

NORTH CAROLINA GEOLOGICAL SURVEY.

J. A. HOLMES, STATE GEOLOGIST.

BULLETIN No. II.

**CORUNDUM AND THE BASIC MAGNE-
SIAN ROCKS OF WESTERN
NORTH CAROLINA.**

BY

JOSEPH VOLNEY LEWIS,

ASSISTANT GEOLOGIST.



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MAP CORRECTIONS.

Through some misunderstanding several small errors have been made in the geological boundaries on the western portion of this map, chiefly in Unicoi, Cocke and Monroe counties, Tennessee, and in Madison and Mitchell counties in North Carolina. The errors were discovered too late to be corrected in this edition. Later work has also shown that the Ocoee rocks should be made to extend across the area left uncolored in Cherokee county (N. C.), and Polk county (Tenn.), and that the uncolored area in Wilkes, Alleghany and Ashe counties should be colored for "gneisses and granite." All needed corrections will be made in a future edition of this map, which it is expected will be published at an early date.

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LETTER OF TRANSMITTAL.

RALEIGH, N. C., December 1st, 1895.

To His Excellency HON. ELIAS CARR,

Governor of North Carolina.

SIR:—I beg to submit for publication as Bulletin 11 of the Geological Survey, a preliminary report on Corundum and the associated basic Magnesian Rocks in North Carolina, by Mr. J. V. Lewis. The larger part of the corundum now produced in the United States is mined in North Carolina, and the increasing demand for information on this subject has led to the preparation of this paper. It is hoped that a more elaborate final report on the subject can be prepared by the close of another year.

With great respect, I have the honor to be, sir,

Yours obediently,

J. A. HOLMES,

State Geologist.

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BY J. VOLNEY LEWIS.

I. INTRODUCTION.

The present incomplete report is issued for the purpose of presenting the field results obtained chiefly during the summer months of 1893 and 1894.

To the fact that it is mainly a report of field observations is due, to a great extent, its incompleteness; and I would urge this consideration as an apology for certain vagaries of mineralogic terminology in the following pages, and for many unsatisfactory points in geologic and petrographic descriptions. As far as possible, I have confined myself to a simple presentation of facts thus far determined, and the more theoretical discussions have been avoided.

In the beginning of the field season of 1893, a rapid reconnaissance of the region under consideration was made with the late Dr. George H. Williams, of Johns Hopkins University; and a portion of the laboratory work and the field studies for both this and the succeeding seasons were prosecuted, to a great extent, under his guidance and general supervision. Specimens were collected from all portions of the region, and by the courtesy and cooperation of the Director of the United States Geological Survey, I have begun the microscopic study of this material in the Survey laboratories, at Washington. A more thorough report on the corundum-bearing rocks, embodying the results of this work, will be published as soon as practicable.

One acquainted with the methods and aims of geology, or of any natural science, needs no argument to point out the necessity of

thorough detailed work for the understanding of any problem in Nature, whether of immediate economic importance or only of scientific interest. 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 actual prospecting and mining. Studies of considerable interest and value in the corundum regions have been made by Chatard, Julien, Shepard, Genth and others, but these have been confined chiefly to local occurrences and special problems, and 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; but it is hoped that even the facts recorded here may add something to the small sum of our knowledge of these interesting formations, and that thereby a somewhat clearer understanding of their geologic relations may be attained.

From the standpoint of the prospector, miner, or land-owner, whose interest in such matters is eminently practical and whose geologic training is entirely the result of work and observations in the mines themselves, it is hoped that this presentation of facts may be found useful, and that the mining interests of every section may be advanced by a study of conditions existing in other portions of the field. In fact, this method of comparison has been found the only practical guide in the search for new localities or in the development of deposits already known. If the rocks and associated minerals of a given locality are the same as found in a corundum mine, the prospector goes to work on the hypothesis that the occurrence there of corundum itself is entirely probable. While characteristic differences are everywhere observed between mines, even in the same immediate neighborhood, yet experience has shown that the conditions for the occurrence of corundum are practically the same throughout the region. The few important

exceptions to this rule are noted further on in describing the modes of occurrence.

For the reasons suggested, then, it has been thought advisable to publish the facts gathered in the field, along with some general observations on the geology of the region and the characteristics of the corundum-bearing rocks, rather than hold these for the appearance of the final report. A knowledge of the facts cannot but advance the interests of legitimate mining, as well as prevent such waste of time and money as may sometimes be observed in western North Carolina.

At the present writing, the only active corundum mining in the world is in this State, and, with the important exception of Georgia, North Carolina has supplied the only corundum on the market since the beginning of the industry more than twenty years ago. Besides regular mining, much work has been done in exploring and prospecting, and considerable investments have recently been made with a view to engaging in active mining at an early date. Explorations have never been more actively prosecuted and it is not unlikely that production will be largely increased in the near future by the opening of new mines. That there is abundant demand for such increase is shown by the fact that, in addition to the available corundum, there are annually imported for consumption in the United States from 3,000 to 5,000 tons of emery, which is practically the only mineral product that competes with corundum in the market.

The combination of circumstances favorable to mining and milling operations in North Carolina—the equable climate and the almost universal presence of water-power—together with the great superiority of corundum as an abrasive, combine to place these formations among the important resources of the State.

2. GEOLOGIC SKETCH OF THE CORUNDUM REGION.

From the accompanying map it will be seen that what we may term the *Corundum belt* in North Carolina is confined to a broad strip of gneisses lying chiefly west of the Blue Ridge and extending northwestward from the Georgia boundary through Clay,

Macon, Transylvania, Jackson, Haywood, Buncombe, Madison, and Yancey counties, while the peridotites with their characteristic chromium- and nickel-bearing minerals, asbestos, etc., extend the belt through Mitchell, Watauga, Ashe, and Alleghany counties to the Virginia line.

This belt is but a portion of the greater belt of crystalline rocks which is coextensive with the Appalachian mountain system (see plate II), and which, on account of its complex and highly crystalline character, is generally considered to be of Archean age. The southern extremity of this belt disappears under the younger formations in central Alabama. Its principal constituent is gneiss, often, through higher development of lamination, passing into schists, and including frequent masses of granitic and other distinctively igneous rocks.

These gneisses have been usually considered to be, in great part, sedimentary rocks that have lost their original clastic characteristics, with the possible exception in some cases of bedding, in the great earth-movements and other metamorphosing agencies in which they have been involved. Some of them, however, are certainly granites or other massive rocks that have been sheared or squeezed by the same agencies—transitions from the massive to the laminated forms being often easily observed and, in fact, almost universally present about the borders of the massive rocks of the region.

When these changes have affected the whole of such an igneous mass, it is obvious that a rock will result that will often be difficult and sometimes impossible to distinguish, in the field, from a metamorphosed sediment of similar composition. As yet the geology of this area is not sufficiently known to map these varieties separately; though such distinctions are highly desirable in considering the questions of origin of some of the massive rocks and their relations to the prevalent structural types of the region.

By the earlier geologists, the lamination of the gneiss was considered true bedding, and their attempts to interpret the structure of the region were based on this misconception. It is well known that lamination is often developed where no such original structure existed, as in the sheared massive rocks alluded to above. It

is also known that such structure produced by movement in the mass of the rock may, and usually does, obliterate whatever original structure may have been present; so that a sedimentary rock thus mechanically laminated and at the same time thoroughly crystallized would no longer show its original stratification. The new structural planes might correspond in certain cases with bedding, but often they would not; and hence the strikes and dips observed in this region and recorded here, being those of lamination planes, are not in any case to be interpreted as true strikes and dips.

The prevailing strike of the lamination planes in the gneiss of western North Carolina is about north 30° east, and the prevailing dip is at a high angle toward the southeast. Very frequently local variations occur, especially in the dips, and often the prevalent southeasterly dip will become vertical and, tipping over, will pass into a northwesterly dip within an outcrop of only a few feet. All stages occur from these local variations in dip and strike to the most gnarled and contorted forms imaginable. In general, the lamination has suffered the most deformation in the immediate vicinity of igneous intrusions; or perhaps the statement might be reversed, as the forces that produced the contortions doubtless formed simultaneously the fissures into which the massive rocks were injected.

Constituting a small proportion of this belt, as regards area, are the basic magnesian rocks, chiefly peridotites, which are here specially considered in their relations to the occurrence of corundum. These occur in small lenticular masses or in narrow strips, rarely exceeding a mile or two in length, and, so far as I am aware, are nowhere intimately associated with the well recognized igneous rocks of the granitic type. Contortions are observed, however, in the adjacent gneisses similar to those in the vicinity of granites, and often a transition to mica-schist gives evidence of an unusual amount of movement.

The magnesian rocks, too, whether peridotites or pyroxenites, have always a sheath of schistose talc developed about their borders and, in the corundum-bearing region, also much chlorite. Hence there is never, as far as observed, an absolute contact between these massive rocks and normal gneiss.

South of Virginia, the gneissic belt is flanked on the west by a broad strip of partially metamorphosed but generally distinct sediments of undetermined geologic age. No fossils have yet been found in them and structures are greatly confused by disturbances that have given rise to the Appalachian system of mountains. Hence their relations to the known Paleozoic rocks, by which, in turn, they are bordered on the west, is, as yet, a matter of controversy. These beds consist of a lower series of shales and limestones lying unconformably on the gneisses, and followed by conglomerates and sandstones above. To the whole formation the name *Ocoee* has been given.

Referring again to the map (plate I.), it will be seen that two belts of *Ocoee* are developed in western North Carolina; the one, lying along the Tennessee border, a broad area of irregular outline and tapering northward to a point just south of Johnson City, Tennessee. Beyond this point, as far as the boundary has been traced northward, the paleozoic formations lie directly in contact with the gneisses. The other *Ocoee* belt forms a narrow strip lying about forty miles further east in its southern portion, and passing northwestward from the upper French Broad valley, approximately in the direction of the Blue Ridge. The irregular boundary of the western area brings the two belts within twenty-five miles of each other in places, but the general trend of them both is the same as that of all the rocks of the region, and corresponds to the axes of Appalachian folding.

The eastern belt is exceedingly narrow in its southern portion, perhaps even narrower in places than indicated on the map, but it broadens northward and becomes involved in extremely complex folds and faults in Mitchell and Watanga counties. It should be stated that, north of the 36th parallel, as the detail on the map would indicate, the boundaries of this belt are much more accurately determined than in its southern extension. East of this narrow strip of *Ocoee*, comes a broad expanse of gneisses and granites, extending beyond Charlotte, Salisbury, and Greensboro, and forming the Piedmont plateau region of the State.

The corundum-bearing peridotite belt lies wholly within the strip of gneiss between these two belts of *Ocoee*. Almost the

whole width of this strip in the southwestern portion of the State is thickly dotted with small peridotite areas, but north of Waynesville they become more irregular and scattering. The manner of distribution is shown on the map, but, for the sake of clearness, the areal proportions are there often necessarily exaggerated. This is especially true of the schistose talc and chlorite rocks, which seldom exceed twenty or thirty feet in width of outcrop.

3. THE PERIDOTITES AND ASSOCIATED MASSIVE ROCKS.

As the corundum deposits of the State are found chiefly in connection with these rocks, it is important, before passing to the consideration of these deposits, to give brief descriptions of the peridotites and related rocks, in order that the descriptions of mines that follow may be more fully understood.

The rocks to be considered may be classed in three groups, namely: *peridotites*, *pyroxenites*, *amphibolites*. Of these, the first group largely predominates, and the others are regarded as only variant or accompanying forms of the same geologic unit. They sometimes, however, attain considerable importance as independent rock masses.

(1.) THE PERIDOTITES.

The peridotites appear in numerous small oval or lenticular masses of dimensions rarely exceeding a few hundred feet. Sometimes these lenses merge into each other and form a narrow strip a mile or two in length with constrictions at intervals, thus resembling, in form, a string of sausages. In rare cases, the outcrops present an irregular boundary, and cover areas of several hundred acres. The Buck creek area in Clay county, and that at Webster in Jackson county, are the largest masses of the belt, and their form and extent are shown approximately on the small scale map, plate I. (See also plates III and V.)

These rocks are in general perfectly massive and structureless, though a parallel structure is often developed about the borders; and at Webster the whole mass is so perfectly laminated as to pre-

sent a striking resemblance to a thin-bedded sandstone. As stated, however, this structure is exceptional, even the small bodies and narrow strips preserving a perfectly massive character.

This is often true, even where there has been considerable movement along the contacts between the gneiss and peridotites, resulting in the frequent development of mica-schist in the adjoining gneisses and the universal presence of schistose talc in the borders of the dunite. The boundaries have thus become veritable slickensides, and hence no true contacts between the peridotites and gneisses have been observed, and original contact metamorphism, if such ever existed here, has been entirely obliterated.

The peridotites of North Carolina represent a petrographic unit; and no extensive field work is necessary to convince one that any attempt to subdivide them must proceed on comparatively slight mineralogical differences, and the classes established regarded as mere varieties. Thin sections cut from different portions of the same outcrop might be made the basis for the establishment of three or four petrographic divisions; but, in the field, the lines of separation cannot be sharply drawn. The classes made in the laboratory are found to merge into each other, forming parts of the same rock mass.

However, with a clear understanding of this unity, the established classification of the peridotites may be useful for purely petrographic purposes; and, in deference to usage, the more prominent types observed in the State are here considered separately. These are *dunite*, the pure olivine rock; *harzburgite* (saxonite), that composed of olivine and orthorhombic pyroxene; *amphibolepicrite*, consisting essentially of olivine and hornblende; *forellenstein* (troctolite), the olivine-feldspar rock, which is not a peridotite according to the definition of that class; namely, that it consists of olivine rocks without essential feldspar. Forellenstein is usually regarded as a phase of olivine-gabbro produced by the suppression of the pyroxene—indeed, it may be questioned whether most peridotites should not also be so considered—but on the ground of geologic unity, it is here classed with the peridotites.

a. DUNITE.

The type of this rock was discovered in Dun mountain, New Zealand, about thirty years ago, and described by von Hochstetter as a light yellowish-green to grayish-green, crystalline granular rock, with an oily to a glassy lustre, and an uneven angular fracture. The dull, rust-brown color of the barren, weathered surface gave the mountain its name and, indirectly, the rock itself. It was found to consist almost exclusively of granular olivine, with chromite or picotite, in octahedral crystals the size of a pin-head, scattered through the mass.

The North Carolina dunite is very close to this type. It is usually composed of quite small grains of olivine, about the size of granulated sugar, though sometimes much coarser rock is found in small quantities, and large grains are often scattered through the fine-grained masses.

Small octahedrons or rounded grains of chromite or picotite are sparsely scattered through nearly all the olivine rocks. Sometimes these become very plentiful, and are then frequently segregated into vein-like streaks or pockets, and attain importance as a chromium ore. Long, glistening needles of tremolite are often observed, and sometimes flakes of talc and chlorite.

The colors include nearly all shades from light brownish yellow to a dark green, though the freshest specimens seem to be those of light oil-green or yellowish green color. Brown and yellow tints are generally more superficial and seem to be the results of oxidation of the iron constituent in the incipient stages of decomposition; and a dark green color may sometimes be seen, by the aid of a lens, to be the result of a partial alteration to serpentine. The dark green, fine grained varieties are usually tough, and the coarser grained, yellowish ones are very friable, being often easily crumbled with the fingers, even when apparently quite fresh. The more thinly laminated varieties about Webster and elsewhere are usually partly altered and quite friable also.

The characteristic dull brown color of the weathered surface is the same here as described for the New Zealand rock. By decomposition, an ochreous soil is produced which, on account of its

infertility and the consequent absence of vegetation, is easily removed by rains; and hence the outcrops are nearly always made conspicuous by barren areas of brown, angular rocks in a region otherwise well wooded.

Under the microscope, in ordinary light, dunite is seen to consist of irregular, angular grains of translucent, colorless olivine. In the fresh specimens, the angles of these grains fit accurately into each other with no interstitial matter whatever (Plate VI, figure 1); though in the great majority of cases there has been a slight alteration along the cracks into serpentine, and this secondary material surrounds every grain completely like mortar in a rubble wall. (Plate VI, figure 2.)

The microscope also reveals the fact that many of these rocks now of fine texture have resulted from cracking up the grains of a much coarser rock. In this process the remnants of these originally large grains have suffered very little or no displacement, for in polarized light they still extinguish together over considerable areas. (Plate VI, figure 3.) In some cases, however, these fractured grains have also been slightly sheared, and, hence, of course, the small fragments have rolled somewhat on each other and the evidence of its having once been a coarse grained rock is more or less completely obliterated. Sometimes, too, these grains show the development of a distinct cleavage parallel to the brachypinacoidal plane of the crystal; and more rarely, a basal cleavage is developed at right angles to this.

Besides olivine, either chromite or picotite, while neither is an essential constituent of dunite, is always present in rounded grains, occasionally in crystals, scattered through the rock; and hence they must be regarded as characteristic accessories. The distinction between these two minerals under the microscope, if indeed a sharp line may be drawn between them at all, is often quite difficult to make. No chemical or other special investigations have yet been made in connection with this work, and the two names are used rather loosely in the descriptions of microscopic characters of the rock. A review of a considerable amount of literature on similar studies shows quite a prevalent indefiniteness in referring to these minerals, and emphasizes the need of more

thorough chemical and microscopic investigation for the purpose of establishing definitely the relations between them.

In the study of these North Carolina rocks, I have called the opaque mineral that shows a dull grayish color by reflected light *chromite*; and for all those varieties that are translucent and of a yellowish or reddish brown color I have used the name *picotite*. The thoroughly unsatisfactory nature of this classification is more readily understood when it is found that every possible gradation between the bright yellowish brown, translucent mineral and the dull, opaque one are found in the same rock, and, indeed, may often be seen in the same thin section. The most natural explanation of these facts seems to lie in the hypothesis that we have here a complete chemical series, as pointed out by Wadsworth*; and further work on the chemical relations of these minerals, to be of the greatest value, should also take into account their microscopic characters.

In some of the olivine-feldspar rocks described below, the relations are even more striking than this; for quite frequently the clear, translucent picotite is surrounded by a border of opaque mineral with a sharp line between them, and the width of this border varies from a thin peripheral line to a band so broad that there appears only a minute grain of translucent mineral in the middle.

The size of the grains of chromite, or picotite, as the case may be, usually does not vary very widely from that of the olivine grains, though sometimes they are conspicuously larger. This is usually true where the quantity present is largely in excess of the normal, so that prominent segregations of it appear, sometimes attaining the importance of an ore, as mentioned above. Masses of such ore have been found in the vicinity of Webster, in Jackson county; near Burnsville, in Yancey county; northwest of Boone, in Watauga county, etc.

Other accessory constituents of dunite which are seen under the microscope, and which sometimes become prominent macroscopically, may be briefly mentioned. Enstatite in irregular grains is quite often seen, and is sometimes pleochroic. Less often, diallage is found. A light green hornblende, in elongated prisms, and giving

*Lithological Studies, Cambridge, 1884, pp. 176-186.

under the microscope properties of actinolite, is often found in the rock at Buck creek, Clay county, and sometimes on Shooting creek.

The minerals described above are the only ones that have been at all commonly observed in the perfectly fresh dunite. As soon as alteration begins, there appear a considerable number of new minerals among the secondary products; and, as has been already mentioned, at least some alteration may be seen in most of the sections when examined microscopically.

By far the most prevalent product of alteration, and one that is to a certain extent well-nigh universal, is serpentine. The first stage in serpentinization of the olivine is seen in the narrow line of yellowish or greenish, low-refracting substance that appears along the borders of the grains, forming a fine network, which completely envelops the olivine. Later, it forms along the irregular fissures and cleavage cracks through the individual grains themselves; and gradually, as these are altered more and more along their borders, the serpentine replaces the olivine till no trace of the original mineral is left.

In the earlier stages, this alteration is very common, almost universal, in the dunite; but, in North Carolina, complete alteration, save in a few small areas, is exceptional. The process is seldom carried so far as to destroy the granular, sandy nature of the rock over any considerable area. Plate VI (figures 1, 2, 4, and 5,) shows successive stages in this process, together with some of the characteristic phenomena that attend it. A deposition of magnetite in fine grains in the beginning of the alteration is very common, and a net-work of black lines is thus formed that often outlines the original olivine grains after the whole has passed into massive serpentine. Sometimes the rejected ferruginous materials take the form of a lower oxid and stain the serpentine and also the olivine remnants a deep yellowish brown. Where cleavages are developed in the olivine, the alteration to serpentine usually takes place more readily along that parallel to the basal plane, though the brachypinacoidal cleavage is always more highly developed.

The same difference in resistance to chemical action along these two planes is observed in the development of chlorite in the olivine.

Chlorite is often present in the partially serpentized specimens and also in many cases where there is no serpentine. The hornblende-bearing variety (amphibole-picrite) generally shows more or less alteration of the hornblende to chlorite, and sometimes only scattered remnants of it are left entirely surrounded by the secondary product.

But chlorite is often distinctly the result of alteration of the olivine also, as seen in its frequent development along cracks and cleavage planes; and still more conclusively in those cases where the chlorite penetrates the solid olivine grains and gradually replaces them, much in the same manner as serpentine. In such alteration there is, of course, an accession of alumina from some source outside of the olivine itself, this mineral being simply a combination of the silicates of iron and magnesium in varying proportions and entirely free from alumina. The same is true of the production of talc, which is much less frequent in these rocks. With the formation of chlorite there also occurs a segregation of the fine grains of magnetite into irregular patches or large grains, and these are frequently given a skeleton appearance by the laths or chlorite that penetrate them. Such masses of magnetite are almost universally surrounded by a zone of chlorite or a mixture of chlorite and talc, in radiating fibres approximately at right angles to their boundaries.

Tremolite, in long slender needles, is often present with serpentine and chlorite, and is sometimes largely developed where very little of the other two has been formed. Its secondary nature is unmistakable, in most cases, from the manner in which it penetrates the olivine grains in every direction, often passing through several in succession without reference to the orientation of cleavages or crystallographic axes. The tremolite, in turn, is frequently more or less altered to talc and chlorite; and most of the specimens showing talc also bear some tremolite, so that such alteration may often, though not always, account for the presence of talc in dunite. In some cases it is evidently the result of alteration of enstatite, as shown by remnants of the original mineral and by the form which the talc still retains.

Enstatite, in some cases at least, is a secondary product, as often

seen in the radial casing which it forms along the joint-planes of the dunite. This is especially prominent at the north end of Corundum Hill, and is more or less developed in a great many of the outcrops throughout the State.

The casing varies from an inch or less in thickness to 12 or 14 inches, and generally contains more or less chlorite in scattering scales through it. It is always fibrous in structure, with the fibres arranged approximately normal to the surface of the enclosed dunite; and may sometimes be separated into two or more consecutive layers, practically identical in structure and composition. The outer portions of these casings are often altered to talc, and sometimes this has been rendered schistose by subsequent shearing so as to wrap these portions round the boulders in thin laminæ. Such layers are seen to be continuous with the unaltered portions of the casing which still stand perpendicular to the surface of the enclosed block of dunite.

Casings of this nature are often broken through in mining for corundum, and the enclosed block found to be completely altered to a yellow ochreous earth that easily crumbles on exposure. The connection of this enstatite with the corundum veins will be discussed later in describing the modes of occurrence of corundum.

Carbonates in small quantities, sometimes forming little veins through the rock, are found in the specimens that have suffered considerable alteration. They are readily recognized under the microscope by their high double refraction and well-developed rhombohedral cleavage. No tests were made of their chemical nature, but they are doubtless ordinary magnesium carbonate, or magnesite.

In the final weathering and disintegration of dunite, silica, in the form of chalcedony, is deposited in irregular masses in the joints and cracks; and garnierite, genthite, and other nickel-bearing silicates are formed in cases where the olivine carries small quantities of nickel. These minerals, however, never form important rock masses, though the nickel minerals have been found in sufficient quantity in some localities to attract attention from a commercial standpoint.

The original minerals and alteration products described above

are found in practically all the dunite localities of the State; in fact, there is remarkably little variation in the characters of the rock throughout the region, much less than in the corundum and its associated minerals. Such variations as do exist are chiefly in the relative proportions of the various minerals resulting from alternation rather than in the original constitution of the rock, and important characters of this nature will be pointed out below in enumerating the peridotite localities.

b. HARZBURGITE (Saxonite).

This is essentially an olivine-enstatite rock and is found in this region chiefly as a transition between the dunite and the enstatite rock described below, though there are a few exceptions and these are of sufficient extent and importance to warrant a separate consideration. The two principal constituents occur in very variable proportions, and, besides these, all the accessory minerals of dunite are also present. The olivine, chromite, etc., are identical with the same minerals as found in dunite, and the enstatite has the same essential characteristics. But here it is much more highly developed and becomes an essential constituent, being always present in macroscopic dimensions, and prominent for its glistening cleavage faces.

The alteration processes are the same as for dunite. The enstatite alters in some cases to serpentine, just as described for olivine, but oftener it changes to talc. This is especially true of the enstatite in the pyroxenites described below. Harzburgite is found principally in large outcrops near Bakersville, Mitchell county, and near Elk Cross Roads, Ashe county; Balsam Gap, Jackson county; and Mine creek, Yancey county.

c. AMPHIBOLE-PICRITE.

This rock is very similar in structure to the harzburgite described above, an amphibole (hornblende) mineral, resembling actinolite, replacing the enstatite as an essential constituent. Enstatite is frequently present, however, and the grains and crystals of chromite or picotite constitute characteristic accessories, as in dunite. The

hornblende is often partially or wholly altered to chlorite, and it is very probable that the chlorite of the olivine rocks of this region may have originated often in this manner. A considerable portion of the Buck creek peridotite mass, especially towards the north end of the mountain, is composed of rock which conforms closely to this type.

d. FORELLENSTEIN (Troctolite).

This rock type, composed essentially of olivine and feldspar, has been found in important development at only one locality; namely, on the eastern border of the dunite area at Buck creek, in Clay county. It is also found in small amounts on Shooting creek, where the rock associations are similiar in many ways to those of Buck creek. The whole outcrop at the former place covers an area of only about two acres, but it is interesting on account of its connection with the dunite, instead of with gabbro, as usually found, and also on account of the rarity of this type of rock. So far as I am aware, this is the first recorded instance of forellenstein as a phase of peridotite.

The rock is composed almost entirely of olivine and a basic feldspar (anorthite), and the zones of intermediate silicates developed along the borders between these minerals.

A small amount of feldspar that was separated by heavy solution for analysis showed some kaolinization when examined with the microscope, but the following partial analysis places it unmistakably with anorthite.

Partial Analysis of Feldspar (Anorthite) from Forellenstein of Buck Creek, Clay County, N. C.

	Percentage Determined.	On basis of 100 per cent.
Silica.....	40.40	42.29
Alumina.....	18.72	19.60
Lime.....	36.40	38.11
	95.52	100.00

The percentages, calculated on a basis of 100, are only approximately correct for the pure mineral, as magnesia probably exists in combination with part of the silica. The quantity available was too small to give more than approximate results.

In this rock, the olivine nowhere borders directly on the feldspar, but it is separated from it by a double zone of fibrous minerals, arranged at right angles to the boundaries. Rarely, one portion is absent and the minerals are separated only by a single zone. Such reaction rims have been described often from olivine gabbros, and their optical properties were carefully studied by Dr. F. D. Adams, in an occurrence in the anorthosites of Canada, which is exactly similar to this North Carolina rock, except that the reaction rims of the latter are somewhat more highly developed than in any occurrence heretofore described.

Dr. Adams found that the portion of this zone adjacent to the olivine corresponded in optical properties with enstatite, and that the other part is made up of a fibrous green hornblende. In the North Carolina rock, this latter is sometimes perfectly continuous with large cleavable masses of hornblende, and its identity is thus easily recognized microscopically. But the other portion cannot be satisfactorily determined without separation of the minerals from the powdered rock, and this I hope to do before the publication of the final report on these rocks.

(2.) PYROXENITES.

Two types of this family are found in closest connection with the peridotites, and sometimes passing gradually into them, though usually much more sharply differentiated than the different varieties of the peridotite from each other. Two very distinct types of pyroxenite have been observed, namely, that composed of orthorhombic pyroxene, *enstatite rock*; and, one consisting of both monoclinic and orthorhombic pyroxenes, *websterite*.

a. ENSTATITE ROCK.

This rock, as its name indicates, is composed chiefly of the orthorhombic pyroxene, which is usually in large bladed, interlocking

crystals of a grayish or yellowish color. In some places where it is considerably developed it forms a mass perfectly continuous with the diorite, as at Corundum Hill, Macon county, and in some of the outcrops of the Sapphire mine in Jackson county. At other Sapphire localities, and especially in Transylvania and Watauga counties, it forms separate rock masses of considerable extent. Besides occasional grains of olivine and chromite, this rock scarcely contains anything else than enstatite and its alteration products.

The alteration consists entirely, so far as observed in this region, of a change into talc. Even the freshest looking specimens often have greenish, transparent talc developed in them, and frequently large masses that have undergone this alteration still retain perfectly the form and appearance of the original mineral. This is often true also of talc in enstatite-bearing peridotite (harzburgite), as may be seen in that near Balsam gap, in Jackson county.

Dr. C. D. Smith considered the chief constituent of this rock to be anthophyllite,* and the same term has been employed by some later writers. Rocks of a similar character at the Pine Mountain mine, Rabun county, Georgia, are also called anthophyllite by Mr. Francis P. King.*

In view of this usage and the extreme scarcity of well determined localities for true orthorhombic amphibole, I had a specimen of the mineral from Corundum Hill analyzed in the laboratory of the Survey by Dr. Charles Baskerville, with the result given below in column I. Talc could be seen in small amounts in the specimen from which the sample was taken. This was carefully excluded from the material analyzed, but the high percentage of water shows that considerable alteration had taken place. There can be no doubt, however, of the true character of the mineral. Deducting the water and calculating the percentage on the basis of 100, we obtain the results given in column II., and these figures represent a normal enstatite with a high iron constituent, and near the bronzite variety.

*Report Geol. Sur. N. C. I., 1875, appendix, page 93.

*Bulletin 2, Geol. Sur. of Georgia, 1894, pages 79, 82, etc.

An analysis of another specimen from the same locality by Mr. Frank Julian* is given in column III, for comparison.

Analyses of enstatite from Corundum Hill, Macon county :

	I.	II.	III.
Silica	51.64	54.95	57.80
Alumina	0.12		trace
Ferrous oxid.....	9.28	9.87	7.45
Lime.....	0.45		
Magnesia	31.93	33.97	34.64
Manganese oxid	0.56		
Water	5.45		1.21
	99.43		100.60

No other specimens have been determined, and the name is applied to rocks of other localities on general resemblance. It is possible that some of them may prove to be of a different nature.

b. WEBSTERITE.

This rock was first described and named by the late Dr. G. H. Williams from specimens collected at Webster, Jackson county.* Thus far, besides the type locality near the town of Webster, it has been observed only in the continuation of the same outcrop of dunite on Cane creek, about six miles further east. It is composed of both orthorhombic and monoclinic pyroxenes in a compact, granular mass, closely resembling the dunite with which it is associated, and forming a part of the same rock mass. So far as observed, however, there is no gradual transition from one to the other, the two types remaining quite distinct.

The Webster dunite, as before stated, is very highly laminated, and in the midst of this rock, which appears on a hillside facing the Tuckasegee river in an outcrop over 1,500 feet wide, the websterite occupies a width of about 300 feet. It may be traced for about a mile in length, in this type locality; then it thins out and does not appear again, except in the Cane creek outcrop mentioned

*Bulletin 74, U. S. Geol. Sur., Minerals of North Carolina, 1891, page 43.

*American Geologist, VI, 1890, pages 41-44.

above. It is more massive in character than the dunite, has a more brilliant green color, and is less altered on the surface. It is also quite prominent in the field, owing to the vigorous vegetation which it supports, in contrast with the barren dunite.

(3.) AMPHIBOLITE.

This term is here used to indicate massive rocks composed wholly or chiefly of amphiboles. The most important to be considered here is the beautiful green, feldspathic, hornblende rock, which often bears pink and red corundum in the Shooting creek and Buck creek localities of Clay county. It is principally composed of grass-green hornblende and the lime-feldspar, anorthite, in greatly varying proportions; and its structure is usually laminated and gneissic, though massive forms are not entirely wanting. The corundum which it bears occurs in masses from the minutest microscopic grains to broad cleavable plates three or four inches in diameter.

The rock is very fine-grained and exceedingly tough; and, hence, it has not been found practicable to crush it for the separation of the corundum. Transitions from this type to the dunite, with which it occurs, are found on top of the mountain west of the mine, at Buck creek. The intermediate stages have about the same composition and structure as the forellenstein described above; but they never assume sufficient importance in this connection to be classed as a separate rock. The relations of this rock to the dunite (see map, plate III) is strongly suggestive of a system of dikes cutting the latter. On Shooting creek, Clay county, it usually occurs in narrow strips beside the dunite, though sometimes in masses of equal size.

The hornblende of this rock has usually been referred to the species *smaragdite*,* but analyses show it to be an aluminous hornblende, and the late Professor Dana classed it with *edenite*. The brilliant color is undoubtedly due to the chromium present. This is more plainly seen when the powder of the rock is examined under the

*F. A. Genth, Bulletin 74, U. S. Geological Survey, 1891, 45. F. P. King, Bulletin 2, Geol. Survey of Georgia, 1894, 44, 45.

microscope. When the mineral is separated from this powder with heavy solutions, the heavier fragments are all seen to contain inclusions of picotite in minute grains, and to be of a much brighter green immediately around these inclusions. This will account for some of the chromic oxid found in analyses. The purer mineral thus separated was analyzed by Dr. Charles Baskerville, with the results given in column I. That in column II is an analysis of the same mineral (without separating the grains with picotite) given by Dr. Genth in the bulletin referred to above.

Analyses of Aluminous hornblende from Buck creek, Clay county:

	I.	II.
Silica	44.38	45.14
Alumina.....	17.32	17.59
Chromic oxid.....	0.38	0.79
Ferrous oxid.....	3.88	3.45
Nickelous oxid.....		0.21
Magnesia	15.48	16.69
Manganese oxid.....	0.90	
Lime	11.51	12.51
Soda.....	1.24	2.25
Potash	0.38	0.36
Water.....	4.63	1.84
	100.03	100.33
Specific gravity.....	3.075	3.120

The specific gravity given by Dr. Genth was determined on the grass-green variety, and it is natural to suppose that picotite inclusions cause the greater weight as well as the higher chrome percentage. Feldspar was separated and found to agree both in specific gravity and extinction angles with typical anorthite.

4. ASSOCIATED SECONDARY AND SCHISTOSE ROCKS.

Besides the schistose phases of the massive rocks described above, there are found frequent large masses of talc- and chlorite-schists in connection with the typical dunite, as well as with the other associated rocks. Serpentine is extensively developed in only one portion of the region, and is evidently an altered dunite.

(1.) MASSIVE ROCKS.

a. SERPENTINE.

Massive serpentine is almost the universal result of exposure of olivine rocks to hydration process. These rocks in North Carolina have been subjected to this alteration in but few places. Throughout the greater portion of the belt, the outcrops of the peridotites are almost perfectly fresh to the very surface of the exposure; and such alteration as has taken place is usually in the nature of a direct decomposition of the olivine, forming magnesium carbonate, which is mostly carried away in solution, and a residue of limonite and silica, the latter remaining as chalcedony. As stated in the description of dunite, however, most of the sections of this rock show, under the microscope, some slight alteration to serpentine along the cracks; and it seems quite probable that this is the first stage in the decomposition and disintegration of the rock through ordinary weathering processes.

The production of serpentine scarcely reaches a greater development, in the majority of cases, than to form a thin net-work along the cracks of the olivine; and this is seldom perceptible to the naked eye. On the most exposed surfaces, where the rock is superficially stained by the iron oxids of the decomposing olivine, the typical granular structure is still retained; and, with the exception of a small area at Buck creek, Clay county, there is no development of massive serpentine south of Waynesville.

But very different conditions have evidently prevailed somewhat further north; for in Buncombe, Madison, and Yancey counties we find these granular rocks largely altered to typical, massive

serpentine. The outcrops appear in the same form as found in the olivine rocks, and the characteristic chromite grains are always present. Under the microscope, thin sections often also show the original granular nature of the rock in the net-like or "mesh" structure of the fibrous serpentine bands that were first formed around the olivine grains. This structure is still more emphasized if, as is often the case, in the early stages of serpentinization, there was a separation of magnetite or other ferruginous material along these bands.

A serpentine retaining quite a large percentage of unaltered olivine is found on Ivy river, in Madison county. Sections of this rock, seen under the microscope, have the appearance of that shown in plate VI, figure 4; and, in some cases, the olivine grains are quite distinctly seen with the unaided eye.

However, most of the serpentine represented on the map, especially that in the vicinity of the French Broad river below Asheville, is massive and of light to dark green color, and is in every way similar to that of Maryland and Pennsylvania, in the northward continuation of the belt. In these States, it is quarried for architectural purposes, and may be seen in many buildings in the cities of Washington, Baltimore, and Philadelphia. There would seem to be no special reason why the serpentine of North Carolina should not be used in the same manner, especially where transportation facilities are good. Stone of good color is available in many of the localities indicated on the map; but thus far, no attempt has been made to utilize it.*

Many people in the corundum region of North Carolina use the term serpentine indiscriminately, and in most cases incorrectly, for any rock of the peridotite belt, especially when associated with corundum.

*See "Notes on Building and Ornamental Stone," by J. V. Lewis. 1st Biennial Report of the State Geologist, 1893, pages 101, 102.

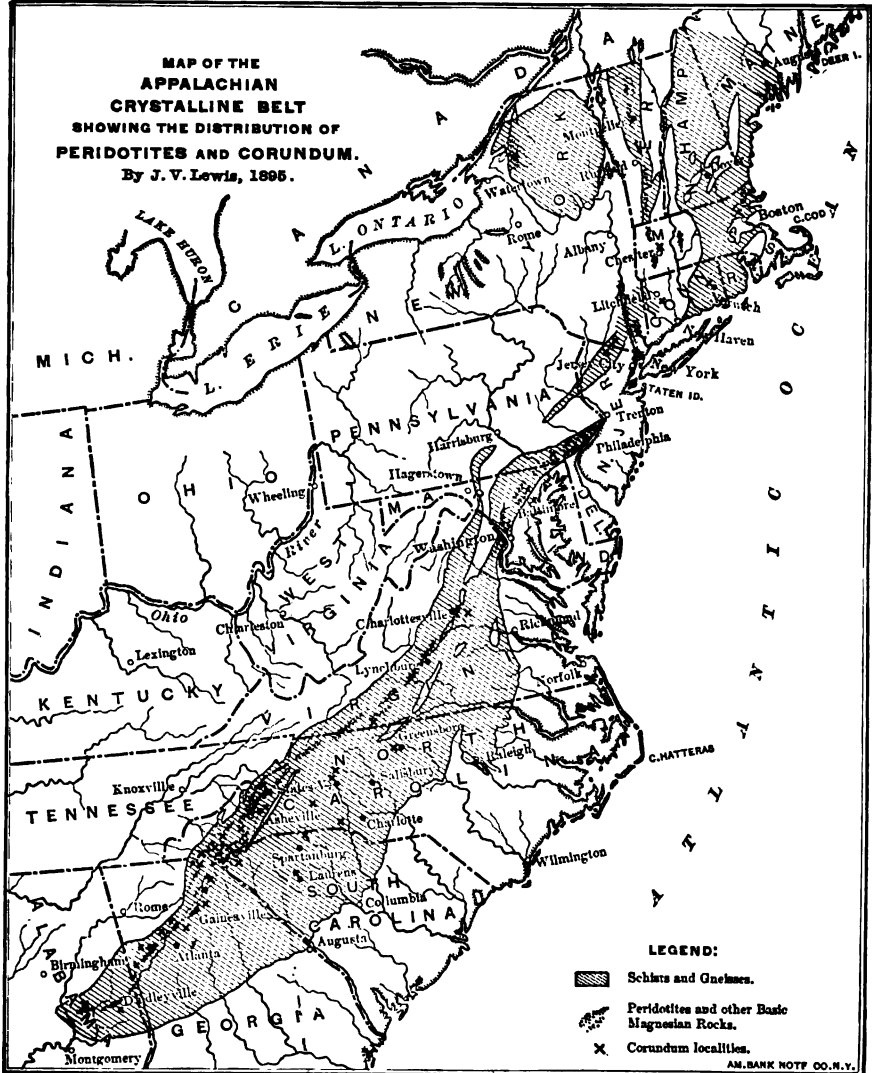
(2.) SCHISTOSE ROCKS.

a. TALC-SCHIST, SOAPSTONE.

As already mentioned in the geologic sketch of this region, there is always a greater or less development of talc along the boundaries of the peridotites and pyroxenites, separating them from the gneisses of the country. But there are considerable masses of enstatite rock sometimes entirely altered to talc. Such rocks may, and sometimes do, retain the form and appearance of the original; but generally they have been rendered schistose by subsequent shearing.

Besides these larger masses, narrow strips of schistose talc are very generally developed along lamination of the gneisses as a continuation of the outcrops of the magnesian rocks; and these sometimes connect two or more lenticular masses of dunite or pyroxenite across intervals of two or three miles. The width of such strips seldom exceeds ten or fifteen feet, and is very frequently less. They are composed of rather pure, white and grayish talc, and are always schistose. Their chief importance, of course, lies in their close connection with the massive rocks. All the talcose rocks, frequently the chloritic schists, and sometimes even the peridotites are locally termed "soapstone," or "serpentine."

In many portions of the peridotite belt, especially in the northwestern counties of North Carolina, soapstone of the firmer and more massive varieties assumes considerable importance on account of its extensive local use. Its great resistance to heat makes it a most enduring material for the construction of fireplaces; and its use for this purpose is almost universal in regions where it can be readily obtained. It is easily cut into desired shapes with ordinary saws, axes, and planes, such as are used in wood-work. While the copper mine was operated at Ore Knob, Ashe county, great quantities of soapstone were used for furnace linings, all of which was cut from the neighboring peridotite belt in Ashe and Alleghany counties. This material also finds an extensive local use for tombstones on account of the ease with which it is shaped and lettered.



b. CHLORITE-SCHIST.

Where corundum is found in connection with dunite, there is always more or less chlorite developed about the borders of the rock mass and through the larger joints; but the chlorite itself, in such cases, never assumes the importance of a rock. In certain localities, however, especially on the waters of the Tuckaseegee river above Webster, there are narrow strips of chlorite rock, comparable in many ways to those of talc described above, but in no way connected with known olivine rocks. They are apparently independent masses, usually schistose in character, and sometimes bear corundum. In these cases the corundum is surrounded by alteration zones of muscovite, but, besides the chlorite, the rock has no other prominent constituent. The chlorite rocks are often talcose, and sometimes pass over into the type described above. Whether talcose or not, they are usually known to the people as "blue soapstone."

5. DISTRIBUTION OF PERIDOTITES AND ASSOCIATED ROCKS.

(1.) IN THE APPALACHIAN BELT.

A great peridotite-serpentine belt, coextensive in length with the Appalachian mountain system (see map, plate II), traverses the crystalline schists and gneisses from Tallapoosa county in eastern central Alabama, where these rocks emerge from beneath the later formations to the southward, to Trenton, New Jersey, where they disappear for a space under the younger sedimentary rocks to the northward. Throughout this distance of over 800 miles, the peridotites are found along a narrow belt of disconnected outcrops with an approximate trend of north 45° east.

In the southern half of this belt, dunite is the prevailing type of rock, but in Virginia, Maryland, and Pennsylvania, it is represented only by the secondary forms—serpentine and talc rocks. Chromite is almost a constant accompaniment throughout the region, and in Pennsylvania, North Carolina, South Carolina, Georgia, and Alabama, corundum is also found in the same connection.

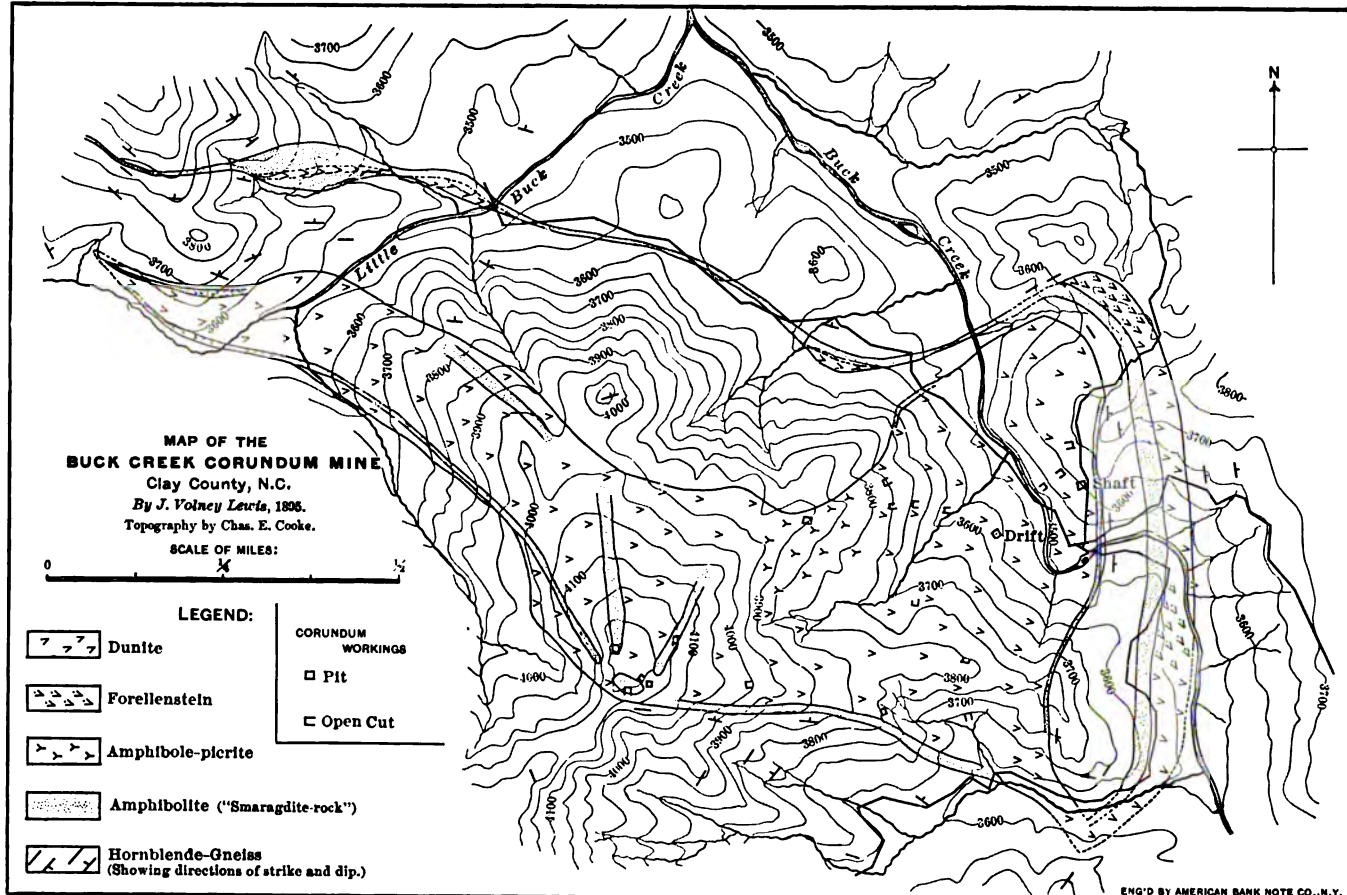
With the reappearance of the crystalline belt, we find serpentine again at Hoboken, New Jersey, and on Staten island. Other occurrences of a similar nature are found in northern New York, Massachusetts, Vermont, northern New Hampshire, and at Deer island on the coast of Maine. The distribution of these rocks is indicated on the accompanying map, plate II. The occurrence of corundum in these regions is discussed further on, but it may be stated here that, with two exceptions, it is not found with olivine rocks north of Pennsylvania. The two localities excepted are the emery deposits of Westchester county, New York, and the corundum found at Pelham, Massachusetts.

(2.) IN NORTH CAROLINA.

The highest development of these magnesian rocks is attained in North Carolina, where, in the southwestern counties, the outcrops are thickly scattered over a region nearly forty miles in width. In this region also—at Buck creek, in Clay county, and at Webster, in Jackson county (see plates III and V)—occur the two largest dunite outcrops of the whole belt, covering areas of approximately three-fourths and one-half a square mile respectively. It will be seen, however, that the amount of corundum bears no relation to that of the dunite; for very little corundum has been found at Webster, while the mine at Corundum Hill, (see plate IV) which has furnished a steady output of corundum for seventeen years, covers an area of only ten acres.

A more detailed description of localities is desirable in order to point out local characteristics and variations in the rocks that could not be represented on the map.

Along the southern boundary of the State, these rocks group themselves roughly into three sub-belts, located approximately in the valleys of the Chattooga, the Little Tennessee, and the Hiwassee rivers, though none of these retains its individuality for any considerable distance. In Union county, Georgia, two and a half miles south of the Towns county line, is the Track Rock corundum mine. The magnesian rocks outcrop here chiefly in the form of talcose chlorite schist. Little typical dunite is found,



CONTOUR INTERVAL 50 FEET; FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL.

though olivine grains are sometimes seen in the chlorite on the fresh fracture, and an altered dunite was found here by Mr. Francis P. King, of the Geological Survey of Georgia.* This outcrop is continued for two or three miles both north and south of the gap, by talcose rocks; and northward the line is almost continuous to the the Hamilton mine, which is located about a mile and a half south of the North Carolina line. Near the road, about a mile north of Young-Harris, is a small mass of forelienstein, and, so far as observed, this is the only exception to the prevalent talc-chlorite rocks of this line.

From this point, the line of outcrop drops back five miles to the east, and appears again in normal dunite a mile and a half north of Hiawasse. Here a long strip of laminated dunite crosses the road and may be followed for more than half a mile; and, a little further up Bell creek, two oval masses occur very near together, with dimensions of 400 or 500 feet. Near this, on the north slope of Bell knob, is a band of talc rocks interlaminated with gneiss, and the talc is found in almost a continuous line to the waters of Shooting creek in Clay county, North Carolina.

a. CLAY COUNTY.

Here considerable chlorite is found, gradually passing into less altered dunite near Shooting creek postoffice. After an interval of two miles, this line is again found at the foot of Chunky Gal mountain, composed of dunite and considerable schistose talc, in a strip rarely attaining a width of forty feet, but continuous for three miles across the mountain, and disappearing within a mile of the great Buck creek area.

Three miles above the mouth of Shooting creek, in the vicinity of Elf postoffice, are two other narrow strips of dunite very close together and lying parallel in the lamination of the gneiss for about a mile. Occasionally feldspathic phases are developed in these rocks, and in one place a peculiar lamination is found where feldspar and enstatite alternate with olivine in laminae of half an inch to three inches in thickness. This lamination is almost at

*Bulletin No. 2, Geological Survey of Georgia, p. 83.

right angles to that of the gneiss, and the whole is enclosed in massive dunite. Accompanying the western strip almost its entire length, is amphibolite, varying all the way from almost pure feldspar to pure hornblende rock. The latter is of a brilliant grass-green, and sometimes bears beautiful red corundum. This strip differs also from the other in being continued northeastward for nearly three miles, by a narrow line of talc outcrops.

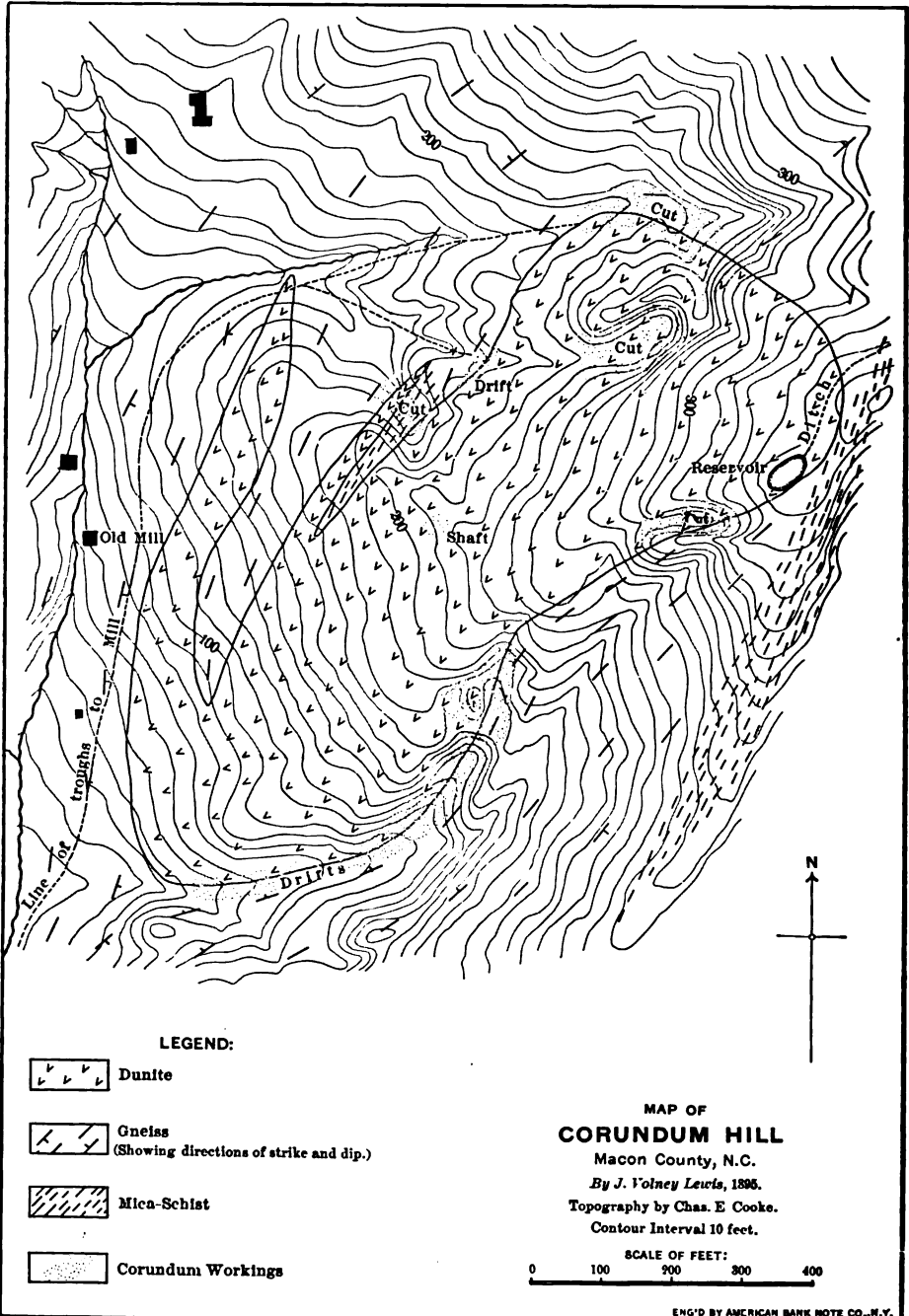
We now come to the Buck creek area, which is the largest compact mass of peridotite in the State, and in fact, the largest yet observed in the Appalachian belt. There is a greater surface exposure in the vicinity of Webster, but it is drawn out into considerable length, and in that respect differs markedly from that at Buck creek.

The form and extent of this outcrop are shown in plate III, which is reduced from a large-scale map made during the summer of 1894. Points of especial interest, which will be dwelt on more fully in a later report, are the amphibolite and forellenstein and their relations to the dunite, the arms (apophyses) passing into the surrounding gneiss, and the structure of the gneiss itself. In a general way these points are shown in the accompanying map (plate III) sufficiently well not to require further description here. The area of this outcrop is approximately half a square mile.

b. MACON COUNTY.

The broad region over which the peridotites occur in this county, as contrasted with the width elsewhere, especially northward, would seem to indicate that considerable disturbance has taken place here. Whatever theory may be adopted to account for the origin of the peridotites, the conclusion that a number of parallel breaks (fault-planes, or fissures) have been formed in this region is one that is readily suggested by a study of the map (plate I). A mile or two south of the State line, in Rabun county, Georgia, small lenticular masses of dunite and enstatite rock are developed on Bettys creek. Much of this enstatite is quite fibrous and abestiform.

On the road from Franklin, North Carolina, to Clayton, Georgia, and almost on the State line, is an outcrop of dunite with consid-



FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE AN ARBITRARY BASE—THE FLAT ROCK BED OF THE BRANCH NEAR THE SOUTHWESTERN CORNER OF THE MAP.

erable schistose talc; and for fifteen miles down the Little Tennessee river, numerous small, often entirely isolated, outcrops are scattered over the country. These arrange themselves approximately in lines and are represented on the map as continuous masses, where, strictly, there should be a number of small dots. Some of these are enstatite, and they are often represented on the surface only by the talc that has resulted from their alteration.

Between the Cullasaja river and the Jackson county line, an area on the spurs of the Cowee mountains is thickly dotted with typical oval masses of normal dunite, of which the well-known Corundum Hill outcrop may be taken as an example (plate IV). Many of the masses are somewhat larger or different in shape from this, but the variation is nowhere very great, and the same general type prevails. Plate IV is a topographic map of Corundum Hill, and shows its most prominent characteristics. This rather blunt, lens-shaped mass of dunite has an extent of about ten acres, and the rock is laid bare over almost the entire surface. Enstatite, which is developed at the south end of this outcrop, is not usually found in the other places in this vicinity, though scattered grains and nodules of it are quite common.

As indicated on the map, corundum is found over this entire area between Walnut and Ellijay creeks, north of the Cullasaja, and considerable activity is manifested in the search for workable deposits.

c. JACKSON COUNTY.

In the line of strike of the gneisses of the Cullasaja region, are found, in Jackson county, a series of long strips of chlorite schist, as mentioned in the description of that rock, in the vicinity of the forks of the Tuckasegee river. Similar narrow bands of talc schist are occasionally seen in the same region.

In some respects the dunite area at Webster (plate V) is the most remarkable outcrop of the whole Appalachian belt. In point of shape it is entirely unique, bearing no resemblance, as a whole, to the prevailing lenticular form. The line of outcrop traces an almost unbroken ellipse, mostly northeast of Webster, with a major axis of six miles lying north 25° east, and a minor axis of three

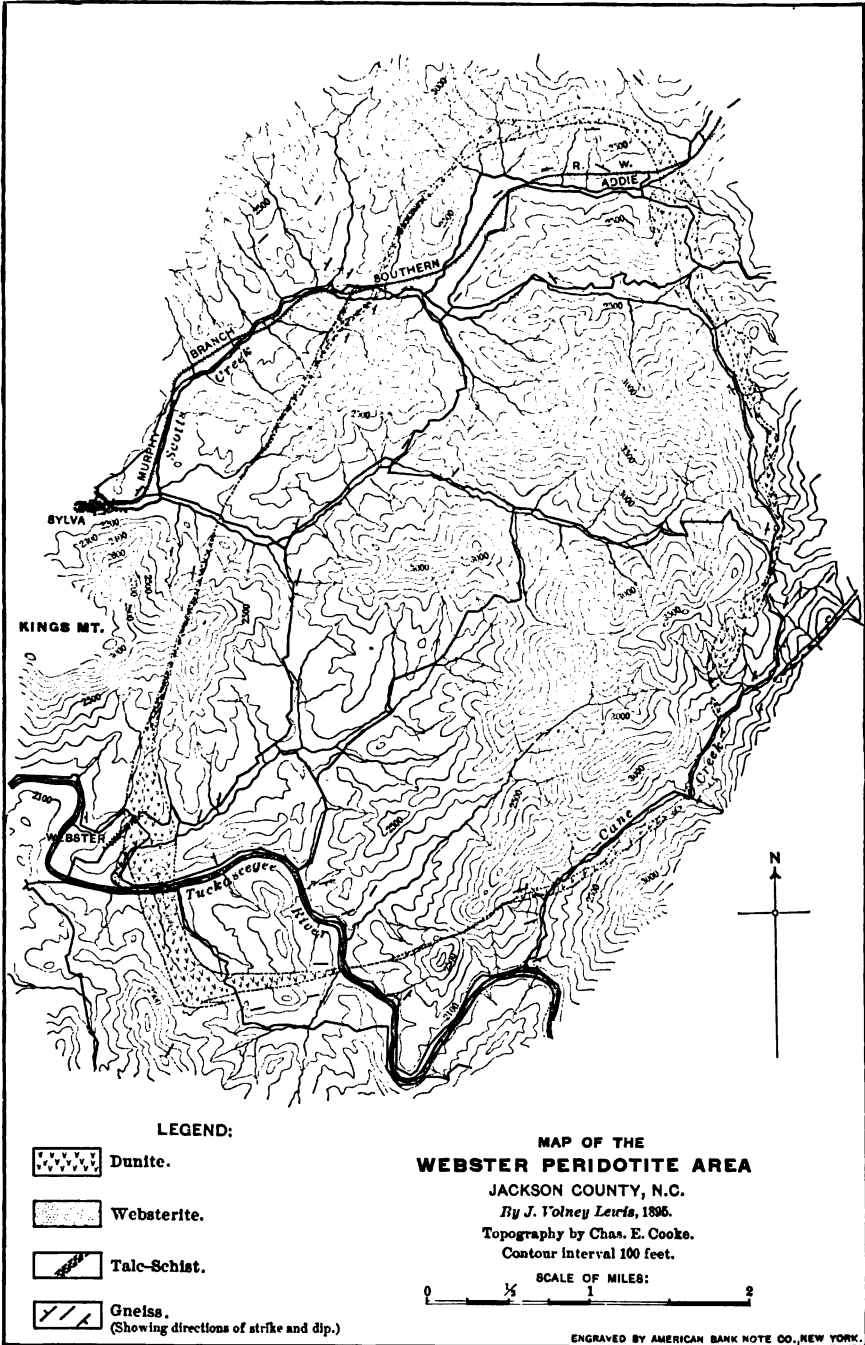
and a half miles. The width of exposure varies from a third of a mile at Webster to extremely attenuated strips of talc in several places; and on the eastern side five complete breaks occur, the smaller disconnected masses having the typical lenticular form.

Near its northern extremity, at Addie, an irregular mass projects into the gneisses within the ellipse; and a little further west, a gneiss area is entirely enclosed by slender strips of dunite and talc. Near Sylva, on the western side of the area, for a short distance, the deep soil covering rendered it impossible to determine whether the belt is continuous or not; and hence it is indicated there by a dotted line on the map. Plate V is reduced from a map of this region which has been prepared for publication in the final report on the corundum belt; but the most prominent features alluded to above are sufficiently well shown as not to require further explanation.

Another important peculiarity of this Webster area is the high development of lamination; and this is best seen in the larger outcrops about Webster and Addie. In its broadest portion, on the hillside facing the river at Webster, is the type locality of websterite, as mentioned in the description of that rock. It forms a strip within the dunite about 300 feet wide in its greatest development, and may be identified for a distance of about a mile. The only other locality where I have seen this rock is on the eastern side of this ellipse, about a mile above the mouth of Cane creek.

The peculiar form of the outcrop renders the structure of this area unusually interesting. The strikes conform to the outline of the ellipse, the dips, both inside and outside, are away from the centre, and, in general, steeper as we go outward. The directions of strike and dip are indicated by the symbols in the gneiss area, near the borders of the dunite.

Near the head of Cane creek, and within half a mile of the isolated dunite masses which form the eastern portion of the Webster outcrop, another line of dunite and talc schists begins, which is continued by a series of disconnected masses in a direction north 45° east almost to the Haywood county line, at Balsam gap. Near the gap, a very coarse grained phase is developed, which bears



FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL

enstatite altered to talc, and good exposures are seen in railroad cuts.

In the southern portion of Jackson county, several small dunite areas are found in the vicinity of Glenville, and associated with these, talc and chlorite schists are developed in narrow belts. But dunite is found in much greater abundance in the region about Sapphire, including portions of both Jackson and Transylvania counties.

Directly southwest of these outcrops and in the direction of trend of the gneiss, is the Laurel creek corundum mine, in Rabun county, Georgia. This mine is very similar in many respects to that at Corundum Hill. The dunite outcrops in an oblong, somewhat irregular mass, covering an area rather larger than that of Corundum Hill; and, so far as observed, no arms branch off into the surrounding gneiss. The nature of the rocks is the same, though a much larger development of enstatite is found. The principal differences between these two mines are found in the minerals developed with the corundum; and further reference will be made to these in describing the modes of occurrence of corundum.

Several small areas of dunite and talc rocks are found between the State line and Sapphire, and quite a large area in the vicinity of the latter place is thickly dotted with dunite and enstatite rocks. Many of the smaller outcrops are necessarily merged into each other on the map.

d. TRANSYLVANIA COUNTY.

In the southwestern portion of the county, adjoining the Sapphire region of Jackson, the rocks are the same as those mentioned above, but enstatite rock becomes more and more prevalent as we pass northeastward into the valley of the upper French Broad river. Often the surface exposures of this rock are entirely altered to talc, and all the northwestern portion represented on the map by the talc-chlorite symbol is composed of narrow strips of talc schist, seldom exceeding twenty feet in width. Those nearer Brevard are similar strips of chlorite, becoming quite talcose towards the northeast. They are made up of several outcrops of "soap-

stone," as it is called, which could not be definitely connected by search for intervening exposures; but, on account of the small scale, they have been thrown into continuous lines on the map.

e. HAYWOOD COUNTY.

From the crest of the Balsam mountains, the Haywood-Jackson county line, a gap occurs in the peridotite belt, to the Pigeon river above Clyde—a distance of 15 miles. Just north of the river, scattering outcrops of soapstone occur over an area of several square miles. But peridotite does not appear till we reach the North Fork of Hominy creek, two and a half miles northeast of Canton, the railroad station at the crossing of Pigeon river. Here a strip of dunite several hundred feet wide and about half a mile long crosses the road near the creek. Another small lens occurs near the head of the creek, and a strip of talc schist and still another dunite outcrop is found in New Found gap. A mile west of this line and on the waters of North Fork is the amphibolite outcrop in which is located the Presley corundum mine.

f. BUNCOMBE COUNTY.

For a distance of seven miles from the county line at New Found gap, the belt is not represented except for a small strip of talc which extends for a short distance from the dunite at the gap. Near Leicester, where the Asheville road crosses New Found creek, another mass of dunite occurs with dimensions not exceeding thirty by one hundred feet. A mile southeast of this, a small serpentine outcrop about ten feet wide is found and, very near this another serpentine mass about forty feet wide and about half a mile long.

Less than a mile further down New Found creek, two outcrops are found about 150 feet apart—one a strip of serpentine ten feet wide, and the other a typical dunite about thirty feet in width. Both of these outcrops have been cut across in search of nickel ore, and their nature is well shown. Decayed gneiss appears between, and, as far as the outcrops show, the two masses have no connection with each other.

For a distance of eight miles from this point, serpentine and talc are the only basic magnesian rocks found. The belt crosses the French Broad river a mile above Alexander—eight miles below Asheville—in two narrow strips of serpentine that may be seen north of the river on the Asheville road.

The river gorge here shows a fine section of the gneiss. It contains many granitic and other igneous intrusions and its lamination planes have been twisted and contorted in the most intricate manner. Doubtless the forces which produced these phenomena have had great influence in the hydration processes that produced the serpentine and talc in the dunite belt through this region.

Through the Flat Creek mountains, only strips of talc and a little serpentine are found, except one small outcrop of dunite five miles from the French Broad river, near the head of Flat creek. The talc outcrop is almost if not quite continuous to Morgan hill, two miles south of the Madison county line. At this point, it connects directly with a typical dunite mass which in a very short distance attains a width of 400 to 500 feet, and is continuous with about the same dimensions for three miles, ending with the Carter corundum mine in Madison county.

This strip is remarkable for its size and the constancy of its characters over so great a distance. Most of it is laminated, though less so than that of Webster, and nickel and chrome stains are quite prominent. Talc is highly developed along the borders, and chalcidony is found in rather larger quantities than usual. Corundum has attracted attention only in the northern portion of the outcrop, beyond Ivy river; and important deposits have been found only in the corner of Madison county, at the Carter mine.

The second parallel strip that was found at the crossing of the French Broad river is still traceable in the narrow strip of talc that appears at intervals from half a mile to a mile east of the principal outcrop.

g. MADISON COUNTY.

The Carter corundum mine is located in the north end of the outcrop last described, which is continuous from Morgan hill, in Buncombe county. Three miles north of this, serpentine again

appears on Paint Fork of Ivy river. Light green, massive rock predominates, but some portions show a considerable amount of unaltered olivine fragments visible to the naked eye. The outcrop at the road is about 100 feet wide and is continuous for about three miles toward Paint gap. At one point, a small mass of unaltered dunite occurs about one-eighth of a mile east of the serpentine, having a width of about fifty feet and interlaminated at the borders with gneiss. This outcrop shows no tendency to the development of massive serpentine.

The second and minor belt is represented in this county by dark green serpentine on the head waters of Terrys Fork, about two miles east of the main belt, in an outcrop about 200 feet wide.

Ten or twelve miles west of the principal peridotite belt just described, is a zone of scattering soapstone outcrops, which crosses the French Broad river two miles below Marshall. This zone seems to have its beginning in a series of similar rocks found north of Clyde, in Haywood county. In the southern part of Madison county, soapstone occurs on the headwaters of Spring and Sandy Mush creeks, and a number of outcrops are found along the course of the latter within a few miles of its mouth. It appears then on Little Pine creek, and on both sides of the French Broad river below Marshall. Outcrops occur at intervals as we pass up Walnut creek, and in a number of places on the waters of Big Laurel creek, on the north side of the county.

The chief constituent of these outcrops is schistose talc with more or less chlorite, the latter in a few places predominating, or occurring almost pure. But one important exception was found to this rule, and that is an outcrop two miles north of Marshall, on Walnut creek, at the county poor-house. The rock here consists largely of talc also; but scattered thickly through it are grains and crystals of olivine, varying in size from a small fraction of an inch to one or two inches in diameter. A rock exactly similar to this, near Philadelphia, except that the olivine has largely altered to serpentine, has been called "*perido-steatite*." Several of the soapstone outcrops in this Madison county zone are full of small "rust-holes," as though similar olivine crystals had weathered out of it.

h. YANCEY COUNTY.

Crossing the mountains about Paint gap, only talc schists represent the belt till near Caney river the serpentine is again found on Possum Trot (McElroys) and Bald creeks.

Here it has the same general characters as that on Paint Fork, and the outcrops indicate masses of approximately the same dimensions. Beyond Caney river, no direct extension of this line is known, but two miles to the eastward, irregular outcrops of dunite occur on the waters of Prices and Banks creeks, accompanied by a little serpentine and a narrow strip of chlorite schist. Small talc outcrops are also found on the Green mountains north of Burnsville.

Four miles north of Burnsville, on Mine Fork of Jacks creek, a very prominent lenticular mass of peridotite appears. It is about half a mile long and 500 feet wide, and forms two small hills, one on either side of the creek. The rock is normal harzburgite of greenish yellow color, rather plentifully sprinkled with chromite grains, and much of it contains talc scales of the form and appearance of the original enstatite. A small peridotite mass occurs half a mile north of this, and then the line of outcrop swerves suddenly eastward, just before reaching the Toe river. For the rest of the distance within the county, it is represented only by narrow talc strips and occasionally a little serpentine.

A still smaller belt appears to the east of this line of principal outcrops, and this is seen in a narrow talc strip about two miles northeast of Burnsville, and in a mass of dunite on Chestnut mountain, four miles east of the locality on Mine Fork described above.

This last locality is perhaps the purest type of olivine rock yet observed in the whole belt. The outcrop is about 300 by 700 feet, oval in shape, and forms a hill about 200 feet high, with a perfectly barren rocky surface except for occasional bunches of sedge that grow in the crevices of the rocks. The longer axis of this mass lies north 10° west. Besides light greenish yellow olivine, the rock contains only a few disseminated scales of chlorite and, in places, small flecks and interlacing veins of talc. The rock has

weathered to a dull brown on the surface, but shows very little alteration of any other kind. At the contact with the mica schist in which it is enclosed there is a radial border of fibrous enstatite altered mostly to talc, but such borders do not follow the joints within the mass, as is often the case in other localities.

Ten miles west of Burnsville, in Egypt township, on the slopes of Sampson and Bald mountains, occurs a strip of rocks that must be considered as belonging here. At its southern extremity is located the Hayes (or Egypt) corundum mine, and the predominant rock is enstatite with a little dunite, the latter considerably altered to tremolite. Three separate masses of enstatite rock occur at the mine, and the line of outcrop is almost continuous across Bald Mountain creek. From this point narrow talc strips were found northward for a distance of four miles.

Again, on the eastern border of the county, we find a belt of enstatite rocks, and talc resulting from their hydration, along the valley of the South Toe river. Six miles south of the forks of Toe river, corundum is found with one of these outcrops on Bailey mountain. A mile east of this, there is a large outcrop of the talc-olivine rock ("perido-steatite") described above (see Madison county). The olivine crystals in this case are, however, much larger, some of them being several inches in diameter.

i. MITCHELL COUNTY.

Eight miles south of Bakersville, and just north of the ford of South Toe river, is an outcrop about one-fourth of a mile long and 300 to 400 feet wide, composed chiefly of dunite, though there is also considerable enstatite rock; and forming the transition between these two types, harzburgite is developed. This locality is very similar to that at the Woody place described next below.

Two and a half miles south of Bakersville is a large lenticular outcrop of dunite on what is known as the *Woody* place. It is about 300 by 600 feet and the long axis lies north 65° east. It is a light green dunite with considerable masses of enstatite rock. Very little chromite was seen. Cellular and compact chalcedony and nickel stauers are abundant. The hillside which is composed of this rock is quite barren and rocky.

From this place a line of eustatite and talc rocks, outcropping at frequent intervals, extends up Cane creek. One small dunite mass appears near the summit of Grassy Ridge Bald, considerably to the north of the general line; but the original direction is continued by the large outcrops on North Toe river, six miles south of Cranberry, near the mouth of Roaring creek. This is a large, irregular area which is continuous for nearly a mile with a width of 150 to 200 feet.

Considerable chromite is found in some portions of the rock, and chrysotile (fibrous serpentine, commonly called asbestos) is highly developed at the north end of the exposure, just below the mouth of Squirrel creek. Another area of dunite occurs near this, on the side of Haw mountain.

At Bellevue, on the summit of Fork mountain, two miles south of Cranberry, dunite also appears in an outcrop about 200 feet wide and greatly altered to serpentine and talc. The outcrop can be traced by a strip of the latter for about one-fourth of a mile.

But here we evidently encounter the results of very great and complex earth movements, as shown by the manner in which the rocks of the Ocoee formation have suffered folding, crumpling and general breaking up; and also by the presence of considerable bodies of massive rocks. In this region of intense confusion, no recognizable peridotites or related rocks have been observed for a distance of about sixteen miles from the outcrop at Bellevue mentioned above.

j. WATAUGA COUNTY.

Normal conditions are somewhat restored in the upturned edges of the gneisses on the western side of Rich mountain, just north of Boone. The first appearance of peridotite is observed in the road about two and a half miles west of Boone, where a typical yellowish dunite appears in a small outcrop. From this point outcrops occur at intervals in a curved line following the general trend of the mountain for a distance of four miles northward. More or less talc and asbestos accompany these occurrences.

Near where the road crosses the mountain at the northern extremity of this line, a considerable body of chromite has been

removed in prospecting. It was in the form of a lenticular mass lying in the pure olivine rock, narrowing within a few feet of the surface to a small vein. These places constitute the last dunite outcrops found on the belt within the State. Further northward, enstatite becomes a predominating element, as in the region about Sapphire, in Jackson county, and in a number of cases constitutes the whole mass of the rock.

Just east of the northern extremity of this Rich mountain dunite, and about four miles north of Boone, an enstatite rock is encountered—in places altered into talc on the surface—forming, in some cases, masses of a hundred feet or more in width and traceable across the country continuously for about two miles. Other areas of less importance are indicated on the map, but it is scarcely necessary to mention them all in detail.

Of the other areas indicated on the map, one six miles east of Boone, on the crest of the Blue Ridge just north of Cook gap, is worthy of mention. Talc, bearing fine radiating actinolite, is the predominant rock in an outcrop about fifty feet wide and, perhaps, three or four times as long. But there are also large masses of dark green serpentine, the only occurrence of this rock that I have found north of Cranberry. About one-fourth of a mile north-east of this, another outcrop of soapstone of about the same dimensions is found on the eastern slope of the Blue Ridge.

k. ASHE COUNTY.

An outcrop of importance, both on account of its unusual size and the type of rock represented, is found on the middle fork of Elk creek three miles from its mouth, and situated just east of the Watauga county line. Here an immense mass of harzburgite, the olivine-enstatite peridotite, forms heavy cliffs on the western slope of Black mountain, and great quantities of it have rolled down into the creek below. The rock consists of about equal parts of enstatite and olivine, and the texture varies from a uniform fine grain to that in which both constituents assume dimensions of three or four inches. Blocks of scaly chlorite, bearing red garnets one-fourth of an inch in diameter and occasional crystals of magnetite, are also found.

Four miles northeast of the outcrop just described, is another great mass of harzburgite, on Bee Ridge, a short spur on the east side of Elk Ridge. The mass is about a thousand feet wide, length undetermined, and presents a forked outline at the south end. Enstatite frequently predominates, and soapstone derived from it constitutes about half of the outcrop. This is sometimes schistose, though it often retains the structure of the mineral from which it is derived. Considerable quantities of this stone have been used for furnace linings in the copper works at Ore Knob. In the surrounding country, most of the fireplaces and many of the chimneys are built of it; and it is found quite suitable for these purposes, both on account of its fireproof qualities and the ease with which it is worked. Soapstone outcrops have been worked at intervals, along the flanks of Elk Ridge, for three or four miles north of this place.

Other small outcrops of soapstone, which have had some local application, are found on Negro mountain, just south of Jefferson, and one and a half miles north of Jefferson, at Phoenix gap.

2. ALLEGHANY COUNTY.

The first appearance of peridotite in this county is found three miles south of Sparta, near Little river, where soapstone is found in the road to Whitehead. From this point, a line of disconnected harzburgite outcrops follows the general direction of Little river almost to the Virginia line. It is typically developed about a mile east of the mouth of Pine Swamp creek, also just north of the mouth of Glade creek, in the great bend of the river, and south of the river, at the mouth of Brush creek. It next appears at Ennis, on Crab creek, and is found in almost a continuous line up the north fork of this creek, in a direction about north 50° east, to the Virginia line. The same rock is said to occur almost continuously for fifteen miles further in the same direction.

This rock has about the same nature as that at Bee Ridge, in Ashe county, described above. All stages are found between pure talc and nearly pure olivine rock, but the latter is never quite free from a certain perceptible amount of talc or enstatite. A coarse lamination is generally discernible, and the purer steatite

portions are usually schistose. The latter also frequently bears a considerable proportion of carbonates; and the numerous "rust-holes" in some portions of the outcrops are doubtless due to the weathering out of these minerals and olivine.

6. CORUNDUM.

For a complete description of the chemical, physical, and crystallographic characters of corundum, the reader is referred to Dana's System of Mineralogy, or to any good text-book on the subject. Only the most important features are related here, and technicalities, while not entirely avoidable, are dispensed with or explained as far as practicable, for the benefit of the general reader.

(1.) CHARACTER AND VARIETIES.

Next to diamond, corundum is the hardest substance known in nature, and on this property, as more or less modified by other qualities named below, depends its commercial value. It crystallizes in the rhombohedral division of the hexagonal system; but the six-sided prism is usually the most prominent form, and the crystals often appear to have the complete hexagonal symmetry (see figures 1, 2 and 3). Sometimes, however, the rhombohedron is quite prominent, but it is usually developed only in small faces truncating the alternate corners of the prism and basal plane or pyramid.

Small crystals are usually quite perfectly formed, but the larger ones are generally rough and irregular, with many of the faces deeply corrugated. Figures 1 and 2 show the hexagonal form as effected by rhombohedral and basal parting, respectively. Figure 3 is a crystal with rhombohedral parting well shown by the faces it has produced on the prism. Figure 8 is a common form of wrapped crystal.

Strictly speaking, corundum has no cleavage, but two forms of parting, often erroneously called cleavage, are frequently met with. This parting is due to multiple twinning, and the form

most commonly seen is that parallel to the rhombohedral faces, which are inclined to each other at an angle of $93^{\circ} 56'$, thus breaking the crystal into almost cubical blocks, (see figures 1, 3, and 7). The other form of parting is parallel to the basal plane, and crystals in which it is developed break square across into a number of thin segments, often resembling buttons, (figure 2). Crystals or masses in which no parting is developed break with a rough, uneven fracture.



Fig. 1.

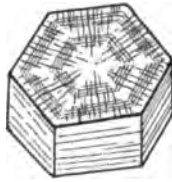


Fig. 2.



Fig. 3.

Fig. 1.—Hexagonal crystal of corundum showing rhombohedral parting. (From Tschermak's Mineralogy.)

Fig. 2.—Corundum crystal showing basal parting and concentric zonal arrangement of colors. (Tschermak.)

Fig. 3.—Corundum crystal from Egypt mine, Yancey county, showing hexagon terminated by rhombohedral parting planes. One-fourth natural size. (Drawn from a photograph.)

Corundum sometimes appears in masses without crystal form, though crystalline in structure, and such masses may have either form of parting described above. Crystalline granular aggregates are also sometimes met with.

All the foregoing varieties of form and crystallization are subject to great variation in color—gray, blue and red being the most common. Corundum is usually more or less translucent, but seldom transparent. The more strongly colored varieties are pleochroic; that is, they show different colors for light passing through them in different directions.

Corundum has a specific gravity of 3.9 to 4.1, which is equivalent to saying that it is about four times as heavy as water. Of the minerals associated with it, only chromite and magnetite are heavier, garnet and spinel are about the same weight; olivine,

chlorite, hornblende, tourmaline and margarite are not so heavy; while quartz, feldspar, serpentine, and talc are much lighter.

Professor Dana, in his description of the varieties of corundum, says: "There are three subdivisions of the species prominently recognized in the arts, and until early in this century regarded as distinct species; but which actually differ only in purity and state of crystallization or structure."*

The three varieties mentioned are; 1. Sapphire, 2. Corundum, 3. Emery.

1. **SAPPHIRE** includes all those transparent and translucent kinds which are of good colors and useful as gems. Jewelers designate the various gems according to colors: 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*; the purple, the *oriental amethyst*; and the opalescent variety showing a six-rayed star of light is called *asteria*, or *star sapphire*. North Carolina has produced the sapphire variety of corundum in every known color.

2. **CORUNDUM**, as the term is used in the arts, "includes the kinds of dark or dull colors and not transparent, colors light blue to gray, brown and black." This is the rough material which forms the bulk of the product of the North Carolina mines.

3. **EMERY** is an intimate mixture of granular corundum and magnetite or hematite. This is the form of much the greater part of the corundum used in the arts; a fact which is due to its comparative abundance and cheapness in Asia Minor and the Grecian Islands, while corundum is obtainable only in much smaller quantities and at greater expense. Emery is mined at Chester, Massachusetts, and has been obtained in small amounts from Westchester county, New York. It was found in Guilford county, North Carolina, in 1871, by Dr. Genth, (see index reference, *Emery*), and has been recently reported from a locality in Macon county, North Carolina, but, so far as I am aware the material has not yet been examined, so no further statement can be made in regard to it at present.

*Dana's System of Mineralogy, 1892, page 212.

(2.) USES OF CORUNDUM.

The use of the sapphire variety for gems has already been pointed out in the description above. The red colors are most highly prized for this purpose, and especially that particular shade known as "pigeon-blood." Fine specimens of two or three carats in weight are equal in value to the diamond.

Corundum and emery are used for the same purposes, and in both the value is due to the hardness as applied to cutting and polishing metals, glass, stone, and all hard substances. The material to be used for polishing is first crushed and then sorted according to size of grain by passing through sieves. For most cutting and grinding purposes, the granular material thus obtained is made into a kind of dough with some cementing material, then moulded into the form of a grindstone and baked. Such artificial stones are called corundum wheels or emery wheels, according to the material of which they are made, and are extensively used in all kinds of metal working, especially the iron and steel industries.

(3.) NORTH CAROLINA CORUNDUM.

The gem varieties of corundum were the chief attraction for the early prospectors and miners. The mine at Corundum Hill, in Macon county, the story of which constitutes the greater part of the history of corundum mining in the United States, was opened and worked for a number of years as a gem mine. Some of the material that came from this mine and other localities in the State has attracted considerable attention, as may be seen from the following mention by Mr. George F. Kunz:

"In variety of color the North Carolina corundum excels. It is found gray, green, rose, ruby-red, emerald-green, sapphire-blue, dark blue, violet, brown, yellow, and of intervening shades, and colorless" "Many specimens [from North Carolina] have been cut and mounted, especially of the blue and red shades, and make good gems, though not of the choicest quality. Several rubies of 1 carat each have been found; a blue sapphire, 1 carat in weight,

is in the United States National Museum at Washington, and a series of fine red and blue crystals has been deposited there by Dr. H. S. Lucas.”*

In several localities, as on Ellijay creek, in Macon county, crystals of a peculiar brown corundum with a beautiful chatoyant lustre have been found. “These (when cut *en cabochon*) all show a slight bronze play of light, and under artificial light they show well defined stars, being really asterias, or star-sapphires, and not cat’s eyes, as might seem at first sight to be the case.”†

Although the principal work in the mining region is now concentrated on the search for commercial corundum, still there is a considerable interest shown in some sections in prospecting for gems; and Mr. Kunz writes again in 1893: “The finding of small rubies of fairly good color in Macon county, North Carolina, gives ground for the belief that larger and better stones may be found there by more extended development.”‡

Commercial corundum does not occur in all the varieties of color that are found in the gems, but there are differences of texture and purity that have no less important bearing on the value of the product than color and transparency in the gems. As mentioned above in describing the varieties, this class includes all those dull and dark colored kinds which constitute the principal product of the mines. The colors are generally gray, or some shade of blue, or mottled white and blue; but the variations in texture are much more important than those of color. The different mines of the State produce every known variety: massive or “block” corundum, crystal corundum, and the fine granular or crystalline variety called “sand” corundum. And all these are sometimes found associated in the same immediate locality or even the same mine. Each mine has its own peculiar characteristics, however, and a kind of family resemblance runs through its whole product. This fact is well recognized by the miners, and they can frequently ascribe a specimen to its proper locality by its general appearance.

Corundum from some localities is chiefly six sided crystals, often

*George F. Kunz, *Mineral Resources of the United States*, 1892, pages 760, 761.

†George F. Kunz, *Gems and Precious Stones of North America*, 1890, page 47.

‡George F. Kunz, *Mineral Resources of the United States*, 1893, page 680.

tapering toward the end like a barrel—hence, we sometimes hear the term “barrel corundum”—and these crystals may or may not have one of the forms of parting developed. If parting is absent or only developed to a slight extent, the crushed product will be solid and tough, even in the coarser numbers; while, if it is very highly developed, the coarse numbers and sometimes also the medium and finer sizes will be full of these parting planes along which it will easily crumble down in use. Besides producing a defective grain, there is always considerable loss in crushing from the production of an unusual amount of “flour.”

The massive or “block” corundum may have the same defects, though this is usually not the case, and hence such material, when in sizes suitable for crushing, produces a good tough grain. But the difficulty encountered in working such corundum lies in the size of the masses, which are frequently intergrown with feldspar and hornblende into blocks so tough that they cannot be profitably broken and crushed. This is the case with some of the material mined at Buck creek, in Clay county. This variety is also found in veins of tough, compact materials which render its removal from the mine a source of considerable expense.

Sand corundum consists of small crystals and irregular grains, which are developed in the soft vermiculites surrounding the peridotites, and hence are always easily dug out and the corundum obtained by washing away the lighter minerals. This variety is not subject to the difficulties and defects of the other two, but, as there is considerable variation in the size of the grains, it is impossible to remove all the lighter minerals by washing, and, of course, the magnetite and chromite cannot be thus removed.

Corundum in place in the rocks is subject to numerous alterations by which its hardness is impaired even in incipient stages; and this property is entirely lost in the complete alteration, which produces a series of aluminous minerals of little or no value as abrasives.

It is a well known fact that chemical action takes place much more rapidly on small grains than on large ones, owing to the greatly increased proportion of surface exposed: hence, sand corundum is more subject to alteration than the larger masses. The sand may

be in some cases only the remnants of larger masses which have disappeared through this means. Still, sand corundum is the kind most sought by the miners, and the usual presence of more or less crystal corundum along with it makes up to a certain extent for its lack of purity. These two forms constitute the product of the mine at Corundum Hill.

(4.) MODES OF OCCURRENCE OF CORUNDUM.

Professor Zirkel enumerates the following modes 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 amphibolites of northwestern Austrian Silesia (largest hazel-nut size, white or blue grains), in the chlorite schist of Nischne-Issetsk in the Urals, in the graphite of 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 diorites of Klausen, in Tyrol. It is also observed as altered foreign inclusions or as real accessory masses in certain eruptive rocks, often with cordierite, spinel, andalusite—as inclusions in the andesite of the Eifel, and similarly in tonalite. Further it appears scattered through a contact product of quartz-mica-diorite on quartz-phylite in Val Moja. Similarly in the kersantite of Michaelstein, Harz.*

Besides these occurrences as a rock constituent, corundum is found in large quantities in feldspar veins and associated with chlorites in the peridotites and serpentines of the Atlantic States of America; and in areas of crystalline rocks in many parts of the earth's surface, in the gravel-beds of streams. Except the occurrences in granular limestone, in graphite, and in association with volcanic rocks, all the various modes enumerated above have been observed in North Carolina. These will be described briefly in the following order:

*F. Zirkel, Lehrbuch der Petrographie, Leipzig, 1898, page 416.

a. Associated with peridotites; *b.* In chlorite schist; *c.* In amphibolite; *d.* In dunite; *e.* In gneiss; *f.* In gravel deposits.

a. CORUNDUM ASSOCIATED WITH PERIDOTITES.

The occurrence of corundum in the State, with few important exceptions, is in association with olivine rocks (peridotites), though rarely occurring in the body of such rocks. It is found in the zone of chlorites and vermiculites developed between the peridotites and the gneisses of the surrounding country, and sometimes near this zone in the gneisses themselves. In some cases this border zone of chloritic minerals carrying corundum has developed along the joints of the peridotites to the very center of the mass. Such a condition is shown in a number of openings at Corundum Hill, though mining operations have been chiefly confined to the border zones. (See figure 6.)

These zones vary exceedingly in thickness, from ten or twelve inches to as many feet, and the proportion of corundum is scarcely more constant, though bearing no relation to the dimensions of the "vein". In places the chlorites are thickly studded with corundum almost from wall to wall, and sometimes this condition prevails for a considerable distance; then the corundum-bearing portion will narrow down to a thin strip in the middle, or perhaps disappear entirely, to be encountered again only after a considerable amount of barren material has been handled.

There is a prevailing impression that peridotite always occurs in hornblende-gneiss. While this is frequently the case it is by no means universally true, as a microscopic examination shows some of these enclosing rocks to be normal gneiss; that is, composed of quartz, feldspar and mica (the mica being chiefly biotite). In other cases, the country rock is mica-schist.

A gneissoid rock resulting from the lamination of the bright green hornblende rock found at Buck creek, in Clay county, and elsewhere, is closely associated with the peridotites of these localities; but it is here regarded as a member of the peridotite group, and is not classed with the country rocks.

The gneiss of this region, wherever found in contact with the

peridotites near the surface is considerably decomposed, crumbling easily into a loose sand, though retaining a fresh appearance and the original structure of the unchanged rock so far as may be seen with the unaided eye.

In the description of the secondary products found in connection with the alteration of dunite, mention was made of the enstatite casing which often surrounds the jointed masses of the rock. In most cases, it is quite clear that these casings are closely connected with the chloritic zones that bear corundum. They are composed of enstatite, often fibrous and usually altered more or less to talc; and the structure is radial, or parallel, the fibres standing normal to the outer surface of the dunite block enclosed. In all cases observed, the enclosed rock is more or less altered, and frequently to such an extent that only a soft ochreous, clay-like mass remains, though the casing may be tough and apparently fresh. These casings often contain more or less chlorite, and especially towards their outer portions; furthermore, they are never developed except in places where chlorite is also formed along the borders and more prominent joints of the peridotites; and, *vice versa*, some slight development, at least, of such enstatite always lies between the chlorite and the olivine rocks.

The whole zone, consisting of chlorite, vermiculite, talc, and the enstatite border is frequently sheared until all original structure is replaced by a high development, of schistosity.

A number of other minerals are always present in minor proportions, varying in importance in the different localities. Some variety of amphibole, pyroxene, spinel, and tourmaline are frequently observed; staurolite, diaspore, and anthophyllite are occasionally seen; and, where the corundum is associated with feldspar, margarite and zoisite are frequent accompaniments. Muscovite, margarite, and other minerals that so often form the wrapping of corundum crystals, appear to be in many cases undoubtedly the results of alteration of that mineral, as indicated by the researches of Dr. F. A. Genth.

The green and yellow micaceous minerals, known respectively as chlorite and vermiculite, have been divided into several more or less

definite species based on chemical analyses. Lucasite, kerrite, calsageeite, jefferisite, wilcoxite, etc., are some of the names that have been given to the yellow and brownish minerals; but the distinctions are almost purely chemical, and the names are of no practical value in the field examinations; and, in most cases, their use would tend only to confusion. These are all grouped here under the name *vermiculite*. Pennine, clinochlor, prochlorite, corundophilite, etc., are some of the more important subdivisions of the chlorite group; but the same condition exists here as in the vermiculite group, so far as field distinctions are concerned, and the term *chlorite* is used for all green colored micaceous minerals associated with corundum and the olivine rocks.*

In the midst of these chlorite zones, corundum is sometimes found in veins of feldspar, as at Buck creek, and with amphibole rocks in Iredell county. In rare cases quartz is intergrown with the feldspar, forming a true pegmatite. Such a vein, without corundum is found at the Hamlin prospecting, on the head-waters of Ellijay creek, in Macon county.

b. CORUNDUM IN CHLORITE SCHIST.

An occurrence in some respects similar to that in the chloritic zones about peridotites, is found in the long belts of chlorite schist that traverse the country ten to twelve miles southeast of Webster. Chloritic rocks here, which sometimes attain a width of several hundred feet are traceable across the country for several miles. Green, scaly chlorite is almost the only constituent of these rocks, though sometimes they are flecked with small white grains of feldspar, and occasionally amphibole needles are seen. The chlorite is in small scales, never very coarse, as is sometimes the case in the zones about peridotite, and often they are so minute as to impart quite a compact appearance to the rock.

In one of these belts, on Caney Fork of Tuckaseegee river, corundum is disseminated through the chlorite in small rounded masses, ranging from an inch in diameter to minute grains. In

*A careful investigation of the chemical and mineralogic relations of corundum and its associated minerals is now being pursued by Mr. Joseph H. Pratt, of Yale University and the most of these minerals are here referred to only in a general way.

these cases, the chlorite is not so tough and compact as elsewhere, and the corundum is invariably wrapped in a coating of white mica, usually in radiating scales perpendicular to the outer surface of the corundum. The mica coating is exceedingly thin in some cases, but it is so variable that many nodules are composed almost entirely of it with only a small grain of corundum in the centre. The secondary nature of this mica and its derivation from the corundum can scarcely be doubted.

C. CORUNDUM IN AMPHIBOLITE.

The beautiful grass-green hornblende rock, which forms important dike-like masses at various peridotite localities in Clay county, was described above among the massive rocks associated with peridotite (p. 28). Besides the green hornblende and the anorthite which constitute the principal constituents of the rock, there is always present, in the corundum-bearing phase, microscopic grains of picotite, and the smaller grains of corundum are usually intergrown with irregular masses of this mineral and enclose many minute particles of it.

The corundum ranges in size from the minute microscopic grains to large masses of several inches in width, and is usually laminated or possesses a parting according to the rhombohedron, which breaks it into small, nearly cubical blocks. It ranges in color, too, from almost white to deep ruby-red, most of it being of quite a decided red color. Some portions of the rock are thickly studded with corundum, and boulders of this kind have been gathered from the surface at Buck creek and hauled on wagons to Corundum Hill to be crushed for separation. It has furnished some handsome cabinet specimens, the contrast of the bright red and green colors producing a striking effect; but it is an exceedingly tough rock and is not likely soon to become a commercial source of corundum.

The corundum that has been found in place in the vicinity of Statesville, Iredell county, is developed in the joint-planes and along the borders of coarse hornblende rocks, much in the same manner as that with dunite at Corundum Hill and elsewhere in the more westerly counties. These hornblende rocks appear in

the gneisses somewhat as the peridotites, so far as may be judged from the meagre outcroppings available, and the corundum is found with fine brown, scaly vermiculite, which is developed in zones from a few inches to three or four feet in thickness, along the borders, and through irregular joints in the hornblende rock (See figure 4). In one or two instances, feldspar veins five or six inches thick, sometimes altered to kaolin, were observed in the midst of the vermiculite zones. This feldspar often bears corundum also, though in prospecting most of it was found with the vermiculite. The corundum is in crystals and rounded masses of crystals clustered together; sometimes margarite accompanies it, and large masses have been found on the surface in this region made up of these two minerals.

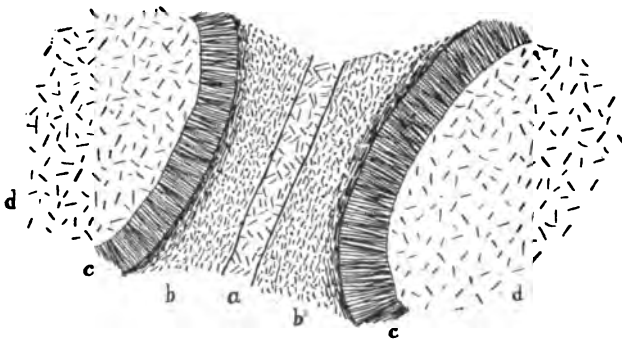


Fig. 4.

Fig. 4. Diagram illustrating the mode of occurrence of corundum in amphibolite at Hunter's, seven miles west of Statesville, Iredell county. *a*, Feldspar vein, (not always present) sometimes carrying corundum; *b*, Fine scaly vermiculite with crystals and lumps of corundum; *c*, Radiating border of actinolite enclosing large blocks of (*d*) dark green hornblende rock.

Still another point of similarity to the occurrences in connection with peridotite is found in the radiating borders that intervene between the corundum-bearing vermiculite zones and the massive rock. In this case, the radiating border is composed of a green hornblende similar to actinolite, instead of the enstatite. Similarly, the rounded blocks thus inclosed are often almost completely decomposed; so that we find, on breaking through this radial

casing, only a mass of ochreous clay bearing occasional needles of hornblende and scales of brown vermiculite.

d. CORUNDUM IN DUNITE.

Thus far I have observed but one instance of this association; and, so far as I am aware, it is entirely unique. This was found at the Egypt mine on the western slopes of the Sampson mountains, in Yancey county, by Mr. U. S. Hayes, who was prospecting at the time of my visit. I am indebted to him for two of the best specimens collected, one of which is shown in figure 5. It consists of a hexagonal crystal of corundum completely surrounded by granular dunite, with none of the chloritic minerals which usually intervene. The dunite is not quite fresh, being stained yellowish brown and rather friable. A little muscovite is developed along the basal parting planes of the corundum, as is often the case in other occurrences.

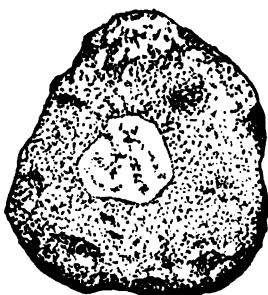


Fig. 5.

Fig. 5. Corundum crystal in altered dunite. From Egypt (Hayes) mine, Yancey county. One-half natural size. (Drawn from a photograph.)

With one *possible* exception, so far as I am aware, this is the first instance of such anomalous mineral association yet recorded. In enumerating the minerals of the Buck creek corundum locality, in 1875, the late Dr. C. D. Smith states that he found "chrysolite attached as an enveloping matter to considerable masses of corundum;" * but as neither Dr. Smith nor any of the numerous writers on this subject during the succeeding twenty years have made any further mention of this extraordinary discovery, it may

*Report of the North Carolina Geological Survey, 1875, Appendix page 96.

be fairly assumed, I think, that this passage refers only to the ordinary occurrence of corundum in the chlorite zones developed within the peridotite and along its borders.

e. CORUNDUM IN GNEISS.

In the same belt of crystalline rocks that carries the peridotite, but apparently in no way connected with the latter, corundum is found in a number of localities in the ordinary gneiss of the country. Five years ago Dr. Genth * described, as a new mode of occurrence for corundum, that discovered in the mica schist region of Patrick county, Virginia. The schists are sometimes garnetiferous and gneissic, and the corundum is associated with andalusite, cyanite, chloritoid, mica, etc. The schists were intersected with granite dikes, and the corundum was found near these in crystals and rounded masses on the surface.

In the North Carolina localities, corundum occurs in place in the gneiss in nodules of half an inch in diameter and smaller, and wrapped in a sheath of radiating muscovite, similar to that in the chlorite schist described above. None of the accompanying minerals described by Dr. Genth were observed, and but for the presence of these nodules, the rock seemed to be in every way normal gneiss. The nodules, on account of their resistance to the decomposing forces of the atmosphere, always stand out prominently on the weathered surface; and they are often present in such proportion as to thickly stud these surfaces with little white and grayish knots.

In one instance, however, the corundum-bearing gneiss is associated with basic magnesian rocks, though such has not yet been shown to be the case in other instances. The basic rock referred to here occurs on the head waters of Shooting creek, in Clay county, and consist largely of fine grained green hornblende and hypersthene—the latter somewhat predominating. The sections of this rock have not been sufficiently studied to determine whether the hornblende is primary or secondary, but the preponderance of the hypersthene would give ground for calling it hypersthenite. This rock cuts through the gneiss in two dikes about ten feet thick

*F. A. Genth, Am. Jour. Science, 3, xxxix, 1890, pages 47, 48.

and about 500 or 600 feet apart. The Corundum is found in the gneiss between, intimately associated with a small pegmatite vein and a band of very black mica.

Just beside one of the dikes also, corundum was found in a zone of fine scaly brown mica. This corundum is in nodules and, like that in the gneiss between the dikes, has two systems of parting well developed.

In other localities, no such relation to magnesian rocks has been observed. The covering of soil and decomposed rock is, however, very deep in some places, and quite sufficient throughout most of this region to render the outcrops rather obscure.

On the western side of Chunky Gal mountain, bands of brown mica, bearing lumps of granular garnet, and both carrying more or less corundum, are found in the gneiss. So far as determinable at the time of my visit, the corundum here has no connection with peridotite or similar rocks.

f. CORUNDUM IN GRAVEL DEPOSITS.

It is well known that the gem varieties of corundum are found chiefly in the soil and gravel beds of Burma, Ceylon, and other regions of southern Asia. Along with these, the common forms of crystalized corundum are also found; and, in some of the localities, the mineral has been traced to its origin in the crystalline rocks.

The gravel beds represent the result of ages of concentration. While the rocks have been slowly decomposing and crumbling away through the agencies of air and water, the stream beds furnished a natural system of sluices in which the heavy and more resistant minerals, including corundum, have been caught and retained, while the lighter material has been carried out to the sea. Hence, although the corundum gems may have been quite rare in the original rock, they are found in these gravel deposits in comparative abundance; and even when the original source is found, the gravels still remain the principal commercial source.

Most of the corundum localities of North Carolina have been found through the discovery of fragments in the soil or in beds of streams; and it is a favorite method with prospectors to wash the

gravels of stream beds for corundum, much in the same manner as search is made for gold. Similarly, corundum crystals have been ploughed up in bottom lands, and further investigation has revealed gravel beds, often of considerable extent, which usually bear several varieties of corundum. Search up the stream and its tributaries till no further trace is found and then up the adjoining hillsides, has in many instances brought to light the source of these valley deposits; but, in a number of cases, such search has proven, thus far, fruitless; and we are led to the conclusion that the corundum must have been concentrated from rocks in which it is only a rare constituent.

Several such deposits, in Macon and Jackson counties, have furnished ruby-colored corundum of nearly every shade, and considerable attention has been devoted to the search for gems. Occasionally pieces are found sufficiently transparent and free from flaws to be cut into fair gems, though most of it is too much clouded and the parting too highly developed to be of any value except as mineral specimens. The principal object of the recent work in these gravels has been to locate the original source of the material in the hope that the finer specimens may be found in sufficient quantity to establish gem mining on a profitable basis.

Small grains and crystals of corundum are found in the gold placers of Rutherford, McDowell and Burke counties, but they are not considered of sufficient importance to be indicated on the map.

(5.) DISTRIBUTION OF CORUNDUM.

As indicated above, in the description of the modes of occurrence, the home of corundum is in the highly crystalline rocks, and chiefly in the region of gneisses. This is true of all occurrences that attain to any but purely scientific interest.

a. IN THE APPALACHIAN BELT.

In describing the distribution of peridotites, mention has already been made of the occurrence of corundum in Pennsylvania, North and South Carolina, Georgia and Alabama. In these states, the corundum localities are found along the peridotite belt indicated on the general map (plate II, p. 32). Other localities are found as

indicated above, which are not intimately connected with these rocks; but thus far none of these, except the emery of Chester, Massachusetts, has become of economic importance.

CORUNDUM IN ALABAMA.—The Appalachian crystalline belt passes under the Cretaceous and later sedimentary formations in the central part of the State near Montgomery. Representatives of the peridotite belt have been found in the vicinity of Dudleyville, in Tallapoosa county, and corundum has been found in fragments on the surface both in this and Coosa, the adjoining county on the west. A little search would doubtless reveal the presence of peridotite, and perhaps also, corundum, to the very borders of the crystalline rocks.

CORUNDUM IN GEORGIA.—A series of scattering deposits extends the peridotite belt through this State in a northeast direction, passing in a general way up the valley of the Chattahoochee river to the western extremities of North and South Carolina. Along this line, corundum has been found in the following counties: Rabun, Towns, Union, Lumpkin, Habersham, Hall, Cobb, Paulding, Douglas, Carroll, Heard, Troup, and somewhat off the line to the east, in Walton. One occurrence is reported in Forsyth county in a region of mica schist and garnetiferous hornblende gneiss. Considerable work has been done along this belt in the nature of prospecting, and for a number of years, a productive mine was operated at Pine mountain, in Rabun county. *

CORUNDUM IN SOUTH CAROLINA.—Corundum is reported from Laurens, Anderson and Oconee counties, and I have seen specimens that were said to have been found in Pickens. The western portion of this State is in the line of peridotites as indicated by the direction of the belt in Georgia and North Carolina, and these rocks are known to exist along the border in the north-western corner; but no work has been done to trace out their distribution nor to develop the corundum deposits, if such exist.

CORUNDUM IN NORTH CAROLINA.—As remarked above, this State presents the greatest development both of peridotite and corundum. The belt here attains its greatest width, and the largest

*A Preliminary Report on the Corundum deposits of Georgia, by Francis P. King, 1884 Bulletin No. 2 of the Geological Survey of Georgia.

outcrops of chrysolitic rocks in the Atlantic States are found in the southwestern counties. As indicated on the map, (plate I) corundum occurs in Clay, Macon, Jackson, Haywood, Transylvania, Buncombe, Madison, Yancey and Mitchell counties along the belt of basic magnesian rocks; and it is found east of the mountains in the counties of Cleveland, Burke, Gaston, Alexander, Iredell and Guilford. More particular mention is made of these localities under another head beyond.

CORUNDUM IN VIRGINIA.—Thus far I have been able to find corundum reported from only two localities in this State. The first is a large deep blue crystal found in Louisa county by Mr. Louis Zimmer, and reported by Mr. George F. Kunz.* The second is that described by Dr. Genth in 1890, and noted above in describing the mode of occurrence in gneiss. The peridotite belt is continued through the State by a great number of talc and serpentine rocks, but no corundum has been reported from any of these localities.

MARYLAND.—Although the peridotite belt is well represented in this State, no corundum localities are known.

CORUNDUM IN PENNSYLVANIA.—The serpentine belt that comes diagonally across Maryland, is continued through the counties of Lancaster, Chester, Delaware, Montgomery and Bucks. Corundum is found associated with it in many places, especially in Chester and Delaware counties, and, a few years ago, was mined to a certain extent in the former. It is found here in chloritic zones about the serpentine, but in larger amounts in granular albite, much like the occurrence in feldspar veins at Buck creek, in Clay county, North Carolina.

Zones of chloritic minerals along the borders of the serpentine masses and in the larger joints, are constantly present in these corundum localities, and chromite is found in the mass of the serpentine itself. Considerable prospecting has been done in Pennsylvania, and corundum has been mined in one or two places but these are now abandoned.

CORUNDUM IN NEW JERSEY.—The crystalline belt disappears

*George F. Kunz, Mineral Resources of the United States, 1883-4, page 736.

under the Jura-Trias near Trenton, almost immediately on crossing the Pennsylvania line. Portions of it outcrop again to the northward in the Highlands, but in the line of the peridotite belt, it does not reappear till we find it on the opposite side of the State at Hoboken, where serpentine is found, but no corundum.

Corundum is found, however, in Sussex county along the borders between the crystalline limestones and the gneiss.

CORUNDUM IN NEW YORK.—Corundum is also found with the white limestone of this State in Orange county. Emery, an intimate mixture of granular corundum and magnetite, is found east of Peekskill, in Westchester county, in basic magnesian rocks, which have been shown to be eruptive in origin.* This Emery is also often intimately intergrown with chlorite and green spinel, though there are no well defined chlorite zones such as are developed about the peridotites of North Carolina. This has been mined to a limited extent, though the product is said to have been too soft, and it is not worked now.

CORUNDUM IN CONNECTICUT.—Connecticut has thus far furnished only surface specimens of corundum, nothing of commercial importance. Early in the century, a mass of cyanite was found at Litchfield, "associated with talc, sulphuret of iron, and corundum . . . supposed to weigh 1500 pounds."† Dana also reports it from Norwich. Both of these localities are in regions of crystalline rocks.

CORUNDUM IN MASSACHUSETTS.—About thirty years ago, the emery vein at Chester was found in a chlorite schist zone lying between a talc rock on the east and a hornblende schist on the west. The vein traverses the mountains on both sides of Westfield river, in a nearly north and south direction, and has been traced for a distance of about four miles. A typical section from west to east would be about as follows: (*a.*) Hornblende schist, black, coarse crystalline, often feldspathic and banded, gneissic; (*b.*) Chloritic schist, bearing lenticular masses of emery and magnetite, sometimes becoming talcose, and often bearing radiating tourma-

*George H. Williams, American Journal of Science, 3, 1886, XXXI, pages 26-41; 1887, XXXIII, pages 135-144 and 191-199; 1888, XXXV, pages 438-448; 1888, XXXVI, pages 254-260.

†Edward Hitchcock, American Journal of Science, 1, VI, 1823, page 219.

line clusters. This belt is usually about twenty feet wide. (c.) Granular quartz in a vein one to two feet wide; sometimes entirely disappearing. (d.) Talc schist, sometimes chloritic and of fine texture, closely resembling serpentine; fifteen to twenty feet wide. (e.) Mica schist to the eastward.

The position of the emery in the chloritic zone (b.) is very variable, and it often lies along the border of this and the talcose rocks (d). The emery is associated with diaspore and margarite, especially about the edges of the lenticular masses. Grains of corundum are said to be found in the talc rocks sometimes. This locality is still worked, and is the only productive emery mine in the United States.

A few years after the discovery of emery at Chester, corundum was found in brown, scaly vermiculite associated with asbestos and other amphibole minerals in Pelham, Massachusetts. Professor B. K. Emerson informs me in a private letter that olivine rocks are also found here, and that the occurrence is very similar to the corundum localities of North Carolina. This locality has thus far proved of only mineralogic interest, however.

In the numerous serpentine localities of the State, no corundum has been found.

b. CORUNDUM IN NORTH CAROLINA.

We come now to a more detailed consideration of the corundum localities of North Carolina. In a general way, these are all indicated on the map (plate I), except those of Gaston and Guilford counties; and in the following enumeration of localities the peridotite belt will be considered first—beginning with the southwest-erly corner of the State—and afterwards, the localities east of the mountains.

CORUNDUM IN CLAY COUNTY.—One mile south of Elf postoffice, on Shooting creek, and five miles southeast of Hayesville, peridotite occurs within about a mile of the Georgia line, and corundum is found associated with it in its most southerly outcrops, on the property of W. C. Ledford. It occurs here in "sand veins" in scaly vermiculites; and, a little further north, it occurs in feld-

spar veins and green chlorite, on the land of Samuel Hogsed. On the same place, it is found in feldspar, associated with zoisite, forming considerable masses; also in rounded nodules with rhombohedral parting (as in figures 1 and 3) highly developed, and covered with a very variable coating of white compact mineral (margarite?) which has undoubtedly been formed from the alteration of the corundum. Sometimes only small grains remain in the center of the nodules, while the coating has developed to great thickness.

About Elf, are found outcrops of the bright green amphibolite; and one place near the postoffice by the roadside, shows beautiful red corundum plates and grains, also having the rhombohedral parting. Sand corundum and the massive variety with feldspar were obtained in the Behr mine, at Elf. Corundum has been found on the surface and ploughed up in fields along the continuation of this peridotite strip up Lick Log branch almost to the gap between this and Tusquittah creek.

Except a few loose surface fragments near Shooting creek postoffice, no corundum has been found along the strip of dunite and talc that passes across the head-waters of Shooting creek, till it reaches the slopes of Chunky Gal mountain at Newton Penland's. From this point it has been found all the way up the mountain side to about half a mile east of the summit, where it narrows to very small dimensions and finally disappears. The occurrence in feldspar predominates toward the point of this outcrop, and this mode is found along with the sand veins and crystal corundum on the mountain side also. A decomposed amphibolite, bearing corundum disseminated through the mass in small grains, is now being extensively prospected near Penland's, and encouraging results are reported.

About three miles from Shooting creek postoffice, on Thumping creek, at Curtis Ledford's, is the corundum locality in gneiss described above under modes of occurrence (p. 61). Corundum is found here in rounded nodules in the gneiss and in veins of black mica; and is also developed in vermiculite beside one of the hypersthene dikes. Some work has been done here, and portions of the rocks exposed are quite thickly studded with corundum.

At the head of Muskrat fork of Shooting creek, and about half way up the side of Chunky Gal mountain, corundum is found in garnet rock and brown scaly mica. This is also described above under the occurrence of corundum in gneiss (p. 61). This was being prospected at the time of my visit in the summer of 1894, and the work is said to have been resumed again this year (1895).

The only remaining deposit in Clay county is that with the great peridotite mass at Buck creek. The corundum mined here is found in veins of coarse feldspar and hornblende near the eastern edge of the peridotite. In fact, only a few feet of these rocks intervene between the corundum-bearing vein and the gneiss. Some corundum is also found in the vermiculite and chlorite that are developed through joints of the peridotite on the hillside west of the creek; and some is found here also in feldspar associated with zoisite and margarite. Portions of the bright green amphibolite at this locality are quite full of corundum; this is especially true of that on top of the mountain west of the creek, where the ground was covered with fragments of this rock; but many of these have been collected and hauled to Corundum Hill to be crushed and separated. The locations of the corundum workings at this place are represented on the map (plate III, page 34).

CORUNDUM IN MACON COUNTY.—I have visited and located on the map a great number of peridotite and soapstone outcrops in the valley of the Little Tennessee river above Franklin; but, so far as I was able to learn, corundum has been found at only one of those places. A number of them show considerable development of chlorite, and a little careful search in such places might be well repaid. The locality referred to is at the head of Hickory Knoll creek, at an elevation of about 4000 feet, on the western slope of Fish Hawk mountain. A number of small dunite outcrops are found here, most of the blocks exposed near the surface having a well developed radial enstatite casing. Some corundum has been found in small encased nodules.

Six miles southeast of this, and just south of mount Scaly, corundum is found in small crystals and grains with outcrops of soapstone and a fibrous, asbestos-like mineral. Radiating casings

of talc here enclosing an ochreous earthy material doubtless represent the peridotite, which does not appear on the surface.

The next corundum region encountered lies seven miles east of Franklin, just north of the Cullasaja river, and included between its tributaries, Ellijay and Walnut creeks. On this, one of the most prominent western spurs of the Cowee mountains, are found more promising corundum localities than in any other region of equal area within the State, or indeed, in the whole Appalachian crystalline belt. At the southern point of this spur is Corundum Hill, the most widely known mine, and the one that has furnished by far the greater part of American corundum since the beginning of the industry. A map (plate IV,) and description of this place are given under the head of the distribution of peridotite (p. 36), and a sketch of its history will be found beyond.

It is entirely unnecessary to add anything further here about the occurrence of corundum at this place. In this region, having a total area of less than twenty square miles, there are at least fifteen outcrops of peridotite; and corundum in greater or less quantity has been found associated with nearly all of them. Considerable prospecting has been and is now being done, and a great deal of capital has been invested there within the past three years.

Corundum has been found and some prospecting done in the gneiss on the summit of Turkey knob, on the Macon-Jackson county line, and fine specimens of red corundum are found in the gravels of Cowee creek. Well formed crystals are also found at Nona postoffice, seven miles west of Franklin, in the soil of gneiss.

CORUNDUM IN JACKSON COUNTY.—Loose fragments and crystals of corundum have been found at Addie, on the ring of peridotite that lies northeast of Webster, (see (plate V, p. 38.) but prospecting has not yet located any important deposit in place. Good specimens of red corundum are found in gravel beds on the headwaters of Cullowhee creek.

On Caney Fork, two miles above its mouth, corundum is found in the chlorite schist in the manner described on page 57, on Mrs. Chastain's place and at Marion Long's. By digging a very shallow pit, a width of eight feet of this rock was exposed which was thickly studded with nodules of corundum. On Johns creek,

half a mile above its junction with Caney Fork, a chlorite schist outcrop occurs with a width of about a thousand feet. Corundum is said to be found in fragments over the surface, but no prospecting has been done.

At the mouth of Chastains creek, five miles up Caney Fork, corundum is found in the gneiss near the residence of W. W. Brown. It is in nodules one-half to one inch in diameter, and surrounded by a thin, compact casing. Two miles up Chastains creek, corundum is found in the same manner in the gneiss, near a belt of chlorite schist. At many points along Caney Fork, corundum is reported to be found in the fields and elsewhere over the surface. So far as I was able to learn, corundum has been found in only one place on West Fork, and that in association with a chlorite rock on Shoal Creek mountain, four miles north of Glenville.

South of Sapphire, corundum is found with peridotite on Snake ridge at several places; and on the lands of Dr. C. Grimshawe, near Montvale postoffice, in both Jackson and Transylvania counties.

At the Sapphire mines, corundum is found in similar associations in a great number of places on both sides of Hoerspature river, and on the spurs of Great Hogback mountain. Several of these localities have been mined by the Sapphire Valley Company, and have yielded considerable quantities of corundum for the market. In a number of the outcrops, enstatite rock predominates, though more or less peridotite may be seen in nearly all of them. The mutual relations of these two rocks at some of the localities, as at the "Sapphire" mine, is such as to strongly point to the derivation of the enstatite from the olivine.

Besides a number of places that have been prospected, the following localities have been mined, to a greater or less extent, and constitute jointly the Sapphire mines. I am indebted to Mr. Charles N. Jenks, the superintendent, for the characterization of the product of the different workings.

The "*Burnt Rock*" mine is a mile and a half northeast of Great Hogback mountain, and produces nodular, massive corundum.

Some of the blocks taken out weighed as much as twenty-five pounds.

The "Brockton" mine is about a mile south of the Burnt Rock, and its product is a dull gray crystal corundum, which is easily separated from the vermiculite gangue.

The "Rattlesnake" mine is a mile and a half southwest of Great Hogback mountain and about the same distance northeast of Sapphire. Crystal and sand corundum are found here in chlorite and vermiculite about the borders of the enstatite rock.

The "Sapphire" mine is somewhat less than a mile northeast of Sapphire, and near where the Brevard road crosses Big Hogback creek. The product of this place is crystals and masses of white and gray corundum specked and mottled with blue.

The "Socrates" mine is half a mile south of Sapphire, on the north end of Bear Pen mountain. The corundum here is neither in crystals nor masses, but occurs in "shotty" nodules in the chlorite veins through enstatite rock. This furnishes the most perfect grain produced by these mines, and is well adapted to the manufacture of either cement or vitreous wheels.

The "Bad Creek" mine is on the west side of Bear Pen mountain and about half a mile from the Socrates mine. The corundum here is massive, and occurs with chlorite, margarite, garnet, biotite, feldspar, and a number of rarer minerals, forming a hard, tough vein. Mr. Jenks informs me that corundum constitutes about 35 per cent. of the whole mass, but that it is very difficult to separate it thoroughly from the gangue.

The "Whitewater" mine is about six miles southwest of Sapphire, on Whitewater river. The corundum occurs here in colored crystals, possessing some gem characteristics, and producing a good solid grain.

All of the localities enumerated lie near the Jackson-Transylvania county line, and the first three are situated in the latter county. A number of intermediate outcrops have been prospected a little, and still others yet remain untouched.

CORUNDUM IN TRANSYLVANIA COUNTY.—The Sapphire mines "Burnt Rock," "Brockton," and "Rattlesnake," described above, are located in this county, on the spurs of Great Hogback mountain.

Corundum is said also to be found with enstatite rocks in the same vicinity, on the headwaters of the Toxaway river.

On the West fork of the French Broad river, I saw corundum with similar rocks on the hill just west of the mouth of Owens creek. A number of shallow pits had been dug in prospecting, and large masses of margarite had been thrown out, bearing corundum and black tourmaline. Asbestiform minerals are also found at the same locality.

A large number of similar outcrops are found to the eastward and northeastward, and corundum is said to occur with some of these on the North Fork of the French Broad river; but I was unable to verify these reports, owing to the profound air of secrecy maintained by the alleged discoverers.

Near the mouth of Owens creek, east of the corundum locality described above, a number of large boulders of disthene (cyanite) have been found on the surface, bearing grains and crystals of deep sapphire-blue corundum. The rocks at this locality are ordinary gneiss.

CORUNDUM IN HAYWOOD COUNTY.—On Pigeon river, at Retreat postoffice, six miles southeast of Waynesville, corundum is found with cyanite and margarite in crystals scattered through the soil. The rocks are garnetiferous mica schist and gneisses, and no deposit has yet been found in place.

Three miles northeast of Canton, corundum has been found on the surface with an outcrop of dunite, but no workable deposit has been discovered. A mile north of this, at the "Presley mine," corundum occurs in pegmatite veins through dark green hornblende rock. The corundum occurs both in the mica and the feldspar of the pegmatite, and is sometimes wrapped in margarite. It often has the appearance of having altered into these minerals.

Just south of Newfound gap, red corundum is found on the surface about a small lenticular mass of dunite. It is also reported from a soapstone outcrop near the gap between Cabes and Crabtree creeks.

CORUNDUM IN BUNCOMBE COUNTY.—Just south of the Carter mine, near the Madison county line, corundum is found about Democrat

with the long strip of peridotite which crosses Big Ivy river at this place. The Carter mine is in Madison, and very little prospecting has been done in Buncombe.

At Swannanoa gap, on the eastern border of the county, corundum is occasionally found in masses of cyanite.

CORUNDUM IN MADISON COUNTY.—The Carter mine is very near the Buncombe county line, in the eastern end of the county, and is situated on Holcombe branch, a tributary of Little Ivy river. It is at the north end of the strip of dunite which is continuous from Morgan Hill, in Buncombe county. The corundum here occurs in a vein of chlorite and vermiculite which is developed at right angles to the lamination of the peridotite. It is in masses of white, pink, and blue colors, and is intergrown with greenish black, massive spinel and feldspar.

Recently, Mr. John A. Carter, of Democrat, has found a crystal of mottled blue and white corundum weighing 46 pounds. It is hexagonal in form, though rough and irregularly broken, and has the rhombohedral parting well developed. It was found loose above the Carter mine in a small stream very near its head, but search failed to discover its source.

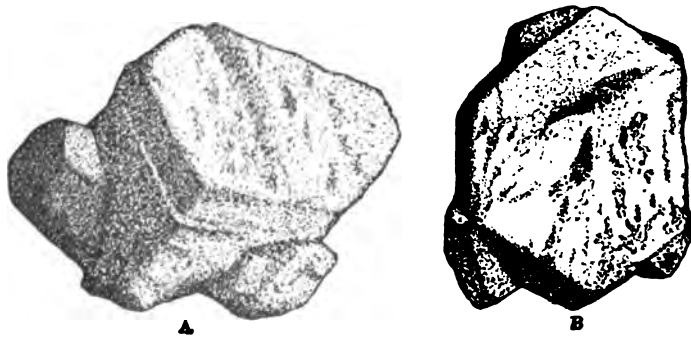


Fig. 7. Hexagonal crystal of corundum showing rhombohedral twinning. A, oblique view; B, end view; one-fourth natural size; weight 17 pounds. From an amphibolite outcrop half a mile north of the mouth of Ivy river, Madison county. (Specimen in possession of Mr. G. C. Haynie, Marshall, N. C. Figure drawn from photographs.)

The first corundum found in North Carolina was picked up from the surface three miles below Marshall, just above the mouth of Little Pine creek. A belt of soapstone and peridotite crosses

the river near this point, but the locality has never furnished a second specimen, so far as I was able to learn.

Three miles above Marshall and half a mile north of the mouth of Big Ivy river, corundum is found in large gray crystals on the surface of a large hornblende outcrop. One crystal from this place (figure 7), which weighs 17 pounds, and exhibits fine rhombohedrol twinning, is in possession of Mr. G. C. Haynie, of Marshall, the owner of the property.

CORUNDUM IN YANCEY COUNTY.—The principal corundum locality of this county is that known as the "Egypt (or Hayes) mine," ten miles west of Burnsville, on the western slopes of Sampson mountain. Corundum occurs in green chlorite along the borders of dunite and enstatite rock, the latter predominating. It is generally in distinct crystals, though granular masses are also found. The prevailing colors are white and banded or mottled blue and white. The corundum imbedded in dunite (figure 5), and the crystal shown in figure 3 are from this locality.

Eight miles southeast of Burnsville, on Celos Ridge, near South Toe river, corundum is found in crystals of two or three inches in diameter in the decomposed gneiss adjoining an outcrop of enstatite rock.

CORUNDUM IN MITCHELL COUNTY.—Three-fourths of a mile west of Bakersville, corundum crystals are found in the gneiss at William Bowman's. I also saw fragments of corundum on the surface and in the dump a mile and a half up White Oak creek from Bakersville, where work had been done for asbestos. The rock is a massive enstatite with fine radiating borders similar to those found about dunite in many places.

Since my visit to this region, Mr. D. A. Bowman, a local mineralogist, of Bakersville, writes me that "one mile due east from Bakersville, a massive blue corundum occurs, with now and then a hair-brown piece." He further states that in the summer of 1888 he obtained about 600 lbs. at this place, one piece of which weighed 23½ pounds. "Some small blue crystals found at this place would cut very nice gems were it not for cleavages."

No corundum has yet been found in North Carolina north of Bakersville.

CORUNDUM IN IREDELL AND ALEXANDER COUNTIES.—The country rock in these counties is ordinary gneiss, and surface specimens of corundum are found scattered over a large number of localities, especially in Iredell. Grayish masses are found several inches in diameter, and the smaller ones frequently have crystal form. All are more or less altered, and most of the specimens have a sheath of compact damourite or margarite, (figure 8) which is sometimes developed to such an extent that only a trace of the original corundum remains in the interior.

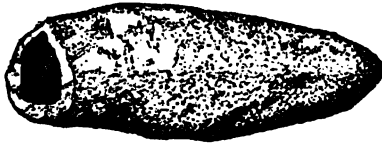


Fig. 8. A tapering crystal of black corundum enclosed in a sheath of compact margarite. One-half natural size. From Belts bridge, Iredell county. (Drawn from a photograph.)

In the alluvial deposits first worked by the Acme company at Statesville, blue and pink corundum was found in clays and sands, either in small loose pieces or in masses with cyanite. On passing through the clays and gravels, a massive hornblende rock was encountered, and a little search discovered a vein of feldspar bearing corundum and separated by vermiculite from the hornblende rock through which it passed. In its widest place, this feldspar-corundum vein had a thickness of two and a half feet, and was very rich in corundum.

The only other locality where corundum has been found in place in this region is eight miles northwest of Statesville, and just north of the Charlotte and Taylorsville railroad, on the Hunter place. Here no such alluvial deposits were encountered, and the amphibolite is of much finer texture than that at Statesville. But otherwise, the occurrence is very much the same. The corundum is almost coal-black and is associated with feldspar and vermiculite in the joint system of the rocks, much in the same manner as that found in some of the dunite localities of the mountain region. The mode of occurrence is described and illustrated

(figure 6) on page 93. Near this place, large masses of corundum with margarite are found on the surface. The soil and decomposed rock are so deep over this region that very little can be determined about the form or extent of these amphibolites. Only occasionally does a stream or a wash in the hill side offer an exposure of rock that may be readily recognized.

CORUNDUM IN BURKE AND CLEVELAND COUNTIES.—I am indebted to Mr. H. B. C. Nitze for the following notes in regard to the occurrence of corundum along the borders of Burke and Cleveland counties, near the corner of Catawba. The rocks of the region are highly garnetiferous, gneissic, mica schist. Grayish blue, tapering corundum crystals are found on the surface along the ridge leading northwest of Carpenters knob. On the waters of the South Fork of the Catawba, in Burke county, corundum of a similar nature is found in "pockets" containing from one to two hundred pounds. Monazite is found in the placers of the streams. Dr. Genth mentions "crystals of corundum surrounded by fibrolite" from this locality.*

CORUNDUM IN GASTON COUNTY.—Corundum was discovered in this county at Crowders, Chubbs, and Kings mountains by Dr. C. L. Hunter, about forty years ago. It was found in masses and six-sided crystals "in place—associated with mica and quartz aggregate." Margarite was found with it; and, in places, by the gradual introduction of iron oxids, a transition to granular emery was observed. No large quantities have been found here, and thus far, the discovery has proved of only mineralogic interest.

CORUNDUM IN GUILFORD COUNTY.—In the titaniferous iron ore belt that traverses the northwest corner of Guilford county, Dr. Genth found true emery at the McChristian (or McCuiston) place, seven miles north of Friendship. One variety was reddish, granular, and had "much the appearance of a granular reddish brown garnet, for which it has been mistaken, until the analysis proved it to be not a silicate, mixed with granular magnetite, but *corundum*." Another, found in the same locality was grayish in color;

*Bulletin 74, U. S. Geological Survey, 1891. The Minerals of North Carolina, page 30.

and "the minute crystals of corundum have a yellowish or brownish white color, and show in many places cleavage fractures, which give it the appearance of a feldspathic mineral."*

The following analyses of these varieties are given in the same place.

Analyses of Emery from the McChristian place, 7 miles north of Friendship, Guilford county.

	REDDISH BROWN.	GRAY.
Silica.....	1.39	0.98
Titanic acid.....	0.78	2.42
Magnetic iron oxid.....	42.77	46.29
Oxid of Manganese and Cobalt.....	1.00	1.27
Chromium oxid.....	0.30	trace
Alumina.....	52.24	44.86
Magnesia.....	0.68	3.27
Lime.....	0.84	0.91
	100.00	100.00

CORUNDUM IN OTHER LOCALITIES.—In the report of the North Carolina Geological Survey for 1875, large hexagonal crystals of corundum are reported from Forsyth county (page 299), and a reddish variety from Polk (Appendix page 65). Small particles are also said to occur in cyanite in Wilkes county; and Dr. Genth says that "rarely small remnants of corundum are found in the pyrophyllite slates of Chatham county." He also mentions the locality of Valley river in Cherokee county for corundum, and says that emery is found near Salem, Forsyth county.† I have not yet had an opportunity to verify these reports, but hope to do so before publishing a final report on this subject.

(6.) METHODS OF PROSPECTING FOR CORUNDUM.

The early discoveries of corundum in North Carolina were not the result of any systematic search; in fact, corundum, as it is now known in this State and Georgia, was not then a commer-

*Report of the Geological Survey of North Carolina, I., 1875, pages 245, 246.

†Bulletin 74, U. S. Geological Survey, 1891, pages 29-31, 96.

cial mineral, and nothing was known of its occurrence with peridotite. Accidental finding of surface fragments led to the discovery of extensive deposits; and the subsequent working of these and other localities has given to mineralogy and mining a great fund of information on this subject that is to a large extent entirely new. As usual in the case of things new, many mistakes were made in early prospecting and attempts at mining. Mistakes are made yet, and they will doubtless continue for some time to come, but many of the earlier errors need not be repeated if due regard is had to the store of information that has been accumulated by more than twenty years of experience.

Those who would search for corundum had best see, first of all, an actual corundum mine or a place where prospecting has been done and corundum found; and note carefully the conditions. In the southwestern portion of the State this may easily be done without great inconvenience. If the preceding pages have been read, or even a small portion of them, it will already be understood that conditions are rarely duplicated exactly, even in localities very near together. Certain types of rocks and minerals, however, may be observed in the greater number of them; and these may be profitably used as guides in searching for new localities. Of course the prospector must be able to recognize corundum itself in all of its common forms.

Loose fragments of corundum in the soil or stream beds are, of course, the surest "signs" of corundum deposits, though not always the most easily traced to their origin. The extreme resistance of the mineral to the ordinary process of abrasion and decomposition render it almost indestructible when exposed on the surface. Hence, it may be transported for great distances down the mountain slopes and streams without showing any appreciable alteration and but little wear. When associated with fragments of peridotite, chlorite, or talc, the corundum is a much more valuable guide. In such cases, it has probably been transported only a short distance, and the search for the source becomes far less difficult. Where no corundum is found with

the rock fragments or minerals indicated, and none is found by panning the soil or sand, as in the ordinary search for gold, there is little encouragement to seek further.

The "indications" are followed up the grade by which they would most naturally have reached their present position: If in a stream bed, the search is made up the stream or its tributaries till fragments are no longer found, and then up the adjoining hillsides till the parent mass of peridotite is reached. The borders of this rock are first examined. If the border is not readily found by inspection, ditches are cut through the soil and decomposed surface materials at right angles to the strike of the country rock. The chlorite and vermiculite along the contact between the gneiss and peridotite should then be examined for corundum. A ditch, passing completely through the soil, should follow this contact zone; and, at intervals, shallow pits or cuts should be sunk to disclose the nature of the deposit. Where no encouraging development is found about the borders, it may be worth while to cut ditches across the peridotite mass for the examination of the joint zones; but these are usually less developed than those about the borders.

Margarite is found abundantly with corundum in some places, but in the majority of the North Carolina localities, this is not true, and its discovery usually follows, rather than precedes, that of the corundum. The emery mine at Chester, Massachusetts, however, was discovered by the finding of this mineral, and, when found, it is to be regarded as a good "indication."

Obviously, the points given above apply chiefly to corundum associated with peridotite. It is found, however, in a number of other associations in the State, and several of those in amphibolite and gneiss give promise of becoming of commercial importance. For these occurrences, there seems to be no important index, except to find the corundum itself. When it is developed in considerable quantity, there should be no difficulty in finding it in the soil and in the gravels of the adjacent streams.

In some cases, where chlorite and vermiculite are found abundantly on the surface, it may be advisable to trace them to their origin, even though corundum may not be found floating

in the soil with them. Corundum itself, however, is the only sure indication of new deposits, and other guides, though often of valuable assistance, should be regarded as pointing only to *probabilities*.

An ordinary wash-pan, or even a shovel, will serve very well in examining the gravels or soil; and any one may readily determine for himself whether corundum occurs in a given locality. By a little practice, all the heavy minerals in the soil or gravel may be shaken to the bottom of the pan and the lighter materials washed off over the edge. The heavy minerals will be found usually to contain grains of magnetite, garnets, dark hornblende, and corundum, if any is present.

Finally, however good the indications, even from the presence of corundum itself, no extravagant anticipation or large investments are justifiable till the deposit has been thoroughly explored by intelligent prospecting. Had this truth been borne in mind, trite as it may seem, much disappointment and financial loss would have been avoided and the mining reputation of the State saved many serious blows.

(7.) MINING AND CLEANING METHODS.

Twenty-five years ago, the corundum fields under consideration were entirely new to the mining world. Corundum itself, as a commercial article was scarcely known except in the forms of emery and the gems; as an associate of peridotite, it was not even known to mineralogy. There were no precedents in mining, and every step was evolved by the slow and expensive process of experiment. Undue excitement had been created by the finding of a few gems, and the idea that corundum might be profitably mined as an ordinary abrasive had scarcely been conceived.

Under these conditions, the first undertaking (at Corundum Hill) was naturally a failure. A hydraulic method with short sluice systems was adopted for working the corundum-bearing soil and gravels, and some of the chlorite zones were opened. Only the larger crystals and promising gem materials were saved.

With the exception of the gems, the product was sold for cabinet specimens and for the manufacture of dental appliances; but the work was soon found unprofitable. The concentrated gem-bearing gravels were exhausted, and the mine abandoned.

Two great mistakes were made in this early work; first, too much importance was attached to gem mining; and, second, the smaller fragments, or "sand-corundum," which afterward became the most important product, were allowed to waste. Prospecting, and some small attempts to mine in other localities during the next few years, soon demonstrated the scarcity of true gems. When Dr. H. S. Lucas reopened the work at Corundum Hill, it was purely for the purpose of mining corundum as an abrasive, and methods were adopted for saving the whole product of the mine. On this basis, the work has been successfully continued to the present time, not even closing down entirely during the panic of 1893 and 1894.

MINING METHODS.—Naturally, the methods of work adopted in the few places that have really been mined, as distinguished from prospecting, have varied greatly, according to location, character of material, and other variable conditions. The area under consideration is located entirely in the mountainous and hilly districts of the western part of the State, and the outcrops are usually on high ground, with abundant natural drainage. These conditions and the nature of the border zones of chlorite and vermiculite, which are the principal deposits worked, have led to the adoption, in the majority of cases, of open cuts and drifts.

So long as the work is confined to the comparatively superficial portions of the deposit, the open cut is the most advantageous. But, with increase in depth, the jointed peridotite, with its great development of slippery magnesian minerals along the cracks, is exceedingly liable to fall in. Such cuts at Corundum Hill, at a depth of twenty to thirty feet, have loosened great masses, and have sometimes produced cracks in the surface at a considerable distance from the working. These are a continual menace to the miners; and, in a few cases, they have slipped into the cuts, though without more serious result than to stop the work.

The same trouble, though to a less degree, is sometimes experienced in drifts, and it is very difficult to timber the workings in such a manner as to be perfectly safe. Much of this trouble, however, is really due to unsystematic work and employment of unskilled men. After the work in open cuts had been rendered impracticable at Corundum Hill, the mining was continued by drifts. In one place, several of these have been driven, one above another, in the same vein.

In a few localities, small shafts have been sunk, but generally, this is done only where the configuration of the surface is not favorable to cuts and drifts. The expense of hoisting and pumping incurred in shafts is probably the chief objection to them.

The material handled, in the great majority of cases, is loose, scaly chlorite and vermiculite with corundum disseminated through it, and is easily removed with a pick and shovel. In solid feldspar veins, however, as in some of the Sapphire mines, and at Laurel Creek (Ga.) and Buck Creek, blasting has to be resorted to, and afterward the material crushed for cleaning. One of the drifts at Corundum Hill is now being cut through the gneiss wall adjoining the peridotite. It is very hard and thickly impregnated with corundum, and must, of course, be removed by blasting. In removing the material from the mines, hand cars and wheelbarrows are employed. It is then, according to its nature, dumped into wagons or sluice-troughs to be carried to the mill for cleaning.

METHODS OF CLEANING.—The prime object of all methods of cleaning corundum is, of course, the removal of all impurities as completely as possible; for any other mineral that is ever found in association with corundum, though it may be very hard itself, is always softer, and if left with it in considerable quantity, will appreciably reduce its abrasive power. But the mere removal of impurities is not the only point to be considered in devising methods of cleaning. This must be done with the least possible injury to the cutting power of the corundum grains. The sharp edges attained by crushing must not be ground off, and no large percentage of it should be lost by reducing it to "flour."

Owing to the high specific gravity of corundum, it can be effectually separated from most of its associated minerals by washing methods in many ways similar to those adopted in placer mining for gold. Where the corundum occurs loose in chlorite and vermiculite scales, little other treatment is necessary; but, when it is enclosed in a tough gangue of feldspar, margarite, and other minerals, or is a constituent of a solid rock, as in the gneiss and some of the amphibolite occurrences, the minerals must be thoroughly broken apart before separation. For the accomplishment of this purpose, the abrasive power of the corundum itself is used, by scouring the crushed material together, so that the particles cut the softer minerals from each other. All cleaning methods, then, involve the three processes, crushing, scouring, and washing. The means by which these processes are applied may be best understood by descriptions of concrete cases.

Methods of cleaning Corundum at Sapphire.—I am indebted to Mr. Charles N. Jenks for the following outline of methods adopted by him at the Sapphire mines.

With crystal corundum, which is found in loose, scaly vermiculite, only the simplest treatment is necessary. It is placed in a box through which flows a strong current of water, and stirred vigorously with hoes. The scaly minerals float off with the current, leaving the corundum about 95 per cent. pure; and this requires only crushing and sifting into sizes to prepare it for the market.

But with every other variety of corundum, the separation of impurities is more difficult and the methods of treatment correspondingly more complicated. The material is first broken into coarse grains by passing through crushers and rolls. In this process, much of the adhering impurities is broken loose; and this may be partly removed by the gravity process described above; that is, by stirring in a strong current of water. It is then passed through a machine in which a coarse worm, like a screw-conveyer, is carried on a revolving shaft. In this the adhering minerals are cut away by the grinding of the corundum grains upon each other; after this it is again subjected to

the gravity treatment in a strong current of water. The last process, and one by which the corundum is brought to a high degree of purity, is in a machine called the "muller", or "chaser". In this machine, two heavy wooden rollers move around the circumference of a shallow tub. The partially cleaned corundum is thrown into this tub, and is stirred constantly by iron teeth that move in front of the rollers. Being thus alternately stirred up by the teeth and pressed down by the rollers, a scouring motion is continually kept up between the grains, and the impurities are gradually cut away. In this action, the impurities are reduced to the form of a fine powder, and are carried away by a small current of water which continually flows through the tub. This process is continued from three to five hours, according to the difficulty of cleaning and the degree of purity required.

Methods of cleaning Corundum at Corundum Hill.—Two classes of material are produced by this mine; namely, the sand corundum (and crystals) contained in the vermiculite and chlorite developed along the borders and in the joints of the peridotite; and the contact gneiss impregnated with corundum. Each of these requires its special mode of treatment.

Until recently, the sand corundum veins were the only deposits worked at this mine. All of the material of this class is sent from the mine to the mill, a distance of a mile and a half, in a small trough carrying a swift current of water. In this course, there are several vertical drops of five to ten feet to facilitate in breaking loose the scaly minerals adhering to and enveloping the corundum. At the mill, all material that will not pass through a screen of 14 meshes to the inch is crushed between rolls and passed, with the originally fine material, to the gravity boxes, or sluices, where it is vigorously stirred in a strong current of water. It is then treated in mullers, as in the process described above.

The gneissic material comes from the mine in hard, tough blocks, sometimes quite large, and is hauled to the mill on wagons. A very primitive method is adopted for breaking the large blocks into sizes suitable for the crushers. A fire is built over them till they are heated through, and then they are suddenly cooled by throwing on water. Fortunately, only a small part of the product

requires this treatment. It is then passed through crushers and coarse and fine rolls till it will all pass through meshes 14 to an inch. It is then subjected to a scouring action in the auger-like machine described above, and passed on to the gravity boxes. The final cleaning, as in the other case, is given by the mullers.

The method of drying in use at Corundum Hill is also worthy of notice. When the material is removed from the mullers, it is allowed to lie over night in a heap on an inclined floor. This material, still wet, is carried up in an elevator and dropped vertically through a distance of about twenty feet down the stack of a furnace. At the bottom of this, it strikes an inclined plane and slides down this for a few feet through the flames of a wood fire. By this time it is thoroughly dry, and is passed into a chamber beneath, whence it is removed with shovels and subjected to a final sifting. All material not fine enough to pass through a screen with 14 meshes to an inch is again passed through the rolls, and the entire cleaning process is repeated.

The corundum thus cleaned is shipped to the company's mills at Chester, Massachusetts, where it is further crushed and sorted into sizes for the market. The coarser numbers are also passed through magnetic separators for the removal of the magnetite.

7. HISTORICAL SKETCH OF CORUNDUM MINING IN AMERICA.

The following chronological outline of the principal discoveries and the development of corundum mining in the eastern United States has been compiled from the sources enumerated in the bibliography at the end. In the main, these sources are considered reliable, and it is believed that the outline here presented indicates with tolerable accuracy, not only the origin of the corundum mining industry, but also the growth of our knowledge of corundum in many of its most important mineralogic and geologic relations.

Besides the enumerations of discoveries, I have given short

sketches of all the corundum mines, properly so called, in North Carolina.

(1.) DISCOVERIES AND EARLY DEVELOPMENTS.

So far as I have found in the literature on the subject, corundum was not known in America before 1819. In that year, Mr. John Dickson, a teacher, of Columbia, South Carolina, sent Prof. Silliman a lot of minerals which he had collected on a tour through the Carolinas. Among these was a regular, six-sided crystal of blue corundum three-fourths of an inch long and one inch in diameter, with parting and striae developed similar to the East Indian corundum. It was sent without label, and in reply to an inquiry as to its locality, Mr. Dickson writes: "I think it was Laurens district; at all events, it was picked up by my own hands, if not *in situ*, in a placewhich it could have reached only by one of the usual and natural accidents which displace minerals of all kinds..... I am sure it is American and Carolinian." ¹

In 1822, both Edward Hitchcock and Parker Cleaveland described the mass of cyanite found at Litchfield, "associated with talc sulfuret of iron, and corundum.....supposed to weigh 1500 pounds." The corundum was massive and in six-sided prisms, of a dark grayish blue color, and imbedded in the cyanite. Both of these authors attribute their information to Mr. John P. Brace. ²

In April, 1827, at a meeting of the Lyceum of Natural History, New York, "Major Delafield.....exhibited crystals of Sapphire from Newton, Sussex county, New Jersey." ³ In 1832, Dr. Fowler described this locality, pointing out the geologic and mineralogic relations of the corundum. It is found along the border of crystalline limestone. ⁴

According to Mr. W. W. Jefferis (as quoted by Mr. Joseph Willcox) John and Joel Bailey claim to have discovered corundum in the serpentine region of Chester county, Pennsylvania, about 1822 to 1825. Dr. Thomas Seal collected specimens at

¹Am. Jour. Sci., 1, III., 1821, 4, 229, 230.

²Am. Jour. Sci., 1, VI., 1823, 219; Cleaveland's "Mineralogy and Geology," Boston, 1822.

³Am. Jour. Sci., 1, XIII., 1828, 380.

⁴Am. Jour. Sci., 1, XXI., 1832, 319, 320.

Unionville about 1832, and Mr. Jefferis himself saw large lumps in the fields there in 1837 or 1838.¹ A ton of surface fragments and boulders was collected about 1839 and shipped to Liverpool. But the search for the source of this material was unsuccessful till 1873, when a large lenticular mass was found in place. This consisted chiefly of corundum and margarite and carried some fine specimens of diaspor.²

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

The first discovery in North Carolina was a large detached block of dark blue, laminated corundum, found three miles below Marshall, in Madison county, in the spring of 1847. Gen. T. C. Clingman, after considerable search, found another piece in the same vicinity in 1848—about a year before the first discovery of emery in place in Asia Minor by Dr. J. L. Smith.³

In 1852, Mr. W. P. Blake described corundum from the new locality at Vernon, Sussex county, New Jersey.⁴ In the spring of the same year, Dr. C. L. Hunter discovered corundum and emery in place in Gaston county, North Carolina.⁵

In 1864, the occurrence of emery at Chester, Massachusetts, was predicted by Dr. C. T. Jackson from his discovery of margarite there—a mineral which Dr. J. L. Smith had just found characteristic of the emery deposits of Asia Minor. On September 6th of the same year, Dr. H. S. Lucas discovered the emery in what had before been considered only deposits of magnetic iron ore.⁶ Two years later, distinct crystals of corundum were found in the same deposits.⁷ This discovery of emery soon led to the establishment of active mining, the first of its kind in America. This mine is still worked, though it has not been operated continuously from the beginning.

In 1870, Mr. Hiram Crisp found the first corundum that attracted attention to the present mining regions of North Caro-

¹*Id* Geol. Sur. Penn., C4, 1883, 348-351.

²*Id* Geol. Sur. Penn., B, 1875, 31-33.

³Bull. 74, U.S. Geol. Sur., 1891, 283-1.

⁴Am. Jour. Sci., 2, XIII., 1852, 116.

⁵Am. Jour. Sci., 2, XV., 1853, 376.

⁶The exact date was furnished me by Dr. Lucas in a private letter.

⁷Am. Jour. Sci., 2, XXXIX., 1865, 37-60; XLII., 1866, 421.

lina. This was found at what is now the Corundum Hill Mine—Mr. Crisp living there at the time. A specimen was sent to Professor Kerr, then State Geologist, for identification, and considerable interest was aroused on the discovery that it was true corundum. In the same year, Mr. J. H. Adams found corundum in very similar relations at Pelham, Massachusetts.*

In 1870-71, considerable activity was displayed in the search for corundum in the dunite regions of the southwestern counties of North Carolina; and new localities were soon brought to light in Macon, Jackson, Buncombe, and Yancey counties. In 1871, Dr. Genth also discovered the emery of Guilford county.† About this time, Mr. Crisp and Dr. C. D. Smith began active work on the Corundum Hill property, and removed about a thousand pounds, part of which was sold to collectors for cabinet specimens. Some of the masses weighed as much as forty pounds.

In the fall of 1871, the property was bought by Col. C. W. Jenks, of St. Louis, Missouri, and Mr. E. B. Ward, of Detroit, Michigan; and mining was soon begun under the superintendence of Col. Jenks.

In reply to my inquiry about the discovery of corundum in Iredell county, Mr. J. A. D. Stephenson, of Statesville, writes me as follows: "The first corundum found in Iredell county was found by myself near where the Collins (Acme) mine is now located, either late in 1874 or early in 1875. It was a mass weighing probably two pounds. I also found a lot of pink fragments near by." It was soon discovered in loose masses and crystals in many parts of the county, and small amounts have been found in Alexander, the adjoining county to the west.

(2) NORTH CAROLINA CORUNDUM MINES.

Mining proper, as distinguished from prospecting, has thus far been restricted to a few localities in the counties of Clay, Macon, Jackson, Madison, and Iredell. Extensive prospecting, however, has been done at a number of places which have come to be known

*Am. Jour. Science, 2, XLIX., 1870, 271, 272.

†Rept. Geol. Sur. of N. C., I., 1875, 246.

locally as "mines;" and more or less work has been done at nearly all the localities where corundum is known to occur in the State. Most of this has been done in the most primitive and unsystematic manner. Little pits are dug here and there, no deeper than a man may conveniently throw the dirt from with a shovel; and trenches are dug, apparently at random, in every direction over the surface about the peridotite outcrops. At few of the corundum localities enumerated, has the work been sufficient or of such a nature as would reveal the extent and value of the deposit.

Much has been learned, however, by the experience of a quarter century; and the prospecting of recent date has been more intelligently directed and the results correspondingly more satisfactory. To find that a place has been prospected and abandoned, however, is still not to be regarded as conclusive evidence that it is worthless; and I have no doubt that the work now under way, and that of the future will, in many cases, prove the correctness of this statement.

Short historical sketches of the following mines are given below:

- a.* The Behr mine, Clay county.
- b.* The Buck creek (Cullakanee) mine, Clay county.
- c.* The Corundum Hill (Cullasaja) mine, Macon county.
- d.* The Sapphire (Hogback) mines, Jackson county,
- e.* The Carter mine, Madison county.
- f.* The Acme mine, Statesville, Iredell county.

In the preparation of these sketches, I have had to rely partly on such information as could be gathered piecemeal here and there through the country; but chiefly, and especially in regard to the more prominent mines, I am indebted to the kindness of superintendents and mine-owners for most of the facts presented here. I would mention especially Dr. H. S. Lucas, who first placed corundum mining on a successful basis, and who has been identified with the industry for twenty years; and Mr. Charles N. Jenks, superintendent of the Sapphire mines, who was associated with his father, Col. C. W. Jenks, in the first work of the kind undertaken on a commercial scale. Valuable information

has also been furnished by Mr. A. M. Stoner, of Franklin; and, in regard to recent developments and prospecting, I am much indebted to Mr. L. S. Ropes, of Franklin, and Dr. C. Grimshawe, of Montvale. Mr. J. A. D. Stephenson, of Statesville, Mr. John A. Carter, of Democrat, and Mr. U. S. Hayes, of Bald Creek, have furnished important data in regard to the operations in their respective localities.

a. THE BEHR MINE, CLAY COUNTY.

This mine is located five miles east of Haysville, at Elf post-office, on Shooting creek. It was opened in 1880 by Dr. H. S. Lucas. It was afterward bought by Herman Behr & Company, of New York, and was operated till 1890. A steam cleaning plant was erected at the mine, and considerable work was done. Much of this was doubtless of the nature of prospecting, but I am informed that several car loads of cleaned corundum were shipped. The location of the mine in a low place by a branch necessitated the constant use of pumps for drainage. The nearest railroad is about twenty-five miles distant.

b. THE BUCK CREEK (CULLAKANEE) MINE, CLAY COUNTY.

In the report of the North Carolina Geological Survey for 1875, Dr. C. D. Smith states that he was the first to find corundum at Buck creek. Large loose blocks with feldspar and black hornblende were found on the surface. The first prospecting was done by Maj. Bryson about 1875; and two years later Mr. Frank Meminger worked for about six months and removed about thirty tons of corundum.

For a period of ten years no further operations were undertaken; then work was resumed by Mr. Ernst and continued for nine months, chiefly in the nature of prospecting. During another period of four years, the mine was idle; then operations on a liberal scale were begun by Mr. Gregory Hart, and continued for a year and a half, during which time a shaft was sunk on the feldspar vein and several open cuts made on the chlorite zones about the eastern border of the peridotite. Considerable quantities of corundum were taken out during this time, but

nothing was shipped. Most of the product, however, was in large massive blocks with feldspar and black hornblende, and there was no economic method of crushing and cleaning it.

In 1893, the mine was purchased by the Hampden Emery and Corundum Company (as it is now styled), and the material already mined was hauled to Corundum Hill and cleaned with the product of that mine. Since that time a little prospecting has been done in the chlorite zones, but no further mining has been undertaken.

The nearest practicable shipping point is forty miles away, but by the construction of a few miles of wagon road, another station could be reached within twenty miles. (See also page 69.)

C. THE CORUNDUM HILL (CULLASAJA) MINE, MACON COUNTY.

This mine is seven miles southeast of Franklin, on Cullasaja, or Sugar Fork of the Little Tennessee river. The postoffice is Cullasaja. It is well known, not only for being the first worked, but also as the most successful corundum mine of the whole belt. Since 1878, it has afforded a constant annual product of 200 to 300 tons of cleaned corundum. During 1893-4, the output was not so large, but the mine was operated continuously during a period when nearly every industry of the country was paralyzed.

The beginning of operations here in 1871, by Col. C. W. Jenks, has already been noted in the sketch of "Discoveries and early developments" given above. This first mining was chiefly for gems; and the work was done by a hydraulic process with sluice boxes, very much in the same manner as the process is applied to gold mining. The surface soil and loose vein material were washed through a series of sluices, or rather boxes, inclined about thirty degrees. The material was constantly stirred so as to allow the lighter minerals to float off, while the corundum and other heavy minerals remained in the boxes. The concentrated corundum thus obtained was then removed and carefully searched for gems. Transparent and translucent fragments of ruby-red, sapphire-blue, yellow, green, colorless, and other shades were found. Some of these cut good gems; but, unfortunately, they were

always small and the quantity too limited to make the business profitable.

The value of the so-called sand corundum was not then realized; and the only material put on the market, besides gems and cabinet specimens, consisted of the larger crystals and lumps. About one hundred tons of this corundum were mined, and sold for dental and other purposes in this country and Europe. This material, however, possessed a degree of purity scarcely attained in the later product of any of the mines. The average force employed in this work was about twelve men.

In 1878, Dr. H. S. Lucas, of Chester, Massachusetts, bought the mine at Corundum Hill for the Hampden Emery Company, and began operations in October of the same year. Profiting by the experience of his predecessors, Dr. Lucas confined his operations to the mining of corundum for abrasive purposes only; and all corundum found—whether sand, crystals, or lumps—was saved and worked into sizes together. The abundant water-power of the Cullasaja was early utilized for the operation of washing and other cleaning machinery; and thus the business was placed on a basis which has continued successful to the present time.

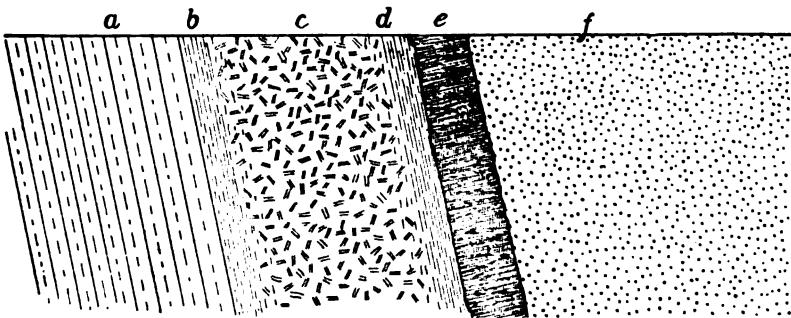


Fig. 6.—Diagrammatic section across the corundum-bearing zone between gneiss and peridotite. Corundum Hill, Macon county. *a*. Gneiss, sometimes bearing corundum near the border; *b*. Schistose talc, chlorite, and vermiculite; *c*. Chlorite and vermiculite in interlocking crystalline plates with disseminated corundum; *d*. Similar to *b* but more talcose; *e*. Border of bladed and fibrous enstatite; *f*. Dunite. [For a description of the formations illustrated by this figure see page 55.]

A line of sluice troughs a mile and a half in length connects the mine with the mill, and the loose chloritic vein material is dumped into this as fast as mined. The rolling, falling, and

scouring action to which it is subjected over this course does much toward separating the corundum from the accompanying impurities, and it arrives at the mill in a condition which renders cleaning comparatively easy. (See fig. 6 [p. 93] and pp. 37 and 55.)

For two or three years, the "Hosea Moses mine" on Ellijay creek was worked by the same company, and, after a partial washing at the mine, the product hauled to Corundum Hill for cleaning. This was closed in 1894, and has not since been worked.

Recently Dr. Lucas has retired from the company, and the mines are under the management of the new president, Mr. Frank E. Bidwell. The force employed in the company's North Carolina mines has been somewhat variable, but it is usually about thirty or forty. The company (now styled the Hampden Emery and Corundum Company) also owns the Buck creek mine, but has not yet attempted to work it; also the Pine Mountain mine, (Laurel creek,) in Rabun county, Georgia, which was operated from 1880 till the spring of 1893; and the emery mine at Chester, Massachusetts, which is still in operation.

d. THE SAPPHIRE (HOGBACK) MINES, JACKSON COUNTY.

Corundum was known in the vicinity of Great Hogback mountain in the southeastern corner of Jackson county at the time when Dr. Smith wrote his report on this region, 1875.* He speaks of several hundred pounds having been taken out by digging small pits.

Work was begun here by the Sapphire Valley Mining Company in 1892, at the "Burnt Rock" mine, seven miles northeast of Sapphire; and shortly afterwards a number of places in the surrounding country were opened. A complete cleaning and crushing plant was erected on Horsepasture river, and considerable expense was incurred in building roads, bridges, stores and other houses, saw-mills, shops, etc. About fifty or sixty men were constantly employed in mining, prospecting, and improvements, during the year in which the mine was operated. Mr. Charles N. Jenks, the superintendent, reports a product of over 400 tons, one-fourth of which was crystal corundum 90 per cent. pure. Work was sus-

*Rept. Geol. Sur. N. C., 1, 1875, Appendix 91-97.

pended during the financial crisis of 1893, and has not yet been resumed. The new railroad to Brevard will affect a considerable saving in transportation, as the product was formerly hauled on wagons to Hendersonville for shipment, a distance of some forty miles. (For descriptions of the various workings, see pages 71 and 72.)

e. THE CARTER MINE MADISON COUNTY.

This mine is in the eastern corner of the county, near Democrat postoffice, in Buncombe county. It is located on Holcombe branch, a tributary to Ivy river, and marks the northern extremity of the belt of dunite which extends over a distance of more than two miles, with an average width of about one-fourth of a mile. Dr. C. D. Smith first found corundum here about fifteen or twenty years ago.

The first work was done by Mr. William Carter and Dr. H. S. Lucas, who took out a few tons in prospecting. Afterward work of a similar nature was done by Mr. M. E. Carter, and by Messrs. Rice and Coleman, who sold the property to Tarr, Hamilton and Company, of New York. This company began regular mining about 1886. A steam crushing and sizing plant was erected on the grounds, and about twenty tons of corundum were cleaned and shipped from Marshall. The work continued only about six months, and has not since been resumed. (See also page 74.)

f. THE ACME MINE, STATESVILLE, IREDELL COUNTY.

This mine is located about three-fourths of a mile west of the town of Statesville, and half a mile south of the Charlotte and Taylorsville Railroad. About 1875, Mr. J. A. D. Stevenson found corundum near the site of the present operations. The Acme Corundum and Mining Company began work here in February 1893 under the management of Mr. H. A. Collins. Some corundum was shipped in the form of large rough blocks and crystals, just as it came from the mine; but this was soon found unprofitable, and a steam mill was erected in March of the same year for cleaning and crushing. The product of cleaned material in 1893 was about fifty tons.

Considerable difficulty was encountered on account of the great

depth of soil and decayed rock. The mine is situated in a depression near the head of a small branch, where the alluvial deposits of clay are about fifteen feet deep. This material and the soft rock underlying it are so thoroughly saturated with water that great difficulty was experienced in holding them back out of the workings.

Mining was resumed in December, 1894, and since then, the work has been of the nature of prospecting for the purpose of locating veins under more favorable conditions.

The mode of occurrence of this corundum and that of the Hunter place, in Iredell, are described under the head of corundum in amphibolite, pages 58 and 59. See also page 76.

8. OTHER ECONOMIC MINERALS OF THE CORUNDUM BELT.

Incidentally the chromic iron and asbestos deposits were noted in passing over the region on the corundum work. These minerals have been found in promising abundance in many places, and hence a word in regard to them is appended here. While the corundum shows a great falling off northward, this is by no means true of the characteristic accompaniments of peridotite—chromite, asbestos, and nickel silicates.

(1) CHROMITE, OR CHROMIC IRON.

This mineral has been found in considerable abundance in Jackson county, near Webster; in Buncombe county, at Morgan Hill; and in several localities in Yancey, Mitchell, and Watauga counties. For analyses and more definite information, the reader is referred to Bulletin No. 1 of the present Survey, Iron Ores of North Carolina, by H. B. C. Nitze, 1893, pages 212-215.

(2) ASBESTOS.

A fibrous mineral which is called by this name has been the object of considerable interest in Jackson county, in the vicinity of Glenville; in Mitchell county, near Bakersville, and near the mouth of Squirrel creek on north Toe river; in Watauga county,

along the western slopes of Rich mountain; in Ashe county, on Elk creek; and it is found with all the enstatite rocks of the north-eastern portion of this belt. Fibre of good length, color, and fineness has been found in many places; and the mineral is of sufficient importance to warrant further investigation. In some places this fibrous mineral is enstatite, while in others it is chrysotile, or fibrous serpentine. In a few cases it is possibly amphibole, the true asbestos.

(3) NICKEL-BEARING MINERALS.

Minute quantities of nickel are often present in the olivine rocks of this belt, but its presence can scarcely be detected in the fresh specimen except by chemical methods. But when the olivine begins to decompose under the influence of the atmospheric agencies, it is readily seen in the characteristic green silicates that are developed along the joints and fissures. Genthite, garnierite, and perhaps other nickel silicates are formed in such relations in the dunite at Webster, in Jackson county. These minerals have attracted considerable attention, and some prospecting has been done, but nothing of importance as an ore has yet been found.

Similar indications of the presence of nickel were observed south of Shooting creek, near Elf, Clay county, and south of Democrat, in Buncombe county. Small amounts of nickel staining have been seen in many places, showing a wide distribution of the metal in our olivine rocks; but no other localities were found that are considered worthy of special mention.

(4) SERPENTINE.

Mention has already been made (page 31) of the adaptation of the serpentines of this belt to architectural purposes. They are identical in every respect with those of Maryland and Pennsylvania, which are largely quarried, especially in the latter state, for both interior decorative work and ordinary building purposes. The dark green and mottled varieties take a fine polish and give very rich effects for ornamental work where not exposed to wear or weather. The peculiar, but not displeasing effect of the

lighter colors for general building purposes may be seen in many structures in Philadelphia, Baltimore, and Washington.

Outcrops of serpentine well suited to both these uses occur abundantly between Weaverville and Leicester, in Buncombe county, in the strip that crosses the French Broad river a mile above Alexander. Other masses equally as large are found on the Paint Fork of Ivy river, in Madison county, and on the waters of Bald creek, in Yancey county; but these are not so conveniently located for transportation.

There seems to be no reason why the Buncombe county serpentine should not come into the market in the near future. The era of substantial building has only just begun in the southern states, and as we learn to build, we should also learn to appreciate and appropriate our own resources.

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EXPLANATION OF PLATE VI.

PHOTOMICROGRAPHS OF THIN SECTIONS OF DUNITE.

Photographed with Feuss' objective No. 0. Magnified 12 diameters.

FIGURE 1.—RAILROAD CUT 2 M. WEST OF BALSAM GAP, JACKSON COUNTY.

This is an exceptionally fresh specimen of the pure olivine type. The perfectly crystalline, even grained texture of the rock, and the generally irregular (hypidiomorphic) structure are well shown; though crystal outlines, like that on the upper left hand side, are frequently seen.

FIGURE 2.—CARTER CORUNDUM MINE, MADISON COUNTY.

This figure represents the prevailing character of the surface exposure of dunite. These first narrow bands of yellowish green serpentine formed about the borders of the olivine grains are minutely fibrous, with the fibres at right angles to the boundaries of the olivine. They look very much like mortar in rubble masonry.

FIGURE 3.—CARTER CORUNDUM MINE, MADISON COUNTY.

This section shows a common type of fine grained olivine rock as seen between crossed nicols (polarized light). The minute grains are found to extinguish together over considerable areas, showing that the fine texture is the result of irregular cracking up of large grains similar to those shown in figure 1.

FIGURE 4.—WEBSTER, JACKSON COUNTY.

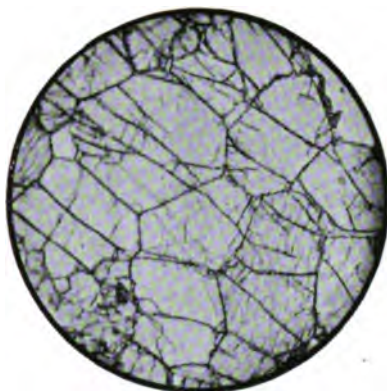
This specimen shows an advanced stage in the alteration of olivine to serpentine, the beginning of which was seen in figure 2. In the process of alteration, a considerable proportion of magnetite has been formed and deposited in dark bands about the olivine remnants, which appear white in the figure.

FIGURE 5.—PAINT FORK OF IVY RIVER, MADISON COUNTY.

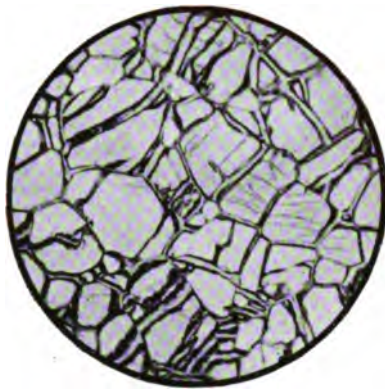
Here we have the final result of the process of serpentinization represented in figures 2 and 4. No trace of unaltered olivine remains. The positions of the last fragments to disappear are marked by black accumulations of magnetite; otherwise the serpentine appears quite homogeneous in ordinary light.

FIGURE 6.—SAME AS FIGURE 5.

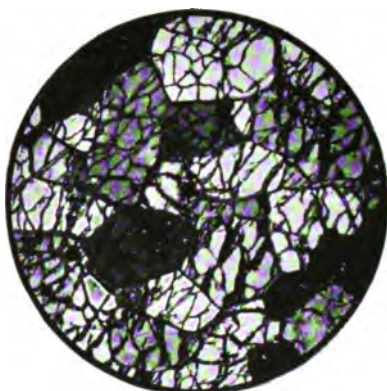
The subject of this figure is identical with the last, except that the section is here viewed between crossed nicols. The network of light bands ("mesh-structure") represents the first serpentine formed in the alteration of olivine, as shown in figure 2, and marks the boundaries of the original grains. (This figure is inverted with reference to figure 5.)



1



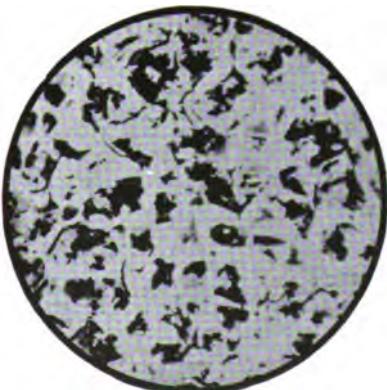
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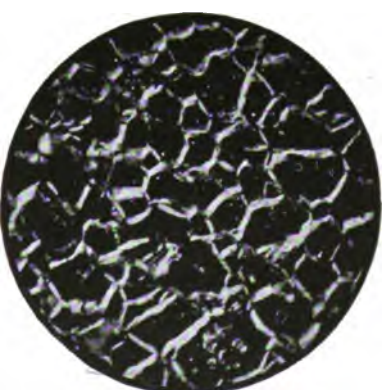
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5



6

THIN SECTIONS OF DUNITE. (MAGNIFIED 12 DIAMETERS).

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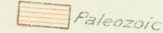
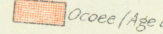
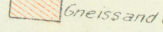
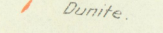
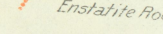
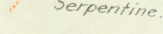
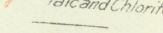

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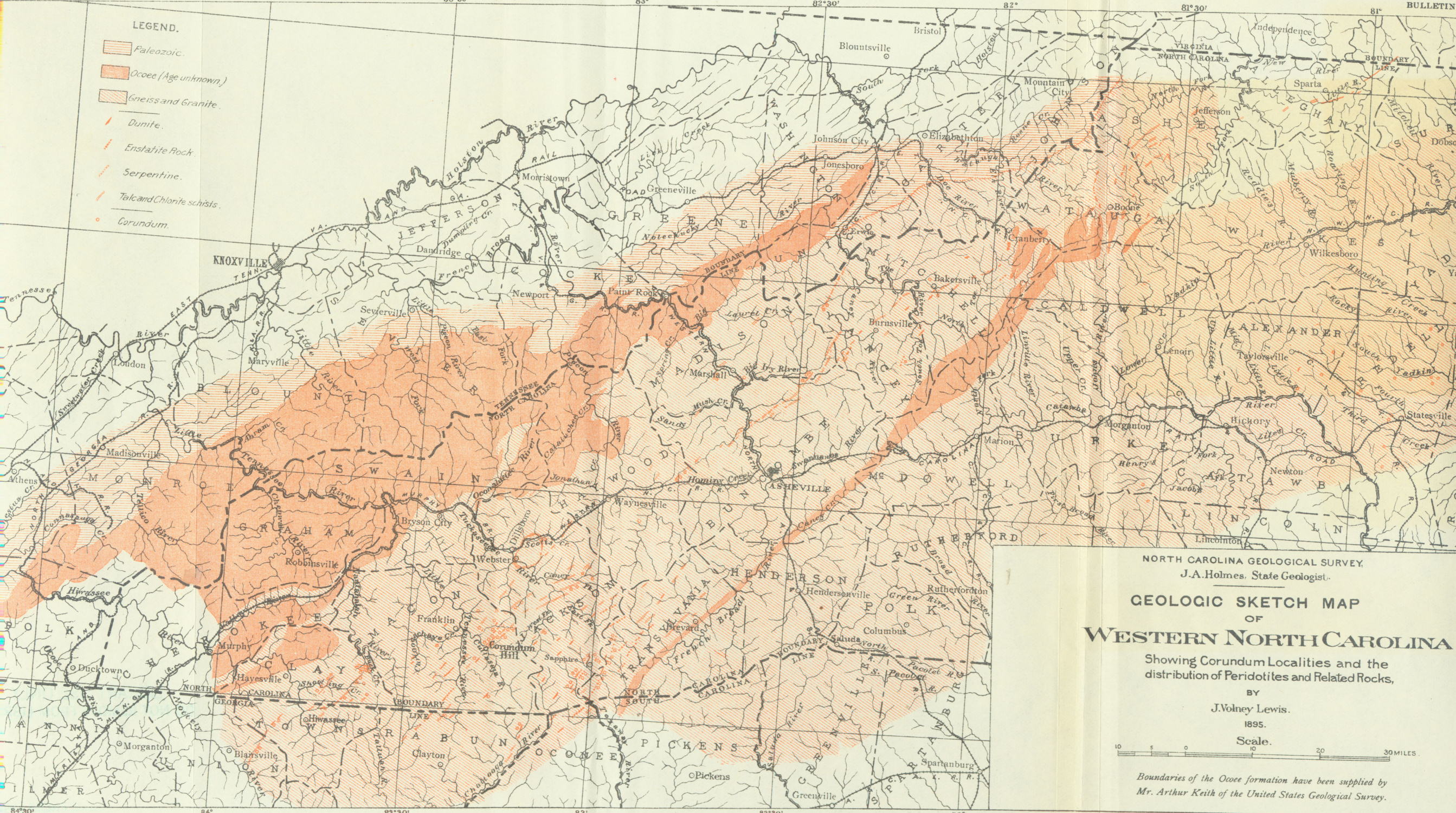
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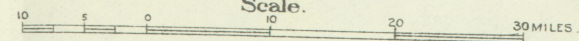
- LEGEND.**
-  Paleozoic.
 -  Ocoee (Age unknown).
 -  Gneiss and Granite.
 -  Dumite.
 -  Enstatite Rock.
 -  Serpentine.
 -  Talca and Chlorite schists.
 -  Corundum.



NORTH CAROLINA GEOLOGICAL SURVEY
J.A. Holmes, State Geologist.

**GEOLOGIC SKETCH MAP
OF
WESTERN NORTH CAROLINA**

Showing Corundum Localities and the
distribution of Peridotites and Related Rocks,
BY
J.Volney Lewis.
1895.
Scale.



*Boundaries of the Ocoee formation have been supplied by
Mr. Arthur Keith of the United States Geological Survey.*