A contribution to U (Th)-Pb dating of epidote and allanite, and its implications for metamorphic and hydrothermal fluid flow histories

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The application of U-(Th)-Pb geochronology to rock-forming silicates has gained significant interest, and improvements in the last few years are due to analytical achievements and due to the development of alternative dating methods. One of these methods, Pb stepwise leaching (PbSL), profits from the advantage that, through acid leaching, radiogenic Pb in a mineral can be preferentially released relative to common Pb supposedly incorporated into the mineral's structure at the time of its formation (e.g. Frei *et al.*, 1997). Distinct, selective dissolution of a host silicate phase may be able to account for an increased data spread along the axes of the Pb-Pb isochron diagram. The selectivity regarding the two types of Pb consequently allows for the assessment of Pb-Pb geochronological data from silicates with unfavourable U/Pb ratios (e.g. Frei *et al.*, 1997; Dahl and Frei, 1998).

This study aims at assessing the utility of epidote group minerals in U-Pb dating of metamorphism and ancient crustal fluid flow, and to place preliminary constraints on closure temperature to Pb diffusion in both, epidote and allanite. Whereby epidote is commonly characterized by low U/Pb, allanite exhibits usually very high Th and high U concentrations, making this mineral a suitable candidate to U-Th-Pb dating (e.g. Barth, 1994; von Blanckenburg, 1992, and others).

Case studies

Lower Calcsilicate Unit metasediments and Napperby Gneiss metagranites at Conical Hill in the Reynolds Range, central Australia, underwent regional upper amphibolite-facies metamorphism at ~1590 Ma. Fluid flow during cooling from the peak of regional metamorphism formed discordant quartz - grandite garnet - epidote veins at ~600°C . PbSL experiments on coexisting garnet and epidote from within one such vein yield 1576 ± 3 Ma (MSWD = 1.59) and 1454 ± 34 Ma (MSWD = 1.28), respectively (Figs. 1a,b). While the garnet date closely approaches the time of peak metamorphic

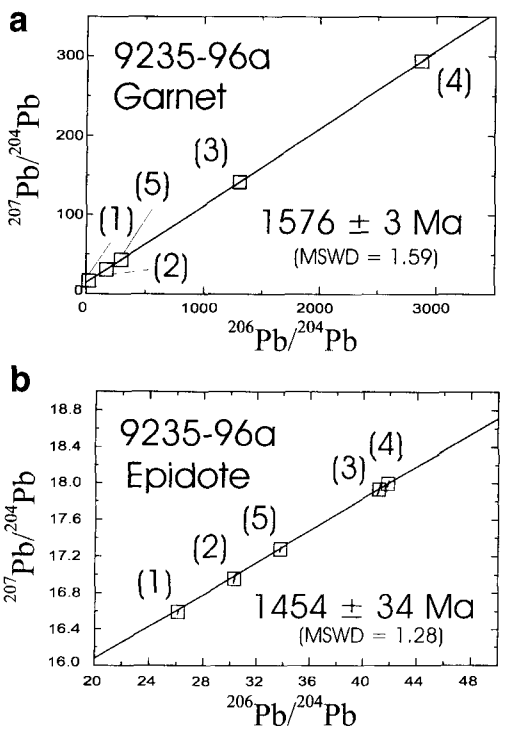

FIG. 1.

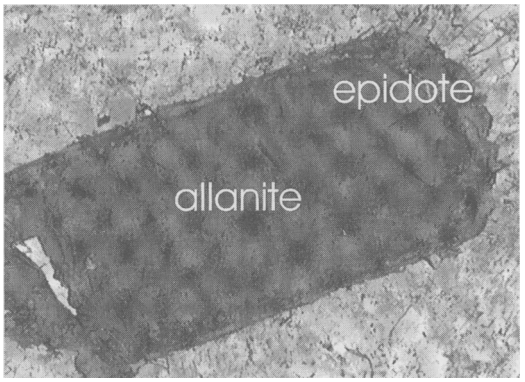

FIG. 2.

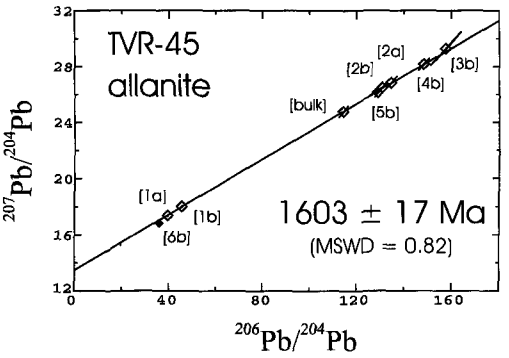

FIG. 3.

conditions (and thus confirms the general consent of a high Tc for garnet), the *c.* 100 Ma younger epidote date has to be interpreted either as a cooling age, or (as may be indicated by the disturbed leach spectra in the corresponding 6/4 *vs* 8/4 diagram) as an age of exsolution of an 'allanitic' phase. The first possibility infers that the closure temperature of epidote to lead diffusion was less than 600°C during retrogression in the Reynolds Range. This is somewhat lower than the temperature range of 685–750°C estimated from ionic porosity modelling of Tc (Dahl, 1997).

The Caledonides of East Greenland are thrust onto a pre-Caledonian basement complex (Central Metamorphic Complex; CMP). The latter was probably exhumed during late orogenic extension (Hartz and Andresen, 1995). Much of the strain took place along an East-dipping shear belt (Fjord Region Detachment) between the CMP and overlying Middle Proterozoic to Ordovician sediments (Eleonore Bay Supergroup).

Allanite occurs as cm-sized crystals in a planar fabric within a quartz-plagioclase gneiss from the CMP just beneath a mylonitic shear zone exposed in the end of Forsblad Fjord. Retrograde epidote is developed as a rim around the allanite laths (Fig. 2). PbSL and bulk U-Th-Pb dating of this allanite yield 1603 ± 17 Ma (MSWD = 0.82; Fig. 3), 1520 ± 15 Ma (Th-Pb) and a slightly discordant U-Pb age of 1487 ± 6 Ma ($^{207}Pb/^{206}Pb$ age: 1598 ± 39 Ma). Discordancy of the U-Pb ages, together with the too young Th-Pb date, indicates a recent partial Pb loss, most probably favoured by increased metamictization. PbSL data of epidote from the rim reveal that its Pb was in isotope equilibrium with that of allanite. This suggests a similarly high closure temperature of the two epidote-group minerals (compatible with ion-porosity reflections; Dahl, 1997; and contradictory to the former case study) and implies a fast middle Proterozoic retrogression of this CMP package.

Outlook

In order to get more detailed constraints on Tc for epidote and allanite we are presently investigating the possibility to date a garnet and apatite bearing paragenesis of one of the adjacent orthogneisses from the CMP complex. The generally high Tc for Pb in garnets, and the low ones of apatite, should allow to bracket the possible range of Tc for these two minerals, and the additional data should yield a consistent picture of the inferred p-T-t path in the investigated Eastern Greenland basement section.

References

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