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Alpine cooling history of the Monte Mucrone Eclogites (Sesia-Lanzo Zone): fission track evidence

by *Anthony J. Hurford*[1] and *J. C. Hunziker*[1]

Abstract

New fission track ages of 35 Ma (zircon) and 25 Ma (apatite) from metagranitoids of the Monte Mucrone area constrain the low temperature cooling path for this part of the Sesia-Lanzo zone, Western Alps. Two possible patterns are considered: model (a) assumes gradual cooling from the Eo-Alpine event to the present day; model (b) requires a thermal break (cooling then reheating) between the Eo-Alpine and Tertiary metamorphisms. The absence of mica ages intermediate between Eo-Alpine and Tertiary, combined with the new fission track results and published isotopic and petrologic data would tend to favour model (b). Both models contrast strongly with areas which have experienced demonstrable Tertiary (Lepontine) metamorphism.

Keywords: Fission track dating, eclogite, cooling history, Sesia-Lanzo Zone, Western Alps.

1. GEOLOGICAL SETTING

The Sesia-Lanzo zone is a tectonic unit in the Western Alps and is considered as a slice of subducted continental crust that underwent high pressure metamorphism in Eo-Alpine times (DAL PIAZ et al., 1972; COMPAGNIONI et al., 1977; COMPAGNIONI, 1977; GOSSO, 1977; POGNANTE et al., 1980; LARDEAUX, 1981; KOONS, 1982; OBERHÄNSLI et al., 1984). This zone is situated between the Mesozoic metasediments of the Piemont trough and the Southern Alpine Ivrea-Verbano zone, from which it is separated by the Insubric Line (see Figure 1). The Sesia-Lanzo zone is comprised mainly of granitic to granodioritic plutons, with related aplites, pegmatites and basic inclusions, metasediments, in addition to mafic and ultramafic rocks. In the southwestern part of the Sesia-Lanzo zone, Eo-Alpine eclogite and blueschist-facies rocks occur whereas in the

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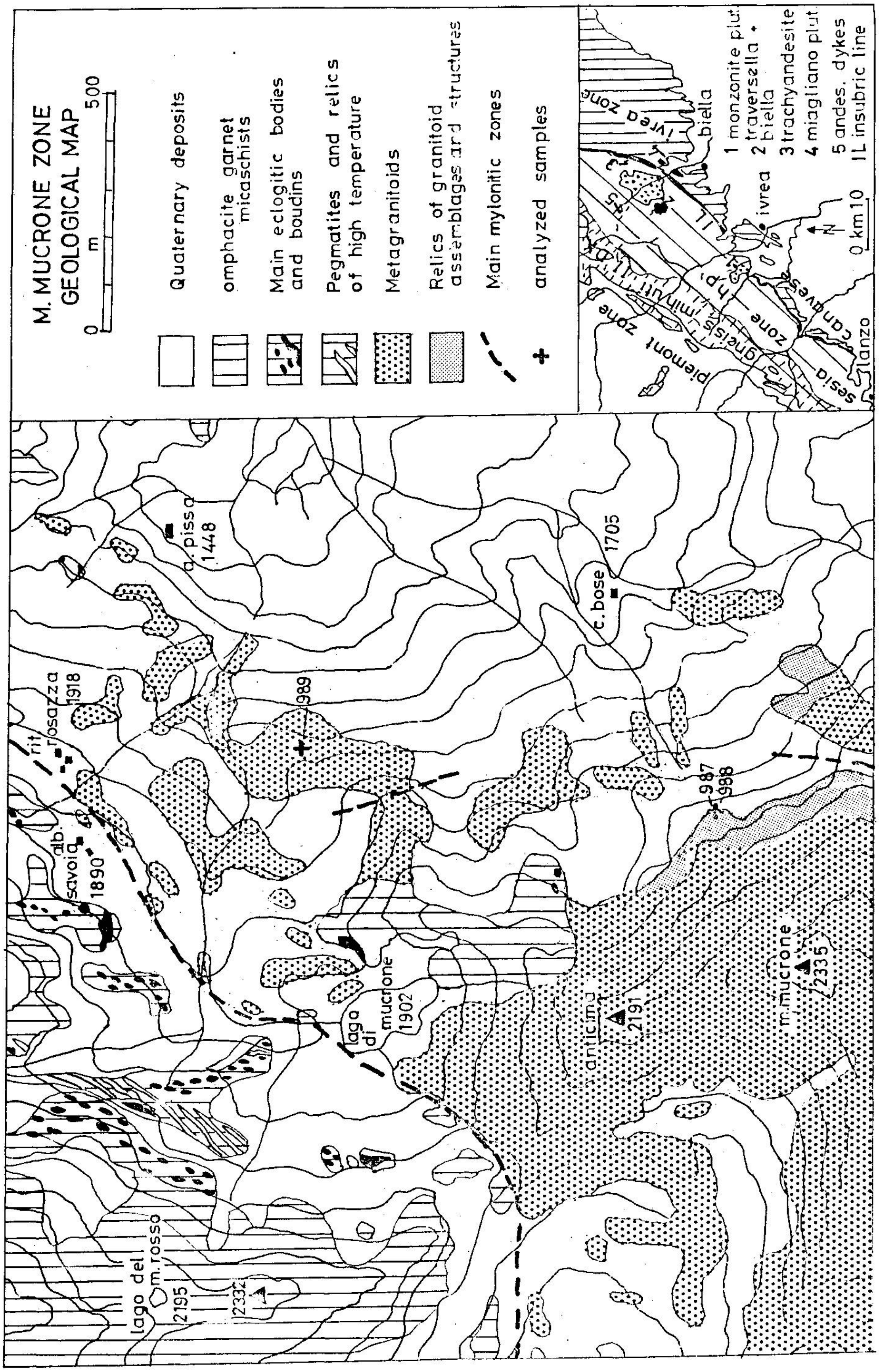

Fig. 1 Geological Sketch Map of the Monte Mucrone Area, showing Sample Localities.

northwest part the so-called Gneiss Minuti unit shows an intense overprint by Tertiary greenschist metamorphism and schistosity.

In the Monte Mucrone area, MARTINOTTI (1970), MAFFEO (1970), DAL PIAZ et al. (1972) and COMPAGNONI and MAFFEO (1974) have established the field relations between meta-granitoids and metasediments. The Monte Mucrone meta-granitoid is one of a number of mappable plutons which still exhibit well preserved granitoid texture (as represented in samples KAW 987, 988) although Alpine deformation is generally high and the major part of the pluton is composed of eclogite facies schists and gneisses (sample KAW 989). From previous dating studies a complex early Alpine pressure/temperature history is evident, although no data has permitted the assessment of the low temperature part of this P/T trajectory. Use of low temperature geothermometers such as fission track (FT) dating of apatite and zircon may detect whether a break exists in the gradual cooling between Eo-Alpine and the Lepontine event in this internal part of the Sesia zone.

2. PREVIOUS DATING STUDIES

KRUMMENACHER and EVERNDEN (1960) determined a K/Ar biotite age of 31 ± 1 Ma for the Traversella syenite, whilst HUNZIKER and BEARTH (1969) report a Rb/Sr biotite age of 28.9 ± 3.6 Ma for the syenite of Biella. Similar Rb/Sr and K/Ar ages of 29 to 33 Ma have been obtained for biotite from tonalites, monzonites and monzodiorites of Miagliano, Biella, which lie astride the Insubric Line (CARRARO and FERRARA, 1968). K/Ar dating of the extensive trachyandesitic volcanism along the Insubric fault line (SCHEURING et al., 1974) yielded an age of 31.5 ± 0.5 Ma., HUNZIKER (1974) and OBERHÄNSLI et al. (1984) detail K/Ar and Rb/Sr results on minerals from the meta-granitoids and metasediments; the age of the plutonic activity is confirmed at around 30 Ma, whilst the age of the high-pressure event is given by a Rb/Sr whole-rock isochron at 129 ± 15 Ma. Fission track dating (DEFERNE, 1976) on apatite and sphene (titanite) separated from the Traversella and Biella plutons produce results which exceed the Rb/Sr ages for the same rocks. A similar anomalously high result for the Bergell granite suggests a probable systematic error in age calculation. The dependancy of neutron fluence measurement upon the value of ^{238}U fission decay constant λ_f has been discussed by HURFORD and GREEN, 1982, 1983. Lack of description of neutron fluence calibration and detail of measurement of age standards prevents assessment of the results and detracts substantially from the geological usefulness of Deferne's data.

3. EXPERIMENTAL

In the present study, three samples previously described by OBERHÄNSLI et al. (1984) were analysed. KAW 987 and 988 (from the same locality–see Figure 1) have relic granitoid assemblages and structures, and the Alpine paragenesis jadeite + garnet + zoisite + quartz. KAW 989 (900 m N of samples 987, 988) is a metagranitoid sample with the Alpine paragenesis albite + glaucophane + phengite + chloromelanite + garnet + clinozoisite. Apatite and zircon were separated from each of the three crushed samples using conventional Wilfley, heavy liquid and magnetic techniques. The apatite concentrate was further refined by hand-picking of crystals. The two zircon concentrates were dated by the External Detector Method (HURFORD and GREEN, 1982); crystals were embedded in FEP-Teflon, polished and spontaneous tracks etsched in KOH: NaOH eutectic for 24 hours at 230 °C (GLEADOW et al., 1977). Low uranium mica was employed as an external detector to record tracks induced during irradiation. Only crystals parallel to the "c" crystallographic axis and possessing a low bulk etch rate (identified by the presence of sharp-bottomed polishing scratches) were counted. For such crystals GLEADOW and LOVERING (1977) have determined a geometry factor of 0.5 to be appropriate.

The apatite was dated by the Population Method: spontaneous tracks were completely annealed in one aliquot by heating in a laboratory furnace at 550 °C for five hours prior to irradiation. Irradiated and natural aliquots were similarly mounted in epoxy resin, polished and simultaneously etched in 1 N HNO_3 at 20 °C for 45 seconds. Samples were counted using a Leitz Orthoplan microscope, zircon with 12.5× ocular and 100× oil objective, apatite with 25× ocular and 63× dry objective. Samples were irradiated in facility J1 of the Herald research reactor, Aldermaston, U.K. using the procedures described by HURFORD and GLEADOW (1977). The thermal neutron fluences were monitored using three uranium dosimeter glasses (SRM 612, CN-1 and CN-2), each in close contact with a mica detector.

4. RESULTS

Counting results and calculated ages are shown in Table 1. Ages have been calculated using the Zeta calibration approach (HURFORD and GREEN, 1983) whereby a calibration baseline factor (ζ) is derived for a dosimeter glass by repeated analysis of mineral age standards. Such an approach circumvents the problems of choice of value for the λ_f fission decay constant of ^{238}U and the complexities of absolute thermal neutron dosimetry. Zeta values for each of the three dosimeter glasses used in this study have been derived from the repeated analysis of Fish Canyon tuff standard zircon by AJH (HUREFORD and GREEN, 1983). This permits calculation of an age for a sample by reference to each glass, thus providing a control of the internal consistency of each dosimeter.

All errors are given at the 1σ level and derive from Poissonian counting statistics (conventional errors of GREEN, 1981) together with an uncertainty on the zeta calibration factor.

Table 1 Fission track dating results from Sesia Zone Zircons and Apatite.

Sample	No. Crystals	N_s	ρ_s ($x10^5 tcm^{-2}$)	N_i	ρ_i ($x10^5 tcm^{-2}$)	Glass	N_d	ρ_d ($x10^5 tcm^{-2}$)	T (Ma., $\pm 1\sigma$)
KAW 987 zircon	12	1221	52.99	846	36.72	SRM 612	3984	1.397	33.9±1.7
						CN 1	5042	4.244	34.4±1.8
						CN 2	4945	4.162	36.1±1.9
								Mean Age =	34.8±1.8
KAW 989 zircon	12	915	63.96	620	43.34	SRM 612	3984	1.397	34.7±1.9
						CN 1	5042	4.244	35.2±2.1
						CN 2	4945	4.162	36.9±2.2
								Mean Age =	35.6±2.1
KAW 988 apatite	100 each for N_s and N_i	458	9.703	2379	55.63	SRM 612	5186	4.365	25.6±1.4
						CN 1	7822	13.17	25.9±1.5
						CN 2	3629	12.22	25.7±1.6
								Mean Age =	25.7±1.5

Notes:

(i). Ages calculated using zeta-612 = 337.5, zeta-CN1 = 112.8, zeta-CN2 = 120.6 (HURFORD and GREEN, 1983).

(ii). Zircon dated using the External Detector Method, assuming a geometry factor of 0.5.

(iii). Apatite dated using the Population Method.

Mean zircon ages of 34.8 ± 1.8 Ma (KAW 987) and 35.6 ± 2.1 Ma (KAW 989) are identical within experimental error. The mean apatite age (KAW 988) is appreciably younger at 25.7 ± 1.5 Ma.

5. DISCUSSION

Extrapolation of laboratory annealing experiments (WAGNER, 1968; NAESER and FAUL, 1969) indicate that apatite will lose its tracks if subjected to temperatures in excess of 100 °C over geological time, results confirmed by natural long-term annealing studies of borehole samples (NAESER, 1979; GLEADOW and DUDDY, 1981).

The closure temperature for the retention of tracks in zircon is less precisely defined: limited laboratory annealing experiments (FLEISCHER et al., 1965; KRISHNASWAMI et al., 1974) indicate a temperature in excess of 300 °C. In a single sample from the Eielson borehole, Naeser estimates the probable closure temperature at ~175 °C by consideration of the position of the zircon sample between the FT apatite and K/Ar biotite curves for reduction of age with borehole depth. Detailed studies comparing FT zircon and apatite ages with Rb/Sr and K/Ar mica ages for the same rocks (in a profile through the slowly cooling gneissic rocks of the Central Alps in the Maggia Valley, Ticino, southern Switzerland, where cooling and uplift has continued slowly since Tertiary Alpine metamorphism) suggests a FT zircon closure temperature of around 225 ± 35 °C (HURFORD, 1984 and 1986).

Combining the FT results of the present study with previously determined radiometric ages, stable isotope data and microprobe work on the partitioning of Fe and Mg in co-existing phases for samples from the Mucrone area of the Sesia-Lanzo zone, a first approximation cooling curve for this region (Figure 2) may be constructed. OBERHÄNSLI et al. (1984) have presented data for the Eo-Alpine thermal and pressure history of the area. The evolution starts at the Jurassic-Cretaceous boundary, with the paragenesis K-feldspar + plagioclase + biotite + quartz and the first movements of crustal thickening and/or subduction, leading to high pressure paragenesis jadeite + garnet + clinozoisite + quartz, for which both stable isotope and partition coefficient work (DESMONS and O'NEILL, 1978; OBERHÄNSLI et al., 1984) yield temperatures in excess of ~500 °C. An increase in temperature coincident with a decrease in pressure, resulted in a progression in metamorphism with the paragenesis chloromelanite + garnet + albite + glaucophane + phengite + quartz indicating temperatures of ~600 °C, 85 Ma years ago, as determined by a clinozoisite-phengite Rb/Sr mineral isochron. Regional Rb/Sr phengite ages of ~80 Ma, regional K/Ar phengite ages of ~70 Ma, and youngest K/Ar phengite ages together with Rb/Sr and K/Ar biotite ages around 60 Ma thus may all be interpreted as cool-

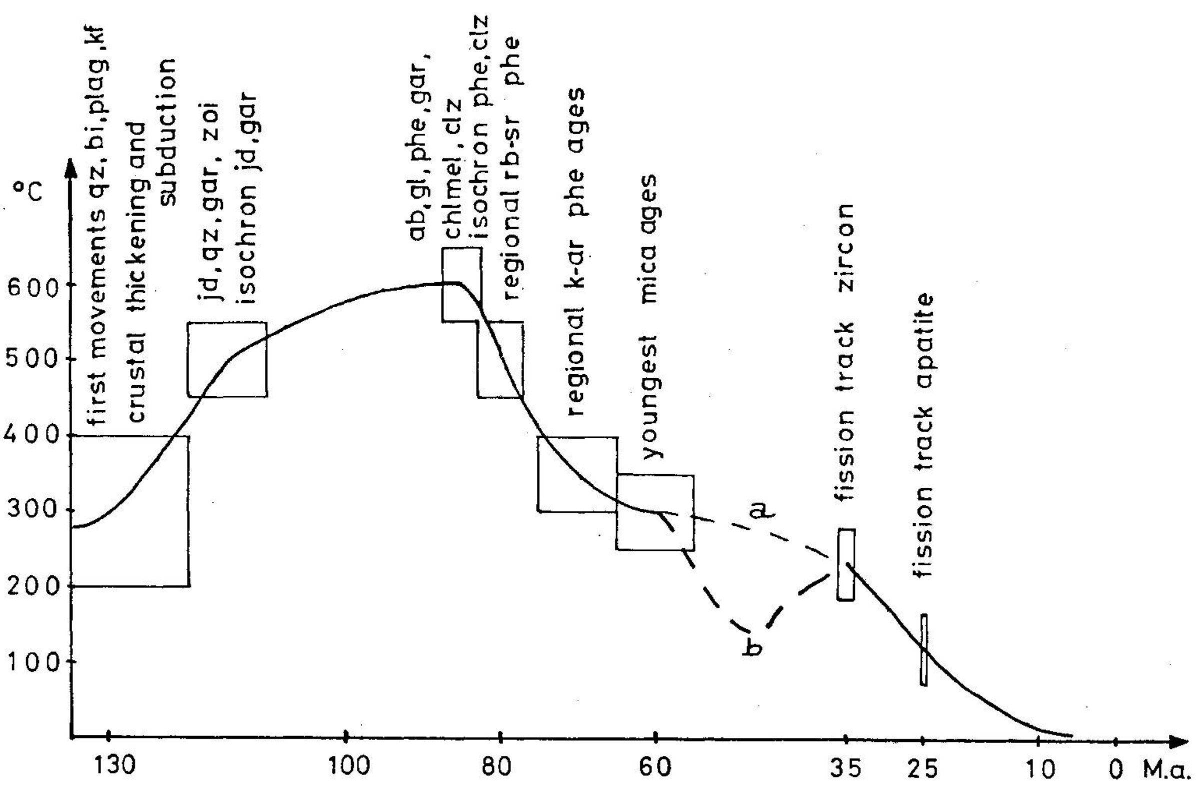

Fig. 2 Proposed Cooling Models for the High Pressure Terrain of the Sesia-Lanzo Zone.

ing ages subsequent to the Eo-Alpine high pressure event. Until the present study, no data existed to document the further thermal evolution of the internal Sesia-Lanzo zone during the Tertiary Alpine metamorphic phase(s).

Although no Tertiary overprint of the Eo-Alpine metamorphism can be recognised on structural or mineralogical grounds in the internal part of the Sesia-Lanzo zone, a low temperature influence could not be excluded until the present data were obtained–with the single exception of the contact aureoles of the Biella and Traversella plutons, where Tertiary green biotite has grown. These observations contrast sharply with the Gneiss Minuti region to the northwest, where HUNZIKER (1974) has demonstrated a 35–40 Ma greenschist facies overprint. The mean FT zircon age of ~35 Ma found in the present study indicates a cooling through the temperature of 225 °C by early Oligocene times, whilst the mean FT apatite age of 25.7 ± 1.5 Ma describes a cooling through ~120 °C by the Upper Oligocene. This age-temperature pattern may be interpreted in two ways: as a steady, progressive cooling after the climax of the Eo-Alpine metamorphism (see Figure 2, curve "a"), with an initial cooling rate of ~18 °C/Ma for the Upper Cretaceous times and a relatively thermally quiescent period (~3 °C/Ma) during the Lower Palaeogene. This may equate with the "Lower Palaeogene Restoration Phase" of TRÜMPY (1960). Subsequent cooling shows a slight acceleration during the Oligocene to ~10 °C/Ma. Alternatively, the rapid cooling of the Upper Cretaceous continued into the early Tertiary, up to the Palaeocene/Eocene, with a moderate reheating to just over 200 °C in the early Oligocene (see Figure 2, curve "b"). The absence of K/Ar mica ages lower than 60 Ma tends to favour the second interpretation, since a longer duration (up to 25 Ma) near the assumed blocking temperature of K/Ar white mica could well produce more dispersed results.

Both of these cooling models contrast strongly with areas which have experienced demonstrable Tertiary metamorphism (Lepontine), where cooling rates in excess of 30 °C/Ma and up to 70 °C/Ma have been determined, for example in the Tertiary amphibolite facies rocks of the Maggia Valley, Ticino (HURFORD, 1984 and 1986). Palaeomagnetic data on the trachyandesites of the Sesia-Lanzo zone (LANZA, 1977) suggest a 40° upward rotation along a hinge parallel to the Insubric Line. The K/Ar age of 31.5 ± 0.5 Ma for the trachyandesites provides a maximum age for this movement. The FT apatite results from the internal part of the Sesia zone point to a cooling below ~120 °C 25 Ma ago, whilst FT apatite data from the NW external part of the zone (WAGNER et al., 1977) suggest a cooling below ~120 °C 8.5 Ma ago. Combining these two data sets constrains the timing of at least part of this rotation to between 25 and 8.5 Ma, in agreement with an age of 18–20 Ma for a pronounced movement on the Insubric Fault in the Maggia area (HURFORD, 1984 and 1986).

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References

CARRARO, F. and FERRARA, G. (1968): "Alpine" tonalite at Miagliano, Biella (Zona Diorito-Kinzigitica). Schweiz. mineral. petrogr. Mitt. 48, 75–80.

COMPAGNONI, R. (1977): The Sesia-Lanzo Zone: high pressure—low temperature metamorphism in the Austroalpine continental margin. Rendiconti Soc. It. Min. e Petrogr. 33, 335–374.

COMPAGNONI, R. and MAFFEO, B. (1973): Jadeite bearing metagranites l.s. and related rocks in the Mount Mucrone Area (Sesia-Lanzo zone, Western Italian Alps). Schweiz. mineral. petrogr. Mitt. 53, 355–378.

COMPAGNONI, R., DAL PIAZ, G.V., HUNZIKER, J.C., GOSSO, G., LOMBARDO, B. and WILLIAMS, P.F. (1977): The Sesia-Lanzo zone, a slice of continental crust with Alpine high pressure—low temperature assemblages in the Western Italian Alps. Rendiconti Soc. It. Min. e Petrogr. 33, 281–334.

DAL PIAZ, G.V., HUNZIKER, J.C. and MARTINOTTI, G. (1972): La zona Sesia-Lanzo e l'evoluzione tettonico-metamorfica delle Alpi Nordoccidentali interne. Mem. Soc. Geol. It. 11, 433–460.

DEFERNE, J. (1976): Essai d'application de la methode des traces de fission a la datation de quelques massifs eruptifs du sud des Alpes. Unpublished thesis, University of Geneva.

DESMONS, J. and O'NEILL, J.R. (1978): Oxygen and hydrogen composition of eclogites and associated rocks from the Eastern Sesia-Lanzo zone (Western Alps, Italy). Contrib. Mineral. Petrol. 67, 79-85.

FLEISCHER, R.L., PRICE, P.B. and WALKER, R.M. (1965): Effects of temperature, pressure and ionization on the formation and stability of fission tracks in minerals and glasses. J. geophys. Res. 70, 1497-1502.

GLEADOW, A.J.W., HURFORD, A.J. and QUAIFE, R.D. (1976): Fission track dating of zircon: improved etching techniques. Earth. Planet. Sci. Letts. 33, 273-276.

GLEADOW, A.J.W. and LOVERING, J.F. (1977): Geometry factor for external detectors in fission track dating. Nucl. Tracks 1, 99-106.

GLEADOW, A.J.W. and DUDDY, I.R. (1981): A natural long-term track annealing experiment for apatite. Nucl. Tracks 5, 169-174.

GOSSO, G. (1977): Metamorphic evolution and fold history in the eclogite micaschists of the upper Gressoney valley (Sesia-Lanzo zone, Western Alps). Rendiconti Soc. It. Min. e Petrogr. 33, 389-407.

GREEN, P.F. (1981): A new look at statistics in fission track dating. Nucl. Tracks 5, 77-86.

HUNZIKER, J.C. (1974): Rb/Sr and K/Ar age determination and the Alpine tectonic history of the Western Alps. Mem. Ist. Geol. Min. Univ. Padova 31, 1-55.

HUNZIKER, J.C. and BEARTH, P. (1969): Rb/Sr-Altersbestimmungen aus den Walliser Alpen, Biotitalterswerte und ihre Bedeutung für die Abkühlungsgeschichte der Alpinen Metamorphose. Eclogae. Geol. Helv. 62, 205-222.

HURFORD, A.J. (1984): Fission track dating, K/Ar and Rb/Sr dating results from the Central Alps (abs). Terra Cognita 4, 24.

HURFORD, A.J. (1986): Uplift in the Lepontine Alps of Southern Switzerland and an age of movement on the Insubric Fault Line. Contrib. mineral. petrol. 92, 413-427.

HURFORD, A.J. and GLEADOW, A.J.W. (1977): Calibration of fission track dating parameters. Nucl. Tracks 1, 41-48.

HURFORD, A.J. and GREEN, P.F. (1982): A users' guide to fission track dating calibration. Earth Planet. Sci. Letts. 59, 343-354.

HURFORD, A.J. and GREEN, P.F. (1983): The zeta age calibration of fission track dating. Isotope Geoscience 1, 285-317.

KOONS, P. (1982): Unpublished dissertation, ETH Zürich.

KRISHNASWAMI, S., LAL, D., PRABHU, N. and MACDOUGALL, D. (1974): Characteristics of fission tracks in zircon: applications to geochronology and cosmology. Earth Planet. Sci. Letts. 22, 51-59.

KRUMMENACHER, D. and EVERNDEN, J.F. (1960): Determinations d'âge isotopique faites sur quelques roches des Alpes par la methode Potassium-Argon. Schweiz. mineral. petrogr. Mitt. 40, 267-277.

LANZA, R. (1977): Palaeomagnetic data from the andesitic and lamprophyric dykes of the Sesia-Lanzo zone (Western Alps). Schweiz. mineral. petrogr. Mitt. 57, 281-290.

LARDEAUX, J.M. (1981): Evolution tectono-metamorphique de la zone nord du Massif de Sesia-Lanzo (Alpes Occidentales): un exemple d'eclogitisation de croûte continentale. Thèse 3^{e} cycle Université Paris VI.

MAFFEO, B. (1970): Studio petrografico dell'ammasso granitico dell'M. Mucrone e dei suoi sapporti con i «micascisti eclogitici». Unpubl. Tesi di Laurea Inst. petrogr., Unive. Turin.

MARTINOTTI, G. (1970): Studio petrografico delle eclogiti della zona del Lago Mucrone e dei loro rapporti con i «micascisti eclogitici» incassanti. Unpubl. Tesi di Laurea Inst. petrogr., Unive. Turin.

NAESER, C.W. (1979): Fission track dating and geologic annealing of fission tracks in Lectures in Isotope Geology, eds. JÄGER, E. and HUNZIKER, J.C., Springer-Verlag, Berlin.

NAESER, C.W. and FAUL, H. (1969): Fission track annealing in apatite and sphene. J. Geophys. Res. 74, 705-710.

OBERHÄNSLI, R., HUNZIKER, J.C., MARTINOTTI, G. and STEIN, W.B. (1984): Monte Mucrone: an example of Eo-Alpine eclogitisation of Permian granitoids, Sesia-Lanzo zone (Western Alps). Isotope Geoscience (in press).

POGNANTE, U., COMPAGNONI, R. and GOSSO, G. (1980): Micromesostructural relationships in the continental eclogitic rocks of the Sesia-Lanzo Zone (Italian Western Alps): a record of subduction cycle. Rendiconti Soc. It. Min. e Petrogr. 36, 169-186.

SCHEURING, B., AHRENDT, H., HUNZIKER, J.C. and ZINGG, A. (1974): Palaeobotanical and geochronological evidence for the Alpine age of the metamorphism in the Sesia zone. Geol. Rundschau 63, 305-326.

TRÜMPY, R. (1960): Palaeotectonic evolution of the Central and Western Alps. Bull. geol. soc. Am. 71, 843-908.

WAGNER, G.A. (1968): Fission track dating of apatites. Earth Planet Sci. Letts., 4, 411-415.

WAGNER, G.A., REIMER, G.M. and 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. Univ. Padova, 30.

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