

Rb/Sr AGES ON BIOTITES FROM THE NORTHERN ÖTZTAL-STUBAI CRYSTALLINE BASEMENT, EASTERN ALPS, TYROL, AUSTRIA

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With 3 figures and 1 table

Abstract: Rb/Sr biotite data on five samples from the northern Ötztal-Stubai Complex of the Austroalpine basement, yield ages varying between 141 ± 8.0 my to 260 ± 10.0 my, indicating weak to moderate reopened isotopic systems during the eoalpine event. These data indicate temperature conditions for the Alpine overprint in the range of $300 \pm 20^\circ\text{C}$ for samples northwest of the chloritoid line and $380 \pm 20^\circ\text{C}$ within and close to the zone of alpine chloritoid. The results are compatible with the observed retrograde AFM-mineral assemblages (Ga-Bi-Chl, Stau-Bi-Chl) and index-minerals (Stilp, Ctd) in pelitic and metasedimentary rocks of the northern Ötztal-Stubai Basement. The regional distribution of garnets that exhibit 'inverse' Mn-zoning at the outermost rim in the northern and NE-part of the Ötztal-Stubai Basement is related to slow Hercynian cooling during the final stages (P3) of the polyphase Hercynian event at temperature conditions in the range of 500°C to 570°C rather than representing the effects of the Cretaceous overprinting metamorphism.

Zusammenfassung: Rb/Sr-Analysen an Biotitkonzentraten aus 5 Proben des nördlichen Ötztal-Stubaier Altkristallins ergeben Alter zwischen 141 ± 8.0 mio.J. und 260 ± 10.0 mio.J., und zeigen damit schwach bis mäßig beeinflusste Isotopensysteme während des eoalpinen Ereignisses. Diese Daten weisen auf Temperaturbedingungen der alpinen Überprägungsmetamorphose zwischen $300 \pm 20^\circ\text{C}$ aus dem Bereich nordwestlich der Chloritoidlinie und $380 \pm 20^\circ\text{C}$ für Proben innerhalb der Chloritoidzone. Die Ergebnisse sind mit den auftretenden retrograden AFM-Mineralparagenesen (Ga-Bi-Chl, Stau-Bi-Chl) und Indexmineralen (Stilp, Ctd) in pelitischen und metasedimentären Serien des nördlichen Ötztal-Stubaier Altkristallins kompatibel. Das regional begrenzte Auftreten von Granat mit "inversen" Mn-Zonarbau in nördlichen und nordwestlichen Bereichen des Altkristallins wird auf den Einfluß einer hercynischen Abkühlung während der finalen Phase (P3) des polyphasen variszischen Ereignisses bei Temperaturbedingungen zwischen 500°C und 570°C zurückgeführt.

1. Introduction

The polymetamorphic Ötztal-Stubai Basement (OeAK; Eastern Alps) is part of the Austroalpine continental nappe system. The whole complex forms an overthrust mass transported from S to N during the Alpine orogenic cycle and emplaced tectonically on Lower Austroalpine/penninic rock series. The thrust mass is limited in the north by the Calcareous Alps, in the west (Silvretta Crystalline of similar tectonic setting, penninic Engadine Window) and in the east (penninic Tauern Window). The margins are defined by tectonic boundaries. To the south no clear tectonic contact can be observed (fig.1). Based on detailed petrological, geochemical, structural and radiometric investigations of various rock types, the general features of the polymetamorphic evolution in the study area have been discussed by a number of authors (PURTSCHELLER,

1967b, 1969, 1978; PURTSCHELLER & VELTMAN, 1988, in prep.; HOINKES, 1981; THÖNI, 1981, 1982; MILLER, 1970; MOGESSIE, 1984; MOGESSIE et al., 1985). The major aspects of the regional geology and tectonometamorphic setting have been reported by HOINKES et al. (1982). At least three successive metamorphic event can be recognized. The most important characteristics include: (1) The presence of eclogites, peridotites and metagabbros within a narrow, inhomogenous amphibolite complex, which suggest an earlier high- to medium pressure facies metamorphism (M1, $P=10$ kb, $T=500^\circ\text{C}$) of pre-Hercynian or possible Caledonian age (500 my). The pre-Hercynian eclogites are suggested to have been gradually retrograded during the (2) Hercynian amphibolite grade metamorphism (M2, ≤ 300 my). This event reached maximum temperatures of $\approx 670^\circ\text{C}$ (4 kb) in the central section (Winnebach migmatite). Hercynian as-

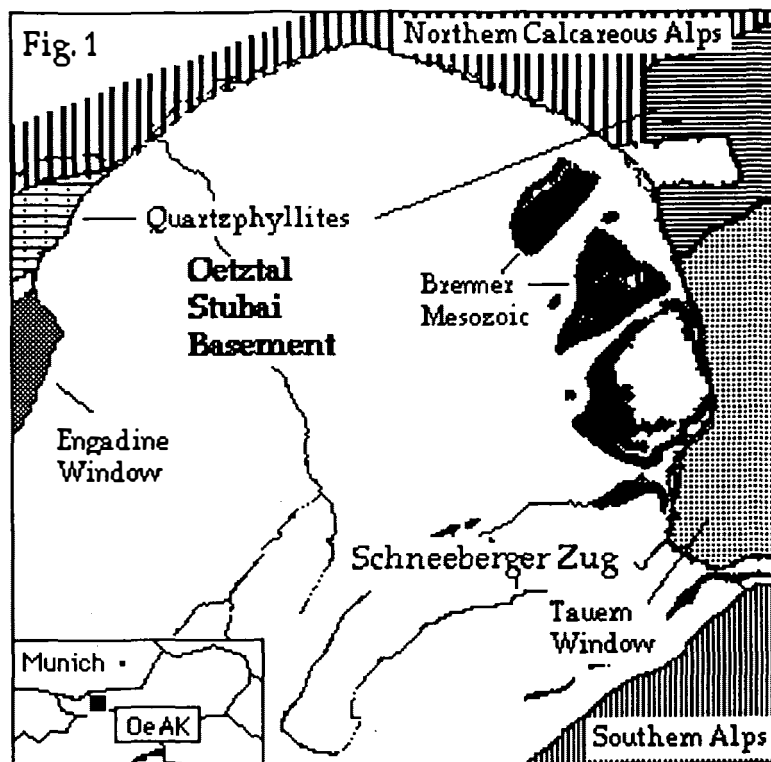


Fig. 1:

Simplified geological sketch map of the Oetztal-Stubai Complex

semblages are (3) partly overprinted by a later Cretaceous (≈ 90 my) metamorphic event. P, T-max conditions of this episode are located in the south (550-580°C, 5 kb, south Schneeberger Zug, fig.1), characterized by a post-tectonic staurolite- and kyanite microblastesis. Decreasing metamorphic grade towards N and NW is indicated petrographically in metapelitic schists by pseudomorphous retrogression including the alteration of stau- \rightarrow ctd and ky- \rightarrow mu, pg (PURTSCHELLER, 1967b, 1978) and the formation of neogenic stilpnomelane in metasedimentary rocks. Different zones of Alpine index minerals discontinuously cut the Hercynian mineral zones. Both heat domes are geographically separated by a distance of 35 km (HOINKES et al., 1982; see fig.2).

Decreasing metamorphic grade for the eoalpine event from the south (the area around Schneebergerzug) to north and north-western parts of the basement is proved by the zonal sequence of mica cooling ages (for a detailed discussion and reference list see THÖNI, 1981, 1982).

- Zone 1: Eoalpine mica cooling ages (Rb/Sr biotite ages of 75-82 m.y.) are interpreted to reflect Alpine amphibolite facies conditions (HOINKES, 1981).

- Zone 2: The "zone of mixed cooling ages" (Rb/Sr biotite of 100-300 m.y.) match the regional distribution of alpine ctd and stil, indicating greenschist facies conditions

in central parts of the OeAK following zone 1.

- Zone 3: Towards the north and northwest the Variscian amphibolite facies assemblages (in pelites: Ga-Stau-Bi, Ga-Ky-Bi, Ga-Stau-Bi-Ky, Ky-Stau-Bi) persisted through the Alpine overprint (Hercynian cooling ages in the range of 330-270 m.y.) and retrograde reactions are only locally observed.

The purpose of this paper is threefold:

- (1) Although a considerable amount of geochronological studies have been performed in the Oetztal-Stubai Complex, only a few data are available for the northern parts of the basement. Additional data should constrain the age patterns and the Alpine temperature zones within pre-Alpine basement rocks based on the "blocking temperature concept" (PURDY & JÄGER, 1976).

- (2) Discontinuously zoned garnets are restricted to the SE-parts of the OeAK (VELTMAN, 1986) and match the zone of affected isotopic systems, e.g. "zone of mixed mica cooling ages" (see fig.2). In NE-parts of the OeAK, but still within the zone of alpine chloritoid, no discontinuous zoning patterns are observed, indicating a S-N temperature gradient. Decreasing temperature conditions towards the north (DIETRICH, 1983; TESSADRI, 1981) should be proved by means of Rb/Sr-biotite data.

- (3) Based on mineral assemblages in amphibolitic rocks, MOGESSIE (1984) suggested temperature condi-

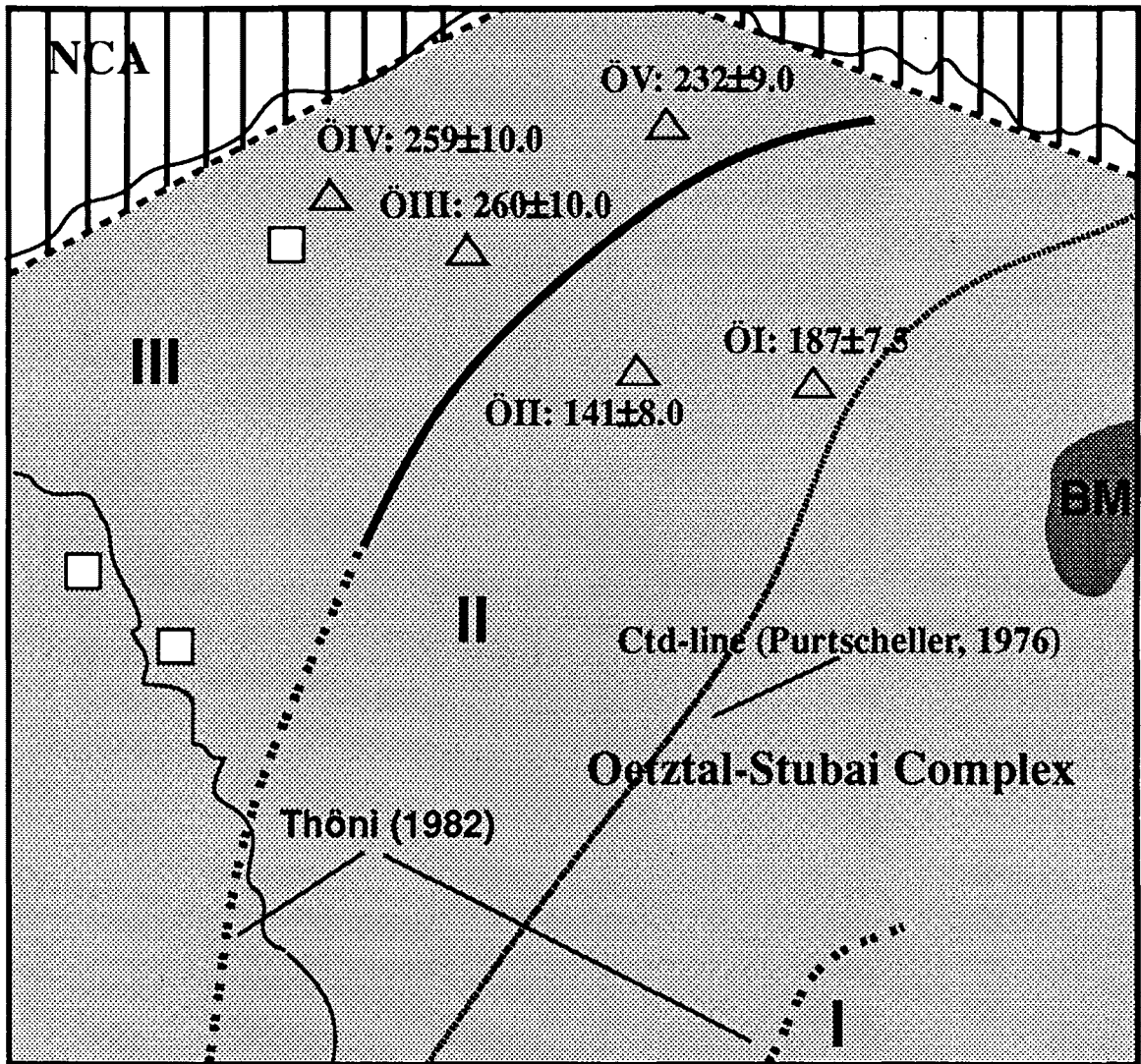


Fig. 2:

(Δ) Sample location and calculated model ages of this study. (\square) refers to HARRE et al. (1968). Mineral age zones according to THÖNI (1982): I - zone of alpine mica cooling ages, II - zone of mixed age (= Alpine temperatures 300°–550°C), III - Hercynian mica cooling ages (= Alpine temperatures \leq 300°C), BM - Brenner Mesozoic, NCA - Northern Calcareous Alps

tions of 475°C–550°C for the Alpine overprint in the Northern OeAK (Location: Zirmalm). The observed retrograde AFM-mineral paragenesis Ga-Bi-Chl and Stau-Bi-Chl in metapelitic rocks from this area have also been interpreted in terms of retrograde reaction mechanisms in the range of 500°C–570°C, 6 Kb (VELTMAN, 1986). Radiometric investigations should place constraints on the timing of this metamorphic episode.

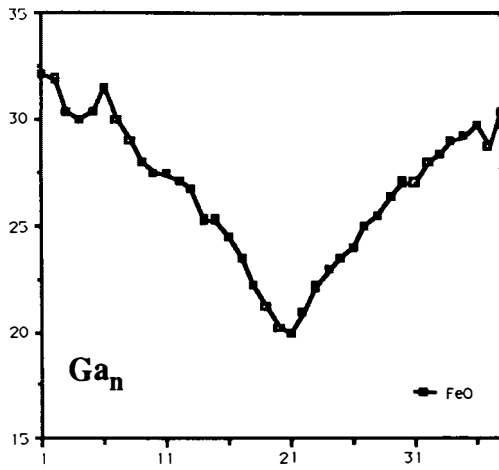
2. Sample preparation and analytical procedure

Chemical treatment and analytical techniques employed for Rb/Sr isotopic analysis closely follow those described

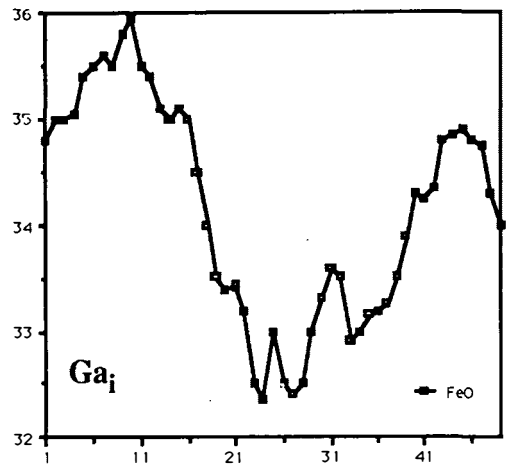
by THÖNI (1981, 1982). The grain sizes of the biotite concentrates analyzed varied between 150 μ and 450 μ . The constants used for the calculations follow the recommendations given by STEIGER & JÄGER (1977).

3. Results

In the northern Ötztal-Stubai Basement the data can be classified in two groups. The analytical results are shown in table 1. 3 out of 5 samples (ÖIII, ÖIV, ÖV) yield ages ranging from 260 \pm 10.0 to 232 \pm 9.0 my (see Fig. 2). The appearance of ages of \leq 270 my may be related to slightly influenced pre-Alpine biotite by the Alpine event at temperature conditions of $T_{\text{alpine}} = 300 \pm 20^\circ\text{C}$. Sample ÖI



1.5 mm



1.3 mm

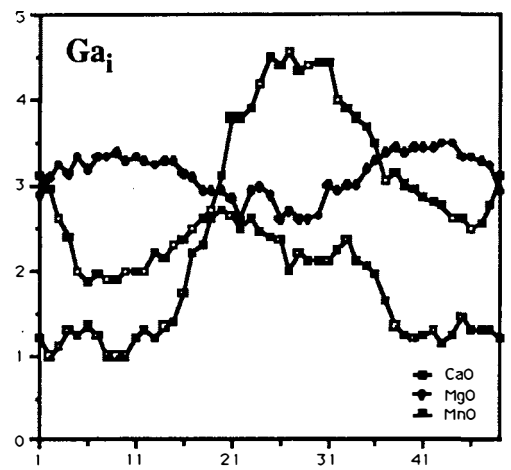
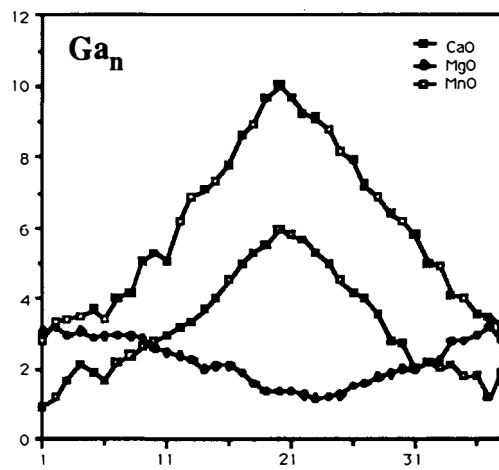


Fig. 3:

Zoning profile across garnets from metapelites from the northern kyanite zone. Note the increase of MnO and concomitantly decrease of FeO (wght-%, y-axis) at the outermost rim of ga_i compared to 'normal' zoned garnet ga_n (x-axis = number of measuring points, y-axis = wght-%)

| Sample Nr. | Locality | ^{87}Rb (ppm) | ^{87}Sr rad (ppm) | Srtot (ppm) | %rad | $^{87}\text{Rb}/^{86}\text{Sr}$ | $^{87}\text{Sr}/^{86}\text{Sr}$ |
|------------|----------------|------------------------|----------------------------|-------------|--------|---------------------------------|---------------------------------|
| Ö I | Almindalm | 160,000 | 0,426 | 5,180 | 56,460 | 346,000 | 1,631 |
| Ö II | St. Sigmund | 69,200 | 0,139 | 4,740 | 30,380 | 154,400 | 1,020 |
| Ö III | Kühtai | 311,000 | 1,150 | 2,720 | 91,450 | 2058,600 | 8,314 |
| Ö IV | Silzer Sattel | 404,000 | 1,487 | 4,100 | 89,220 | 1597,300 | 6,587 |
| Ö V | Flauringer Alm | 161,100 | 0,535 | 3,190 | 74,400 | 624,630 | 2,774 |
| Ö III tot | Kühtai | 61,400 | 0,372 | 47,290 | 10,290 | 13,420 | 0,792 |
| Ö IV | Silzer Sattel | 67,400 | 0,463 | 29,720 | 18,610 | 23,630 | 0,873 |

Table 1:
Analytical results

as well as ÖII give 187 ± 7.5 and 141 ± 8.0 my respectively, indicating isotopic readjustment of pre-Alpine biotite ('mixed cooling ages') at alpine temperatures of 380-420°C (cf. THÖNI, 1981, 1982).

4. Discussion

The Rb/Sr-radiometric age results on biotites and the deduced temperature variation is in good agreement with petrographic observations (ÖI, ÖII → Ctd-zone; ÖIII, ÖIV, ÖV → Stlp-zone) and microchemical data (variation of garnet zoning patterns, VELTMAN, 1986).

Based on mineral assemblages in amphibolitic rocks (recrystallization of amphiboles to actinolite + albite + epidote + quartz + chlorite ± biotite ± sphene, MOGESSIE (1984) suggested temperature conditions of 475°C–550°C related to late Hercynian cooling or possibly due to the Alpine overprint in the northern basement. Occurrence of biotite as a retrograde phase in northern Ötztal-amphibolites additionally confirms metamorphic conditions representing the transition zone between the upper greenschist and lower amphibolite facies.

As mentioned above, metapelitic rocks of the northern Kyanite-zone show hypidiomorphic garnet grains that are locally replaced by secondary chlorite at the rim and along cracks. Staurolite porphyroblasts within the same samples often exhibit similar replacement structures. The chemical zonation of these garnets (ga_i) is characterized by Mn, Ca-enriched core compositions and Fe, Mg-enriched rims, similar to garnets (ga_n) in the parageneses Ga_n -Stau-Bi (see fig. 3), representing Hercynian amphibolite facies conditions. However, contrary to ga_n , the chemical composition of ga_i shows an increase of Mn-concentration and a concomitant decrease in FeO at the outermost rim, reflecting different p,t-conditions. The interpretation of different zoning patterns within the framework of 'reaction-modelling' yields the following scheme on the nature and occurrence of prograde and retrograde reactions that have taken place in northern parts of the OeAK (cf. VELTMAN, 1986; PURTSCHELLER & VELTMAN, 1988 in prep.):

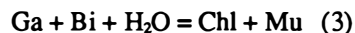
The zoning trend of ga_n may be related to the continuous reaction



at temperature conditions above the nominally KFMASH-discontinuous reaction



The equilibrium conditions for reaction (1) have been estimated in the pure KFMASH-system with 575°C, 620°C, and 680°C at pressure conditions varying between 5-7 kb (THOMPSON, 1976 b). It is proposed that the continuous AFM-reaction responsible for the formation of "inverse" (Mn)-garnet zoning patterns (ga_i) at the outermost rim is (proceeding with decreasing temperature)



with end-member temperatures in the order $(TMn) < TFe < TMg$, at temperature conditions below reaction (2). Reaction (2), which actually is multivariant in natural systems due to additional components, is suggested to gradually release H_2O with increasing temperature conditions. Declining temperatures after the thermal climax of the Hercynian event will therefore lead to a local increase in aH_2O (cf. THOMPSON et al., 1977) and reaction (1) could proceed with falling temperature conditions. The occurrence of "inverse" zonation (ga_i) and Mn-"bell shaped" trends (ga_n) in the same thin section due to "small-scale equilibrium effects" confirms this interpretation.

Based on the geochronological data, amphibolite petrology, AFM-topologies observed in pelitic rocks and related garnet zoning patterns, the Hercynian metamorphism is proved to be polyphase P1, P2, and P3 corresponding to an early (HP?-MP/LT) greenschist facies metamorphism, a MP/HT-MT metamorphic episode and an LP-MP/MT event respectively. The results of this study indicate that the temperatures for the Alpine overprint did not exceed 380°C in the region around Kühtai. The occurrence of the above assemblage must therefore be related to slow Hercynian cooling during the final stages (P3) of the polyphase Hercynian event rather than representing the effects of the Cretaceous overprinting metamorphism at lower amphibolite facies conditions.

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