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U–Pb ages of magmatic rocks of the western Austroalpine Dent-Blanche-Sesia Unit*

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Abstract

Conventional U–Pb ages on zircon and monazite demonstrate that granites and gabbros intruded during a short time span of 5 Ma between 293 and 288 Ma in several polycyclic basement units of the Western Austroalpine domain. This bimodal activity reflects increasing underplating of an upwelling mantle at the base of a thinning post-Variscan continental crust.

Keywords: U–Pb ages, zircon, granite, magmatism, Sesia zone, Austroalpine.

Introduction

The Dent-Blanche / Sesia tectonic units belong to the western Austroalpine domain of the Alpine belt. They recorded a widespread acid-basic bimodal magmatism of Late Carboniferous-Lower Permian age, ascribed to the incipient stages of the Triassic continental rifting (DAL PIAZ, 1993). These units experienced a severe polyphased metamorphic overprint during the Alpine orogeny, which disturbed most isotopic systems, except the U–Pb one in refractory minerals such as zircon and monazite. In situ U–Pb age determinations on zircons using an ion probe (SHRIMP) have been recently performed (RUBATTO and GEBAUER, 1997; RUBATTO et al., 1997) with the main purpose to selectively date thin zircon overgrowths related to post-magmatic metamorphic events. Conversely, the present paper focuses on primary zircon and monazite crystallization ages obtained on abraded grains by the conventional U–Pb isotope dilution method. This approach obviously prevents any metamorphic age determination but does not preclude inheritance in rocks of anatectic origin. If suitable crystals are selected, intrusion ages of highest precision are obtained.

Geological outline

The Austroalpine system represents the uppermost element of the Europe-vergent Alpine nappe pile. It comprises several polycyclic basement units of pre-Alpine and/or Alpine age, and minor monometamorphic Permo-Mesozoic cover units. The Austroalpine system can be subdivided into an eastern and a western sector, the latter being present in the Aosta valley (Italy) and southwestern Valais (Switzerland). Many subdivisions have been proposed in the literature for the *western Austroalpine system* (see VENTURINI et al., 1994; VENTURINI, 1995, and references therein); it basically comprises the Sesia (or Sesia-Lanzo) zone and the Dent-Blanche system.

The Sesia zone is located between the Mesozoic metasediments of the Piemont trough and the southern Alpine Ivrea-Verbano zone, from which it is separated by the Insubric line. It consists of polycyclic metamorphic rocks derived from pre-Alpine lithologies (mainly high grade

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paragneisses, granulites and amphibolites) into which intruded km-size bodies of Upper Carboniferous calc-alkaline quartz-diorites to granites. The Alpine orogeny reworked these protoliths according to different P-T-t paths. In the southwestern part of the Sesia zone, eclogites and blueschist facies rocks occur, whereas in the northwestern part, the so-called "Gneiss Minuti unit" shows an intense overprint by a subsequent greenschist metamorphism and deformation.

The *Dent-Blanche system* is composed of the Dent-Blanche nappe s.s. with lower and upper tectonic elements (Arolla and Valpelline series, respectively) and of several klippen, including the Mont Emilius unit. The Arolla series consists of the same lithologic units as the polycyclic basement rocks of Sesia, with similar calc-alkaline granitic intrusions, as well as large bodies of continental gabbroic rocks in mylonitic contact with their host rocks (Matterhorn and Mont-Collon/Dent-de-Bertol, DAL PIAZ et al., 1977). The Alpine metamorphic overprint is of greenschist grade north of the Aosta valley and eclogitic south of this valley (including the Mont Emilius klippe).

Analytical procedure

Zircon and monazite were separated using conventional heavy liquid and magnetic separation techniques. Chemistry and measurements were made following the standard procedure developed at the Royal Ontario Museum (KROGH, 1973) and detailed e.g. in BUSSY and CADOPPI (1996). Air-abrasion was applied systematically to eliminate surface-correlated lead loss and younger overgrowths (KROGH, 1982). When present, initial common Pb was subtracted using the isotope ratios of STACEY and KRAMERS (1975) at the calculated $^{207}Pb/^{206}Pb$ age. Regression lines were computed using the ISOPLOT program of LUDWIG (1988). Errors were calculated using the unpublished ROMAGE program of Davis (Royal Ontario Museum); they are quoted at the 95% confidence level.

The Monte Mucrone metagranite

The Monte Mucrone metagranite is a granodiorite emplaced within the polycyclic basement of the Sesia zone (OBERHÄNSLI et al., 1985). It has S-type characteristics such as primary muscovite, high A/CNK (1.6) and high initial Sr isotopic ratios (0.7135), low ε_{Nd} values (–4.8) (PAQUETTE et al., 1989) and many inherited zircon cores (Fig. 1a). It experienced a pervasive Alpine eclogitization (1.4 GPa, 600 °C) of still debated age. Early work yielded Rb–Sr mica dates of 85 ± 1, 72 ± 2 and 66 ± 1 Ma and K–Ar phengite ages of 71 ± 3 Ma (OBERHÄNSLI et al., 1985). $^{40}Ar–^{39}Ar$ plateau ages between 75 and 65 Ma (mostly around 65 Ma) were obtained on phengites from various high-pressure rocks of the polycyclic basement by VENTURINI (1995). In situ $^{40}Ar–^{39}Ar$ laser probe studies yielded plateau ages between 65.9 ± 0.4 and 109.5 ± 0.4 Ma (RUFFET et al., 1997) and revealed complex isotope systematics with excess argon, which led REDDY et al. (1996) to question the significance of ages older than 60 Ma. On the other hand, U–Pb ages of ca. 65 Ma on zircon (RUBATTO et al., 1997) and 66 Ma on sphene (RAMSBOTHAM et al., 1994), as well as a Lu–Hf garnet age of 69.2 ± 2.7 Ma (DUCHÊNE et al., 1997) consistently point to an Uppermost Cretaceous eclogitic event in the Sesia zone. The mineral paragenesis of the Monte Mucrone metagranite is quartz, omphacite, phengite, rutile, epidote ± garnet, glaucophane and albite. This rock (samples KAW987 and 989; for localization, description and chemical composition, see OBERHÄNSLI et al., 1985) yielded euhedral, sharp faceted, colorless zircons with minor resorption features. Most analyzed crystals (KAW989, [1]–[4], Tab. 1) show an inherited component, but an 8-prism fraction ([5], Tab. 1) is perfectly concordant at 293 Ma. This age is confirmed by three concordant monazite fractions from a nearby sample (KAW987, [6]–[8], Tab. 1, Fig. 1b), which overlap within errors at a mean $^{207}Pb/^{235}U$ age of 291 Ma. The proposed age of 293 +1/–2 Ma relies primarily on the zircon data. It is slightly older than the lower intercept zircon age of 286 ± 2 Ma proposed by PAQUETTE et al. (1989).

The Mont Emilius orthogneiss

The Mont Emilius klippe consists of polycyclic basement units (kinzigites, granulites), reworked by the Alpine eclogitic metamorphism. Massive acidic gneisses have been recognized by several authors and interpreted as strongly transformed Late Paleozoic granitoids. The latter consist of quartz, albite, phengite, omphacite ± garnet, zoisite, sphene and rutile. Zircons were extracted from two samples, KAW3101 being more intensely deformed than KAW3100. Both samples yielded strongly resorbed zircons with rough and pitted surfaces. Most of them retained a slight lead loss after the abrasion procedure ([9]–[16], Tab. 1) and many contained between 5 and 60 pg of initial common lead, which is very unusual for inclusion-free zircons and might be related to the high-pressure metamorphic overprint. Both samples yield-

Tab. 1 U–Pb isotopic results.

#	Mass	Concentrations			Atomic ratios				Apparent ages (Ma)		
		U	Pb*	$^{208}Pb^{*}$	206/204	206/238	207/235	207/206	6/38	7/35	7/6
	mg	ppm		a	b	c	c	c			
Mte Mucrone metagranite – KAW989 – zircons											
[1]	0.005	467	23	8	3354	0.05028 ± 23	0.4003 ± 22	0.05774 ± 11	316.3	341.9	519.8
[2]	0.003	510	25	11	2650	0.04826 ± 22	0.3954 ± 22	0.05943 ± 12	303.8	338.3	582.7
[3]	0.014	308	16	8	2859	0.05319 ± 25	0.3946 ± 22	0.05381 ± 10	303.8	338.3	582.7
[4]	0.013	355	20	9	10949	0.05634 ± 26	0.4654 ± 25	0.05994 ± 9	353.4	388.2	601.3
[5]	0.007	402	19	10	5794	0.04650 ± 22	0.3345 ± 18	0.05218 ± 10	293.0	293.0	293.4
Mte Mucrone metagranite – KAW987 – monazites											
[6]	0.003	1422	675	91	2005	0.04590 ± 24	0.3298 ± 20	0.05212 ± 12	289.3	289.4	290.7
[7]	0.009	1177	509	90	6155	0.04626 ± 22	0.3315 ± 18	0.05198 ± 10	291.5	290.7	284.5
[8]	0.002	1207	403	87	2560	0.04638 ± 28	0.3336 ± 24	0.05217 ± 20	292.2	292.3	292.8
Mt Emilius orthogneiss – KAW3100 – zircons											
[9]	0.013	749	34	9	3887	0.04522 ± 24	0.3250 ± 20	0.05213 ± 10	285.1	285.7	291.0
[10]	0.005	843	42	10	686	0.04535 ± 22	0.3266 ± 28	0.05223 ± 32	285.9	287.0	295.7
[11]	0.009	661	30	9	11809	0.04532 ± 24	0.3262 ± 20	0.05219 ± 10	285.8	286.6	293.9
[12]	0.004	499	23	8	3899	0.04602 ± 22	0.3310 ± 20	0.05217 ± 14	290.0	290.3	292.7
Mt Emilius orthogneiss – KAW3101 – zircons											
[13]	0.008	804	37	7	1104	0.04536 ± 24	0.3262 ± 22	0.05216 ± 20	286.0	286.7	292.2
[14]	0.011	514	24	10	9142	0.04593 ± 22	0.3304 ± 18	0.05217 ± 10	289.5	289.9	292.7
[15]	0.016	524	27	11	394	0.04458 ± 22	0.3211 ± 36	0.05224 ± 48	281.1	282.7	296.0
[16]	0.009	665	30	5	3218	0.04628 ± 22	0.3329 ± 20	0.05217 ± 12	291.6	291.8	293.0
Arolla orthogneiss – KAW983 – zircons											
[17]	0.004	580	27	12	6610	0.04579 ± 20	0.3287 ± 18	0.05206 ± 10	288.6	288.6	288.2
[18]	0.004	141	7	11	2722	0.04580 ± 22	0.3292 ± 22	0.05213 ± 24	288.7	288.9	291.1
Sermenza gabbro – 913az – zircons											
[19]	0.039	501	25	18	19433	0.04497 ± 24	0.3226 ± 18	0.05202 ± 8	283.6	283.9	286.5
[20]	0.029	672	33	17	27969	0.04503 ± 24	0.3232 ± 18	0.05205 ± 8	283.9	284.4	287.8
[21]	0.042	261	13	17	8157	0.04509 ± 24	0.3236 ± 18	0.05204 ± 10	284.3	284.6	287.3

*: radiogenic; **a**: in mole-% relative to total radiogenic Pb; **b**: corrected for spike Pb and for fractionation; **c**: corrected for fractionation, spike, U and Pb blanks, and initial common Pb, error estimates (95% confidence level) refer to the last significant digits of the isotopic ratios and reflect reproducibility of standards, measurement errors and uncertainties in the common Pb correction.

ed collinear data points (Fig. 1 c+d) with at least one concordant fraction in each case ([12] and [16], respectively). No inheritance has been observed. Discordia lines have been drawn and forced through 30 ± 30 Ma to take into account the polyphased (eclogitic + greenschists facies) Alpine metamorphic disturbances. Upper intercept ages are identical as expected for duplicate samples. 293 ± 3 Ma is interpreted as the intrusion age of the granite.

The Arolla orthogneisses

The Arolla series is the lower tectonic element of the Dent-Blanche system, and is thought to be tectonically related to the Mont Emilius klippe. This polycyclic basement has been affected by Alpine greenschist facies reequilibration. It mainly consists of several stocks of granitoids intruded into paraschists and gneisses. A greenish orthogneiss has been sampled south of the Matterhorn (Swiss coordinates: 616900/89250/2600); it consists of quartz, plagioclase, phengite, hornblende with brown cores, and minor amounts of chlorite, calcite and epidote (HUNZIKER, 1974). This sample yielded small euhedral, pink zircons with some resorption features. Two multigrain fractions (8 short prisms [17] and 4 needles [18], Tab. 1) yielded the same concordant age of 289 ± 2 Ma (Fig. 1e), interpreted as the intrusion age of the metagranite.

The Sermenza gabbro

The Sermenza gabbroic and dioritic masses belong to the internal unit of the polycyclic basement complex of the Sesia zone (VENTURINI, 1995; VENTURINI et al., 1996). The main rock type is a layered cumulitic high-Mg, low-Ti gabbro, consisting of plagioclase, hornblende, clinopyroxene, magnetite ± zoisite, white mica, chlorite. Magmatic textures are preserved. Geochemical characteristics (VENTURINI et al., 1996) are very similar to those of other Mg-rich metagabbros of the

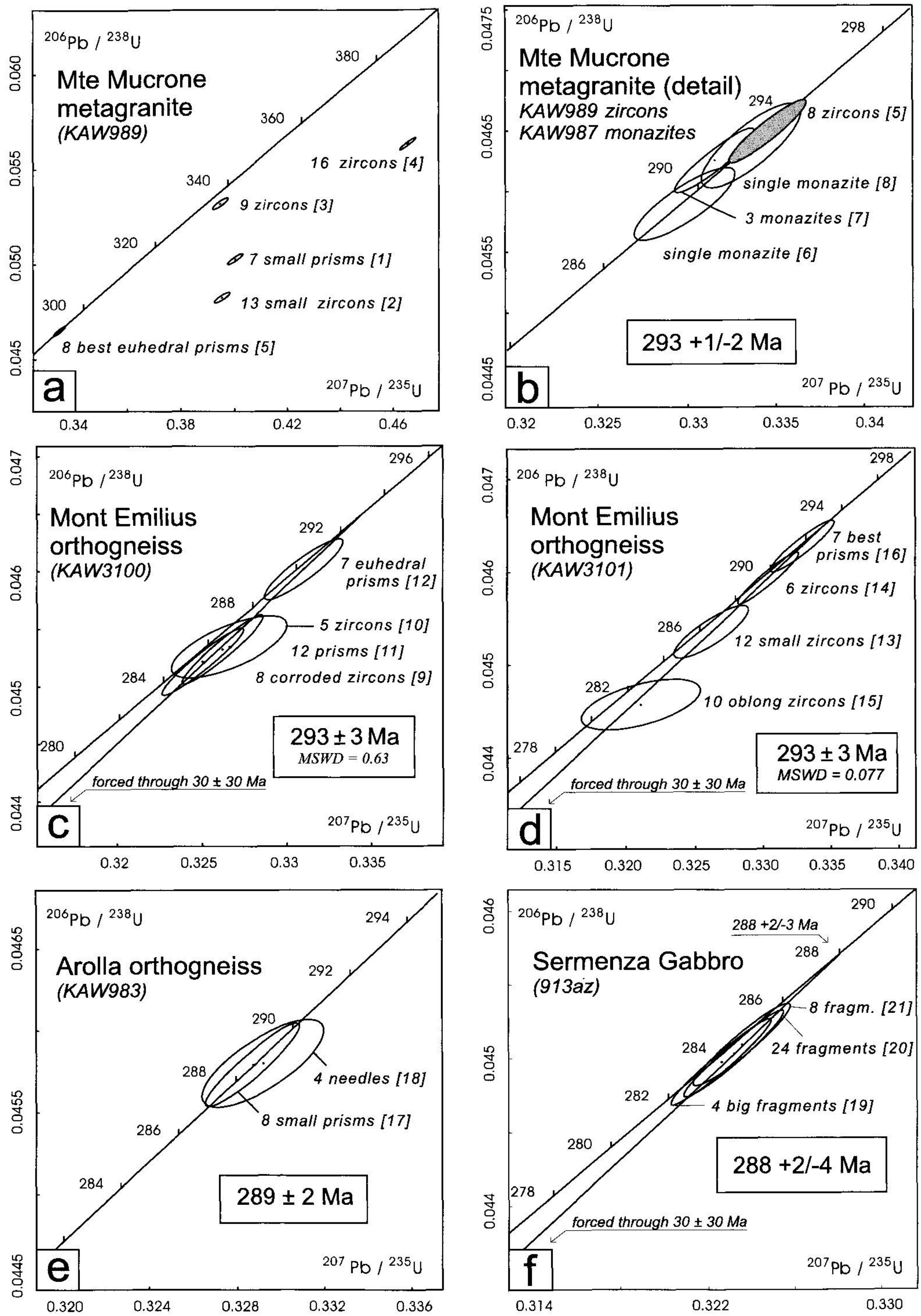

Fig. 1 U–Pb Concordia diagram. Error ellipses are given at the 95% confidence level, numbers in [ ] refer to the mineral fractions listed in table 1. Preferred ages are framed and discussed in the text.

Dent-Blanche/Sesia unit, in particular the Matterhorn and Collon stocks (DAL PIAZ et al., 1977). A hornblende-layer mylonitic metagabbro sample (913az, for sample location, description and chemical composition, see VENTURINI et al., 1996) yielded large pink zircon fragments from which three multigrain fractions were selected ([19]–[21], Tab. 1). All Data points plot close to 284 Ma (Fig. 1e). This is a somewhat ambiguous case, where the slight discordancy (1.0 to 1.4%) could be ascribed either to a small and systematic analytical bias, or to a small lead loss of all fractions, which would imply a slightly older crystallization age for the system. In the former case, 284 Ma could be the true age, whereas in the latter, a discordia line forced through 30 ± 30 Ma would yield an upper intercept at 288 +2/–3 Ma (MSWD = 0.233). Consequently, an age of 288 +2/–4 Ma is proposed for the intrusion of the Sermenza mafic stock, which is younger than the nearby Bonze metagabbros dated at 351 Ma (RUBATTO and GEBAUER, 1997), but contemporaneous to the Val Mastallone gabbroic mass from the neighbouring Ivrea zone (285 Ma, Pin, 1986).

Conclusion

As expected from previous geochronological work on highly metamorphic rocks, zircon and monazite survived the high pressure Alpine metamorphism without significant isotopic resetting; well abraded grains yield concordant primary ages. There is a widespread magmatic activity within a short time span (5 Ma) at the end of the Carboniferous in the western Austroalpine Sesia-Dent-Blanche system. Granites from different units have identical ages, which is in agreement with the proposed large-scale tectonic correlations within the Austroalpine domain. A voluminous basic magmatism is associated in space and time to the granites, a feature typical of the late- and post-Variscan transtensional/extensional tectonic regime in western Europe (BONIN et al., 1998). This association of layered gabbros on the one hand and granites of contrasting (crustal and mantellic) origin on the other hand, reflects the increasing underplating effect of an upwelling mantle at the base of a thinning and stretching post-orogenic crust, which finally disrupted at time of opening of the Neotethys. The observed time range is in keeping with the overall tendency for younger granite ages from the outer towards the internal (southern) parts of the Variscan orogen (BUSSY and CADOPPI, 1996).

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