ART. XXXI.—*On the Paragenesis of Allanite and Epidote as Rock-forming Minerals;* by WM. H. HOBBS, Ph.D.

THE interesting discovery of Messrs. Cross and Iddings,* of the U. S. Geological Survey, that the mineral allanite or orthite occurs widely distributed as a constituent of many varieties of rocks, has placed this mineral in the list of important accessory rock-constituents, and called the attention of American geologists to its distinguishing characters. In Europe, allanite, or orthite, which is the term commonly used in Germany for the same mineral, had already become recognized as one of the rarer constituents of a few rock species. As early as 1860, K.

* Cross and Iddings. Wide-spread Occurrence of Allanite as an accessory constituent of many Rocks, this Journal, III, xxxii, p. 108, Aug., 1885.

von Fritsch* described this mineral in the granitite of Ilmenau in the Thuringian Forest. Vom Rath† recognized it as an important accessory constituent of the tonalite of Mt. Adamello. Interesting occurrences are mentioned by Liebisch‡ in the granite porphyry of Erdmannsdorf and other localities in Lower Silesia, and by Törnebohm§ in an amphibole-biotite granite from Eastern Siberia. Our knowledge of the optical properties of allanite has been much advanced by the investigation of this mineral in the granite of Pont Paul near Morlaix, Finisterre.‖

The occurrence of allanite and epidote as constituents of the same rock has been several times observed, and by two investigators these minerals have been found so intergrown, as to add evidence of isomorphous character to that already known to exist in the similar crystal form and analogous chemical composition.

In 1854, Blomstrand¶ described from Wexio in Sweden crystals of pistazite arranged radially about cores of allanite; and somewhat later Ewald Becker** mentioned inclusions of orthite in the epidote of a granite from Striegau. Messrs. Cross and Iddings†† observed apparent inclusions of epidote in allanite. It is further stated in many text-books‡‡ that cores of allanite in epidote and cores of epidote in allanite, occur at Sillböhle in Finland. After some search I am unable to designate the original paper by Nordenskiöld, but through the courtesy of Professor Wiik of Helsingfors, I have a copy of the catalogue to the mineral collection of the Helsingfors University§§ in which the interesting intergrowths are figured. A similar intergrowth has been recently found by Törnebohm‖‖ to characterize the epidote-gneiss of a considerable portion of Wermland. "Small crystals which have been taken for orthite and which are crystallographically similar and oriented like their host, occur in the epidote."¶¶

* Geognostische Skizze der Umgegend von Ilmenau im Thüringer Walde. Zeitsch. d. d. Geol. Ges., xii, 105.

† Beiträge zur Kenntniss der eruptiven Gesteine der Alpen, I, ibidem, xvi, 255, 1864.

‡ Ueber die Granitporphyre Niederschlesiens, ibid., xxix, 725, 1877.

§ Vega Expedition IV, 115–140, Stockholm, 1884. Ref. Neues Jahrb. f. Min., etc., 1885, i, 429.

‖ Michel Lévy et Lacroix. Note sur un gisement français d'allanite, Bull. soc. minèr. de France, xi, No. 2, 64, Feb., 1888

¶ Blomstrand, Oefvers. af akad. Förhandl., 1854, No. 9, p. 296. Ref. Journ. f. prakt. Chem., lxvi, 156.

** Ewald Becker, Ueber das Mineralvorkommen im Granit von Striegau insbesondere über den Orthoklas und dunkelgrünen Epidot, Breslau.

†† Loc. cit.

‡‡ Dana, Brooke and Miller, etc.

§§ F. J. Wiik, 1887. p. 27, pl. II, fig. 7.

‖‖ Törnebohm. Mikroskopiska bergartsstudier, XIII Epidotgneiss. Geol. För. i Stockholm Förhandl., 1882, No. 75, vi, 189.

¶¶ Ref. Cohen, Neues Jahrb. f. Min., etc., 1883, i, 245.

While engaged in the study of the geology of a section of the Johns Hopkins University map, two epidotic minerals were found to play an interesting rôle as accessory constituents of the porphyritic granite of Ilchester. A short notice on the geological relations of the rocks of this area, together with mention of parallel growths of epidote and allanite, appeared in April, 1888.* After a further examination of these interesting intergrowths, it is my purpose in the present paper to consider them more fully in connection with what has already been said concerning epidote and allanite.

The Ilchester granite, in which they occur, is one of the youngest of a series of eruptions in the gneiss and crystalline schist of eastern Maryland. It is a medium to coarse-grained rock, with a porphyritic aspect caused by the large microcline crystals scattered through the holo-crystalline to granophyric ground-mass. This ground-mass contains as essential constituents, varying proportions of monoclinic and triclinic feldspar, and biotite By the more or less complete replacement of biotite by hornblende, the granitite develops facies of hornblende granite. Besides allanite and epidote the only important accessory constituent is a colorless mica. Throughout the entire area of the section studied, the granite shows evidence of "stretching" in its more or less perfect "parallel structure," and in the broken character and disturbed optical properties of the constituent minerals.

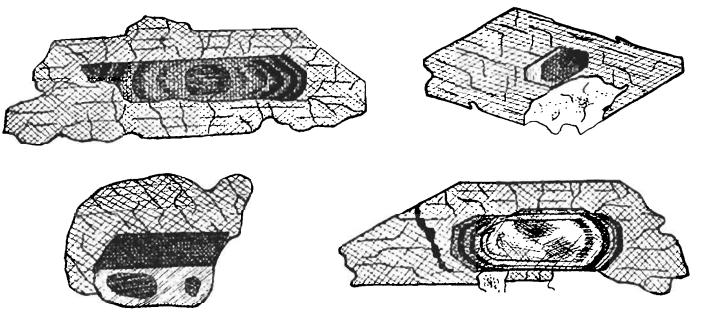
The epidote is macroscopically visible in the rock, generally as yellow columnar crystals one to three millimeters in length, though it is often without crystalline form. A brownish kernel is frequently visible within the epidote, and when prismatic planes are developed upon the latter, the perfect parallelism of the corresponding faces of the two minerals can be observed. The junction of the included mineral with its host appears as a sharp line, owing to the difference in color of the two minerals. The included mineral shows no distinct cleavage, is very brittle, and is found in some specimens of the granite decomposed to a brown powder. The brittle character of this mineral has prevented its removal from the matrix and examination with the goniometer.

Under the microscope its isomorphous relation to epidote is strikingly shown in many instances by the parallelism of the bounding planes of the two minerals and its distinct character

* Wm. H. Hobbs, On the rocks occurring in the neighborhood of Ilchester, Howard County, Maryland; being the detailed study of the area comprised in sheet No. 16 of the Johns Hopkins University map. Johns Hopkins University Circulars No. 65. (Preliminary notice of a dissertation for the degree of Doctor of Philosophy).

marked by a beautiful zonal structure absent in the epidote. The forms observed were M (001), $r$ ($\bar{1}01$), T (100), and somewhat imperfect terminal planes, the symbols of which could not be determined. When not too deeply colored the long

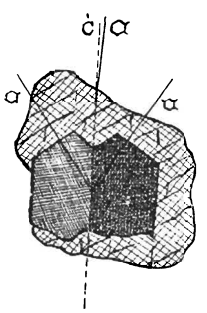
1.



Sections of intergrowths in the Ilchester granite, × 50.

sections yield an optic axis, which shows the plane of the axes to be the clino-pinacoid (010). Such sections therefore extinguish the light parallel and perpendicular to the long axis ($b$). The index of refraction is strong, while the double refraction is feeble, the interference colors between crossed nicols being of the first order, even when the slides are above the usual thickness. The dispersion is very strong, making indistinct the extinctions in polarized light. Twins parallel to the ortho-pinacoid were rarely observed. A chance section of such a twin appears in fig. 2. The symmetry of extinction with reference to the composition seam and the form of the section, are evidence that the plane of the section, lies nearly or quite perpendicular to the axis $b$. In either individual the axis of maximum elasticity makes an angle of 36° with the vertical axis, but in the absence of cleavage and perfect planes, it was impossible to determine whether this axis of elasticity lies in the obtuse or in the acute angle $\beta$. The surrounding epidote is allotriomorphic and a single individual, but orientated like one of the included crystals, as is shown by its axis of maximum elasticity, which makes an angle of 3° with the twinning plane of the inclusion. The pleochroism of the included mineral is one of its most marked characters, and has been determined to be as follows: a light yellowish-brown, b chestnut-brown, and c dark greenish-brown. The absorption is like epidote $c > b > a$.

2.




Section of twinned allanite crystal with mantle of epidote, × 5.

These characters belong to the mineral allanite and a comparison shows that they are the same as are possessed by the allanite of the Ten Mile Region of Colorado.* Further comparison with slides from the epidote-gneiss of Wermland in Professor Rosenbusch's collection shows that in this case, as in the Ilchester granite, we have to do with parallel intergrowths of allanite in epidote.

Since publishing my first notice of these intergrowths, the suggestion has been made that the surrounding mineral may not be epidote, but that it may be allanite whose color and optical differences are to be accounted for by slight differences of chemical composition; in other words that we have to do with a case of zonal structure in allanite. The characters of the epidote require therefore careful consideration.

The examination in thin section under the microscope shows the epidote to possess, in the majority of cases, the prismatic planes, M, *r*, and T. The longer sections of these crystals exhibit cleavage lines parallel to the longer axis, and yield in converging polarized light an optic axis, which often appears on the edge of the field. The plane of the optic axes is perpendicular to the ortho-diagonal and the optical angle is large. The cross-sections of crystals show an imperfect cleavage parallel to M (001), and a poor cleavage parallel to T (100). The cleavage angle measured 115°. The angle of maximum elasticity lies in the acute angle $\beta$ and makes with the vertical axis an angle of 3° to 3° 3′. The pleochroism is distinct and as follows: a nearly colorless, b light straw-yellow, c siskin-green The absorption is written $c > b > a$.

By the use of the Thoulet solution a quantity of epidote together with some admixed allanite and titanite was separated from the rock, and ·45 gram obtained pure by the tedious process of picking out the fragments of allanite and titanite, their darker brown color serving to distinguish them. I am indebted to the U. S. Geological Survey for an analysis of this powder by Dr. W. F. Hillebrand. Special examination was made to determine the presence or absence of the rare earths, but no trace of any was discovered. The material used in this examination necessitated a determination of the alumina by difference. The amount of ferrous oxide was not determined. The water was determined by loss on glowing. The results of Dr. Hillebrand's analysis are given under I. An analysis of the Untersulzbach epidote by Ludwig is introduced under II by way of comparison.

* The sections of the biotite-porphyrite of this region were kindly loaned me by Dr. Cross of the U. S. Geol. Survey.

| | I. | II. |
|---|---|---|
| $SiO_2$ | 37·63 | 37·83 |
| $Al_2O_3$ | [20·86] difference | 22·63 |
| $Fe_2O_3$ | 15·29 | 15·02 |
| $FeO$ | | 0·93 |
| $MnO$ | 0·31 | ---- |
| $CaO$ | 22·93 | 23·27 |
| $MgO$ | 0·31 | ---- |
| $H_2O$ | 2·23 | 2·05 |
| $P_2O_5$ | 0·44 | ---- |
| | 100·00 | 101·73 |

If we consider the phosphoric oxide as due to inclusions of apatite, and disregard the traces of manganese and magnesia, the analysis corresponds very closely with the formula $2H_2Ca_4Al_6Si_6O_{26}+H_2Ca_4Fe_6Si_6O_{26}$.

The peculiar intergrowths that have been described are characteristic of the Ilchester granite throughout the twenty-five square miles of the section studied.* Colorless inclusions, probably apatite, as well as biotite, are occasionally found in the allanite. With little doubt, the latter is one of the earliest separations from the magma. The origin of the epidote is not so easily settled, but the "stretched" character of the granite is in favor of a metamorphic origin through pressure. Against such a view is the discovery by Professor Williams that the Woodstock granite, which is particularly rich in these intergrowths, shows no evidence of cataclastic action.

In conclusion I would gratefully acknowledge obligation to my much honored teachers, Professor Williams of the Johns Hopkins University in Baltimore, and Professor H. Rosenbusch of Heidelberg, Germany.

After the foregoing article left my hands, there was brought to my notice the recent important paper of Lacroix on Pyroxene-gneiss and Wernerite Rocks (Contributions à l'étude des gneiss à pyroxène et des roches à wernerite, Bull. de la Soc. française de Minéralogie, tome xii, No. 4, April, 1889). The author describes similar epidote-allanite intergrowths in the pyroxene-amphibole gneiss of Finisterre (pp. 138–9, fig. 21); in the pyroxene-wernerite gneiss of the Lower Austrian Waldviertel (p. 157, pl. I, fig. 5); and in the wernerite gneiss of Odegården in Norway (p. 210). M. Lacroix has found the same properties to characterize the allanite and epidote of these localities as have been determined for the Ilchester intergrowths, specimens of which he has used for comparison. He considers the epidote primary in all the occurrences described by him (p. 353).

* I am informed by Prof. Williams that he has found such epidote-allanite intergrowths to be characteristic of the surrounding Ellicot City and Woodstock granites, but wanting in the Guilford granite which occurs farther to the south.