed, comes back through the same elevators. The pulp passing through the 4 millimetre holes on the first set of trommels passes to the second trommels, covered for the first 6 feet with screens having 2 millimetre holes, the pulp passing through the 2 millimetre holes goes on to the next set of trommels, and that passing over the 2 millimetre holes is sized on the next 5 feet of the trommel with 2½ millimetre holes; the pulp passing through the 2½ millimetre holes is treated on six Overstrom tables; this size is a little large for these tables, but it is done in the meantime for lack of jigs. The oversize of the 2½ millimetre holes goes downward to a double three compartment iron Hartz jig. The pulp passing through the 2 millimetre holes on the second set of trommels then passes to a third set, of which the whole length is covered with screens having 1½ millimetre holes; the undersize goes to the next set of trommels and the oversize to three Overstrom tables. The fourth set of trommel screens has 1 millimetre holes, the undersize going to the fifth set and the oversize to the concentrating tables. The pulp passing through the fifth trommel and the three-quarter millimetre holes goes into a V box, and (the heavy particles settling) is fed to a concentrating table and the surplus water is run into the tail race. The twenty Overstrom and four Wilfley concentrating tables, the two sets of double three compartment iron Hartz jigs, and the double two compartment wooden Hartz jigs, are placed on the floor below the trommels. The screen area of the iron jig is 24 inches by 36 inches, and the screens are of the same sizes in the hole as the trommel which supplies the material, but the top of the screen has 1½ inches of oversize material for a head. The speed of the jigs is 220 revolutions per minute; for the fines, up to 170 revolutions per minute; for the coarser sizes, the stroke is three-quarters to 1 inch.

The product of the jigs' first hutch goes to the finishing rolls on the roll floor below, where it is crushed and goes to the bin; being finished in the crushing part of the mill; the second and third hutches of the jigs, not being so clean, go to the rolls again and are crushed finer; and, owing to the want of a separate elevator and screen, they have to go back into the main elevator, where, if fine enough, they go to concentrating tables, and if coarse, are returned to the jigs. Tests made on the product of the jigs showed that the first hutch cleaned it to about 50 per cent of corundum, and the second and third hutches to 35 or 45 per cent of corundum: that is, from an ore which carries 10 per cent of corundum and 6 to 7 per cent of magnetic iron The tailings from the jigs showed a loss of 3 per cent, but, as they were much overloaded, this did not give a fair showing; and, no doubt, with ample jig capacity, the losses would be reduced by 50 per cent.

The following is about the average percentage of corundum in the end products:

	Per cent
Ore fed to mill	10½
Jig concentrates	50
Jig partial concentrates	40
6 millimetre screen, jig tailings	3

	Per cent
4 millimetre screen, jig tailings......	3
2½ millimetre screen, jig tailings.......	3
Table concentrates..............	60
2½ to 2 millimetre, table tailings.........	2
2 to 1½ millimetre, table tailings......	2
1½ to 1 millimetre, table tailings.......	2
1 millimetre to zero, table tailings...........	2
Magnet tailings, coarse........................	7
Magnet tailings, fine.......................	3
Average................................	5
Rewash table tailings......................	5
Total mill tailings........................	5

The corundum is cleaned to 90 or 95 per cent.

On the same floor as the jigs, are the Overstrom and Wilfley concentrating tables; and on an intermediate floor are six more Overstrom tables, to treat the middlings from the preceding Overstrom tables.

The losses from the concentrating tables vary from 1½ to 2 per cent, principally carried off floating in the water; as, in the crushing of the corundum crystals, owing to the hardness and the strain which is required to crush it, a percentage of the corundum goes to very fine powder and floats off in the water. The product from the concentrating tables and the finishing rolls is spouted into a small elevator, which raises it to another trommel for sizing, before being run into storage tanks. No. 12 mesh is the size of screen on this trommel, and all coarser than this to No. 10 mesh is rejected, and goes back to the finishing rolls and is crushed smaller. The corundum concentrates are now deposited in the five storage tanks; they are also used as filter tanks to take off the moisture, and are fitted with a little false bottom for drainage. The corundum concentrates, which now run about 50 per cent of corundum, are then sent from the crushing department to the grading room.

In the crushing part of the mill, there are four sets of heavy rolls, 14 inches by 40 inches, with shafts, 10 inches in diameter, fitted with brass sleeves, which slip on to the shafts and take all wear. The roll-shells are made of Hadfield manganese steel, and do the work with very little wear, and the jaw plates on all the crushers are made of the same material.

The Gates rolls, 14 inches by 24 inches, crush the product from the second and third hutches of the jigs. Adjacent are the Colorado or finishing rolls, 6 inches by 30 inches. There is another set of smaller rolls, but they have not been set to work yet.

The intention, when this part of the mill was built in 1903, and finished in the beginning of [illegible]4, was to crush everything in the rolls small enough to c[illegible]ate on the Overstrom and Wilfley tables. This was found to be impossible, owing to the high percentage of fines, and the large amount carried off in the tailings in the form of fine slimes; the demand for the very fine sizes is small, and they are not so easily cleaned as the coarser sizes.

The crushing part of the mill containing the above machinery is a building 145 feet long, 36 feet wide, and 85 feet high, with five doors. On the second floor is the machine shop, equipped with a lathe, drilling machine, and two small shearing machines worked by hand.

The engine house is equipped with a Corliss engine of 225 horse-power, a Corliss engine of 125 horse-power, and an auxiliary engine of 20 horse-power.

The f[illegible] engine transmits power by means of six cotton ropes, 1½ i[illegible]s in circumference, to the main shaft on the same floor, for d[illegible]ng all the jigs and concentrating tables, the trommels and the large elevator in the top of the building; also driving all the grading machinery in the grader building by a rope-drive from the same shaft. The other six grooves on the engine pulley drive the main shaft for the roll floor by means of one continuous rope, with a tightener pulley and a balance weight. This arrangement is being taken out, as in the event of this rope breaking, all the machines on this engine are stopped until the rope is straightened out and replaced. This means a stoppage of several hours, whereas, if the ropes were all single drives, the breakage of a rope would cause no stoppage, as the other five would have sufficient power to drive the full load until the first stop, when another rope could be slipped on to it, having been prepared and spliced over the two shafts. From the main shaft of the jig and table floor a rope drive goes back into the engine room to drive a small dynamo of 220 lights of 16 candle power capacity. The little auxiliary engine drives the dynamo by means of a belt and countershaft, in the event of any stoppage of the large engine, and at the same time it runs the machine shop for repairs.

The second engine, of 125 horse-power, runs the crushers and a small Root pump. The power is transmitted from the engine to the countershaft by a continuous manilla rope, 1½ inches in circumference, with a tightener pulley; this also is being changed to single ropes.

In the same room as the engines is a cross-compound air compressor, with intermediate and after coolers, condenser, and air receiver, having an air capacity of 1,700 cubic feet of free air per minute, and compressing it to 100 pounds per square inch, thus providing the quarries with sufficient air to run about thirty drills.

Steam is supplied to the engines from three return tubular boilers, 5 feet diameter and 18 feet long, with furnaces and flues built up with bricks. Wood fuel is used, dry pine, maple, birch, and poplar being the principal woods, the consumption amounting to 25 to 30 cords per 24 hours. The boilers are placed in a building apart from the mills.

The water to supply the crushing and concentrating part of the mill is pumped by a Root pump from the basement of the grader building, to a tank placed behind the first set of coarse rolls. This pump has a capacity of 1,000,000 gallons per 24 hours, and throws it against a head of 60 feet. From this tank, the water runs to the rolls, tables, jigs, and launders. A jet of water is used to feed the ore into the rolls, and to keep down any dust.

GRADER BUILDING. The grader building is 135 feet long, 60 feet wide, and 80 feet high. The concentrates are brought into this building by a conveyor, and dropped on to a dryer.

The double-decked dryer, made of iron pipes, 1¼ inches in diameter, is heated by exhaust and live steam. The wet concentrates are distributed from the conveyor upon a No. 4 mesh wire screen, through which the stuff as it dries drops on to a conveyor belt, thence to an elevator, and is raised to the top of the building. The stream of concentrates is then divided over magnetic separators, one being of the cone and the other of the drum type. The concentrates contain 12 to 15 per cent of magnetic iron; the non-magnetic concentrates go down to the splitter on the floor below, and the magnetic iron, containing 4 to 5 per cent of corundum, is dropped outside of the building for further treatment.

Roughing splitters, with three screens, divide the concentrates into three sizes: No. 1 takes all sizes, from 8 to 24 meshes inclusive, and sends them to No. 1 graders; No. 2 takes all sizes, from 30 to 70 meshes inclusive, and sends them to No. 2 graders; No. 3 takes all sizes from 80 to 200 meshes inclusive, and sends them to No. 3 graders.

The roughing grader gives sizes passing through the screens: No. 1 is divided into sizes 24, 20, 16, 14, 12, 10, and 8 is over-size; No. 2 into sizes 70, 60, 54, 46, 36, 30, and 24 is over-size; and No. 3 into 200, 180, 150, 100, 90, 80, and 70 is over-size. These products all go into bins above the rewashing tables and Hooper air jigs. Steel wire screen-cloth is used, from 8 meshes to 30 meshes; and silk screen-cloth is used for all of the other sizes, from 36 meshes to 200 meshes.

The Hooper air jig is a good machine for concentrating dry-sized concentrates; it works well on concentrates from 24 meshes to 70 meshes, and gives four grades of produce from 50 per cent corundum as follows: firsts, or heaviest portion, magnetite and pyrites which have escaped the magnetic separators are extracted and sent to piles outside the building; seconds, or lighter portion, is clean corundum 90 to 95 per cent pure; thirds, or middlings, are held for retreatment, until a quantity is accumulated; and fourths, tailings or waste carrying off 4 to 6 per cent of corundum. The clean corundum passes from the Hooper jigs to an elevator, which raises it to the top of the building.

Five Wilfley rewash tables are used for cleaning up the coarse and the fine sizes. The Wilfley tables, running at 250 revolutions per minute, treat the fines, and the Wilfley table treating the coarse sizes runs at 215 revolutions per minute; the coarse tables have a stroke of three-quarter inch and the finest table a stroke of three-eighths inch. The products are: firsts, on the high side of the table, a little magnetite and pyrites; seconds are clean corundum, 88 to 90 per cent; thirds or middlings are re-treated on the same table; and fourths, tailings or waste containing 5 per cent of corundum.

The clean corundum from the rewash tables is carried to the second deck of the dryer, dried and dropped down to the conveyor, taken to the clean elevator, and goes to the top of the building along with the corundum from the Hooper jigs: then it goes over the finishing magnetic separator, drops through the floor, and passes the final magnetic separator. The process leaves a corundum carrying from 1 to 2½ per cent of iron, in the form of combined iron in the crystal corundum.

The corundum leaving the magnetic separator goes to the finishing splitters, of the same type as those already mentioned. This last operation must be carefully effected, as the exact sizing is very important to wheelmakers and users of loose corundum.

From the finishing grader, the product drops into bins in the floor, from which it is drawn into bags containing 100 pounds. Samples are taken from all the sizes each day, before the bags are sewn up, and as soon as the results are sent from the assay office, the grade of quality is marked on each bag, and it is then ready to be sent to market.

Three grades are made to suit the wheelmaker. The vitrified wheel requires the highest grade, the silicate wheel takes the next grade, and the third grade goes to the cement wheelmaker and the polishing trade. The corundum for vitrified wheels varies from 90 to 95 per cent pure.

The cost of producing finished corundum, including mining, milling, concentrating, sizing, packing, office expenses, insurance, and general charges, had not yet been reduced below £8 ($40) a ton; but with a well equipped mill, crushing 150 tons per 24 hours of a grade of ore containing 10 to 12 per cent of corundum, the cost should not exceed £6 to £7 ($30 to $35) per ton.

CHAPTER XV.

STATISTICS OF CORUNDUM.

In the first years of the collection of statistics of corundum in the United States the figures of production were very difficult to obtain, and those quoted are only, therefore, approximate. In the annual returns published by the United States Geological Survey the productions of corundum and emery are stated together, the explanation being that "the producers of both emery and corundum are averse to giving publicity to their business, and in order to maintain the confidential nature of the statistics the production of the two minerals is stated together". Lately, however, this reticence on the part of mine owners and companies has been largely overcome, and the figures now obtained are much more reliable.

From the beginning of the industry of corundum mining in Canada the figures of production and shipments as furnished to the Ontario and Dominion Departments of Mines have been complete and reliable. The demand for corundum is increasing, due not only to the large increase in general manufacture, but also to the improved methods of cleaning corundum, and the wider application of the material thus obtained. Besides, its manifest superiority as an abrasive over many of the ordinary impure products sold as emery is being more generally recognized. It is confidently believed that the Canadian occurrences stand unrivalled, not only by reason of the great area covered by the corundum-bearing rocks, but also in regard to the comparative richness of the individual deposits, as well as the purity and unaltered character of the material secured. The Canadian product is now without a rival in the market for natural corundum, for the United States, its most serious competitor, has practically withdrawn from the field ever since and including 1905. At the present time, therefore, the corundum industry of Canada is the greatest natural corundum industry in the world.

Corundum Ore Mined and Annual Production of Graded Corundum in Canada.

Year	Corundum bearing rock treated. Tons	Grain corundum graded. Tons	Percentage of corundum in rock as determined by recovery. %
1900........	......	60	.....
1901........	4,134	444	10·74
1902........	7,996	806	10·08
1903........	(a) 8,877	839	9·45
1904........	28,187	1,654	5·87
1905........	23,571	1,681	7·13
1906........	45,719	2,914	6·37
1907........	60,532	2,682	4·43
1908........	2,678	106	3·96
1909........	35,894	1,579	4·40
1910........	37,183	1,686	4·53
1911........	41,795	1,641	3·93
1912........	36,879	1,620	4·39
1913........	12,290	763	6·21

(a) In addition to this amount which was milled in Canada, 267 tons of ore were mined and shipped to the United States for treatment there.

Annual Sales and Shipments of Grain Corundum from Canada.

	Grain corundum sold in Canada Tons	Grain corundum sold for export Tons	Total sales and shipments Tons	Value $	Average value per pound $ Cts.
1900.....	3	.....	3	300	5.00
1901.....	85	302	387	46,415	5.97
1902.....	106	662	768	84,465	5.49
1903.....	85	618	703	77,510	5.51
1904.....	116	8 7	993	109,545	5.51
1905.....	140	1,504	1,644	149,153	4.48
1906.....	162	2,112	2,274	204,973	4.50
1907.....	164	1,728	1,892	177,922	4.70
1908.....	99	990	1,089	100,398	4.60
1909.....	129	1,362	1,491	162,492	5.45
1910.....	106	1,764	1,870	198,680	5.31
1911.....	92	1,380	1,472	161,873	5.50
1912.....	64	1,896	1,960	239,091	6.10
1913.....	23	1,154	1,177	137,036	5.80

Corundum Exports.

(Department of Customs, Canada.)

	Great Britain		United States		Other countries		Total	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1911 (Last 9 mos.)	170	$17,800	399	$42,347	173	$17,630	742	$77,777
1912............	219	28,370	1,459	152,249	280	25,200	1,928	205,819
1913............	157	21,585	920	100,156	.....	....	1,077	121,741

These figures of exports have only been recorded separately by the Department of Customs of Canada since April, 1911. The record may differ somewhat from that shown in a preceding table owing to the time taken in shipment between the mills and the port of export.

Production of Corundum and Emery in the United States, 1881-1912, inclusive, from returns of U. S. Geological Survey.

Year	Short tons	Value	Year	Short tons	Value
1881.....	500	$80,000	1897	2,165	$106,574
1882.....	500	80,000	1898	4,064	275,064
1883.....	550	100,000	1899	4,900	150,600
1884.....	600	108,000	1900	4,305	102,715
1885.....	600	108,000	1901	4,305	146,040
1886.....	645	116,190	1902	4,251	104,605
1887.....	600	108,000	1903	2,542	64,102
1888.....	589	91,620	1904	1,916	56,985
1889.....	2,245	105,567	1905	2,126	61,464
1890.....	1,970	89,395	1906	1,160	44,310
1891.....	2,247	90,230	1907	1,069	12,294
1892.....	1,771	181,300	1908	669	8,745
1893.....	1,713	142,325	1909	1,580	18,185
1894.....	1,495	95,936	1910	1,028	15,077
1895.....	2,102	106,256	1911	659	6,778
1896.....	2,120	113,246	1912	992	6,652

Since and including the year 1905 the production of corundum has ceased. The tables of production, therefore, from 1905 to 1912, both years inclusive, are of emery only. North Carolina and Georgia were the first states in the United States to produce corundum and until 1900 furnished all the corundum used in that country. In this year the import from Canada began. From 1901-1905 a small part only of the corundum used in the United States was from North Carolina and Montana. In this year the mining of corundum was discontinued in this country and has not since been resumed.

Production of Corundum in the United States from the "Mineral Industry", 1895-1900.

Year	Short tons	Value	Per ton	Year	Short tons	Value	Per ton
1895..	385	$25,989	$67.50	1898	786	$63,630	$80.96
1896..	250	17,000	68.00	1899	970	78,570	81.00
1897..	293	19,810	67.61	1900	830	58,100	70.00

These values are based on the price at the mines and are of slight significance owing to the great range between the different grades of the mineral. The changes in the annual average do not indicate fluctuations in market quotations so much as changes in the proportion of different grades of minerals grouped in the total.

On a number of islands in the Grecian Archipelago emery has been found in considerable quantities. The most important mines are on the island of Naxos. Equally good emery has been found on the island of Nicaria, but not in such great quantity. A little has also been found on the island of Samos. The port of shipping is Syra. The deposits belong to the Grecian government and for a long time were leased to a German company known as the Naxos Union, with headquarters in the vicinity of Frankfurt and Offenbach, who required the sole right of selling the Naxos emery for a long term of years. At present the output of emery from Naxos is under the control of the International Finance Commission, representing the foreign governments in Greece, and the revenue is used in payment of the old international debt.

The following table of exports has been taken from the Mineral Industry (1912):

Exports of Emery from the Island of Naxos, Greece.

Year	Metric tons	Value	Year	Metric tons	Value
1897.....	3,125	$65,683	1905	6,395	$132,090
1898.....	4,500	93,166	1906	8,030	166,251
1899.....	5,139	106,181	1907	10,982	221,154
1900.....	6,023	124,503	1908	7,471	164,520
1901.....	6,080	125,582	1909	8,193	164,762
1902.....	4,315	88,841	1910	12,939	255,053
1903.....	5,813	120,348	1911	9,845	202,119
1904.....	6,353	131,531	1912	7,837	157,452

The cost of production at the mines is about $10.50 per metric ton and the price obtained fee quay at Syra varied from $19.71 per metric ton in 1910 to $20.09 per metric ton in 1912. As shown in the above table the export of Naxos emery in 1911 amounted to 9,845 tons and was distributed as follows: United States 4,322 tons, Germany 1,400 tons, Holland 1,378 tons, France 1,165 tons, Belgium 670 tons, Great Britain 540 tons, Spain 350 tons, and Austria-Hungary 20 tons.

The emery deposits of Asia Minor were first investigated by Dr. J. Lawrence Smith in 1849, but it was not until 20 years later that much attention was given to their exploitation. They are in the villayet of Aidin and within a circle of about 125 miles from Smyrna, which is the centre of trade of the province. Two lines of railways run into the interior along the valleys of the Sarabat (Hermus) and Mender rivers. The principal deposits are at Gumuch Dagh and on the slopes of the Ak Sivri (Kulah district) which is about 125 miles south of the ruins of Ephesus. The annual production varies from about 17,000 to

25,000 metric tons. The quality of the emery is considered decidedly inferior to that from Naxos. The price varies from $14 to $20 per ton at Smyrna. The last official report of the Department of Mines and Forests for Turkey for the fiscal year ending March, 1909, showed a production in 1908 of 26,352 metric tons valued at £85,381, and in 1909 of 24,475 metric tons valued at £80,000.

There is still and has been for many generations a certain trade in Indian corundum, but the returns for production are manifestly incomplete. No workings exist of the kind that could be ordinarily described as mines, but attempts have been made to increase the scale of operations at Palakod and Paparapatti in the Salem district, near Hunsur in Mysore, and in South Rewah. Much of the corundum which is a regular item of trade in the bazaars of cities like Delhi, Agra, and Jaipur, where the Indian lapidary still flourishes, is collected in a casual way by agriculturists and cowherds, who dispose of it through the village "bania" to the larger dealers of the great cities.[1] In 1907 the well known corundum deposits of Pipra in Rewah were attacked by prospectors and during the year 28 tons of the mineral mined for experimental purposes.[2]

H. H. Hayden in his review of the mineral production of India during 1912 states that "there was a considerable rise in the output of corundum from 3676 cwt. in 1911 to 8707 cwt. in 1912. The greater part of this came from Mysore and Madras, but 1400 cwt. were produced in Assam. The total value of the production for the year was £1295."

Germany also produces some emery and according to the "Mineral Industry" the emery which came from Bavaria in 1910 amounted to 270 tons valued at 12,050 marks and in 1911, 210 tons valued at 9,400 marks.

Alundum or artificial corundum, as well as carborundum, are now the competitors of Canadian corundum, especially in Canada and the United States. The following are the figures of production and values of alundum in the United States from

[1]T. H. Holland, "Sketch of the Mineral Resources of India, Calcutta" 1908, p. 47.

[2]Rec. Geol. Sur. Ind. Vol. 37, 1908-9, p. 87.

the beginning of the industry in 1905 to 1912 inclusive (Mineral Industry):

Production of Alundum in the United States, 1905-1912.

Year	Pounds	Value
1905	3,612,000	$252,840
1906	4,331 233	303,186
1907	6,751,441	405,086
1908	3,160,000	189,600
1909	13,578,000	811,680
1910	13,410,000	804,600
1911	11,116,000	666,960
1912	13,266,486	795,989

The progress of the carborundum industry may be seen from the following table of production and values from 1892-1912 (Mineral Industry):

Production of Carborundum, 1892-1912.

Year	Pounds	Metric tons	Value
1892	2,145	1	....
1893	15,200	7	......
1894	52,190	24	......
1895	225,930	102	....
1896	1,190,600	540	$365,612
1897	1,242,929	564	153,812
1898	1,594,152	724	151,444
1899	1,741,245	791	156,712
1900	2,401,000	1,089	168,070
1901	3,838,175	1,742	268,672
1902	3,741,500	1,698	261,905
1903	4,760,000	2,160	333,200
1904	7,060,380	3,203	494,227
1905	5,596,280	2,539	391,740
1906	6,225,280	2,824	435,770
1907	7,532,670	3,418	451,960
1908	4,907,170	2,226	294,430
1909	6,478,290	2,938	388,697
1910	10,707,110	4,857	642,427
1911	10,376,620	4,707	622,597
1912	12,042,550	5,461	722,353

Carborundum stands next to diamond as regards its chemical composition, at the same time presenting certain strong resemblances in its physical properties, especially in the brilliancy and extreme hardness of its crystals. This substance owes its discovery to certain experiments carried on by Edward G. Acheson of Monongahela City, Penna. Using a mixture of carbon and clay, an electric current was passed through of sufficient intensity to fuse the mass. Thinking that the resultant product was mainly at least composed of carbon and alumina, the name carborundum was proposed (recomposed from the two words carbon and corundum). The first experiments were undertaken in the year 1890 and were suggested in an endeavour to prepare a new abrasive material that should be still harder than corundum. On analysis carborundum proved to be carbide of silicon with the formula SiC. with Si 69.61, C. 29.40; Al_2O_3 0.59; Fe_2O_3 O.15. In the United States the Carborundum company of Niagara Falls is the only producer. The increase in the use of silicon carbide has been chiefly for refractory purposes. This field is becoming wider each year, extension being dependent on a low cost of production. In this connexion it may be stated that carborundum has fallen from an average of $2,125 per ton in the first years, for which prices are not quoted in the above table of production, to $612 per ton in 1896. In the following year $250 per ton was the average price received for the product, while in 1912 the average price for carborundum grains and powder was 6 cents per pound f.o.b. Niagara Falls, New York. Thus from 1896 to 1912 the price has been lowered from $30\frac{3}{5}$ cents per pound to 6 cents per pound. The average price of alundum has varied from 7 cents per pound in 1905 to 6 cents per pound in 1912. The average price for Canadian corundum in 1912 was 6.10 cents and in 1913, 5.82 cents per pound.

CHAPTER XVI.

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Explanation of Plate II.

The Laurentian peneplain, Carlow township. Fraser lake in foreground (See page 41.)

PLATE II

Explanation of Plate III.

Granite-gneiss, pegmatite, and amphibolite; Laurentian batholith, east end Robillard mountain, Craigmont, Ont. (See page 46.)

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The Princess quarries (sodalite), Dungannon township. (See pages 94, 182).

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Corundum crystals in craigmontite, Craigmont, Ont. (See page 76.)

Plate XIII.

Explanation of Plate XIV.

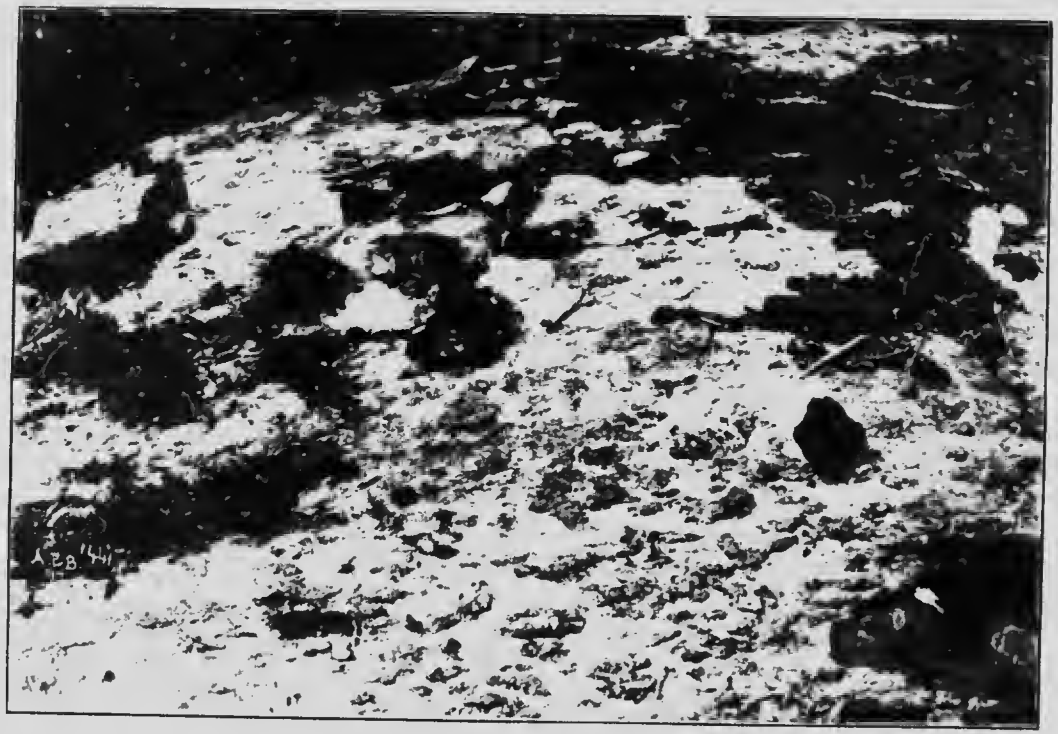
Corundum in albitic phase of nepheline syenite at contact with red alkalic syenite, lot 34, concession V, Brudenell township. (See pages 71, 109, 181, 187.)

Plate XIV

EXPLANATION OF PLATE XV.

Corundum in nepheline syenite: lot 34, concession VII, Brudenell township. (See pages 71, 109.)

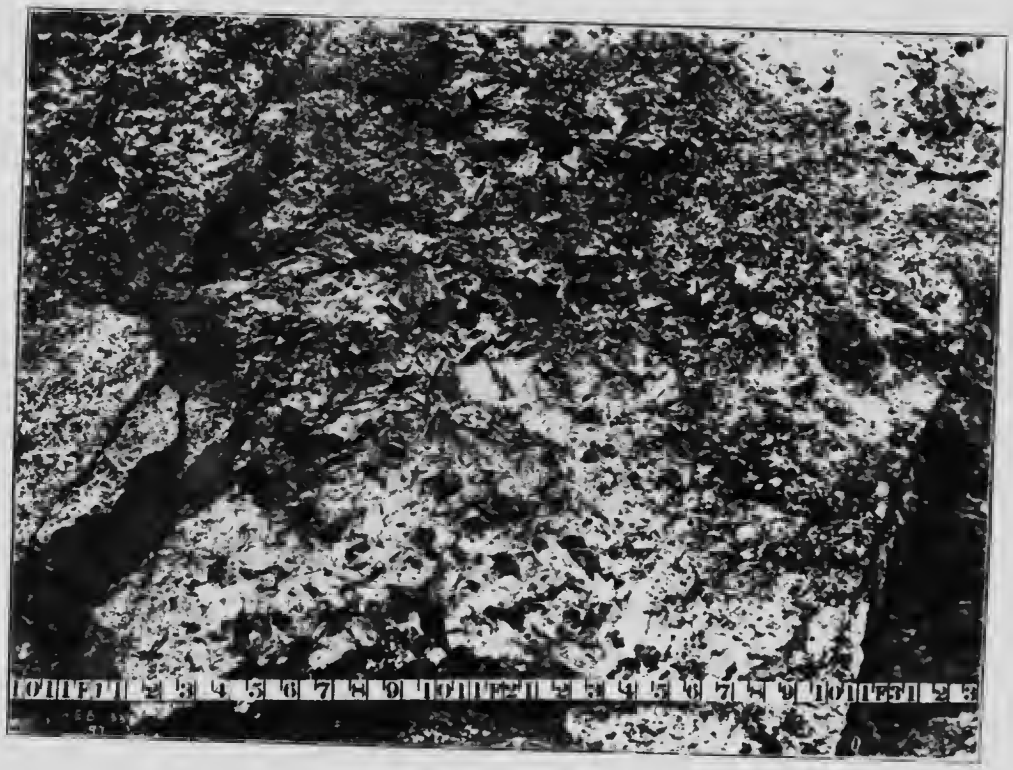
PLATE XV.



Explanation of Plate XVI.

Corundum in corundum pegmatite, lot 14, concession XIV, Carlow township. (See pages 88, 199.)

PLATE XVI.



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EXPLANATION OF PLATE XVIII.

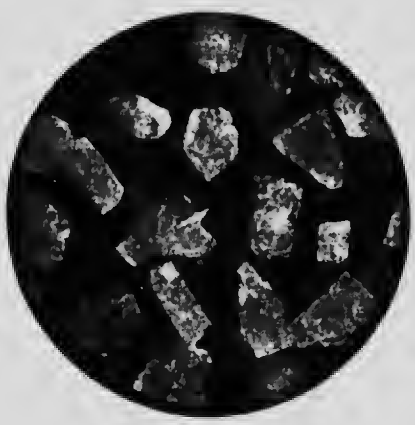
Corundum crystal (natural size), Craigmont, Ont. (See pages 88, 109, 128.)

Plate XVIII

Explanation of Plate XXIV.

Microphotograph of Canadian corundum grains. Note the crystalline appearance and sharp cutting edges. Their similarity to rough diamonds is striking. (See page 144.)

PLATE XXIV



Explanation of Plate XXV.

View of Craigmont and east end of Robillard mountain. (See pages 10, 26, 296.)

PLATE XXV

Explanation of Plate XXVI.

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MICROCOPY RESOLUTION TEST CHART

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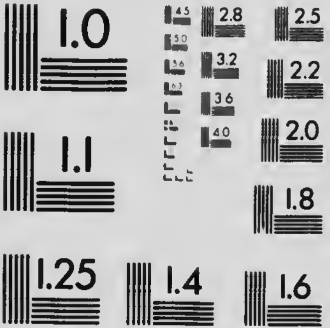

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LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising cn this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.,—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern p[illegible] of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of LakeTimiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

Memoir 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

Memoir 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

Memoir 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

Memoir 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

Memoir 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

Memoir 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

Memoir 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

Memoir 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

Memoir 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

Memoir 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

Memoir 28. *No. 18, Geological Series.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the Coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 25. *No. 21, Geological Series.* Report on the clay and shale deposits of the western provinces (Part III)—by Heinrich Ries and Joseph Keele.

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

MEMOIR 52. *No. 42, Geological Series.* Geological notes to accompany map of Sheep River gas and oil field, Alberta—by D. B. Dowling.

MEMOIR 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neill.

MEMOIR 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.

MEMOIR 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks, in southern Quebec—by J. A. Dresser.

MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.

MEMOIR 47. *No. 39, Geological Series.* Clay and shale deposits of the western provinces, Part III—by Heinrich Ries.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.

MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.

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MEMOIR 41. *No. 38, Geological Series.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick—by Marie C. Stopes.

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Report from Topographical Division. Separate from Summary Report 1913.

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