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COMPOSITION OF ALLANITE IN THE FOOTWALL OF THE SULLIVAN OREBODY, BRITISH COLUMBIA

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ABSTRACT

Fresh and metamict portions of allanite grains from a vein in footwall rocks of the Sullivan orebody, British Columbia, have been analyzed by means of the electron microprobe. The metamict zones show enrichment in magnesium and thorium as well as water (implied). In the rare-earth-ratio plots of Fleischer (1965), the Sullivan samples resemble granitic and pegmatitic allanite; the authors, however, favor a multiple-stage genesis, which recognizes the potential of contributions of constituents from the original Aldridge Formation, the alteration minerals and the Purcell sills.

Keywords: allanite, Sullivan deposit, British Columbia, origin.

SOMMAIRE

On a analysé par microsonde électronique les portions saine et métamicte de cristaux d'allanite provenant d'un filon situé dans les roches sous-jacentes du gîte Sullivan (Colombie-britannique). Les zones métamictes sont enrichies en Mg, Th (et eau, par implication). Sur les diagrammes de Fleischer (1965) fondés sur les rapports des terres rares, l'allanite de Sullivan ressemble à celle des granites et des pegmatites; nous préconisons toutefois un mode de formation à stades multiples, qui prend en considération la contribution des roches originelles de la formation Aldridge, des minéraux d'altération et des filons-couches de Purcell.

(Traduit par la Rédaction)

Mots-clés: allanite, gîte Sullivan, Colombie-britannique, origine.

INTRODUCTION

Allanite has been identified in a vein in metasedimentary rocks of the Aldridge Formation 1.5 m below the footwall contact of the western portion of the Sullivan ore zone. The vein was noted in a sample of drill core during a study of alteration assemblages associated with the orebody. It is 0.5 mm wide and is clearly later than the tourmalinized Aldridge metasedimentary rocks. Adjacent to the vein, these rocks consist of tourmaline, chlorite, quartz, calcite, pyrrhotite and titanite. The main constituents of the vein are quartz and allanite with accessory tourmaline and minor calcite. A later minor fracture containing chlorite transects the vein. The Sullivan orebody is the largest of several stratiform lead–zinc deposits occurring in Helikian rocks of the Aldridge Formation in southeastern British Columbia (Hamilton *et al.* 1982, 1983, Campbell & Ethier 1977, Ethier *et al.* 1976). This is the first report of allanite in veins within the metasedimentary rocks from this area. Bishop (1976) reported that allanite occurs as an accessory in the quartz dioritic and granophyric phases of differentiated Purcell sills. He gave no compositional data for the mineral, but presented whole-rock data indicating the presence of rare-earth elements. The Purcell sills, which consist of continental tholeiite, were intruded into the tourmalinized Aldridge Formation during several events commencing at 1450 Ma (Hamilton *et al.* 1982).

PETROGRAPHY

The allanite occurs in a rock composed predominantly of magnesium-rich tourmaline and quartz, with accessory titanite, pyrrhotite and magnesium-rich chlorite. The grains average 300 μm (long dimension), with a maximum birefringence of approximately 0.02. Metamict areas are not truly isotropic (birefringence 0.002) and occur as patches not necessarily in the core of crystals, and commonly as a rim (Fig. 1). Pleochroism is very faint and largely masked by the strong pleochroic effects of adjacent grains of tourmaline.

ANALYTICAL CONDITIONS

Analytical data were collected using an ARL-EMX electron probe microanalyzer operated at 15 kV. Elemental standards were used for Y, Sm, Th and Gd. A monazite standard, for which Jaffe (1955) reported a chemical composition, was used for Nd, Pr, Ce and La. These elements were checked, where possible, against other rare-earth standards with acceptable results for Nd, Ce and La. Count rates suggest significantly higher Pr in the monazite standard than the chemical analyses indicated; consequently, the Pr content of the Sullivan allanite may be lower than reported. All rare earths were measured using $L\alpha$ emission; Pr and Nd were corrected for interfer-

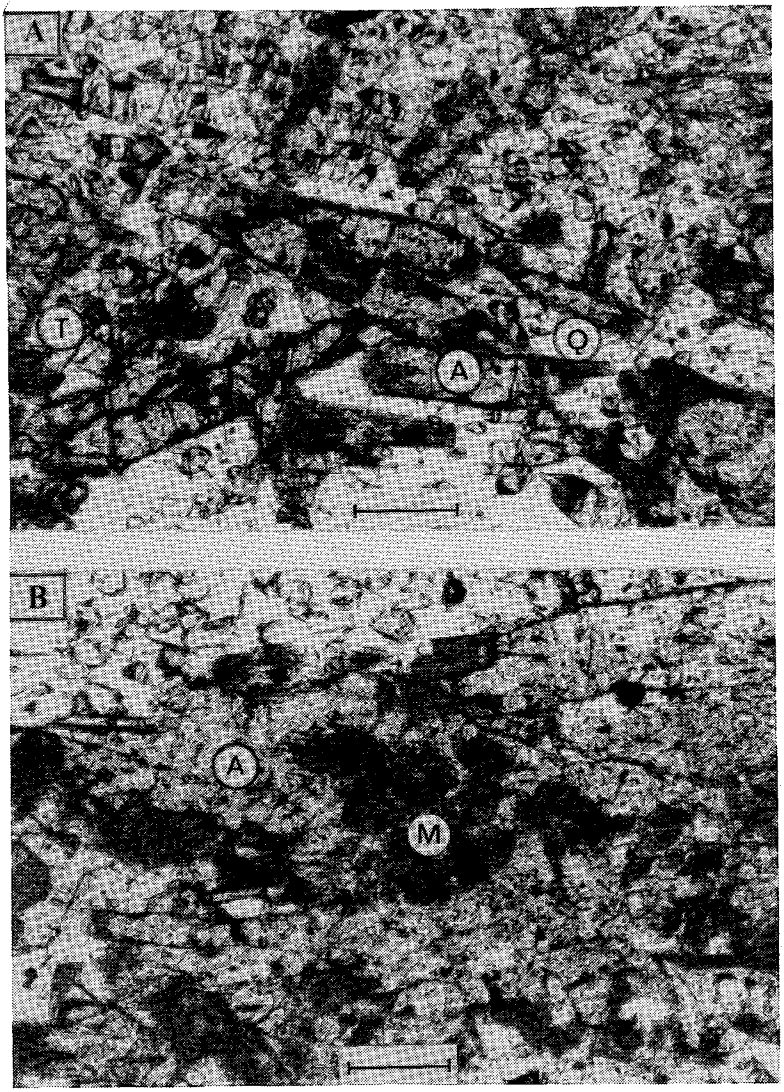

FIG. 1. Photomicrographs of allanite from the footwall of the Sullivan orebody. Scale bar 100 μm. A. Metamict areas irregularly within and at the edge of prismatic grains (A), associated with quartz (Q) and tourmaline (T). B. Allanite (A) with irregular areas of metamict material (M); some tourmaline and quartz at top and left of photograph.

ence by La and Ce $L\beta$ emission, respectively. Matrix corrections were carried out following the method of Bence & Albee (1968), using correction factors of Albee & Ray (1970) and the procedure of Nicholls *et al.* (1977).

COMPOSITION

Microprobe data on allanite grains are presented in Table 1. Estimates of water content for the clear areas are included, based on chemical data for allanite reported by Deer *et al.* (1962). The same value (2.00 wt.%) is tabulated for the metamict samples and should be considered a minimum. In comparison with the clear areas, metamict areas have a lower content of the rare-earth elements but contain significantly more Mg and Th. The analytical total for a metamict area is lower than for a clear area, presumably owing to additional water entering a crystal lattice structurally damaged by bombardment

TABLE 1. COMPOSITION OF ALLANITE IN THE FOOTWALL AT SULLIVAN

Sample Grains	1C*	1M*	2C	2M	3C	3M	Avg.C	Avg.M
SiO_2	32.96	33.58	31.63	32.69	32.27	31.51	32.29	32.59
Al_2O_3	18.96	18.54	19.29	17.46	19.25	17.21	19.17	17.74
FeO	10.09	11.15	10.18	11.60	10.27	11.21	10.18	11.32
MgO	0.60	5.88	0.88	4.84	1.01	3.16	0.83	4.63
CaO	11.21	9.73	11.18	9.01	10.99	10.00	11.13	9.58
MnO	0.54	0.72	0.57	0.64	0.39	0.74	0.50	0.70
Y_2O_3	0.51	0.55	0.41	0.36	0.38	0.53	0.43	0.48
ThO_2	nd	0.51	nd	0.11	nd	0.33		0.32
Ce_2O_3	10.62	7.63	11.92	7.43	12.13	8.78	11.56	7.95
La_2O_3	4.38	2.74	4.94	3.00	5.08	3.48	4.80	3.07
Sm_2O_3	0.86	0.45	0.82	0.41	0.94	0.59	0.87	0.43
Pr_2O_3	0.76	0.50	0.83	0.51	0.96	0.58	0.85	0.53
Gd_2O_3	1.44	1.30	1.69	1.35	1.76	1.40	1.63	1.35
Nd_2O_3	3.82	3.62	4.62	3.74	4.84	3.97	4.43	3.78
H_2O	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total	98.74	98.90	100.95	95.15	102.27	95.49	100.67	96.47
Number of ions on the basis of 13 O, (OH)								
Si	3.057	3.001	2.936	3.051	2.961	3.005	2.983	3.010
Al	2.073	1.957	2.111	1.921	2.081	1.936	2.088	1.932
Fe	0.782	0.835	0.790	0.906	0.788	0.894	0.787	0.875
Mg	0.084	0.785	0.122	0.674	0.084	0.449	0.114	0.638
Ca	1.114	0.933	1.112	0.901	1.080	1.022	1.102	0.948
Mn	0.042	0.054	0.045	0.050	0.030	0.060	0.089	0.054
Y	0.025	0.026	0.020	0.018	0.019	0.026	0.021	0.023
Th	0.000	0.010	0.000	0.002	0.000	0.009	0.000	0.007
Ce	0.361	0.250	0.405	0.253	0.408	0.306	0.391	0.268
La	0.149	0.090	0.169	0.103	0.172	0.123	0.163	0.104
Sm	0.028	0.014	0.027	0.013	0.030	0.019	0.028	0.013
Pr	0.025	0.016	0.028	0.018	0.032	0.021	0.029	0.052
Gd	0.045	0.039	0.052	0.042	0.053	0.045	0.050	0.041
Nd	0.126	0.116	0.153	0.125	0.159	0.135	0.147	0.125
OH	1.238	1.184	1.238	1.245	1.224	1.272	1.232	1.232

*C clear, M metamict region of grain

Limits of detectability: MgO 0.03, MnO 0.07, Na_2O 0.05, Y_2O_3 0.06, ThO_2 0.06, Ce_2O_3 0.14, La_2O_3 0.14, Sm_2O_3 0.08, Pr_2O_3 0.07, Gd_2O_3 0.11, Nd_2O_3 0.13, P_2O_5 0.05. Na_2O and P_2O_5 below detectability level.

Precision (3δ) SiO_2 1.2, Al_2O_3 0.77, FeO 0.41, MgO 0.08, MnO 0.14, Y_2O_3 0.14, ThO_2 0.10, CaO 0.29, Ce_2O_3 0.80, La_2O_3 0.60, Sm_2O_3 0.14, Pr_2O_3 0.16, Ce_2O_3 0.23, Nd_2O_3 0.48.

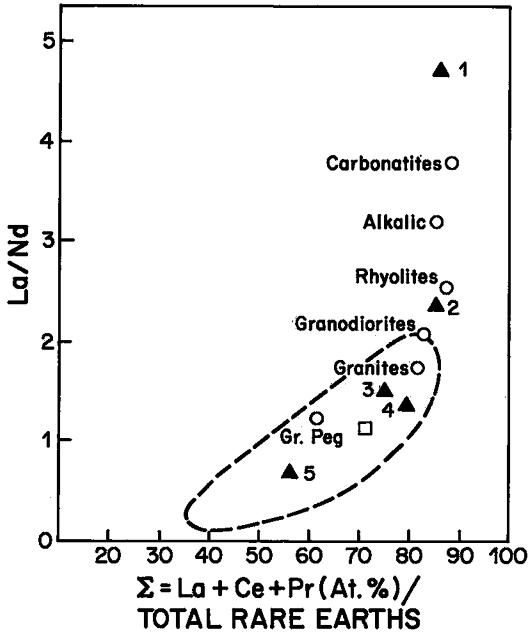

FIG. 2. Variation in La/Nd *versus* (La + Ce + Pr)/total rare-earth elements in allanite. Open circles: data from Fleischer (1965). Triangles: data from the literature as follows: 1) Ghent (1972): Mt. Falconer pluton, Antarctica; 2) Cech *et al.* (1972): granite – syenite gneiss, Zambia; 3) Hickling *et al.* (1970): Boulder Creek batholith, Colorado; 4) Damange & Elsass (1973): stratifrom copper deposit, Morocco; 5) Adams & Sharp (1972): pegmatite, Colorado. Square symbol: Sullivan footwall.

by alpha particles and nuclei recoil from radioactive elements (Pabst 1952). The structural formula for the average clear material is $(Ca_{1.10}RE_{0.87})(Fe_{0.79}Mg_{0.11})Al_{2.07}Si_{3.00}O_{12}(OH)$, and the average for the metamict material is $(Ca_{0.95}RE_{0.69})$ $(Fe_{0.88}Mg_{0.64})Al_{1.93}Si_{3.00}O_{12}(OH)$.

DISCUSSION

Allanite is a common accessory in granites, granodiorites and granitic pegmatites (Deer *et al.* 1962). Partial and nearly complete compositions of allanite from plutonic rocks are reported by Adams & Sharp (1972), Hickling *et al.* (1970), Ghent (1972) and Lee & Bastron (1967). Allanite from a granitic gneiss is described by Cech *et al.* (1972) and from a dolomitic skarn by Geijer (1927). A more unusual occurrence, in banded Precambrian siltstones associated with stratiform copper mineralization, was described by Demange & Elsass (1973).

The MgO content of allanite is typically 1% or less (Deer *et al.* 1962). An exception is the magnesian allanite (Geijer 1927) associated with a magnetite deposit in a Mg–Ca-silicate skarn; here, the allanite contains 7.42 and 14.15 wt.% MgO. The increase in Mg in the Sullivan allanite, from 1% MgO in clear areas to 4.6% MgO in metamict areas, suggests that not only water but also magnesium may enter the damaged lattice.

In general, the ThO_2 content of allanite averages about 1% (Deer *et al.* 1962); the ThO_2 content for the clear areas of the Sullivan allanite is less than 0.06%. In contrast, the average for the metamict areas is 0.32%, representing an enrichment factor of at least five with respect to the clear areas. The relatively high Th content in metamict areas raises a question of cause and effect. The Th may have caused the metamictization, with the patches in part related to original distribution of Th; additional Th may have moved into the damaged lattice along with water and magnesium. It has been demonstrated that Th is concentrated in weathered portions of allanite and that the rare-earth elements are depleted (Deer *et al.* 1962, p. 216). The trend in element behavior in the samples being described is the same, but weathering is not a possible mechanism in the case of this fresh material taken from drill cores.

Hickling *et al.* (1970) investigated the variation in birefringence (as an indicator of degree of metamictization) as an inverse function of age in allanite.

Precambrian allanite should be essentially isotropic owing to the long interval of time during which the radiation damage occurs. The high birefringence of the clear areas of the Sullivan allanite suggests that they have been recrystallized, perhaps as late as during the Columbian orogeny.

Fleischer (1965) attempted to classify allanite samples according to the ratios of various rare-earth elements. His data are shown in Figure 2 along with the Sullivan data and the compositions cited previously. The Sullivan allanite and that from the stratiform copper deposit plot close to allanite from granites and pegmatites, although neither occurrence has an obvious spatial or temporal association with igneous rocks of these or any other composition. In view of the variation in the data for plutons shown in Figure 2, it seems unlikely that this approach can be used to directly deduce the environment of formation.

In the case of the Sullivan occurrence, the source of the allanite-forming solutions is speculative. Evidence from Bishop (1976) clearly indicates that allanite is present in the Purcell sills. These rocks alter the tourmalinite and are therefore clearly later than that phase of alteration (Hamilton *et al.* 1982). The allanite-bearing veins cut the tourmalinite, contain quartz and some redistributed tourmaline, and therefore are perhaps associated with the stage of alteration accompanying the intrusion of the Purcell sills. However, as indicated earlier, the entire area has been affected by the Columbian orogeny, so that the allanite in the Purcell rocks and footwall veins could be associated with this event. The multiple-stage type of sequence documented by Hickling *et al.* (1970) seems more likely to explain the genesis of the Sullivan allanite than does a single event. Such an origin recognizes that the constituents forming the vein could have been gleaned from one or a combination of: the original Aldridge minerals, the altered Aldridge rocks, or the Purcell sills.

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