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ELECTRON MICROPROBE STUDY OF ALLANITE FROM THE MT. FALCONER QUARTZ MONZONITE PLUTON, LOWER TAYLOR VALLEY, SOUTH VICTORIA LAND, ANTARCTICA

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Abstract

Electron microprobe analyses have been made on fresh and metamict portions of allanite grains from the Mt. Falconer quartz monzonite pluton, Antarctica. In addition to probable uptake of water upon alteration, electron probe analyses indicate leaching of cations from the Ca-rare earth sites during alteration.

Introduction

Allanite is a common accessory mineral in the Mt. Falconer pluton, an epizonal quartz monzonite body which crops out in the ice-free Lower Taylor Valley, Antartica (77°34'S, 163°08'E). The allanite crystals show varying degrees of metamictization and during the course of a petrographic and geochemical study (Ghent & Henderson 1968, Ghent 1970, McDougall & Ghent 1970) an electron microprobe study of both the fresh and altered portions was made in an attempt to determine the pattern of alteration.

Petrography

Allanite occurs as well terminated prisms up to about 0.4 × 0.8 mm in size. The pleochroic scheme on fresh portions of grains is : X = light brown ; Y = reddish brown ; Z = dark reddish brown. Maximum birefringence is near 0.027 and this allanite often shows simple twins on {100}. Thorium content and birefringence are compatible with data presented by Hickling *et al.* (1970, p. 1980).

Alteration is recognized by two criteria : 1) a decrease in birefringence, some portions of grains are nearly isotropic ; and 2) changes in the color of the mineral, altered portions of grains are brownish yellow to gold in color (Fig. 1). Altered portions of grains often show a concentric zonal structure defined by color banding.

Where biotite is in contact with allanite it typically shows pleochroic haloes.

Electron Microprobe Analyses

Eight grains of allanite in four different samples were studied by electron microprobe techniques on carbon-coated polished thin sections. Three elements were analyzed simultaneously and Ce was run in each set of analyses to provide a basis for comparison.

For analyses of all elements except Si, F and Pr the operating conditions were : accelerating potential 20 kv, emission current 200 μa, beam current 0.2 μa (measured by a Keithley electrometer), take-off angle 52.5°, and spot size 5 μm on periclase. For Si and F the accelerating potential used was 15 kv and for Pr analyses the beam current was 0.4 μa and the spot size 10 μm on periclase. Beam current integration was used and the integration times were approximately 20 sec.

For the rare earths wavelength scans were made on both a spencite (synchisite Y) standard described by Joensuu & Ingamells (1966) and allanite ; peaks were identified and areas free of interference were chosen for background measurements. Except for Pr, the $L\alpha$ lines were used in all analyses of rare earths. For Pr the $L\beta$ line was used to avoid interferences from La$L\beta_1$ and this resulted in a much lower sensitivity.

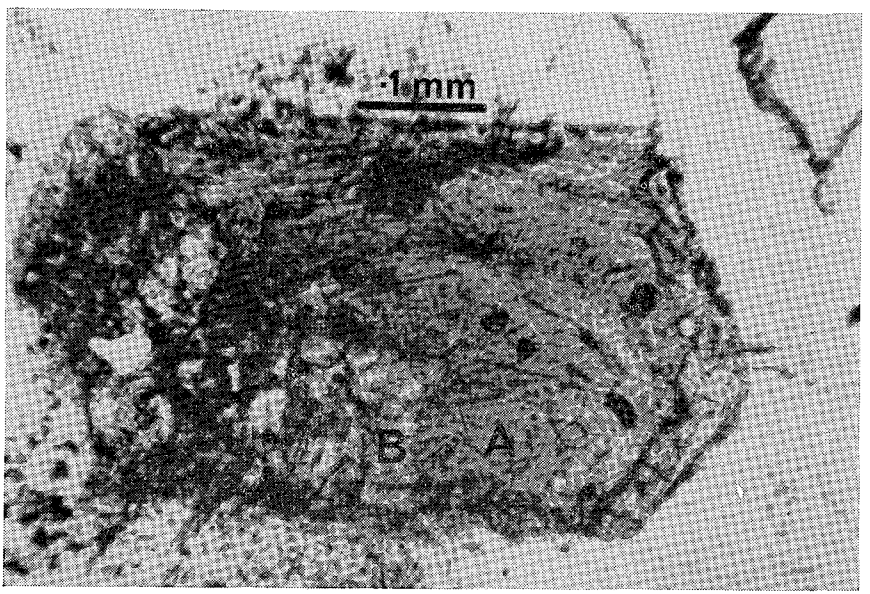

Fig. 1. Allanite grain showing partial metamictization. Note color differences between fresh portion of grain (B) and metamict portion (A). Also note color banding in altered portion of grain (particularly in the upper right hand corner of the grain).

TABLE 1. ELECTRON MICROPROBE ANALYSES OF ALLANITE GRAINS.

Sample	1	1'**	2'	3	4	4'	5	5'
SiO_2	30.4	35.8	32.2	31.2	31.0	31.2	29.9	32.6
Al_2O_3	13.5	13.9	14.1	11.9	12.8	13.0	14.1	13.3
Fe_2O_3*	17.4	15.6	16.8	13.7	13.8	13.7	16.0	16.6
MgO	1.0	1.1	0.6	0.4	0.7	0.8	0.9	0.6
CaO	9.2	5.7	6.2	12.0	11.5	7.6	9.4	8.6
MnO	0.4	0.3	0.1	0.5	0.4	0.2	0.2	0.2
TiO_2	3.0	2.9	2.4	1.9	2.2	2.7	2.0	—
Na_2O	<0.1	<0.1	0.2	<0.1	<0.1	0.1	0.2	<0.1
Ce_2O_3	9.5	6.7	5.7	10.7	10.8	8.1	10.8	8.0
La_2O_3	8.3	4.7	4.0	6.8	8.0	4.8	7.6	8.4
Pr_2O_3	1.6	0.8	0.5	1.6	1.4	1.0	1.5	—
Nd_2O_3	1.9	1.4	0.5	2.1	2.1	1.3	1.5	1.3
Sm_2O_3	0.4	0.2	0.2	0.4	0.4	0.2	0.4	0.3
Gd_2O_3	1.2	0.7	0.6	1.4	1.3	0.9	1.2	0.8
Er_2O_3	0.2	0.1	0.1	0.2	0.1	0.1	0.2	—
Y_2O_3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ThO_2	0.7	0.3	0.8	0.5	0.4	0.4	0.3	0.3
F	0.6	<0.05	0.2	0.4	0.4	0.3	0.5	<0.1
TOTAL	99.3	90.2	85.2	95.7	97.3	86.4	96.7	91.0

Structural formula calculated on basis of — 25 anionic charge

Sample	1	1'	2'	3	4	4'	5	5'
Si	2.90	3.39	3.23	3.07	3.01	3.21	2.88	3.18
Al	0.10						0.12	
	3.0						3.0	
Al	1.42	1.55	1.67	1.38	1.46	1.57	1.48	1.53
Fe^{+3}	1.25	1.11	1.27	1.01	1.01	1.06	1.16	1.22
Mg	0.14	0.10	0.09	0.06	0.10	0.12	0.13	0.09
Ti	0.11	0.10	0.09	0.07	0.08	0.10	0.07	—
	2.92	2.86	3.12	2.52	2.65	2.85	2.84	2.84
Ca	0.94	0.58	0.67	1.26	1.19	0.84	0.97	0.90
Mn	0.03	0.02	0.01	0.04	0.03	0.02	0.02	0.02
Ce	0.33	0.23	0.21	0.39	0.39	0.30	0.38	0.29
La	0.29	0.16	0.15	0.25	0.29	0.18	0.27	0.30
Pr	0.06	0.03	0.02	0.06	0.05	0.04	0.05	—
Nd	0.06	0.05	0.02	0.07	0.07	0.05	0.05	0.04
Sm	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gd	0.04	0.02	0.02	0.05	0.04	0.03	0.04	0.03
Th	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Na			0.04			0.03	0.03	
	1.78	1.11	1.17	2.14	2.08	1.51	1.83	1.60

* = Total iron expressed as Fe_2O_3.
** = ' by numbers indicates altered grain or portion of grain.

The allanites were analyzed using the following analyzed standards for specific elements : Y, La, Ce, Pr, Nd, Sm, Gd, Er and Th using spencite, Si using olivine, Al using adularia and garnet, Fe using olivine and garnet, Ca and Mg using clinopyroxene, Na using plagioclase, Ti using rutile, Mn using rhodonite and F using fluorphlogopite.

The data were corrected for drift and background. Because the counting rates were low, no deadtime correction was made. Analyses were corrected according to the scheme outlined in Bence & Albee (1968) using correction factors kindly supplied by A. Albee.

Because of low concentrations of rare earths in the standard, the relative inhomogeneity of both the spencite standard and the allanite and the uncertainty in the correction factors, the accuracy of the analyses is not as high as might be hoped for. Where the spencite could be checked against other standards, e.g., Y garnet, the accuracy was on the order of $\pm 5\%$ of the amount present; however, the differences between altered and unaltered grains is the important point to be considered and the conclusions as to the pattern of alteration would be the same even if uncorrected counts per second were employed.

Discussion of analyses — Analyses of fresh and altered portions of 5 grains are presented in Table 1. Since ferrous and ferric iron cannot be measured quantitatively, all iron is reported as ferric iron. Allanites carry primary ferrous iron so that this will lead to a systematic error in structural formulas and analytical totals.

Structural formulas of the analyzed allanites have been calculated on the basis of an anionic charge of -25. Structural formulas obtained from analyses of fresh portions of grains show deficiencies, particularly in the Al-Fe site. Comparison with published analyses of allanites suggests there is a systematic error in the Al analyses. However, the lack of distinction between ferrous and ferric iron does not allow one to draw a firm conclusion on this point. Variable totals in the Ca-rare earth site may be largely due to the strong zoning in the mineral making it difficult to obtain good average analyses.

The altered portions of grains have analytical totals which are several percent lower than those of the adjacent fresh portions of grains. This is probably due to uptake of water in the structurally damaged portions of the grains (e.g. Hickling *et al.* 1970, p. 1878 ; Deer *et al.* 1963, pp. 213-216). In addition, the structural formulas of the altered portions of allanite grains deviate more widely from the ideal allanite formula than do the structural formulas for the fresh portions. There is a systematic reduction in the occupancy of cations in the Ca-rare earth cation sites, however, there appears to be no significant difference in the occupancy of the Al-Fe sites. A slight

enrichment in Si in the tetrahedral sites of altered grains is also possible. An examination of individual analyses of elements indicates leaching of the following elements during alteration — Ca, Mn(?), Ce, La (except for one case), Pr, Nd, and Gd. These results are supported by additional analyses on allanites not reported in Table 1. Fluorine contents appear to be generally lower in the altered portions of grains, but this could be ascribed to a primary difference rather than due to metamictization. According to data cited in Deer *et al.* (1963, p. 216) Th is enriched in weathered portions of allanite grains. However, the microprobe analyses reported here reveal no significant changes in Th content upon alteration in two grains and a decrease in Th content in a third grain.

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