On some simple Massive Minerals (Crystalline Rocks) from India and Australia.

By Professor JOHN W. JUDD, C.B., LL.D., F.R.S., &c.

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IN recent years, the respective provinces of Mineralogy and Petrography have become much more clearly defined than was formerly the case. We no longer include uncrystallised substances, like obsidian, tachylyte and coals among mineral species; and, on the other hand, we recognise the fact that many materials originally analysed and treated as homogeneous—such as lapis-lazuli, emery, and many similar materials—are really mineral aggregates or rocks, and thus come within the domain of the petrographer. This last advantage has been one of the most important of those which have resulted from the application of the microscope to the study of inorganic bodies.

There still remains, however, one class of substances which may be regarded as equally within the spheres of study of the mineralogist and the petrographer. I refer to the materials called by the former "massive varieties of a mineral," and by the old petrographers distinguished as "simple crystalline rocks." These substances are essentially composed of crystals of one species of mineral, more or less perfectly developed, such as olivine, augite, garnet, epidote, topaz, &c. It would, I think, be a great convenience if, instead of giving fanciful names from localities to these rocks, they were distinguished as olivine-rock, augite-rock, garnet-rock, &c., as was done by Macculloch and the old German petrographers.

While engaged in studying the fine series of rocks and minerals brought from Upper Burma by Mr. C. Barrington Brown, I have had my attention directed to some rocks of this class which have not hitherto been described. The circumstance that a number of my friends and former students, resident in India, were able to make inquiries and supply me with trustworthy information with respect to localities, &c., has led me to try to clear away some errors that had crept into the labelling of specimens in public collections, and to obtain new light on

the nature and mode of occurrence of very interesting materials. To Mr. T. H. Holland, F.G.S , Deputy Superintendent of the Geological Survey of India, Mr. P. Bosworth Smith, F.G.S., formerly Government Mineralogist at Madras, and Dr. J. W. Evans, F.G.S., formerly in the service of the Rajah of Junagadh, I am particularly indebted. I have also received much aid from Mr. F. R. Mallet, F.G.S., who has supplied me with valuable specimens and information, and from Mr. C. Barrington Brown, F.G.S., who has visited both Ceylon and New South Wales since his exploration of Upper Burma.

Corundum-Rock.

Corundum often occurs in the Eastern States of North America in crystals of large size, but these crystals are seldom, if ever, aggregated into a rock. Emery is a rock, but not a simple one ; for the researches of J. Lawrence Smith and Tschermak show that emery is made up of corundum (sapphire), magnetite, tourmaline and some other minerals.

In several parts of India, however, we find massive rocks made up, essentially, of corundum crystals, and these may fitly be called "corundum rocks."

The best known, and probably the largest deposit of corundum-rock which has been described, is that made known to geologists by the researches of Mr. F. R. Mallet, F.G.S., formerly Superintendent of the Geological Survey of India,[1] as being found at Pipra in South Rewah.

The rock is described by Mr. Mallet as occurring in a small hill between Pipra and Kádopání, about a mile east of the River Rehr, the rocks here striking irregularly about E.N.E. and W.S.W. The thickness of the mass could not be accurately determined owing to the quantity of *débris* 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.

c. White tremolitic quartz-schist (fibrous).

d. White and green jade, containing some purple corundum, "euphyllite" and schorl.

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[1] *Records of the Geological Survey of India*, Vol. V. p. 20, and Vol. VI. p. 43. Also *Manual of the Geology of India. Mineralogy*, p. 48.

e. Bed of corundum-rock, reddish, purplish, or gray, with "euphyllite," schorl and diaspore in the cracks.

f. Porphyritic gneiss with hornblende-rock.

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.

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.

The green mica was analysed by Mr. Tween, with the following result:

Silica	43·53
Alumina	43·87
Oxide of Chromium	·91
Lime	1·45
Potash	7·80
Water	4·60
	102·16

This mineral, though in composition similar to "euphyllite," may equally well be placed with the chromiferous muscovite or Fuchsite.

By the kindness of Mr. Mallet I have been able to study microscopically two varieties of this rock, and a third specimen, almost certainly from the same locality, which was preserved in the British Museum collection, has been supplied to me by Mr. Fletcher.

The 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-poicilitic" structure.

A somewhat similar case of the occurrence of an intensely coloured and highly pleochroic variety of a mineral, side by side with the ordinary type, is afforded by the variety of epidote from Glencoe, to which the name of "withamite" has been given. To all appearance the colour of this mineral must be ascribed to a manganese-compound, and the colour and pleochroism is much more striking than that of piedmontite itself. Dr. Heddle, in his analysis of withamite, however, found only 0·14 per cent. of MnO, while the piedmontite of St. Marcel contains, according to Rammelsberg, 15 per cent. of Mn_2O_3. In studying cases like these, one cannot help being reminded of the interesting researches of Senarmont, which proved that a colourless salt may be rendered intensely pleochroic by introducing into it, while crystallisation is going on, a dye stuff like logwood. It is probably the condition of oxidation, and not the quantity of the manganese compound which determines the colour and pleochroism both in Withamite and in these corundums.

Mr. Holland has, at my request, made careful inquiries as to the existence of a similar purple corundum-rock in the Salem district, and he has visited the district; but can find no evidence of any such rock having ever been detected in it. I think there can be little, if any doubt, that the rock in the British Museum, which was supposed to have come from Salem and to have formed part of the Greville collection, is really from South Rewah.

Mr. Holland has, however, furnished me with a specimen of another corundum-rock, and much valuable information concerning its mode of occurrence. It is found at Hunsúr Talúg in the Mysore State. The rock is stated by Mr. Holland, who visited the district during one of his vacations, to crop out along a line running N.N.W. and S.S.E. or N.W. and S.E., at Singanamasanhalli and Nadapanhalli, whilst water-worn fragments have been found along the same line at Hunsúr, Modur and Ramenhalli—a line about 30 miles long to the N.N.W. Still farther

N.N.W., corundum is found again at Upinangadi in the South Kanara district. Associated with the corundum-bearing band are various hornblendic rocks with an imperfect foliation N.N.W. and S.S.E. to N.W. and S.E. The most prominent of these are hornblende-felspar granulitic rocks and narrower bands of amphibolite. Although the amphibolite bands are generally parallel to the common foliation, they sometimes break across the older rocks and prove their intrusive nature by bifurcating in veins. The corundum-rock is very frequently decomposed to a fine soft product, like agalmatolite, and in this pinitic product Mr. Holland has found abundant scales of graphite (Nadapanhalli); but he has never seen graphite in fresh specimens of corundum-rock itself.

The corundum-rock of the Mysore State, of which a specimen from Hunsúr Talúg has been sent to me by Mr. Holland, presents many features which distinguish it from that of Pipra in South Rewah. It is of a gray colour, composed of crystals of much larger size than those of the Pipra rock, and has a specific gravity of 3·63. Studied in microscopic sections it is seen to be made up of grains of nearly colourless corundum, almost all of which exhibit the secondary twinning-planes parallel to the faces of the primitive rhombohedron. In very thin sections the gray colour of the mass is seen to be due to the 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. The decomposition products scattered through this corundum-rock are in places stained red by hydrous ferric oxide, and in other places green by chlorites.

Massive corundum or corundum-rock has been reported to occur at other points in India, but as yet I have received no definite information or specimens to substantiate the statements.

Fibrolite-Rock.

Among the minerals which de Bournon pointed out as frequently accompanying corundum in India were the two new species which he named "indianite" (anorthite) and "fibrolite" (sillimanite). The latter mineral is now known to occur very frequently in the more acid metamorphic rocks, and to frequently accompany corundum. Among the rocks which are found with the corundum-rock of the Mysore State two very interesting kinds have been sent to me by Mr. Holland. One of these is a hornblende-olivine rock, which may be referred to the cortlandites of the late Dr. G. H. Williams and the "hornblende picrites" of many

authors. The other rock is almost wholly made up of matted prisms of fibrolite. The rock is remarkable for the different sizes of its constituent minerals; the fibrolite sometimes forming crystals 10 to 20 millimetres in length and 2 or 3 millimetres broad, while others are of microscopic dimensions. All give the usual optical characters of the mineral, its cleavage, high double-refraction, and characteristic cross-fractures. The rock is of a dark gray colour, and has a specific gravity of 3·05.

Tourmaline-(Schorl)-Rock.

Petrographers are well acquainted with many rocks in which tourmaline, and especially the variety schorl, is one of the principal constituents. Most of these rocks can be shown, like the luxullianite, so fully described before this Society by Professor Bonney, to be alteration products from granite and similar rocks.

Among the remarkable Indian rocks which have recently been brought to my notice, however, is a tourmaline- or schorl-rock, of a totally different character to any hitherto described. I am indebted to my friend Mr. P. Bosworth Smith for specimens of this remarkable rock and notes upon its mode of occurrence.

The rock has been found over a very wide area. It occurs as fragments in the Kolar gold-field in the Mysore State, and has been traced thence into the North-Arcot and Salem districts of the Madras Presidencies. The rock has not been found *in situ* in the Kolar district, but veins of quartz full of tourmaline, some of which, like one at Nandydroog mine, are 7 to 8 feet wide, cut across the gold-bearing reef of the district nearly at right angles. Mr. Bosworth Smith subsequently found the rock *in situ* at Chota Nagpur, and in pebbles at Barry's Hill in the Bengal gold-mines in Northern India.

The rock from all these districts presents tolerably uniform characters—it is of a black colour, sometimes dull in the fractured surface, and sometimes with a velvety lustre. It nearly always presents a strikingly fibrous appearance, and the specific gravity of the rock was found, as the result of many careful determinations made by Mr. Bosworth Smith, to vary between 3·02 and 3·11.

In thin sections, the rock is seen to be made up of acicular crystals, often twisted and bent, of a mineral with very marked pleochroism and high absorption. These fibres often show the cross-fractures so constantly seen in fibrolite—and it was at first thought that the mineral might be a highly coloured and abnormal variety of sillimanite—though the optical characters pointed so strongly to tourmaline.

All doubt as to the nature of the mineral has been set at rest, however, by the following analysis made for me in the chemical laboratories of the Royal College of Science under the superintendence of Mr. Chapman Jones, F.C.S., F.I.C.:—

Silica	35·94
Alumina	31·22
Ferrous Oxide	9·23[1]
Lime	1·66
Magnesia	5·53
Soda	3·96
Water	3·55
Boric Acid...	9·08[2]
	100·17

Lithium was found spectroscopically in the residue of the alkalies.

The following were tested for particularly, but no traces of them could be detected: fluorine, phosphoric acid, manganese, potassium and titanium.

Mr. Riggs, in his investigation of the chemical character of the tourmaline, was unable to find fluorine in many examples of the mineral.[3]

The microscopic characters of this rock are very interesting. The portions with dull lustre and wood-like fracture are seen to contain many prisms from 0·1 to 0·2 of a millimetre in diameter; the prisms, which are sometimes straight and at other times bent and twisted, possess all the optical characters of tourmaline—the strong absorption for the ordinary ray and the dichroism (O, blackish brown; E, bluish gray),—and they exhibit a marked parallel arrangement. Between them is a material which by higher and higher powers of the microscope is resolved into aggregations of similar prisms of minute dimensions. The portions of the rock which have a velvety or almost resinous lustre, inclining to vitreous, can only be partially resolved even by the highest powers of the microscope into crystalline individuals, but the interstitial matter does not behave like a glassy substance by being isotropic between crossed nicols. The dull and fibrous and the black velvety portions of the rock alternate with one another like the different portions of a banded lava.

[1] No attempt was made to separate the FeO from any Fe_2O_3 that might have been present.

[2] A second determination of the boric acid gave 9·11.

[3] *Am. Jour. Sci.*, Vol. XXXV. (1888), p. 35.

Among the different varieties of schorl-rock from Cornwall, Saxony, &c., I have never seen any fibrous forms in the least resembling this remarkable Indian variety.

From the neighbourhood of Bingera, in New South Wales, Mr. C. Barrington Brown has collected two very interesting rocks, each essentially composed of a single mineral. These rocks occur as dykes in a great mass of serpentine forming the south-east side of the Bingera Valley, and situated between the Bingera River and the Barricks Creek.

Green-garnet-(Grossularite?) Rock.

This is a dull-green granular rock with a specific gravity of 3·31, which under the microscope is seen to be made up of crystals of a pale-green garnet. These appear to be perfectly isotropic, and show none of the anomalous double-refraction found in some varieties of this mineral. Although many rocks have been described which consist mainly of garnets of different varieties, there is only one, so far as I know, composed mainly of green varieties of the mineral. This is a rock from Dobschau, in Hungary, which has a somewhat different colour and aspect from the rock brought from Bingera. Besides the garnets, which make up the mass of this rock, there are particles of low double-refracting materials between the grains, which are in all probability decomposition products of garnet, like the well-known "kelyphite."

This green-garnet rock of Bingera sometimes contains native gold and also chrysocolla. The rock is now being worked for the gold it contains, yielding about two ounces to the ton. The dyke, which varies in width from 4 feet to 6 inches, has been traced for more than a mile.

Picotite-Rock.

A second dyke, about 2 ft. 6 inches wide, in the mass of serpentine at Bingera is a very dense, well-crystallised black material with a specific gravity of 3·90. Under the microscope it gives the characters of a chrome-spinel, being isotropic and of a rich coffee-brown colour by transmitted light. Professor Wadsworth has pointed out the close analogies between the two spinellids, chromite and picotite, and the frequent transitions between the one mineral and the other. The density and colour of the Bingera mineral lead me to refer it to picotite rather than chromite. The only other mineral associated with the spinellid in the rock is serpentine, which occurs in small quantities.

Picotite is a frequent constituent of lherzolites and other ultrabasic rocks, but I am not aware that any rock, entirely composed of that mineral, has hitherto been described.