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Eo/Oligocene (35 Ma) high-pressure metamorphism in the Gornergrat Zone (Monte Rosa, Western Alps): implications for paleogeography

by *Daniela Rubatto* [1,2] and *Dieter Gebauer* [1]

Abstract

Zircons from a phengite-rich metaquartzite of the Gornergrat Zone (Monte Rosa nappe) have rims with irregular shape and weak cloudy zoning. Their apparent ages scatter from Late Permian to Eo/Oligocene. These rims are thought to have formed during a metamorphic event, which is dated by the four youngest rims that have very low Th/U ratios and yield an age of 34.9 ± 1.4 Ma. The rock paragenesis (quartz, phengite, epidote, albite and titanite) indicates equilibration at HP conditions ($P < 14$–15 kbar and $T < 500$–550 °C) and is not compatible with greenschist-facies retrogression. Based on the rock assemblage and the geological evolution of the area, this age is interpreted as dating the high-pressure/medium-temperature metamorphism in the Gornergrat Zone. The new age confirms the hypothesis of Tertiary subduction in the Western Alps. The metamorphic assemblage in the sample dated is very similar to the one found in high-pressure rocks of the Monte Rosa basement, suggesting that these two units shared the same Alpine evolution. In our view, the new data are best explained with a paleogeographic location of the Monte Rosa nappe on the European margin of the Tethys.

Keywords: Gornergrat Zone, Monte Rosa, SHRIMP, high-pressure metamorphism, zircon geochronology.

Introduction

The age of high-pressure (HP) metamorphism in the Western Alpine nappes has been a matter of debate over more than 20 years. Its understanding is crucial for geodynamic models and paleogeographic reconstructions. Several geochronological works indicating Late Cretaceous to Early Oligocene HP metamorphism in the Western and Central Alps have been produced in recent years (Fig. 1a). They comprise dating of garnet by Sm–Nd (BECKER, 1993; BOWTELL et al., 1994) and Lu–Hf (DUCHÊNE et al., 1997) as well as U–Pb dating of titanite (RAMSBOTHAM et al., 1994; INGER et al., 1997) and zircon (GEBAUER et al., 1992; GEBAUER, 1996; GEBAUER et al., 1997; RUBATTO et al., 1998; RUBATTO et al., 1999). These data contrast with the previous idea of a long-living subduction from Early Cretaceous to Tertiary (for a review see HUNZIKER et al., 1992). The new data have shown that subduction in the Alps was diachronous in the different part of the chain, following the Cretaceous paleogeographic location of the present tectonic units (RUBATTO et al., 1998). However, this new model still needs to be confirmed in some portions of the Western and Central Alps and to be followed up in the Eastern Alps.

This work contributes to the new picture of Alpine Tertiary subduction by presenting the first U–Pb age determination on zircons from the Monte Rosa (MR) nappe. The new age has implications for the Cretaceous paleogeographic reconstruction of the Alpine area. In the text European margin refers to both, the European continental block and the Briançonnais domain. This latter is a continental block located on the European side of the ocean and detached from the European plate by the Late Jurassic–Early Cretaceous opening of the Valais ocean (e.g. STAMPFLI et al., 1998).

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Geological setting

The MR nappe is a slice of continental crust located in the Penninic zone of the Western Alps (Fig. 1a). It is tectonically emplaced between the ophiolitic nappes of Antrona and Zermatt–Saas-Fee, which separate the MR from the underlying Briançonnais domain and the overlying Austroalpine (Sesia-Lanzo Zone), respectively (Fig. 1b). The MR nappe is composed of a crystalline basement overlain by a thin sedimentary cover. The basement mainly consists of Variscan metagranites that intruded paragneisses. The cover includes the Furgg Zone, a sedimentary-volcanic sequence of presumably Permo-Carboniferous age (BEARTH, 1952 and 1964; WETZEL, 1972), and the Gornergrat Zone (Fig. 1c). The Gornergrat Zone is a thin slice occurring between the Zermatt–Saas-Fee ophiolites, remnant of the Piemontese-Ligurian ocean, and the MR crystalline basement. It consists of gneisses, micaschists and quartzites with variable mica contents. The Gornergrat Zone has been mainly investigated by BEARTH (1952 and 1964). Most of the sequence has been described to be derived from sedimentary rocks, but part of the albite-muscovite gneisses may represent volcanic (rhyolitic) intercalations (BEARTH, 1964). The age of the sequence is constrained by conglomerates at the base, which are interpreted to represent Permian Verrucano, and cornieule of presumed Triassic age in the upper part (BEARTH, 1964; BEARTH and SCHWANDER, 1981). Although a stratigraphic primary contact with the basement of the MR is not preserved (BEARTH, 1952), the Gornergrat Zone, because of its stratigraphy and tectonic position, has been always regarded as the cover on the MR basement (BEARTH, 1964; BEARTH and SCHWANDER, 1981).

The MR nappe records Alpine eclogitic metamorphism and a later greenschist-facies retro-

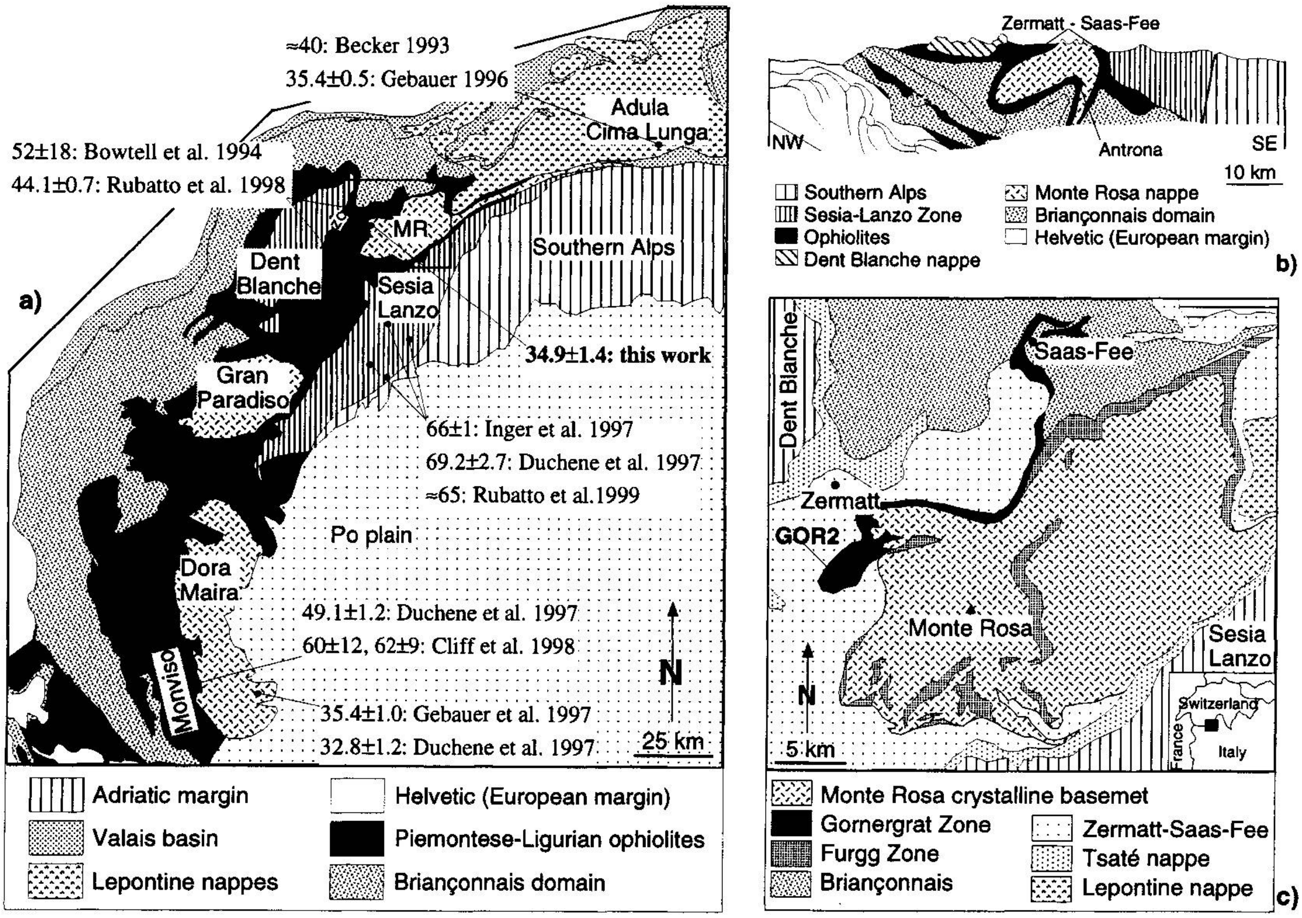

Fig. 1 (a) Simplified tectonic sketch of the Western Alps reporting the geochronological data in support of Late Cretaceous-Tertiary subductions. Ages are given in Ma. Units derived from Adria: Southern Alps, Sesia-Lanzo and Dent Blanche. Units derived from Europe: Helvetic, Briançonnais, Dora Maira, Gran Paradiso, Monte Rosa (MR) and Adula-Cima Lunga. ZO = Zermatt-Saas-Fee ophiolites. The rectangle corresponds to figure 1c. (b) Schematic profile across the Western Alps depicting the tectonic position of the Monte Rosa with respect to the ophiolites (simplified after POLINO et al., 1990). (c) Geological map of the Monte Rosa region and sample location. After BEARTH (1952) and WETZEL (1972).

gression. The metamorphic conditions have been estimated in the basement rocks. The peak was reached at around 500–550 °C and 10–16 kbar (CHOPIN and MONIÉ, 1984; DAL PIAZ and LOMBARDO, 1986; BORGHI et al., 1996). The greenschist-facies overprint implied decompression to ~ 5 kbar and ~ 450 °C (FREY et al., 1976: BORGHI et al., 1996). BORGHI et al. (1996) proposed that the low-grade event was prograde and followed cooling to 400–430 °C after HP metamorphism. This reconstruction would imply that the P-T path of the MR was characterised by two peaks at similar temperatures but very different pressures.

In the cover unit of the Furgg Zone, garnet-omphacite-glaucophane assemblages overprinted by low-grade assemblages have been described by WETZEL (1972), suggesting a similar Alpine evolution of basement and cover. In the Gornergrat Zone indication of HP metamorphism are provided by the presence of high-Si phengite in the metaquartzites (CHOPIN and MONIÉ, 1984).

Tab. 1 Representative analyses and cation proportions of phengite, titanite, epidote and albite.

	Phengite	Titanite	Epidote (rim)	Albite
SiO_2	49.36	30.12	37.41	68.68
TiO_2	0.59	37.08	< 0.08	0.00
Al_2O_3	25.96	2.20	24.27	19.57
Fe_2O_3	2.32	0.00	12.15	0.00
FeO	2.83	0.67	0.00	0.00
MgO	2.48	0.11	< 0.08	< 0.08
CaO	< 0.06	27.37	22.76	< 0.06
Na_2O	< 0.15	< 0.15	< 0.15	11.81
K_2O	11.68	< 0.05	< 0.04	0.17
H_2O	4.41	0.41	1.87	0.00
Total	99.65	97.96	98.46	100.23
Si	3.357	0.995	2.995	2.988
Ti	0.030	0.922	0.000	0.000
Al	2.081	0.086	2.290	1.004
Fe(III)	0.119	0.000	0.732	0.000
Fe(II)	0.161	0.019	0.000	0.000
Mg	0.251	0.005	0.000	0.000
Ca	0.000	0.969	1.952	0.000
Na	0.000	0.000	0.000	0.996
K	1.013	0.000	0.000	0.009
Cations	7.013	2.996	7.969	4.998

Analyses performed with a JEOL 6400 SEM fitted with an EDS detector.

Petrology

Sample description: The metaquartzite sample GOR2 was collected near the Gorner glacier, along the path to the Rotenboden train station (Fig. 1c). In this locality, quartzites varying in mica content and grain size form interbedded levels up to 20 cm thick (Fig. 2a). The sample GOR2 is a foliated rock (Fig. 2b) composed of quartz (55%) and phengite (40%) with minor epidote, titanite and albite, which display equilibrium textures with the phengite. Carbonates occur occasionally as ribbon parallel to the main foliation or associated with epidote. Accessory phases are apatite and zircon, which was found as inclusion in phengite. Low-grade retrogression is documented by rare Fe-biotite rims on phengite.

Mineral chemistry (Tab. 1): Phengite has a high celadonitic content with Si = 3.35 (p.f.u.). Titanite displays zoning in Al_2O_3 content, which increases from 1% in the core up to 2.2 wt% in the rim. Epidote is strongly zoned in CaO content with some allanitic cores having 11 wt% of CaO and rare

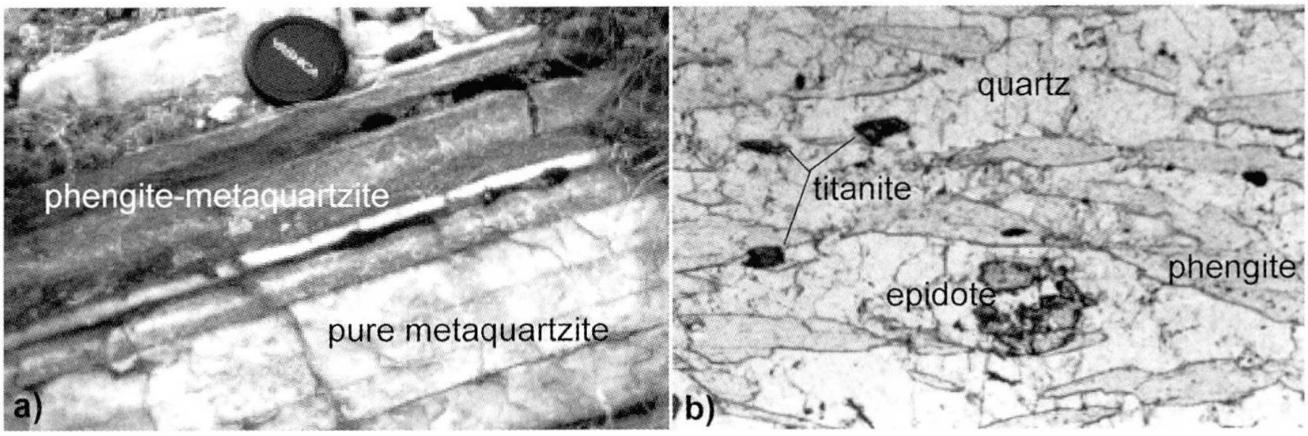

Fig. 2 (a) Phengite-rich metaquartzite (sample dated) occurring as intercalations is nearly pure quartzites. (b) Photomicrograph of the sample which is composed of quartz (55%) and phengite (40%) with minor epidote, titanite and albite. Hardly any retrograde products of phengite have been observed. Base of the picture 3.5 mm long.

earth elements content up to 25 wt%. The epidote rims and some unzoned crystals have nearly 23 wt% in CaO and limited trace elements content. Nearly pure albite is present in equilibrium with the main assemblage.

Metamorphic conditions: The paragenesis in the sample dated indicates HP conditions. Although the assemblage in the metaquartzite is not suitable for the application of any thermobarometers, some indications on the metamorphic conditions can be obtained. The presence of albite + quartz demonstrates pressure conditions below the reaction Ab → Jd + Qtz that corresponds to 14–15 kbar at 500–550 °C (HOLLAND, 1980). The coexistence of albite and epidote indicates that metamorphic conditions did not reach the oligoclase-in reaction (MARUYAMA et al., 1983), i.e. the temperature was below 550 °C. Phengite is the only Fe–Mg phase in the paragenesis. Talc or chlorite, which would buffer the celadonitic substitution in phengite, were probably consumed during prograde metamorphism. Thus, Si = 3.35 is indicative of minimum pressure only. The Al_2O_3 zoning in the titanite is incompatible with retrogression and rather reflects prograde metamorphism.

In summary, the petrological data suggest that the investigated paragenesis reflects prograde HP metamorphism with P < 14–15 kbar and T < 550 °C and is not compatible with greenschist-facies overprint.

Methods

Zircons were separated from a rock powder according to magnetic properties and density and finally selected by hand picking. They were embedded in epoxy and polished down to half sections. Cathodoluminescence analyses were carried out at the Institut für Metallforschung und Metallurgie at the ETH in Zürich with a CamScan4 scanning electron microscope (SEM) supplied with an ellipsoidal mirror for cathodoluminescence imaging. Operating conditions for the SEM were 13 kV/120 μA.

Zircons selected according to cathodoluminescence images were analysed for U, Th and Pb using the sensitive high resolution ion microprobe (SHRIMP II) at the Australian National University in Canberra. Reference zircon from a pegmatite from Sri Lanka (SL13) was used. Instrumental conditions, data acquisition and reduction were generally as described by COMPSTON et al. (1992). The data were plotted on the classical Concordia diagram and on the Tera-Wasserburg diagram (TW; TERA and WASSERBURG, 1972). Data plotted on the TW diagram were not corrected for common lead. The common lead correction was done using Broken Hill lead, which represents the common lead isotopic composition in the laboratories of Canberra.

Geochronological data

The zircons recovered from this sample are coloured from pink to yellow and, in most of the cases, preserve an euhedral, elongated shape with an irregular profile and uneven surface. In cathodoluminescence (Fig. 3), the zircons show a core with more or less regular oscillatory-zoning

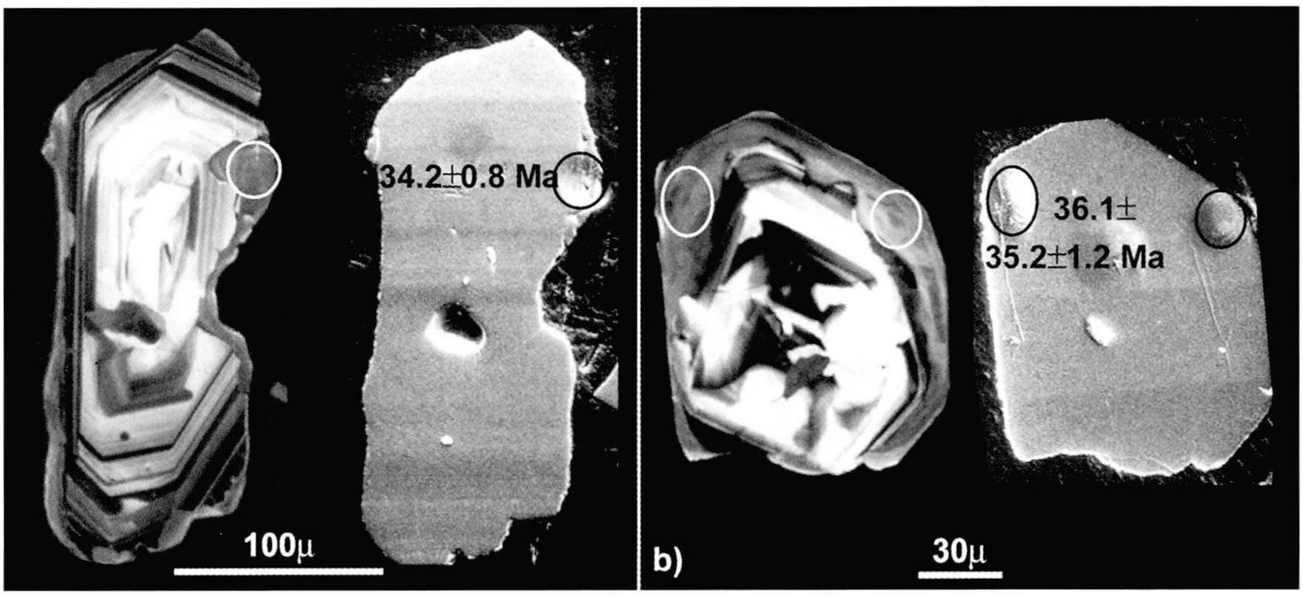

Fig. 3 Cathodoluminescence image (left) and secondary electron image (right) of two zircons dated. The Late Eocene/Early Oligocene rims are unzoned or irregularly zoned and have Th/U ratios below 0.01.

Tab. 2 U, Th and Pb SHRIMP data from the metaquartzite of the Gornergrat Zone (GOR2). When the CL domain is given in brackets the zoning pattern is not well defined. Errors are at 1σ level.

Spot name	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	Common Pb %	Uncorrected $^{207}Pb/^{206}Pb$	Uncorrected $^{238}U/^{206}Pb$	$^{206}Pb/^{238}U$	Age (Ma) $^{206}Pb/^{238}U$	CL domain
11.1 !	693	3	< 0.01	3	22	0.2510 ± 0.0060	146.3 ± 3.2	0.0053 ± 0.0001	34.2 ± 0.8	unzoned rim
38.1 !	651	3	< 0.01	3	1.7	0.0620 ± 0.0020	185.0 ± 4.4	0.0053 ± 0.0001	34.2 ± 0.8	unzoned rim
26.1 !	638	2	< 0.01	3	3.1	0.0750 ± 0.0040	177.0 ± 5.8	0.0055 ± 0.0002	35.2 ± 1.2	cloudy rim
26.2 !	735	3	< 0.01	4	4.7	0.0900 ± 0.0030	169.4 ± 3.8	0.0056 ± 0.0001	36.1 ± 0.8	cloudy rim
18.1	668	14	0.02	4	1.3	0.0590 ± 0.0020	164.6 ± 3.8	0.0060 ± 0.0001	38.5 ± 0.9	cloudy rim
36.1	780	61	0.08	9	43	0.4400 ± 0.0100	53.8 ± 1.5	0.0107 ± 0.0004	68 ± 3	unzoned rim
5.1	670	114	0.18	17	10	0.1420 ± 0.0060	33.8 ± 1.3	0.0266 ± 0.0010	169 ± 7	light rim
30.1	426	172	0.40	12	2.0	0.0680 ± 0.0010	35.4 ± 0.7	0.0277 ± 0.0006	176 ± 4	cloudy rim
34.1	767	578	0.75	28	20	0.2300 ± 0.0040	28.5 ± 0.6	0.0208 ± 0.0006	179 ± 4	(oscillatory rim)
6.1	5687	41	0.01	165	0.33	0.0531 ± 0.0003	31.1 ± 0.8	0.0321 ± 0.0008	203 ± 5	dark rim
23.1	536	274	0.51	20	18	0.0670 ± 0.0010	27.7 ± 0.5	0.0355 ± 0.0006	225 ± 4	(oscillatory core)
14.1	475	261	0.55	21	0.49	0.0561 ± 0.0008	23.5 ± 0.4	0.0424 ± 0.0007	268 ± 4	(oscillatory core)
27.1	324	156	0.48	14	1.0	0.0610 ± 0.0010	23.8 ± 0.4	0.0417 ± 0.0008	263 ± 5	light core
8.1	175	51	0.29	12	5.0	0.1000 ± 0.0030	14.0 ± 0.4	0.0678 ± 0.0020	423 ± 12	light core
6.2	380	70	0.18	40	2.5	0.0900 ± 0.0100	8.6 ± 0.5	0.1136 ± 0.0073	694 ± 42	light core

Pb* = radiogenic lead
! = Data points considered in calculating the Eo/Oligocene age

which can display different patterns cross-cutting each others, as usually observed in detrital grains. Rims characterised by an irregular shape and a weak cloudy zoning occasionally surround the cores.

The zircon cores are characterised by medium U- and Th-contents (175–536 ppm and 51–274 ppm, respectively), and Th/U ratios higher than 0.2. They yield ages ranging from Triassic to Proterozoic (Tab. 2). The scattering of the ages of the cores is in line with a sedimentary protolith. The age of the youngest core, which is concordant at the 2σ level (Fig. 4a), may suggests a Triassic (225 ± 4 Ma, 1σ) maximum depositional age for the quartzite, however a single data point is not necessarily geologically meaningful. The age of 225 Ma is unusual for Alpine rocks and it may be due to lead loss from an older lead component. Two other cores yielded Early Permian ages (263 ± 5 Ma and 268 ± 4, 1σ) that may be more indicative of a maximum depositional age.

The age obtained in the irregularly shaped and zoned rims varies from Late Permian to Eo/Oligocene (Tab. 2 and Fig. 4). The rims have medium to high U-contents (426–5687 ppm). The Th-contents vary from few ppm to nearly 600 ppm showing, with the exception of the oldest rim, a positive correlation to age. As a consequence, the Th/U ratios vary from below 0.01 for the Eo/Oligocene rims to 0.75 for the Early Jurassic rim. The scattering of ages suggests a mixing between a Permian or older age component and a radiogenic Pb component produced since a metamorphic event, the maximum age of which is given by the youngest measured ages. The four youngest rims show cloudy or no zoning, have the lowest Th/U ratios (< 0.01) and group around 35 Ma. In the TW diagram (Fig. 4b) these four analyses fit a mixing line with Broken Hill common lead that has a lower intercept at 34.9 ± 1.4 Ma (weighted mean at the 95% c.l.). Using another method for common Pb correction (the ^{208}Pb method as described by COMPSTON et al., 1992) the data can be plotted on the classical Concordia diagram (Fig. 4a). The four analyses are concordant and yield a mean age of 34.6 ± 1.4 Ma, that is indistinguishable from the results obtained in the TW diagram. However, the four data points do not fit a Th/U versus $^{208}Pb/^{206}Pb$ isochron, suggesting differential movement of U and Th after zircon crystallisation, which would affect the ^{208}Pb common lead correction. Hence the age shown in the TW diagram and calculated using

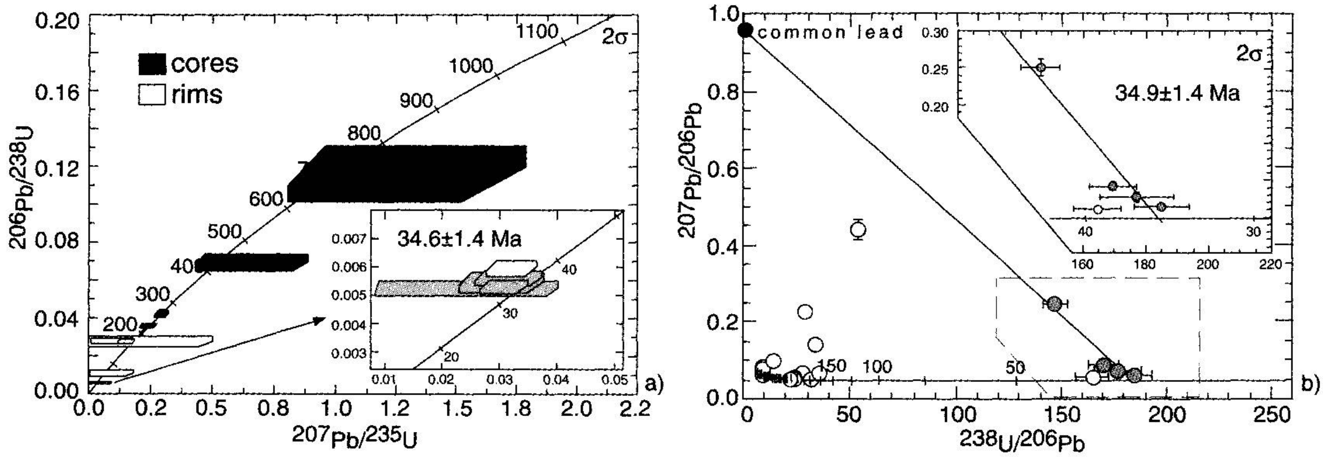

Fig. 4 Geochronological data plotted on a Concordia diagram (a) and on a Tera-Wasserburg diagram (b). The Tera-Wasserburg diagram depicts uncorrected data, whereas the data plotted on the Concordia diagram are corrected for common lead via ^{208}Pb. See text for discussion.

the ^{207}Pb technique for common Pb correction (COMPSTON et al., 1992) is preferred.

A slightly older rim does not fit the mixing line in the TW diagram and plots discordantly in the Concordia diagram. This rim probably retains a minimum amount of the older Pb component. However, if this data point is included in the group at ≈ 35 Ma, the age obtained would not significantly change. The oldest rims, which yield ages between the Eo/Oligocene and the Early Jurassic, are thought to represent mixing ages and therefore are considered geologically meaningless.

Discussion

AGE OF HP METAMORPHISM

In metaquartzite GOR2, the four zircon rims yielding the ≈ 35 Ma age are characterised by irregular/patchy zoning in cathodoluminescence and the lowest Th/U ratios of all the analyses. These features have been observed in rims formed under HP, low temperature metamorphic conditions in which the re-orientation of a pre-existing crystal structure deleted previous oscillatory or regular zoning and reduced the Th/U ratio of the zircon domains (e.g. RUBATTO and GEBAUER, in press and reference therein). The ≈ 35 Ma old zircon rims are particularly similar to zircon rims from the HP metasediment sampled in the near Sesia-Lanzo Zone (RUBATTO et al., 1999), which formed during eclogite facies metamorphism. It is therefore suggested that the ≈ 35 Ma old zircon rims record a metamorphic event that affected the rock during Alpine compression.

The paragenesis of the sample dated reflects HP metamorphism rather than greenschist-facies retrogression. The presence of albite + epidote + quartz, the high-Si content in phengite ($Si_{3.35}$) and the Al_2O_3 zoning in titanite suggest HP metamorphic conditions of maximum 14–15 kbar at 500–550 °C and argue against low-pressure greenschist facies re-equilibration in this sample. The relative coarse grained texture is also in line with HP conditions. Zircon is found as inclusion in phengite that defines the foliation. The very limited occurrence of retrogression of phengite (rare biotite rims) suggests that no dehydration occurred during decompression, which may have opened the U–Pb system in the zircon. Therefore, we interpret the 34.9 ± 1.4 Ma age as dating the HP metamorphism in the Gornergrat Zone.

Paragenesis and metamorphic conditions in the Gornergrat sample are similar to the HP rocks of the MR basement (CHOPIN and MONIÉ, 1984; BORGHI et al., 1996). The phengites in the micaschists of the MR basement have Si contents between 3.35 and 3.44. These values are in agreement with composition of the Gornergrat sample, in which the $Si_{3.35}$ of phengite is only a minimum estimate because it is not buffered by any other Fe–Mg phase. Similar to the Gornergrat sample, HP micaschists of the MR basement contain albite + quartz indicating HP metamorphic conditions below the jadeite-in reaction (BORGHI et al., 1996). The Gornergrat sample equilibrated below the oligoclase-in reaction, which has been used to mark the retrogression from HP conditions to greenschist–low-amphibolite facies in the rocks of the MR (BORGHI et al., 1996). The P-T conditions in the Gornergrat sample are compatible with the estimates of BORGHI et al. (1996) for the MR micaschists (13 kbar and 500–550 °C). Therefore, the petrologic data are in agreement with a common evolution of the MR basement and the Gornergrat cover during Alpine compression.

In conclusion, although a stratigraphic primary contact between the Gornergrat Zone and the basement of the MR is not described, similar metamorphic conditions and geological observations (BEARTH, 1964; BEARTH and SCHWANDER, 1981) suggest that the Gornergrat Zone is the autochthonous cover of the MR basement, sharing the same Alpine evolution. Therefore, we propose that the 34.9 ± 1.4 Ma old metamorphic rims date the subduction to HP conditions of the Gornergrat Zone together with the MR basement in the Late Eocene / Early Oligocene (geological time scale according to HARLAND et al., 1989).

COMPARISON WITH EXISTING DATA

Previous geochronological studies in the MR nappe proposed a Cretaceous age for the HP metamorphism. An ^{40}Ar–^{39}Ar age of 110 ± 3 Ma obtained by CHOPIN and MONIÉ (1984) on phengite from a quartz-rich metapelites of the basement has been interpreted either as due to excess argon or as dating the closure of the K–Ar system in HP phengite. After further ^{40}Ar–^{39}Ar analyses, MONIÉ (1985) reinterpreted the 110 Ma age as dating the subduction of the MR nappe. According to this author, after the Early Cretaceous subduction, the MR basement was deformed under blueschist-facies conditions at around 65 Ma as documented by ^{40}Ar–^{39}Ar ages from a second generation of phengite and phlogopite. This interpretation would imply that the MR nappe was exhumed from eclogite-facies conditions (ca. 500 °C and 16 kbar; CHOPIN and MONIÉ, 1984) to blueschist-facies conditions (ca. 500 °C and 8 kbar; MONIÉ, 1985) in 45 Ma. It is expected that such a slow uplift would have allowed the relaxation of the isotherms and prevented the preservation of eclogite-facies minerals. More likely, the Cretaceous ^{40}Ar–^{39}Ar ages on HP micas are caused by excess argon, as largely demonstrated for the Sesia-Lanzo Zone and the Dora Maira nappe (FERAUD et al., 1994; KELLEY et al., 1994; RUFFET et al., 1995; REDDY et al., 1996; RUFFET et al., 1997).

A Rb–Sr whole rock age of 125 ± 20 Ma was obtained from a strongly deformed orthogneiss of the MR basement (HUNZIKER, 1970). By the same technique, an age of 102 ± 2 Ma was obtained on a metapelite and a Rb–Sr analysis on phengite from the same sample produced an age of 91 ± 2 Ma (PAQUETTE et al., 1989). In the light of the new zircon data, it is more likely that the significantly scattering Rb–Sr data reflect disequilibrium caused mainly by inherited components from the pre-Alpine evolution of the rocks.

The 35 Ma age for the HP metamorphism in the Gornergrat Zone is in agreement with the cooling ages obtained in the MR nappe. Data obtained by argon techniques on HP minerals are not considered here because these data sets appear to be affected by excess argon in many Alpine nappes. Rb–Sr isotopic analysis of a gneiss from the MR basement yielded a cooling age of 32.2 ± 0.7 Ma (FREY et al., 1976). Fission tracks on zircon yielded ages in the range 33–34 Ma indicating cooling below ≈ 230 °C (HURFORD et al., 1991). Hydrothermal veins that cut the nappe stacking were dated with K–Ar at around 33–31 Ma (DIAMOND and WIEDENBECK, 1986). The Oligocene formation of the veins indicates that the MR nappe was already emplaced in the upper crust at that time. The late stage of cooling is described by apatite fission tracks at around 10–14 Ma (HURFORD et al., 1991). These geochronological data suggest rapid cooling of the MR nappe during a first stage of fast uplift followed by a relatively slower decrease in temperature when the nappe was already emplaced at upper crustal level.

COMPARISON WITH OTHER ALPINE NAPPES

The age obtained from the zircon rims of the metaquartzite of the Gornergrat Zone is in agreement with the subduction ages obtained for other two Alpine units. In the Dora Maira nappe (Fig. 1a) SHRIMP zircon dating indicated an age of 35.4 ± 1.0 Ma for the UHP metamorphism (GEBAUER et al., 1997). Similar ages were obtained with Lu–Hf on garnet (DUCHÊNE et al., 1997), U–Pb on monazite and rutile (SCHÄRER et al., 1999) and by U–Pb dating of titanite (Rubatto and Hermann, in prep.) The Dora Maira occupies a tectonic position in the Alpine edifice similar to the MR.

In the Adula–Cima Lunga nappe (Fig. 1a), ages around 40 Ma have been obtained by Sm–Nd age determinations on mafic and ultramafic rocks (BECKER, 1993). On the basis of U–Pb dating of zircons from Alpe Arami, GEBAUER (1996) proposed an age of ≈ 35 Ma for the partial melting of mafic/ultramafic rocks, which has been interpreted to have occurred at HP conditions.

THE MONTE ROSA AS PART OF THE EUROPEAN MARGIN?

Reconstructions of the paleogeography of the Alpine area before the onset of compression is extremely difficult because of the complexity of the

Alpine edifice and the numerous tectonic events that occurred during the Alpine orogeny. The several attempts of paleogeographic reconstruction reported in the literature are constructed around few arguments such as: (a) The tectonic position of the different nappes with respect to the ophiolites of the Piemontese-Ligurian ocean (ESCHER et al., 1988; ESCHER et al., 1997; FROITZHEIM, 1997). As the nappe stacking proceeded from the Adriatic to the European margin, assuming a simple geometry, the nappe tectonically overlying the Piemontese-Ligurian ophiolites are regarded as Adriatic margin and those underlying the ophiolites are considered of European affinity. (b) The opening of the Atlantic and the plate tectonic constraints coming from magnetic anomalies which are good indicators of time, amount and rate of compression in the Alpine area (e.g. STAMPFLI and MARCHANT, 1997; STAMPFLI et al., 1998). (c) The age of subduction. The age of HP metamorphism in the Western and Central Alps is diachronous in the different tectonic units (Fig. 1a). The geochronological data suggest progressive southwards subduction from the SE to the NW between the Late Cretaceous and the Eo/Oligocene. In fact, this subduction process was recorded at ca. 65 Ma to the south of the Piemontese-Ligurian ocean (the Sesia-Lanzo Zone: RAMSBOTHAM et al., 1994; INGER et al., 1996; DUCHÊNE et al., 1997; RUBATTO et al., 1999), around 44 Ma in the oceanic units (the Zermatt–Saas-Fee ophiolites: RUBATTO et al., 1998) and in the Late Eocene / Early Oligocene in the European continental units of the Adula–Cima Lunga (BECKER, 1993; GEBAUER, 1996) and Dora Maira (GEBAUER et al., 1997; DUCHÊNE et al., 1997; SCHÄRER et al., 1999).

The authors which based their reconstruction on the tectonic position located the MR nappe on the NW margin of the Piemontese-Ligurian ocean, as either part of the Briançonnais domain (ESCHER et al., 1988; ESCHER et al., 1997) or of the European continental block (FROITZHEIM, 1997). On the other hand, according to the preliminary ≈ 100 Ma age for the HP metamorphism in the MR nappe (HUNZIKER, 1970; MONIÉ, 1985; PAQUETTE et al., 1989), this nappe was tentatively regarded as part of the Adriatic plate (LAUBSCHER and BERNOULLI, 1982; POLINO et al., 1990; STAMPFLI and MARCHANT, 1997; STAMPFLI et al., 1998).

The new zircon data, far from resolving the complex problem of Cretaceous paleogeography in the Alpine area, suggest that the age of HP metamorphism in the Gornergrat Zone and possibly in the MR is younger than in the ophiolites. Assuming that (a) the present nappe stacking reflects, to a certain extent, the paleogeographic position before Alpine compression and that (b) a simple subduction process with progressive involvement of units from SE to NW occurred, the new age suggests that the MR nappe was subducted after the Piemontese-Ligurian ocean. This interpretation would bring the tectonic and geochronological data in agreement and supports a paleogeographic location of the MR nappe on the European margin, as part of the Briançonnais domain or, more likely, of the European continental block.

Conclusions

Metamorphic zircon rims from a metaquartzite of the Gornergrat Zone yielded an age of 34.9 ± 1.4 Ma. The zircon rims have low Th/U and are unzoned in cathodoluminescence, which are typical features of zircon domains recrystallised under HP conditions (RUBATTO and GEBAUER, in press). Similar to HP rocks of the underlying MR basement, the sample dated contains high-Si phengite ($Si_{3.35}$) and albite + quartz, which indicate equilibration at HP conditions below 14–15 kbar at 500–550 °C. The presence of albite + epidote and not oligoclase together with the absence of pervasive retrogression on phengite argue against low-grade overprint in the sample dated. Therefore, the age of 34.9 ± 1.4 Ma is interpreted as dating the HP metamorphism in the Gornergrat Zone. Geological observations (BEARTH, 1964; BEARTH and SCHWANDER, 1981) and the similar metamorphic conditions recorded in the Gornergrat sample and the MR crystalline basement would suggest a common Alpine evolution for these two units. This would imply that both the MR basement and its cover (the Gornergrat Zone) were subducted beneath the Adriatic plate around the Eocene-Oligocene boundary. This conclusion, in agreement with the tectonic position of the MR below the Zermatt–Saas-Fee ophiolites, suggests that the Monte Rosa nappe is of European affinity.

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