MICA, GRAPHITE, ETC.

MICA DEPOSITS OF WESTERN NORTH CAROLINA.[a]

By DOUGLAS B. STERRETT.

INTRODUCTION.

Though one of the lesser minerals, mica is of considerable importance in the industrial world. It receives its most important application in the electrical industry. It is also used in the manufacture of stoves, lighting apparatus, wall papers, lubricants, paints, boiler coverings, fireproof apparatus, etc. About half of the mica consumed in the United States is of home production. The remainder is imported, chiefly from India, with smaller amounts of phlogopite, or "amber" mica, from Canada. The States contributing to the home production in 1905, in order of relative rank, are given by G. O. Smith[b] as North Carolina, Colorado, New Hampshire, Georgia, South Dakota, and New Mexico. Of the total production, amounting to $201,155, North Carolina is credited with over two-fifths. During some previous years this State has contributed over two-thirds of the domestic production.

The mica deposits of western North Carolina have been examined by several investigators in the interest of the State Geological Survey. The subject receives only brief treatment here, as it is expected that a nearly complete report will be prepared by the State Survey during the coming year. The present paper represents, in part, the results of field work by the writer, under the direction of the North Carolina Geological Survey, chiefly during the field season of 1906. Certain data used, however, were obtained in 1905 during the joint survey of

[a] Published by permission of the State geologist of North Carolina.

[b] Mineral Resources U. S., 1905, U. S. Geol. Survey, 1906, p. 1281.

the Balsam Mountain region, in parts of Haywood, Jackson, and Transylvania counties, by the Federal and State surveys. The writer wishes to express his appreciation of the aid rendered him by Mr. Arthur Keith in the preparation of these pages.

Active mica mining has been carried on in North Carolina for the last thirty-eight years, though with varying degrees of energy and success. The remains of ancient workings with crude stone tools around some of the better deposits give evidence of early mining by the aborigines or prehistoric people. The starting of the present industry is generally credited to Thomas L. Clingman, who had the Silvers mine opened in Yancey County in 1868. After taking out some good blocks of mica he was called away by other duties without disposing of them. The mica was brought to the attention of Heap & Clapp, stove dealers, of Knoxville, Tenn., who recognized its value and shortly after started work on this and other mines.

It is claimed that the earliest mica mining in North Carolina was done in Jackson County in 1867 by a Mr. Person, of Philadelphia. In 1858 a specimen of mica from Jackson County was exhibited at the State fair in Columbia, S. C., by D. D. Davies. Nine years later, after the value of mica was better recognized, Mr. Person came to Jackson County and started operations on numerous prospects known to Mr. Davies.

After a number of years of depression due to low market values at the time when India mica was imported into the country in large quantities, the production is again increasing. Especially during the last two years has the industry gained strength, and at the present time many companies and private persons are examining or developing old and new mines and prospects.

For more detailed information on mica than it is possible to give in a brief report of this nature, the reader is referred to the following publications:

PRATT, J. H. The Mining Industry in North Carolina, annual publication of North Carolina Geol. Survey, 1900-1904.

Production of mica in the United States: Mineral Resources for 1905 and several years preceding, U. S. Geol. Survey. Especial attention is called to the report by J. A. Holmes in the volume for 1898 (Twentieth Ann. Rept., pt. 6, continued, 1899, pp. 691-707).

ELLS, R. W. Mica deposits of Canada: Mineral Resources of Canada, 1904, Canada Geol. Survey.

CIRKEL, FRITZ. Mica, Its Occurrence, Exploitation, and Uses, Mines Branch, Dept. Interior, Canada, 1905.

COLLES, G. W. Mica and the mica industry: Jour. Franklin Inst., Philadelphia, vol. 160, 1905, pp. 275-294. Reprinted in book form in 1906.

DISTRIBUTION AND GENERAL CHARACTER.

Mica-bearing pegmatites occur over a wide area in North Carolina, roughly bounded by the State lines on the northeast and southwest. This area extends about 50 miles southeast of the Blue Ridge and northwestward nearly to the Tennessee line. (See fig. 13.) Mica mining has been carried on in eighteen or more of the counties included in this area. The largest producers have been Mitchell, Yancey, Macon, Jackson, Haywood, Ashe, and Cleveland counties. Good deposits have been discovered in other counties, and some have yielded considerable mica.

Most of the mica mined comes from three belts in the western part of the State. These may be called the Cowee-Black Mountain belt,

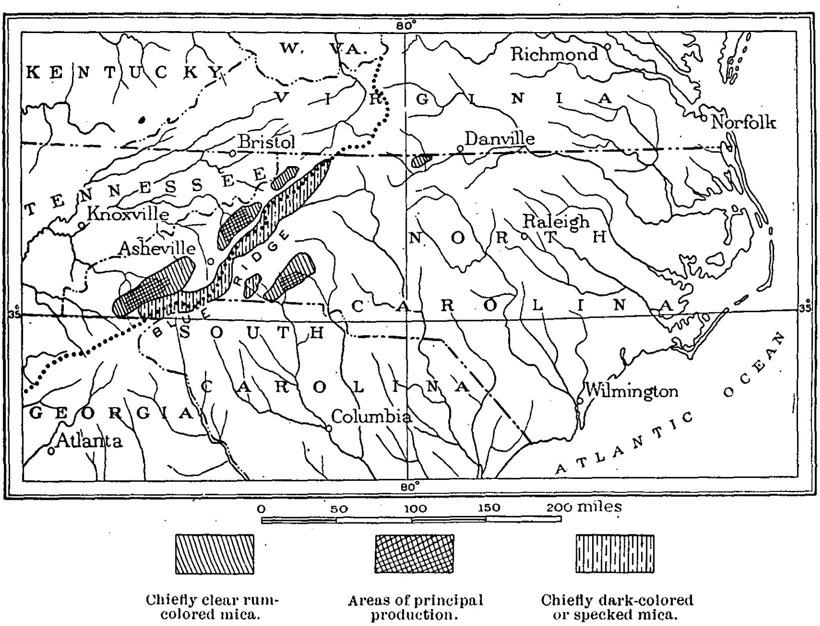

FIG. 13.—Map showing areas in North Carolina in which mica has been mined.

the Blue Ridge belt, and the Piedmont belt. The first of these extends nearly through the State, parallel to and near its northwestern border. It lies northwest of the Blue Ridge and includes part of Macon, Jackson, Transylvania, Haywood, Buncombe, Yancey, Mitchell, Watauga, and Ashe counties. The second belt follows the Blue Ridge through the State and extends several miles to the southeast among the foothills of the ridge. It is of relatively small importance as compared with the other two. The Piedmont belt lies wholly in the Piedmont Plateau, southeast of the Blue Ridge, mainly in Cleveland, Lincoln, Burke, and Stokes counties. Commercial mica deposits have not been found in unbroken succession through the whole length of any one of these belts.

The quality of the mica obtained from different localities varies considerably. In general it may be said that the mica of the Cowee-Black Mountain belt is chiefly clear and of light color (as a rule "wine" or "rum"). That from the Blue Ridge belt has a dark smoky-brown color and much of it is more or less "specked." In much of the Piedmont belt the mica is of good quality and similar to that of the Cowee-Black Mountain belt. Of course there are exceptions to these characteristics, in part connected with geologic conditions which will be mentioned in another place (p. 407).

The Cowee-Black Mountain mica belt is in the heart of the Appalachian Mountains. The deposits lie at various elevations between 2,000 feet above sea level and that of the highest mountains, or over 6,500 feet. Some are high up on the rugged slopes, where the soil covering is thin. Others are on the gentle slopes of the valleys, covered by deep residual clays. Much the same could be said of the Blue Ridge belt, though the elevations are not so great. In marked contrast with the high relief of the mountain region that includes these belts is the topography of the Piedmont Plateau southeast of the Blue Ridge. The general elevation in the mica-bearing areas of the plateau belt is from 1,000 to 1,500 feet above sea. Though typically a plateau, it is more or less dissected by river and creek valleys 200 or 300 feet deep.

The rainfall in western North Carolina is heavy, and, as the climate is not severe, vegetation flourishes, and large areas are covered with dense forests. The residual soil covering due to rock decay is in many places very thick, especially where the slopes are gentle and the removal of decomposition products is slow. These features combine to make the discovery of mica deposits difficult.

GENERAL GEOLOGY.

The mica-bearing pegmatites of North Carolina are found chiefly in rocks of Archean age, and are practically confined to mica, garnet, cyanite, hornblende, and granite gneisses and schists. Other rocks in the region are granites, diorites, and peridotites, also of Archean age, as well as younger granites, volcanics, and sediments. The metamorphism, folding, and faulting of the gneisses and schists have been extreme. In most of the Archean rocks it is difficult to determine the original nature of the formations, since much of the sedimentary bedding and igneous texture has been destroyed by mashing and recrystallization.

The majority of the mica deposits occur in two formations as mapped by Keith,[a] namely, the Carolina gneiss and Roan gneiss. The Carolina gneiss includes most of the gneisses and schists mentioned above that are not hornblendic in composition. The Roan

[a] Geologic Atlas U. S., Asheville (116), Cranberry (90), Mount Mitchell (124), Nantahala (143), Pisgah and Roan Mountain folios, U. S. Geol. Survey.

gneiss is composed of hornblende gneiss and hornblende schist with smaller beds of mica gneiss and mica schist included. Large areas of the other rocks mentioned above are mapped as separate formations. These are principally granites and granite gneisses of Archean age. In the mica regions by far the most important formation is the Carolina gneiss. It extends from the northwestern side of the Cowee-Black Mountain belt to and beyond the southeastern side of the Piedmont belt. In a northeast-southwest direction it extends far beyond the State boundaries. The age of the Carolina gneiss is greater than that of any other formation in the region. Igneous rocks of later epochs have been intruded into this gneiss, which has been gashed and cut by them into irregular-shaped masses, in many places forking out into long tongues or occurring as long, narrow streaks in the intrusives, or vice versa. This feature is common to both the granite intrusives and the Roan gneiss, which is the next oldest formation of the region. Rocks of still later age, as Cambrian sediments, have been metamorphosed into gneiss and schist and folded with the older formations by movements associated with the Appalachian uplift. The Carolina and Roan gneiss formations have been interbanded with and cut at all angles by numerous streaks of granitic or pegmatitic material. These range from a fraction of an inch upward in thickness, and locally pass into mica-bearing pegmatites. In some places pegmatization is so thorough that mica gneisses become strikingly like granite gneisses. This is especially characteristic of the Carolina gneiss in the Piedmont region.

The study of the geology in this region is exceedingly difficult, because the rocks have been so intensely folded, faulted, and metamorphosed. The enormous amount of erosion the region has undergone and the present depth of atmospheric decomposition also complicate the task.

OCCURRENCE OF MICA.

Mica deposits of commercial value in this State are confined to pegmatites. These rocks vary considerably in form, some being typically lenticular in shape and others more or less persistent in length. The lens-shaped bodies are generally conformable with the schistosity of the inclosing rock. They may lie in the same line of bedding or schistosity and be connected by smaller streaks or stringers of pegmatite or by mere seams in the rock. Many of them, on the other hand, lie in planes of schistosity more or less separated from one another and form parallel or overlapping bodies. In cross-section some of these lenses are short and bulky, with a length only two or three times the thickness; others are long and tapering, and may constitute simply a bulge in a sheet of pegmatite. In most places the schistosity of the inclosing rock bends around the lenses.

Some of the more persistent pegmatites occupy straight fissures that hold their direction for some distance. Elsewhere they are folded with the country rock or bent and twisted into various shapes. Many are more or less conformable with the bedding of the gneisses and schists. In the latter case they are, in a large measure, subject to the deformations of the country rock. In many places, however, the pegmatites are conformable for some distance, and then branch out, cutting from one layer to another across the bedding. Locally there is an elbowing or bulging out on one wall, without a similar irregularity on the other wall of the pegmatite. It is not uncommon for pegmatite masses to cut across the country rock for long distances.

Though pegmatites have been worked for mica in regions of hornblende gneiss and hornblende schist, where they are directly associated with those rocks, the majority of the deposits are in small biotite-gneiss or schist masses included in the hornblende areas. Where the pegmatite is in contact with hornblende gneiss, the latter may be highly biotitic.

Pegmatites occur in irregular masses, streaks, lenses, augen, or balls, some of them having no visible connection with other pegmatite bodies. They range from a fraction of an inch up to many yards in thickness. The limit of size below which they can not be profitably worked for mica might be placed arbitrarily at from 1 to 2 feet for rich and regular "veins." In the very large pegmatites the mica is not in general evenly distributed through the mass, but is richer in one portion than another, so that the entire bulk of the rock does not have to be removed in mining. The irregularities of pegmatites and the consequent difficulties in mining mica from them are well illustrated in road cuts or similar excavations where pegmatized gneiss or schist has been cut into. The lenticular shapes, pinching and swelling, crumpling, folding, and faulting to be observed in these cuts are found to be nearly duplicated in larger pegmatites opened for mica. As stated before, these smaller masses may grade into those containing mica of commercial value. Here and there the two can be seen at the same locality.

Horses or inclusions of wall rock are common in pegmatites. Some of them are in the form of bands or sheets parallel to the walls, and the schistosity of these bands is also parallel to the walls. They range from an inch or two up to a couple of feet in thickness and their length may be many times their width. Elsewhere they occur as irregular-shaped masses from a few inches up to several feet thick. If the bedding has been preserved, it may lie at any angle with that of the inclosing wall rock. In some places the horses are partially pegmatized by streaks of pegmatite ramifying through them and the development of considerable feldspar and quartz through their mass.

In such places no sharp line can be drawn between the point where the pegmatite ceases and original horse begins.

Pegmatite is closely allied to granite in composition. As in granite, the essential constituents are feldspar and quartz, with more or less mica and other accessory minerals. Though hornblende is a rather common mineral in granite, it is less so in pegmatite. Orthoclase or microcline are the most common varieties of feldspar found in pegmatite. In many places, however, a variety of plagioclase, either albite or oligoclase, makes up part or all of the feldspar component. The feldspar occurs in masses and rough crystals with a diameter of several feet. In the old Mart Wiseman mine near Sprucepine, Mitchell County, orthoclase crystals 2 by 4 feet and larger have been cut through. From their whole rectangular cross section, as exposed in the walls of the tunnel, a simultaneous reflection of light is obtained from the cleavage faces.

Quartz assumes various forms and positions in the pegmatite. In many places it bears much the same relation to the feldspar and mica as in granite, the three minerals being thoroughly mixed with one another; but the individual grains are many times larger than in ordinary granite. Not uncommonly the quartz and feldspar assume a graphic-granite texture in a portion of the pegmatite. Another common feature is the occurrence of large separate masses of quartz occupying various positions in the pegmatite. Such quartz masses may be irregular in form and but little influenced by the shape of the pegmatite or inclosing walls. Generally, however, they occur in bands or sheets lying parallel to the walls. There may be one or more of these quartz bands constituting varying proportions of the pegmatite. Their thickness ranges from a fraction of an inch up to 6 or more feet. Many of them are lenticular in shape, the length varying from four or five to twenty or more times the thickness. In numerous places these quartz streaks or veins are persistent through the whole length of the pegmatite exposed. Some inclose feldspar or mica bodies; others do not. The quartz of these segregations is massive and generally granular, though locally crystallized. In the latter case it may be translucent or clear and of a dark smoky or light color. It is generally rather pure and does not contain feldspar or mica in any quantity.

Muscovite is the common mica of pegmatite and is the only variety mined in North Carolina. Biotite occurs in some quantity in a few deposits and in smaller amount in many others. Where muscovite and biotite occur together in a deposit, the muscovite is generally clear and of good color. It is not unusual for the two to occur in intergrown crystals with a common cleavage plane. Again, mica from deposits in rock formations where the ferromagnesian minerals are abundant, as hornblende or biotite gneiss and schist, is generally found to be clear and of light color. Where the pegmatite is closely associated with or occurs in granite with a paucity of the ferromagnesian minerals, the mica is generally of dark color and much of it "specked." The true color of mica is best observed in sheets from one-sixteenth to one-fourth inch in thickness when examined in transmitted light.

The mica occupies various positions in the pegmatite. Where the rock has a typical granitic texture, the mica may be found evenly distributed through it. More commonly the larger crystals will be found either in clusters at intervals through the "vein," in places connected by streaks of small crystals, or collected along one or both walls of the pegmatite, with some of the crystals partly embedded in the wall rock. Where there is a quartz streak within the pegmatite, the mica occurs on either or both sides of it, being in places partly embedded in the quartz or occupying any of the positions noted above in the remaining portion of the pegmatite, which generally is composed largely of feldspar.

ASSOCIATED MINERALS.

Over forty different minerals have been found in the pegmatites of North Carolina.[a] Besides muscovite mica, several others of commercial importance are found, including quartz in large masses, feldspar in considerable quantity, kaolin in large deposits, beryl of several gem varieties, zircon, uranium minerals carrying radium, samarskite, and columbite. Most of the rare minerals, as gem beryl, columbite, those of uranium, etc., are found in Mitchell and Yancey counties; though beryl of gem quality is found also in many other counties. The beryls from the pegmatites have furnished handsome gems, as emerald, aquamarine (sea green and blue), and the golden variety. The potash feldspar removed in mica mining should prove of value if shipped to manufacturers. Kaolin results from the decomposition of the feldspar of the pegmatites by weathering. In the majority of the pegmatites of North Carolina that have been opened for their valuable minerals the feldspar is found to have partially or entirely altered to kaolin from the outcrop down to depths varying from a few to 100 feet or more. In this way valuable deposits of kaolin have formed.

DESCRIPTION OF MINES.

MILTON ENGLISH AND NEIGHBORING MINES.

The Milton English mine, about 1 mile northeast of Plumtree, Mitchell County, furnishes one of the most typical examples of pegmatite lens formation known. The pegmatite lies in one of the

[a] Pratt, J. H., Mining industry in North Carolina in 1901: Economic Paper North Carolina Geol. Survey No. 6, 1902.

smaller biotite-gneiss bodies included in the large area of hornblende gneiss which forms the country rock of the region. The rocks as exposed in the mine are approximately horizontal, with only a few gentle monoclinal folds dipping southward.

A tunnel has been driven in over 450 feet in a southerly direction. From this drifts have been run off both to the east and the west for distances varying from 25 to 60 feet. The main tunnel was carried back by a series of rooms, some being about 25 feet wide, where the "vein" was found sufficiently rich. The size and shape of these rooms depended on the pegmatite lens that was removed for mica as they were being made. In some places all of the pegmatite had been removed on one side of the room or the other. In others, however, a streak a few inches thick was left in the walls, showing where the lens had pinched down from several feet (the height of the room) to a few inches. The structure of the pegmatite is strikingly illustrated in the walls and faces of the workings, where cross sections of the lenses can be seen. Some are 6 to 10 inches thick and a couple of feet long, others are of much greater thickness (up to 5 or 6 feet) and of proportional or even greater length. These lenses overlap or lie parallel to each other. Many of them lie in the same strata of the gneiss, though separated by several feet. A thin seam or parting, locally containing a little pegmatite material, can generally be traced between two such lenses. Here and there the pegmatite occurs in sheets or streaks, which in places bulge out into lenticular form. These streaks may pinch down to mere threads, but when followed a little way open out into other lenses. The full thickness of the belt of overlapping and parallel pegmatite lenses and streaks is generally under 8 feet. The mica gneiss curves around swells and bulky parts of the lenses.

From the mouth of the tunnel the pegmatite outcrop has been traced both to the east and the west for some distance around the contour of the mountain side. A diabase dike, called "the iron bar" by the miners, follows the pegmatite back as far as development work has been carried. It is very irregular, appearing in one place cutting into the pegmatite and then not seen again for some distance.

The texture and composition of the pegmatite are those of very coarse granite. The three constituent minerals are thoroughly mixed and have separated out in large masses. Even in lenses only 10 inches thick mica crystals 5 or 6 inches in diameter have been found. The quality of the mica is excellent. The color is a clear light "rum" when the sheets are about one-eighth inch thick. The lamination is perfect, and beautiful sheets for glazing purposes can be obtained. The yield for the amount of rock removed is satisfactory and contains a fair proportion of larger sizes.

Other mines have been opened to the southeast and east of the Milton English, apparently in the same formation. At the Johnson mine, nearly 2 miles to the southeast, the pegmatite is included in a hornblende gneiss, lying nearly flat, biotitic near the contact and conformable with it. It is sheetlike in form, pinching down to a few inches and beyond swelling to several feet.

McKINNEY OR POWDERMILL CREEK MINE.

The McKinney is a new mine, about 3 miles northwest of Plumtree, on the north slope of a mountain south of Powdermill Creek. The work consists of an open cut nearly 100 feet along the strike of the "vein" and not over 15 feet deep in any part. Only the width of the pegmatite has been removed. This rock lies in a biotite-gneiss streak, a few yards north of its contact with the hornblende-gneiss formation, which is the country rock of the region. The pegmatite is conformable with the gneiss and strikes due east at the west end of the cut and about N. 80° E. in the eastern part. The dip is about 80° S. The average width is about 6 feet, though it increases to 8 feet or more near the middle of the cut. At one point, near the west end, the south wall elbows out, causing the pegmatite to pinch abruptly from 6 feet down to 4 feet. In general, however, the variations in size are more gradual. The pegmatite has been traced by prospect pits for some distance farther east.

The texture of the pegmatite is that of coarse granite, except for a width of a few inches along the contact, where it is very fine grained and of dark color, thus being in marked contrast with the rest of the mass. The feldspar is chiefly a plagioclase. The mica is generally disposed near one wall or the other, though some large blocks occur nearer the middle of the "vein." It has a rather dark brown color and part of it is somewhat "specked." It is fairly plentiful, however, and blocks of good size are frequently obtained.

BIG RIDGE MINE.

The Big Ridge mine is about 6 miles east of south of Waynesville, Haywood County, high up on the southwest side of Lickstone Bald, at an elevation of about 4,500 feet. The mine is equipped with air drills and a steam pump. The mica-bearing pegmatite is conformable with the mica-gneiss country rock, and is folded with it into an anticline, the axis of which strikes about N. 80° E. and pitches 20° or more into the mountain side. The angle of the fold is not sharp, yet the legs dip about 45° a few rods from the axis. The workings consist of tunnels and drifts along the pegmatite, with stopes and raises between. On the north leg of the fold the "vein" has been removed for a depth of about 300 feet, but on the south it has been worked for only about 100 feet. The pegmatite is fairly regular in thickness and would probably average 8 feet through a large part of the mine. In certain places where the full width of the "vein" had been removed rooms 12 to 15 feet high were left. The greater part of the pegmatite has a coarse granitic texture. A peculiar graphic-granite texture has been observed, in smaller portions of the pegmatite, caused by a parallel orientation of biotite plates in a feldspar-quartz matrix. A thin section cut from a piece of this nature showed, under the microscope, a semimicrographic arrangement of quartz in feldspar crystals. The feldspar is largely albite. A large amount of biotite, probably amounting to one-fourth or one-third of all the mica contained in the "vein," is found with the clear mica. In places the two form intergrowths with one another. Apatite, hornblende, and garnet are found as accessory minerals. The mica is of clear, light "rum" color and excellent quality. The mine has been worked for many years and has been a good producer. It is often closed during part of the winter, as it is found difficult to keep up sufficient steam to run the air compressor at such an elevation during the cold weather.

CATTAIL BRANCH MINE.

The Cattail Branch mine is near the head of Cattail Branch, in Yancey County, about 5,500 feet above sea level and nearly a mile southwest of Celo Mountain, the north end of the Black Mountains. It was discovered about 2 years ago by Silvers & Son and B. Rolland, all of Yancey County. The developments consist of open cuts at three different points on the outcrop. The country rock is biotite gneiss. Near the pegmatite it is much flexed and folded, striking northeastward with nearly vertical folds. The pegmatite is in the form of an inclined trough with a horseshoe or U-shaped cross section. The bottom of the trough pitches about 55° SW. and cuts directly across the country rock. The sides are nearly vertical and, at a little distance from the bottom of the trough, conform in a general way with the strike of the country rock. The thickness of the pegmatite varies from 3 feet in the curve of the horseshoe to 20 feet or more some distance out from the curve. This includes horses or tongues of wall rock around which the pegmatite has forked. About 30 feet southwest of the curve the northwest arm is nearly 25 feet thick, the greatest thickness exposed. The "vein" must have bulged out abruptly to attain such a thickness at this point. It contains mica-gneiss bands or horses, from a few inches up to a maximum in one place of several feet in thickness, and oriented parallel to the walls. The southeast arm shows a similar bulging, being about 12 feet thick at a distance of 25 feet from the curve.

The texture of the pegmatite is very coarsely granitic. The larger portion of the mica is found in the interior of the pegmatite, though some occurs scattered along the walls. The quality is excellent and the color a beautiful "rum." The yield in larger sizes is good, and smaller sizes are plentiful.

THORN MOUNTAIN MINE.

The Thorn Mountain mine is on the south side of Thorn Mountain, about 3 miles south of Wayah Gap, in the Nantahala Mountains, Macon County. There are two mines about a quarter of a mile apart on this mountain. The one chosen for description is sometimes called the No. 2 mine. The work consists of a good-sized open cut carried back about 40 feet on the strike of the pegmatite, and about

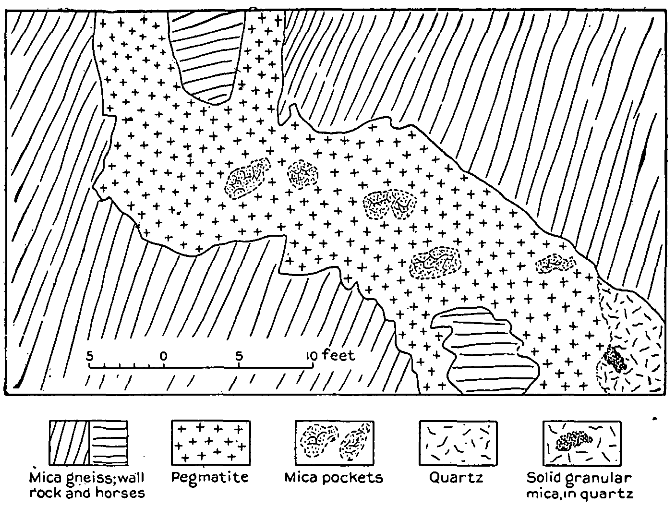

FIG. 14.—Section across pegmatite at Thorn Mountain mine, Macon, county, N. C.

25 feet deep at the farther end. The country rock is pegmatized mica gneiss, which strikes about N. 50° E. and has a high northwest to vertical dip. The pegmatite is from 10 to 15 feet thick, and cuts the gneissic country rock with a strike of about N. 25° E. and a dip of 50° SE. (See fig. 14.) At least one horse of mica gneiss is included in it and exposed near the bottom of the cut. This horse is a large one, with its schistosity turned at an angle to that of the wall rock. In the face of the cut, just below the top, the pegmatite either forks or, more probably, includes another horse of wall rock. The schistosity of this inclusion is also out of parallel with that of the walls. These horses are even more highly pegmatized than the country rock, and the lower one has a very irregular outline.

The texture of the pegmatite is that of very coarse granite. The mica does not seem to be confined to any one portion, but is found in bunches or pockets of crystals at varying intervals through the mass. It is said that in mining often several feet of barren "vein" would have to be removed before one of these pockets was encountered. They generally yielded a good quantity of mica, however. In the bottom of the cut on the southeast side a mass of quartz had been laid bare, but it was not sufficiently exposed to determine its relation to the rest of the pegmatite. An irregular band of solid mica composed of an aggregate of small crystals, one-eighth to one-half inch or more in diameter was included in this quartz. It was 6 to 10 inches thick and 8 feet long. A little biotite is found with the muscovite at this mine. The two are in places intergrown, and in one specimen seen a sheet of black mica inclosed a rhombic-shaped plate of clear mica. The latter had very much the appearance of a fancy window in a dark wall. A small amount of pyrrhotite carrying a little chalcopyrite is scattered through this quartz in lumps up to half a pound in weight.

This mine has not been worked for several years. The "vein" material that had to be removed was found to be exceedingly hard. The distance of the mine from any settlements made it difficult to obtain labor. The mica was reported to be fairly plentiful, however, and this combined with its light color and excellent quality ought to equalize any disadvantages due to location.

MINES IN THE WAYAH BALD REGION.

Four mines have been opened in the Nantahala Mountains on the east and northeast side of Wayah Bald, Macon County. These are the Turkey's Nest, Lyle Cut or Evans, Wayah Bald, and Raven Cliff. All but the Raven Cliff were examined, and since they have so many features in common, a description of one with reference to the other two will answer for all three. The Lyle Cut has been chosen for description. It has been worked by an open cut the width of the pegmatite and about 40 yards back into the side of the ridge leading eastward from Wayah Bald. The depth is nowhere over 35 feet.

The country rock is mica gneiss, which strikes N. 80° E. and dips 60° NW. The pegmatite cuts across the gneiss with a strike of N. 40° E. and a dip of about 70° SE. It is 7 feet wide in places, but pinches down to about 3 feet at the entrance to the cut. These variations in thickness are rather gradual and the deposit appears to be very regular. The strike and dip remain uniform as far as the rock is exposed in the cut. A persistent quartz streak of variable thickness and continuity occurs within and near the middle of the pegmatite. It varies from 10 inches up to 2 feet in thickness, and is present in the full height of the pegmatite exposed in the face of the cut. It has a peculiar banding parallel to its direction and the walls of the pegmatite. In hand specimens the texture is granular and the banding appears as alternating portions of more or less translucent and white quartz. Small mica plates lie in certain streaks or seams parallel to this banding. Under the microscope a thin section proved to be almost entirely composed of rather fine-grained quartz. The grains are angular and fit somewhat closely together. Some of them show evidence of moderate strain. Between crossed nicols a slight banding is apparent in certain directions by the extinction of the quartz grains. Parallel to this banding are two streaks of minute black particles, probably magnetite. These lie chiefly between separate grains of quartz, though some are included in the quartz grains. The quartz contains many inclusions. Some of them seem to be irregular cavities, with or without gas; others have a reddish color, and may be iron oxide which has worked its way from the pores between the grains into the cavities in the quartz.

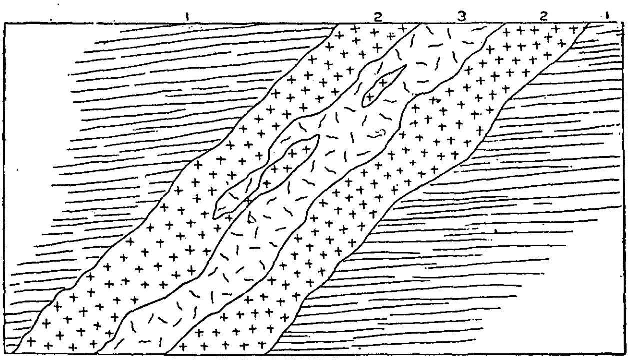

FIG. 15.—Pegmatite, 2½ feet thick, at Wayah Bald mine, Macon County, N. C. 1, Wall rock (mica gneiss); 2, pegmatite, mostly feldspar, quartz, and mica; 3, quartz.

The mica was reported to be plentiful in the feldspar-quartz streak between the quartz band and the wall rock. The color is a beautiful "rum" and the quality excellent.

In the other two mines the pegmatite cuts the mica-gneiss country rock, as in the Lyle Cut. There is also a regular quartz vein within the pegmatite. The mica occurs in a matrix consisting mostly of feldspar with some quartz, between the quartz band and the walls. In the Wayah Bald mine the quartz forks in one place, nearly inclosing a small mass of feldspar (see fig. 15), and in another part it completely envelops a mass of feldspar 3 or 4 inches thick. Banding of the quartz was not observed in the Wayah Bald mine. Both mines produce "rum"-colored mica of the same excellent quality as that of the Lyle Cut.

All are old mines except the Wayah Bald, which is the only one that has been worked recently. It shut down, however, in the fall of 1906.

HORACE THOMPSON MINE.

The Horace Thompson mine is about 3½ miles northeast of Fallston, in Cleveland County. It has been opened by half a dozen shafts with considerable tunneling from them. Much material has been removed, and owing to the decomposed nature of the rock formations and the probably scant timbering used most of these workings have fallen in and the ground above them has subsided several feet. The openings are within an area about 60 yards east and west by 20 yards north and south. The country rock is garnetiferous gneiss and schist. Cyanite is another important constituent in parts of it. The garnets, which are up to 1½ inches in diameter, weather out in the soil near the mine. The products of weathering consist chiefly of clay through which abundant fragments of hematite and tufts of cyanite impregnated with hematite are scattered. The strike of the rock near the mine is mostly east and west, swinging to northwest in places, and the dip is nearly vertical. In two of the shafts with their tunnels on the north side of the deposit (not yet fallen in) there were quartz ledges and streaks in the large kaolinized feldspar formation exposed. Blocks of mica several inches in diameter had been left in the roof of one of these tunnels lying in the feldspar between the wall and one of the quartz masses. Small blocks were included in the quartz itself. It seems probable that this pegmatite formation is limited in extent, for an opening made about 20 yards east of the main workings exposed a small pegmatite body 2 or 3 feet thick with a northwest strike, thus cutting across the direction in which the main mass appeared to be running.

This mine has produced a large amount of good-sized mica. The color of the mica is clear "rum" and the quality excellent. The same may be said of the majority of the mines of this part of Cleveland County and Lincoln County adjoining. Quartz ledges are other features common to many of the mines of this section. The difficulties encountered in working the Thompson mine are found in nearly all the mines of this region, namely, large amounts of water to handle, formations that require much timbering, and the apparent pinching out of the mica-bearing rock in one or more directions.

COWARD MOUNTAIN MINE.

The Coward Mountain mine is near the top of the south end of Coward Mountain, on the north side of the Caney Fork Valley, Jackson County. The notable features are the occurrence of sheetlike horses of wall rock and streaks of quartz parallel to the walls of the pegmatite. The country rock is hard garnetiferous mica gneiss, somewhat schistose near the contact with the pegmatite. The latter is about 10 feet thick and strikes about N. 45° E., with a dip of 75° NW.

Where seen near the surface, it is nearly or quite conformable with the inclosing rock. Quartz is the predominant mineral and occurs in veins and streaks parallel to the wall rock. These streaks range from 1 or 2 inches up to a couple of feet in thickness. Feldspar is nowhere very abundant in the pegmatite and is confined chiefly to a streak 2 or 3 feet thick near the hanging wall, where with quartz and mica it forms the "vein." Horses or sheets of schistose wall rock are included in the pegmatite in several places. They range from 2 or 3 to several inches in thickness. These horses, together with the quartz bands and mica streak, all parallel to the walls, give a marked banded structure. Such inclusions of sheetlike horses of wall rock and veins of quartz in parallel position are not uncommon in this region.

This mine has not been worked in recent years. The developments consist of a shaft on the "vein" reported to be 100 feet deep, with sufficient open-cut work at the surface to give working room on the mountain side. The mica is of a clear "rum" color, and to judge from smaller pieces seen, of good quality. Some biotite is found with the clear mica. A little sulphide of iron is scattered through the "vein" and wall rock.

COX & DAVIES MINE.

The Cox & Davies mine is about three-fourths of a mile south of Cullowhee, Jackson County, on the point of a ridge, 200 or 300 feet above the road. The developments consist of open cuts, shafts, and tunnels, mostly in bad repair. There are two parallel "veins" about 70 feet apart, and both have been worked for about 100 yards across the top of the ridge. The mica-gneiss country rock strikes about N. 80° E., with a southerly dip. The pegmatite masses conform with this in a general way, though they cut the gneiss in places.

A tunnel on the north "vein" was examined for about 150 feet into the hillside. The thickness of the "vein" was in the main from 2 to 4 feet, but in places it swelled to 6 or 8 feet. At one point the pegmatite was warped, the strike shifting from N. 70° E. to S. 80° E. and back again, with a varying southerly dip. It cut across the mica gneiss, which at this point had a strike of N. 45° E., and a vertical dip. Quartz was exposed only in smaller masses and ledges in this tunnel. The feldspar was partly kaolinized and easily removed in mining. Quartz was found to be more plentiful in the south "vein." In one of the tunnels still open a quartz streak nearly 2 feet thick was exposed in the roof and extended some distance back. Both veins have been more or less "ground-hogged" through their whole length. This has been done mostly by petty leasers, who did not care what happened to the mine after their leases expired. Mica of excellent quality and in large quantity has been removed from each vein. The color is a fine clear light "rum" or "wine," and the mica is said to have brought always the highest prices.

CHINK KNOB PROSPECT.

South of Chink Knob, near the main road through Canada Township, Jackson County, is a small opening several feet deep, which is described here only because of the peculiar type of pegmatite exposed. The country rock is mostly mica gneiss, with smaller granitic masses included. These are doubtless outliers of the larger intrusions of granite in the neighborhood. Some of them assume a pegmatitic texture in places. The prospect reveals a vein of pegmatite from 3½ to 4 feet wide. (See fig. 16.) It strikes about N. 5° W. and dips from 75° to 80° E., cutting one of the coarse granite masses already mentioned. The mica-gneiss country rock a few rods from the prospect had a strike of N. 55° E. and a dip of 50° NW.

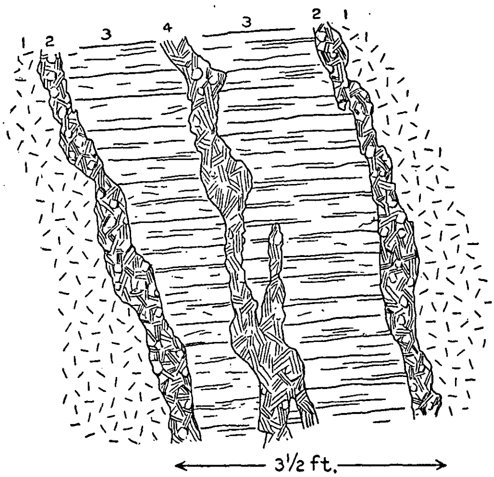

FIG. 16.—Section of pegmatite at mica prospect near Chink Knob, Jackson County, N. C. 1, Coarse granite; 2, mica and feldspar; 3, quartz, jointed; 4, feldspar with little mica.

The vein is composed largely of quartz. On each side and down through the interior of this quartz there is a streak or band of feldspar and mica. The interior band consists chiefly of feldspar with a small amount of mica, but in the bands between the walls and the quartz mica is probably in excess of the feldspar. The quartz is massive and of a dark smoky color. It has a sheety columnar jointing about normal to its walls, probably caused by later rock movements. The mica is mostly wedge-shaped and "A." It is of a dark smoky color and partly "specked." Blocks from 3 to 5 inches across were probably the largest found during the prospecting.

ADAMS MINE.

The Adams mine, 1½ miles southeast of Webster, Jackson County, is unique. A small granite dike from 4½ to 8 feet thick cuts sharply across the mica-gneiss country rock. The dike strikes N. 25° to 30° W. and dips from 55° to 70° NE.; the mica gneiss has about a northeasterly strike, with a dip varying from nearly vertical to 70° SE. This granite is rather fine grained and light gray to nearly white in color. It has an even texture and shows no banding. The dike has been traced over 100 yards along the strike by prospects, openings, and tunnels. On each side of the granite throughout its exposure there is a pegmatite streak from 1 to 2 feet thick. (See fig. 17.) In some places this pegmatite is made up chiefly of mica; in others feldspar with some quartz is equally important. The contact between the pegmatite and granite is irregular and not sharp. Many of the mica crystals, especially those near the contact with the mica gneiss, have their cleavage planes normal to the walls of the pegmatite. They do not exhibit any other definite orientation, however. The feldspar has been kaolinized to some extent near the surface. The mica blocks are chiefly small (under 4 or 5 inches in diameter). They have a clear "rum" color, but many are damaged by clay stains between the laminæ. They are plentiful, however, and yield much punch and scrap material.

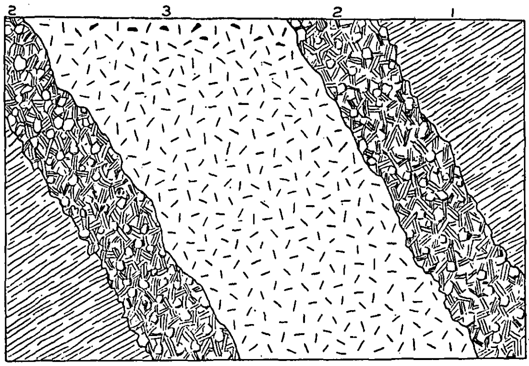

FIG. 17.—Section of pegmatite at Adams mine, 1½ miles southeast of Webster, Jackson County, N. C. 1, Wall rock (mica gneiss); 2, pegmatite, mostly mica; 3, granite, rather fine grained. Distance from wall to wall, 7 feet.

A pretty example of faulting is exposed in this mine. The mica streak on the southwest side of the granite has been brought nearly opposite that on the northeast side by a fault with an 8-foot throw. This fault strikes a little east of north and is nearly vertical. The formations on the east side of it have slipped to the north a few feet, or vice versa.

MINING AND TREATMENT OF MICA.

The methods employed in working most of the mines are simple. Open cuts are started on the outcrop, followed by shafts or tunnels when the "vein" is found sufficiently rich. In some of the larger mines power drills and steam pumps are employed and development proceeds rapidly. As a rule, however, simple tools are used, such as pick and shovel in decomposed formations and hand drills where hard rock is encountered. Dynamite is used chiefly in breaking down hard rock. The "vein" is worked out by shafts (generally inclined), tunnels, drifts, winzes, and stopes. The minimum of timbering is used, and pillars are left only where absolutely necessary. The workings generally have a very irregular shape, since they follow the mica streaks or pockets wherever found. Too often, in the past especially, the deposits have been so irregularly worked that the term "ground-hogging" has been applied to the methods employed. "Ground-hog" workings consist of irregular openings at the surface, shallow shafts, and small crooked tunnels, scarcely large enough for a man to work in. The term might also be appropriately used to describe the irregular stopes made by "jayhawkers" and petty leasers in underground workings. These people cut down all the mica-bearing material available and leave the waste to accumulate in the mine until further work is difficult or impossible.

Some of the mines are located in rather inaccessible places, to which tools and provisions have to be packed on men's shoulders, and from which the mica is brought away by the same methods. As the needs of the mountaineer and the variety of tools required are small, even these mines can often be operated at a profit.

At most of the mines blacksmith forges of suitable size to meet the requirements are set up so that drills and tools can be sharpened and other shop work done. Each mine generally has a storage bin or house where the mica is kept and sorted over before selling or hauling to trimming establishments. At some mines the output is sold in the rough. At others it is split and sized either with or without trimming off the rough corners and edges. Part of the production is shipped to the manufacturers after rough trimming and sizing, and the remainder is prepared for the market in local establishments by cutting into patterns and punching. The waste from the mines and scrap from the cutting houses is ground in local mills or shipped to mills outside of the State.

ORIGIN.

Mica of commercial size in North Carolina occurs only in pegmatite. It is uncertain whether this rock should be classed with dikes or veins. It is probable that some bodies are true dikes, whereas others may be vein formations. A large number fall into an intermediate class, of which it is not likely that a reference to either origin can ever be made. There seems to be no reason against accepting an intrusive origin for the majority of those pegmatites which have a typical granitic texture and in which none of the constituent minerals are separated out in sheetlike masses parallel to the walls, especially those that are more persistent in extent in regions where granite intrusions are of large size or plentiful. On the other hand, it does not seem reasonable to consider certain forms of pegmatite, occurring in the region studied, as true igneous injections. In this statement are included such pegmatites as are illustrated in figs. 16 and 17 and probably also in fig. 15. In each of these masses banding is evident.

Fig. 16 represents a vein cutting a mass of coarse granite or pegmatite in a region of granite intrusions. The vein is composed of the same minerals, coarsely crystallized, as in pegmatite, and is itself pegmatite. It is evident that there have been several stages in its formation. Apparently the mica-feldspar bands along the walls were first formed, followed by the quartz, and then in the middle by the streak composed chiefly of feldspar. It is possible that the feldspar formed in a fissure in a once solid mass of quartz; though it probably occupies the portion of the original fissure that was never quite closed by the quartz. Fig. 17 represents an occurrence that is uncommon, though it possesses certain features bearing on the origin of pegmatite. The history shown by this deposit may be briefly described as follows: After movements associated with mountain building had ceased—that is, in Carboniferous time or later—the granite dike was forced into a fissure or line of weakness cutting across the foliation of the country rock. Cooling was fairly rapid, and the texture was consequently rather fine. This was followed by the deposition of pegmatite from solutions passing along each side of the dike. A source for such solutions could be found in the final stages of activity of the magma from which the granite was formed.

These two illustrations are given to show that the formation of certain pegmatites is much more readily explained by referring it to aqueous agencies than to intrusion as an igneous body. With the probability thus established of an aqueous origin for certain pegmatites and an intrusive origin for others, we are confronted by a large number the nature of whose origin is difficult to decide. Among these are many pegmatites like that represented in fig. 15, in which there is a banding consisting of a streak of feldspar with a little quartz mixed through it lying on each side of a quartz band. Locally there are several quartz bands in the pegmatite. It is the opinion of the writer that such pegmatites are in part, if not wholly, of vein origin. The feldspar component, in many places containing more or less quartz mixed through it, may have been intruded as a magma and the whole modified by the secondary introduction of quartz by solutions. It seems more likely, however, that if a part is to be considered the result of aqueous agencies the whole pegmatite should be so considered. A strong argument in favor of the deposition of these quartz bands from solution is afforded by the peculiar banding, apparently not due to strain, observed in the quartz streak at the Lyle Cut mine. (See p. 412.)

The blending between the conditions of fusion and solution conceived to exist under heat and pressure, such as prevail in deeply buried granite magmas where water is present in considerable quantity, has been well set forth by Van Hise,[a] Crosby and Fuller,[b] and Williams.[c] As stated by Van Hise, given the two conditions, a magma and a solution with no sharp line of demarcation between them, we may expect to have injections of dikes and aqueous cementation, which grade into each other and between which no sharp distinction

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[a] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904.

[b] Crosby, W. O., and Fuller, M. L., Origin of pegmatite: Am. Geologist, vol. 19, 1897.

[c] Williams, G. H., General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895.

can be drawn. Van Hise further cites the occurrence of pegmatite in metamorphic rocks in the Marquette district of the Lake Superior region, where no parent granite mass was found, and concludes that the pegmatite was formed by the metamorphism of the rocks through mechanical action aided by aqueous agencies.

It is thought that these views are applicable to the pegmatites of North Carolina. Some are so clearly associated with large granite intrusions and are so like granite in their behavior toward the country rock that the theory of intrusive origin seems particularly appropriate. Others also in regions of granite masses exhibit structures so similar to those generally attributed to vein formations that they must be considered of aqueous origin. Still others show structures common to both igneous masses and vein formations and must be placed in the intermediate stage set forth by Van Hise. There are pegmatites within the areas of the Carolina and Roan gneisses which are so far removed from any known granite masses that it seems probable that they were produced during the metamorphism of the inclosing rocks, like those of the Marquette district. This theory is more plausible when the great extent of the regional metamorphism of the Carolina and Roan gneiss formations and the large number of small pegmatite streaks cutting them at all angles are taken into consideration.

The occurrence of drusy cavities, comb structure, and regular banding, such as is common in many fissure-vein deposits, is observed in few places, if anywhere, in the mica-bearing pegmatites of North Carolina. This is not to be wondered at when the conditions of the formation of pegmatite are considered. The materials are probably derived from deep-seated magmatic or metamorphic sources, and the pegmatite was formed at great depth under conditions of heat and pressure. If the material was itself a magma, the resulting form would be a dike, in which formation cavities are never looked for, except near the surface. If the material was a solution, either of magmatic or metamorphic origin, a vein would be produced. That veins do not necessarily have banded structure nor drusy cavities is plainly shown by many of the auriferous quartz veins of the southern Appalachians, in which genuine banding or crustification is rare and the majority show no trace of either. These veins are the mere stumps of a once extensive vein system that has been eroded away along with several thousand feet of the formations in which they occurred. According to Graton,[a] these veins were formed by heated solutions forced, under great pressure, into what in many cases may have been the merest fractures and depositing their loads. The force of crystallization may also have aided in expanding the openings, but the principal force is supposed to be due to the pressure exerted by the weight of overlying formations on these solutions at a lower depth than that at which the vein

[a] Graton, L. C., Gold and tin deposits of the southern Appalachians: Bull. U. S. Geol. Survey No. 293, 1906, p. 60.

was formed. It is thought that pegmatite veins may have formed in very much the same way as these auriferous quartz veins. Under similar conditions heated solutions, carrying the constituents of pegmatite instead of those of gold-bearing quartz veins, would form regular veins of pegmatite. Any irregularities in the composition of the solutions would produce the banding already described as of common occurrence in pegmatites.

It is difficult to conceive of the formation by injection, as an ordinary magma, of pegmatite in streaks or bands a fraction of an inch thick in gneissic rocks, in many places having no visible connection with other pegmatite bodies. On the other hand, it is easy to conceive of a solution being forced through the smallest fractures or working its way between the mineral particles and depositing its load. The latter process would not require such high temperatures, either in the solution or country rock, as would be required for the injection of a magma in order that it might not be cooled so quickly as to prevent coarse crystallization. The possibility of the formation of these smaller pegmatites by the injection of a highly fluid aqueo-igneous magma is not denied, especially if the magma approaches closely the conditions of a solution. It is thought, however, that aqueous processes afford a simpler and, therefore, more reasonable explanation.

Pegmatization of rock masses, so common in the Carolina gneiss, especially in the Piedmont Plateau region, has probably resulted from one or both of two causes—namely, either recrystallization due to aqueous agencies or the addition of more material from solutions passing through the formations. In the first process occluded water in the rock, aided by the heat generated during regional metamorphism, may have caused recrystallization and consequent pegmatitic texture. In the second process it is probable that pegmatization has resulted from solutions which were forced through the rock along cracks, seams, or bedding planes and there deposited their load. Where pegmatization is characterized by much feldspar, it is probable that these solutions were of magmatic origin, and one generally does not have to look far to find a granite intrusion in the neighborhood.

It is thought that pegmatites occurring in irregular masses, streaks, lenses, augen, or balls, and having no visible connection with other pegmatite bodies, are generally the result of aqueous action. A solution could be readily forced through fractures or seams along the bedding planes and deposit its load only in the more favorable places. If such bodies were formed by intrusions, it would be necessary to consider that the walls of the dike had been forced together, closing the passage through which the magma had passed. Though the possibility of such conditions is not denied, a simpler method of formation, as deposition from solution, is considered more probable. In augen and ball-shaped bodies of pegmatite without visible connection with other pegmatite masses, room for the segregation was probably produced by the expansive force of the growing feldspar crystals, which have crowded the gneiss or schist out on each side.

SUMMARY OF CONCLUSIONS.

It is uncertain whether pegmatites should be called intrusions or vein formations. It is probable that some are dikes and others are veins. Those with a typical coarse granitic texture are probably of intrusive origin; those with a banded structure are probably the result of aqueous deposition. In view of certain examples, already illustrated by figures, these statements become more acceptable. Van Hise's conception of the condition of pegmatite material before the pegmatite was formed seems particularly applicable in this region; that is, given a magma and a solution with no sharp line of demarcation between them there may be intrusions and aqueous cementation also grading into each other. Graton's interpretation of the formation of the auriferous quartz veins of the southern Appalachians also seems particularly appropriate in accounting for pegmatite veins; that is, the solutions were forced into fractures or fissures under great pressure and by the aid of the expansion produced by the crystallization of the minerals being deposited, spread the walls apart sufficiently to allow the formation of the veins. The occurrence of much pegmatite in small streaks through the rock formations is probably caused either by recrystallization through the combined action of water and heat or by solutions being forced through fractures or seams and depositing their loads, or by both. It might also be possible for such pegmatization to be produced by the injection of an extremely fluid aqueo-igneous magma into and through the formations. Disconnected bodies of pegmatite are also more readily explained by deposition from solution than by intrusion as dikes.

The question of the origin of pegmatites is chiefly of scientific interest rather than of commercial importance; for good deposits of mica are found in rocks of both dike and vein types. The quality of the mica from one type is in general no better than that from the other. It is probable, however, that those pegmatites which are typically of intrusive origin will be found to hold out longer than those with veinlike structure. Although the available evidence is insufficient to prove this definitely, there are certain dikelike masses that have been followed long distances or to considerable depth and found to carry paying mica to the limits worked. On the other hand, many veinlike deposits have been opened and large quantities of mica recovered from certain portions, and then the "vein" has abruptly become poorer or pinched out. Of course there are veinlike deposits which have been worked through considerable distances; though probably none have held out so persistently as the bodies of intrusive origin.

MICA IN THE HARTVILLE UPLIFT, WYOMING.

By Sydney H. Ball.

INTRODUCTION.

During the field season of 1906 the writer examined the mica prospects of the Hartville uplift, situated in the rugged hills among which Haystack Peak is the most prominent. (See fig. 5, p. 192.) They are located upon pegmatite dikes cutting pre-Cambrian schists. These schists, which form the uppermost member of the older sedimentary series,[a] are closely folded and intensely metamorphosed near the granite of the Haystack Hills. The mica-bearing area lies to the east of Whalen Canyon and to the west of Cottonwood Canyon, and its north and south boundaries are respectively McCanns Pass and an east-west line passing through Haystack Peak. The possibly productive area includes all or parts of secs. 25, 26, 27, 34, 35, and 36, T. 28 N., R. 65 W., and secs. 1, 2, and 3, T. 27 N., R. 65 W.

The first mica claim, named the Savage, was located by Joseph L. Stein in 1881. Other prospects were soon taken up, and work has been done on some of them up to the present day, but with an unimportant exception no muscovite has been shipped. At present four prospects appear promising.

Muscovite in commercial quantities is confined to dikes of pegmatite, which cut the schists. These dikes were intruded after the schist became fissile, and in consequence trend in the main parallel to the schistosity, although in places they cut across it. The dikes vary from thin stringers to irregular intrusive masses one-fourth mile wide. In many places their width is constant, but here and there it changes markedly within a short distance. The pegmatite is composed of the following minerals, named in the order of their abundance: Feldspar (orthoclase, microcline, and albite), quartz, muscovite (white mica), black tourmaline, beryl, brown garnet, and biotite. It is in general coarsely granular, the mineral bodies varying in diameter from one-fourth inch or less to 2 feet or more. Such extreme variations are rarely seen in a single dike, although important changes in the sizes of grains take place within comparatively short distances. The distribution of the minerals in the pegmatite is, as a rule, fairly even, although

[a] For the succession of the pre-Cambrian rocks of the Hartville uplift see pp. 193–194 of this volume.

locally muscovite in particular occurs in bunches of books. Liquids and gases originating from the pegmatitic magma have considerably metamorphosed bands of schist on either side of the pegmatite dikes.

DESCRIPTION OF PROSPECTS.

The principal mica prospects of the Hartville uplift are the Crystal Palace, the Savage, the New York, and the Minnie.

The Crystal Palace claim, owned by Lauck & Stein, is situated on the south side of a steep valley in the center of the NE. ¼ sec. 34, T. 28 N., R. 65 W. An open cut 60 feet long has been made on a pegmatite dike 6 feet wide at its floor and 15 to 18 feet wide at its top. At the southwest end of the cut the pegmatite is covered by talus, but it is exposed for a long distance along its strike, which is N. 60° E. It is a coarsely crystalline aggregate of feldspar, white quartz, muscovite, tourmaline, brown garnet, and a little beryl. The black tourmaline is not prominent and is largely confined to the edges. Quartz was the last mineral of the pegmatite to solidify and a portion of it was still held in solution by the magmatic waters after the pegmatite had consolidated, since it also occurs in indistinct veins which cut the pegmatite. The distribution of the muscovite is bunchy and in consequence an estimation of the amount of muscovite in the walls of the open cut is difficult, although it probably forms from 10 to 15 per cent of the pegmatite. The muscovite tends to form hexagonal plates, some of which are 2 feet across and 3 or 4 inches thick. It is a good-grade "water" mica, although rulings are common and in some of it plates of feldspar and quartz lie between the mica leaves. To the northeast across the gulch the pegmatite contains a greater proportion of tourmaline and beryl, and though muscovite is equally abundant, the plates are much smaller. At present there are 2 or 3 tons of mica on the dump. Some of this is high-grade material which could be used for sheets.

The Savage claim, also the property of Lauck & Stein, is situated near the center of the S. ½ sec. 26, T. 28 N., R. 65 W. An open cut is here located on a pegmatite dike 10 feet wide, which courses N. 65° E. About 200 feet farther southwest the dike either pinches out or plunges beneath the surface, and to the northeast it becomes narrower and the muscovite plates become smaller. The composition of this pegmatite is similar to that at the Crystal Palace claim, although bluish-green beryl is more abundant. In many places thin distorted crystals of tourmaline lie between the muscovite leaves. Muscovite in plates, some of them 12 inches in diameter, forms 10 to 15 per cent of the pegmatite. From this prospect sheets of mica 11 by 13 inches and free from flaws have been obtained.

The New York claim is situated in the northeast corner of sec. 35, T. 28 N., R. 65 W., and is owned by Mr. Frederick. At the open cut the pegmatite dike is from 6 to 10 feet wide; it narrows to 5 feet 350 feet to the west, but widens to 50 feet 500 feet still farther west. The pegmatite varies considerably in the size of its constituent minerals. Muscovite occurs in plates up to 20 inches in diameter, although the largest plates are commonly ruled. The larger flawless plates are from 6 to 8 inches in diameter.

The Minnie claim, situated southwest of the center of sec. 35, T. 28 N., R. 65 W., is also owned by Mr. Frederick. The largest sheets obtainable on this claim are 8 inches in diameter.

Plates of mica 10 inches across were seen in a pegmatite dike in the north center of sec. 35, T. 28 N., R. 65 W. This dike is characterized by beryl crystals 4 feet long. Plates of muscovite 8 inches in diameter occur in a pegmatite dike in the center of the SE. ¼ sec. 35.

COMMERCIAL CONDITIONS.

The pegmatite dikes in which large sheets of mica occur vary in width from 5 to 18 feet and carry from 10 to 15 per cent of muscovite. It is probable that at least in the four prospects described, muscovite is present in commercial quantities. There is a marked variation in the width of the dikes, along both the strike and the dip, and the size of the mica plates is by no means uniform in different portions of the same dike. The mica is clear and of good quality, although varying amounts of it are ruled and feldspar, quartz, and tourmaline occur between the leaves of some of the books.

Mica mines situated in the Western States are operated at a considerable disadvantage on account of the high freight rates to the eastern market. A mine in the Black Hills, South Dakota, however, whose transportation facilities are comparable in a general way to those of the prospects at the Hartville uplift, has shipped mica to Illinois, apparently at a profit. High freight rates also prohibit the utilization of feldspar and quartz, common by-products of mica mines, in the manufacture of pottery. These Wyoming prospects would furnish a considerable percentage of sheet mica for the glazing trade. Although large mica plates are in less demand than formerly for stove doors, since smaller sheets are now used in paneled doors, the introduction of mica lamp chimneys has perhaps offset this decrease in the demand. Smaller plates could be used in making composite sheets of mica called mica board or micanite, and the waste mica could be shipped for grinding. The mica of these prospects would probably bring from 35 to 50 cents per pound. The Crystal Palace and Savage claims can readily be reached by road, and the mica can be hauled to Ironton, Wyo., on the Chicago, Burlington and Quincy Railroad, for $1.25 per ton. The cost of transportation from the New York and Minnie claims would be somewhat greater. It is probable that under careful management mica of excellent quality could be produced in the Haystack hills at a small profit.

GRAPHITE IN THE HAYSTACK HILLS, LARAMIE COUNTY, WYO.

By Sydney H. Ball.

GEOGRAPHY AND GEOLOGY.

In the summer of 1906 the writer examined the graphite properties of Laramie County, Wyo., situated in the rugged hills around Haystack Peak, which lies to the east of Whalen Canyon and to the west of Cottonwood Canyon. (See fig. 5, p. 192.) The most promising graphite-bearing area includes secs. 14, 15, 22, 24, 25, 26, 27, 34, 35, and 36, T. 28 N., R. 65 W., and sec. 1, T. 27 N., R. 65 W., although graphitic schist occurs in the vicinity of Rawhide Buttes.

The first prospecting for graphite in these hills was done by Messrs. Lauck & Stein, who in 1881 located the so-called Sentinel claim, south of Hamilton Pass. Since that time little interest has been shown in the graphite and no shipments have been made.

The graphite occurs in the immediate vicinity of granite and pegmatite as a constituent of the pre-Cambrian muscovite schist of sedimentary origin.[a] Of the larger intrusive granite masses of the Haystack Hills one alone—that to the north of McCanns Pass—has metamorphosed this schist to a graphitic phase. The schist varies from a silvery muscovite variety containing but little graphite to a grayish-black sectile rock. Such gradations occur, as a rule, across the strike, although to a less degree along it. On microscopic examination the schist unaffected by the granitic and pegmatitic intrusions is seen to contain carbonaceous matter, and the graphite is this material altered by the intense heat and other agents attendant on the intrusions.

OCCURRENCES.

The most extensive graphite showing is on the north side of McCanns Pass, 2,000 feet east of the summit, in sec. 26, T. 28 N., R. 65 W. About 300 feet of schist, which, although it is intruded by a large pegmatite dike, is of the normal muscovitic variety, lies between the granite and the graphitic band, striking N. 55° E. and

[a] For an account of the pre-Cambrian succession of the Hartville uplift, see pp. 193–194 of this volume.

dipping 70° NW. The graphitic schist is exposed in two outcrops 2 feet apart, each 4 feet wide measured across the bedding, indicating, if each is in place, a thickness of 10 feet. This rock varies in composition across the strike from a coarsely schistose muscovite-graphite phase to a graphite schist of grayish-black color. Beyond this point the rocks are covered by alluvium for 1,000 feet to a second exposure along the same strike, showing an 8-foot band of rather high-grade semischistose graphitic rock, portions of which are considerably iron stained. From this exposure the band can be traced westward 1,000 feet on the north side of McCanns Pass, at first by abundant and then by fewer outcrops and many residual masses. The graphitic band gradually approaches the granite and is finally cut out by it. At the contact of the schist with the granite a tunnel exposes 10 feet of graphitic schist.

A band of graphitic schist 2 feet wide occurs on the south side of the gap in the center of the NE. ¼ sec. 1, T. 27 N., R. 65 W. This band has a strike of N. 70° E. and a vertical dip. It can be traced along the strike for several hundred feet to the alluvium on either side. Large bodies of pegmatite lie within 35 feet north and south of the graphite. The grade of the graphite is lowered by the presence of contorted veins of quartz which lie along the foliation planes of the schist. High-grade graphitic schist has also been thrown from a prospect pit in the center of the W. ½ sec. 14, T. 28 N., R. 65 W. It occurs also in the north-central part of the NE. ¼ sec. 26, in the northeast corner of sec. 27, in the center of the SW. ¼ SE. ¼ sec. 23, and in the northwest corner of sec. 26, T. 27 N., R. 65 W. In sec. 26 some tourmaline is associated with the graphitic schist.

COMMERCIAL CONDITIONS.

As seen under the microscope the graphitic schists contain much finely disseminated graphite associated with quartz, tourmaline, and a little biotite, muscovite, and feldspar. The richest specimens appear to contain up to 16 per cent of carbonaceous matter, all of which is either in ragged particles or hexagonal plates and has the microscopic habit of graphite. One of the richer specimens analyzed by E. C. Sullivan afforded by the Wittstein method 13 per cent total carbonaceous matter and 5 per cent graphite. Doctor Sullivan states that this method may not determine all of the graphite and that the other carbonaceous matter present is practically nonvolatile. On chemical and microscopic grounds, then, it is probable that all the carbonaceous matter present may be commercially considered graphite. It is estimated that the 10-foot bed in McCanns Pass would run from 6 to 8 per cent graphite. The graphite individuals are very small, having an average diameter in various thin sections of 0.04 to 0.15 mm. To separate such finely divided graphite from the minerals associated with it would require very fine grinding and, although the percentage of mica in the schist is small, the expense of a clean separation of the graphite and mica to form a high-grade product would be prohibitive. The graphite is of the variety known in the trade as amorphous graphite and is suitable only for paint, other coloring matter, and foundry facings.

Haulage from the graphite bed to the Chicago, Burlington and Quincy Railroad at Ironton, Wyo., costs, approximately, $1.25 to $1.50 per ton.

Under the conditions which control the American graphite trade at present, it is exceedingly improbable that these deposits can be worked at a profit. At some future time, however, they may be of commercial importance. This is more particularly likely to be true of the bed in McCanns Pass, which is 8 to 10 feet wide.

SURVEY PUBLICATIONS ON MICA, GRAPHITE, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various nonmetallic mineral products:

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HAYES, C. W., and ECKEL, E. C. Occurrence and development of ocher deposits in the Cartersville district, Georgia. In Bulletin No. 213, pp. 427-432. 1903.

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