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On a new mode of occurrence of Ruby in North Carolina.

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With Crystallographic Notes by Dr. J. H. PRATT.

[Read Jan. 31st, 1899.]

PARTS of the State of North Carolina, with adjoining areas in South Carolina and Georgia, have long been known to mineralogists and geologists as among the most interesting of corundum localities; and the researches of the late Dr. Genth, Col. Joseph Willcox, Mr. J. Volney Lewis and many other authors have done much to make clear the mode of occurrence and associations of corundum in this area and in the great corundiferous belt stretching along the line of the Appalachian crystalline area from Alabama in the south to Maine in the north. Quite recently Dr. J. H. Pratt has published a very interesting and admirable discussion of "The origin of the Corundum associated with the Peridotites of North Carolina."[1]

But of the existence in any part of this area, or indeed in any part of the continent of America, of the red transparent variety of the mineral, which the term Ruby is properly restricted, there appears to have

[1] *Amer. Journ. Sci.* 4th Ser. Vol. VI. 1898, p. 49.

been no knowledge till about 15 years ago (1884). Nor has there been, as yet, any notice published of the discovery in any scientific journal or magazine, unless we except the brief mention made in the Annual Statistical volumes entitled *Mineral Resources of the United States*, published under the auspices of the U.S. Geological Survey.[1]

Some few additional notes upon this interesting occurrence have been published, including press notices, but nothing of a strictly scientific character. We may state that one of us has during the past five years frequently visited the scene of this discovery, and that from time to time we have conjointly examined many of the cut specimens and natural crystals of the rubies from the Cowee district of North Carolina, and that in our opinion their beauty and colour appear to be in no way inferior to those from the Mogok district of Burma.

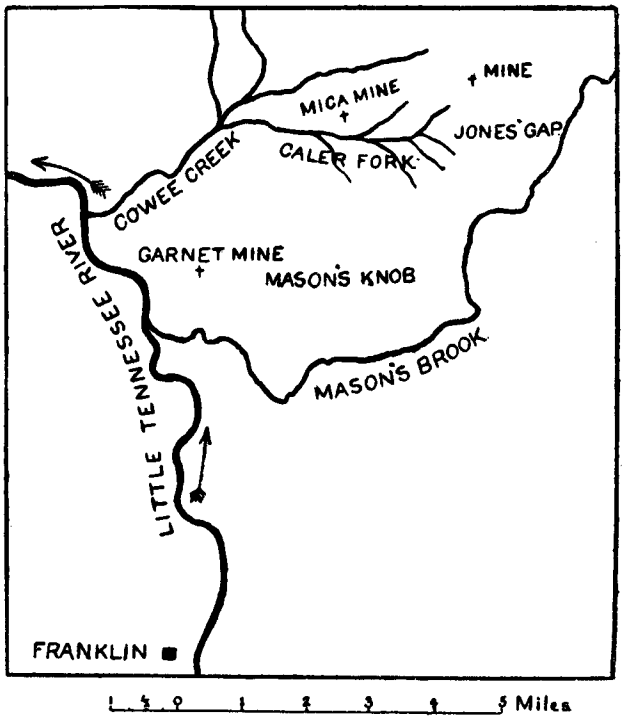

FIG. 1.—Sketch Map of the district in which Ruby and Rhodolite are found.

[1] 15th Annual Report, 1893–94, U.S. Geol. Survey, Volume on *Mineral Resources of the United States* (Washington, 1894), p. 693.
Ibid. 16th Annual Report, Part IV. p. 599.
Ibid. 17th Annual Report, Part III. p. 905.

As the material in which these rubies were found appeared so strikingly similar to the alluvium and gravel in which the Burma rubies are obtained, it at one time seemed highly probable that when the thick masses of superficial and detrital material could be sunk through, the rock in which the rubies would be found *in situ* would prove to be a limestone like that of Burma. This expectation was strengthened by the finding in the gravels of corundum crystals of similar form, with almost precisely the same association of minerals as occurs in Burma.

The district in which these interesting discoveries have been made is situated in the State of North Carolina and in the County of Macon, rather more than 20 miles from the borders of Georgia. Some five or six miles below the town of Franklin the Little Tennessee River receives on its right or eastern side two affluents, the Cowee Creek with its tributary the Caler Fork, and the Mason Branch. It is the tract between these two brooks, some 10 square miles in area, which has proved to be of such exceptional mineralogical interest, and has yielded a very large number of remarkable species and varieties of minerals.

The bottoms of the valleys of this mountain district are about 2,500 feet above the sea-level, and the various hills ("knobs") in and immediately around it rise to the height of from 3,000 to 3,500 feet; but at no great distance to the west there occurs much higher ground (the Nantahaleh Mountains) up to 5,000 and 5,500 feet.

In 1896 the district was visited and examined by Mr. C. Barrington Brown, who had made the examination for the British Government of the well-known ruby district of Mogok in Burma. He found that the country was one of gneissose rocks, the gneiss often containing garnets and corundum,[1] not of gem quality, and that this mass of gneissose rocks is probably traversed, like that of Burma, by great dykes of pegmatite and more basic rocks, for blocks of these materials are abundantly scattered through the gravels of the district.

Garnets are so abundant in some of the rocks of the district that mines have been opened to work the rocks for abrasive materials. In some of the pegmatites the crystals of muscovite are so well developed that several "mica mines" have been opened. There are other mines which have been worked for copper with some prospects of success; while, as we shall see in the sequel, gold, monazite, and sperrylite (the rare

[1] The corundum in these gneissose rocks usually occurs in long hexagonal prisms with basal planes, but no other forms, and the mineral nearly always exhibits purplish tints.

arsenide of platinum) have been obtained in the alluvial deposits which are so extensively present in this region.

Although only a few miles away from Corundum Hill, Buck Creek, Ellijay, and other famous corundum localities, where, as shown by Lewis, Pratt, and other authors, corundum is found in the intrusive dunites, near their junction with the crystalline schists of the district, *no* olivine rocks, or serpentines derived from them, have been found in the immediate neighbourhood of the new ruby locality.

Neither have limestone rocks been found in close proximity to the alluvia containing these fine rubies. In fact, the nearest point at which any limestone bands have been found is about eight miles away. Here the bands consist of a "calciphyre," not unlike some of those found in Burma, and, like them, containing many silicates, such as wollastonite, scapolite, pyroxenes, hornblendes, biotite, &c., with graphite, pyrrhotite, and many other minerals.

When the alluvium and the gravels below them (the latter being from 2 to 10 feet in thickness) are penetrated, they are often found to rest on a soft rock known to American petrologists as "saprolite," which is the result of the weathering in place of basic silicate rocks. This "saprolitic" rock can often be pierced to considerable depths, without the undecomposed rocks from which it has been derived being reached.

Washing and microscopic examination of the saprolitic material shows that it is largely made up of scales of various hydrous silicates, among which damourite and other hydrous micas, with margarites and other clintonites, are very conspicuous. The unaltered minerals present consist of fibrolite, staurolite, and some other silicates, with menaccanite, rutile, monazite, spinel, and considerable quantities of garnet (including the rhodolite variety) and corundum (of various shapes and tints), and minute quantities of gold and sperrylite.

The trial shafts and gravel-washing operations which have been undertaken in this district, with a view to discover the extent and nature of the valuable minerals, have shown that at depths of 35 feet and upwards the saprolitic rock includes fragments, and is seen to pass into various basic rocks. These include hornblende-eclogite (garnet-amphibolite of some authors), amphibolite, and a basic hornblendic gneiss containing labradorite and perhaps anorthite. The full description of these rocks is deferred until the exploration now going on shall have more fully displayed their relations in the field, and have enabled more satisfactory and less altered specimens to be obtained. It is as yet uncertain whether these rocks occur as dykes or as alternating interfoliated masses in the crystalline series.

The great band of basic and garnet-bearing rocks, in the decomposed materials derived from which are found the rubies, is traversed by a remarkable series of slickensides. Four parallel slides have been exposed at one place in the workings, the direction being generally N. 75° E. Continuous slickensides of 70 feet in length, and of unknown depth, can be seen, and, with some interruptions, they can be traced for several hundreds of feet east and west. It is probably the breaking up of these rock-masses by faulting, leading to the ready influx of water (which so readily attacks the basic silicates of which the rock is composed), that has led to their reduction to the saprolitic condition.

Scattered through the saprolitic material are nuclei of eclogite and amphibolite, which have to some extent escaped disintegration, and in the centre of the mass lenticles of pure hornblende rock are found. In one place one of these lenticles of hornblende rock is nearly a rod in width, and in nearly all cases the saprolite adjoining these lenticles of hornblende rock is seen to contain, very abundantly, either corundum or more commonly the pseudomorphs after corundum.

The corundum occurring in these rocks varies in colour from ruby red through various shades of pink to white and nearly colourless varieties. Many of the red crystals exhibit the beautiful so-called pigeon's-blood tint, which is so much admired in the gems from Burma, and the colours seen in the Cowee-Creek stones with the dichroscope are almost identical with those exhibited by the stones from Burma. As at Mogok, Sagyin, and other Burmese localities, the rubies of very fine tint are mingled with others of lighter or darker shades, and with varieties which exhibit more or less of a purplish tint mingled with the red.

The Cowee-Creek rubies very frequently contain inclusions of various kinds. Sometimes these are extremely minute ("silk" of jewellers), and give rise to a cloudiness ("sheen") in the polished gems; at other times minute reniform masses of clear red rutile and black menaccanite occur, and mar their beauty. The included crystals of garnet, to be hereafter more particularly noticed, do not greatly destroy the transparency or impair the fine character of the stones. Some specimens have been found, however, from which gems of fair size could be cut, quite free from inclusions and of fine colour and transparency.

The clearest crystals of the Cowee-Creek rubies nearly always show the tabular habit which Lagorio regards as characteristic of the varieties of corundum that have separated from an igneous magma. Indeed, so common is this form, that any long prismatic crystals found with them may be suspected of having been derived from the surrounding gneisses,

in which such forms occur sometimes abundantly. The most common combination of forms is that shown in the accompanying drawing, which has been made by Professor S. L. Penfield, of the Sheffield Scientific School, Yale University.

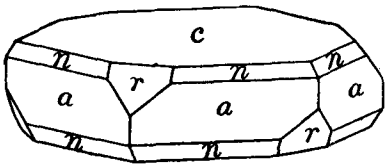

FIG. 2.

Common form of Corundum Crystals at Cowee-Creek.

In an appendix to this paper Dr. Pratt has drawn and described some of the chief types of corundum crystals obtained in the Cowee district, and it will be found interesting to compare these with the combinations of forms which the same author has described as occurring at Yogo Gulch, Montana,[1] and which Dr. Max Bauer has described from Burma.[2]

The corundum crystals, whether ruby-red or pink in colour, occur in "nests" and "bands," and also in what appear to have once been empty spaces in the rocks, either amphibolite, or eclogite, or hornblendic gneiss. The spaces, when the corundum is pale-coloured, appear to have been filled up with felspathic material; but when the corundum is of a ruby-red colour, the surrounding space is filled up with chloritic material.

Corundum is not, however, confined wholly to these bands, which were once druse-like cavities in the rock, but it often happens that the mineral, sometimes red and transparent, is found in the midst of the rock.

One respect in which the corundum of Cowee-Creek resembles that of Burma is in the readiness with which it seems to have undergone pseudomorphous change by hydration followed by combination of the resulting diaspore with surrounding silicates. The pseudomorphous material often retains the shape and occupies the place where crystals of corundum were originally firmly embedded in the hard matrix. Often only a thin flake of corundum remains in the midst of a mass of alteration products to tell the character and colour of what was once a large crystal.

It is surprising to see the positive evidence of the former existence of hundreds of pounds weight of ruby and other varieties of corundum, where, to-day, only a few ounces of fragments or flakes remain.

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[1] *Amer. Journ. Sci.* 4th Ser. Vol. IV. (1897), pp. 424–428.

[2] *Neues Jahrb. für Min.* &c. 1896, Bd. II. pp. 197–238.

The most notable of the minerals associated with the rubies and other forms of corundum at Cowee-Creek is garnet, and this garnet is remarkable for its colour and beauty as a gem-stone. The colour is unlike that either of pyrope or almandine, and lacks that depth and intensity which usually makes garnets such dark-looking stones, especially by artificial light. These garnets, on the contrary, have a peculiar and very beautiful tint, combined with a transparency and brilliancy which is more striking in artificial light than in ordinary daylight. From the resemblance of its colour (a pale rosy tint inclining to purple) to that of certain roses and rhododendrons, this variety of garnet has received the name of "rhodolite."[1]

The rhodolite usually occurs in water-worn fragments, mixed with corundum and the other minerals found in the "saprolitic" rock and in the gravels of the district. Only minute crystals, occurring as inclusions, have as yet been found, and these are sometimes rhombic-dodecahedra and at other times trapezohedra (icositetrahedra). The garnets show the same tendency to alteration as the corundum, and pseudomorphs of the mineral abound, as is the case in Burma.

The association of rubies and rhodolite in this district is not only proved by their constant occurrence together in the saprolitic material and in the gravels, but we find indisputable evidence that the garnets have crystallised first, and that the corundum has solidified afterwards, and has enclosed the garnets partially or entirely in its crystals. Some

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[1] The rhodolite of the Cowee-Creek and Mason's Branch district has been recently carefully studied by Dr. Pratt in conjunction with one of us.

"On Rhodolite, a new variety of Garnet," by W. E. Hidden and J. H. Pratt. *Amer. Journ. Sci.* 4th Ser. Vol. V. (1898), pp. 294–296. [Abstr. *Min. Mag.* xii, 133.]

Analysis shows that it has the following composition:—

Silica	41·59
Alumina	23·13
Ferric Oxide	1·90
Ferrous Oxide	15·55
Magnesia	17·23
Lime	·92
	100·32

This analysis corresponds, almost exactly, to a combination of two molecules of the magnesium-aluminium garnet (pyrope) with one molecule of a ferrous iron-aluminium garnet (almandine). There is considerable variation in the tint of rhodolite, the approach being sometimes towards the pyrope colours, at others towards the almandine. Probably the proportion of the two molecules is by no means constant. In spite of the preponderance of the pyrope molecule, as shown by analysis, an examination of the absorption bands of rhodolite, which was kindly made for us by Professor Church, F.R.S., shows that it gives the same characteristic spectrum as is found in almandine.

of the ruby crystals bear impressions, of which a mould can be taken in wax, and these impressions give with a goniometer the angles of the rhombic-dodecahedron or the trapezohedron. In some cases clear crystals of ruby corundum have been broken open, and minute garnets actually taken out of the middle of them. In other cases fractured surfaces of the basic rocks show corundum surrounding and enclosing garnet crystals, while in other cases cut gems of ruby can be seen to have in their midst a garnet crystal.

So far as our experience goes, this enclosure of garnet by corundum is peculiar to this special Cowee district, and serves to distinguish the corundum found in it from that occurring in any of the tracts where the mineral occurs in peridotites (dunite, &c.), or at the junction of peridotites with the crystalline schists.

This remarkable association of garnet and corundum is well illustrated by a drawing (Fig. 3) made upon the spot by one of us from a specimen that was of too friable a character to bear removal intact. Although the sketch is to a certain extent ideal, it faithfully represents the undoubted relations of the garnets and corundum as seen in one very interesting specimen.

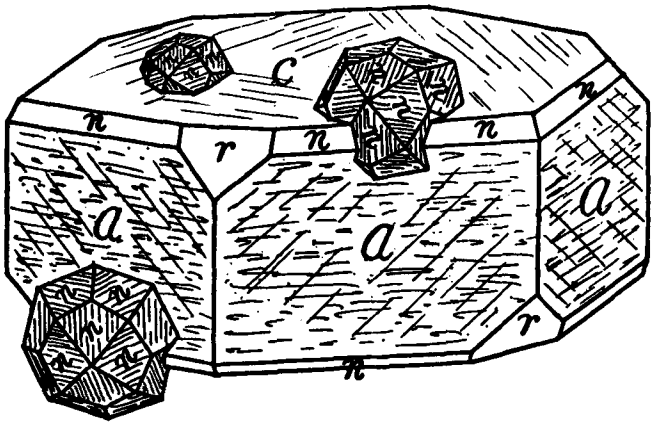

FIG. 3.

Corundum enclosing crystals of Garnet.

Specimens are occasionally found in the district which appear to be pseudomorphs of quartz after dodecahedral garnets.

Spinel, which is so constantly associated with the corundum (ruby) of Burma, is rare in the American locality. The fine red spinels, so similar

in tint to the rubies themselves, and so conspicuous in the Burma localities, appear to be entirely wanting in the North-Carolina area. Three varieties of spinel, namely, picotite, gahnite, and chromite (the last being rare), have been found both in the alluvial deposits and *in situ* in the basic rocks.

Of minerals specially characteristic of materials formed by contact metamorphism, the following have been found:—Sillimanite (fibrolite), cyanite, staurolite (often very clear and gem-like in character), and cordierite (or iolite, colourless and without dichroism).

The chief ferro-magnesian silicates are hornblende (a variety rich in soda) and bronzite (in clear transparent masses suitable for gems).

Among the accompanying minerals are zircon (with the variety cyrtolite), monazite (the macroscopic brown and green varieties appear to be rare, but a minute brilliant yellow granular variety with only 0·03 per cent. of thoria abounds), rutile and menaccanite.

Among metallic minerals the chief are pyrite, chalcopyrite, nickeliferous pyrrhotite, blende, sperrylite, and gold.[1]

Conclusions.

Corundum has now been shown to occur in North Carolina and the adjoining States in three different forms: —

(1) In the ordinary crystalline schists of the district, long prismatic crystals, usually of gray, pink and blue tints, occur.

(2) In the peridotites (dunites, &c.), intrusive in the crystalline schists, and especially in and near the zones of contact, crystals, some of very great size, and of great variety of colour, but seldom or never clear and translucent, are found.

(3) In certain garnet-bearing basic rocks at Cowee-Creek, small tabular and short prismatic crystals are abundant, and these very frequently exhibit the transparency and colour of the true ruby.

Dr. Pratt, in his recent discussion on the second of these modes of occurrence of corundum, has shown grounds for concluding that the alumina of the corundum was in these cases originally dissolved in the fused basic magma of the peridotites, and that crystals of corundum separated from that magma in the manner which has been illustrated by the interesting experiments of Morozewicz.[2]

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[1] For fuller details concerning these accompanying minerals with analyses consult a paper "On the Associated Minerals of Rhodolite," by W. E. Hidden and J. H. Pratt. *Amer. Journ. Sci.* 4th Ser. Vol. VI. (1898), pp. 463–468.

[2] *Zeits. Kryst.* Vol. XXIV. (1895), p. 281, and *Tscherm. Min. und Petrog. Mitt.* (*Neue Folge*), Vol. XVIII. (1898), pp. 1–90, 105–240.

The tabular form of the crystals of corundum has been shown by Lagorio[1] in his well-known memoir on the subject to be characteristic of corundum found in igneous rocks. And this conclusion has been supported by the researches of Professor L. V. Pirsson and Dr. Pratt.[2]

If we compare the forms figured by Dr. Pratt in the appendix to this paper with those described by him from Yogo Gulch, the resemblance will be seen to be very striking. But it may at first sight appear that it is impossible to ascribe an igneous origin to corundum enclosing a mineral with so much lower a fusing point as that of garnet.

A little consideration will, however, show that this objection has little validity. The temperature at which alumina is dissolved in a mixture of silicates has no necessary connection with the fusing point of alumina itself. That the magma from which these basic rocks consolidated was fluid at a temperature lower than the fusing point of the garnets, or at all events that the rock was in a state of aqueo-igneous fusion at a lower temperature, is evidenced by the condition of the beautifully crystallised garnets scattered through the basic rocks. At such temperatures, according to the experiments of Morozewicz, alumina may be largely dissolved in the basic fluid magma, and may slowly crystallise out from it. In this way we may conceive of the garnets being enclosed in a later formed corundum.

There are many points of resemblance between the association of minerals and the forms of crystallisation of the Cowee-Creek rubies and those of Burma. This will become apparent if we compare the figures now published with those given by Prof. Max Bauer of the Burma rubies.[3]

In considering the association of minerals described by Prof. Max Bauer in his paper it should be remembered that the material on which that author worked came almost entirely from Sagyin, while those described by Mr. Barrington Brown and one of us were derived from the Mogok district, nearly 60 miles away. There is reason for concluding that the associations of minerals in these two districts of Burma present some interesting points of difference.

Although, at first sight, the matrix of the Burma rubies (a crystalline

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[1] *Zeits. Kryst.* Vol. XXIV. (1895), p. 285.

[2] "Corundum-bearing Rock from Yogo Gulch, Montana," by L. V. Pirsson. *Amer. Journ. Sci.* 4th Ser. Vol. IV. (1897), p. 421.

"Crystallography of the Montana Sapphires," by J. H. Pratt. *Ibid.* p. 424.

[3] *Neues Jahrb. Min.* &c., 1896, Bd. II. Taf. VII.

limestone) may seem so different from that of the rubies of Cowee-Creek (an amphibolite with garnets, and sometimes with a basic felspar), yet a connection may still be shown to exist between the two cases. One of us has brought forward evidence to show[1] that the limestone of Burma has been formed by the slow alteration of a lime-felspar. Whether the corundum pre-existed in the highly-basic felspathic rock, however, or was formed at a later stage, there is no positive evidence to show. But the idea of its existence in the silicate rock originally is supported by the wonderfully corroded state of the corundum crystals.

The magma giving rise to pyroxene gneisses and granulites of Burma may not have differed greatly in composition from that giving rise to the amphibolites, eclogites, and basic gneiss of North Carolina; and, in either case, corundum may have been formed by the separation of dissolved alumina. The great promise which is held out by the fine colour and quality of many of the ruby crystals from this new locality would seem to warrant a continuance of the prospecting work lately inaugurated there, and it is to be hoped that the interesting problem of *the true origin of these rubies* may be definitely settled when the explorations on Cowee-Creek shall have furnished fuller data and more conclusive evidence concerning the primary condition of the associated minerals and the nature and relations of the rocks of the district.

[1] *Phil. Trans.* Vol. 187A (1896), pp. 151–228.