ALLANITE FROM YOSEMITE NATIONAL PARK, TUOLUMNE CO., CALIFORNIA

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Abstract

Allanite-bearing rocks have been found in two localities in Yosemite National Park, Tuolumne County, California, *viz.* in narrow pegmatitic veins at Long Gulch, approximately one mile north-east from Aspen Valley, and in quartz-orthoclase pegmatite boulders in scree in the south slopes of Ragged Peak. Optical properties for these two occurrences are as follows: Long Gulch: $\alpha=1.769$; $\beta=1.784$; $\gamma=1.791$; $\gamma-\alpha=0.022$; $2V=60°$ (−); dispersion is distinct with $r>v$; pleochroism is brown (Z) to pale yellowish brown (X); $D_{20°C}=3.87$. Ragged Peak: $\alpha=1.791$; $\beta=1.815$; $\gamma=1.822$; $\gamma-\alpha=0.031$; $2V=40°$ (−); dispersion is distinct with $r<v$; pleochroism is deep warm brown (Z) to pale brown (X); $D_{22°C}=3.95$. Both minerals are readily decomposed by warm concentrated hydrochloric acid. Semiquantitative tests show that the Long Gulch allanite contains approximately 0.6 per cent MnO, whereas a complete quantitative analysis of the Ragged Peak mineral indicates that it contains 6.74 per cent and 2.02 per cent of MnO and TiO_2, respectively.

Both minerals exhibit only slight evidence of metamictization and both contain no lead. Acid treatment of allanite is discussed and it is shown that the degree of solubility is a function of composition and that true gelatinization will only result if the minerals are in a metamict condition.

Previous Work

Allanite has been described from Yosemite National Park and adjacent country by Ries (1900), Pabst (1928, 1938), Calkins (1930), and others, but so far as the writer is aware neither analyses nor optical data are available for occurrences of this mineral from this general area.

Long Gulch Occurrence

The cerium-bearing epidote forms prismatic crystals that occasionally measure up to 15 mm. in length and these are sporadically distributed in narrow sheets of mineralogically simple pegmatite 3–4 inches in width. In general the allanite crystals are elongated parallel to the *b* crystallographic axis, and in sections that are cut parallel to a plane containing the *a* and *c* axes, a roughly hexagonal outline due to approximately equal development of basal planes, orthopinacoids, and hemiorthodomes is evident.

Mineralogy of the Pegmatite and Host Rock

The host rock is a granodiorite with about 50 per cent of plagioclase that exhibits strong zoning of a normal oscillatory type, and a range of composition from An_{32}–An_{39}. However, in a number of crystals peripheral zones were observed that averaged in width about one-fifth of the grain diameters, in which there was little if any range of composition. Albite twinning is ubiquitous and is in most instances combined with twinning according to the Carlsbad law. Where andesine adjoins orthoclase, narrow selvedges show a myrmekite-like structure with minute vermicular interpenetration of plagioclase by orthoclase or microcline. Orthoclase, which makes up about 15 per cent of the total rock, is usually untwinned and here and there a few crystals of microcline with poorly developed cross-hatch twinning were observed. In the pegmatite itself microcline and orthoclase are pink in color and more plentiful than in the granodiorite; and in addition both potash feldspars exhibit a regular arrangement of inclusions of minute blebs of plagioclase (An_{26}; $\alpha = 1.542$; $\gamma = 1.550$) of the same composition as the associated pegmatitic plagioclase, although the latter it will be noted, is less calcic than the plagioclase in the enclosing granodiorite. The potash feldspar of the pegmatite zone shows strong replacement structures where it adjoins the plagioclase of the host rock. In these instances large poorly twinned but irregularly shaped grains of microcline exhibit peripheral zones heavily studded with remnants or islands of calcic oligoclase (Fig. 1, *B*).

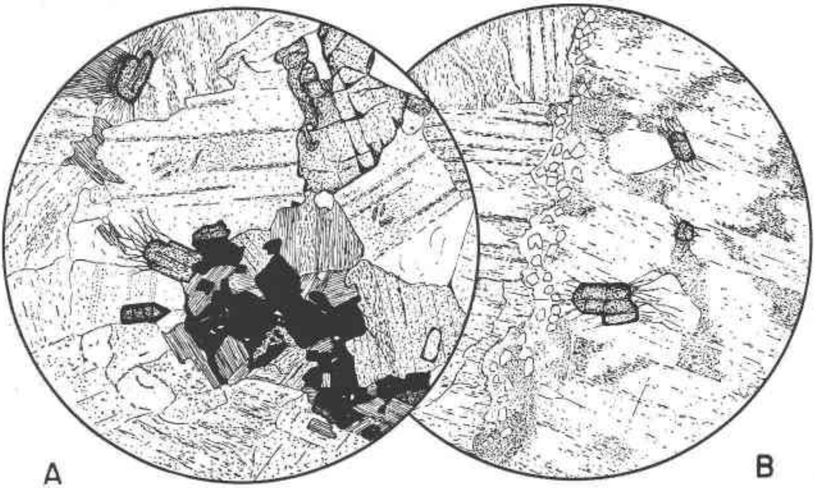

FIG. 1. *A*. Granodiorite showing allanite with cracks radiating therefrom, ferruginous epidote closely associated with a glomeroporphyritic segregation of titaniferous iron ore, chlorite, partially chloritized biotite, and sphene, in addition to feldspars and quartz. A weak pleochroic halo has developed at the biotite-allanite junction in one case (top left-hand area). Locality: Long Gulch, Yosemite National Park, California. Magnification ×10. *B*. Potash feldspar-oligoclase pegmatite with allanite; note the evidence of expansion in allanite crystals and the interpenetrative border associated with "islands" or relicts of plagioclase between microcline (right half of field) and oligoclase (left half). Locality: Long Gulch, Yosemite National Park, California. Magnification ×10.

About 10 per cent of quartz is present in the host rock but it is more plentiful in the pegmatite, and whereas about 15 per cent of biotite is found in the former rock only occasional plates were found in the latter.

In the granodiorite, biotite is considerably altered to fine flaky chlorite, often in the form of tiny rosettes, and this transformation appears to have in some way facilitated the crystallization of ferriferous epidote and wedge-shaped crystals of sphene (average length 1.5 mm.), since these two minerals are frequently closely associated with the assemblage of chlorite and biotite (Fig. 1, *A*). Chlorite has the following optical properties:

$\alpha=\beta=1.616\pm0.002$
Birefringence$=0.002$ (visual estimation)
$2V=0°\ (+)$
$X=Y=$green
$Z=$very pale yellow
Absorption: $X=Y>Z$

These data suggest that the chlorite is an iron-poor member of the ripidolite group (Winchell, 1936, p. 649). Occasional crystals of allanite, iron-ores, apatite, and zircon complete the mineral assemblage.

Here and there the pegmatite band is intersected by narrow veinlets (10–20 mm.) that are composed entirely of radiating, finely prismatic, bright green crystals of iron-rich epidote.

Accessory Minerals of the Pegmatite

The following constituents were recognized in the heavy residue separated from a two-pound sample of pegmatite by centrifuging the crushed rock in bromoform of density 2.88 *ca.*:—

Sphene. Sphene made up slightly more than one half of the total residue. It occurs as subhedral grains, and occasional "envelope"-shaped euhedra that exhibit prominent development of flat domes.

Iron oxides. Ilmenite and magnetite are both present in subhedral fragments, with the latter mineral exhibiting some peripheral oxidation to limonitic material.

Tourmaline. Only very occasional pale greenish-blue, fractured, prismatic crystals of tourmaline were observed.

Epidote. A few irregularly shaped fragments of yellow ferriferous epidote ($\gamma-\alpha=0.025$ *ca.*) were found.

In addition the following minerals were observed as members of the heavy mineral assemblage although altogether they did not exceed approximately 5 per cent of the total residue: allanite; clear, colorless zircon; faintly pink garnet with $n=1.825$; clear, colorless prisms of apatite devoid of inclusions; biotite; and monazite (one grain only). Finally one anhedral fragment of an unidentified golden-yellow isotropic mineral was observed which caused distinct darkening when placed on the emulsion of an α-ray track plate, and for which a refractive index of 1.650 was determined.

Chemical Properties of Allanite

The finely crushed mineral was completely decomposed, except for the production of pulverulent but not gelatinous silica, after treatment on the water-bath for five minutes with concentrated hydrochloric acid. Chemical tests showed that approximately 0.7 per cent of ThO_2 and 0.6 per cent of MnO is present, but no reaction for uranium was detected.

Physical Properties of Allanite

Subhedral to euhedral crystals of allanite are distributed haphazardly throughout both pegmatite and granodiorite, but are more plentiful in the former. The allanite crystals are black, but crushed fragments exhibit a resinous to vitreous luster with pronounced conchoidal fracture. An imperfect cleavage parallel to the length of the crystal, presumably the basal cleavage, was observed in only a few instances.

The following optical data were obtained for Long Gulch allanite:

$\alpha = 1.769 \pm 0.003$
$\beta = 1.784$
$\gamma = 1.791$
$\gamma - \alpha = 0.022$
$2V = 60° (-) \pm 3°$
Dispersion: Distinct with $r > v$.
Pleochroism:
X = pale yellowish-brown
Y = dark brown
Z = brown
Absorption: Y > Z > X
$D_{20°C.} = 3.87 \pm 0.02$ (torsion balance determination).

Although the optical properties of Long Gulch allanite appear to suggest an unaltered mineral, incipient change towards a metamict condition appears to have commenced because a study of thin sections reveals a delicate system of anastomosing cracks that radiate away into the surrounding feldspar from several allanite crystals (Fig. 1, *A* and *B*). The cause of the development of the radiating fissures in such instances has been discussed by several writers (Ellsworth, 1922, p. 58; 1927, p. 367; Walker and Parsons, 1923, pp. 27–28; Hutton, 1950*A*, pp. 695–697).

Ragged Peak Manganoan Allanite

Occurrence

At this locality roughly shaped crystals of manganoan allanite that measured up to 45 mm. in length and exhibited only traces of any development of crystal faces, were found embedded in blocks of quartz-orthoclase pegmatite. Rocks of this type made up a considerable proportion of a coarse scree that had accumulated on the lower slopes of Ragged Peak and a search for occurrences *in situ* were unsuccessful, but nevertheless these must be near.

CHEMICAL PROPERTIES

Large anhedral fragments of allanite were readily separated from matrix in the first instance by hand-picking of coarsely crushed pegmatite. This concentrate was then crushed to pass a 230-mesh screen, freed of dust by careful elutriation and a sample of relatively homogeneous material was finally obtained by electromagnetic fractionation of the elutriated material by means of a Frantz Separator. With the Separator adjusted at a slope of 15°, a tilt of 5°, and a current of 0.10 ampere the attracted portion consisted chiefly of opaque iron oxides, and uniaxial, possibly oxidized, allanite. At 0.15 ampere and the same setting additional oxidized allanite and allanite with iron oxide inclusions were obtained, whereas at 0.20 ampere a nearly pure homogeneous allanite sample separated. This material was ground finely and centrifuged in Clerici solution over a range of densities to ensure purification of allanite from traces of cryptocrystalline quartz and iron oxides. The altered material and foreign particles did not exceed approximately 3 per cent of the unfractionated and uncentrifuged mineral fragments.

The analysis of this material (Table 1, analysis A) is interesting in several respects, *viz.* the high content of iron, mainly in the higher valency state, titanium, and particularly manganese as Mn^{2+}. The low percentages of SiO_2 and combined H_2O, and an absence of K_2O and Na_2O are indicative of the purity of the sample as analyzed. Analyses that are comparable in every respect to that of Ragged Peak manganoan allanite have not been found, since allanites with a high content of manganese, either as Mn^{2+} or Mn^{3+} appear to be uncommon, and furthermore, allanites combining a high percentage of ferric iron, manganese, and titanium appear to be decidedly rare. However, so far as these three constituents are concerned a mineral from the Vishnevy Mountains described by Ovchinnikov and Tzimbalenko (1948) as mangan-orthite (Table 1, analysis D) is rather similar to the Ragged Peak occurrence, although the latter differs on account of the higher manganese content, the lower alumina, and the presence of both uranium and thorium. Unfortunately the constituents in the rare earth group in analysis D have not been differentiated. From the point of view of the content of Al^{3+}, Fe^{3+}, and Ti^{4+} in particular, the Ragged Peak mineral is remarkably similar to allanite from Colorado (Table 1, analysis F) described by Goddard and Glass (1940, p. 398) and furthermore, the optical properties of these two occurrences are almost identical.

Accordingly Ragged Peak allanite appears to contain a higher percentage of both manganese and titanium than in other analyses so far reported and this unusual composition taken in conjunction with the high figure for Fe^{2+} and Fe^{3+}, and particularly the latter, undoubtedly accounts for the unusually high values recorded for the refractive indices and birefringence of this mineral.

When the analysis of Yosemite manganoan allanite is recalculated (Table 2) on the basis of 13 (O, OH, F) atoms to the unit cell it conforms

TABLE 1. ANALYSES OF ALLANITES

	A.	B.	C.	D.	E.	F.
SiO_2	28.80	30.60	32.93	29.60	30.76	30.40
Al_2O_3	10.00	16.18	14.51	14.34	13.50	10.25
Fe_2O_3	10.25	3.52	nt.dt.	8.38	3.87	10.33
FeO	7.33	8.60	15.23	9.38	12.21	10.29
TiO_2	2.02	0.36	nt.dt.	1.96	0.13	1.46
MgO	0.58	0.46	0.74	0.82	0.45	1.44
MnO	6.74	4.48	4.32	5.37	4.87	0.66
CaO	10.08	7.76	12.61	10.56	7.35	7.47
Na_2O	nil	nil	nt.dt.	nt.dt.	nt.dt.	0.02
K_2O	nil	nil	nt.dt.	nt.dt.	nt.dt.	0.16
ThO_2	0.95	1.02	1.64	nt.dt.	2.26	nil
UO_2	0.015	nt.dt.	trace	nt.dt.	nil	nt.dt.
Ce_2O_3	9.06	19.36	4.87	17.20	22.82	14.61
La_2O_3	13.36	nil	8.19	nt.dt.	nt.dt.	10.32*
Y_2O_3	nil	2.22	nt.dt.	nt.dt.	nt.dt.	nt.dt.
H_2O+	1.32	5.07	4.58	1.08	1.36	1.95
H_2O-	nil	0.22	nt.dt.	nt.dt.	0.31	nt.dt.
	100.505	99.85	99.73	99.68	100.24	99.36

* The figures 10.32 are simply listed as "other rare earths" by the analyst.

A. Manganoan allanite from Ragged Peak, Yosemite National Park, Tuolumne County, California. Analyst: Johnson, Matthey. The following constituents were looked for but found to be absent: ZrO_2, V_2O_3, P_2O_5, Zn, Ni, Co, Pb, Cu, Ag, Cr_2O_3.

B. Allanite from Woodstock, N. W. Division, Western Australia. Analyst: D. G. Murray (Simpson, 1931).

C. Allanite from Ishikawa, Iwaki Province, Japan. Total includes: VO_2 tr., SnO_2 tr., CO_2 0.11 (Kimura, 1925).

D. Mangan-orthite from Vishnevy Mts., Russia. Total includes: ZnO 0.72; V_2O_5 0.27. Analyst: I. B. Petropavlovsky (Ovchinnikov, L. N., and Tzimbalenko, M. N., 1948, p. 192).

E. Allanite from Ryôzen, Japan. Total includes: SnO_2 0.13; P_2O_5 0.07; CO_2 0.15; Y_2O_3 included with Ce_2O_3. Analyst: S. Hata (Hata, 1939, p. 116, table 2, analysis 2).

F. Allanite from southern cerite deposit, near Jamestown, Colorado. Analyst: C. Milton (Goddard and Glass, 1940, p. 398, table 4).

TABLE 2. RECALCULATION OF ANALYSIS OF MANGANOAN ALLANITE

	Wt. per cent	(O, OH)	Metals		
SiO_2	28.80	.960	2.874		3.00
				.126	
Al_2O_3	10.00	.297	1.185		
				1.059	
TiO_2	2.02	.050	.149		
Fe_2O_3	10.25	.192	.766		3.00
FeO	7.33	.101	.605		
MgO	0.58	.014	.084		
				.337	
MnO	6.74	.094	.563		
				.226	
CaO	10.08	.180	1.077		
ThO_2	0.95	.006	.018		2.135
Ce_2O_3	9.06	.081	.323		
La_2O_3	13.36	.123	.491		
H_2O	1.32	.073	.874		.874

The formula derived is: $(Ca, Th, Ce, La, Mn)_{2.13}(Al, Fe''', Fe'', Mg, Mn)_{3.00}[(Si, Al)_3O_{12}](OH)_{.87}$

closely to the formula $X_2Y_3z_3(O, OH, F)_{13}$ developed by Machatschki (1930, p. 96) for allanite, in which the X-group includes cations with ionic radius about 1.0 Å ± 0.10, the Y-group ions of intermediate size, and *z*, silicon, although aluminum and rarely beryllium may be present in the tetrahedra. In this connection three points deserve comment: (1) The low figure for Si^{4+} is balanced by an appreciable quantity of aluminum in the silicon-oxygen tetrahedral groups;* it should be observed that four-fold coordination of aluminum, normal in a great many silicates, is usually of little moment in allanites as Lokka (1935, pp.11–12) has made clear for some Finnish occurrences. (2) In order to satisfy the requirements of the structural formula manganese has been divided between the six-fold coordinated group and the *X*-group of higher coordination, a mode of distribution that is permissible owing to the intermediate size of the manganese ion. Machatschki (1930, p. 91) has included manganese in the *X*-group of his generalized formula, although in one of the analyses recalculated by him (Machatschki, 1930, p. 93) distribution of manganese between the *X*- and *Y*-groups was found to be necessary; this is in conformity with the circumstances usually found in

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* It is interesting to note that Petropavlovsky and Tzimbalenko (1948, p. 192) have chosen to group Ti^{4+} with Si^{4+} in the tetrahedral assemblage but not Al^{3+}.

piedmontite (Machatschki, 1930, p. 89). (3) The figure for hydroxyl is slightly less than theoretical requirements and on this account it was suspected that fluorine might be present; however, tests for the halogen were negative.

The reaction of the finely powdered mineral with acid is comparable to the behavior of the Long Gulch mineral under similar circumstances, *viz.* complete decomposition and solution except for the separation of insoluble, non-gelatinous silica, after boiling in concentrated HCl for about five minutes.

PHYSICAL PROPERTIES

The roughly shaped and dominantly anhedral crystals are black in color and when broken exhibit subconchoidal fractures that have a decided pitch-like aspect. A distinct cleavage is evident on broken surfaces in hand specimen.

In thin sections cut from large crystals of manganoan allanite zoning and heterogeneity were observed although the former development was in the main restricted to narrow and intermittent border phases in its distribution. Cleavage, believed to be parallel to {001}, is often very well developed in the peripheral zones, but it is indistinct and interrupted in the main part of any crystal, that is in the unaltered allanite. The peripheral zones are generally pale brown in contrast to the deep red-brown color of the phase which makes up the main body of the crystals, and they differ in other respects as well (Table 3). In turn the pale brown modification of the normal allanite is outwardly but patchily fringed by colorless clinozoisite (Fig. 2*A*). In the border areas chalcedonic quartz and opaque iron oxides occur (Fig. 2*A*) and here and there aggregates of diminutive and almost euhedral crystals of albite ($\alpha' = 1.526$) that exhibit twinning according to the albite law. Blebs and lenses of a golden yellow to red-brown phase occur throughout much of the border areas of the crystals (Fig. 2*B*). In some instances there is no clearly defined preferred orientation of this modification, whereas in others it forms narrow ribbon-like areas arranged parallel to the {001} cleavage as well as less regularly shaped patches that appear to follow fissures; and finally it occurs in rectangular and dart-like shapes, arranged *en echelon*, or very occasionally distributed along a curious linear feature with re-entrant angle (Fig. 2*B*). The optical properties of the golden yellow to red-brown phase are listed in Table 3, but unfortunately the writer is unable to show what the exact nature of this modification is. With some diffidence it is suggested that it may represent the combined effects of incipient metamictization and oxidation of allanite and its distribution in most instances along channels that would allow relatively easy access for solutions gives some support to this suggestion. The refractive indices are distinctly lower but the birefringence is higher than the figures obtained for unaltered allanite. Undoubtedly transformation to a metamict condition would ordinarily tend to produce a product with lower refractive indices and birefringence, but on the other hand oxidation of both manganese and iron would be likely to increase the value of these figures, and there are large amounts of these metals in lower valency states in the unaltered allanite (*vide* Table 1, anal. *A*). The cumulative effects on the optical properties of allanite of these two processes acting simultaneously but to different degrees of completeness cannot be adequately assessed in this case.

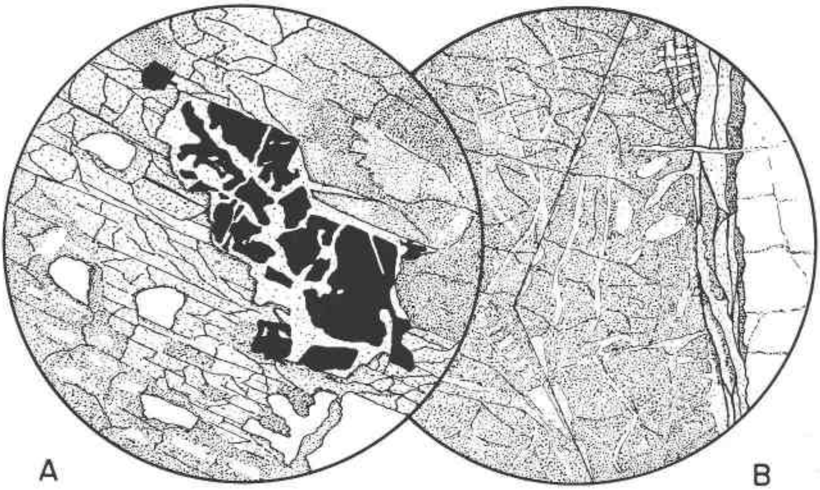

FIG. 2. *A*. Narrow altered and zoned peripheral area in large crystal of manganoan allanite. Areas exhibiting cleavage consist of pale colored allanite with large optic axial angle, and clinozoisite. Note the ragged grains of magnetite set in a patch of chalcedonic quartz. The relatively homogeneous areas are brown allanite with poorly developed cleavage and occasional patches and blebs of red-brown uniaxial allanite (the less dense areas). Clear patches are holes in, and edge of, thin section. Locality: Ragged Peak, Yosemite National Park, California. Magnification ×25. *B*. Thin section of manganoan allanite showing junction with quartz of pegmatite vein and distribution of blebs of red-brown uniaxial allanite. Note also the unusual linear feature, as yet unexplained, and distribution of wedge-shaped areas of uniaxial phase along that direction. Locality: Ragged Peak, Yosemite National Park, California. Magnification $\times 5\frac{1}{2}$.

The linear feature already mentioned (Fig. 2*B*) does not seem to be the result of twinning because a careful check with the universal stage showed no change whatever in the positions of any element of the indicatrix in the mineral on either side of this boundary. Nor does it seem likely that it is the result of an abrupt change in chemical composition, because the optic axial angle is constant and in allanite 2V is fairly sensitive to compositional changes. Accordingly the writer is unable to offer a satisfactory explanation for the linear feature at this time.*

In accordance with Marble's (1937, p. 66) recommendation a radiograph of manganoan allanite was made, using a large crystal on which a carefully polished surface measuring 35×10 mm. was prepared. This surface was cleaned and then placed on a Kodak nuclear track plate type NTB for twenty-one days after which the plate was developed in Kodak solution D-8. The radiograph very clearly demonstrated the lack of homogeneity in the crystal as a whole because slightly greater density was apparent in those areas of the plate adjacent to the golden yellow to deep red-brown modification than in the emulsion that was in contact with the homogeneous deep brown allanite, that is, the analyzed material. In addition three very dense spots were found on the plate that indicated points of intense radioactivity, but a study of the thin section subsequently cut parallel to the polished surface did not reveal any obvious source for the radioactive particles that produced the over-exposed spots.

The following physical properties were determined for Ragged Peak allanite and its variants:

TABLE 3. OPTICAL PROPERTIES OF MANGANOAN ALLANITE AND ITS PHASES

	Pure analyzed allanite	Peripheral zone	Blebs
$\alpha=$	1.791 ± 0.005	1.779*	1.729*
$\beta=$	1.815	—	—
$\gamma=$	1.822	1.797*	1.770*
$\gamma-\alpha=$	0.031	0.018	0.041
2V	40°±2°	80°±2°	0°
Sign.	negative	negative	negative
Dispersion	$r<v$, distinct	$r<v$, distinct	—
Pleochroism:			
X=	pale brown	pale yellowish-brown	golden yellow to brown
Y=	brown	pale brown	—
Z=	deep warm-brown	pale brown	deep red to red-brown
Absorption=	Z>Y>X	Z≥Y>X	Z>X
$X\wedge c=$	20°	27°	—
$D_{22°C.}=$	3.95 ± 0.02	—	—

* A slight range of values was observed for the refractive indices and the data cited are averages.

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* It should be noted that Russell (1937, pp. 1328–1329) has described an occurrence of twinning in allanite but gave no crystallographic data beyond stating that extinction was inclined to the composition plane.

The refractive indices recorded here appear to be distinctly higher than any previously recorded for allanite and undoubtedly they are a reflection of the unusually high percentage of Fe^{3+}, Mn^{2+}, and Ti^{4+} in the mineral. The only instance of allanite with comparable optical properties appears to be allanite described by Goddard and Glass (1940, p. 398) from the southern cerite deposits near Jamestown, Colorado, which as pointed out earlier, contains an unusually high content of Fe^{3+} and Ti^{4+}.

At this juncture it would be pertinent to call attention to the attempt made by Hata (1939, pp. 124–128) to correlate chemical composition with optical properties and particularly to an analysis of allanite from Kido, Japan (Hata, 1939, p. 127, Table 8, analysis 13). Hata plotted the percentages of $Fe^{2+}+2Fe^{3+}$ in the Y-group against the percentage of rare earth elements in the X-group and some relationship would seem to exist between these data and the beta refractive index of the minerals concerned. Now the value of this relationship is, according to Hata, confirmed because the plot of the appropriate chemical data of an allanite with an unusually high percentage of Fe^{3+} (Hata's analysis 13) falls in his diagram on the correct refractive index line. However, the present author is of the opinion that this is entirely coincidental. If this particular analysis is treated as was done by Machatschki (1930) it is found not to agree with the formula $X_2Y_3z_3$ (O, OH, F)$_{13}$ but instead the X- and Y-groups are 1.52 and 3.46, respectively, if manganese is placed with the ions of higher coordination, or 1.39 and 3.58 respectively, if manganese is placed in six-fold coordination. Clearly then the allanite used for analysis by Hata was either impure or considerably oxidized, or alternatively the material employed for determination of the beta refractive index was not representative of the composition as stated in the analysis. When the appropriate data for Ragged Peak allanite are plotted on Hata's diagram it would appear that this mineral should have a beta refractive index of 1.775, a value that is very clearly distinct from that determined on material used for the purposes of analysis, *viz.* 1.815. And if Goddard and Glass's allanite is treated in the same fashion the value for beta as determined from Hata's diagram should be 1.799 instead of their value of 1.810. Clearly then factors other than those considered by Hata must be taken into account but these will be discussed in a later paper.

AGE OF YOSEMITE PARK ALLANITE

Although both thorium and uranium have been found in manganoan allanite and thorium only in the specimen from Long Gulch, lead was not detected in either specimen in spite of the fact that the host rocks, the granodioritic intrusives of the Sierra Nevada Range, are Jurassic in age. In a recent paper the writer (Hutton, 1951) has discussed a similar condition in allanite from New Zealand. In this case determination of the age of the allanite by the "lead-ratio" method gave an approximate figure only but certainly one that could not have exceeded 14–15×10^6 years although the mineral was unaltered and found in rocks that are of late Paleozoic age. In like manner the Californian allanites described in the present paper exhibit little transition towards a metamict state, a condition that has been tested chemically as well as optically; therefore, it appears reasonable to assume that there has been little or no loss of radiogenic lead by solution.

In an attempt to explain the wide discrepancy between the age determined by the "lead-ratio" method and the age of the host rocks determined by geologic field studies, the writer advanced the view that the New Zealand allanite is the product of very late redistribution and recrystallization of original pegmatitic allanite by solutions acting along old pegmatite or other solution channels; in other words, it is suggested that allanite may be as mobile a mineral as are members of the clinozoisite-epidote group. In the absence of any indications to the contrary it is suggested that similar conditions, *viz.* solution, redistribution, and resegregation at a fairly late date, could explain the absence of lead in these Californian occurrences. This view is not intended to infer that allanites are generally valueless for purposes of age determination since many examples are available in which the "lead-ratio" agrees satisfactorily with geological field evidence (Marble, 1935, 1943), although in other instances (Marble, 1940) it has been quite unsatisfactory. Finally, it must be borne in mind that allanite need not necessarily contain any thorium or uranium (Marble, 1942, p. 63), and such specimens are naturally useless for age determination by the "lead-ratio" method.

EFFECT OF CONCENTRATED ACID ON ALLANITE

When fine powders of Long Gulch and Ragged Peak allanites are heated with concentrated hydrochloric acid on the water-bath, solution is complete within about five minutes except for the separation of pulverulent but not gelatinous silica. Nor did gelatinization occur when powdered allanite was first ignited to dull-red heat for five minutes before acid treatment. This is not in accord with the behavior suggested for allanite (Murata, 1943, pp. 552, 555), since it is an orthosilicate, but nevertheless it does seem to be similar to that recorded for nagatelite, a phosphorian allanite. However, the reaction of acid on the Yosemite allanites is in marked contrast to the behavior of allanite from Wilmot Pass, Fiordland, New Zealand, under similar circumstances (Hutton, 1951). These distinctions in behavior invite some investigation and discussion.

First of all so far as the behavior of allanite in concentrated acid is concerned it would seem to be necessary to differentiate between metamict and nonmetamict varieties. To check this it was found that the fine powders of two metamict allanites* from different localities underwent rapid decomposition when treated with hot concentrated hydrochloric acid, and provided the volume of acid initially employed was small the solution rapidly set to a thick rigid jelly. However, if these metamict allanites are heated first to bright-red heat for about five minutes and then treated with acid, decomposition of the minerals still occurred but in this instance the silica which separated was pulverulent and did not set to a thick jelly. Now the two allanites from Yosemite National Park exhibit only very slight indications of metamictization whereas the mineral from Wilmot Pass, Fiordland, New Zealand, shows no evidence of this transformation; the high birefringence and normal density determined for these minerals would seem to support this observation. Yet the Yosemite allanites are readily soluble in concentrated acid with separation of pulverulent silica whereas the New Zealand mineral is only slowly decomposed after the most drastic treatment, *viz.* prolonged heating with fuming sulfuric acid or perchloric acid. Unfortunately the composition of the allanite from Long Gulch is not exactly known except that the high refractive indices suggest a fairly ferriferous condition. Fortunately we can compare the composition of manganoan allanite from Ragged Peak with that of Wilmot Pass allanite (Table 4) and the outstanding and most significant differences between these analyses are the high percentage of octahedral positions occupied by iron and manganese in Ragged Peak allanite on the one hand and the dominance of aluminum in the octahedrally coordinated positions in Wilmot Pass allanite on the other. Now it is well founded that substitution of octahedrally coordinated aluminum by iron and (or) manganese leads to structural weakening which results in greater ease of chemical solution. This is found, for example, in andradite as compared with grossularite or spessartite; and lepidomelane as compared with muscovite among the sheet structures or disilicates.

However, it must be borne in mind in this connection that so far as orthosilicates are concerned other factors than replacement of six-fold coordinated aluminum by iron are undoubtedly of importance. For instance, clinozoisite and iron-rich epidote are both equally insoluble in

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* The allanites employed in these tests were found at Albany, Wyoming, and Barringer Hill, Llano Co., Texas; the Wyoming mineral, which was not completely isotropic, although the birefringence did not exceed 0.005, has an average refractive index of 1.718, whereas for the Texas mineral a range of 1.718–1.724 was found. The composition of the Texas allanite must exhibit a distinct range since the refractive index recorded for a specimen from that locality by Glass (*vide* Marble, 1940, p. 172) lies outside the range of the values determined by the writer.

acid, and accordingly accurate determination of ferrous iron is notoriously difficult. However after preliminary ignition these epidote group minerals are readily decomposed by acid supposedly with the separation of a gel according to most texts. To verify this condition two clinozoisites ($\beta=1.709$, 1.712) and two ferriferous epidotes ($\beta=1.750$, 1.755) were ignited at bright red heat for five minutes and then treated with boiling concentrated HCl for a similar period. Although decomposition was rapid a gel, that is a thick rigid jelly, did not develop even after evaporation of liquid almost to the point of dryness but instead a globular form of silica separated that readily settled to the bottom of the test tube. Since both clinozoisite and ferriferous epidote reacted towards acid in a similar manner, replacement of octahedrally coordinated aluminum by iron clearly produced little change in the stability of the ferriferous variety, whereas loss of hydroxyl through ignition must have caused a breakdown of the structure in both minerals with the result that solution in acid was easily accomplished.

Table 4. Analyses of Allanites

	A.		B.	
Si^{4+}	2.986		2.874	
		3.00		3.00
		0.014		0.126
Al^{3+}	1.871		1.185	
		1.857		1.059
Fe^{3+}	.267		.766	
Fe^{2+}	.796	3.06	.605	
Ti^{4+}	.050		.149	3.00
Mg^{2+}	.095		.084	
				0.337
Mn^{2+}	.016		.563	
				0.226
Ca^{2+}	1.192		1.077	
Th^{4+}	.022	1.89	0.018	2.13
Ce^{3+}	.301		.323	
La^{3+}	.323		.491	
Y^{3+}	.034		—	
H^{+}	1.169	1.169	.874	0.874

A. Allanite from Wilmot Pass, Fiordland, New Zealand (Hutton, 1951).
B. Manganoan allanite, Ragged Peak, Yosemite National Park, Tuolumne County, California.

The nature of the reaction of allanites with hot concentrated acid may be summed up as follows:

(1) Metamict varieties: rapid production of a stiff jelly of gelatinous silica.

(2) Non-metamict varieties:

  (*a*) When the octahedral positions in the lattice are dominantly occupied by aluminum the mineral appears to be insoluble or only slowly decomposed after prolonged and drastic acid treatment.

  (*b*) When the octahedral positions show considerable replacement by iron and (or) manganese the mineral is readily decomposed with the separation of pulverulent silica.

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Manuscript received Aug. 14, 1950.