

Fluid Evolution and The Formation and Alteration of Allanite in Skarn from the Beinn an Dhubaich Granite Aureole, Skye

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Introduction

Allanite $((Ca,REE)_2(Al,Fe^{2+})_3(SiO_4)_3OH)$ is important in geochronology and petrology as it typically contains both uranium and thorium as well as the REE. It is therefore important to understand its genesis and behaviour during hydrothermal alteration. In this study we investigated the genesis and chemistry of allanite from the Beinn an Dubhaich granite aureole, Skye. The locality studied consists of a hedenbergite-anorthite-allanite-hastingsite endoskarn, and a diopside-magnetite-pargasite-vesuvianite exoskarn. Both of these lithologies contain late stage fluorite and calcite.

Allanite chemistry

Allanite was analysed using the electron microprobe method of Williams (1996). ThO_2 was analysed separately using a 100s count time and 60nA beam current. Four generations of allanite were defined using chemical and textural characteristics. These include primary granite allanite and three types of zoned and altered metasomatic allanite. The zonation is a function of variation in the content of Fe, Al and total REE (Fig. 1a), and includes growth zonation, and alteration and replacement textures. Estimates of Fe(III) content indicate a significant proportion of epidote and ferriallanite. Britholite $((Ca, REE)_5(SiO_4,PO_4)_3(OH,F))$ also occurs as discrete grains, or concentrated along the margins between oscillatory zoned cores and altered low Fe+REE content rims in Type 1 allanites.

Allanite is light REE enriched and dominated by Ce, whilst britholite shows much flatter REE patterns, and is dominated by Y. Altered zones of allanite grains are generally more Nd-rich than the cores, but there is a wide variation in the La/Nd ratio. In britholite, Y is generally enriched relative to the predicted chondrite normalised concentration of Ho. U was below the detection limits for the method used, but ThO_2 contents of allanite varied from ~0 to 1.2 wt.% and show a broad correlation with major element chemistry (Fig. 1b). UO_2 contents in britholite vary from 0.2 to 1.2 wt.% and ThO_2 from 0.1 to 3.5 wt.%.

Metasomatic conditions

Assuming a pressure of 500bars, fluid inclusion studies indicate formation of diopside and hedenbergite at temperatures in the range 600-700 °C from saline Na-K-Fe-Ca bearing brines (45-60 wt.% NaCl eq.). Allanite and amphibole formed from

similar brines at 500-600 °C (mean ~550 °C). Vesuvianite and fluorite formed at much lower temperatures (230-250 °C) from fluids with a bimodal salinity distribution. High F contents in both pargasite and vesuvianite indicate that the fluids were F-bearing at all stages in the paragenesis.

We propose a model of allanite formation involving the reaction of hedenbergite and anorthite with REE- and Th-bearing fluids during cooling of a high salinity, late magmatic fluid. If the oxygen fugacity of such a fluid was externally buffered by a granitic mineral assemblage this cooling model could also account for the significant levels of Fe(III) in allanite by the oxidation of hedenbergite plus anorthite to produce an epidote component in allanite.

Discussion and conclusions

Allanite from the Beinn an Dubhaich contact aureole is clearly of metasomatic origin and its formation conditions can be estimated with some confidence. Previous studies have concluded that whilst U may be remobilised, Th effectively remains immobile under hydrothermal conditions (Barth et al., 1994). In this instance our analyses have shown that Th may be both leached and added to allanite during hydrothermal alteration. Th may have potentially been incorporated into britholite during this process. The hydrothermal mobility of the REE and Th was almost certainly a result of high F contents in the hydrothermal fluids. High F activities during allanite formation are indicated by the high F content of exoskarn pargasite. The critical role of F complexing in REE transport and allanite alteration is also indicated by the positive Y anomaly in britholite. Y-Ho fractionation is strongly favoured by F complexing in hydrothermal fluids (Bau and Dulksi, 1995). That F-rich fluids are capable of transporting Th is supported by experimental evidence (Keppler and Wyllie, 1990).

The conditions of allanite formation and alteration determined in this study are relevant to other metasomatic and magmatic occurrences, and may also have relevance to studies of metamorphic allanite. In many environments high-temperature, F-rich fluids may be responsible for the remobilisation of the actinides at temperatures below the inferred closure temperature of a mineral. Further work is planned using laser ablation ICP-MS analysis to study the behaviour of the actinides in more detail.

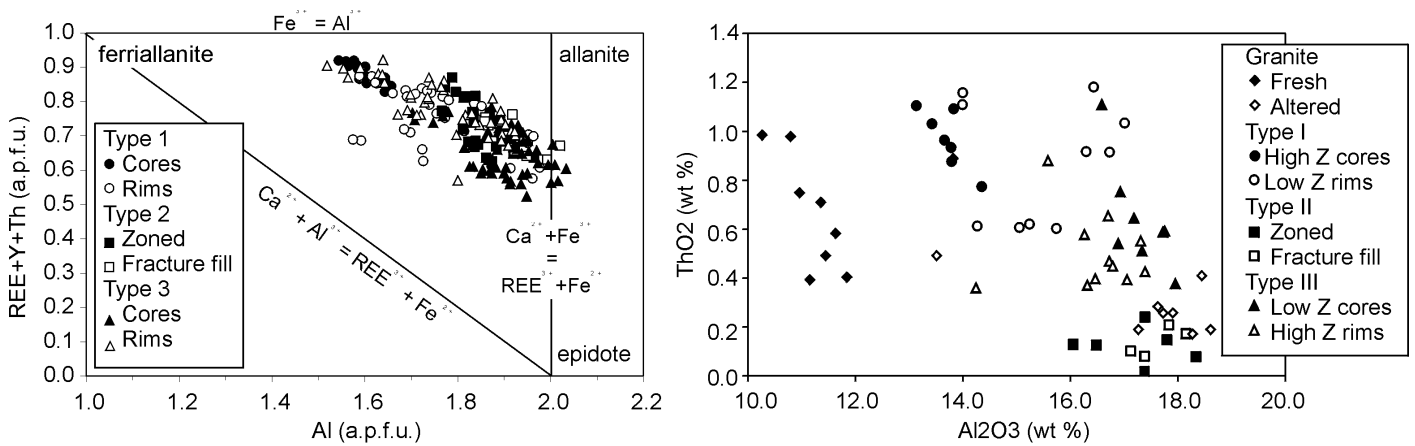


Figure 1: (a) Variation in major element chemistry of allanite. Substitution mechanisms from Petrik et al., (1995). (b) Variation in thorium content of allanite with aluminium content.

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