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Autor: Schaltegger, Urs / Gebauer, Dieter

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Pre-Alpine geochronology of the Central, Western and Southern Alps

by *Urs Schaltegger*[1] and *Dieter Gebauer*[1]

Abstract

Geochronology plays a crucial role in unravelling the complex and polyphase evolutionary history of the Alpine basement. In this review, mostly recent data will be used to set up an "orogenic timetable" for the pre-Alpine evolution, starting with Archean information hidden in zircon cores and finishing with widespread metasomatic alterations of Triassic/Liassic age, detected best in the Southalpine domain. The evolution of the Alpine basement confined by these age limits comprises post-Panafrican clastic sedimentation on the Gondwana shelf, the Cambrian – Early Ordovician oceanic period, Devonian mafic and felsic magmatism, orogenic cycles in the Ordovician and Permo-Carboniferous and voluminous magmatism at different moments during this evolution.

Keywords: Alpine basement, geochronology, U–Pb, Sm–Nd, K–Ar, Ar–Ar, Re–Os, Rb–Sr.

Introduction

Over three decades of isotopic dating in the Alpine basement have repeatedly shown pieces of evidence that this basement is polyphase and consists of recycled components as old as 3.43 Ga (GEBAUER, 1993)! The aim of reconstructing such a complex evolution seems too difficult to reach, especially in the high-grade metamorphic terrains of the Central Alps where many ages are partly or completely obliterated. Various new technologies offer, however, new means with highest temporal resolution that allow to decipher multistage evolutions to a high degree of precision even in the areas of strongest Alpine overprint. The pre-Alpine evolution has mainly been recorded by the U–Pb zircon and Sm–Nd whole-rock and mineral systems, which can be exploited by means of microanalytical approaches such as single grain or insitu spot dating.

This review of pre-Alpine isotopic ages will sum up the present day knowledge of the geochronology of mainly crystalline parts of the Central Alps and presents a kind of geodynamic time-table for its evolutionary history. We will concentrate on key areas within the Central, Western and Southern Alps. For a more comprehensive overview on the Pre-Alpine evolution of different tectonic units of the Central Alps, we also refer to review articles of GEBAUER (1993) and SCHALTEGGER (1994).

Proterozoic and Archean inheritance

DETRITAL ZIRCONS IN METASEDIMENTS

The oldest age record comes from detrital zircons and zircon cores from metasedimentary gneisses. Age determinations of different units revealed the existence of ancient components of 3.43, 2.8–2.6, 2.3–2.1, 1.0, 0.65–0.57 Ga age (BÖHM, 1996; GEBAUER, 1992, 1993; GEBAUER and QUADT, 1991; SCHALTEGGER, 1993). In most metasedimentary rocks the inheritance turned out to be of polyphase character. Conventional upper intercept ages are therefore considered as mixtures of different components, even in the case of abraded single crystal analyses. The distribution of ages suggests that the provenance of the detritus was one or more ancient craton(s) with Gondwana affinity. Some detrital zircons occasionally yielded Grenville ages around 1 Ga (GEBAUER, 1992; BÖHM, 1996). Presence or absence of a 1.0 Ga oro-

[1] Department of Earth Sciences, Swiss Federal Institute of Technology, ETH-Zentrum, CH-8092 Zürich, Switzerland. <schaltegger@erdw.ethz.ch> <gebauer@erdw.ethz.ch>

genic phase is a determining factor for speculations about the provenance. The existence of 1 Ga-old detrital zircons thus suggests that the Brasilian and/or the Guyana shield may be the provenance area for metasediments of the Alpine basement rather than the West African Craton. The 0.6 to 0.65 Ga age is found in upper intercepts of many granitoid rocks of Ordovician to Tertiary age, suggesting that most of the source rocks show a predominant imprint of the Pan-African orogeny. The youngest detrital zircon components in metasediments of the Gotthard (GEBAUER et al., 1988) and Aar massifs (SCHALTEGGER, 1993), or the Southern Alps (GRÜNENFELDER et al., 1984) are of Pan-African age, similar to metasediments of the European Variscides outside the Alps. They thus indicate post Pan-African deposition of the sedimentary protoliths. A recent river sand of the Po-delta, which samples large proportions of the Western-, Central- and Eastern Alps contains, as expected, only ca. 4% Alpine, i.e. almost exclusively Oligocene zircons (GEBAUER, 1992). Detrital zircons from a Miocene marine molasse sandstone, on the other hand, are mostly of Alpine age, the pre-Alpine grains being predominantly of Hercynian age, followed by Caledonian and Panafrican ages. Only few older grains at ca. 1.0 Ga, 2.1–2.3 Ga and 2.7 Ga were detected (GEBAUER, 1992).

Nd, Hf MODEL AGES

Another piece of information about provenance is offered by Nd and Hf model ages on a variety of mafic to acid rocks. Model ages of granites from the Alpine basement scatter around a mean value of 1.5–1.6 Ga. Only the Austroalpine Silvretta nappe seems to comprise older components in higher proportions, indicated by model ages ranging between 1.9 and 1.7 Ga (POLLER et al., 1997a; BIINO et al., 1994). Hf model ages of 1 Ga from highly evolved granites of the Aar massif (SCHALTEGGER and CORFU, 1992) may be caused by addition of juvenile partial melts in late Variscan magmatic activity (ca. 300 Ma). Addition of subcontinental mantle-derived magmas to ca. 1.7 Ga-old crust was postulated to produce model ages at around 0.9 to 1.3 Ga (STILLE and STEIGER, 1991). It is important to note that these model ages reflect mean ages of mantle differentiation ("mean crustal residence ages") and only accidentally date a geological event.

MANTLE EVENTS

Mafic to ultramafic rocks often display Nd and Hf model ages of 0.9–1.0 Ga, interpreted as a memory of a mantle event, which can be either partial melting and/or metasomatism in the subcontinental lithosphere (STILLE and SCHALTEGGER, 1993). Beside Nd model ages, discrete mantle events may be recorded by zircons of mafic and ultramafic rocks that were formed during partial melting of mantle material and survived the subsequent high-T evolution within the mantle. Ages of 3.17, 2.67, 2.45, 1.72 and 1.27 Ga were reported from the Alpe Arami peridotite of the Cima-Lunga nappe (GEBAUER et al., 1992a) and an eclogite from the Gotthard massif (GEBAUER et al., 1988).

Sm–Nd whole-rock reference lines from MOR-type amphibolites, banded amphibolites and ultramafic rocks of the Penninic domain (SCHENK-WENGER and STILLE, 1990; STILLE and TATSUMOTO, 1985) have been interpreted to date their emplacement 1.0 Ga ago. This interpretation is challenged by U–Pb age determinations on zircons of the Cima di Gagnone eclogites (GEBAUER, 1994), which yielded a much younger age of 528 ± 6 Ma, interpreted as emplacement as well.

Late Precambrian mafic to ultramafic igneous rocks

The polyphase Alpine metamorphic basement hosts large volumes of mafic rocks, today occurring as amphibolites of mid-ocean ridge to island-arc composition. They are part of ancient continental margin or wedge sequences including metasediments of all kind plus obducted remnants of oceanic crust (Gotthard: BIINO, 1995; Silvretta: BIINO et al., 1994). Direct dating of the emplacement of these rocks is precluded by their lack of primary zircon, with a few exceptions: GEBAUER et al. (1988) reported a SHRIMP U–Pb age of 870 Ma from eclogite zircons of the Gotthard massif and interpreted it as dating the intrusion of the protolith. A diorite of the Silvretta nappe with an age of 609 ± 3 Ma (SCHALTEGGER et al., 1997) post-dates the formation of the volcano-sedimentary sequences in which it intruded.

Precambrian-Early Cambrian sedimentation

The metasedimentary sequence of the Southern Alps, the Austroalpine nappes and the External Massifs contain a mixed association of clastic sediments and meta-carbonates, interlayered with amphibolites of igneous and sedimentary origin. Their sedimentation age is constrained by the youngest detrital zircons, which have been dated between 0.62 and 0.55 Ga (SCHALTEGGER, 1993; BÖHM, 1996; GEBAUER and VON QUADT, 1991; GRÜNENFELDER et al., 1984). These sedimentary basins have been interpreted as continental margin deposits during the break-up of the Gondwana continental margin ca. 0.6 Ga ago into several microcontinents or continental fragments, which have been re-assembled during the Variscan collision. The resulting sediment series became part of the accretionary wedge in the Ordovician orogenic cycle in the Alpine realm, during which they were overprinted in eclogite and/or granulite facies (see below).

Cambrian magmatism

The Cambrian time period is characterized by the existence of several ocean basins that developed between different microcontinents, Gondwana and Laurasia. Remnants of oceanic sequences can be found spread over the whole Alpine range. Metagabbros and metabasalts display very different geochemical characteristics, which allow the interpretation that constrasting types of oceanic and active margin settings must have been preserved in the Penninic area (Cima di Gagnone, 528 ± 6 Ma, GEBAUER, 1994; Biasca, 521 ± 8 Ma, GEBAUER, 1994) and in the Silvretta nappe (Older Orthogneisses, 525 ± 5 Ma; SCHALTEGGER et al., 1997, MÜLLER et al., 1995). An ophiolitic sequence is known from the western Alps (Chamrousse, 496 ± 6 Ma; MÉNOT et al., 1988). Coeval granitoid rocks are interpreted as plagiogranites (Silvretta nappe, 532 ± 30 Ma; MÜLLER et al., 1996) or alkali granites, e.g. the 500 +3/–4 Ma old Thyon metagranite (Siviez-Mischabel; BUSSY et al., 1996). A granitoid pluton intruded into dacites of the Southern Vanoise (western Alps) yielded an age of 507 ± 9 Ma (GUILLOT et al., 1991). The anatectic Mönchalp granite in the Silvretta nappe yielded conflicting data between 527 and 460 Ma, indicating a complex evolution in a polyphase continental basement (POLLER, 1997; POLLER et al., 1997b).

Ordovician magmatism and metamorphism

A complete orogenic cycle of Ordovician age has been discovered and dated by means of U–Pb on zircon in the Helvetic, Penninic, Austroalpine and Southern Alpine domains. Metagabbros from the Silvretta nappe were dated at 467 ± 14 Ma (POLLER, 1997), from the Gotthard massif at 467 +5/–4 Ma, from the Tavetsch unit at 471 +6/–7 Ma (both in OBERLI et al., 1994), and from the Aar massif at 479 ± 5 Ma (ABRECHT et al., 1995). These ages were interpreted as intrusion ages; since the rocks were overprinted by HP-metamorphism subsequent to intrusion, the ages might be slightly biased towards younger lead loss at ca. 468 Ma (GEBAUER, 1990; GEBAUER and VON QUADT, 1991). This is also indicated by a Sm–Nd garnet age of 461 ± 25 Ma (GEBAUER et al., 1988). The Oberstaffelgneis in the Gotthard massif has an age of 478 +8/–4 Ma and is thus coeval with the gabbros (SERGEEV and STEIGER, 1995). The same age 479 ± 6 Ma has been reported from the Briançonnais domain (Vanoise; BERTRAND and LETERRIER, 1997). The "Younger Orthogneisses" of the Austroalpine Silvretta nappe present the largest magmatic area of Ordovician age. They include mainly granitoid rocks (Flüela granite association) and intruded within a time range of 460 to 420 Ma (POLLER et al., 1997 a, b).

A metamorphic evolution of Ordovician age has been reported from the Aar massif, including U–Pb age data from zircons in metapsammites at 450 ± 5 Ma and a subsequent anatectic stage represented by migmatites, dated at 456 ± 2 and ca. 445 Ma (SCHALTEGGER, 1993). The anatectic Streifen gneiss (Gotthard massif) fits into the same scenario, with an age of 445 +4/–5 Ma (SERGEEV and STEIGER, 1995), as well as augengneisses from the Mont Blanc massif at 453 ± 3 Ma (BUSSY and VON RAUMER, 1993). In the South Alpine Strona Ceneri Zone acid Ordovician magmatism (BORIANI et al., 1981) with ages between ca 450 Ma and 480 Ma (KÖPPEL and GRÜNENFELDER, 1971; HUNZIKER and ZINGG, 1980) is a common phenomenon; the existence of a metamorphic overprint of Ordovician age is, however, quite controversely debated (e.g. recently by BORIANI and VILLA, 1997; ZURBRIGGEN et al., 1997; ROMER and FRANZ, 1998).

Devonian – Lower Carboniferous magmatism

Devonian oceanic basalts and gabbros have been found in different portions of the Variscan orogen, e.g. in monometamorphic series of the western External Massifs (MÉNOT et al., 1987). Nothing equivalent is known from the Central Alps. Alpine HP metagabbros and one eclogite from the Western Alpine Sesia-Lanzo Zone yielded U–Pb zircon ages around 355 Ma for the intrusion of the MORB-type protoliths (RUBATTO and GEBAUER, 1997). Calcalkaline volcanism at 355 ± 6 Ma has also been inferred from granulite-facies metagranitoids of the Ivrea Zone (VAVRA et al., 1996). This implies that at least parts of the Ivrea Zone were in a supracrustal position around the Devonian-Carboniferous boundary.

Variscan metamorphism

The age of the Variscan metamorphic overprint in the Alpine basement is not known at a high level of confidence. The degree of Variscan metamorphism seems to be variable among central Alpine basement units: Aar and Gotthard massifs only record lower to middle amphibolite facies parageneses, whereas in the other areas upper amphibolite-facies conditions leading to anatexis were reached. High-temperature metamorphism was dated at 330 ± 2 Ma (BUSSY et al., 1996) in metasedimentary sequences of the middle Penninic area. Migmatites from the Aiguilles Rouges and Mont Blanc massifs show ages at 317 ± 2 and 321 Ma (BUSSY and VON RAUMER, 1993; BUSSY and HERNANDEZ, 1997). In the lower-grade Aar and Gotthard massifs, zircons do not define Variscan but Ordovician U–Pb ages in many cases. Exceptions are zircons in retrograded Ordovician eclogites, which formed 330 ± 3 Ma ago by decomposition of mainly omphacite; this age agrees with a rutile U–Pb age of 329 ± 2 Ma from the same area (Susten; both ages in SCHALTEGGER, 1993). Variscan metamorphism seems to be coeval to or even younger than the magmatism; this fact might be indicative for an elevated heat flow due to the thermal impact of large masses of granitoid melts intruding into the crust, creating a regional contact-metamorphic overprint.

The Variscan metamorphic event in the Silvretta nappe seems to be slightly younger, indicated by U–Pb ages around 306 ± 2 Ma on staurolites (FREI et al., 1995), identical to retrograde zircon crystallization in a former eclogite in the same area at 301 ± 3 Ma (LIEBETRAU et al., 1996). BORIANI and VILLA (1997) deduced an age of ca. 340 Ma from complex Ar–Ar mineral patterns for Variscan amphibolite-facies metamorphism in the Southalpine Strona-Ceneri Zone.

Variscan to Permian late-orogenic magmatism

Variscan magmatism of the Central Alps is described in detail in the review articles of BONIN et al. (1993) and SCHALTEGGER (1994). Therefore, mainly recently published data will be treated in the next paragraph. The late Variscan magmatic activity can be separated into several distinct episodes:

Visean magmatism: High-K diorites, syenites and granites occurring in the Aar massif (Tödi, Giuv-Punteglias) were dated at 334 ± 2 Ma (SCHALTEGGER and CORFU, 1992, 1995). A recent age determination of the Pormenaz monzonite in the Aiguilles-Rouges massif yielded an identical age of 333 ± 2 Ma (BUSSY et al., 1998). A calc-alkaline granitoid suite in the Bernina nappe intruded between 338 and 330 Ma (VON QUADT et al., 1994).

Westphalian-Stephanian magmatism: Calc-alkaline granitoids and diorites of the Aar massif intruded between 310 ± 3 and 308 ± 2 Ma (SCHALTEGGER and CORFU, 1992). Different gabbroic to granitoid rocks from the Aiguilles-Rouges (Vallorcine and Montenvers granites; gabbroic, dioritic and granitoid portions of the Fully intrusive complex), as well as a rhyolite at the contact of the Mont Blanc granite are precisely dated at an age of 307 ± 1 Ma (BUSSY and HERNANDEZ, 1997); the Mont Blanc granite itself is dated at 304 ± 3 Ma (BUSSY and VON RAUMER, 1993). The volcano-sedimentary basin of Salvan-Dorénaz was deposited within an time frame from 307 to 297 Ma (CAPUZZO and BUSSY, 1998). The subalkaline Central Aar granite and Gamsboden and Fibbia gneisses from the Gotthard massifs have intrusion ages of 298–300 (SCHALTEGGER and CORFU, 1992; SERGEEV et al., 1995), a slightly younger pulse at ca. 295 Ma is found in the Gotthard massif only (SERGEEV et al., 1995). The orthogneisses containing the UHP-peridotites at Alpe Arami (Cima Lunga-Adula nappe) are also derived from 296 Ma old granites (GEBAUER, 1996). A similar age range (288 ± 7 to 295 ± 12 Ma) is given by VON QUADT et al. (1994) for granites of the Austroalpine Bernina nappe.

Generation and emplacement of these granitoid melts are suggested to be short-term pulses that are controlled by basin-and-range-type extensional tectonic processes, thermal relaxation and erosion of the lithospheric mantle, uplift and decompressional melting (SCHALTEGGER, 1997).

Permian to Triassic magmatism: Granitoid rocks in upper crustal Penninic units ranging from calc-alkaline to alkaline compositions have intrusion ages scattering between ca 270 and 280 Ma: Truzzo and Roffna granitoids in the Tambo and Suretta nappes (268 ± 2 Ma; MARQUER et al., 1998), Grand-Laget and Randa (Siviez-Mischabel; 269–275 Ma; BUSSY et al., 1996) and Dora Maira granitoids (300–265 Ma; BUSSY and CADOPPI, 1996; GEBAUER et al., 1997). This age range overlaps with gabbro intrusions at the base of the crust: e.g. the Fedoz/Braccia gabbro at 270 +6/–4 Ma (HERMANN et al., 1997).

Similar lower crustal intrusions are typical for the Ivrea Zone and Southern Alpine basement: The Main Gabbro-Diorite Body yielded ages around 280 Ma for both Main Gabbro (GEBAUER, 1993) and Diorite bodies (PIN and SILLS, 1986). The zircon data from further mafic rocks of the Ivrea Zone (GEBAUER et al., 1992b; GEBAUER, 1993) have not substantiated interpretations of Sm–Nd whole rock data (PIN and SILLS, 1986; VOSHAGE et al., 1987; LU et al., 1997) that part of the Mafic Formation in the Ivrea Zone is of Early Paleozoic age. Many felsic to intermediate magmatic rocks of the Southern Alpine domain outside the Ivrea Zone yielded ages in a wide range between 262 Ma and 295 Ma (BARTH et al., 1994; BORIANI et al., 1981; HUNZIKER and ZINGG, 1980; KÖPPEL, 1974; STILLE and BULETTI, 1987). As the range of initial Sr-isotopic compositions is similar to those of the Main Gabbro-Diorite Body of the Ivrea Zone (PIN and SILLS, 1986; VOSHAGE et al., 1987), a genetic relation between these rocks is possible. However, a derivation of the felsic magmatic rocks by degranitization of metasediments of the Ivrea Zone can be excluded with the same arguments from Sr isotope geochemistry.

In the Austroalpine-derived Sesia-Lanzo Zone predominantly bimodal magmatism is of Permo-Carboniferous age. This applies for a number of the granitic and gabbroic protoliths of Alpine HP rocks in the Monte Mucrone area and the Aosta Valley (BUSSY et al., 1998; RUBATTO and GEBAUER, 1997).

The Permian magmatism is geochemically bimodal: Mafic intrusions at the base of the crust seem to trigger acid volcanism and plutonism in the upper crust in an overall divergent, strike-slip dominated setting. The geodynamic scenario comprises large shear zones running through the Variscan orogen, reaching deep into the lithosphere and causing lithospheric extension along narrow corridors.

Triassic to Jurassic metasomatism, metamorphism and magmatism

Determination of the age of Variscan regional metamorphism in the Ivrea Zone is rendered difficult by a series of thermal and/or hydrothermal pulses probably related to multi-episodic underplating after 270 Ma. As a consequence, data for the peak of metamorphism range from ca 296 Ma to 273 Ma (HENK et al., 1997; KÖPPEL, 1974; VAVRA and SCHALTEGGER, 1999; VAVRA et al., 1996, 1997). Local thermal pulses, at least partly accompanied by fluid infiltration are documented by zircon and monazite at 261 ± 4 Ma, 226 ± 5 Ma and 210 ± 10 Ma in the Mastallone and Fiorina valleys (VAVRA et al., 1996, 1997; VAVRA and SCHALTEGGER, 1999).

A magmatic-metamorphic episode around 250 Ma has been derived from different lithologic units from the Ivrea and Strona-Ceneri zones, e.g. from muscovites of pegmatites of the Ivrea Zone (Rb–Sr; 252 ± 10 Ma; HUNZIKER, 1974) and the Lake Massif (259 ± 8 Ma; BORIANI et al., 1981), which somewhat disagree with ages for Southern Alpine pegmatites between 200 and 230 Ma (SANDERS et al., 1996). Sm–Nd mineral ages by VOSHAGE et al. (1987) gave ages between about 230 Ma and 270 Ma for granulite facies rocks of the Ivrea zone, arguing that at least locally amphibolite facies conditions prevailed during the Triassic between Val Sesia and Val Strona. Similarly, metamorphic zircon domains of a pyroxenite within the Lower Layered Group close to the Balmuccia peridotite also argue for local high-grade metamorphic conditions, in this case at 265 +4/–5 Ma (GEBAUER et al., 1992b). In the NE part of the Ivrea Zone close to Ronco, metasediments contain a boudinaged amphibolite with a preserved gabbroic core that yielded an age of 238 ± 1 Ma, interpreted as protolith age (GEBAUER, 1993). Based on this value, local deformation under amphibolite facies conditions would have to be considered contemporaneous or younger than 238 Ma.

The 250 Ma age is common value for acid volcanic rocks and tuffs interlayered in carbonates that were deposited at the Anisian/Ladinian boundary in the southern Alps (MUNDIL et al., 1996; BRACK et al., 1996).

An important thermal and hydrothermal event at around 210 Ma has repeatedly been reported by zircon and monazites from different parts of the Ivrea zone, causing the formation of metasomatic mineral assemblages. The same age is recorded by Re–Os and Rb–Sr ages from alkaline ultramafic pipes crusscutting gabbros (BIINO and MEISEL, 1996). Gabbros from around the ultramafic Finero complex were dated at between 230 and 210 Ma by Sm–Nd mineral isochrons and Pb–Pb zircon ages (LU et al., 1997); zircon from stratiform chromitite layers was dated at 207 ± 5 Ma (VON QUADT et al., 1993). The intrusion of a syenite pegmatite within the Finero peridotite yielded a Pb/Pb zircon evaporation age of 225 ± 13 Ma (STÄHLE et al., 1990). Finally, mica ages range from 230 Ma to 180 Ma (MCDOWELL and SCHMID, 1968; HUNZIKER, 1974) indicating that cooling below the individual blocking temperatures occurred at different times in different parts of the Ivrea Zone. The youngest pre-Alpine intrusions in the Ivrea zone are Middle Jurassic old gabbros

(177 Ma) of the Sesia valley (GEBAUER, 1993). The effects causing this range of apparent ages around 210 Ma are assigned to pervasive fluid flow through the crust during multi-episodic underplating of mainly mafic rocks into the lower crust and by incipient continental rifting at the onset of the opening of the Neo-Tethys ocean, coeval to voluminous sedimentation in the Rhetian of the Southern Alps.

Similar effects are also registered in middle and upper crustal levels of many areas of the Central, Western and Southern Alps. Rb–Sr whole-rock ages of 230 ± 8 Ma (SCHALTEGGER, 1990) and 185 ± 17 Ma (KNILL, 1996) were reported for granitoids from Helvetic and Penninic domains, respectively.

For the internal Dora Maira Massif of the Western Alps, SHRIMP-data indicated that numerous zircon domains were partly or completely reset in the time range 260–210 Ma (GEBAUER et al., 1997), linked to a pervasive Mg-metasomatism, which developed along former shear zones within a 275 Ma-old granite. The resulting Mg-rich rocks, Mg-chlorite-quartz-muscovite schists are comparable to the "leucophyllites" of the Eastern Alps and very probably represent the second-stage protoliths to the Alpine UHP pyrope quartzites (GEBAUER et al., 1997).

Conclusions

A wealth of new geochronological information has been acquired since our last reviews from the Alpine basement (GEBAUER, 1993) and the external massifs of the Central Alps (SCHALTEGGER, 1994). Recent data shed new light onto two very interesting and enigmatic time periods: (i) the Cambrian to Ordovician orogenic cycle, and (ii) the Triassic-Liassic metasomatic and/or thermal overprint of the Southern Alpine basement.

The presence of an Ordovician orogenic cycle going through subduction, eclogite- and subsequent granulite-facies metamorphic overprinting and finally decompressional melting of the crust between ca 480 and 440 Ma has one important implication: the pre-Alpine dominant metamorphic overprint is clearly of Ordovician age in areas, where Variscan metamorphic conditions remained in amphibolite facies. The recent debate about the age of metamorphism in the Southern Alpine basement (BORIANI and VILLA, 1997; ZURBRIGGEN et al., 1997; ROMER and FRANZ, 1998) originates from this problem. The Upper Triassic thermal and/or hydrothermal overprint of the Southern Alpine crust at ca 220 to 200 Ma has even more spectacular implications: monazite U–Pb and other mineral ages (Ar–Ar, Rb–Sr) are very likely biased by this event and only carry incomplete and disturbed information about regional metamorphism. Former ideas about metamorphic zoning, uplift histories and crustal tectonics derived mainly from the Ivrea and Strona-Ceneri zones become strongly questionable in this light and the evolutionary history may be resolved into a series of distinct thermal/hydrothermal events between 300 and ca. 180 Ma.

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