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DATING OF ANDALUSITE BY GECHRONOLOGICAL METHODS (SM-ND AND U-PB) – A FAILURE

by

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Introduction: Andalusite, sillimanite and cordierite are index minerals for high-temperature/low-pressure (HT/LP) metamorphic rocks. These rocks occur in different tectonic settings related to contact metamorphism, exhumation of thickened crust or lithospheric extension. Their formation age respectively the formation age of their peak metamorphic assemblages is of interest for some geodynamic questions. If they formed during contact metamorphism this age can be determined by dating the intrusion age of the related magmatic body. For the other cases dating is much more difficult because of the following reasons: The HT/LP assemblages contain andalusite, sillimanite, biotite, plagioclase, muscovite and quartz, whereas garnet suitable for dating by the Sm-Nd method is not in equilibrium with the HT/LP assemblage, respectively it is consumed by the aluminumsilicat-forming reactions. On the other hand dating of zircon or monazite by the U-Pb method is problematic, because it is difficult to prove their formation during the peak of the HT/LP event. The most convenient age determination would be dating of the index minerals andalusite, sillimanite or cordierite itself. Being aware of the bad chance, but facing that it has not been reported before, we launched dating of metamorphic and magmatic andalusite.

Analytical techniques: Minerals used for isotope determinations were hand-picked under a binocular microscope, except biotite which was separated on a vibrating table and by grinding in alcohol. Chemical sample digestion and element separation for the Sm-Nd method follows standard procedures [1]. To remove surface contaminations minerals were leached in 2.5 N HCl before decomposition for 5 minutes. Overall blank contributions are ≤ 0.2 ng for Nd and Sm. Errors quoted in table 1 correspond to 2σ of the block mean (1 block = 10 isotope ratios). The $^{143}Nd/^{144}Nd$ ratio for the La Jolla international standard during the course of this investigation was 0.511846 ± 8 (35 runs). Errors for the $^{147}Sm/^{144}Nd$ ratio are ± 1%, or smaller, based on iterative sample analysis and spike recalibration. The U/Pb leaching experiment was performed on 50.7 mg of andalusite with grain size 0.20 to 0.25 mm. It includes one cleaning step (A), three leaching steps (B: 1N HBr + 6N HCl, 2h, 70°C; C: 1N HBr, 16h, 70°C; D: 15N HNO_3, 16h, 70°C) and complete dissolution (E: HF+ HNO_3, 48h, 170°C). Element separation follows the normal U/Pb method of titanite [2].

Sample material: Three samples from Austroalpine basement units have been investigated: Samples RS13/97 [3] and NM93/128 [4] represent Al-rich metapelites with a polyphase metamorphic history. Andalusite formed by the breakdown of Variscan staurolite during a Permo-Triassic HT/LP event. It developed by the reaction St + Ms ⇔ And + Bt + Qtz + H_2O. In both cases andalusite exhibites up to 1cm large porphyroblasts which form a significant part of the rock. The third sample (92T32) is an andalusite-muscovite-quartz vein. Andalusite was separated from a several centimeter large, pinkish colored, euhedral crystal. A Variscan formation age of the vein is suggested by geochronological age data from the sample area [5].

Results: Andalusite from sample RS13/97 contains 0.25 ppm Nd and 0.035 ppm Sm. It is characterised by lower $^{147}Sm/^{143}Nd$ and $^{144}Nd/^{143}Nd$ ratios than the whole rock and two biotites. The spread of all four data points is too low to calculate an isochron age. Concentrations of 8.2 ppm Nd and 1.4 ppm Sm have been found in andalusite of sample NM93/128. Within the error bars andalusite shows the same isotopic ratios than the whole rock and the biotite but lower ratios than plagioclase. The much higher concentrations of Sm and Nd and the similar isotopic ratios might indicate a contamination of the andalusite by inclusions of REE-rich minerals such as zircon or monazite. Magmatic andalusite of sample 92T32 exhibites very low concentrations of 0.019 ppm Nd and 0.012 ppm Sm and a higher $^{147}Sm/^{143}Nd$ and $^{144}Nd/^{143}Nd$ ratio than the metapelites. The higher ratios might be due to partial melting during the mobilisation of the vein material.

Sample	unit / locality	Nd [ppm]	Sm [ppm]	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$+/-2s_m$
RS13/97 WR	Strieden Complex,	79,610	12,982	0,09856	0,511859	5,7E-06
RS13/97 And	Carinthia (Austria)	0,245	0,035	0,08545	0,511834	1,3E-05
RS13/97 Bt1		1,726	0,359	0,12590	0,511923	1,8E-05
RS13/97 Bt2		1,199	0,252	0,12697	0,511952	1,0E-05
NM93/128 WR	Öbrennberg-Kaltes	47,626	8,286	0,10516	0,511882	6,2E-06
NM93/128 Pl	Bründl Serie,	1,109	0,214	0,11682	0,511903	7,1E-06
NM93/128 And	Burgenland (Austria)	8,186	1,407	0,10389	0,511873	6,2E-06
NM93/128 Bt		2,399	3,296	0,83049	0,511871	1,1E-05
92T32 And	Ötztal C., Tyrol (Austria)	0,019	0,012	0,37968	0,512135	9,3E-06

sample	step	U [ppm]	Pb [ppm]	% Pb rad	Th/U	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
RS13/97 And	B	0.242	4.526	7.6	1.472	0.4432	0.7139	1.4722
	C	1.571	17.365	16.4	3.075	0.1732	0.2030	5.1394
	D	1.155	10.325	16.9	3.146	0.1841	0.2296	2.1111
	E	0.016	4.091	21.5	3.447	0.1632	1.9360	1.8533

Table 1

Sm-Nd and U-Pb analytical data from mineral concentrates and whole rocks.

Assuming that the andalusite preparate of sample RS13/97 was not contaminated by other mineral phases, it was used for investigations by the U/Pb leaching method. Observed concentrations are 0.016 to 1.57 for U and 4.09 to 17.4 for Pb. U/Th ranges from 1.5 to 3.4 and is comparably low. The content of radiogenic Pb is low and varies (7.6 - 21.5 %) during the leaching experiment. Obviously it is not possible to separate the common Pb component from the radiogenic lead with the applied leaching procedures.

It is therefore concluded, that the common Pb is included in the crystal lattice and not in the form of inclusions. Calculated $^{207}Pb/^{206}Pb$, $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$ ages are scattering and give no geological information. This might be due to primary unequilibrium or problems of the leaching technique. A Pb-Pb errorchron yields c. 2.0 Ga, a typical average "age" value for the Alpine basement units.

Conclusions: Pure andalusite is poor in Sm, Nd, U and Pb. Andalusite is fractionating the LREE and therefore it exhibites lower $^{147}Sm/^{143}Nd$ and $^{144}Nd/^{143}Nd$ ratios than the whole rock. The U-Pb leaching experiment yielded complex mixtures of common and radiogenic lead, leading to disequilibrium and meaningless age informations. Andalusite is not suitable for geochronological dating by the Sm-Nd method or the applied U-Pb leaching technique.

References

[1] THÖNI, M. & JAGOUTZ, E. (1992): Some new aspects of dating eclogites in orogenic belts: Sm-Nd, Rb-Sr and Pb-Pb isotopic results from the Austroalpine Saualpe and Koralpe type-locality (Carinthia/Styria, SE Austria). - Geochim. Cosmochim. Acta, 56: 347-368.

[2] PERRISH, P. P., RODDICK, J. C., LOVERIDGE. W. D. & SULLIVAN, R. W. (1987): Uranium-lead analytical techniques at the geochronology laboratory, Geological Survey of Canada. - Geol. Surv. of Canada Paper, 87/2: 3-7.

[3] SCHUSTER, R., SCHARBERT, S. & ABART, R. (1999): Permo-Triassic crustal extension during opening of the Neotethyan ocean in the Austroalpine-South Alpine realm.- Tübinger Geowissensch. Arb., Serie A, 52: 5-6.

[4] DRAGANITS, E. (1998): Seriengliederung im Kristallin des südlichen Ödenburger Gebirges (Burgenland) und deren Stellung zum Unterostalpin am Alpenostrand. - Jb. Geol. B.-A., 141: 113-146.

[5] THÖNI, M. (1981): Degree and evolution of the Alpine Metamorphism in the light of K/Ar and Rb/Sr age determinations on micas. - Jb. Geol. B.- A., 124/1: 111-174.