PHOSPHATE-ALLOPHANE IN AN EPIDOSITE FROM NORTH CAROLINA[1]

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Abstract

Phosphate-allophane has been found replacing oligoclase in an epidosite from North Carolina. A chemical analysis of the allophane and a petrographic description of the rock are given.

Introduction

An epidosite containing phosphate-allophane replacing feldspar was recently submitted to the Eastern Experiment Station, Bureau of Mines, for identification. The sample was found by J. H. Parrish, on his own property about 2 miles south of Whittier, North Carolina. Whittier is located in Swain County, where the Great Smoky Mountains of the Blue Ridge form a natural boundary between North Carolina and Tennessee. Epidosites and epidote-rich rocks are abundant throughout much of the Blue Ridge of North Carolina and Virginia. Unakite, a rock composed essentially of epidote, pink orthoclase and quartz was named by Bradley[4] from its occurrence in the Unaka (Unicoi) Range of the Great Smoky Mountains bordering North Carolina and Tennessee. The Unaka Range lies a little southwest of Whittier.

Another unakite from Millam's Gap in the Blue Ridge of Virginia was described by Phelan.[5] He describes this rock as being composed essentially of "old-rose feldspar (orthoclase) and green epidote." In both the North Carolina and Virginia occurrences of the unakites, the epidote is considered to be a secondary mineral. Johannsen,[6] discussing the Virginia unakite, concurs, and suggests that the rock was derived from a hypersthene akerite by dynamic metamorphism and the percolation of meteoric waters.

Chemistry

Phosphate-allophanes have been described by Ross and Kerr[7] and more recently by Gordon.[8] It has long been recognized that allophane is an

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[4] Bradley, F. H., On unakite, an epidotic rock from the Unaka Range, on the borders of Tennessee and North Carolina: *Am. Jour. Sci.*, **VII**, 519–820 (1874).

[5] Phalen, V. W., A new occurrence of unakite: *Smithsonian Miscell, Coll.* **XLV**, 306–316 (1904).

amorphous clay mineral or mineraloid having no definite crystalline structure or chemical composition. Ross and Kerr have indicated that allophane and the other mineraloids, evansite (hydrated aluminum phosphate), and chrysocolla (hydrated copper silicate) may occur as mixtures. These investigators have shown that mixtures of allophane and evansite may occur in all proportions. The previously ill-defined

Table 1. Analysis of Phosphate-Allophanes

	1	2	3	4
SiO_2	25.00	27.61	21.26	17.76
Al_2O_3	34.20	32.29	34.95	32.77
Fe_2O_3	1.02	.23	.10	3.02
P_2O_5	6.76	1.31	7.15	7.97
H_2O-	11.40	19.36	14.85	19.24
H_2O+	19.30	18.05	21.38	17.72
CuO	none	—	—	—
ZnO	none	—	—	—
MgO	tr.	.10	.05	.16
CaO	1.20	.02	none	.62
CO_2	tr.	.72	—	—
SO_3	none	.12	—	—
TiO_2	tr.	none	—	—
Org. matter	—	—	tr.	—
Na_2O	tr.	} .10	—	—
K_2O	—		—	—
	98.88	99.91	99.74	99.26

1. Whittier, North Carolina, A. M. Sherwood, analyst.
2. Morehead, Kentucky, J. J. Fahey, analyst (Ross and Kerr[7]).
3. Huron, Indiana, J. J. Fahey, analyst (Ross and Kerr[7]).
4. Cerro de Llallagua, Bolivia, E. V. Shannon, analyst (Gordon[8]).

schroetterite and viterbite are also to be grouped with the allophanes. In all probability, phosphatic allophanes are more common than has been recognized, as the phosphorus is not always readily detected. In Table 1, the analysis of the phosphate-allophane from North Carolina is compared with others of similar composition. The separation of the analytical sample of the allophane from the epidote and feldspar in the

[6] Johannsen, Albert, A Descriptive Petrography of the Igneous Rocks: Vol. II, 59–60, *Univ. of Chicago Press* (1939).

[7] Ross, C. S., and Kerr, P. F., Halloysite and allophane: *U.S.G.S., Prof. Paper* **185–G,** 144–148, (1934).

[8] Gordon, S. G., The mineralology of the tin mines of Cerro de Llallagua, Bolivia: *Proc. Acad, Nat. Sci. Phila.*, **XCVI,** 355, (1944).

North Carolina occurrence was difficult. It was finally accomplished by a combination of stage-grinding and high-intensity magnetic separation. A preliminary rough concentration was made of allophane+feldspar by selecting particles of the whitest material available. It was then determined that, with only a slight amount of grinding, the allophane, the softest constituent present, concentrated in the very fine screen fractions. The −200+400 mesh screen separation was composed entirely of allophane and fine grained epidote with a little sphene. The feldspar, because of superior hardness and coarser grain size, remained in the coarser screen fractions. After several passes at 1.5 amperes on the Franz Isodynamic Magnetic Separator, a small but microscopically clean allophane product was separated from the epidote and sphene. The complete chemical analysis was made on a one-half-gram sample.

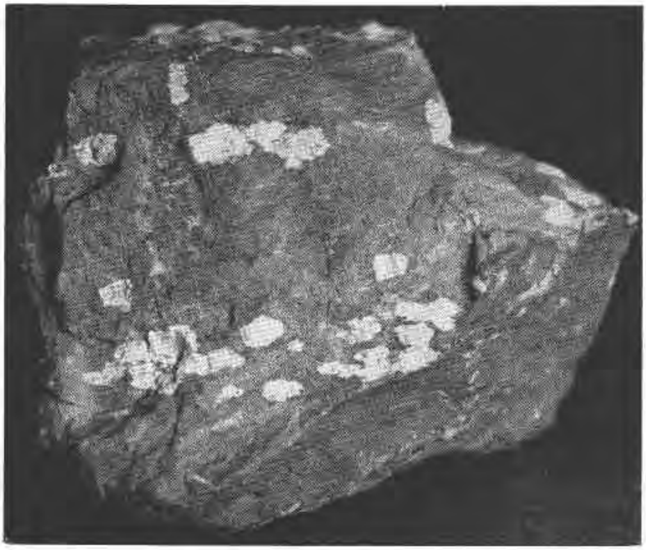

FIG. 1. Epidosite from North Carolina showing coarse-grained, oriented, altered oligoclase (white) in a matrix of fine-grained epidote. (Natural size.)

PETROGRAPHY

The North Carolina phosphate-allophane occurs as an alteration product of oligoclase in a weathered epidosite. The rock is not classified as a unakite because the feldspar in the type unakite is orthoclase rather than oligoclase. In a hand specimen, the rock is seen to consist of fine-grained, equigranular, green epidote sprinkled with medium- to coarse-grained, subhedral to euhedral, white insets of altered oligoclase (Fig. 1). The feldspar insets are oriented in the same manner as phenocrysts in a volcanic flow rock.

Thin-section studies show that the rock is composed of pale-green epidote (60–80%), oligoclase+allophane+sericite (20–40%) and light brown sphene (1–5%). Calcite is sparingly present, associated with patches of sericite. A more detailed mode of the rock is unjustified, owing to the marked variation in different samples. Epidote, oligoclase, and sphene are subhedral to euhedral and all show a tendency toward a preferred orientation. Aggregates of sphene grains form narrow, parallel islands in the otherwise monomineralic epidote matrix. Several of the

FIG. 2. Phosphate-allophane (narrow strips) replacing oligoclase along twin lamellae to produce rectangular lattice dissection patterns. (Plane-polarized light, ×70.)

large oligoclase insets show albite twinning; others show none. The feldspars commonly contain small euhedral inclusions of epidote and may be penetrated by larger peninsulas of epidote aggregates. Oligoclase is the only altered mineral and may be replaced by phosphate-allophane, sericite, or mixtures of sericite and a little calcite. The chief alteration product, however, is a colorless, glassy phosphate-allophane. It usually replaces the plagioclase along twin or cleavage planes forming rectangular lattices within the former (Fig. 2). In other instances the allophane forms wormy streaks embaying the feldspar. All degrees of alteration may be observed, beginning with (*a*) peripheral replacement, passing through (*b*) rectangular lattice dissection patterns into (*c*) almost complete alteration, leaving only the original outlines of the plagioclase insets (Fig. 3). The average grain diameter of the epidote and sphene is 0.04 mm.; a maximum of 0.2 mm. was recorded for the former. The large insets of plagioclase attain maximum diameters of three-eighths of an inch.

The absence of phosphate minerals other than allophane is unusual. Gordon[8] found vivianite, wavellite, and vauxite associated with the phosphate-allophane from Cerro de Llallagua, Bolivia. He states that the allophane "was found interlaminated with marcasite, pyrite and sphalerite and probably derived from the weathering of pyrrhotite." Ross and Kerr[7] do not state whether any phosphate minerals were associated with the phosphatic allophanes from Kentucky and Indiana.

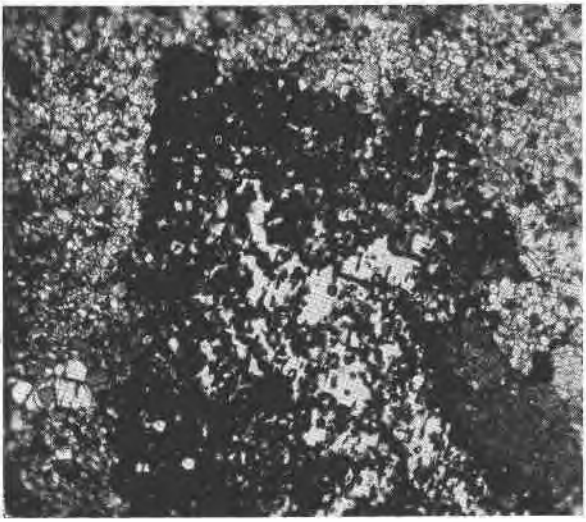

Fig. 3. A large grain of oligoclase (white) almost completely replaced by phosphate-allophane (black). The pseudomorph is bounded by fine-grained, granular epidote. (Crossed nicols, ×25.)

The phosphate-allophane from Indiana, however, occurs in intimate association with halloysite ("indianite") and alunite and may have had an origin similar to the *Bolivian* material. Ries[9] attributed the origin of the "indianite" to the decomposition of pyrite, the subsequent action of ground waters containing sulfuric acid on aluminous materials such as shale, and finally the replacement of quartz by halloysite, allophane, and alunite. The presence of lead, copper, iron, and zinc in allophanes associated with ore deposits is further testimony to the importance of the oxidation of sulfides in the formation of allophanes. Ross and Kerr[7] make no mention of the origin of the phosphate found in several of the allo-

[9] Ries, Heinrich, High-grade Clays of the Eastern United States: *U.S.G.S., Bull.* **708,** 156 (1921).

phanes. Gordon[8] does not discuss the matter either, but inasmuch as the Cerro de Llallagua tin deposits are very rich in phosphate minerals, the sources of phosphorus does not pose a problem. In the case of the North Carolina occurrence of phosphate-allophane, insufficient field data do not permit much theorizing on the origin of the material; however, the authors believe that the action of underground waters containing sulfuric and phosphoric acids was responsible for the alteration of the oligoclase to a phosphate-allophane. The sulfides, pyrrhotite, pyrite and chalcopyrite are abundant in Swain County, North Carolina. Their oxidation by meteoric waters may have been the source of circulating groundwaters carrying the sulfuric acid necessary for the alteration of feldspar to allophane.

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