

Radiometric geochronology of Central Alps

ATTILIO BORIANI, ANNITA COLOMBO

Dipartimento di Scienze della Terra dell'Università, Centro di Studio per la Stratigrafia e Petrografia delle Alpi Centrali del C.N.R., Via Botticelli 23, 20133 Milano

PATRIZIA MACERA

Dipartimento di Scienze della Terra dell'Università, Via S. Maria 53, 56100 Pisa
Istituto di Geocronologia e Geochimica Isotopica, C.N.R., Via Cardinale Maffi 36, 56100 Pisa

ABSTRACT. — Isotope geochronology has contributed a great deal to reconstruction of the geological evolution of Central Alps, since it has enabled the difficulties arising from the absence of geological evidence for most of the pre-Carboniferous events to be overcome.

Three main petrogenetic periods can be identified:

1) Between 480 and 420 m.y. a metamorphic event (whose importance can be only guessed at), followed by discrete intrusive activity, formed the stratigraphical framework of all Units of the Central Alpine basement, although its ensialic character points to the presence of an unknown (or unidentifiable) substratum.

2) Between 350 and 270 m.y.: the important Hercynian diastrophism and metamorphism followed by an intense, mostly acidic magmatic activity that probably remobilised the substratum. This event is actually the most important, for both the South-alpine and the Austroalpine basement, but it is also responsible for most of the features of the Penninic domain.

3) From 90 m.y. (Eoalpine phase) till today, though with a metamorphic climax at 38 m.y., a differentiated cooling history and a complex post-orogenic intrusive activity: this is the Alpine Orogeny. Detailed isotopic surveys have allowed a mantle origin with different degrees of crustal contamination to be attributed to most of the Alpine magma.

Key words: Central Alps, Geochronology, Southern Alps, Austroalpine Domain, Penninic Domain.

RIASSUNTO. — La geocronologia isotopica ha fornito un contributo considerevole alla ricostruzione dell'evoluzione geologica delle Alpi Centrali. Sono stati distinti tre periodi petrogenetici principali:

1) Tra 480 e 420 m.a.: un evento metamorfico (sulla cui importanza si possono fare solo congetture), seguito da una discreta attività magmatica,

formò l'impalcatura stratigrafica di tutte le unità del basamento delle Alpi Centrali, sebbene il carattere ensialico dell'evento testimoni l'esistenza di un substrato sconosciuto o non identificabile.

2) Tra 350 e 270 m.a.: l'importante diastrofismo e metamorfismo Ercinico, seguito da una intensa attività magmatica, che probabilmente fu il risultato di una generale rimobilizzazione del substrato. L'evento Ercinico fu, in effetti, il più importante per il basamento Sudalpino e Austroalpino, ma fu anche responsabile della creazione di molti dei caratteri litologici del dominio Penninico.

3) Da 90 m.a. (fase Eoalpina) fino ad oggi, ma con un culmine metamorfico a 38 m.a., una storia differenziata di raffreddamento ed una complessa attività intrusiva postorogenica: questa è l'orogenesi Alpina. Ricerche isotopiche di dettaglio hanno permesso di attribuire alla maggior parte dei magmi alpini un'origine dal mantello, con diversi gradi di contaminazione crostale.

Parole chiave: Alpi Centrali, Geocronologia, Sudalpino, Austroalpino, Penninico.

Introduction

The central sector of the Alps is probably the part of the Earth's crust that has been studied in the greatest detail and for the longest time, since modern geology was born here in the nineteenth century. Its radiometric data are also very abundant, mostly thanks to the presence of the important schools of Berne, Zürich and Pisa.

Surprisingly enough, many geochronological problems are still open and many controversies still survive, demonstrating that the deeper the studies and the harder the problems of interpretation become.

For the sake of clarity we will divide our discussion into three parts:

- 1 - Prealpine history of the Southalpine and Austroalpine basement.
- 2 - Prealpine and Alpine history of the Penninic domain.
- 3 - Post-collisional Alpine magmatism.

1. Prealpine history of the Southalpine and Austroalpine basements

1.1. SOUTHALPINE BASEMENT

Once the Archaic age of the «crystalline rocks» postulated by the neptunists was put aside, it became clear that the metamorphic rocks composing most of the Southalpine basement have undergone at least one pre-Alpine orogeny. Their dominating meta-sedimentary nature was immediately understood, whilst the igneous origin of the inter-layered «granitic» gneisses was not fully recognized, since «transformism», the dominating theory of the first half of our century, induced many investigators to see in them only the product of extensive metasomatism.

NOVARESE (1929) recognized the pre-Carboniferous age of metamorphism and proposed a Silurian age for sedimentation, on the basis of lithological analogy with other non-metamorphic shales.

The granites cutting the metamorphic rocks were identified as pre-Alpine (except by STAUB, 1949).

The only geochronological evidence was, at that time, the «Hercynian unconformity», i.e. the folded and eroded metamorphic rocks were overlain by a pre-Triassic continental conglomerate that VENZO & MAGLIA (1947) identified as Carboniferous (Westphalian B) on the basis of its fossiliferous content.

Rb-Sr and K-Ar mineral ages

The first geochronological data on metamorphic rocks appeared in 1966 (HANSON et al.), when a K-Ar age was assigned to a biotite from a schist, and several Rb-Sr ages on white mica from the pegmatite on the eastern shore of Lake Como. The ages (table 1) range from 200 to 250 m.y.; since they appeared too young to be attributed

to the Hercynian metamorphism, the authors proposed that the formation underwent a radiogenic loss during a thermal event connected with the Permian magmatic activity. This Permian thermal event is evoked from time to time as a «deus ex machina» to explain radiogenic loss, even though it has not yet gained geological or petrographic support. The possibility that radiogenic loss was due to Alpine rejuvenation was considered less likely.

Rb-Sr and K-Ar mineral ages on para- and ortho-metamorphic rocks of the central Southalpine basement, offered by MC DOWELL & SCHMID (1968), MC DOWELL (1970), HUNZIKER (1974), BOCCHIO et al. (1981), BORIANI et al. (1982-83), MOTTANA et al. (1985) (tables 1 and 2), have confirmed the Hercynian age of the last detectable metamorphic event; moreover it has become evident that there is a constant decrease in mineral ages from SE to NW.

The most obvious meaning of this pattern, if we interpret mineral ages as cooling ages, is that it reflects the post-Hercynian cooling history of the Southern Alps; this is geologically substantiated by the evidence that the degree of metamorphism also increases from SE to NW. Moreover, the increasing Rb-Sr white mica age towards E (up to 364 ± 15 m.y. in Val Trompia: DEL MORO in RIKLIN, 1983) may reflect an older age in the more easterly part (i.e.: the metamorphic «thermal wave» propagated from SE to NW). Yet one must remember that, depending on the crustal level, the lower the metamorphic grade, the faster the cooling down during the uplift of the Hercynian belt. Nevertheless, other explanations have been considered, such as the possibly more conspicuous radiogenic loss near the Insubric Line during the Alpine orogeny; in this case, we would be dealing with mixed ages and not with cooling ages.

The particular K-Ar mica and whole rock pattern found by BOCCHIO et al., 1981, was initially ascribed to the presence of two distinct events: a Caledonian and a Hercynian metamorphism. This interpretation has never been shared by other workers and is no longer held by the authors themselves (MOTTANA et al., 1985), who now attribute the younger ages to a late-Triassic metamorphic event.

U-Pb mineral ages

U-Pb zircon and monazite ages both on para- and ortho-gneisses have made a very important contribution to reconstruction of the geological history. They have also been a source of confusion, since the «transformist» interpretation of the granitic gneisses as granitized rocks («*Orthogneis Typus*», REINHARD, 1964), led authors to confuse intrusion ages with metamorphic ages.

If we separate para- from ortho-metamorphic rocks we find the following distribution:

1 - U-Pb zircon ages of paragneisses are all discordant, with an upper intercept between 1900 and 2500 m.y., and a lower intercept between 400 and 500 m.y. (except in the Ivrea-Verbano Zone, about 300 m.y.).

2 - U-Pb zircon ages of orthogneisses are all concordant or nearly so around a value of 420-465 m.y.

3 - U-Pb monazite ages of paragneisses are concordant in the Ivrea-Verbano Zone around a value of 275 m.y.; a granitic gneiss, with post-kinematic mobilization near the contact between Strona-Ceneri and Ivrea-Verbano in Valle Strona di Omegna, also contains a monazite with concordant age of 275 m.y. (KÖPPEL, 1974).

4 - A U-Pb concordant monazite age of 450 m.y. was obtained by KÖPPEL & GRÜNENFELDER (1971) on a paragneiss (*Cenerigneiss*) of the Strona Ceneri Zone occurring at Ponte Casletto (Valle S. Bernardino).

Particular problems have been encountered in the U-Pb zircon dating of the «*Gneiss Chiari*» of the Val Colla Zone, a leucocratic coarse grained gneiss that seems to form the uppermost horizon of the metamorphic basement of the Southern Alps. The «*Gneiss Chiari*» have been interpreted as metaarkose (EL TAHLAWI, 1965), migmatites (LIBORIO & MOTTANA, 1971; KÖPPEL & GRÜNENFELDER, 1971), and metarhyolites (BORIANI & COLOMBO, 1979); their zircons give highly discordant ages (KÖPPEL & GRÜNENFELDER, 1971), ranging from 140 to 580 m.y.. The problem of their age is still open.

All these data were seen as evidence of two metamorphisms («Caledonian» and Hercynian, the former being cancelled in

the high-grade Ivrea-Verbano Zone). In view of the initial error concerning the origin of orthogneisses, however, there is very little evidence of a significant «Caledonian» metamorphism. Concordant zircon ages clearly date the intrusion of the Ordovician plutonic rocks, whilst the interpretation of the lower intercept of discordant zircons is far from being universally accepted. Only the concordant monazite age of 450 m.y. of the *Cenerigneiss* of Ponte Casletto seems to indicate a real metamorphic event at that time: why not a contact metamorphism induced by an Ordovician intrusion? The *Cenerigneiss* of Ponte Casletto is bordered by an orthogneiss.

In view of the purpose of this paper, mention must also be made of the very different interpretation proposed by ALLÈGRE et al. (1974) for the discordant zircon ages: using a multiepisodic model of lead loss, they dated the source rocks of the original sediments at about 2500 m.y., with losses at 520-580 m.y. (Cadomian), 300 m.y. (Hercynian) and 30 m.y. (Alpine).

Rb-Sr w.r. isochrons

Only two good isochrons are available for the zone under consideration and both are on its westernmost part. One isochron (HUNZIKER & ZINGG, 1980) — on the paragneisses of the Ivrea-Verbano Zone — indicates isotopic homogenization at 478 ± 20 m.y. ($i.r. = 0.7086$). Since generalized degranitization through partial melting is assumed, it is regarded as dating the climax of metamorphism and not the first weak metamorphic episode. The conclusion is thus drawn that the Ivrea-Verbano zone underwent a strong «Caledonian» metamorphism and then cooled down slowly through the Upper Paleozoic without a real Hercynian disturbance.

The other isochron was obtained by BORIANI et al. (1982-83) on the «Serie dei Laghi» orthogneisses, and gave an age of 466 ± 5 m.y. ($i.r. = 0.7087$). The most obvious interpretation is that this age records the intrusion of the tonalites, granodiorites and granites from which the orthogneisses derived; ZINGG (1983) suggests it may represent the age of the metamorphism of the orthogneisses, even though many isochrons (see for example: BORSI et al., 1973-

1980) clearly demonstrate Ordovician magmatism in the analogous Austroalpine domain.

Reference must also be made to the isochron obtained by HAMET & ALBARÈDE (1973), from five samples of Strona-Ceneri paragneisses: 555 m.y. (543 with $\lambda = 1.42$) and an $i.r. = 0.713$ (errors not quoted), indicative of a significant Cadomian event. The meaning of this isochron is discussed by HUNZIKER & ZINGG (1980) who suggest that the size of the samples may have been a source of error.

DEL MORO (pers. com.) obtained a preliminary reference isochron of 459 ± 66 m.y. on the « Scisti di Edolo ».

As can be seen, the Rb-Sr isochrons on paragneisses point to a « Caledonian » metamorphic event. The intensity of that event, however, is still matter of speculation. In our opinion, there is much geological and petrographical evidence of a significant Hercynian diastrophism and metamorphism; the « Caledonian » w.r. isochrons may reflect a weak, petrographically undetectable, regional metamorphism, or even a thermal event connected with the Ordovician magmatism.

A very interesting attempt to estimate the maximum age of deposition of the sediments from which the Ivrea-Verbano paragneisses derived has been made by HUNZIKER & ZINGG (1980). Extrapolation of the Sr isotopic ratio on a combined Compston/Jeffery/Nicolaysen diagram, gave a maximum age of 700 m.y.. The upper intercept of the discordant zircons indicated 1900-2500 m.y. for the very old continental crust that was the source of the sediments deposited over an unknown continental substratum in the Late-Precambrian or in the Cambro-Ordovician.

The source area cannot be identified. It must have been in either the North European or the African shield.

Turning to the Ordovician magma, BORIANI et al. (1982-83) maintain that the initial Sr ratio of 0.7087 reflects its crustal origin, though hornblende-bearing orthogneisses, plotting below the isochron, point to a deeper origin. HUNZIKER & ZINGG (1980) had proposed a connection between « degeneration » of the granulite facies Ivrea-Verbano zone and the origin of these orthogneisses.

ZINGG (1983) now admits that this is not possible in the light of KÖPPEL & SCHROLL's (1983) new data on the isotopic composition of Pb in the two formations.

1.2. SYN-, POST-METAMORPHIC MAGMATIC ROCKS OF THE SOUTHALPINE

The Southalpine basement contains small and large bodies of intrusive rocks and is overlain by Permian rhyolitic volcanites.

The oldest intrusive body seems to be that of the Ivrea Zone; it consists of a layered basic complex intruded into high-grade paragneisses and marbles, and of minor mafic bodies (of debated origin) interlayered in the same country rocks; the igneous rocks show textures and parageneses fully or partly re-equilibrated at granulite facies conditions.

Intrusion of the Ivrea body is seen by HUNZIKER & ZINGG (1980) as the cause of high-grade metamorphism, whereas GARUTI et al. (1980) suggest that it occurred after the regional metamorphic peak. Unfortunately, no direct isotopic age measurements are available for the mafic rocks.

GRAESER & HUNZIKER (1968) obtained an isochron of about 310 m.y. (338 ± 41 m.y., $i.r. = 0.7128$, recalculated by HUNZIKER & ZINGG, 1980, for $\lambda = 1.42$) on paragneiss bands near the contact with the Anzola gabbro (Val d'Ossola) and concluded that the maximum age for the gabbro intrusion was 300 m.y.. HUNZIKER & ZINGG (1980) argue that all these bands, when taken together as one big sample, plot on the 478 m.y. isochron of the paragneisses. This corresponds to a change of mind: the 338 m.y. isochron is geologically meaningless and solely determined by the size of the sample.

The intrusion becomes « Caledonian » and its emplacement supplied the heat for the high-grade metamorphism.

The presence of mantle-derived ultramafics in close relationship with the mafic bodies (LENSCH, 1971; RIVALENTI et al., 1975; GARUTI et al., 1980), may represent a crust-mantle transition or emplacement of mantle slabs in the lower continental crust. The petrological data indicate that, if emplaced, they were subsequently re-equilibrated at the granulite facies conditions.

The K-Ar phlogopite age of the phlogopite-peridotite of Finero is 246 m.y. according

to KRUMMENACHER et al. (1960) and 206 ± 9 m.y. according to HUNZIKER (1974). Hornblende (same source), gives a meaningless age of 1290 m.y., due to excess argon (HUNZIKER, 1974).

A Rb-Sr w.r. isochron (HUNZIKER & ZINGG, 1982) on the same rock gives an age of 305 ± 10 m.y. with an $i.r. = 0.7062 \pm 0.0005$: this phlogopite-peridotite represents a contaminated mantle (see also COLTORTI & SIENA, 1984). By linear extrapolation of Sr isotopic ratio values to the values of common mantle peridotite of the Ivrea zone on a combined Compston/Jeffery/Nicolaysen diagram (HUNZIKER & ZINGG, op. cit.), put the age of contamination at 350 ± 20 m.y..

In their view, emplacement occurred in « Caledonian » times and crustal contamination in Variscan times owing to the tectonic activity that uplifted the Ivrea-Verbano Zone (see also ZINGG, 1983).

Geochronological study of the other, mostly granitic, igneous rocks of the Southern Alps has not raised any particular problems, though their detailed dating is far from being complete. The first real age determinations were performed by JÄGER & FAUL (1959) on the granites of Baveno and Montorfano, who obtained a Rb-Sr age of about 290 m.y. on biotite and K-feldspar and a K-Ar age of about 260 m.y. on biotite. They attributed the discordance to Ar loss due to weak metamorphism after their emplacement.

The late-Hercynian age of these granites was later confirmed by the U-Pb age measurements on zircons performed by PASTEELS (1964) and by KÖPPEL (1974).

In 1980, HUNZIKER & ZINGG published a Rb-Sr w.r. isochron giving an age of 276 ± 5 m.y. with an $i.r. = 0.7087 \pm 0.0009$. Another isochron published by HUNZIKER (1974) on the Permian volcanites giving an age of 269 ± 13 m.y. with an $i.r. = 0.710$ was recalculated by HUNZIKER & ZINGG (1980) for $\lambda = 1.42$ in 280 ± 5 and an $i.r. = 0.7071 \pm 0.0013$. Plutonites plus volcanites define an isochron of 278 ± 3 m.y. with an $i.r. = 0.7082 \pm 0.0007$.

The six samples from which the granite isochron was obtained are from Camponi (Val d'Ossola) granodiorite, Roccapietra (Valsesia) granodiorite, the pink, alkali-granite of Baveno (two samples), the white

calcalkaline granite of Montorfano and a similar rock from Alzo (Lake Orta). Recent studies (BORIANI et al., in preparation) show that the Camponi granodiorite belongs to the earlier cycle of the late-to-post-Hercynian magmatism, a stage that we can define as late-orogenic and pre-uplift: calcalkaline basic-to-intermediate magma was intruded at the border between the Ivrea-Verbano and Strona-Ceneri Zones, inducing anatexis melting of Strona-Ceneri gneisses (evidence of the deep-seated environment of the intrusion; see also BORIANI et al., 1977).

The Mottarone-Baveno, Montorfano and Alzo-Roccapietra granites belong to the second, post-uplift cycle and were emplaced as a batholith formed by many plutons intruded by a multiepisodic cauldron subsidence mechanism. A detailed survey, including geochronological and isotope geology studies, is now under way or planned to distinguish intrusions of different ages and sources.

1.3. AUSTRALPINE BASEMENT (E OF BEL-LINZONA)

The chronological picture of the Austroalpine basement is much less clear. The reason is very simple: age determinations have been mainly concentrated on Alpine and pre-Alpine formations. The Austroalpine rocks bear a fundamental pre-Alpine imprint, but were more or less weakly overprinted by the Alpine metamorphism and this caused a loss of radiogenic isotopes. In other respect, their main metamorphic and igneous events, and the lithological characters are very similar to those of the Southalpine basement. This similarity was not always clear and the age attributions of the recent geological maps of Valtellina need substantial correction in the light of the new evidence.

Rb-Sr and K-Ar mineral ages

The only published mineral ages for the metamorphic rocks are those of HANSON et al. (1966) for a pegmatite of Valle Grosina (Sondrio): the muscovite gives a Rb-Sr age of 252 m.y. and a K-Ar age of 217 ± 11 m.y.. This pegmatite had previously been considered Alpine by KÖNIG (1964). At that time, the age of pegmatite dykes was regarded as independent of metamorphism.

The Valle Grosina pegmatites, as well as all the « pegmatite fields » connected with the transition between medium- and high-grade metamorphism, are now seen as the product of partial melting of muscovite + plagioclase + quartz under hydrous conditions (BORIANI, 1982-83). The muscovite age thus reflects the cooling history after the metamorphic peak, if the region did not suffer a later metamorphic event.

U-Pb mineral ages

Only one measurement has so far been published (even if we are aware that many exist in the drawers of some prudent geochronologists): a U-Pb zircon determination (GRAUERT et al., 1973) on a paragneiss from the contact aureole of the Sondalo basic pluton of Northern Valtellina. The ages are discordant: the upper intercept is about 2050 m.y. and the lower intercept about 400 m.y.. They are similar to those obtained by the same authors on the Austroalpine quartzites of Val Martello and Landeck, as well as those for the Silvretta Nappe and the Southalpine basement.

1.4. MAGMATIC ROCKS OF THE AUSTRALPINE

In contrast with the almost constant late-Hercynian age of the plutonic rocks of the Southern Alps (the exceptions are the Adamello pluton and the small stock of Mialigiano-Biella), the Austroalpine intrusives belong to either the pre-Alpine or the Alpine magmatic cycles. Each magmatic body must be studied in detail geochronologically and geologically. The best evidence is given by the sequence of the metamorphic events: if the Alpine regional metamorphism overprints both the intrusive and the country rocks, the intrusion is pre-Alpine; if the contact metamorphism overprints the Alpine regional metamorphism, the intrusion is late- or post-Alpine.

The Rb-Sr muscovite age of the small granite bodies of the Upper and Medium Austroalpine Nappes of Valtellina (showing greenschist-facies Alpine overprint) is between 259 and 282 m.y., while biotite gives very variable younger ages (224-78 m.y.) (DEL MORO et al., 1982-83; BORIANI

et al., 1982-83). This pattern clearly reflects the lower blocking temperature of the biotite Rb-Sr system, which may have been re-opened by the Alpine metamorphism, resulting in a variable loss of radiogenic Sr, mostly in this mineral.

Only one Rb-Sr biotite age measurement has been performed on the Sondalo basic pluton (242 ± 4 m.y., pers. com. from DEL MORO, NOTARPIETRO and POTENZA).

Pb- α zircon ages of 295-260 m.y. were obtained by BUCHS et al. (1962) on the Bernina intrusive rocks. A U-Pb zircon age of 305 ± 10 m.y., performed by Grünfelder on a Bernina granite, is cited by RAGETH (1984).

A reference isochron of about 285 m.y. has been published by BORIANI et al. (1982-83) for the Brusio granite.

The radiometric ages of the Austroalpine basement of Central Alps (E of Bellinzona) are enough to show that the pre-Alpine evolution is the same as that of the Southalpine basement. The presence of Permian volcanic rocks in the Bernina group and the few age determinations also suggest that the post-Hercynian igneous activity was similar, though the age and the genetic relationships between the basic and acidic igneous rocks are not yet fully understood.

The Alpine metamorphism induced a grade-dependent loss of radiogenic isotopes; since it was retrogressive, the loss is strictly related to the fluid circulation and hence the degree of Eo-Alpine tectonization.

2. Prealpine and Alpine history of the Pennidic domain

In the Western Alps the Ossola Valley l.s. is one of the most studied geological sections since the past century, because of the complete exposure of Pennidic Units.

All the lower and upper nappes are overthrust on the deepest, probably autochthonous, element, i.e. the Verampio «granite» in the Antigorio Valley. In Tessin there is another corresponding axial culmination. Here the deepest Unit is the Leventina gneiss. Between these two culminations, there is a synform structure running NS with the Maggia Querzone in the core and hence no continuity between the two areas.

In the Ossola-Antigorio Valley, the ascending lower Penninic Units are: Antigorio, Lebendun and Monte Leone nappes. The Antigorio nappe is separated from the Verampio «granite» by the «Scisti di Baceno», a complex of metapelitic rocks with minor marble intercalations.

It mostly consists of granitic orthogneisses with different degrees of deformation, minor paragneisses and rare mesozoic sedimentary sequences occurring as small «klippen» (e.g. Monte Forno, Antigorio Valley).

The Monte Leone nappe, too, mostly consists of granitic orthogneisses with a very typical banded texture recalling the texture of primary rhyolitic volcanites.

The Lebendun Unit needs special attention. It is probably not a classic nappe because it appears to have no root zone. It may be a flake of Permo-Carboniferous and Mesozoic cover from the north (ultrahelvetetic?) and wedged between the Antigorio and Monte Leone nappes. Its lithological association is strictly analogous to that of the «Bedretto synform» separating the Penninic Units from the parautochthonous Aar-Gotthard Massif. The series includes a very characteristic horizon on the bottom of Jurassic «Bündnerschiefer» (represented by «Quartenschiefer» or «Garbenschiefer») and begins with conglomeratic rocks containing pebbles of granitic orthogneisses. These have been given Rb-Sr and K-Ar dates.

The upper Penninic Units consist of the Monte Rosa nappe and the Moncucco-Orselina-Isorno Series. To the east of Ossola Valley only the vertical southern zone of the Monte Rosa nappe occurs. Known as Monte Rosa Zone, it is separated from the Moncucco Series l.s. by a thin horizon of serpentinites and metabasites (Antrona synform granitic orthogneisses (quartz, megacrysts of «root zone» auct.) and mostly consists of K-feldspar, plagioclase, muscovite/phengite, biotite) and rare paragneisses; these may be the primary basement intruded by granites. The orthogneisses show flaser texture along the border of the mass and augen texture internally.

The Moncucco-Orselina-Isorno Series is an «anomalous» element when compared with the other Penninic Units. It mostly consists of banded paragneisses l.s. and amphibolitic

paragneisses, with minor orthogneisses, amphibolites and rare serpentinites. The orthogneisses occur in continuous, but rather thin horizons. The Moncucco Series l.s. can be related to the S. Bernardo nappe because of its lithological composition. To the west of the Ossola Valley, at the southern border of the Moncucco Series, there is a thick mass of augengneisses with megacrysts of K-feldspar (Camughera gneisses). This was once regarded as connected to the Moncucco Series; but it shows clear microtextural and structural analogies with the gneisses of the Monte Rosa nappe. The preliminary radiometric data also substantiate the strong analogy between the Camughera and Monte Rosa gneisses and raise the same evolutionary problems. The Camughera gneiss is separated from the Moncucco Series l.s. by a thin and discontinuous horizon of metarhyolites, quartzites and marbles, which may be Permo-triassic (primary sedimentary cover?).

In the core of a synform structure in this Series there is a very problematic Unit: the so-called Pioda di Crana Zone. This tectonic element consists of a large, rather homogeneous «slab» of granitic banded gneisses, formerly correlated with the Antigorio nappe. Because of its strongly banded texture and its mineralogical composition it may be of volcanic or volcano-sedimentary origin. Moreover it can probably be correlated with the Monte Leone rather than the Antigorio nappe.

In Tessin, the Simano nappe overlies the Leventina gneisses at the same structural level as the Antigorio nappe. It mostly consists of orthogneisses. The uppermost nappe, the Maggia nappe, seems to be analogous to the Moncucco Series l.s. lithologically, but is not directly connected with it.

In Alpine age, all the Simplon-Tessin area underwent a metamorphic event of medium to high grade from west to east, which almost completely obliterated the older metamorphic features. The tectonic Units are all within the staurolite isograds; to the east, there is a transition from staurolite to kyanite and to sillimanite. Sillimanite appears in the eastern Vigizzo Valley and coincides with the occurrence of unmetamorphosed pegmatites. These are more frequent in Tessin near Locarno and Bellin-

zona, which is right in the thermal core of the Lepontine dome.

In the Penninic Units of the Western Alps the radiometric datings are mostly for orthogneisses. Few pegmatites and paragneisses have been studied. There are also Rb-Sr whole rock isochrons. The methods most used are Rb-Sr and K-Ar on biotite and muscovite/phengite. There are few U-Pb data on zircons and monazites and very few on the apatite fission track.

The geological setting described is based on several notes and maps, mainly STEINER (1984 a), BIGIOGGERO et al. (1980), TRÜMPY (1980 a, b), CARTA TETTONICA DELLA SVIZZERA (1980), CARTA GEOLOGICA DELLA SVIZZERA (1980), KLEIN (1978), BOCQUET et al. (1973-74).

2.1. LOWER PENNINIC UNITS

Rb-Sr and K-Ar ages

There are only ages on biotite and muscovite/phengite from Verampio, Antigorio and Monte Leone orthogneisses; in the Lebendun Series there are ages on micas from psammitic gneisses and their embedded orthogneiss pebbles.

The data are not problematic: in the Ossola area Rb-Sr ages on biotite and K/Ar ages on biotite and muscovite (blocking temperature around 300°C) are relatively concordant between 12-14 m.y. (JÄGER et al., 1967; PURDY & JÄGER, 1976); Rb/Sr ages on muscovite/phengite (blocking temperature = 500°C) are a little more variable between 16 and 20 m.y.. They are regarded as cooling ages postdating the Lepontine thermal peak (38 m.y. - HUNZIKER, 1970, 1974; JÄGER, 1973) and are undoubtedly the youngest ages Rb-Sr and K-Ar in the Ossola-Tessin area.

The Verampio, Antigorio and Monte Leone orthogneisses outcrop in a north-western, rather external, zone of the Lepontine dome, and their ages point to later uplifting compared with more internal zones. The Antigorio orthogneisses in Tessin show slightly different ages. The few data (for biotite only) give ages around 14-16 m.y., i.e. an earlier uplift compared with the Ossola area. STEIGER and BUCHER (in KÖPPEL & GRÜNENFELDER, 1980) regard the Rb-Sr biotite ages of the cross-biotite bearing

rocks from the southern Gotthard Massif (16-15 m.y.) as crystallization ages corresponding to the last phase of prograde alpine metamorphism. This, however, would postdate the intrusion of the tertiary granitoid rocks: this is not true in the Bergell intrusion since its contact metamorphic aureole overprints regional metamorphism.

The Rb-Sr and K-Ar ages for the Lebendun gneisses agree with those of the Antigorio and Monte Leone gneisses. The micas of the orthogneiss pebbles embedded in conglomeratic gneisses also have alpine ages indicative of complete reequilibration of the Rb-Sr and K-Ar system. The Lebendun Unit, like the other lower Penninic Units, is well within the staurolite isograd. Persistence at $T > 500^\circ\text{C}$ for a long time may explain the complete rehomogenization of the isotopic systems as evidenced by the very young cooling ages.

U-Pb ages

Here, too, the data are confined to zircons and monazites of orthogneisses (ALLÈGRE et al., 1974; KÖPPEL et al., 1980). The U-Pb ages on zircons do not reflect the alpine event; all are older, between 100 and 250 m.y., except LEB 2 (300-450 m.y.) and SIM 1 (450-500 m.y.). The $^{207}\text{Pb}/^{206}\text{Pb}$ ages are always higher than the U-Pb ages: according to KÖPPEL et al. (1980), this is due to uncertainty of the common Pb correction, the radioactive disequilibria at the time of crystallization and to analytical errors. As the Alpine event is undeniable, it is clear that the U-Pb ages reflect a drastic lead loss during post-Hercynian times. Even though the U-Pb system on zircons is resistant to complete resetting due to metamorphic events, the Alpine event can have partially opened it. The U-Pb ages for the lower Penninic orthogneisses thus fail to give a complete account for their prealpine history. On the basis of the upper intercept ages < 340 m.y. on the concordia curve, the Verampio, Antigorio and Leventina orthogneisses are interpreted as Hercynian granites. In Tessin, the Simano gneiss, though similar to the Antigorio, is much older, suggesting Caledonian intrusion age or drastic resetting around 450 m.y. due to anatexis of sedimentary rocks: in this case, the zircons would be inherited. The old age of LEB 2

(augengneiss pebble in metaconglomerate) seems to be its intrusion age or further evidence of drastic resetting around 450 m.y.

On the large scale, a relationship is noticeable between U-Pb zircon age and alpine metamorphism intensity (ALLÈGRE et al., 1974): the younger the age, the higher the intensity. The Simplon Units are younger than the Silvretta nappe (Austroalpine domain) or the Gotthard Massif. On a small scale, this is not true. In Tessin, the Maggia gneisses are older than those of the Ossola area, though the intensity of the Alpine metamorphism was higher.

Only the monazites of the Maggia and Simano nappes (Tessin) have been dated with U-Pb and Pb-Pb methods (KÖPPEL et al., 1980). The ages around 22 m.y. are seen as formation ages of the monazites during the Alpine event, whereas for HUNZIKER & JÄGER they are cooling ages (blocking temperature = 530°C). Furthermore, according to KÖPPEL et al. (1980), the age of 22 m.y. would indicate the end of the medium-grade conditions, owing to the absence of monazites in low grade rocks.

The older ages between 200 and 300 m.y. are more problematic. They may be mixed ages due to partial opening of the U-Pb system in the Alpine time or to the presence of two populations of monazites.

2.2. UPPER PENNIDIC UNITS

Rb-Sr and K-Ar ages

In the upper Pennidic domain, too, dating has been virtually confined to orthogneisses in the Moncucco-Orselina-Isorno Series and in the Monte Rosa nappe (BIGIOGGERO et al., 1982-83; PURDY & JÄGER, 1976; JÄGER et al., 1967; FERRARA et al., 1962; FREY et al., 1976; HUNZIKER, 1970, 1969).

The Rb-Sr whole rock isochron on eight orthogneisses of the Moncucco Series l.s. gives an age of 271.6 ± 4.8 m.y. with an initial isotopic strontium ratio of 0.712 ± 0.0004 (BIGIOGGERO et al., 1982-83). This is regarded as the intrusion age of granites in late-Hercynian time. The strontium ratio points to crustal genesis of the melt. These orthogneisses are thus late-Hercynian granites that underwent the alpine metamorphism.

The Rb-Sr and K-Ar ages for biotites and muscovites are cooling ages postdating the thermal Lepontine peak. The Rb-Sr biotite and K-Ar muscovite data are homogeneous, whereas the Rb-Sr muscovite data range between 25 and 29 m.y., probably due to imperfect correction for the common strontium. The Rb-Sr muscovite isochron gives 36.9 ± 1.7 m.y. (BIGIOGGERO et al., 1982-83) in agreement with the Lepontine metamorphic phase: the strontium i.r. (0.7162 ± 0.0029) indicates that the muscovites are pre-alpine and recrystallized during the alpine event. The Rb-Sr and K-Ar ages for micas of some paragneisses in this Series, also agree with those of the orthogneisses (JÄGER et al., 1967).

The data from some pegmatite samples are more problematic (JÄGER et al., 1967; FERRARA et al., 1962). On one hand, there is a single Rb-Sr biotite age (25.9 ± 5.4 m.y.) that is a little higher than those of the orthogneisses, but still an alpine cooling age; on the other hand, there are some Rb-Sr muscovite ages either around 25 m.y. or 200 m.y. (Montescheno, I Mondei Quarry - Antrona Valley). The latter may correspond to the intrusion age. Triassic pegmatites are unknown in the Central Alps; however, the presence of old ages in a zone within the staurolite isograd where the temperature was $> 500^\circ\text{C}$ requires explanation. Since the oldest ages were found in coarse grained muscovites, it may be that they have much better Sr retention and that the pegmatites underwent a temperature $> 500^\circ\text{C}$ for a relatively short time. The age of 37 m.y., in fact, was obtained from a muscovite isochron. Moreover, the sampling area is quite near the clorithoid-out—staurolite-in isograd, in the western part of the Lepontine dome: the temperature may not have been uniform everywhere.

Old Rb-Sr ages (around 200 m.y.) have also been found on muscovite of the Camughera orthogneisses occurring in the middle and upper Antrona Valley (data in press): this area is nearer to the clorithoid zone but still within the staurolite isograd. The Camughera gneisses show isotopic disequilibrium similar to those of the Monte Rosa gneisses. The latter have an age of 310 ± 50 m.y. obtained with the Rb-Sr isochron method on whole rock (Sr i.r. = $0.712 \pm$

0.007). This age is interpreted as the formation age of granite. Another isochron on more gneissic orthogneisses gives an age of 260 ± 10 m.y. with $Sr\ i.r. = 0.713 \pm 0.004$. HUNZIKER (1970), FREY et al. (1976) consider this age as due to a late-metamorphic phase of the Hercynian event. However, there is no large scale evidence of the Permian metamorphism in the Alps.

Apatite Fission Track - Lower and Upper Penninic Units

Few data are available. The apatite fission track (FT) ages are cooling ages (WAGNER et al., 1977) when the rock temperature was $120 \pm 20^\circ C$ during the post-metamorphic cooling process (WAGNER & REIMER, 1972).

The apatite FT ages increase with altitude in the same area. In the Central Alps, the Gotthard and Ossola area show the youngest ages (< 5 m.y.) and were therefore uplifted later than other more easterly zones. On a small scale, the upper Penninic Units seem to have been uplifted earlier than the lower Units.

Moreover the apatite FT and Rb-Sr ages have been used by WAGNER et al. (1977) to calculate the uplift rate of the Lepontine dome, assuming $30^\circ C/Km$ as geothermal gradient. Generally speaking, the eastern zones have generally decreased their uplift rate, while the western areas have increased it. On a small scale, the lower Penninic Units in Ossola accelerated their uplift rate from 0.7 to 1.1 mm/y. about 3 m.y. a. and the upper Units from 0.3 to 0.7 mm/y. about 6 m.y. a., whereas in Tessin the uplift rate decreased from 1.3 to 0.4 mm/y. about 20 m.y. a..

3. Post-collisional Alpine magmatism

3.1. ADAMELLO

The Adamello pluton, the largest Alpine igneous body of Alpidic age, lies at the intersection of two late-Alpine fundamental tectonic lineaments, i.e. the Tonale and the Giudicarie faults. Its Tertiary age was deduced from the geological evidence (CORNELIUS, 1928; BIANCHI & DAL PIAZ, 1937) and has been radiometrically demonstrated by FERRARA (1962), BORSI et al. (1966),

BORSI et al. (1977), DEL MORO et al., (1983 a).

The pluton was intruded discordantly into the Southalpine basement and its Permo-Mesozoic cover after the compressive phase responsible for the large E-W folds immediately W of the massif. The age of this folding is not precisely known. The youngest intruded terrain is the *Dolomia principale* of Carnian-Norian age (BRACK, 1983). The basement consist of metasedimentary rocks showing pre-Alpine metamorphism of chloritoid and staurolite grade followed by a retrogressive overprint in which the contact metamorphism generated new biotite, andalusite, cordierite and sillimanite, in order of increasing temperature (BORIANI & GIOBBI, 1982-83).

Emplacement seems to have taken place through successive inputs of analogous magma associations (gabbro, tonalite, granodiorite, quartzdiorite) starting from the south (M. Re di Castello) 42 m.y. a. and ending 29 m.y. a. in the northeastern sector (M. Presanella) (DEL MORO et al., 1983 a).

The geochemical, petrological and textural characters of the Adamello pluton permit its division into five units:

- 1 - Re di Castello (gabbro, tonalite, granodiorite);
- 2 - Adamello (gabbro, tonalite, leucotonalite);
- 3 - Avio (biotite-tonalite);
- 4 - Corno Alto (trondhjemitite);
- 5 - Presanella (hornblende-tonalite and biotite-tonalite).

Each unit displays basic to acidic magmatic fractionation particularly evident in the Re di Castello Unit. The five units share a clear genetic link: evolution of the same primary calcalkaline basic magma through fractional crystallization and assimilation of crustal material (DEL MORO et al., 1983 b; MACERA et al., 1983).

The first age measurements on this massif were performed by FERRARA (1962) with the Rb-Sr method on a very limited number of samples from the main pluton and the Sostino stock. The ages range from 33 m.y. to 45 m.y. (table 13 a). BORSI et al. (1966) determined Rb-Sr and K-Ar ages of 31 and 30 m.y. on samples from Corno Alto, i.e. the Corno Alto rocks appear to be younger

than most of the tonalites in the rest of the massif (tables 13, 13 a).

Further Rb-Sr and K-Ar radiometric analyses presented by BORSI et al. (1977) at the 5th ECOG in Pisa showed decreasing ages from SW to NE, i.e. from the more basic rocks of M. Re di Castello to the granodiorites-tonalites of Presanella in a range between 52 and 29 m.y.. BORSI et al. (1977) see this as evidence that the pluton formed through a polyphasic magma generation in a layered crust, beginning in the deep crust and continuing at a shallower level.

The most recent K-Ar and Rb-Sr age measurements on micas and amphiboles from Adamello were presented by DEL MORO et al. (1983 a) at the Padua meeting of the Soc. Geol. Italiana (proceedings in press). They corroborate the pattern revealed by BORSI et al. (1977). Nevertheless, more complete sampling and improved analytical techniques have allowed DEL MORO et al. (1983 a) to assign more precise ages to each Unit. There is a general decrease from 42 m.y. (Re di Castello leucoquartzdiorites) to 29 m.y. (Presanella granodiorites) in the NE part of the massif (tables 13, 13 a). The Corno Alto and Sostino Units, also in the NE sector, depart from this sequence, since their Rb-Sr muscovite age of 41-42 m.y. is comparable to that of the M. Re di Castello leucoquartzdiorites.

VILLA (1983) has performed K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ determinations on amphiboles from the gabbros occurring at the margin of main units (table 13); the age of M. Mattoni gabbro (the most southerly Unit) is between 49 and 42 m.y., that of the M. Blumone gabbro is 41.7 m.y., and that of the M. Marser gabbro is 37 m.y. (max. age).

DEL MORO et al. (1983 a) have interpreted these ages as intrusion ages. Intrusion was followed by rapid cooling, except that the Corno Alto and Sostino bodies cooled much more slowly owing to their different intrusion history. According to these authors, the age decrease from SW to NE of the pluton can be attributed to a magma source migration, or to northward migration of the fractured zones through which the magma raised up.

One of the more difficult problems in the Adamello geochronology is that of the discordant ages given by the same method for different minerals. In particular, the K-Ar

age of the amphibole is often older than that of the micas. Comparison of the K-Ar and the $^{40}\text{Ar}/^{39}\text{Ar}$ results reveals that the discordance is due to Ar excess in the amphibole. This is attributed by VILLA (1983) to assimilation of the crystalline basement. Since the $^{40}\text{Ar}/^{39}\text{Ar}$ method does not always reveal the amount of the excess argon, the ages must be considered as max. ages.

Summing up, geochronological study of the Adamello pluton has contributed much to its geological reconstruction. According to DEL MORO et al. (1983 a, b), the intrusion sequence is accompanied by a regular increase in the initial $^{87}\text{Sr}/^{86}\text{Sr}$ as well as the $^{18}\text{O}/^{16}\text{O}$, due to an increase in crustal assimilation with time. Northward migration of the intrusive activity towards the Insubric line was a consequence of the extensional tectonics, that followed the compressional regime of the Alpine orogeny.

3.2. VAL MASINO - VAL BREGAGLIA (OR BERGELLER) MASSIF

North of the Insubric Line, at the confluence of Valtellina and Valle della Mera, the Alpine units are intruded by a late-Oligocene calcalkaline igneous body of predominantly tonalitic and granodioritic composition that extends westwards in a long tail, known as the « San Iorio intrusion »; the « Novate granite » or « San Fedelino granite » is a two-mica leucogranite geographically connected with the Val Masino - Val Bregaglia pluton, but may not be genetically related to the other lithologies (TROMMSDORF & NIEVERGELT, 1983).

The southern part of the massif is dominated by hornblende-biotite tonalite (« serizzo ») with minor ultramafic cumulates and cumulitic gabbros, while the northern and central part consist of a younger, porphyritic biotite-granodiorite (« ghiandone »).

The tonalite is almost concordant in the southern part. Here a true contact aureole cannot be discerned and post-intrusion plastic deformation gives the tonalite a variously pronounced gneissic fabric.

In the northern and eastern parts, cross cutting is clear. There is a distinct contact aureole and only brittle post-crystalline deformation.

These differences reflect a difference in intrusion level. The depth of intrusion increases from NE to SW by at least 8 Km.

The Val Masino - Val Bregaglia intrusion is later than the Lepontine regional metamorphism. In its easternmost contact aureole, NIEVERGELT & DIETRICH (1977), GAUTSCHI & MONTRASIO (1978) and WENK (1980) have found andesitic-basaltic dykes that are undeformed and crosscut the folded and metamorphosed country rocks, but were affected by contact metamorphism induced by the tonalite intrusion.

The Alpine, post-nappe age of the intrusion was demonstrated by CORNELIUS (1913), who observed that the pluton crosscuts the Alpine Nappe boundaries. A different interpretation was put forward by DRESCHER-KADEN (1940, 1969), ARTUS (1959), WENK (1973, 1983) who attributed the Val Masino - Val Bregaglia pluton to granitization of pre-existing rocks.

Boulders of tonalite are present in the « Como conglomerate », dated as Lower Miocene by PFISTER (1921), Early Oligocene by CITA (1957) and Late Oligocene - Lower Miocene by LONGO (1968) and ROEGEL et al. (1975).

ARMSTRONG et al. (1966) performed Rb-Sr and K-Ar age measurements on biotites of the granodiorite, obtaining values of 24 ± 2.5 and 24.8 ± 1.5 m.y. respect (tables 14, 14 a). JÄGER & HUNZIKER (1969) measured a Rb-Sr muscovite age of 35.5 m.y. and a biotite age of 24 m.y. for the tonalite and granodiorite, while for the « Novate granite » they found 22-24 m.y. and 18 m.y.. This discordance was ascribed to the time elapsed between magma generation and intrusion. The most recent age determination on the Val Masino - Val Bregaglia pluton are those of BORSI (Rb-Sr on biotite), though they have remained unpublished owing to his untimely death.

GRÜNENFELDER & STERN (1960) obtained values of 25 ± 10 and 30 ± 10 m.y. with U-Pb method on two zircons from Albigna. CHESSEX (1964) obtained values of 25 ± 3 m.y. for the « quartzmonzonite » of the northern part and 32-33 m.y. for the « diorite » of the southern part, using the radiation damage method on zircons.

In 1973, GULSON & KROGH analysed zircons, monazites and sphenes from tonalites,

and granodiorites and from the « Novate granite ». The oldest apparent age (65 m.y.) determined on the « Novate granite » was attributed to the presence of an inherited lead component. From the concordant monazite age, and from the lower intercept of a chord joining monazite, zircon and sphene, those workers obtained an age of at least 30 m.y. for the granodiorite crystallization. The intrusion postdates the piling up of the nappes and the main Alpine metamorphism. On comparing the U-Pb monazite and Rb-Sr biotite ages for the same samples, KÖPPEL & GRÜNENFELDER (1975) found that monazite ages are always older: 30 m.y. and 24.8 ± 1.5 m.y. in the Val Masino - Val Bregaglia granodiorite; 26.6 m.y. and 17.7 ± 1 m.y. in the « Novate granite ». According to KÖPPEL & GRÜNENFELDER (1975) the monazite ages of the Lepontine area do not reflect its cooling history, but the crystallization time under high grade metamorphic conditions: the 30 m.y. monazite age of the granodiorite also represents the time of crystallization of the Val Masino - Val Bregaglia pluton, while the Rb-Sr biotite age (25 m.y.) is a cooling age that fits in well with the cooling pattern of the country rocks W of the pluton.

GULSON (1973) could not find a Rb-Sr w.r. isochron for the pluton and the Novate stock because of the low Rb/Sr ratio (always less than 1), and the young age of the intrusion.

Some granodiorite, aplite and pegmatite samples from the Val Masino - Val Bregaglia rocks and Novate granite gave two reference lines at 65 ± 17 m.y. and 25 ± 80 m.y. resp. (table 14 a).

Two age determinations on Bregaglia granodiorite and Novate granite performed by WAGNER et al. (1977, 1979), with apatite FT, gave 13.5 m.y. and 11.2 m.y. respectively. The importance of apatite FT ages in intrusive and metamorphic rocks, when compared with mica Rb-Sr and mica K-Ar ages (considered as cooling ages), is due to their ability to exhibit the uplift history of a region since the uplift rate is considered to be proportional to the cooling rate (WAGNER et al., 1977).

Later WAGNER et al. (1979) extended their apatite FT age determinations in the Val Masino - Val Bregaglia region and also

dated the boulders of the Como Conglomerate from the pluton. Their aim was to determine the uplift history of the Bregaglia region in comparison to that of the Central Alps and reassign the granitic boulders of the conglomerate to their original vertical position within the Bregaglia granodiorite prior to erosion. Comparison between apatite *FT*, mica Rb-Sr and mica K-Ar ages for samples collected at different levels of the Bregaglia region showed that the uplift rate of the pluton decreased with time. A similar study of the boulders embedded in Late Oligocene sediments indicated that the body from which they derive must have reached

the erosional surface between 24.5 and 22 m.y. ago.

According to WAGNER et al. (1979) the boulders are derived from an higher, now eroded, part of the pluton, because their apatite *FT* ages are older than those of the granodiorite now outcropping in the Bregaglia region.

The original elevation of the top of the Bregaglia intrusive body must have been 8 Km higher than at present.

Lavoro eseguito nell'ambito dei programmi del Centro di Studio per la Stratigrafia e la Petrografia delle Alpi Centrali del C.N.R. di Milano.

TABLE 2 (continued)

TABLE 2 (continued)

Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	Sr ppm	⁸⁷ Rb/ ⁸⁶ Sr _c	(⁸⁷ Sr/ ⁸⁶ Sr) _m	(⁸⁷ Sr/ ⁸⁶ Sr) _i	AGE Ma	Ref.
Orthogneiss S.L.	LM 80-2	Bi	416	4.7	290	1.9378 ± 30		298 ± 5	1
"		WR	61	378	0.47	0.7071 ± 3			1
"	LM 80-3	WR	70	343	0.59	0.7093 ± 2			1
"	LM 80-4	Bi	700	3.0	977	5.1082 ± 90		316 ± 5	1
"		WR	146	119	3.54	0.7320 ± 2			1
"	LM 80-5	WR	154	118	3.79	0.7325 ± 2			1
"	LM 80-6	WR	143	142	2.92	0.7285 ± 2			1
"	LM 80-8	WR	95	202	1.36	0.7180 ± 4			1
"	LM 80-10	WR	95	197	1.39	0.7177 ± 2			1
"	LM 80-12	WR	90	193	1.35	0.7180 ± 2			1
"	LM 80-13	WR	87	192	1.32	0.7175 ± 2			1
"	LM 80-14	Mu	757	6.9	373	2.4561 ± 34		325 ± 5	1
"		WR	209	62	9.91	0.7762 ± 2			1
"	LM 80-15	WR	59	343	0.49	0.7077 ± 2			1
Augengneiss S.L.	LM 80-17	WR	215	72	8.73	0.7652 ± 2			1

$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$
S.L. = Serie dei Laghi
1) Boriani et al. (1982-83)

TABLE 2 (continued)

Rb-Sr ages

Rock type	Sample n.	Material	⁸⁷ Rb ppm	⁸⁷ Sr ppm	%rad	Sp comm ppm	⁸⁷ Sr/ ⁸⁶ Sr	⁸⁷ Rb/ ⁸⁶ Sr	AGE Ma	Ref.
Stronalite	KAW 447	Bi	180	0.490	20.6	27.3	0.8976	66.185	185 ± 15	184 1
Ivrea-Verbano		Bi	181	0.498	21.1	27.0			187 ± 16	
	448-454	Bi	182	0.502	34.7	13.7	1.0860	136.45	187 ± 9	
Pegmatite	KAW 484	Mu	118	0.410	42.2	2.33	1.229	521.24	236 ± 10	
Amphibolite	KAW 84	Bi	156	0.396	23.7	18.4			172 ± 13	2
Peridotite	KAW 81	Phl	128	0.304	3.1	140			160 ± 100	2
Pegmatite	B 44	Bi	103	0.245	34.2	6.83			162 ± 8	3
		Bi	106	0.245	34.0	6.90			157 ± 8	3
	KAW 51	Mu	139	0.442	62.1	3.9			216 ± 9	3
Granite (Montorfano)	A 8	Bi	233	0.941	76.4	4.20			274 ± 11	3
Granodiorite (Campioni)	KAW 80	Bi	132	0.368		3.7			189 ± 8	4

1) Graeser & Hunziker (1968); 2) Jäger (1962); 3) Jäger, Niggli & Wenk (1967)
4) Hunziker (1974)

$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$

TABLE 2 (continued)

Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr ppm	$^{\circ}\text{rad}$	Sp. concn. ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Rb}/^{86}\text{Sr}$	AGE Ma	Ref.
Stronalite	KAW 472	WR	22.6	0.185	2.2	118	0.7252	1.9730	555 $\pm$ 500	1
Ivrea-Verbano	471	WR	33.8	0.357	3.9	128	0.7379	2.7285	715 $\pm$ 370	980 1
Zone	447	WR	23.6	0.200	2.0	143	0.7235	1.6945	575 $\pm$ 585	1
(Anzola)	448	WR	20.0	0.206	2.1	142	0.7244	1.4510	695 $\pm$ 680	1
	449	WR	14.6	0.225	1.7	192	0.7212	0.7824	1040 $\pm$ 1260	1
	450	WR	9.2	0.193	1.3	207	0.7187	0.4518	1410 $\pm$ 2170	1
	451	WR	13.0	0.310	1.1	390	0.7172	0.3423	1600 $\pm$ 2890	1
	452	WR	9.5	0.202	1.3	226	0.7175	0.4357	1290 $\pm$ 2500	310 1
	453	WR	23.8	0.204	1.9	148	0.7233	1.9959	580 $\pm$ 595	1
	454	WR	22.1	0.144	2.5	113	0.7276	2.0187	440 $\pm$ 355	1
	477	WR	33.0	0.212	3.3	91.5	0.7332	3.7189	440 $\pm$ 270	1
	478	WR	25.7	0.145	3.2	63.4	0.7325	4.1669	385 $\pm$ 240	1
	468	WR	33.3	0.259	3.8	131	0.7371	3.6051	530 $\pm$ 275	1
Gabbro (id.)	446	WR	0.15	-	-	129	0.7083	0.012	-	1

$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$

1) Graeser & Hunziker (1968)

TABLE 2 (continued)

Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_m$	$(^{87}\text{Sr}/^{86}\text{Sr})_i$	AGE Ma	Ref.
Augengneiss	LM 80-19	Mu	753	2.5	1458	7.2692 $\pm$ 49		311 $\pm$ 5	1
		Bi	1528	1.9	10638	36.267 $\pm$ 167		234 $\pm$ 4	1
(M. Vadà)		WR	252	16	47.94	1.0371 $\pm$ 2			1
	LM 80-20	WR	221	65	9.94	0.7745 $\pm$ 2			1
	LM 80-21	WR	182	88	6.02	0.7490 $\pm$ 2			1
	LO 81-2	Bi	563	5.6	321	1.8315 $\pm$ 31		244 $\pm$ 4	1
		WR	128	129	2.88	0.7275 $\pm$ 3			1
	LO 81-7	WR	193	62	9.11	0.7702 $\pm$ 2			1
Orthogneiss (including the Augengneisses)									
Isochron		WR					0.7087 $\pm$ 0.0002	466 $\pm$ 5	1

$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$

1) Boriani et al. (1982-83)

TABLE 2 (continued)

Rb-Sr ages

Rock type	Sample n.	Material	⁸⁷ Rb ppm	⁸⁷ Sr ppm	Sr concn ppm	⁸⁷ Rb/ ⁸⁶ Sr	⁸⁷ Sr/ ⁸⁶ Sr	Isochron AGE Ma	Ref.
Rhyolite	KAW 183	WR	60.2	0.242	25.8	23.96	0.8055	$269 \pm 13^*$ <i>(i.r.=0.710±0.004)</i>	1
"	KAW 184	WR	64.0	0.260	18.0	36.61	0.8577		1
"	KAW 908	WR	70.2	0.278	9.2	79.05	1.0185		1
"	KAW 909	WR	60.6	0.240	81.5	7.637	0.7386		1
Rhyolite tuff	KAW 910	WR	60.1	0.254	132	4.690	0.7291	278 ± 3 <i>(i.r.=0.7082±0.0007)</i>	1
Granodiorite	KAW80(Camponi)	WR	35.3		450	0.80246	0.71144		2
Granite	KAW 598(Baveno)	WR	62.4		20.1	31.688	0.83341		2
"	KAW 907(Baveno)	WR	69.1		22.4	31.531	0.83040	276 ± 5 <i>(i.r.=0.7087±0.0009)</i>	2
"	KAW 906(Montor.)	WR	56.9		85.6	6.7961	0.73590		2
"	KAW 565 (Alzo)	WR	56.1		78.7	7.2885	0.73938		2
"	KAW1204(Roccap.)	WR	37.9		196	1.9785	0.71516		2

$\lambda^* = 1.47 \times 10^{-11} \text{ a}^{-1}$; $\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$
 1) Hunziker (1974); 2) Hunziker & Zingg (1980)

TABLE 3 - U-Pb ages

Rock type	Sample n.	grain size Mag. suscept.	Mat.	U ppm	Th ppm	Pb rad ppm	Atomic ratios				AGE Ma				Ref.
							$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{207}{206}\text{Pb}$	$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{208}{232}\text{Pb}$	$\frac{207}{206}\text{Pb}$		
							238 U	235 U	Pb	238 U	235 U	232 Th	206 Pb		
Orthogneiss	1A	150-75	Zr	1403		94.9	0.07077	0.5715	0.05857	445	465		564	1	
(Strona-Ceneri)	1B	75-53	Zr	1617		107.1	0.06893	0.5394	0.05675	434	444		494	1	
	1C	53-42	Zr	1620		107.0	0.06880	0.5369	0.05660	433	442		488	1	
	1D	<42	Zr	1626		108.1	0.06882	0.5357	0.05645	433	441		482	1	
Paragneiss	2A	150-75 n.m.	Zr	431		58.0	0.1297	1.540	0.08607	794	959		1362	1	
(Strona-Ceneri)	2A	150-75 n.m.	Zr	444		59.2	0.1283	1.532	0.08654	786	956		1374	1	
	2B	75-53 n.m.	Zr	473		62.1	0.1271	1.490	0.08505	778	938		1340	1	
	2C	53-42 n.m.	Zr	519		64.7	0.1220	1.404	0.08346	749	902		1302	1	
	2D	<42 n.m.	Zr	593		69.4	0.1154	1.289	0.08102	711	852		1244	1	
	2AM	150-75 m.	Zr	733		85.0	0.1137	1.248	0.07973	702	834		1212	1	
	2CM	53-42 m.	Zr	690		80.8	0.1150	1.247	0.07867	708	833		1184	1	
	2DM	<42 m.	Zr	862		95.6	0.1092	1.157	0.07689	674	791		1138	1	

1) Pidgeon et al. (1970)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	grain size Mag. suscept.	Mat.	U ppm	Th ppm	Pb rad ppm	Atomic ratios			AGE Ma				Ref.
							$\frac{206}{238}\frac{Pb}{U}$	$\frac{207}{235}\frac{Pb}{U}$	$\frac{208}{206}\frac{Pb}{Pb}$	$\frac{206}{238}\frac{Pb}{U}$	$\frac{207}{235}\frac{Pb}{U}$	$\frac{208}{232}\frac{Pb}{Th}$	$\frac{207}{206}\frac{Pb}{Pb}$	
Orthogneiss (Strona-Ceneri)	MAL 1	150-75	Zr	1403		94.9	0.07077	0.5715	0.05857	445	465		564	1
	MAL 1	75-53	Zr	1617		107.1	0.06893	0.5394	0.05675	434	444		494	1
	MAL 1	53-42	Zr	1620		107.0	0.06880	0.5369	0.05660	433	442		488	1
	MAL 1	> 42	Zr	1626		108.1	0.06882	0.5357	0.05645	433	441		482	1
	FM 17	tot. fract.	Zr	1031		70.0	0.07057	0.5583	0.05739	444	456		518	1
	FM 7	"	Zr	1102		81.0	0.07747	0.6150	0.05757	486	493		526	1
	FM 12	"	Zr	1028		76.2	0.07226	0.5602	0.05622	454	457		473	1
Paragneiss (Strona-Ceneri)	MAL 2	150-75 n.m.	Zr	431		58.0	0.1297	1.540	0.08607	794	959		1362	1
	MAL 2	150-75 n.m.	Zr	444		59.2	0.1283	1.532	0.08654	786	956		1374	1
	MAL 2	75-53 n.m.	Zr	473		62.1	0.1271	1.490	0.08505	778	938		1340	1
	MAL 2	53-42 n.m.	Zr	519		64.7	0.1220	1.404	0.08346	749	902		1302	1
	MAL 2	> 42 n.m.	Zr	593		69.4	0.1154	1.289	0.08102	711	852		1244	1
	MAL 2	150-75 m.	Zr	733		85.0	0.1137	1.248	0.07973	701	834		1212	1
	MAL 2	53-42 m.	Zr	690		80.8	0.1150	1.247	0.07867	708	833		1184	1
	MAL 2	> 42 m.	Zr	862		95.6	0.1092	1.157	0.07689	674	791		1138	1

1) Köppel & Grünfelder (1971)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	Grain size Mag. suscept.	Mat.	U ppm	Th ppm	Pb rad ppm	Atomic ratios			AGE Ma				Ref.
							$\frac{206}{204}\frac{Pb}{U}$	$\frac{207}{204}\frac{Pb}{U}$	$\frac{208}{204}\frac{Pb}{Pb}$	$\frac{206}{238}\frac{Pb}{U}$	$\frac{207}{235}\frac{Pb}{U}$	$\frac{208}{232}\frac{Pb}{Th}$	$\frac{207}{206}\frac{Pb}{Pb}$	
Paragneiss (Ivrea-Verbano)	ANZ 1	> 75	Zr	462.5		28.5	1102	91.65	133.3	390	483		960	1
		75-53	Zr	501.5		30.1	1152	92.60	132.4	381	464		891	1
		53-42	Zr	528.6		29.9	1504	114.1	150.2	364	436		837	1
		> 42	Zr	554.5		29.7	1225	91.89	116.0	349	405		740	1
		Mo		2936	41540	598	4516	247.4	19840	275	275	264	277	1
Granite (Montorfano)	ORF 1	> 75 n.m.	Zr	1118	252	44.4	2616	152.2	231.9	261	268	268	325	1
		< 42 n.m.	Zr	1317	394	55.0	3007	171.1	316.0	270	273	261	301	1
		53-42 m.	Zr	6068	917	197.6	2556	152.6	183.3	219	226	246	298	1
		Mo		799	37040	492.0	292.5	29.69	4041	290	293	282	317	1

1) Köppel (1974)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	Grain size Mag. suscept.	Mat.	U ppm	Th ppm	Pb _{rad} ppm	AGE Ma				Ref.			
							$\frac{^{206}\text{Pb}}{^{204}\text{U}}$	$\frac{^{207}\text{Pb}}{^{204}\text{U}}$	$\frac{^{208}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$		$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{208}\text{Pb}}{^{232}\text{Th}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$
Migmatite (Strona-Ceneri)	STR0-1	> 75 n.m.	Zr	1104		69.1	2878	181.4	135.2	418	440	545	1	
		75-53 n.m.	Zr	1346		81.6	3316	204.1	131.7	409	425	514	1	
		53-42 m.	Zr	1520		88.0	3317	199.8	101.1	395	405	461	1	
		< 42 m.	Zr	2212		121.3	3570	213.1	94.16	376	387	452	1	
		>125	Mo	10200	62870	1263	3452	193.9	7156	289	290	301	295	1
		<125	Mo	13730	63130	1428	2972	171.0	4542	297	301	306	327	1
Paragneiss (Ivrea-Verbano)	STR0-2	> 75 n.m.	Zr	352.3		46.4	969.7	109.2	161.9	763	1019	1625	1	
		75-53 n.m.	Zr	399.6		45.6	1809	186.3	252.6	674	916	1562	1	
		53-42 m.	Zr	447.7		46.1	4046	377.3	431.2	611	822	1446	1	
		< 42 n.m.	Zr	495.6		43.0	4118	361.4	473.6	538	714	1324	1	
			Mo	4699	39390	658	992.8	65.9	2660	275	277	273	293	1
			Mo	2562	38480	643	7876	421.1	21220	277	277	280	279	1
Pyroclastic (Ivrea-Verbano)	STR0-3	>125 n.m.	Zr	443.3		19.4	1160	79.04	111.2	289	308	455	1	
		> 75 n.m.	Zr	447.4		19.9	1917	123.3	165.3	293	317	499	1	
		75-53 n.m.	Zr	457.8		20.7	1969	126.8	172.8	301	326	510	1	
		53-42 n.m.	Zr	512.3		22.9	1198	82.16	112.4	296	319	491	1	
		< 42 m.	Zr	641.0		28.6	1347	87.82	109.8	299	311	406	1	
1) Köppel (1974)														

1) Köppel (1974)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	Grain size Mag. Suscept.	Mat.	U ppm	Th ppm	Pb rad ppm	Atomic ratios				AGE Ma				Ref.
							$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{208}\text{Pb}}{^{232}\text{Th}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{208}\text{Pb}}{^{232}\text{Th}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	
Paragneiss (Strona-Ceneri)	2FM5	53-42n.m.	Zr	705		64.0	0.09088	0.9542		0.07625	566	689		1122	1
	2FM5	< 42	Zr	718		62.2	0.08743	0.8775		0.07289	545	648		1029	1
	FM5	tot.fract.	Zr	629		58.7	0.09349	1.011		0.07844	582	719		1178	1
	2FM7	>75n.m.	Zr	488		65.9	0.1304	1.572		0.08753	798	972		1396	1
	2FM7	75-53n.m.	Zr	578		71.7	0.1208	1.365		0.08203	742	885		1268	1
	2FM7	75-53 m.	Zr	665		79.3	0.1163	1.269		0.07922	716	843		1199	1
	2FM7	53-42n.m.	Zr	638		74.9	0.1150	1.262		0.07968	708	839		1211	1
	2FM7	53-42 m.	Zr	783		86.1	0.1079	1.122		0.07553	667	774		1103	1
	2FM7	<42 n.m.	Zr	715		76.9	0.1065	1.125		0.07665	659	776		1132	1
	CHI1	>42n.m.	Zr	1582	279	50.7	0.0336	0.268	0.00905	0.0582	215	245	185	550	1
Chiari (Val Colla)	CHI1	> 53 m.	Zr	4660	1278	113.3	0.0236	0.192	0.01126	0.0590	152	180	229	580	1
	CHI1	< 42 m.	Zr	6370	1322	136.6	0.0214	0.165	0.01095	0.0558	138	157	223	460	1
Quartzite (Suello)	SUE/1	< 42	Zr	551		65.4	0.1185	1.474		0.09033	728	932		1456	
	SUE/2	> 75	Zr	481		68.8	0.1397	1.894		0.09846	851	1.093		1621	

1) Köppel & Grünenfelder (1971); 2) Grauert et al. (1973)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	Grain size Mag. suscept.	Mat.	U ppm	Th ppm	Pb rad ppm	Atomic ratios				AGE Ma				Ref.
							$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{208}{232}\text{Pb}$	$\frac{207}{206}\text{Pb}$	$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{208}{232}\text{Pb}$	$\frac{207}{206}\text{Pb}$	
Paragneiss (Strona-Ceneri)	CEN1	+ 75 n.m.	Zr	437		68.7	0.1488	2.314		0.1129	903	1232		1876	1
	CEN1	75-53n.m.	Zr	516		68.0	0.1274	1.734		0.09885	780	1035		1629	1
	CEN1	53-42n.m.	Zr	567		66.5	0.1148	1.448		0.09157	707	921		1483	1
	CEN1	53-42 m.	Zr	590		68.0	0.1129	1.398		0.08991	696	900		1448	1
	CEN1	> 42 m.	Zr	631		66.8	0.1043	1.194		0.08393	646	808		1295	1
	CAS1	> 75 n.m.	Zr	532	174	60.6	0.1111	1.227	0.03688	0.08023	685	824	742	1224	1
	CAS1	75-53n.m.	Zr	610	186	63.9	0.1033	1.033	0.03467	0.07224	640	727	698	1012	1
	CAS1	53-42n.m.	Zr	683	196	64.7	0.09401	0.8994	0.03202	0.06948	586	660	646	931	1
	CAS1	< 42	Zr	746	181	67.3	0.09060	0.8335	0.03243	0.06682	564	624	654	849	1
	CAS1	tot.fract.	Mo	8361	37600	1230	0.07027	0.5393	0.02077	0.05580	442	444	421	456	1
	CAS1	> 75	Mo	7980	37100	1256	0.07191	0.5601	0.02202	0.05647	452	458	446	481	1
	CAS1	< 42	Mo	7940	34730	1229	0.07275	0.5618	0.02229	0.05600	457	459	452	464	1
	2FM5	>75n.m.	Zr	455			0.1228	1.612		0.09522	755	988		1558	1
	2FM5	75-53n.m.	Zr	573			0.1041	1.184		0.08257	645	804		1281	1

1) Köppel & Grünenfelder (1971)

TABLE 3 (continued)

U-Pb ages

Rock type	Sample n.	U ppm	Pb rad ppm	$\frac{204}{206}\text{Pb}$	$\frac{206}{206}\text{Pb}$	$\frac{207}{206}\text{Pb}$	$\frac{208}{206}\text{Pb}$	Age Ma			Suppl. error. for 206/207 Age Ma	Ref.
								$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{206}{207}\text{Pb}$		
Granite (Baveno)	Pa 59/4 + 1*			0.2475+ 0.0023	100	8.905+ 0.016	22.05+ 0.036			310+ 35	+ 61	1
	Pa 60/2	2	2720	117				269+11	273+14			1
	3											1
	4			0.1032+ 0.0019	100	6.709+ 0.017	17.65+ 0.06			285+ 27	+ 60	1
Granite (Montorfano)	Pa 60/3	1		0.0754+ 0.0011	100	6.518+ 0.011	10.84+ 0.020			385+ 20	+ 62	1
	2	1765	68.7					253+9	266+11			1
	3		67.6									1

1) Pasteels (1964)

* = chemical attack

TABLE 4 - *FT ages*

Rock type	Sample n.	Material	Sp. tracks Ind.tracks	Ind.tracks (10^5 cm^{-2})	U (g/t)	AGE Ma	Altitude (m)	Ref.
Granodiorite	KAW 80	Ap	0.663	0.50	8.6	14.2	-	1
Paragneiss	KAW 85	Ap	0.515	1.60	28	10.8	210	1
Micaschist	KAW 504	Ap	0.606	1.37	25	12.3	300	1
Micaschist	KAW 506	Ap	0.523	1.58	27	11.2	210	1
Stromalite	KAW 509	Ap	0.483	1.01	20	9.2	1100	1
Micaschist	KAW 592	Ap	0.544	1.00	18	11.4	205	1

1 = Wagner & Reimer (1972)

VALTELLINA PLUTONIC ROCKS

TABLE 5 - *Rb-Sr ages*

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{m}}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{i}}$	AGE Ma	Ref.
Granite - M. Pagano	VA 79 10	WR	190	163	3.38	.7224+ 4			1
"	VA 79 10	Bi	1156	2.2	1931.58	3.2229+ 61	91+1		1
"	VA 79 10	Mu	556	12.7	133.12	1.2430+ 19	182+4		1
Granodiorite - Cima Verda	VA 78 12	WR	141	183	2.23	.7211+ 1			1
"	VA 78 12	Bi	802	4.6	550.34	1.6970+ 15	125+2		1
"	VA 78 12	Mu	443	14.5	91.33	1.0499+ 19	259+4		1
Diorite - Cima Verda	VA 78 11	WR	32	314	.29	.7051+ 3			1
"	VA 78 11	Bi	404	8.5	139.18	.8592+ 7	78+2		1
Granodiorite - La Motta	VA 78 10	WR	105	154	1.97	.7230+ 2			1
"	VA 78 10	Bi	575	6.8	253.13	1.0580+ 35	94+2		1
"	VA 78 10	Mu	285	12.7	66.39	.9646+ 7	264+4		1
Granodiorite - Vernuga	VA 79 4	WR	203	110	5.34	.7320+ 4			1
"	VA 79 4	Bi	1002	2.5	1428.30	2.8895+ 85	107+2		1
Granodiorite - Val Ferrata	VA 2	WR	126	150	2.43	.7224+ 7			1
"	VA 2	Bi	638	4.1	532.27	2.4129+117	224+4		1
Granodiorite Tremoncelli	VA 79 6	WR	148	176	2.44	.7183+ 3			1
"	VA 79 6	Bi	751	3.3	750.49	1.9951+ 26	120+2		1

$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$

1) Del Moro et al. (1981)

CENTRAL PENNIDIC DOMAIN

VERAMPIO - LEVENTINA GNEISSES

TABLE 6 - K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Verampio gneiss (orthogneiss)	KAW 201	Bi	7.74-7.74	4.00×10^{-6}	68.8	12.9 ± 0.8	1
		Mu	8.77-8.75	4.96×10^{-6}	72.0	14.1 ± 0.8	1
		Pl, Qz	0.530-0.530 0.531	0.493×10^{-6}	26.3	23.2 ± 3.5	1
		Kf	12.01-12.07	4.12×10^{-6}	73.1	8.56 ± 0.47	1
Leventina gneiss (orthogneiss)	KAW 140	Bi	7.86-7.86-7.90	4.95×10^{-6}	66.4	15.7 ± 1.2	1
		Mu	8.87	5.71×10^{-6}	77.1	16.1 ± 0.8	1
	KAW 137	Bi	7.84-7.89	5.04×10^{-6}	69.7	16 ± 0.9	1
		Mu	8.83-8.95	$6.01-6.12 \times 10^{-6}$	75.1-75.3	17 ± 0.7	1
	KAW 138	Bi	8.17-8.14	5.74×10^{-6}	62.6	17.6 ± 1.1	1
		Mu	8.97-8.98	$6.29-6.21-6.09 \times 10^{-6}$	80.8-72.8-80.6	17.2 ± 0.7	1

1) Purdy & Jüger (1976)

TABLE 6 a - Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr radiogen ppm	% radiogen	Sr concn ppm	Uncorrected Age ± Ma	Corrected Age ± Ma	Ref.
Verampio gneisses (orthogneiss)	B 4	Bi	378	0.0784	53.4	0.99	14.1 ± 0.6		1
			380	0.0788	55.0	0.93	14.1 ± 0.6	13.4 ± 0.5	1
	KAW 201	Bi	412	0.0847	47.1	1.38	14.0 ± 0.6	13.4 ± 0.5	1-2
			412	0.0855	45.3	1.49	14.1 ± 0.6		1
		Mu	250	0.0692	16.6	5.04	18.8 ± 2.8		1
			250	0.0687	17.5	4.72	18.7 ± 2.7	15.1 ± 2.3	1
			256	0.0686	17.9	4.57	18.2 ± 2.3	14.9 ± 1.9	1-2
Leventina gneisses (Orthogneisses)	KAW 75	Bi	243	0.0600	30.6	1.97	16.8 ± 1.1		1
			242	0.0593	35.6	1.55	16.7 ± 1.0		1
	KAW 140	Bi					16.5 ± 0.9	15.9 ± 0.7	2
							26 ± 10	18 ± 8	
	KAW 74	Mu							
			217	0.0634	9.8	8.47	19.9 ± 4.1		1

1) Jüger, Niggli, Wenk (1967)

2) Purdy & Jüger (1976)

$$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$$

$$\approx \frac{^{88}\text{Sr}}{^{86}\text{Sr}} / \frac{^{86}\text{Sr}}{^{86}\text{Sr}} = 8.432$$

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}} / \frac{^{86}\text{Sr}}{^{86}\text{Sr}} = 0.7091$$

TABLE 6 b - U-Pb ages

Rock type	grain size mag. suscept.	Sample n.	Mat.	U ppm	Th ppm	Pb rad ppm	AGE Ma							Ref.
							$\frac{206\text{Pb}}{204\text{Pb}}$	$\frac{207\text{Pb}}{204\text{Pb}}$	$\frac{208\text{Pb}}{204\text{Pb}}$	$\frac{206\text{Pb}}{238\text{U}}$	$\frac{207\text{Pb}}{235\text{U}}$	$\frac{208\text{Pb}}{232\text{Th}}$	$\frac{207\text{Pb}}{206\text{Pb}}$	
Verampio gneiss		VER 1												1
(orthogneiss)	>65 n.m.		Zr	1993	470	51.8	239.8	26.95	59.44	168	177	222	288	
	<65 m.			3255	654	64.8	116.1	20.47	45.57	131	140	174	294	
		LEV 1												1
	>53 n.m.		Zr	1826	341	69.2	1843	111.3	154.4	252	259	268	322	
	53-42 n.m.			1890	393	69.5	2265	132.8	204.6	243	249	268	309	
	<42 n.m.			2077	451	73.4	3110	176.7	258.4	232	239	265	303	
		LEV 2												1
	- n.m.		Zr	791	213	28.3	1864	114.2	222.5	231	243	265	364	

1) Allegre et al. (1974)

TABLE 6 c - FT ages

Rock type	Sample n.	Material	$\frac{\text{Sp. tracks}}{\text{Ind. tracks}}$	Ind. tracks (10^5 cm^{-2})	U (g/t)	AGE Ma	Altitudine (m)	ref.
Verampio gneiss	KAW 201	Ap	0.098	0.30	5.0	2.2	500	1-2
Leventina gneisses	KAW 75	Ap				6.4	310	2
	KAW 140	Ap				4.6	700	2
	KAW 137	Ap				6	300	2
	KAW 138	Ap				5.9	300	2

1) Wagner & Raimer (1972); 2) Wagner, Reimer, Jäger (1977)

ANTIGORIO NAPPE - SIMANO NAPPE

TABLE 7 - K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Orthogneiss	KAW 159	Bi	8.03-8.07	3.75×10^{-6}	64.3	11.6 ± 0.7	1
(v. Ossola l.s.)		Mu	8.90-8.96	$4.96-4.90 \times 10^{-6}$	61.9-66.0	13.8 ± 0.9	1
Orthogneisses (Tessin)	B 7	Bi	8.13-8.14	4.98×10^{-6}	62.5	15.3 ± 1	1
SIMANO NAPPE							
Pegmatites	B 2	Mu	8.86-8.96	6.75×10^{-6}	63.0	18.9 ± 1.2	1
	B 3	Bi	8.03-8.07	5.33×10^{-6}	70.6	16.5 ± 0.9	1
	B 9	Mu	8.72-8.80	6.81×10^{-6}	57.0	19.4 ± 1.4	1
Gneisses	KAW 4	Bi	7.90	$5.33 \times 10^{-6} \pm 0.08$	67.6 ± 4.6	16.8 ± 0.7	1
		Mu	8.70 ± 0.05	$6.32 \times 10^{-6} \pm 0.07$	54.7 ± 3.1	18.1 ± 0.7	1

1) Purdy & Jäger (1976)

TABLE 7a - Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr radiogen ppm	% radiogen	Sr concn ppm	Uncorrected Age @ Ma	Corrected Age Ma	Ref.
Orthogneisses (v. Ossola l.s.)	B 26	Bi	189	0.0358	14.8	2.98	12.9 + 1.9		1
			188	0.0347	17.7	2.35	12.6 + 1.7		1
	B 27	Bi	135	0.0263	8.5	4.08	13.4 + 3.4		1
	B 30	Bi	207	0.0428	13.4	4.00	14.1 + 2.2		1
	B 35	Bi	139	0.0262	3.9	9.25	13 + 7		1
	B 36	Bi	202	0.0433	6.7	8.78	14.6 + 4.5		1
	KAW 261	Bi	181	0.0344	14.1	3.04	12.9 + 2.0		1
	KAW 159	Bi	190	0.0321	11.8	3.48	11.5 + 2.1		1-2
			192	0.0323	14.1	2.85	11.4 + 1.7	11.4 + 1.3	1-2
		Mu	107	0.028	1.7	24.0	$t_{\text{max}} = 40$		1
	KAW 408	Mu	122	0.0400	2.4	23.5	49.0 + 12.4	26.9 + 9.6	3
Orthogneisses (Tessin)	B 7	Bi	99.6	0.0235	11.6	2.59	16.0 + 3.2		1
	B 21	Bi	207	0.0448	24.6	1.99	14.7 + 1.4		1
			205	0.0441	24.3	1.99	14.6 + 1.3		1
	B 22	Bi	263	0.0560	30.1	1.89	14.5 + 1.0		1
	B 31	Bi	140	0.0343	17.5	2.34	16.7 + 2.1		1
	B 32	Bi	129	0.0310	19.1	1.90	16.3 + 1.9		1
<u>SIMANO NAPPE</u>									
Gneisses	B 12	Bi	150	0.0374	14.1	3.31	17 + 2.7		1
			151	0.0377	14.1	3.33	17 + 2.7		1
	KAW 4	Bi	169	0.0393	22.5	1.96	15.9 + 1.4		1
			167	0.0405	21.2	2.18	16.6 + 1.4		1
			168	0.0395	21.9	2.04	16.0 + 1.6		1
		Mu	92.9	0.0262	1.2	30.4	16.8 + 0.5*		1-2
		91.9				$t_{\text{max}} = 50$		1	
Pegmatite	B 3	Bi	307	0.0838	18.1	5.52	18.6 + 2.1		1
			308	0.0833	20.0	4.83	18.5 + 1.9		1-2
	B 2	Mu	164	0.0646	9.9	8.56	26.8 + 5.5		1
			168	0.0654	11.8	7.10	26.6 + 4.6		1-2
	B 9	Mu	177	0.0577	7.4	10.0	21.4 + 6		1
Aplite	KAW 6	Bi	258	0.0657	15.8	5.10	17.3 + 2.5		1
1) Jäger, Niggli, Wenk (1967);							* mean and standard deviation of 13 measurements		
2) Purdy & Jäger (1976)							$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$		
3) Hunziker (1969)							$\theta = \frac{^{88}\text{Sr}/^{86}\text{Sr}}{^{87}\text{Sr}/^{86}\text{Sr}} = 8.432; \frac{^{87}\text{Sr}}{^{86}\text{Sr}} = 0.7091$		

TABLE 7 b - U-Pb ages

Rock type	Grain size mag. suscept.	Sample n.	Mat.	U ppm	Th ppm	Pb rad ppm	AGE Ma							Ref.
							$\frac{206}{204}\text{Pb}$	$\frac{207}{204}\text{Pb}$	$\frac{208}{204}\text{Pb}$	$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{208}{232}\text{Pb}$	$\frac{207}{206}\text{Pb}$	
Orthogneisses		ANT 1												1
	>100 n.m.		Zr	818	304	28.3	1234	78.41	176.3	221	227	209	291	
	75-53 n.m.			970	405	34.4	1926	114.2	282.6	223	229	212	289	
	42-30 n.m.			909	399	32.8	1942	115.7	303.2	225	232	219	303	
	< 42 n.			1146	561	33.4	1307	82.06	219.8	182	190	163	286	
		ANT 2												1
	> 53 n.m.		Zr	1362	431	38.8	329.4	31.65	75.64	181	191	218	324	
	- m.			1540	524	40.8	318.7	30.96	76.41	167	175	195	276	
<u>SIMANO NAPPE</u>														
Orthogneisses		SIM 1												1
	> 75 n.m.		Zr	415	86.4	30.5	1138	84.34	116.2	473	510	502	677	
	75-53 n.m.			419	84.0	30.4	1984	130.7	162.5	472	489	469	572	
	53-42 n.m.			482	85.0	32.6	2292	147.5	174.1	442	460	471	548	
	< 42 n.m.			507	81.8	34.0	3301	206.0	229.4	439	457	492	547	
		BRI 1												1
	75-50 -		Zr	689	-	29.0	962.6	67.9	79.67	283	303	-	456	
	150-75-			-	-	-	1242	82.6	103.1	-	-	-	422	
Granoblastic - gneisses	> 150 -			861	-	35.0	204.7	26.03	46.06	272	301	-	526	
		BRI 2	Mo	7156	-	61.9	662.2	45.61	1122	22.7	22.8	-	37+21	2
		BRI 4	Mo	6549	-	50.5	1081	64.87	1777	20.9	20.8	-	21+10	2
1) Allegre et al. (1974) 2) Köppl, Günthert, Grünenfelder (1980)														

1) Allegre et al. (1974) 2) Köppl, Günthert, Grünenfelder (1980)

TABLE 7 c - FT ages

Rock type	Sample n.	Material	Sp.tracks Ind.tracks	Ind.tracks (10^5 cm^{-2})	U (g/t)	AGE Ma	Altitude (m)	Ref.
Orthogneisses	KAW 159	Ap	0.140	0.28	4.8	3.0	86.0	1-2
<u>SIMANO NAPPE</u>								
Gneisses	KAW 4	Ap				7.1	800	2
Aplite	KAW 6	Ap				6.7	530	2

1) Wagner & Reimer (1972)

2) Wagner, Reimer, Jäger (1977)

LEBENDUN SERIES

TABLE 8 - K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Lebendun gneisses	KAW 160	Bi	8.22 - 8.20	3.69×10^{-6}	72.5	11.2 ± 0.6	1
		Mu	8.81 - 8.79	5.12×10^{-6}	74.0	14.2 ± 0.6	1
				4.96×10^{-6}	74.4		
				4.89×10^{-6}	66.6		
	KAW 286	Bi	7.77 - 7.78	4.56×10^{-6}	52.7	14.6 ± 1.1	1
		Mu	8.59 - 8.58	5.70×10^{-6}	60.8	16.6 ± 1.1	1
		P1, Qz	0.486 - 0.402	0.684×10^{-6}	24.9	35.1 ± 5.6	1
		Kf	11.96 - 11.94	6.07×10^{-6}	50.9	12.7 ± 1.0	1
	KAW 358	Bi	7.85 - 7.84	3.88×10^{-6}	68.7	12.2 ± 0.7	1
		Mu	8.76 - 8.80	5.23×10^{-6}	76.5	14.9 ± 0.8	1

1) Purdy & Jäger (1976)

TABLE 8 a - Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr radiogen ppm	% radiogen	Sr concn ppm	Uncorrected Age Ma	Corrected Age Ma	Ref.
Lebendun gneisses	B 28A	Bi	325	0.0714	32.2	2.18	14.9 ± 1.0		1
	KAW 160	Bi	291	0.0501	17.5	3.42	11.7 ± 1.4	11.0 ± 1.1	1-2
		Mu	146	0.0477	5.6	11.7	22.2 ± 9.0	17.3 ± 7.8	1-2
	KAW 286	Bi					14.7 ± 1.0	13.6 ± 0.8	2
		Mu					25.8 ± 5.5	19.0 ± 3.0	2
	KAW 358	Bi	408	0.0760	37.8	1.81	12.7 ± 0.7	11.9 ± 0.6	1-2
		Mu	238	0.0810	16.1	6.11			
				0.0824	16.4	6.09	23.3 ± 3.4	19 ± 2.8	1-2
granite in Lebendun conglomeratic gneisses	B 28c	Bi	337	0.0721	31.6	2.26	14.6 ± 1.0	13.2 ± 0.8	1
gneiss in Lebendun conglomeratic gneisses	B 28b	Bi	334	0.0708	38.6	1.63	14.4 ± 0.8	13.5 ± 0.7	1
Augengneiss in Leb. conglom. gneisses	B 24	Bi	171	0.0358	8.6	5.52	14.2 ± 3.4		1

$$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$$

$$\otimes \frac{^{88}\text{Sr}}{^{86}\text{Sr}} = 0.432$$

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}} = 0.7091$$

1) Jäger, Niggli, Wenk (1967);

2) Purdy & Jäger (1976)

TABLE 8 b - U-Pb ages

Rock type	grain size mag. suscept.	Sample n.	Mat.	U ppm	Th ppm	Pb rad ppm	Pb total ppm	AGE Ma						Ref.
								$\frac{206}{204}\text{Pb}$	$\frac{207}{204}\text{Pb}$	$\frac{208}{204}\text{Pb}$	$\frac{206}{238}\text{Pb}$	$\frac{207}{235}\text{Pb}$	$\frac{208}{232}\text{Pb}$	
Lebendun gneiss		Leb 1												1
	> 65 n.m.		Zr	2058	466	42.6		355.9	32.96	68.15	135	145	169	296
	< 65 n.m.			2464	476	42.0		448.9	37.73	75.11	112	121	155	297
	< 65 m.			2820	719	40.5		177.6	23.48	51.94	94	101	103	262
		Leb 2												2
	>100 n.m.		Zr	648			51.3	611.1	58.48	82.08	451	554		1000 $\pm$ 14
	100-75n.m.			711			52.1	614.3	55.34	78.93	423	493		833 $\pm$ 13
	75-53n.m.			730			51.1	519.9	47.52	68.84	400	454		736 $\pm$ 21
	75-53 m.			960			55.9	460.7	41.52	66.13	330	361		560 $\pm$ 24
	< 42 m.			1018			59.8	421.16	38.70	59.01	332	356		515 $\pm$ 28
		BRA 1												2
	>100 n.m.		Zr	418			26.08	1705	114.36	186.9	382	404		552 $\pm$ 11
	53-42n.m.			442			26.87	1040	73.64	144.0	360	377		448 $\pm$ 11
	< 42 m.			496			29.29	814.7	60.50	126.7	342	359		472 $\pm$ 15
		BRA 2												2
	100-75n.m.		Zr	530			34.4	715.8	56.15	74.88	388	411		540 $\pm$ 14
	75-53n.m.			594			35.2	564.7	46.59	64.56	348	367		488 $\pm$ 30
	53-42 m.			666			39.1	467.0	40.98	59.34	339	358		483 $\pm$ 21
	< 42 m.			734			41.6	414.3	38.05	56.83	321	343		489 $\pm$ 25

1) Allegre et al. (1974)
2) Köppel, Günthert, Grünenfelder (1980)

TABLE 8 c - FT ages

Rock type	Sample n.	Material	$\frac{\text{Sp. tracks}}{\text{Ind. tracks}}$	Ind. tracks (10^5 cm^{-2})	U (g/t)	AGE Ma	Altitude (m)	Ref.
Labendun gneisses	KAW 160	Ap	0.118	0.59	10	2.5	1160	1-2
	KAW 286	Ap	0.215	0.50	8.8	4.5	1670	1-2

1) Wagner & Reimer (1972);
2) Wagner, Reimer, Jäger (1977)

MONTE LEONE NAPPE

TABLE 9 - K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Orthogneisses	KAW 165	Bi	7.95 - 8.04	4.45×10^{-6}	66.4	13.9 ± 0.8	1
		Phe	9.10 - 9.0	6.58×10^{-6}	83.7	18.1 ± 0.9	1
	KAW 164	Bi	8.09 - 8.08	4.46×10^{-6}	74.6	13.8 ± 0.7	1
		Phe	9.03 - 9.05	6.63×10^{-6}	87.7	18.3 ± 0.8	1
	KAW 161	Bi	8.17 - 8.26	4.00×10^{-6}	76.3	12.2 ± 0.6	1
		Mu	8.96 - 9.05	5.64×10^{-6}	60.0	15.6 ± 1.0	1
	KAW 372	Bi	8.00 - 7.97	4.53×10^{-6}	71.3	14.2 ± 0.8	1
		Mu	8.90 - 8.90	$5.78 - 5.93 \times 10^{-6}$	66.1-60.1	16.4 ± 1.0	1
	KAW 399	Bi	8.03 - 8.00	4.43×10^{-6}	71.6	13.8 ± 0.8	1
		Phe	8.73 - 8.72	6.09×10^{-6}	80.3	17.4 ± 0.9	1
	KAW 400	Bi	6.15 - 6.15	3.15×10^{-6}	42.1	12.8 ± 1.2	1
		Phe	9.13 - 9.09	7.07×10^{-6}	81.5	19.4 ± 1.0	1
	KAW 401	Bi	7.39 - 7.36	4.23×10^{-6}	70.9	14.3 ± 0.8	1
		Phe	9.11 - 9.04	7.88×10^{-6}	83.3	21.6 ± 1.0	1

1) Purdy & Jäger (1976)

TABLE 9 a - Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr radiogen ppm	% radiogen	Sr concn ppm	Uncorrected Age Ma	Corrected Age Ma	Ref.
Orthogneisses	KAW 165	Bi	235	0.0466	11.2	5.37	13.5 ± 2.6	6.2 ± 2	1-2
			232	0.0461	11.1	5.36	13.5 ± 2.6		
		Phe	149	0.0588	15.8	4.56	26.8 ± 3.6	16.7 ± 2.9	1-2
			152	0.0565	14.5	4.81	25.3 ± 4.1		
	KAW 164	Bi	188	0.0365	10.1	4.69	13.2 ± 2.8	11.7 ± 1.8	1
			190	0.0346	10.7	4.17	12.4 ± 2.3		
		Phe	106	0.0370	4.3	12.0	24 ± 12	21 ± 10	1-2
	KAW 161	Bi	162	0.0269	20.8	1.49	11.3 ± 1.3	11.0 ± 1.0	1-2
			90.3	0.0291	2.8	14.6	22 ± 22	18 ± 14	
		Mu	90.3	0.0304	2.8	15.2	23 ± 18	18 ± 14	1
	KAW 372	Bi					15.4 ± 0.6	14.4 ± 0.6	2
		Mu	271	0.111	23.4	5.3	27.8 ± 2.2	21.1 ± 1.7	3
	KAW 399	Bi					17.2 ± 2.9	10.3 ± 2.3	2
	KAW 400	Bi					22.6 ± 6.3		2
		Phe	172	0.0853	14.7	7.2	33.7 ± 4.3	21.4 ± 3.4	3
	KAW 401	Bi					23.4 ± 3.5	11.0 ± 2.8	2
		Phe	178	0.121	11.6	13.3	46.3 ± 7.7	25.1 ± 6.0	3
	KAW 102	Mu	97.3	0.0555	4.3	17.7	38.8 ± 17.6		3
	KAW 409	Mu	188	0.119	12.4	12.1	43.1 ± 6.5	22.2 ± 5.1	3
Paragneiss	B6	Mu	91.1	0.0262	2.6	14.2	20 ± 14		1
Pegmatite	KAW 106	Mu	348	0.183	21.7	9.56	35.8 ± 3.1	19.2 ± 2.6	1
			351	0.179	22.2	9.10	34.7 ± 3.0		

1) Jäger, Niggli, Wenk (1967); 2) Purdy & Jäger (1976); 3) Hunziker (1969)

 $\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$ * $^{88}\text{Sr}/^{86}\text{Sr} = 8.432$; $^{87}\text{Sr}/^{86}\text{Sr} = 0.7091$

TABLE 9 b - U-Pb ages

Rock type	Grain size / mag. suscept.	Sample n.	Mat.	U ppm	Th ppm	Pb rad ppm	AGE Ma							Ref.
							$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{207}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{208}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{208}\text{Pb}}{^{232}\text{Th}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	
Orthogneisses		MLE 1												1
	<53 n.m.		Zr	2828	647	57.5	726.9	51.06	101.9	133	138	166	225	
		GAT 1												1
	>100 n.m.		Zr	507	245	19.3	372.6	34.48	96.83	231	246	248	368	
	53-42 n.m.			759	393	25.8	629.5	47.33	146.7	206	215	220	316	
	< 42 -			970	537	31.4	470.6	39.12	121.6	194	205	201	323	
		EIS 1												1
	> 75 n.m.		Zr	459	118	11.6	181.0	23.93	56.54	161	173	225	336	
	53-42 n.m.			838	180	19.5	388.5	34.75	77.16	150	161	230	317	
	< 42 m.			1747	410	23.5	254.7	27.44	63.35	87	94	124	262	

1) Allegre et al. (1974)

1) Allegre et al. (1974)

TABLE 9 c - FT ages

Rock type	Sample n.	Material	$\frac{\text{Sp. tracks}}{\text{Ind. tracks}}$	$\frac{\text{Ind. tracks}}{10^5 \text{ cm}^{-2}}$	U (g/t)	AGE Ma	Altitude (m)	Ref.
Orthogneisses	KAW 161	Ap	0.135	0.06	1.2	2.6	1200	1-2
	KAW 164	Ap				4.2	1410	2
	KAW 165	Ap				4.4	1390	2
	KAW 399	Ap	0.145	0.86	15	3.1	1720	1-2
	KAW 400	Ap				3.4	1480	2
	KAW 401	Ap				5.6	2300	2
	KAW 372	Ap	0.163	0.51	9.3	3.3	500	1-2

1) Wagner & Reimer (1972);

2) Wagner, Reimer, Jäger (1977)

MONCUCCO - ORSELINA ZONE Ls.

TABLE 10 - K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rds	AGE Ma	Ref.
Orthogneisses	MD 79-1	Mu	9.17	8.688×10^{-5}	48	21.7 ± 1.1	2
	MD 79-2	Mu	8.91	8.646×10^{-5}	44	21.6 ± 1.1	2
	MD 79-5	Mu	8.91	7.968×10^{-5}	39	19.9 ± 1.0	2
	KAW 82	Bi	7.71	6.08×10^{-6}	64.4	19.6 ± 0.8	1
			7.75	6.10×10^{-6}	65.8		
		Mu	8.69-8.72	8.10×10^{-6}	65.4	23.2 ± 1.4	1
		P1,Qz	0.286-0.286-0.294	0.639×10^{-6}	61.6	54.7 ± 3.6	1
		Kf	12.09-12.16	9.58×10^{-6}	87.8	19.7 ± 0.9	1
Paragneiss	B 8	Bi	7.82-7.73	6.02×10^{-6}	58.2	19.3 ± 1.3	1
		Mu	8.99-8.93	6.89×10^{-6}	75.2	19.2 ± 1.0	1

1) Purdy & Jäger (1976)
2) Bigoggero et al. (1981)

TABLE 10 a - Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_m$	$(^{87}\text{Sr}/^{86}\text{Sr})_i$	AGE Ma	Ref.
Orthogneisses	MD 79-1	WR	246	116	6.14	0.7352 ± 6	0.7123 ± 0.0004	271.6 ± 4.8	1
	MD 79-2	WR	147	180	2.37	0.7217 ± 4			
	MD 79-3	WR	150	110	3.94	0.7300 ± 2			
	MD 79-4	WR	248	109	6.62	0.7378 ± 3			
	MD 79-5	WR	223	107	6.05	0.7360 ± 4			
	MD 79-6	WR	238	103	6.70	0.7381 ± 5			
	MD 81-7	WR	237	85	8.08	0.7434 ± 3			
	MD 81-8	WR	191	109	5.11	0.7352 ± 2			
	MD 81-9	WR	204	212	2.78	0.7227 ± 4			
	MD 81-10	WR	233	106	6.34	0.7372 ± 3			
	MD 79-1	Bi	1085	1.48	2265	1.4249 ± 36	0.7162 ± 0.0029	36.9 ± 1.7	1
		Mu	541	9.78	161.6	0.7992 ± 8			
	MD 79-2	Bi	703	2.7	776.5	0.9534 ± 67			
		Mu	347	20.1	50.0	0.7395 ± 15			
	MD 79-3	Bi	825	1.9	1309	1.1147 ± 2			
		Mu	402	10.9	107.9	0.7728 ± 6			
	MD 79-4	Bi	1192	2.22	1636	1.2216 ± 57			
		Mu	580	10.3	164.8	0.8004 ± 15			
	MD 79-5	Bi	1003	1.4	2231	1.3833 ± 12			
		Mu	425	14.8	97.6	0.7691 ± 5			
	MD 79-6	Bi	1069	1.1	2988	1.5982 ± 50			
		Mu	531	11.3	136.8	0.7886 ± 6			
	MD 79-1/6	Mu Isochron							

1) Bigoggero et al. (1981)

$$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$$

TABLE 10 d - U-Pb ages

Rock type	Grain size mag. suscept.	Sample n.	Mat.	U ppm	Th ppm	Pb _{rad} ppm	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{207}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{208}\text{Pb}}{^{204}\text{Pb}}$	AGE Ma				Ref.
										$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{208}\text{Pb}}{^{232}\text{Th}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	
Migmatite		TEG 1	Zr											1
	> 75 n.m.			1433	222	33.5	416.5	36.09	67.20	155	165	232	305	
	75-53n.m.			1247	184	27.0	611.8	46.00	83.36	144	152	233	283	
	53-42n.m.			1425	195	28.7	918.5	61.91	106.00	133	142	229	285	
	< 53 m.			1745	252	32.4	657.2	48.41	86.01	123	132	200	287	

1) Allegre et al. (1974)

TABLE 10 e - U-Pb and Pb-Pb ages

Lead Isotopic Composition								
Rock type	Sample n.	Material	204/206	207/206	208/206	Pb ²⁰⁶ / _{AGE Ma} ²⁰⁷ / _{AGE Ma}	Pb ²⁰⁶ / _{AGE Ma} ²³⁸ / _{AGE Ma}	Ref.
Pegmatites	4f	Ur	0.00021 ±	0.0827 ±	0.0886 ±	-	152 ± 8	1
			0.00001	0.0019	0.0015			
	4g	Ur	0.00070 ±	0.0597 ±	0.025 ±	175 ± 100	-	1
			0.00005	0.0028	0.0020			
	4h	Ur	0.00057 ±	0.0573 ±	0.0023 ±	150 ± 35	-	1
			0.00003	0.0005	0.0002			
	Remark: No ²⁰⁶ Pb/ ²⁰⁷ Pb age is given for sample 4f because of the magnitude of common lead correction							
	RaD measurements							
	Pb-Pb							
	Sample n.	Material	Pb ²⁰⁶ rad tot Pb %	dis/sec/mg tot Pb	dis/sec/mg Pb ²⁰⁶ rad	AGE Ma	Ref.	
	4f	Ur	81.9	448 ± 18	547 ± 20	167 ± 7	1	
	4 g	Ur	90.9	514 ± 21	565 ± 24	162 ± 7	1	
4h	Ur	91.6	594 ± 24	648 ± 26	142 ± 6	1		

1) Ferrara et al. (1962)

TABLE 10 f - FT ages

Rock type	Sample n.	Material	$\frac{\text{Sp.tracks}}{\text{Ind.tracks}}$	Ind.tracks (10^5 cm^{-2})	U (g/t)	AGE Ma	Altitude (m)	Ref.
Orthogneiss	KAW 82	Ap	0.233	0.37	6.6	4.8	270	1

1) Wagner, Reimer, Jäger (1972)

MAGGIA NAPPE

TABLE 11 - *K-Ar ages*

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Cocco gneiss	B 1	Bi	7.77	6.04×10^{-6}	70.2	19.4 ± 1.1	1
Pegmatite	B 11	Mu	9.09-9.04	6.90×10^{-6}	79.4	19.0 ± 1.0	1

1) Purdy & Jäger (1976)

TABLE 11 a - *Rb-Sr ages*

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr radiogen ppm	% radiogen	Sr comm ppm	Uncorrected Age @ Ma	Corrected Age Ma	Ref.
Cocco gneiss	B 1	Bi	188	0.0443	27.1	1.73	16.0 ± 1.3		1
			187	0.0441	26.4	1.79	16.0 ± 1.2		1
Gneiss	B 5	Bi	134	0.0370	15.7	2.88	19.1 ± 2.7		1
				0.0381	14.6	3.22			
Pegmatite	B 11	Mu	482	0.141	66.0	1.05	19.9 ± 0.8		1
			487	0.140	47.1	2.29	19.7 ± 0.8		1-2

1) Jäger, Niggli, Wenk (1967);
2) Purdy & Jäger (1976)

$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$

TABLE 11 b - Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	⁸⁷ Rb ppm	Sr ppm	⁸⁷ Rb/ ⁸⁶ Sr	(⁸⁷ Sr/ ⁸⁶ Sr) _i	(⁸⁷ Sr/ ⁸⁶ Sr) _i	AGE Ma	Ref.
Augengneisses	KAW 1958	WR		51.140	93.543	5.6131	0.752966	0.7161	409	1
	KAW 1959	WR		62.941	72.105	8.9833	0.776849			
	KAW 1960	WR		67.253	49.698	13.9842	0.798757			
	KAW 1961	WR		38.155	97.600	4.0075	0.736796			
	KAW 1962	WR		61.426	50.607	10.2922	0.767934			
	KAW 1963	WR		47.880	71.247	6.9034	0.758180			
	KAW 1874	WR		50.908	69.397	7.2605	0.753203			
		Bi 35/50	812.212		3.749	637.4554	0.881449		14.3±0.2	1
		WM 35/50	547.318		11.515	139.0329	0.820132		35.8±0.4	1
		WM 50/80	533.553		12.826	121.3850	0.795008		25.8±0.3	1
Paragneisses	KAW 1964			34.092	184.296	1.8941	0.724584	0.7191	228	1
	KAW 1965			30.527	184.993	1.6896	0.724617			
	KAW 1970			36.943	153.867	2.4587	0.726183			
	KAW 1971			39.398	133.475	3.0238	0.729874			
	KAW 2069			50.542	106.930	4.8443	0.734413			
	KAW 2070			40.243	172.898	2.3839	0.727501			
	KAW 1877	Bi 35/50	394.629		7.537	152.1102	0.750049		15.4±0.2	1
		WM 50/80	240.923		51.876	13.4542	0.720852		22.5±1.9	1
	Aplites	KAW 2064		29.284	87.524	3.4254	0.723132	0.7106	258	1
		KAW 2065		31.194	120.335	2.6529	0.719379			
		KAW 2066		31.544	144.586	2.2325	0.718768			
Lamprophyric dyke	KAW 2067			31.646	115.922	2.7942	0.720900	0.70847±0.00018	16.8±0.9	2
	KAW 2063									

*WM - White Mica

1) Steiner (1984a); 2) Steiner (1984b)

$$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$$

TABLE 11 c - U-Pb ages

Rock type	Grain size mag. suscept	Sample	Material	U ppm	Pb total ppm	$\frac{206}{204}\text{Pb}$	$\frac{207}{204}\text{Pb}$	$\frac{208}{204}\text{Pb}$	AGE Ma			Ref.
						$\frac{206}{204}\text{Pb}$	$\frac{207}{204}\text{Pb}$	$\frac{208}{204}\text{Pb}$	$\frac{206}{238}\text{U}$	$\frac{207}{235}\text{U}$	$\frac{207}{206}\text{Pb}$	
Granodioritic gneiss		MATO 1	Zr									1
	> 150			415	25.6	246.1	27.63	59.80	309	312	338 ⁺⁵³	
	150-75 n.m.			458	25.1	484.5	40.16	85.89	306	310	323 ⁺³¹	
	53-42 n.m.			669	32.1	1496	93.35	203.7	290	294	317 ⁺¹²	
Paragneiss	< 53 m.	MATO 2	Zr	789	37.6	887.2	60.92	140.1	279	282	297 ⁺¹⁷	2
	> 75 n.m.			500	55.1	2757	253.0	360.9	638	820	1349 ⁺⁴	
	53-42 n.m.			641	59.1	6000	493.4	680.5	552	696	1195 ⁺³	
	53-42 m.			785	66.7	3876	306.4	461.5	508	614	1079 ⁺⁴	
Aplitic gneiss	< 42 m.	RUSCADA	Zr	882	67.7	3369	261.9	388.6	463	570	1129 ⁺³	2
	100-75 n.m.			2547	96.9	883.9	64.20	57.89	241	262	463 ⁺³¹	
	75-53 n.m.			2697	99.0	858.0	62.04	55.43	232	251	437 ⁺¹⁴	
	< 42			3316	107.0	2054	125.50	77.74	215	229	372 ⁺⁷	
Granodioritic gneiss		COCCO 1	Mo	4605	61.6	436	34.92	1397	22.3	22.3	24 ⁺⁴¹	2
	>125 n.m.			615	27.9	2740	159.0	253.3	287	291	317 ⁺⁹	
	75-53 n.m.			753	32.2	8543	466.3	778.7	273	278	323 ⁺⁴	
	75-53 m.			870	37.5	2122	126.34	257.4	266	271	316 ⁺⁹	
Granoblastic gneiss	< 53 m	GIUM 2	Zr	1036	43.3	4036	226.7	470.1	260	266	310 ⁺⁶	2
	>100			4107	530	6971	375.8	18700	252	255	277 ⁺⁴	
	<100			4467	500	5884	320.2	17160	206	213	283 ⁺⁴	
Paragneiss	> 90 n.m.	GIUM 1	Zr	2606	100.1	5792	335.4	183.3	258	276	429 ⁺³	2
	75-53 n.m.			2538	97.1	12484	701.6	342.4	259	275	414 ⁺¹²	
	53-42 m.			3755	128.2	2194	139.19	131.1	227	236	336 ⁺⁹	
	< 42 m.			4034	129.4	15130	812.6	388.6	219	227	318 ⁺²	
Paragneiss	>100	GIUM 1	Mo	9044	667	11637	617.2	12320	255	257	275 ⁺³	2
	< 53			9392	699	7412	699.0	8910	241	244	277 ⁺²	
	> 53			10379	661	8284	447.2	8448	219	231	294 ⁺³	
	< 53			8214	614	6626	360.7	7873	204	212	295 ⁺³	
Paragneiss		FUSIO	Mo	6577	55.4	476.7	36.70	792.6	22.0	21.9	11 ⁺³¹	2
				12520	48.3	860.3	54.72	178.2	22.1	22.2	28 ⁺¹⁶	

1) Allegre et al. (1974)

2) Küppel, Günthert, Grünenfelder (1980)

MONTE ROSA NAPPE

TABLE 12 - *K-Ar ages*

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Orthogneisses	KAW 86	Mu	8.98	23.23×10^{-6}	61.1	63.8 ± 3.1	1
	KAW 92	Mu	9.23	9.41×10^{-6}	87.3	25.4 ± 0.9	1
	KAW 366	Mu	8.97	20.40×10^{-6}	91.4	57.0 ± 2.5	1
	KAW 371	Bi	7.21-7.29	6.41×10^{-6}	69.6	22 ± 1.3	2
		Phe	9.09-9.08	12.4×10^{-6}	84.7	33.9 ± 1.6	2
	KAW 405	Bi	7.94-7.91	9.10×10^{-6}	79.3	28.6 ± 1.4	2
		Mu	9.07-9.10	13.4×10^{-6}	87.4	36.6 ± 1.7	2
	KAW 416	Mu	9.31	19.79×10^{-6}	89.1	52.6 ± 1.8	1

1) Frey et al. (1976);
2) Purdy & Jäger (1976)

TABLE 12 a - *Rb-Sr ages*

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr rad ppm	Sr concn ppm	% rad	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Rb}/^{86}\text{Sr}$	Isochron AGE Ma	Ref.
Orthogneisses	KAW 83	WR	55.8	0.298	147		0.7294	3.984	260 ± 10	3
		Bi	272	0.0847	2.35	34.4			20.1 ± 1.1	1
		Mu	135	0.0693	7.83	11.4			28 ± 6	1
	KAW 86	WR	73.3	0.353	76.3	6.3	0.7541	9.85	310 ± 20	4-2
		Mu	196	0.718	6.4	62.1	1.8644	318.7	248 ± 10	4-2
		Bi	377	0.504	1.19	86.0	5.0349	3252	90 ± 4	1-4
		Kf	137	0.744	154	6.6	0.7566	9.139		4
	KAW 91	Mu	93.4	0.391	23.4	19.5			255 ± 22	2
	KAW 92	Mu	133	0.395	10.7	34.8			197 ± 8	2
	KAW 322	Bi	90.7	0.0389	2.92	16.2			28 ± 3.5	1
	KAW 366	WR	88.5	0.377	44.5	5.1	0.7451	9.01	260 ± 10	4-3
		Mu	206	0.738	7.55	58.7	1.7075	279.5	242 ± 6	4-2
		Mu+Phe	206	0.702	15.6	39.5	1.1642	134.8		4
		Phe	284	0.247	25.5	12.3	0.8039	114.0	40.4 ± 1.9	4
		Bi	488	0.236	13.0	21.0	0.8933	387.2	27.0 ± 0.8	4
		Pf	32.5	0.289	85.8	4.6	0.7393	3.870	40.4 ± 1.9	4
		Kf	171	0.778	231	4.6	0.7391	7.555	40.4 ± 1.9	4
		Gr	32.8	0.070	17.4	5.6	0.7461	19.29	40.4 ± 1.9	4
	KAW 367	Mu	151	0.108	6.3	19.8			33.1 ± 3.5	2
	KAW 369	Mu	213	0.144	12.7	14.1			29.7 ± 4.8	2
	KAW 371	Mu	230	0.141	3.4	37.6			37.4 ± 1.5	2

TABLE 12 a (continued)

Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr rad ppm	Sr comm ppm	% rad	$\text{Sr}^{87}/\text{Sr}^{86}$	$\text{Rb}^{87}/\text{Sr}^{86}$	Isochron AGE Ma.	Ref.
Orthogneisses	KAW 377	WR	56.1	0.428	185	3.3	0.7308	3.127	125 $\pm$ 6	4-2
		Phe	154	0.105	12.8	10.6	0.7913	124.2	34.5 $\pm$ 1.7	4-2
		Bi	284	0.131	9.5	16.6	0.8470	306.7	26.3 $\pm$ 0.8	4
		Alb	4.56	0.278	55.3	6.8	0.7269	0.8444	34.5 $\pm$ 1.7	4
		Kf	54.2	0.500	216	3.25	0.7284	2.562	34.5 $\pm$ 1.7	4
	KAW 402	Mu	150	0.100	4.3	25.3			34.4 $\pm$ 2.6	2
	KAW 405	Mu	213	0.159	15.7	12.8			37.9 $\pm$ 5.9	2
	KAW 411	Mu	153	0.509	11.8	38.5			222 $\pm$ 12	2
	KAW 412	Mu	139	0.196	89	3.1			95.8 $\pm$ 64 ⁹	2
	KAW 413	Mu	282	0.244	7.4	32.4			45.4 $\pm$ 2.6	
	KAW 416	WR	81.8	0.388	64.2	8.1	0.7690	13.10	310 $\pm$ 20	4-2
		Mu	262	0.953	1.2	72.8	2.5956	521.8	246 $\pm$ 10	4-2
		Mu+Phe	250	0.848	6.2	66.7	2.1203	417.7		4
		Phe+Mu	272	0.490	10.8	39.5	1.1647	255.4	110 $\pm$ 2.5	4
		Bi	431	0.216	2.1	59.6	1.7504	2094	32.2 $\pm$ 0.7	4
		Pl	146	0.930	175	7.2	0.7592	8.523	32.2 $\pm$ 0.7	4
		Kf	33.2	0.308	58.4	7.1	0.7584	5.813	32.2 $\pm$ 0.7	4
		Gr	48.6	0.180	30.0	8.0	0.7657	16.54	32.2 $\pm$ 0.7	4
		Ep	35.8	2.804	541	7.0	0.7577	0.676	32.2 $\pm$ 0.7	4
		Mu	302	0.205	3.4	46.7			26.3 $\pm$ 1.4	2

TABLE 12 a (continued)

Rb-Sr ages

Rock type	Sample n.	Material	^{87}Rb ppm	^{87}Sr rad ppm	Sr comm ppm	% rad	$\text{Sr}^{87}/\text{Sr}^{86}$	$\text{Rb}^{87}/\text{Sr}^{86}$	Isochron AGE Ma.	Ref.
Less deformed gneisses	KAW 86	WR	73.3	0.353	76.3	6.3	0.757	9.85	310 $\pm$ 50	2
	KAW 92	WR	60.9	0.350	195	2.5	0.728	3.21		
	KAW 369	WR	77.9	0.357	74.9	6.1	0.755	10.01		
	KAW 376	WR	71.2	0.362	81.1	6.1	0.755	9.03		
	KAW 411	WR	65.5	0.297	122	3.35	0.734	5.50		
	KAW 416	WR	81.8	0.388	64.2	8.1	0.772	13.10		
Two-Mica-Oligoclase-Microcline-Augengneiss	KAW 83	WR	55.8	0.298	147		0.7294	3.984	260 $\pm$ 10	3
Leucocrate-Biotite-Muscovite-Albitgneiss	KAW 366	WR	88.5	0.377	44.5		0.7476	9.01		
Biotite-Phengite-Albite-K-feldspar-Augengneiss	KAW 405	WR	78.7	0.330	111		0.7396	7.279		
Phengite-Albitgneiss	KAW 418	WR	87.9	0.348	21.7		0.8736	41.85		
Fine-grained Albite microcline two Micagneiss	KAW 514	WR	103	0.438	47.2		0.8043	22.43		
Alcalifeldspar-Oligoclase-Muscovitegneiss	KAW 522	WR	69.8	0.275	16.3		0.8824	43.96		

ADAMELLO

TABLE 13 - *K-Ar ages*

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g ·10 ⁻³	^{40}Ar rd%	AGE Ma	Ref.
Granodiorite	A/4	Bi	7.58	.118		30 ± 2	2
Tonalite W Adamello	A76 22	Bi	7.90	10.9	92	35.7± .4	1
" "	A76 22	Ho	.60	.97	63	42.4± .5	1
" "	A77 25	Bi	7.20	10	58	35.3± 1.0	1
" "	A77 25	Ho	.74	1.22	39	41.9± 1.2	1
" "	A77 25	P1+Qz	.12	1.12	50	229 ±20	1
" "	A77 29	Bi	7.71	10.1	62	33.4± 1.6	1
Gabbro M. Marsère	A78 8	Bi	6.94	10.6	88	39.1± 1.2	1
" "	A78 9	Bi	6.99	10.6	92	38.6± 1.2	1
" "	A78 10	Bi	6.13	9.8	90	40.8± .8	1
Quartzdiorite Avio	A76 24	Bi	7.59	10.3	48	34.7± 1	1
Gabbro Avio	A78 4	Bi	6.99	9.5	91	34.4± .6	1
Tonalite Central Presanella	A76 32	Bi	7.94	10.5	74	33.5± 1.6	1
" "	A76 32	Ho	.68	1.01	66	38.3± .5	1
" "	A76 32	P1	.40	.87	80	57.3± .8	1
Tonalite NE Presanella	A76 38	Bi	8.02	9.4	59	29.9± .9	1
" "	A76 38	Ho	.52	.89	35	44.2± 1.2	1
" "	A78 35	Bi	7.89	10	70	32.2± .9	1
" "	A78 35	Ho	.60	.90	42	37.6± 1.2	1
" "	A78 37	Bi	7.72	10.1	67	33.2± .9	1
" "	A78 37	Ho	.63	.74	32	29.8± 1.5	1
Pegmatite NE Presanella	A77 3	Mu	8.35	10.4	51	32.5± .6	1
Leucoquartzdiorite Val Fredda	A 19	Bi	7.57	12.7	81	42.4± 2.1	1
Diorite Val Cadino	A77 11	Bi	7.35	12	64	41.3± .8	1
" "	A77 14	Bi	7.60	12.8	55	41.9± 1	1
" "	A77 18	Bi	7.74	12.7	60	41.7± 1	1
" "	A77 18	Ho	.61	1	26	41.8± 1.4	1
1) Del Moro et al. (1983); 2) Borsi et al. (1966)							
Diorite Val Cadino	A77 19	Bi	7.89	12.4	77	39.9±1.6	1
" "	A77 19	Ho	.56	.9	43	41.6±1.6	1
Granodiorite Lago Boazzo	A76 1	Bi	7.70	11.7	61	38.6±2	1
" "	A76 1	Ho	.90	1.4	48	39.5±1.8	1
Tonalite Re Castello	A76 19	Bi	7.57	12.1	40	40.6±1.2	1
" "	A76 19	Bi	7.57	11.7	66	39.1±1	1
Pegmatite Re Castello	A76 11	Mu	8.65	13.4	77	39.3±1.6	1
" "	A76 12	Mu	8.65	12.9	68	38.1±1.5	1
Trondhjemite Corno Alto	A77 5	Mu	8.74	11.5	57	33.6±1	1
" "	A77 5	Bi	7.86	10.2	61	33.1±1	1
" "	A77 9	Mu	9.06	12.3	70	34.6±1	1
" "	A77 9	Bi	7.75	10.3	45	33.8±1	1
" "	A78 33	Mu	8.60	12.2	63	36.2±1.2	1
" "	A78 33	Bi	8.07	10.4	67	32.7± .9	1
Granodiorite Malga Sostino	A78 31	Bi	7.75	11.5	64	37.9±1.1	1
Gabbro M. Mattoni	A 15	Ho	.28	2.1	61	182 ±5.3	2
" "	A 16	Ho	.30	.9	41	79.1±2.3	2
" "	A 17	Ho	.34	1.1	51	79.8±2.3	2
" "	A 18	Ho	.42	1.2	41	70.3±2.1	2
" "	A77 21b	Ho	.25	.8	27	77.3±2.2	2
" "	A77 21g	Ho	.21	.9	26	102 ±3	2
" "	A81 3	Ho	.29	1.6	69	136 ±1.4	2
" "	A81 4	Ho	.16	.6	49	87.6± .9	2
Gabbro M. Blumone	A77 1	Ho	.39	.8	34	49.2±3.8	2
" "	A77 16	Ho	.26	.6	14	60.3±1.8	2
" "	A78 20	Ho	.25	.7	39	72.1±2.2	2
" "	A78 21	Ho	.35	.9	20	61.1±1.8	2

TABLE 13 (continued)

K-Ar ages

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Gabbro M. Blumone	A81 9	Ho	.56	1.1	49	45.3 $\pm$.6	1
Gabbro Val Cadino	A78 23	Ho	.69	1.3	50	47.4 $\pm$ 1.7	1
" "	A 105	Ho	.33	.6	45	47.5 $\pm$ 1.7	1
Gabbro Val Braone	A 107	Ho	.27	.6	35	53.4 $\pm$ 2.5	1
Gabbro M. Campellio	A78 29	Ho	1.15	1.9	58	43.2 $\pm$ 1.2	1
Gabbro M. Marsere	A78 8	Ho	.31	1.4	80	111.6 $\pm$ 1.1	1
" "	A78 9	Ho	.56	2.6	82	113.6 $\pm$ 1.1	1
" "	A78 10	Ho	.48	2.5	62	129.4 $\pm$ 3.8	1

1) Villa (1983)

TABLE 13 a - Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_0$	$(^{87}\text{Sr}/^{86}\text{Sr})_t$	AGE Ma	Ref.
Tonalite S.E. Adamello	A/0	Bi	586	5.16	320.77	.928	.712	* 45 $\pm$ 2	3
Tonalite	A/1	Bi	372	4.96	211.86	.816	.712	* 33 $\pm$ 3	3
Pegmatite	A/2	Bi	1066	4.23	711.81	1.149	.712	* 41 $\pm$ 2	3
Granodiorite - Sostino	A/5	Bi	531	5.32	281.92	1.016	.712	* 33 $\pm$ 3	3
Granodiorite - Corno Alto	A/4	Bi	434	6.93	176.89	.793	.712	* 31 $\pm$ 3	2
Leucoquartzdiorite	A 19	Bi	372	9.5	113.35	.7694	.7052	40 $\pm$.9	1
Val Fredda	A77 22	Bi	482	5.8	244.13	.8473	.7059	40.8 $\pm$ 1.2	1
Diorite Val Cadino	A77 11	Bi	414	3.5	350.38	.9059	.7041	40.6 $\pm$.7	1
" "	A77 14	Bi	585	9.1	187.89	.8132	.7044	40.8 $\pm$ 1.1	1
" "	A77 19	Bi	482	3.6	387.34	.9240	.7040	40 $\pm$.6	1
" "	A81 1	Bi	339	10.4	94.41	.7607	.7067	40.3 $\pm$ 1.0	1
Tonalite Lago Vacca	A77 17	Bi	438	3.0	434.18	.9580	.7075	40.7 $\pm$.8	1
" "	A78 22	Bi	415	4.5	268.73	.8650	.7059	41.7 $\pm$.9	1
Granodiorite	A76 1	Bi	526	7.8	196.70	.8164	.7060	39.5 $\pm$.4	1
Lago Boazzo	A76 1	Ho	32	57	1.62	.7069	.7060	39.5 $\pm$.4	1
" "	A76 1	Pl	9	973	.03	.7060	.7060	39.5 $\pm$.4	1
" "	A76 1	Kf	378	460	2.38	.7070	.7057	39.5 $\pm$.4	1
" "	A78 16	Bi	333	3.5	279.40	.8681	.7044	41.3 $\pm$ 1.2	1
" "	A78 24	Bi	417	8.4	145.20	.7887	.7056	40.3 $\pm$ 1	1
Tonalite Re Castello	A 54	Bi	690	3.5	573.20	1.0010	.7075	36.1 $\pm$.6	1
" "	A 56	Bi	587	3.6	476.50	.9662	.7075	38.3 $\pm$ 1.1	1
" "	A76 17	Bi	490	6.4	220.86	.8215	.7069	36.6 $\pm$.7	1
" "	A76 19	Bi	551	7.3	220.92	.8270	.7070	38.3 $\pm$.6	1
Pegmatite Re Castello	A76 11	Mu	579	2.9	581.07	1.0192	.7124	37.2 $\pm$.6	1
" "	A76 12	Mu	680	1.5	1261.77	1.3296	.6495	38 $\pm$.6	1
" "	A76 12	Kf	289	4	15.49	.7199	.7116	38.1 $\pm$ 1.5	1

1) Del Moro et al. (1983); 2) Borsi et al. (1966); 3) Ferrara (1962).

$$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$$

$$^*\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$$

TABLE 13 a (continued)

Rb-Sr ages

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{m}}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{f}}$	AGE Ma	Ref.
Pegmatite Re Castello	A78 27	Mu	864	2.7	977.35	1.2625	.7269	38.6 $\pm$.7	1
"	A78 27	Kf	492	54	26.53	.7415	.7270	38.6 $\pm$.7	1
Trondhjemite Corno Alto	A77 5	Mu	235	31.8	21.41	.7183	.7056	41.7 $\pm$ 3.5	1
"	A77 5	Bi	456	2.9	460.96	.9246	.7061	33.4 $\pm$.8	1
"	A77 8	Bi	333	4.7	208.38	.8045	.7043	33.9 $\pm$.8	1
"	A77 9	Mu	387	22.0	50.64	.7362	.7061	41.9 $\pm$ 1.1	1
"	A77 9	Bi	613	5.5	326.91	.8646	.7064	34.1 $\pm$.7	1
"	A78 33	Mu	239	30.9	22.42	.7183	.7052	41.1 $\pm$ 2.6	1
"	A78 33	Bi	453	5.5	240.23	.8213	.7055	34 $\pm$.8	1
Granodiorite M. Sostino	A77 10	Bi	484	5	285.17	.8608	.7062	38.2 $\pm$ 1.2	1
"	A78 31	Bi	478	4.8	290.77	.8677	.7063	39.1 $\pm$.9	1
"	A04	Bi	563	2.3	699.66	1.0832	.7068	37.9 $\pm$.7	1
Tonalite W Adamello	A76 4	Bi	485	2	692.70	1.0487	.7079	34.7 $\pm$.6	1
"	A76 5	Bi	465	2	676.76	1.0440	.7077	35 $\pm$.6	1
"	A76 22	Bi	415	2.1	559.84	.9794	.7084	34.1 $\pm$.6	1
"	A77 25	Bi	453	2.9	465.50	.9409	.7091	35.1 $\pm$.5	1
"	A77 27	Bi	601	3.6	487.07	.9435	.7073	34.2 $\pm$.6	1
"	A77 28	Bi	725	3.2	673.52	1.0444	.7090	35.1 $\pm$.7	1
"	A77 29	Bi	509	2.7	557.19	.9846	.7077	35 $\pm$.7	1
Gabbro W Adamello	A78 14	Bi	321	5.2	179.44	.7975	.7051	36.3 $\pm$ 2	1
Gabbro M. Marsère	A78 8	Bi	298	6.4	135.24	.7791	.7086	36.7 $\pm$ 1	1
"	A78 10	Bi	245	7.7	91.77	.7557	.7078	36.8 $\pm$.7	1
Tonalite Baitone	A78 11	Bi	426	2.4	529.33	.9789	.7063	36.3 $\pm$.6	1
Quartzdiorite Central Adamello	A76 21	Bi	467	1.1	1252.04	1.3091	.7094	33.8 $\pm$.6	1
Quartzdiorite Avio	A x 2	Bi	386	2.3	478.23	.9412	.7112	33.9 $\pm$.6	1
"	A76 23	Bi	443	3.8	339.99	.8664	.7110	32.2 $\pm$.5	1
Quartzdiorite Avio	A76 24	Bi	432	4.1	308.48	.8519	.7125	31.9 $\pm$.5	1
"	A76 24	Kf	192	333	1.67	.7127	.7119	31.9 $\pm$.5	1
"	A76 24	P1	18	439	.12	.7123	.7122	31.9 $\pm$.5	1
"	A77 31	Bi	434	2.3	535.35	.9750	.7122	33.5 $\pm$.6	1
Gabbro Avio	A78 1	Bi	406	3.8	310.80	.8566	.7105	33.1 $\pm$ 1.1	1
"	A78 4	Bi	316	3.4	276.35	.8373	.7080	33 $\pm$ 1.6	1
Leucoquartzdiorite Avio	A78 12	Bi	375	4	273.55	.8474	.7109	35.2 $\pm$.7	1
Quartzdiorite Val di Genova	A76 25	Bi	465	1.3	1043.97	1.1564	.7106	30.1 $\pm$.5	1
"	A76 34	Bi	442	2.1	608.59	.9904	.7123	32.2 $\pm$.6	1
"	A78 34	Bi	426	2.8	451.97	.9241	.7126	33 $\pm$.6	1
Aplite Val di Genova	A76 28	Bi	721	1.1	1843.71	1.5251	.7120	31.1 $\pm$.6	1
Tonalite Central Presanella	A x 1	Bi	409	2.6	460	.9243	.7095	32.9 $\pm$.9	1
"	A 3	Bi	411	2.5	482.21	.9264	.7089	31.8 $\pm$.8	1
"	A76 26	Bi	489	1.4	990.69	1.1527	.7089	31.6 $\pm$.6	1
"	A76 32	Bi	496	1.3	1115.32	1.2221	.7091	32.4 $\pm$.5	1
Tonalite NE Presanella	A 2	Bi	465	4	336	.8620	.7101	31.9 $\pm$.9	1
"	A76 38	Bi	350	10	101.03	.7519	.7098	29.4 $\pm$ 1.2	1
Pegmatite NE Presanella	A77 3	Mu	3096	1	13695	6.9435	.7291	31.4 $\pm$.7	1
"	A77 3	Kf	2191	20.9	302.68	.8437	.7090	31.4 $\pm$.7	1

$$\lambda = 1.42 \times 10^{-11} \text{ a}^{-1}$$

1) Del Moro et al. (1983)

MASINO - BREGAGLIA MASSIF

TABLE 14 - *K-Ar ages*

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Granite	Z 6	Bi	7.86	$76 \cdot 10^{-3}$	50	24	1

1) Armstrong et al. (1966)

TABLE 14 a - *Rb-Sr ages*

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{in}}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{i}}$	AGE Ma	Ref.
Granodiorite	KAW 780	WR	219	206	3.03	.7149	.703+-.003	65 +17	2
"	KAW 781	WR	265	133	5.71	.7170			2
Granite	KAW 737	WR	179	156	3.28	.7135	.705+-.005	25 +80	2
"	KAW 738	WR	210	98.8	6.06	.7145			2
Aplite	KAW 735	WR	187	84.6	6.31	.7152			2
"	KAW 931	WR	238	49.3	13.76	.7237			2
Granite	Z 6	Bi	1551.2	1.58	2769.2	1.7436	.712	25.3+ 1	1
"	Z 6	Bi	1303.4	4.06	907.5	1.0475	.712	25.1+ 1.5	1
"	Z 6	Bi	1317.8	4.09	910.7	1.0422	.712	24.6+ 1.5	1

$\lambda = 1.47 \times 10^{-11} \text{ a}^{-1}$

1) Armstrong et al. (1966); 2) Gulson (1973)

TABLE 14 b - *U-Pb ages*

Rock type	Sample n.	Mat.	U ppm	Th ppm	Pb _{tot} ppm	AGE Ma							Ref.
						²⁰⁶ Pb ²⁰⁴ Pb	²⁰⁷ Pb ²⁰⁴ Pb	²⁰⁸ Pb ²⁰⁴ Pb	²⁰⁶ Pb ²³⁸ U	²⁰⁷ Pb ²³⁵ U	²⁰⁸ Pb ²³² Th	²⁰⁷ Pb ²⁰⁶ Pb	
Granodiorite	KAW919 MO	Zr	3072	--	0.28	3030	--	--	32.05	33.08	--	109.4	1
"	KAW935 MO	Zr	4090	--	0.37	2270	--	--	32.63	33.64	--	107	1
"	KAW918 MO	Zr	822	--	.31	890	--	--	37.68	39.06	--	125.8	1
"	KAW1002 MO	Zr	3499	--	.37	2703	--	--	32.92	33.67	--	87.8	1
"	KAW 1040	Zr	2249	--	.71	1887	--	--	64.97	78.04	--	505.3	1
"	KAW 935	Al	204.7	--	14.30	23.45	--	--	34.4	55.8	--	--	1
"	KAW 935	Mo	106457	--	1.68	14200	--	--	30.31	30.26	--	26.55	1
"	KAW 935	Ap	39.6	--	7.48	20.20	--	--	28.2	33	--	--	1
"	KAW 935	Sph	172.6	--	3.62	31.65	--	--	29	75	--	--	1
"	KAW 918	Sph	63	--	3.38	24.51	--	--	32.8	38.7	--	--	1

1) Gulson & Krogh (1973)

TABLE 14 c - FT ages

Rock type	Sample n.	Material	Pf tracks/cm ² (tracks)	Pi tracks/cm ² (tracks)	Φ neutrons/cm ²	D_W/D_H or temper.	AGE Ma	Elevation (m)	$\bar{S}\%$	Ref.
Intrusive rocks	BM-2	Ap	1321	3074	7.64	1.64/ 3.71	16.8 $\pm$.8	2340	3.3	1
"	BM-3	Ap	2228	5483	7.64	4.42/11.0	15.3 $\pm$.7	1860	3.3	1
"	BM-7	Ap	1557	4212	7.64	4.10/11.1	14 $\pm$.6	1080	3.1	1
"	KAW-132	Ap					11.2	310		2
"	KAW-553	Ap					13.5	800		2
Granitic boulders	KAW-1003	Ap	2105	3433	7.64	2.98/ 4.84	23.4 $\pm$ 1		2.9	1
"	KAW-1004	Ap	2058	3218	7.64	2.87/ 4.52	24.1 $\pm$.9		2.5	1
"	KAW-1005	Ap	2000	3268	7.64	3.12/ 4.58	25.9 $\pm$.8		2.2	1

1) Wagner et al. (1977, 1979)

REFERENCES

- ALLÈGRE C.J., ALBARÈDE F., GRÜNENFELDER F., KÖPPEL V. (1974) - $^{238}\text{U}/^{206}\text{Pb}$, $^{235}\text{U}/^{207}\text{Pb}$, $^{232}\text{Th}/^{208}\text{Pb}$ zircon geochronology in Alpine and non Alpine environment. *Contr. Min. Petr.*, 43, 173-194.
- ARMSTRONG R.L., JÄGER E., EBERHARDT P. (1966) - A comparison of K-Ar and Rb-Sr ages on Alpine biotites. *Earth Plan. Sci. Lett.*, 1, 13-19.
- ARTUS F. (1959) - Über metamorphe Breccien basischer Gesteine im Granit des Bergeller Massivs. *Hamb. Beitr. Miner. Kristallophys. Petrogen.*, 2, 1-39.
- BIANCHI A. & DAL PIAZ G.B. (1937) - Il settore meridionale del massiccio dell'Adamello. Relazione sul rilevamento e studi preliminari della zona compresa fra la Valle di Stabio e l'alta Valle del Caffaro. *Boll. Uff. Geol. It.*, 62.
- BIGIOGGERO B., BORIANI A., COLOMBO A., GREGNANIN A. (1980) - Carta geolitologica delle valli Vigizzo, Feneccio e basso Isorno. SELCA, Firenze, Regione Piemonte.
- BIGIOGGERO B., BORIANI A., COLOMBO A., TUNESI A., FERRARA G., TONARINI S. (1982-83) - Età e caratteri petrochimici degli ortogneiss della zona Moncucco-Orselina nell'area Ossolana. *Rend. SIMP*, 38 (1), 207-218.
- BOCCHIO R., DE CAPITANI L., LIBORIO G., MOTANA A., NICOLETTI M., PETRUCCIANI C. (1981) - K-Ar radiometric age determinations of the south-Alpine metamorphic Complex, western Orobic Alps (Italy). *N. Jb. Miner. Mh.*, 19, 289-307.
- BOCQUET J., DAL PIAZ G.V., HUNZIKER J.C., MARTINOTTI G., PECHER A. (1973-1974) - Carta delle facies metamorfiche dell'Europa, Foglio speciale Alpi e note illustrative (The Western Alps). Sub-Commission Cartography Metamorphic Belts of the World, Leiden-UNESCO.
- BORIANI A. (1982-83) - The medium-grade - high-grade transition in the regional metamorphism: an example from the Ivrea-Verbano zone (Italy). *Rend. Soc. It. Min. Petr.*, 38 (2), 543-548.
- BORIANI A., BIGIOGGERO B., ORIGONI GIOBBI E. (1977) - Metamorphism, tectonic evolution and tentative stratigraphy of the « Serie dei Laghi ». Geological map of the Verbano area (Northern Italy). *Mem. Soc. Geol.*, 32, 26 pp.
- BORIANI A. & COLOMBO A. (1979) - Gli gneiss chiari fra la Val Sesia e il Lago di Como. *Rend. Soc. It. Min. Petr.*, 35, 299-312.
- BORIANI A., TRAVERSI G.L., DEL MORO A., NOTARPIETRO A. (1982-83) - Il « granito di Brusio » (Val Poschiavo - Svizzera): caratterizzazioni chimiche-petrologiche e radiometriche. *Rend. Soc. It. Min. Petr.*, 38 (1), 97-108.
- BORIANI A. & GIOBBI ORIGONI E. (1982-83) - Heat transfer in the thermo-metamorphic aureole of the north-eastern sector of M. Adamello (Trento - Italy). *Rend. Soc. It. Min.*, 38 (1), 1351-1360.
- BORSI S., FERRARA G., TONGIORGI E. (1966) - Rb-Sr and K-Ar ages of intrusive rocks of Adamello and M. Sabion (Trentino - Italy). *Earth Plan. Sci. Lett.*, 1, 55-57.
- BORSI S., CALLEGARI E., DEL MORO A., FERRARA G., FRATTA M., GIULIANI O., MACERA P., PARDINI G., PESCIA A., TONARINI S., VILLA I.M. (1977) - Geochronological investigations on the Adamello-Presanella massif. *V ECOG*, Pisa 1977.
- BORSI S., DEL MORO A., SASSI F.P., ZIRPOLI G. (1980) - New petrographic and radiometric data on the Oetztal and Stubai orthogneisses (Eastern Alps). *N. Jb. Miner. Mh.*, 75-87.
- BORSI S., DEL MORO A., SASSI F.P., ZIRPOLI G. (1973) - Metamorphic evolution of the Austridic rocks to the south of the Tauern Window (Eastern Alps): radiometric and geopetrologic data. *Mem. Soc. Geol. It.*, 12, 549-571.
- BRACK P. (1983) - Le sequenze triassiche della V. Caffaro: inquadramento strutturale e stratigrafico. In: « Il magmatismo tardo-alpino nelle Alpi ». Guida all'escursione Adamello-Bregaglia, parte I.
- BUCHS A., CHESSEX R., KRUMMENACHER D., VAUGNAT M. (1962) - Ages « Plomb total » déterminés par fluorescence X sur les zircons de quelques roches des Alpes. *SMPM*, 42, 295-304.
- CARTA TETTONICA DELLA SVIZZERA (1980) - Scala 1: 500.000, II edizione.
- CARTA GEOLOGICA DELLA SVIZZERA (1980) - Scala 1: 500.000, II edizione.
- CHESSEX R. (1964) - Determinations d'age sur les zircons de roches des Alpes et des Appenins par la methode des « Radiations damages ». *SMPM*, 44, 1-27.

- CITA M.B. (1957) - *Studi stratigrafici sul terziario subalpino lombardo: sintesi stratigrafica della Gonfolite*. Ist. Geol. Paleont. Univ. Milano, Serie G, pubbl. no. 97.
- COLTORTI M. & SIENA F. (1984) - *Mantle tectonite and fractionated peridotite at Finero (Italian western Alps)*. Neues Jahrb. Min. Abh., 149, 225-244.
- CORNELIUS H.P. (1913) - *Geologische Beobachtungen im Gebiete des Forno-gletschers (Engadin)*. Zbl. Mineral. Geol. Paleont., pp. 246-252.
- CORNELIUS H.P. (1928) - *Zur Alterbestimmung der Adamello und Bergeller Intrusion*, Sitzungsber. Akad. Wiss. Wien, Math. Nat. Kl. Abt., 1, 137.
- DEL MORO A., NOTARPIETRO A., POTENZA R. (1982-83) - *Revisione del significato strutturale e geocronologico delle masse intrusive minori dell'alta Valtellina: risultati preliminari*. Rend. Soc. It. Min. Petr., 38, 89-96.
- DEL MORO A., PARDINI G., QUERCIOLO C., VILLA I.M., CALLEGARI E. (1983 a) - *Rb-Sr and K-Ar chronology of Adamello granitoids, southern Alps*. Conv. Soc. It. Geol., Padova 1983 (in press).
- DEL MORO A., FERRARA G., TONARINI S., CALLEGARI E. (1983 b) - *Rb-Sr systematics on the Adamello plutonic rocks*. Conv. Soc. Geol. It., Padova 1983 (in press).
- DRESCHER-KADEN F.K. (1940) - *Beiträge zur Kenntnis der Migmatit- und Assimilationsbildungen, sowie der syntektischen Reaktionsformen. I. Über Schollenassimilation und Kristallisationsverlauf im Bergeller Granit*. Chemie der Erde, 12, 157-238.
- DRESCHER-KADEN F.K. (1969) - *Granit-Probleme*. Berlin. Akad. Verlag.
- EL TAHLAWI M.R. (1965) - *Geologie und petrographie des nordöstlichen Comersegebietes (Provinz Como, Italien)*. Mitt. Geol. Inst. ETH Univ. Zürich, N.F. 27, 199 pp.
- FERRARA G. (1962) - *Primi risultati e considerazioni sulla datazione assoluta delle rocce intrusive del massiccio dell'Adamello*. Atti Soc. Tosc. Sc. Nat., Ser. A, fasc. 2.
- FERRARA G., HIRT B., JÄGER E., NIGGLI E. (1962) - *Rb-Sr and U-Pb age determinations on the pegmatite of I-Mondei*. Eclogae Geol. Helv., 55, 443-450.
- FREY M., HUNZIKER J.C., O'NEIL J., SCHWANDER H.W. (1976) - *Equilibrium-disequilibrium relations in the M. Rosa granite, Western Alps: petrological Rb-Sr and stable isotope data*. Contr. Min. Petr., 55, 147-179.
- GARUTI G., RIVALENTI G., ROSSI A., SIENA F., SINIGOI S. (1980) - *The Ivrea-Verbano mafic-ultramafic complex of the Italian Western Alps: discussion of some petrologic problems and a summary*. Rend. Soc. It. Min. Petr., 36, 717-749.
- GAUTSCHI A., MONTRASIO A. (1978) - *Die andesitisch-basaltischen Gänge des Bergeller Ostrandes und ihre Beziehung zur Regional- und Kontaktmetamorphose*. Schweiz. Mineral. Petrogr. Mitt., 58, 329-344.
- GRAESER V.S. & HUNZIKER J.C. (1968) - *Rb-Sr und Pb-Isotopen Bestimmungen an Gesteinen und Mineralien der Ivrea-Verbano Zone*. Sond. Schw. Min. Petr. Mitt., 48, 189-204.
- GRAUERT B., HÄNNY R., SOPTRAJANOVA G. (1973) - *Age and origin of detrital zircons from the Pre-Permian basements of the Bohemian Massif and the Alps*. Contr. Min. Petr., 40, 105-130.
- GRÜNENFELDER M. & STERN T.W. (1960) - *Das zirkonaler des Bergeller massivs*. SMPM, 40, 253-259.
- GULSON B.L. (1973) - *Age relations in the Bergell region of the South-East Swiss Alps; with some geochemical comparisons*. Eclogae Geol. Helv., 66, 293-313.
- GULSON B.L. & KROGH T.E. (1973) - *Old lead components in the young Bergell Massif, South-East Swiss Alps*. Contr. Min. Petr., 40, 239-252.
- HAMET J. & ALBAREDE F. (1973) - *Rb-Sr geochronology of the Ceneri Zone (Southern Alps)*. Firtschr. Min., 50, 80-82.
- HANSON G.N., EL TAHLAWI M.R., WEBER W. (1966) - *K-Ar and Rb-Sr ages of pegmatites in the south-central Alps*. Earth Plan. Sci. Lett., 1, 407-413.
- HUNZIKER J.C. (1969) - *Rb-Sr Altersbestimmungen aus den Walliser Alpen Hellglimmer und Gesamtgesteinsalterswerte*. Eclogae Geol. Helv., 62/2, 527-542.
- HUNZIKER J.C. (1970) - *Polymetamorphism in the M. Rosa, Western Alps*. Ecl. Geol. Helv., 63, 151-161.
- HUNZIKER J.C. (1974) - *Rb-Sr and K-Ar age determinations and the Alpine tectonic history of the western Alps*. Mem. Ist. Geol. Min. Univ. Padova, 31, 54 pp.
- HUNZIKER J.C. & ZINGG A. (1980) - *Lower Paleozoic amphibolite to granulite facies metamorphism in the Ivrea Zone (Southern Alps - Northern Italy)*. SMPM, 60, 181-213.
- HUNZIKER J.C. & ZINGG A. (1982) - *Zur genese der ultrabasischen Gesteine der Ivrea Zone*. SMPM, 62, 483-486.
- JÄGER E. (1973) - *Die Alpine orogenese im Lichte der radiometrischen Altersbestimmung*. Ecl. Geol. Helv., 66, 11-21.
- JÄGER E. & FAUL H. (1959) - *Age measurements on some granites and gneisses from the Alps*. Bull. Soc. Geol. Am., 70, 1553-1557.
- JÄGER E., NIGGLI E., WENK E. (1967) - *Rb-Sr Altersbestimmungen an Glimmern der Zentralalpen*. Beitr. Geol. Karte Schweiz. NF Liefg. 134, Kümmerly and Frey, Bern.
- JÄGER E. & HUNZIKER J.C. (1969) - *Geochronology field guide*.
- KLEIN J.A. (1978) - *Post-nappe folding southeast of the Mischabelstock (Pennine Alps) and some aspects of the associated metamorphism*. Leidse Geol. Meded., 51/2, 233-312.
- KÖNIG M.A. (1964) - *Geologisch-petrographische Untersuchungen in Oberen Veltlin*. Doktorarbeit, E.T.H. Zürich.
- KÖPPEL V. (1974) - *Isotopic U-Pb ages of monazites and zircons from the crust-mantle transition and adjacent units of the Ivrea and Ceneri Zones (Southern Alps - Italy)*. Contr. Min. Petr., 43, 55-70.
- KÖPPEL V., GRÜNENFELDER M. (1971) - *A study of inherited and newly formed zircons from paragneisses and granitized sediments of the Strona-Ceneri (Southern Alps)*. SMPM, 51, 385-409.
- KÖPPEL V. & GRÜNENFELDER M. (1975) - *Concordant U-Pb ages of monazite and xenotime from the*

- Central Alps and the timing of the high temperature Alpine metamorphism, a preliminary report. Bericht über die Jubiläumstagung in Neuenburg 49. Haupt.
- KÖPPEL V. & GRÜNENFELDER M. (1980) - *Geochronological data*. In Switzerland, 26th Congress IGC, G 10, 87-89.
- KÖPPEL V., GÜNTHER A., GRÜNENFELDER M. (1980) - *Patterns of U-Pb zircon and monazite ages in polymetamorphic units of the Swiss Central Alps*. Schweiz. Min. Petr. Mitt., 61, 97-119.
- KÖPPEL V. & SCHROLL E. (1983) - *Lead isotopes of Paleozoic, strata-bound to stratiform galena bearing sulfide deposits of the Eastern Alps (Austria), implications for their geotectonic setting*. S.M.P.M., 63, 347-360.
- KRUMMENACHER D., EVERNDEN J.F., VUAGNAT M. (1960) - *Sur l'âge absolu de la peridotite micacée de Finero (Zone d'Ivrea)*. Arch. Sci. (Genève), 13, 369-373.
- LENSCH G. (1971) - *Die ultramafite der Zone von Ivrea*. Ann. Univ. Sarav., H. 9, 6-146.
- LIBORIO G. & MOTTANA A. (1971) - *Gneiss chiari del Corno Stella*. Boll. Serv. Geol. Ital., 92, Suppl., 43-51.
- LONGO V. (1968) - *Geologie und Stratigraphie des Gebiets zwischen Chiasso und Varese*. Dissertation, Universität Zürich.
- MACERA P., FERRARA G., PESCIA A., CALLEGARI E. (1983) - *A geochemical study of the acid and basic rocks of the Adamello batholith*. Mem. Soc. Geol. It., 26, in press.
- MC DOWELL F.W. (1970) - *Potassium-Argon ages from the Ceneri Zone, Southern Swiss Alps*. Contr. Min. Petr., 28, 165-182.
- MC DOWELL F.W. & SCHMID R. (1968) - *Potassium-Argon ages from the Valle d'Ossola Section of the Ivrea-Verbano Zone (Northern Italy)*. SMPM, 48, 205-210.
- MOTTANA A., NICOLETTI M., PETRUCCIANI C., LIBORIO G., DE CAPITANI L., BOCCHIO R. (1985) - *Pre-Alpine and Alpine evolution of the South-Alpine basement of the Orobic Alps*. Geol. Rundsch. (in press).
- NIEVERGELT P. & DIETRICH V. (1977) - *Die andesitisch-basaltischen Gänge des Piz Lizum (Bergell)*. S.M.P.M., 57, 267-280.
- NOVARESE V. (1929) - *La zona del Canavese e le formazioni adiacenti*. Mem. Descr. Carta Geol. It., 22, 65-198.
- PASTEELS P. (1964) - *Measures d'âges sur les zircons de quelques roches des Alpes*. SMPM, 44-2, 519-541.
- PFISTER M. (1921) - *Stratigraphie des Tertiär und Quartär am Südfuss der Alpen mit spezieller Berücksichtigung der miozänen Nafelfluf*. Diss. ETH, Zürich.
- PURDY J.W. & JÄGER E. (1976) - *K-Ar ages on rock forming minerals from the Central Alps*. Mem. Soc. Geol. Univ. Padova, 30, 32 pp.
- REINHARD M. (1964) - *Über das Grundgebirge des Sottoceneri im Sud-Tessin und die darin auftretenden Ganggesteine*. Beitr. Geol. Karte Schweiz., NF, 117.
- RAGETHI R. (1984) - *Intrusiva und extrusiva der Bernina deke, Zwischen, Mortsch- und Berninapas (Grüben)*. SMPM, 64, 83-109.
- RIKLIN K.A. (1983) - *Kontaktmetamorphose Permischer Sandsteine im Adamello Massif*. Dissertation ETH, Zürich. Abh. z. Erlang. d. Titels eines Dokt. Naturwiss.
- RIVALENTI G., GARUTI G., ROSSI A. (1975) - *The origin of the Ivrea-Verbano basic formation (Western Italian Alps). Whole rock geochemistry*. Boll. Soc. Geol. It., 94, 1149-1186.
- RÖGEL R., CITA M.B., MÜLLER C., HOCHULI P. (1975) - *Biochronology of conglomerate bearing molasse sediments near Como (Italy)*. Riv. Ital. Paleontol., 81, 57-88.
- STAUB R. (1949) - *Betrachtungen über den Bau der Südalpen*. Ecl. Geol. Helv., 42/2, 215-408.
- STEINER H. (1984 a) - *Radiometrische Alterbestimmungen an Gesteinen der Maggia-Decke (Penninikum der Zentralalpen)*. SMPM, 64, 227-259.
- STEINER H. (1984 b) - *Mineralogisch-petrographische, geochemische und isotopengeologische Untersuchungen an einem Meta-Lamprophyr und seinem granodioritischen Nebengestein (Matorello-Gneiss) aus der Maggia-Decke*. SMPM, 64, 261-271.
- TROMMSDORFF V. & NIEVERGELT P. (1983) - *The Bregaglia (Bergell)-Iorio intrusive and its field relations*. Mem. Soc. Geol. It., 26, in press.
- TRUMPY R. (1980 a) - *Penninic and higher nappes of Valais*. In: Switzerland - An outline of geology of Switzerland. 26th Congress IGC, G 10, 61-64.
- TRUMPY R. (1980 b) - *Penninic and lower nappes of Ticino (Lepontine Alps)*. In: Switzerland - An outline of the geology of Switzerland. 26th Congr. IGC, G 10, 65-67.
- VENZO S. & MAGLIA L. (1947) - *Lembi carboniferi trasgressivi sui micascisti alla «fronte sedimentaria sudalpina» del Comasco*. Atti Soc. It. Sci. Nat., 86, 33-70.
- VILLA I.M. (1983) - *⁴⁰Ar/³⁹Ar chronology of the Adamello gabbros, southern Alps*. Conv. Soc. Geol. It. Padova, luglio 1983 (in press).
- ZINGG A. (1983) - *The Ivrea and Strona Ceneri Zones (Southern Alps, Ticino and North Italy). A review*. SMPM, 63, 361-392.
- WAGNER G.A., MILLER D.S., JÄGER E. (1979) - *Fission-Track ages on apatite of Bergell rocks from Central Alps and Bergell boulders in Oligocene sediments*. Earth. Pl. Sc. Lett., 45, 355-360.
- WAGNER G.A., REIMER G.M., JÄGER E. (1977) - *Cooling ages derived by apatite fission track, mica Rb-Sr, and K-Ar dating; the uplift and cooling history of the Central Alps*. Mem. Ist. Geol. Min. Padova, XXX, 1-27.
- WAGNER R. & REIMER G.M. (1972) - *Fission track tectonics: the tectonic interpretation of apatite fission track ages*. Earth. Pl. Sc. Lett., 14, 263-268.
- WENK H.R. (1973) - *The structure of the Bergell Alps*. Submitted to Ecl. Geol. Helv.
- WENK H.R. (1980) - *More porphyritic dikes in the Bergell Alps*. SMPM, 60, 145-152.
- WENK H.R. (1983) - *A geological history of the Bergell granite and related rocks*. In: Transformist Petrology, Theophrastus Publications, Athens 1982.