Achieving geological precision in metamorphic geochronology: a Th-Pb age for the syn-metamorphic formation of the Mallnitzermulde Synform, Tauern Window, from individual allanite porphyroblasts

R. A. Cliff — School of Earth Sciences, University of Leeds, Leeds, LS2 9JT, UK

F. Oberli
M. Meier — Inst. f. Isotopengeologie und Mineralische Rohstoffe, Departement Erdwissenschaften, ETH Zentrum, CH-8092 Zürich, Switzerland

G. T. R. Droop — Department of Earth Sciences, University of Manchester, Oxford Rd, Manchester, M13 9PL, UK

Determining accurate age information on the thermal and tectonic evolution of metamorphic belts requires both precise analytical techniques and thorough understanding of the relationship between the dated material and the metamorphic crystallisation history. Achieving both simultaneously has proved difficult: the most precise analytical data comes from the U-Th-Pb system but generally from minerals which cannot be directly linked by petrographic observation to metamorphic history or from minerals where there is doubt whether the observed isotope systematics relate to the minerals analysed or to U-Th rich inclusions they contain. In most cases high analytical precision is linked to low Pb concentrations which limits how small the analysed sample can be. In this study we show that it is worth forfeiting some analytical precision in order to analyse relatively lead-rich minerals for which individual porphyroblasts, with clearly defined microstructural relationships to fabric development, can be analysed. The sample analysed is a mica-rich pelitic schist which contains micro-porphyroblasts of allanite. The full mineral assemblage is: garnet, muscovite, biotite, quartz, allanite, magnetite, ilmenite, apatite, tourmaline, with some retrograde chlorite. It comes from the lower part of the Peripheral Schieferhülle, from the NE limb of the Mallnitzer Mulde synform in the south east Tauern Window. Structurally it is close to the hinge of a fold which is believed to be of the same age as the major Mallnitzer Mulde synform. In the fine-grained muscovite-rich matrix the S1 schistosity was extensively crenulated during folding; locally randomly oriented recrystallised muscovite flakes overprint the crenulated schistosity. Euhedral 1.5mm diameter garnets and allanites contain inclusion trails of aligned ilmenite (Fig. 1). In detail the textures indicated porphyroblast growth after original fabric formation during the period of crenulation development.

The mineral assemblage of the sample itself does not provide tight constraints on metamorphic conditions but it is interbedded with pelites containing typical assemblages of the chloritoid-biotite zone mapped by Droop (1985) for which conditions of 7 ± 1 kb and 550 ± 10°C are estimated.

Previous geochronological studies in the south east Tauern Window show marked geographic variations in post-metamorphic cooling history, with biotite ages of 16 Ma 10km to the east of the present locality (Cliff *et al.*, 1985) and 21 Ma 12 km to the W in the Sonnblick Dome (Reddy *et al.*, 1993). Metamorphic crystallisation ages are less well known; in a detailed study of white mica Rb-Sr ages in the schists from the Mallnitzer Mulde, 6 km NW of the present study, Inger and Cliff (1994) found a range from 32 Ma down to 23 Ma which they correlated with variations in textural relationships between white micas and fabric development; samples with well developed crenulation, correlated with formation of the Mallnitzer Mulde, gave ages of 28–29 Ma.

The new data presented here were obtained by analysis of allanite, which has two properties of particular value for dating metamorphic crystallisation:

(1) its closure temperature for Pb isotopic diffusion is well above the temperature of metamorphism (von Blanckenburg, 1992; Oberli *et al.*, 1996)

(2) its typically high Th concentration makes it feasible to analyse individual grains only tenths of a millimetre in diameter.

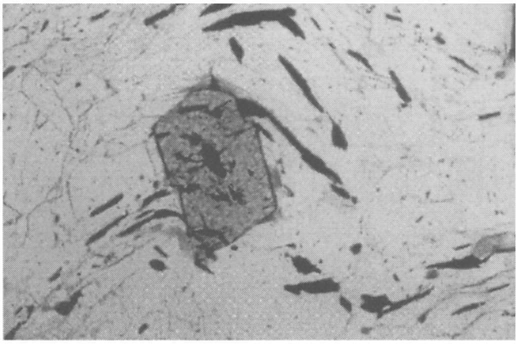

FIG. 1. Photomicrograph of allanite porphyroblast; inclusion trails of ilmenite define a crenulated fabric which continues within the porphyroblast. (*Field of view 0.7 mm wide*).

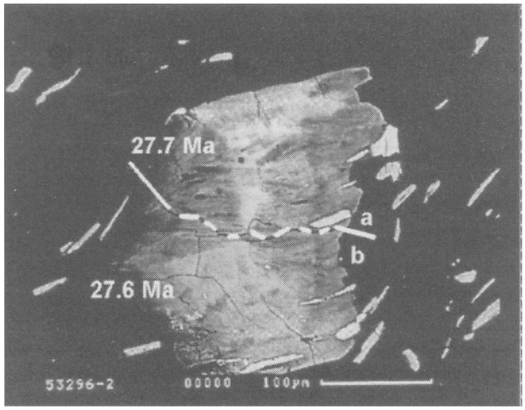

FIG. 2. Back-scattered electron image showing the first analysed allanite grain. The fracture which divided the two fragments is highlighted.

Because allanite incorporates Th preferentially to U, ^{206}Pb abundances in young samples are often enhanced as a result of incorporation of unsupported ^{230}Th and more reliable ages are obtained from the ^{232}Th-^{208}Pb system.

Samples were obtained from polished, 150 µm thick sections after petrographic examination by SEM. Individual allanite porphyroblasts were extracted under the petrographic microscope using a stage-mounted drill. Initial Pb isotopic composition was estimated by analysis of a conventional white mica separate. Th-Pb (and U-Pb) isotopic measurements were made on three samples, two of them separate fragments of a single allanite porphyroblast. The samples yielded approximately 2–5 ng total Pb, with radiogenic contributions between 6–10 wt.%; blanks were less than 1% of the Pb analysed. Th concentrations range from 0.8 to 1.2% and U concentrations are between 500 and 800µg/g. The two fragments of one porphyroblast (Fig. 2) have ^{232}Th-^{208}Pb ages of 27.6 $\pm$ .9 and 27.7 $\pm$ 1.0 Ma while the second porphyroblast has a ^{232}Th-^{208}Pb age of 27.9 $\pm$ .6 Ma. The corresponding ^{238}U-^{206}Pb ages are slightly older at 28.8, 28.9 and 29.6 Ma; as noted above these are biased by excess ^{206}Pb and they are not considered further. The three ^{232}Th-^{208}Pb ages agree well within error and taken together indicate that the allanites were formed at 27.8 $\pm$ .5 Ma. Given their microstructural relationships we conclude that the Mallnitzermulde fold was actively developing at this time. Peak metamorphic temperatures were reached at the same time or immediately afterwards. The white mica Rb-Sr ages reported by Inger and Cliff (1994) are slightly (1 Ma) older which may reflect incomplete recrystallisation of older white mica during crenulation.

Where metasediments contain allanites with clear-cut microstructural relationships to fabric development and metamorphic crystallisation ^{232}Th-^{208}Pb dating on microsamples offers a particularly powerful geochronological tool.

References

Cliff, R.A., Rex, D.C. and Droop, G.T.R. (1985) *J. Metam. Geol.*, **3**, 403–15.

Droop, G.T.R. (1985) *J. Metam. Geol.*, **3**, 371–402.

Inger,S. and Cliff, R.A. (1994) *J. Metam. Geol.*, **12**, 695–707.

Oberli, F., Meier, M., Berger, A., Rosenberg, C. and Gieré, R. (1996) *J. Conf. Abstr. V.M. Goldschmidt Conf.*, **1**, 439.

Reddy, S.M., Cliff, R.A. and East, R., 1993, *Geol. Rundschau*, **82**, 667–75.

von Blanckenburg, F. (1992) *Chem. Geol.*, **100**, 19–40.