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Cadomian magmatism in the Alps recorded in Late Ordovician sandstones of the Carnic Alps: preliminary results from zircon Pb/Pb evaporation dating

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Abstract

$^{207}Pb/^{206}Pb$ evaporation age dating of euhedral detrital zircons from the Late Ordovician Uggwa Formation, eastern Carnic Alps, yields two age groups, including (1) a group with a pooled age of 650 ± 24 Ma and (2) a bad constrained age group of 518 ± 76 to 533 ± 106 Ma. The younger age group is similar to acidic orthogneisses of the Austroalpine basement complex. The older ages coincide with $^{40}Ar/^{39}Ar$ ages of detrital white mica from the same stratigraphic level, and suggest together with mica ages, therefore, the presence of a Cadomian metamorphic/magmatic orogenic belt. We interpret the new zircon ages to record two stages of magmatism related to Late Cadomian tectonic events. Ages of inherited zircon cores include apparent minimum ages ranging from c. 2.0 Ga to c. 900 Ma displaying possible close paleogeographic relationships with Gondwanan and/or Baltic tectonic elements.

Keywords: zircon, Cadomian, Pb/Pb evaporation technique, paleogeography, Eastern Alps.

Introduction

The paleogeographic origin and relationships of basement units within the Southalpine unit as exposed in the Carnic Alps and Karawanken Mountains (Fig. 1) are still a major problem, although some new data were added during recent years. Detrital white mica from the Late Ordovician Himmelberg Sandstone yield a $^{40}Ar/^{39}Ar$ age of c. 640 Ma (DALLMEYER and NEUBAUER, 1994). This age was interpreted to record a Cadomian tectonothermal event of a magmatic or metamorphic unit. A metamorphic unit appears to be more likely because dated grains were fine-grained (c. 80–225 μm).

Here we report $^{207}Pb/^{206}Pb$ evaporation ages from detrital zircons of the Upper Ordovician, which put new constraints on the hinterland (source region of clastic material) of the Carnic Alps. These ages reveal two magmatic episodes during the Late Precambrian and at the Precambrian/Cambrian boundary.

Regional geology

The Ordovician stratigraphic succession of the Central and Eastern Alps includes from bottom to top: the Middle to Late Ordovician Fleons/Val Visdende Formations, the Obstanser/Comelico Porphyroid, a Late Ordovician ignimbrite, and an overlying series of clastic formations. The latter spread from west to east from the rather coarse-grained Himmelberg Formation with sandstones and some conglomerates, via the Trieb and Himmelberg Formations, which include mainly medium-grained sandstones, to the Uggwa Formation (Fig. 2), a shale with subordinate sandstone intercalations (HEINISCH, 1981; POSCHESCHNIK, 1993; SCHÖNLAUB and HISTON, 2000 with references). These clastic sequences are interpreted to record a succession deposited from littoral to inner shelf areas (e.g. SCHÖNLAUB and HISTON, 2000).

Porphyroids are widespread in the South Alpine basement of the Carnic Alps, Brixen and Agordo regions (MELI, 1998 and references there-

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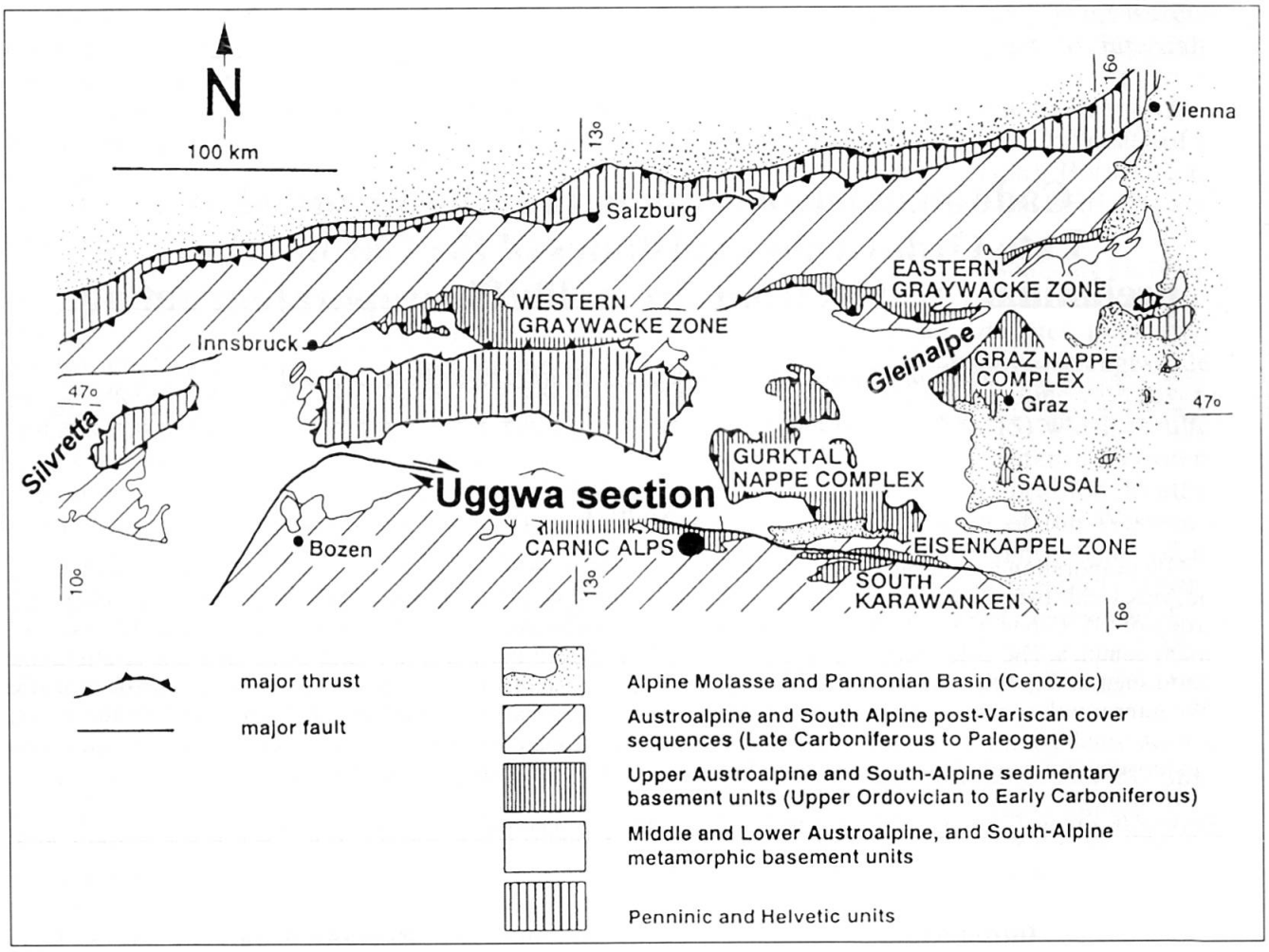

Fig. 1 Location of the Uggwa section in the Carnic Alps.

in), although their age of formation is not well-dated up to now. A major portion corresponds to the Austroalpine Blasseneck Porphyroid for which a biostratigraphic age at the Caradocian to Ashgillian boundary was reported (FLAJS and SCHÖNLAUB, 1976). However, LOESCHKE et al. (1990) found additional acidic tuffs in deeper stratigraphic levels for which the age is still unconstrained by biostratigraphic and geochronological data. A conventional U–Pb zircon age of 468 +6/–5 Ma was recorded from the Blasseneck Porphyroid (SÖLLNER et al., 1991).

Uggwa section

The Uggwa section is exposed in the Italian side of the eastern Carnic Alps (Fig. 1) in the Uggwa (or Uqqwa in some Italian topographic maps) Valley to the north of the village Uggovizza, 200 meters NNE to Rifugio Fratelli Nordio (Italian Topographic 14 I SE Campor, 1 : 25'000, sheet Camporosso in Valcanale or Austrian Topographic Map 1 : 25,000 V, sheet 199 Hermagor). The 36 meter long section was described by VAI (1970), SCHÖNLAUB (1980) and POSCHESCHNIK (1993). It exposes mainly shales and a c. seven meters thick intercalation of carbonate grainstone, micritic limestone, silty sandstone and pebble-bearing sandstone (Fig. 2). Both the shales and sandy to limy intercalations are rich in fossils, which indicate a Caradocian age for most portions of shales and an Ashgillian age of the sandy/limy intercalations (VAI, 1970; SCHÖNLAUB, 1980). The sandstone samples comprise c. 85 volume percent monocrystalline quartz, c. 8 percent feldspar and c. 7 percent lithic fragments. The heavy minerals are dominated by zircon, tourmaline and rutile. Both the framework constituents and the heavy minerals indicate a rather mature sediment, long transport and/or abundant redeposition.

More euhedral zircons (c. 4 percent of all zircon grains) are present in sample UQ5 than in all other investigated samples from other Late Ordovician formations (POSCHESCHNIK, 1993). Consequently, this sample was chosen for $^{207}Pb/^{206}Pb$ evaporation dating of single zircons. A morphological study of the typology of euhedral, sharply faceted zircons following the method of PUPIN

(1980) yielded predominant S2–S17 morphologies (Fig. 3). These are interpreted as a clear indication for a S-type magmatic suite with crust-derived acidic plutonic and/or volcanic rocks (PUPIN, 1980).

Zircon evaporation data

$^{207}Pb/^{206}Pb$ analysis follows the evaporation method described by KOBER (1987) and was performed at the Laboratory of Geochronology at the University of Vienna. The analytical techniques are described in KLÖTZLI (1997). 2σ errors include error propagation of the analytical error, error of fractionation and error of common lead correction. The $^{206}Pb/^{204}Pb$ ratios are partly low and range between 143 and 1500. The low values suggest low U contents and/or the presence of high common lead components and result in large 2σ errors. Note that $^{207}Pb/^{206}Pb$ single grain evaporation ages represent minimum ages as there is no control on possible lead loss.

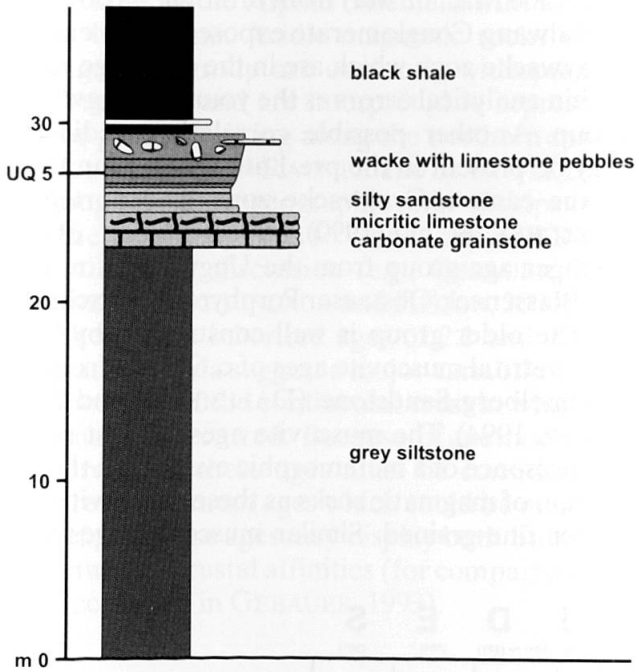

Fig. 2 Uggwa section with the stratigraphic position of the investigated sample UQ5.

Nine single euhedral grains were investigated. The analytical data are reported in table 1. The $^{207}Pb/^{206}Pb$ ages monitor a relatively large scatter of apparent ages, which can be clustered to a number of age groups as follows: Grains A, B, C give $^{207}Pb/^{206}Pb$ ages of 518 ± 76, 533 ± 106 and 492 ± 156 Ma, which are similar within analytical errors. A further grain, F, gave a similar age of 554 ± 260 Ma with a very large error. Grain G gave an age of 598 ± 134 Ma. The $^{208}Pb/^{206}Pb$ ratios of grains A, B, C, F, G are variable, and therefore the Th/U ratio too. Although the ages of these five grains are within a similar age range, the Th/U ratio suggests that these may originate from different magma sources or batches. Because of the smaller uncertainties grains A and B may represent the best estimate within the age range of 518 ± 76 and 533 ± 106 Ma of this distinct magmatic suite.

Grains I, J, K and O gave similar $^{207}Pb/^{206}Pb$ ages within 2σ errors with similar $^{208}Pb/^{206}Pb$ ratios and consequently similar Th/U ratios between 0.157 and 0.176. We consider therefore that

Tab. 1 Mean zircon evaporation ages of sample UQ5 from the Uggwa Formation, Carnic Alps.

Sample	Typology	Evaporation steps	207/206	2 SD	2 SD %	207/206 Ma	2SD Ma	2SD %	208/206	2SD	Th/U	2SD
			a)	b)	b)	c)	b)	b)	b)	b)	d)	b)
UQ5-A	S6	5	0.05770	0.00198	3.4	518	76	14.6	0.0353	0.0088	0.107	24.6
UQ5-B	S1	4	0.05809	0.00282	4.8	533	106	19.9	0.0540	0.0100	0.163	18.6
UQ5-C	S7	6	0.05702	0.00402	7.0	492	156	31.6	0.0483	0.0086	0.146	17.8
UQ5-F	S12	3	0.05865	0.00698	11.7	554	260	46.8	0.0587	0.0032	0.177	5.4
UQ5-G	S6	3	0.5985	0.00370	6.2	598	134	22.4	0.0557	0.0103	0.167	18.2
UQ5-I	L1	4	0.06202	0.00234	3.8	675	80	12.0	0.0528	0.0104	0.158	19.8
UQ5-J	S2	5	0.06100	0.00162	2.6	639	58	9.0	0.0526	0.0114	0.157	21.8
UQ5-K	S6	3	0.06118	0.00144	2.4	646	50	7.8	0.0587	0.0124	0.176	21.0
UQ5-O	S7	6	0.06128	0.00140	2.2	649	50	3.6	0.0595	0.0080	0.176	13.4
weighted mean I to O			0.06131	0.00070	1.2	650	24	3.6				
Grand mean			0.05964	0.00342	2.9	591	126	21.2				

a) Mean from individual scan ratios.
b) All errors reported are 2σ standard deviation.
c) Mean ages derived from individual scan ratios and not from individual scan ages.
d) Th/U at apparent $^{207}Pb/^{206}Pb$ age.

Erratic ages of zircon cores:
UQ5-B: 1439 ± 74 Ma
UQ5-F: 2085 ± 22 Ma
UQ5-I: 876 ± 140 Ma
UQ5-O: 1964 ± 46 Ma

these four grains are cogenetic. The ages are 675 ± 80, 639 ± 58, 646 ± 50 and 649 ± 50 Ma with a weighted mean age of all four grains of 650 ± 24 Ma. The age is considered to be geologically significant and suggests the presence of a distinct magmatic suite in the respective hinterland.

An inherited component was identified in the cores of some zircon grains. The ages are: grain B with 1439 ± 74 Ma, grain F with 2085 ± 22 Ma, grain I with 876 ± 140 Ma and grain O with 1964 ± 46 Ma. A detailed survey of the inherited component was beyond the scope of this investigation. However, we note that the inherited component is highly variable and is partly similar to ages which were previously reported from the Alps (GEBAUER, 1993 and references therein).

Discussion and conclusions

Our new $^{207}Pb/^{206}Pb$ single zircon evaporation ages constrain two episodes of acidic magmatism in the Late Ordovician hinterland of sedimentary sequences of the Carnic Alps: (1) an age group with a pooled $^{207}Pb/^{206}Pb$ age of 650 ± 24 Ma and (2) a second age group ranging between 518 ± 76 and 533 ± 106 Ma. The older age of magmatic suites in the hinterland was not identified until now. The younger age group may correspond to acidic rocks exposed in the Silvretta (Austroalpine unit; Fig. 1), where MÜLLER et al. (1995) reported conventional U–Pb and $^{207}Pb/^{206}Pb$ evaporation zircon ages ranging from 568 ± 6 to 526 ± 7 Ma from the so-called "older orthogneisses" comprising calcalkaline (older) to alkaline (younger) suites. In the Gleinalpe, HAISS (1991) reported a U–Pb zircon age older than 500 Ma from acidic orthogneisses too, from which FRANK et al. (1976) found a Rb–Sr whole rock age of 518 ± 44 Ma. Furthermore, NEUBAUER and FRISCH (1993) reported two U–Pb zircon upper intercept ages (500 Ma, 502 Ma) from orthogneiss boulders of Kalwang Conglomerate exposed in the eastern Graywacke zone which are in the same age range within analytical errors as the younger Uggwa age group. Another possible correlative acidic tuff may be present in the pre-Late Ordovician rocks of the eastern Graywacke zone, as reported by LOESCHKE et al. (1990). A correlation of the younger age group from the Uggwa section with the Blasseneck/Obstanser Porphyroids is excluded.

The older group is well-constrained by $^{40}Ar/^{39}Ar$ detrital muscovite ages of c. 640 Ma from the Himmelberg Sandstone (DALLMEYER and NEUBAUER, 1994). The muscovite ages suggest rather the presence of a metamorphic event than the formation of magmatic rocks as these muscovites are rather fine-grained. Similar muscovite ages were

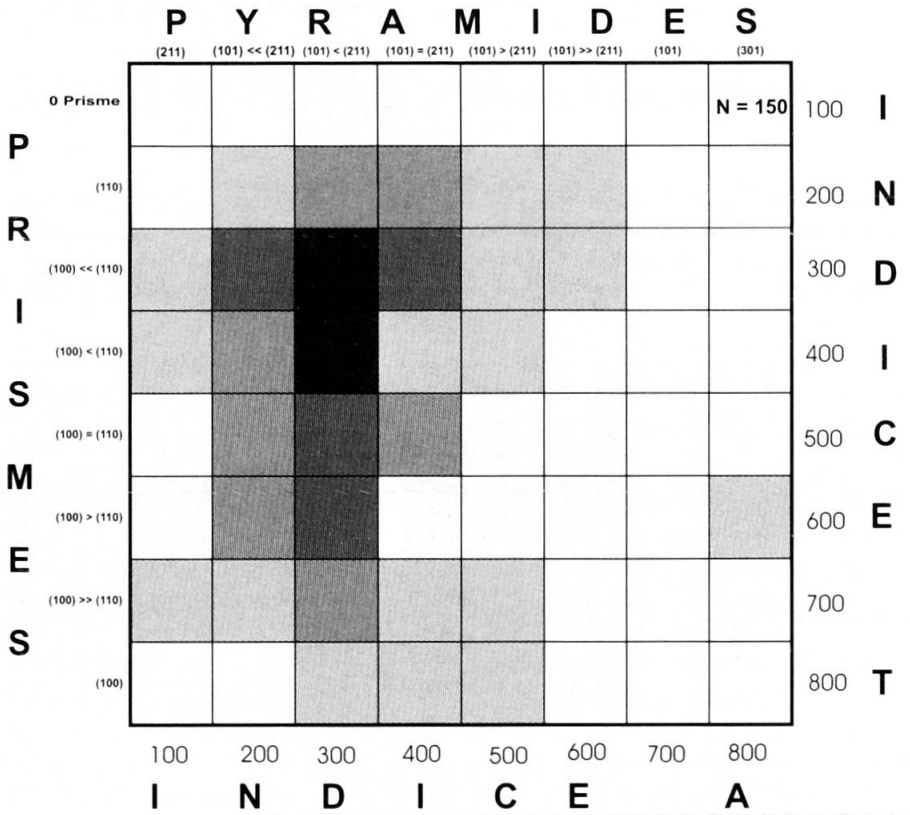

Fig. 3 Zircon typology of sample UQ5 following the approach of PUPIN (1980). The density of ornamentation indicates decreasing abundance: 10–20, 5–10, 2–5, 0.5–2 percent.

found both in the eastern Graywacke zone (HANDLER et al., 1997) and western Graywacke zone (PANWITZ et al., 2000). We conclude therefore that the hinterland was dominated by a Cadomian orogenic belt with magmatic and metamorphic rocks which most likely were formed at c. 650–640 Ma. In contrast, the younger age group may record a purely acidic magmatic period as detrital white mica of this age has never been identified until now in the Southalpine unit of the Carnic Alps or in the Austroalpine units of the Eastern Alps.

Together, the new ages constrain the close relationships of the Alpine basement with a Cadomian hinterland. Acidic magmatic rocks of the younger age group are obviously widespread in the Variscides and are interpreted to represent a major phase of rifting along the northern margin of Gondwana (VON RAUMER and STAMPFLI, 2000), although the paleogeographic relationships of the Alpine basement units to Gondwana and Baltica are still under discussion (e.g., GEBAUER, 1993; THÖNI, 1999; SCHÖNLAUB and HISTON, 2000).

The erratic inherited ages of 2.1 and 2.0 Ga, 1439 and 876 Ma suggest a major variability in the composition of the continental crust in which this magmatism occurred. Because of method-inherent problems these ages must be considered as apparent minimum ages which could be meaningless. If any, these ages may display both Baltic and Gondwanan crustal affinities (for comparison, see data compiled in GEBAUER, 1993).

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