

**Zeitschrift:** Schweizerische mineralogische und petrographische Mitteilungen =  
Bulletin suisse de minéralogie et pétrographie

**Band:** 75 (1995)

**Heft:** 3

**Artikel:** The Passeier-Jaufen Line : a tectonic boundary between Variscan and  
eo-Alpine Meran-Mauls basement

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**DOI:** <https://doi.org/10.5169/seals-57165>

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## The Passeier–Jaufen Line: a tectonic boundary between Variscan and eo-Alpine Meran-Mauls basement

by Richard Spiess<sup>1</sup>

### Abstract

A cataclastic to mylonitic horizon, called here the Passeier–Jaufen Line, has been recognized within the Austroalpine Meran-Mauls basement, running from north-west of Meran to south of Sterzing and passing through the Passeier valley and the Jaufen pass. The pattern of radiometric mica age distribution within this basement strongly depends on the trend of the Passeier–Jaufen Line. Micas north-west of this line are Cretaceous, while Variscan or partially reset mica ages prevail south-east of it. These age data together with the recognition of the tectonic boundary in the field, definitely document a tectonic juxtaposition of the Cretaceous and Variscan Meran-Mauls basement portions, and a general north-west side up movement along the Passeier–Jaufen Line. The trend of the Line reflects strong affinities with that of the Periadriatic Lineament between Pustertal and Meran and with another Tertiary mylonitic horizon within the Variscan Meran-Mauls basement. The Passeier–Jaufen Line is therefore interpreted as coeval with the Periadriatic Lineament which evolved as a result of the Tertiary indentation of the Southern Alps.

**Keywords:** Austroalpine, Meran-Mauls basement, Passeier–Jaufen Line, mylonitic-cataclastic horizon, Rb–Sr and K–Ar systematics.

### Introduction

The occurrence of Cretaceous mica ages within the Austroalpine Meran-Mauls basement is restricted to its north-western part (AMMB in Fig. 1; SCHMIDT et al., 1967; SATIR, 1975; THÖNI, 1980, 1981, 1983), while Variscan cooling ages or mixed ages are only reported from the south-eastern part (VMMB in Fig. 1; THÖNI, 1981, 1983; DEL MORO et al., 1982). This distribution pattern has been interpreted as an effect of juxtaposition of two different crustal levels along a tectonic boundary (DEL MORO et al., 1982; THÖNI, 1983). Unfortunately, except for a very short segment at the Jaufen pass (DEL MORO et al., 1982), such a tectonic boundary has never been recognized in the field, nor has its trend been sufficiently constrained by radiometric age data. Probably because of the possibility that this tectonic boundary directly coincides with the Passeier, Wannser and Jaufen valleys, further field research was not encouraging. However, since this tectonic boundary has recently received much attention in the

literature (SELVERSTONE, 1988; SCHMID and HAAS, 1989), recognition of its exact location was inevitably required. This recognition is the purpose of the present paper: two distinct approaches have been chosen. First, direct evidence for a tectonic horizon was sought along the above-mentioned valleys. Once such a horizon was found, biotite- and white mica-bearing samples for radiometric geochronological analysis were collected along both sides of it (Fig. 2). Second, in areas where morainal or alluvial deposits prevented the recognition of any cataclastic or mylonitic zone, as in the most part of the Passeier and the Jaufen valleys, samples for geochronology were taken as close as possible along the projected trend of the tectonic horizon. This horizon is called here the Passeier–Jaufen Line.

### Analytical techniques

White mica and biotite concentrates for Rb–Sr and K–Ar analysis were obtained by mechani-

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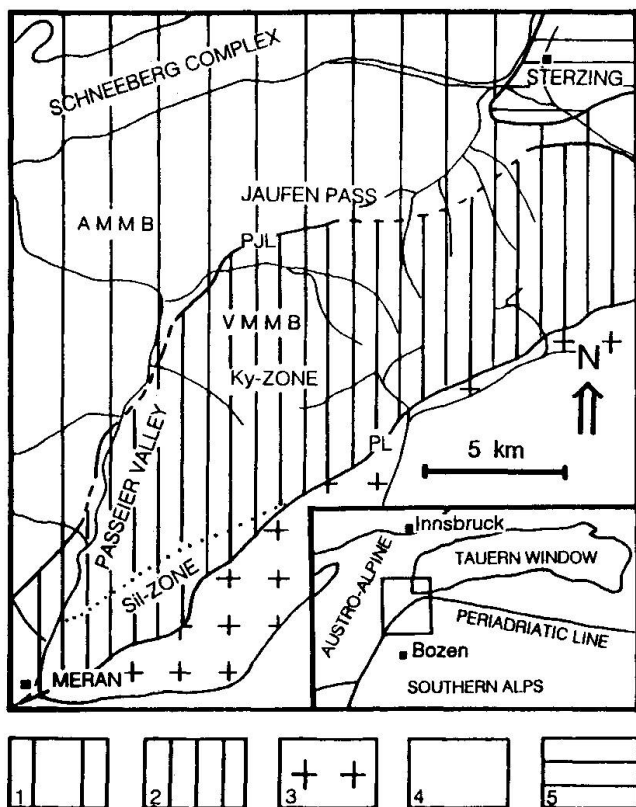


Fig. 1 Simplified geologic-tectonic sketch of the basement in the surroundings of Meran. Inset shows location within the Alps.

1 = Alpine Meran-Mauls basement (AMMB) plus Schneeberg Complex; 2 = Variscan Meran-Mauls basement (VMMB); 3 = Variscan granitoid; 4 = South Alpine basement; 5 = Tauern Window; P.J.L. = Passeier-Jaufen Line; Ky-zone = Kyanite-zone; Sil-zone = Sillimanite-zone; PL = Periadriatic Lineament.

cally crushing the rock samples and grinding the mineral concentrates in an agate mill according to standard procedures. The purity of all mica concentrates was higher than 99%, and the grain size taken for analysis was 150–250  $\mu\text{m}$ .

Ar measurements were made on a VG5400 gas mass spectrometer (Vienna). Reproducibility was better than 5% with the muscovite Bern 4M standard. K was measured by atomic absorption (Perkin-Elmer A.A.S. 5000) using international standards. The calculated correlation coefficient was  $0.999822 \pm 5$ .

The isotopic dilution method was used for all Rb/Sr analyses. All Rb and Sr measurements were made on a VG ISOMASS 54E (Padua). The reproducibility in time for the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio using the NBS987 Sr-standard is better than 0.15‰ (1 $\sigma$ ); the measured mean  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio for this standard is  $0.71018 \pm 2$ . The blank for the whole chemical treatment is < 2 ng Sr. All uncorrected Rb–Sr model ages were calculated using an initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of 0.71014.

The following constants were used for age calculations (STEIGER and JÄGER, 1977):

K–Ar method:

$$\lambda(^{40}\text{K}_\beta) 4.962 \times 10^{-10} \text{y}^{-1}$$

$$\lambda(^{40}\text{K}_\epsilon) + \lambda'(^{40}\text{K}_\epsilon) = 0.581 \times 10^{-10} \text{y}^{-1}$$

$$^{40}\text{K} = 0.01167\% \text{ (atomic percent)}$$

Rb–Sr method:

$$\lambda(^{87}\text{Rb}) = 1.42 \times 10^{-11} \text{y}^{-1}$$

$$\text{strontium atomic ratio: } ^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$$

The error values of the K–Ar ages were calculated according to the following formula:  $\text{error} = 5 \times \text{age} / \% \text{Ar}_{\text{rad}}$ .

The error values reported for the Rb–Sr ages were calculated combining the error of the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio with that of the  $^{87}\text{Rb}/^{86}\text{Sr}$  ratio in an unfavourable way. The error of the  $^{87}\text{Rb}/^{86}\text{Sr}$  ratio is usually about 1.5%.

Considering the analyzed grain size of 150–250  $\mu\text{m}$ , the blocking temperature model of JÄGER (1973) and PURDY and JÄGER (1976), combined with the reopening concept of THÖNI (1981), were applied to interpret the radiometric mica ages. These concepts assume that white mica behaves as a closed system for Rb–Sr at temperatures below ca. 500 °C and for K–Ar below ca. 350 °C, while biotite behaves as a closed system for K–Ar and Rb–Sr at temperatures below ca. 300 °C. The first loss of  $^{40}\text{Ar}_{\text{rad}}$  and  $^{87}\text{Sr}_{\text{rad}}$  within biotite and of  $^{40}\text{Ar}_{\text{rad}}$  within white mica during metamorphic overprinting of already metamorphosed rocks should not occur at temperatures under 300 °C and 350 °C respectively, while the first loss of  $^{87}\text{Sr}_{\text{rad}}$  within white mica occurs at temperatures over 500 °C. According to these concepts, mica ages obtained from the eo-Alpine basement are either cooling ages (K–Ar mica ages and Rb–Sr biotite ages), partially reset Rb–Sr white mica ages, or totally reset Rb–Sr white mica ages if they come from rock samples overprinted in middle amphibolite facies conditions. The mica ages of the Variscan basement are either pure Variscan cooling ages or, when affected by very low grade Alpine metamorphism, partially reset Rb–Sr biotite and K–Ar mica ages.

#### Preliminary location of the Passeier-Jaufen Line: radiometric geochronological constraints from the literature

Although a huge number of radiometric mica ages have been produced for that portion of the Meran-Mauls basement with an eo-Alpine amphibolite facies overprint (SCHMIDT et al., 1967; SATIR, 1975; THÖNI, 1981, 1983; DEL MORO et al., 1982; ZANTEDESCHI, 1991), only a few of them are located close to the presumed trend of the

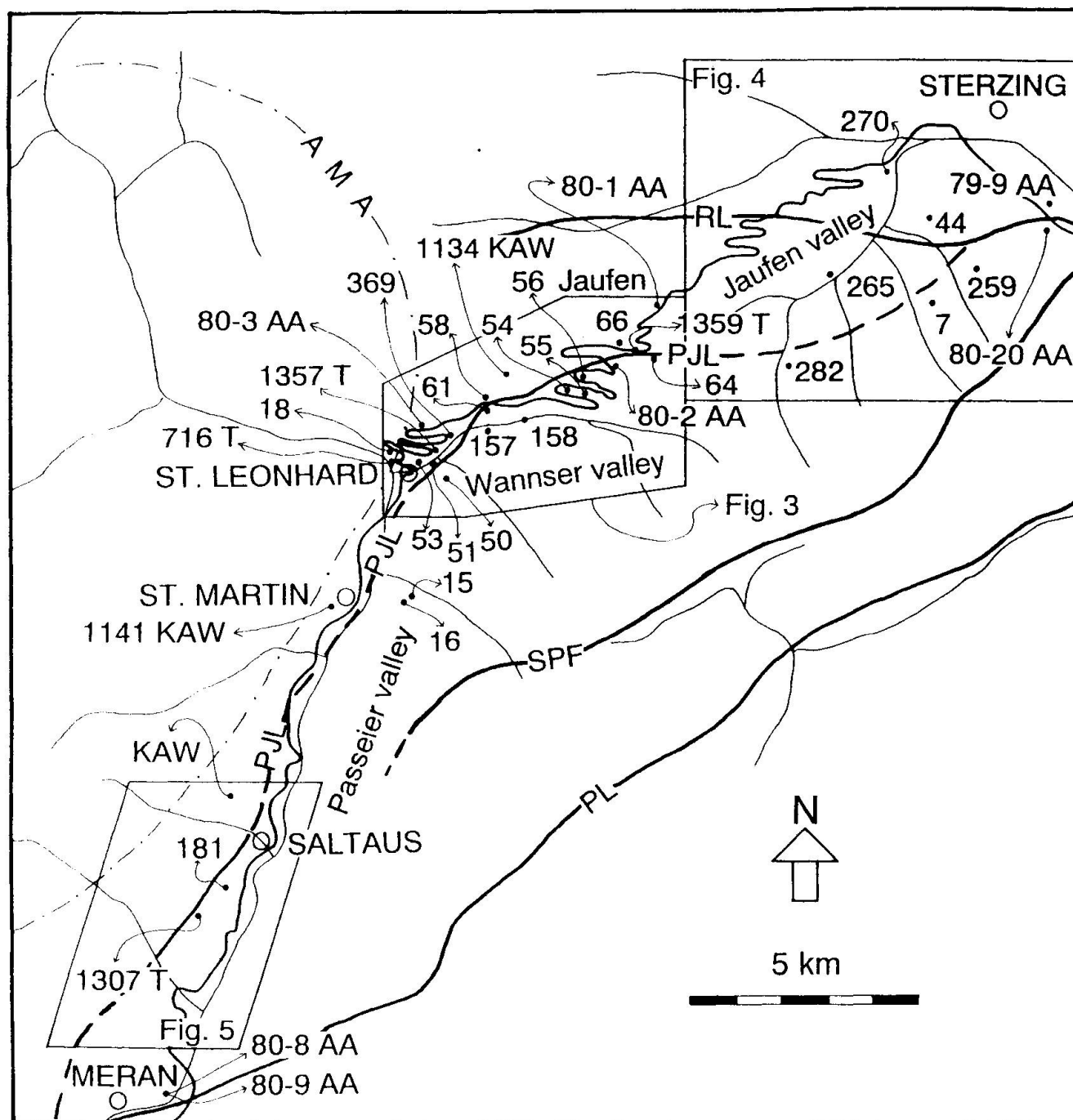


Fig. 2 Sample locations: small full dots are sample locations of new radiometric age data and data from the literature. Sample numbers marked with letters AA, KAW and T refer respectively to data from DEL MORO et al. (1982), SATIR (1975, and unpubl. data) and THÖNI (1980, 1981 and 1983). Abbreviations: AMA = area with Rb-Sr eo-Alpine white mica ages (THÖNI, 1983); PJP = Passeier-Jaufen Line; SPF = Stilfes-Penserjoch-Fartleis Line, PL = Periadriatic Lineament. Inserts labeled Fig. 3, Fig. 4 and Fig. 5 refer respectively to those figures.

Passeier-Jaufen Line (SATIR, 1975; THÖNI, 1980, 1981 and 1983; DEL MORO et al., 1982). Even worse is the situation along the Variscan part of the boundary, since for the whole Variscan Meran-Mauls basement not more than 12 Rb-Sr or K-Ar mica ages are available in the literature (THÖNI, 1981, 1983; DEL MORO, 1982), of which

seven are located near the supposed tectonic horizon (Figs 2, 3, 4, 5 and Tabs 3, 4).

Altogether, the few radiometric age data known from the literature suggest that, from Meran to Saltaus, the Passeier-Jaufen Line runs somewhere within the western slope of the Passeier valley, while from Saltaus to St. Leonhard it



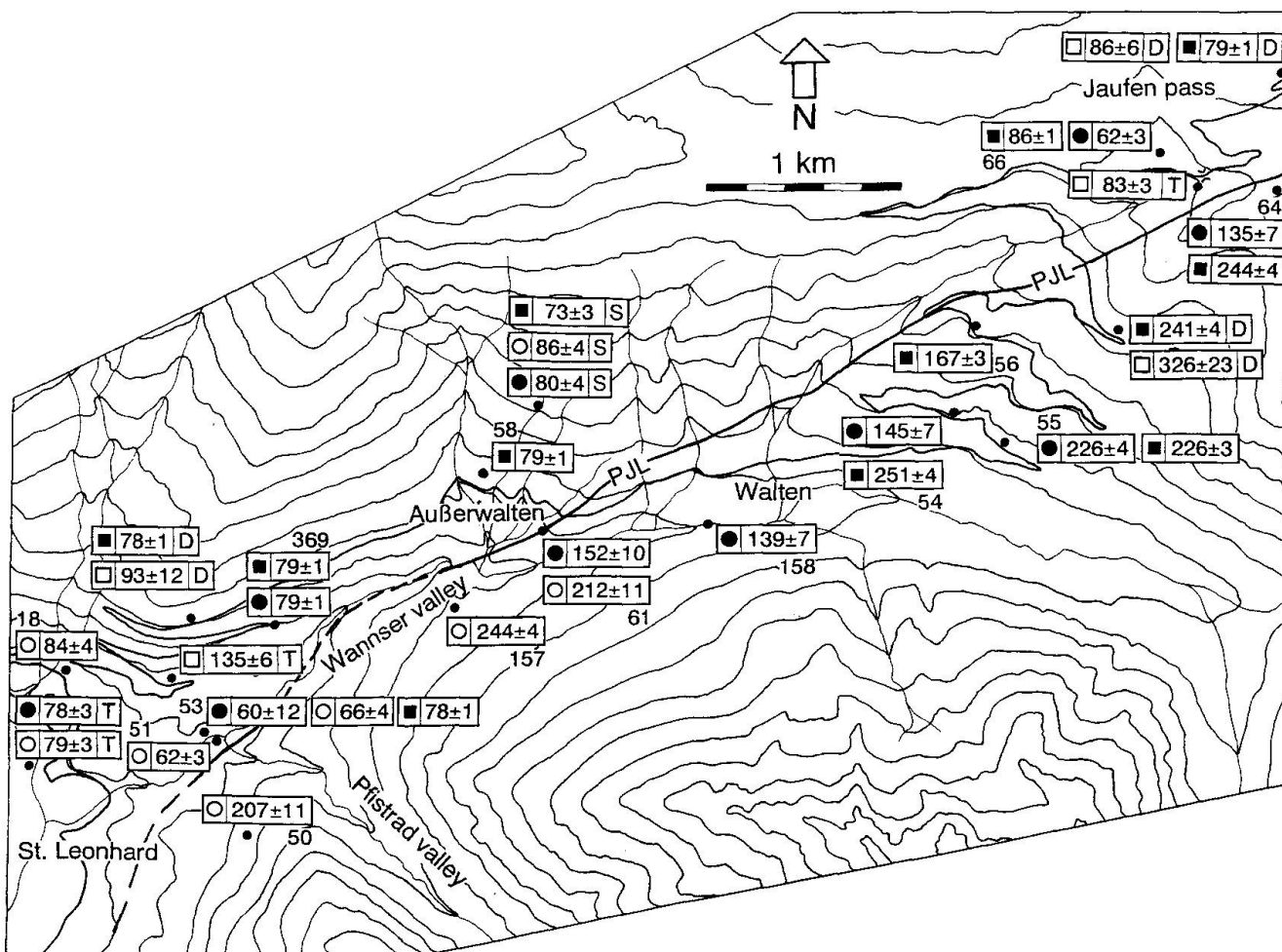
may follow the covered floor. Besides this, the ages from the Jaufen pass (DEL MORO et al., 1982; THÖNI, 1983) clearly show that the Passeier-Jaufen Line runs across this pass. However, further mica ages are lacking, and in the Jaufen valley DEL MORO et al. (1982) traced the Passeier-Jaufen Line exclusively according to the trend of the valley.

**New field evidence of the Passeier-Jaufen Line: cataclastic and mylonitic zones along the Passeier, Wannser and Jaufen valleys**

**PASSEIER VALLEY  
(MERAN-SALTAUS-ST. LEONHARD)**

In the southern Passeier valley, a cataclastic zone follows the western slope continuously from

north-west of Riffian to Saltaus (Fig. 5). This cataclastic zone is mainly bounded to the east by a muscovite-bearing granite gneiss body, with a margin greatly reduced in grain size due to brittle deformation, appearing in the field as a 10–30 m thick blue band. A further short segment of this cataclastic zone outcrops along the Passeier valley road at km 13 from Meran, cutting through brittly deformed amphibolites and paragneisses. From this point northwards it can no longer be recognized within the western slope. Between Saltaus and Riffian its trend coincides substantially with the boundary traced by LORENZONI and ZANETTIN-LORENZONI (1966) which, according to these authors, separates "strongly crenulated paragneisses without sillimanite" to the west from "non-crenulated paragneisses with sillimanite" to the east. These au-



**Fig. 3** Passeier-Jaufen Line (PjL) between St. Leonhard and Jaufen pass. A sudden change of isotopic ages occurs across this tectonic line. North-west of PjL, Rb-Sr and K-Ar mica ages are eo-Alpine, south-east of it they are Variscan or partially reset.

Numbers in rectangles: ages in millions of years  $\pm$  error; Symbols: squares Rb-Sr mica ages; circles: K-Ar mica ages; open symbols: white micas; full symbols: biotites. Letters D, S and T: data respectively from DEL MORO et al. (1982), SATIR (1975) and THÖNI (1980, 1981, 1983). Sample numbers of new data shown outside rectangles. Small full dots outside rectangles: sample locations. Full marked line: observed tectonic lines; dashes: proposed continuation.

thors traced the boundary even further to the south-west, as far as "Schloss Thurnstein" above Meran (Fig. 5).

#### WANNSEER VALLEY (ST. LEONHARD-JAUFEN PASS)

The term "Jaufen Line" was first introduced by DEL MORO et al. (1982), when they recognized a sudden change in mica ages in rock samples collected on opposite sides of a fault zone situated at the Jaufen pass. Now, on the basis of new field evidence, this tectonic zone can be traced continuously from the Jaufen pass to St. Leonhard (Fig. 3). From the Jaufen pass to the floor of the Wannser valley below Außerwalten, intense ductile deformation in lower greenschist facies conditions led to the formation of a 5 km long and sometimes up to 200 m thick mylonitic horizon. From Außerwalten towards St. Leonhard, the actual mylonitic zone is mostly hidden by the alluvial deposits of the Wannser valley but it arises again within the Pfistrad stream.

#### JAUFEN VALLEY (JAUFEN PASS-STERZING)

DEL MORO et al. (1982) postulated that the Passeier-Jaufen Line coincides with the trend of the Jaufen valley. The existence of a tectonic line cutting the Jaufen valley near St. Anton in an NW-SE direction had already been recognized by FRIZ (1975), who called it the Ratschings Line (Fig. 4). Some Tertiary mica ages north of the Ratschings Line but within the Austroalpine (SATIR, 1975; THÖNI, 1980; DEL MORO et al., 1982) suggested that the Ratschings Line is younger than the Passeier-Jaufen Line and offsets the latter, so that the Passeier-Jaufen Line only appears south-west of St. Anton. However, mylonites were only recognized near St. Anton and not further south-west, and their nearly horizontal attitude makes it unlikely that they belong to the vertically oriented mylonites of the Passeier-Jaufen Line.

A strongly tectonized zone outcrops east of the Jaufen valley between Gospeneid and Elzenbaum and may correspond to FRIZ's (1975) Ratschings Line (Fig. 4). It seems reasonable that the Passeier-Jaufen Line, running south of the Jaufen valley and not along the valley floor, was not displaced by the Ratschings Line but joins it near Gospeneid. However, this hypothesis cannot be corroborated by direct field evidence because of the thick morainal and alluvial cover of the southern slope of the Jaufen valley.

#### The Passeier-Jaufen Line: effect on the pattern of radiometric age data distribution

37 new mica ages are presented here. These new ages can be added to those already reported in the literature (SATIR, 1975; THÖNI, 1983; DEL MORO et al., 1982) which come from samples located along the recognized Passeier-Jaufen Line. Therefore, the Line can be traced not only by field evidence but also by a total of 60 radiometric mica ages.

To prove whether or not the eo-Alpine and Variscan basement was really juxtaposed along the recognized mylonitic zone, most of the new data (22) were collected specifically from between St. Leonhard and the Jaufen pass. Eleven new mica ages come from the area around the Jaufen valley. The remaining four come from the Variscan basement along the Passeier valley. These new data (Tabs 1 and 2) are discussed together with those already reported in the literature (Tabs 3 and 4) with the discussion following the various segments outlined in the previous section.

#### ST. LEONHARD TO JAUFEN PASS

*Data:* The samples selected for geochronological analysis were taken from a 500 m wide band flanking the mylonitic zone on both sides. Exact sample locations are shown in figure 3 and listed in table 5. New data are reported in tables 1 and 2, and data from the literature in tables 3 and 4.

The trend of the age data recognized at Außerwalten, where samples 157, 61 and 58 were collected (Fig. 3), is representative of the general pattern of mica age distribution along the whole mylonitic zone. At Außerwalten, sample 61 was taken from a two mica gneiss lens preserved within anastomosing mylonites of the central part of the strongly tectonized horizon. Sample 58, a coarse-grained biotite-, garnet- and staurolite-bearing paragneiss, comes from north of the horizon and was collected approximately 400 m from sample 61. Sample 58 lacks practically any retrograde overprint and its mineral assemblage reflects the peak temperature conditions reached during eo-Alpine amphibolite facies metamorphism. Sample 157 is a white mica-bearing granite gneiss, located south of the mylonitic zone. The distance between samples 58 and 157 is approximately 700 m; the shortest distance between the mylonitic zone and sample 157 is about 200 m.

Sample 58 gives a Rb-Sr biotite age of  $79 \pm 1$  Ma, i.e. perfectly consistent with the general trend of biotite ages within the eo-Alpine Meran-Mauls basement reported in the literature

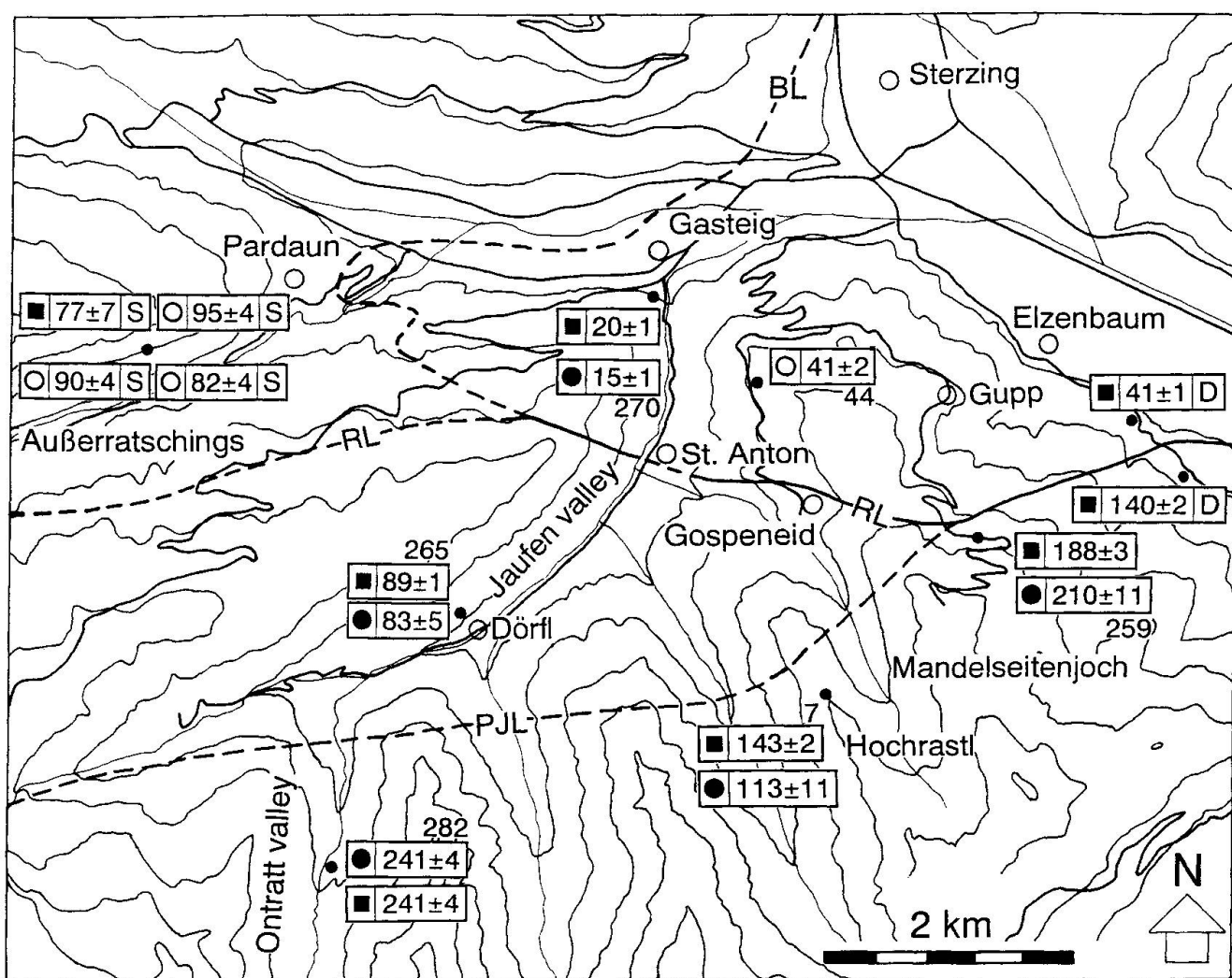
(SATIR, 1975; DEL MORO et al., 1982; THÖNI, 1983; see also Tabs 3 and 4). Sample 61 gives K–Ar ages of  $152 \pm 10$  Ma on biotite and  $212 \pm 11$  Ma on muscovite, while the white mica of sample 157 gives a K/Ar age of  $244 \pm 4$  Ma (Tabs 1 and 2).

**Interpretation:** Interpretation of the obtained age data is unambiguous. The juxtaposition of eo-Alpine cooling ages ( $79 \pm 1$  Ma) and mixed ages ( $152 \pm 10$ ,  $212 \pm 11$  and  $244 \pm 4$  Ma) along the tectonic line emphasises the perfect correlation between dramatically changing mica ages and the occurrence of the mylonitic zone in the field. Both features demonstrate that the basement portions, overprinted in clearly different meta-

morphic conditions during the eo-Alpine orogeny, with temperatures up to amphibolite facies conditions on one side, but too low to reset the Variscan mica ages thoroughly on the other, were juxtaposed tectonically. The  $212 \pm 11$  and  $244 \pm 4$  Ma K/Ar white mica ages reflect the fact that white mica is more retentive than biotite for  $Ar_{rad}$  during heating.

#### JAUFEN VALLEY AREA

**Data:** Rock samples for geochronological analysis were collected in two locations along the val-



**Fig. 4** Passeier–Jaufen Line (PJL) near Jaufen valley. South of PJL all Rb–Sr and K–Ar biotite ages are only partially reset. North of PJL, Cretaceous mica ages prevail west of RL (Ratschings Line) and Tertiary mica ages prevail east of it. Across dashed segment of RL, no evidence of a change in age can be observed. Boundary of Tertiary mica ages (BL = Brenner Line and full line marked RL) may define detachment surface along which Austroalpine basement slipped off the upcoming Tauern units.

Numbers in rectangles: ages in millions of years ± error. Symbols: squares Rb–Sr mica ages; circles: K–Ar mica ages; open symbols: white micas; full symbols: biotites. Letters D and S: data respectively from DEL MORO et al. (1982) and SATIR (1975). Sample numbers of new data shown outside rectangle. Small full dots outside rectangles: sample locations. Full marked line: observed tectonic lines; dashes: hypothesized continuation.

Tab. 1 New Rb–Sr biotite ages. All ages are uncorrected model ages, calculated using an initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of 0.71014. Last column shows location of samples in basement portion. Ages are ordered in three groups and listed according to increasing sample number. First group: PJL between St. Leonhard and Jaufen pass; second group: Jaufen valley area; third group: Passeier valley.

sample	lithology	locality	mineral	grain size	$^{87}\text{Rb}$ ppm	$^{87}\text{Sr}$ ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	age (Ma)	basement
53	paragneiss	St. Leonhard	biotite	150–250 $\mu\text{m}$	455.60	5.10	264.23	$1.00235 \pm 39$	$78 \pm 1$	eo-Alpine
54	micaschist	Jaufen pass road	biotite	150–250 $\mu\text{m}$	612.70	8.00	238.95	$1.562449 \pm 60$	$251 \pm 4$	Variscan
55	micaschist	Jaufen pass road	biotite	150–250 $\mu\text{m}$	609.60	13.70	134.37	$1.14206 \pm 10$	$226 \pm 3$	Variscan
56	paragneiss	Jaufen pass road	biotite	150–250 $\mu\text{m}$	555.00	8.00	210.12	$1.20932 \pm 15$	$167 \pm 3$	Variscan
58	paragneiss	Jaufen pass road	biotite	150–250 $\mu\text{m}$	462.20	3.40	411.83	$1.17127 \pm 15$	$79 \pm 1$	eo-Alpine
64	paragneiss	Jaufen pass	biotite	150–250 $\mu\text{m}$	583.90	6.60	280.70	$1.68529 \pm 15$	$244 \pm 4$	Variscan
66	micaschist	Jaufen pass	biotite	150–250 $\mu\text{m}$	359.70	5.48	194.30	$0.94753 \pm 13$	$86 \pm 1$	eo-Alpine
369	micaschist	Jaufen pass road	biotite	150–250 $\mu\text{m}$	423.10	4.30	295.22	$1.04059 \pm 13$	$79 \pm 1$	eo-Alpine
7	paragneiss	Hochrastl	biotite	150–250 $\mu\text{m}$	405.60	10.70	111.77	$0.93684 \pm 26$	$143 \pm 2$	Variscan
259	paragneiss	Gupp forest road	biotite	150–250 $\mu\text{m}$	405.80	10.50	115.16	$1.018375 \pm 77$	$188 \pm 3$	Variscan
265	paragneiss	Jaufen valley	biotite	150–250 $\mu\text{m}$	623.30	16.40	111.67	$0.851465 \pm 42$	$89 \pm 1$	eo-Alpine
270	augen gneiss	Jaufen valley	biotite	150–250 $\mu\text{m}$	561.80	13.40	121.80	$0.745463 \pm 29$	$20 \pm 1$	Alpine
282	paragneiss	Ontratt vally	biotite	150–250 $\mu\text{m}$	653.90	5.10	421.84	$2.15746 \pm 15$	$241 \pm 4$	Variscan
181	granite gneiss	Vernuer road	biotite	150–250 $\mu\text{m}$	387.10	15.90	71.76	$0.866383 \pm 37$	$153 \pm 2$	Variscan

Tab. 2 New K–Ar model ages. Last column shows location of samples in basement portion. Ages are ordered in three groups and listed according to increasing sample number. First group: PJL between St. Leonhard and Jaufen pass; second group: Jaufen valley area; third group: Passeier valley.

sample	lithology	locality	mineral	grain size	% K <sub>2</sub> O	<sup>40</sup> Ar <sub>rad</sub> ccm10 <sup>-6</sup>	% Ar <sub>rad</sub>	age (Ma)	basement
18	micaschist	St. Leonhard	muscovite	150–250 µm	6.60	21.50	83	84 ± 4	eo-Alpine
50	granite gneiss	Pfistrad	muscovite	150–250 µm	10.92	93.09	93	207 ± 11	Variscan
51	paragneiss	St. Leonhard	muscovite	150–250 µm	9.44	23.17	91	62 ± 3	eo-Alpine
53	paragneiss	Jaufen pass road	biotite	150–250 µm	9.09	21.57	24	60 ± 12	eo-Alpine
53	paragneiss	St. Leonhard	muscovite	150–250 µm	9.48	24.80	88	66 ± 4	eo-Alpine
54	micaschist	Jaufen pass road	biotite	150–250 µm	8.98	52.80	97	145 ± 7	Variscan
55	micaschist	Jaufen pass road	biotite	150–250 µm	8.31	49.51	28	226 ± 4	Variscan
61	paragneiss	Jaufen pass road	biotite	150–250 µm	9.06	55.88	80	152 ± 10	Variscan
61	paragneiss	Jaufen pass road	muscovite	150–250 µm	10.94	95.63	93	212 ± 11	Variscan
64	paragneiss	Jaufen pass	biotite	150–250 µm	9.23	50.28	95	135 ± 7	Variscan
66	micaschist	Jaufen pass	biotite	150–250 µm	9.44	23.17	91	62 ± 3	eo-Alpine
157	granite gneiss	Ausserwalten	muscovite	150–250 µm	9.23	50.28	95	244 ± 4	Variscan
158	paragneiss	Ausserwalten	biotite	150–250 µm	9.28	52.11	94	139 ± 7	Variscan
369	micaschist	Jaufen pass road	biotite	150–250 µm	9.00	24.39	87	79 ± 1	eo-Alpine
7	paragneiss	Hochrastl	biotite	150–250 µm	8.99	41.04	51	113 ± 11	Variscan
44	paragneiss	Gospeneid	muscovite	150–250 µm	11.10	18.02	84	41 ± 2	Alpine
259	paragneiss	Gupp forest road	biotite	150–250 µm	8.54	74.14	96	210 ± 11	Variscan
265	paragneiss	Jaufen valley	biotite	150–250 µm	8.21	27.24	83	83 ± 5	eo-Alpine
270	augen gneiss	Jaufen valley	biotite	150–250 µm	9.49	5.58	65	15 ± 1	Alpine
282	paragneiss	Ontratt valley	biotite	150–250 µm	9.10	53.51	95	241 ± 4	Variscan
15	augen gneiss	Fartleis	muscovite	150–250 µm	8.60	92.58	97	274 ± 11	Variscan
15	augen gneiss	Fartleis	biotite	150–250 µm	6.90	33.44	85	125 ± 6	Variscan
16	granite gneiss	Prantach	muscovite	150–250 µm	7.90	76.22	97	246 ± 16	Variscan



Tab. 3 Rb-Sr mica ages from literature. All ages were corrected with whole rock. Last column shows location of samples in basement portion. Ages are ordered in three groups and listed according to increasing sample number of the same author. First group: PJL between St. Leonhard and Jaufen pass; second group: Jaufen valley area; third group: Passeier valley. For detailed sample locations see figure 2.

sample	lithology	locality	mineral	grain size	$^{87}\text{Rb}$ ppm	$^{87}\text{Sr}$ ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	age (Ma)	author	basement
1357T	granite gneiss	Jaufen pass road	muscovite	> 150 $\mu\text{m}$	192.1	0.393	279.1	1.2797	$135 \pm 6$	THÖNI, 1983	eo-Alpine
1359T	leucocratic gneiss	Jaufen pass	muscovite	150–430 $\mu\text{m}$	90.5	0.158	21.73	0.7480	$83 \pm 3$	THÖNI, 1983	eo-Alpine
1134KAW	micaschist	Ausserwalten	biotite	not sp.	203.1	0.2261	734.1	1.537	$73 \pm 3$	SATIR, 1975	eo-Alpine
80-1AA	not specified	Jaufen pass road	biotite	not sp.	not sp.	not sp.	169.72	$0.9397 \pm 10$	$79 \pm 1$	DEL MORO et al., 1982	eo-Alpine
80-1AA	not specified	Jaufen pass road	muscovite	not sp.	not sp.	not sp.	3.90	$0.7224 \pm 1$	$86 \pm 6$	DEL MORO et al., 1982	eo-Alpine
80-2AA	not specified	Jaufen pass road	biotite	not sp.	not sp.	not sp.	328.51	$1.8501 \pm 32$	$241 \pm 4$	DEL MORO et al., 1982	Variscan
80-2AA	not specified	Jaufen pass road	muscovite	not sp.	not sp.	not sp.	3.82	$0.7366 \pm 2$	$326 \pm 23$	DEL MORO et al., 1982	Variscan
80-3AA	not specified	St. Leonhard	biotite	not sp.	not sp.	not sp.	260.71	$1.0074 \pm 19$	$78 \pm 1$	DEL MORO et al., 1982	eo-Alpine
80-3AA	not specified	St. Leonhard	muscovite	not sp.	not sp.	not sp.	4.48	$0.7230 \pm 5$	$93 \pm 12$	DEL MORO et al., 1982	eo-Alpine
79-9AA	not specified	Elzenbaum	biotite	not sp.	not sp.	not sp.	110.06	$0.7761 \pm 1$	$41 \pm 1$	DEL MORO et al., 1982	Alpine
80-20AA	not specified	Elzenbaum	biotite	not sp.	not sp.	not sp.	218.91	$1.0421 \pm 5$	$140 \pm 2$	DEL MORO et al., 1982	Variscan
1141KAW	orthogneiss	St. Martin	muscovite	not sp.	124.5	0.2216	84.40	0.8601	$111 \pm 10$	SATIR, 1975	eo-Alpine
KAW		W of Saltaus	muscovite						$146 \pm 5$	SATIR, unpublished	eo-Alpine
80-8AA	not specified	Meran	biotite	not sp.	not sp.	not sp.	803.37	$3.0842 \pm 89$	$208 \pm 3$	DEL MORO et al., 1982	Variscan
80-9AA	not specified	Meran	biotite	not sp.	not sp.	not sp.	647.96	$2.4588 \pm 15$	$189 \pm 3$	DEL MORO et al., 1982	Variscan
1307T	granite gneiss	near Gfeis	muscovite	150–250 $\mu\text{m}$	444	1.960	1639.2	7.954	$305 \pm 12$	THÖNI, 1983	Variscan



Tab. 4 K–Ar model ages from literature. For detailed sample locations see figure 2. Last column shows location of samples in basement portion. Ages are ordered in two groups and listed according to increasing sample number of the same author. First group of ages comes from PJJL between St. Leonhard and Jaufen pass; second group: Passeier valley.

sample	lithology	locality	mineral	grain size	% K <sub>2</sub> O	<sup>40</sup> Ar <sub>rad</sub> ccm10 <sup>-6</sup>	% Ar <sub>rad</sub>	age (Ma)	author	basement
716T	Paragneiss	St. Leonhard	muscovite	150–450 µm	7.45	23.42	95.21	79 ± 3	THÖNI, 1981	eo-Alpine
716T	Paragneiss	St. Leonhard	biotite	150–450 µm	7.42	23.119	95.28	78 ± 3	THÖNI, 1980	eo-Alpine
1134KAW	micaschist	Ausserwalten	muscovite	not specified	6.77	23.9	86.0	86 ± 4	SATIR, 1975	eo-Alpine
1134KAW	micaschist	Ausserwalten	biotite	not specified	7.23	23.5	91.7	80 ± 4	SATIR, 1975	eo-Alpine
1141KAW	orthogneiss	St. Martin	muscovite	not specified	9.16	28.6	91.7	77 ± 3	SATIR, 1975	eo-Alpine
1141KAW	orthogneiss	St. Martin	biotite	not specified	8.04	24.1	93.7	74 ± 3	SATIR, 1975	eo-Alpine
1307T	granite gneiss	near Gfais	muscovite	150–250 µm				27 ± 11	THÖNI, 1983	Variscan

ley floor (samples 265 and 270) and in four locations respectively south and east of the Jaufen valley (samples 7, 44, 259 and 282). Exact sample locations are given in figure 4 and table 5. New data are reported in tables 1 and 2, data from the literature in table 3.

At Dörfel in the inner Jaufen valley, sample 265 from the valley floor gives a Rb–Sr biotite age of  $89 \pm 1$  Ma and a K–Ar biotite age of  $83 \pm 5$  Ma. Three samples (7, 259 and 282), from south and east of the Jaufen valley respectively, give Rb–Sr and K–Ar biotite ages ranging between 241 and 113 Ma. Sample 270 from the outer Jaufen valley gives a K–Ar biotite age of  $15 \pm 1$  Ma and a Rb–Sr biotite age of  $20 \pm 1$  Ma. Sample 44 from the eastern slope of the outer Jaufen valley gives a K–Ar white mica age of  $41 \pm 2$  Ma. All the new ages agree perfectly with those already known from the literature (SATIR, 1975; DEL MORO et al., 1982).

*Interpretation:* For morphological reasons, DEL MORO et al. (1982) presumed that the Passeier–Jaufen Line coincided with the trend of the Jaufen valley. The Cretaceous cooling ages of sample 265 certainly prove that the rocks of the northern slope belong to the eo-Alpine basement. However, the low K–Ar and Rb–Sr biotite mixed ages of sample 7 ( $113 \pm 11$  and  $143 \pm 2$  Ma) rather support the previously mentioned hypothesis that the Passeier–Jaufen Line essentially runs south of the Jaufen valley and joins the Ratschings Line at Gspeneid. Unfortunately, because of the bad outcrop conditions, the samples collected for radiometric analysis are too widely spaced to solve this problem unequivocally. Nevertheless, the sudden change in ages clearly demonstrate that the Passeier–Jaufen Line passes through the Jaufen valley area. The data also unambiguously show that the Passeier–Jaufen Line does not cut the outer Jaufen valley, since young mica ages prevail on both sides of its outlet (Fig. 4). However, it is worth stressing that these young ages are Tertiary and not Cretaceous.

#### PASSEIER VALLEY

*Data:* SATIR (unpubl. data quoted in THÖNI, 1983) analyzed white mica from a rock sample located approximately 500 m west of the now recognized cataclastic zone, and THÖNI (1983) analyzed white mica from the leucocratic granite gneiss body flanking the cataclastic horizon to the east. Sample 181 is a biotite granite gneiss located 300 m east of the cataclastic horizon (Fig. 5). Mica ages tracing the Passeier–Jaufen Line further

Tab. 5 Exact sample location of new age data. Maps of "Istituto Geografico Militare Italiano" (IGMI), 1:25,000, were used for exact location of samples. Reported co-ordinates refer to universal transverse Mercator projection, which allows sample location within an error of max. 100 m (for details, see IGMI maps). Detailed description of sample location also reported.

sample	lithology	coordinates	IGMI 1:25,000 map	sample location description
7	paragneiss	32TPS847914	Vipiteno	Hochrastl, mountain ridge Hühnerspiel-Durraspitz, alt. 2020 m
15	augen gneiss	32TPS714839	S. Leonardo in Passiria	Fartleis valley, alt. 1000 m
16	granite gneiss	32TPS713838	S. Leonardo in Passiria	Prantach, Fartleis valley forest road 500 m after branch, alt. 1000 m
18	micaschist	32TPS712876	S. Leonardo in Passiria	Jaufen pass road km 21,5
44	paragneiss	32TPS841935	Vipiteno	500 m NNW of Gspeneid
50	granite gneiss	32TPS723868	S. Leonardo in Passiria	Forest road St. Leonhard-Pfistrad, alt. 950 m
51	paragneiss	32TPS721872	S. Leonardo in Passiria	St. Leonhard, outlet Pfistrad crick
53	paragneiss	32TPS719872	S. Leonardo in Passiria	St. Leonhard, bridge to Jaufenburg
54	micaschist	32TPS759889	S. Leonardo in Passiria	Jaufen pass road km 31.6
55	micaschist	32TPS761888	S. Leonardo in Passiria	Jaufen pass road km 31.4
56	paragneiss	32TPS759893	S. Leonardo in Passiria	Jaufen pass road km 34.8
58	paragneiss	32TPS734886	S. Leonardo in Passiria	Jaufen pass road km 28, above road tunnel
61	paragneiss	32TPS737883	S. Leonardo in Passiria	Außerwalten, 300 m SE after branch from Jaufen pass road at km 28.1
64	paragneiss	32TPS777901	Vipiteno	300 m SE Jaufen pass
66	micaschist	32TPS769903	Ridanna	300 m NW Jaufen pass, alt. 2145 m
157	granite gneiss	32TPS736880	S. Leonardo in Passiria	Außerwalten, orographic left valley slope, alt. 1200 m
158	paragneiss	32TPS745883	S. Leonardo in Passiria	Walten, Walten crick alt. 1200 m
181	granite gneiss	32TPS673765	Merano	Gnealer, road Riffian-Vernuer
259	paragneiss	32TPS861926	Vipiteno	Forest road Gupp-Mandelseitenjoch, alt. 1770 m
265	paragneiss	32TPS817921	Vipiteno	Dörf, Jaufen valley
270	augen gneiss	32TPS833945	Vipiteno	Jaufen valley, 200 m S of Gasteig
282	para gneiss	32TPS806899	Vipiteno	1.5 km S of Obertal along the Ontratt valley road, alt. 1590 m
369	micaschist	32TPS723878	S. Leonardo in Passiria	Jaufen pass road km 24.7

north come from an augen gneiss and a granite gneiss located some hundreds of meters east of St. Martin (samples 15 and 16) and a granite gneiss (SATIR, 1975) located some hundreds of meters south-west of it (Fig. 2).

The following mica ages were obtained from the samples occurring east of the tectonic zone. Sample 181 gave a Rb–Sr biotite age of  $153 \pm 2$  Ma (Tab. 1). The white mica of the leucogranite gneiss gave a K–Ar age of  $271 \pm 11$  Ma and a Rb–Sr age of  $305 \pm 12$  Ma (THÖNI, 1983; Tabs 3 and 4). Samples 15 and 16 gave K–Ar ages of  $274 \pm 11$  Ma and  $246 \pm 16$  Ma for muscovite and  $125 \pm 11$  Ma for biotite (sample 15; Tab. 2). Clearly different mica ages were obtained from samples collected west of the tectonic horizon. The Rb–Sr white mica age of the sample north-west of Saltaus is  $146 \pm 5$  Ma (SATIR, unpubl. data). Micas from the granite gneiss sample south-west of St. Martin gave a Rb–Sr age of  $111 \pm 10$  Ma for muscovite and K–Ar ages of  $77 \pm 3$  Ma for muscovite and  $74 \pm 3$  Ma for biotite (Tabs 3 and 4).

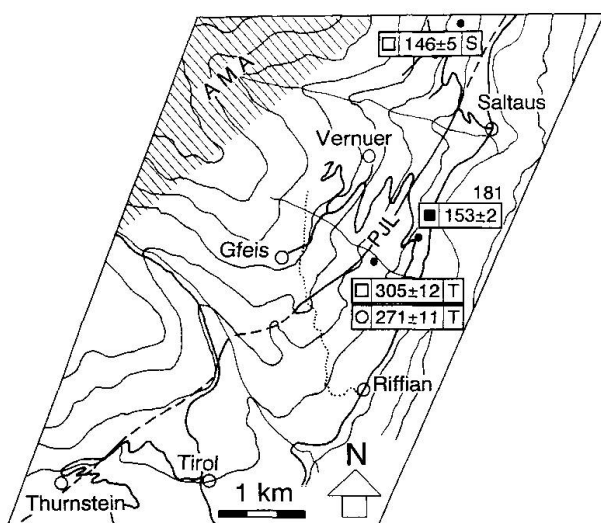


Fig. 5 Passeier–Jaufen Line (PJL) in southern Passeier valley. West of PJL, Rb–Sr Cretaceous white mica ages prevail within AMA and partially reset Rb–Sr white mica ages between AMA and PJL (data S plus sample 1141KAW Fig. 2), which prove that amphibolite facies to upper greenschist facies temperature conditions prevailed during eo-Alpine metamorphism west of PJL. East of PJL, Rb–Sr white mica age is Variscan and K–Ar mica ages are only partially reset. Overall, ages prove a sudden change in temperature conditions during eo-Alpine metamorphism across PJL. Numbers in rectangles: ages in millions of years  $\pm$  error; Symbols: squares: Rb–Sr mica ages; circles: K–Ar mica ages; open symbols: white micas; full symbols: biotites. Letters S and T: data respectively from SATIR (unpubl. data) and THÖNI (1983). Sample numbers of new data shown outside rectangles. Small full dots outside rectangles: sample locations.

**Interpretation:** THÖNI (1983) defined an area of Cretaceous Rb–Sr white mica ages within the eo-Alpine Meran–Mauls basement and called it "AMA" (Alpine mica ages). It coincides with the area defined by HOINKES and THÖNI (1982) where eo-Alpine staurolite crystals appear and amphibolite facies metamorphic conditions prevailed. Figure 5, which shows the eastern border of AMA, reveals that west of Saltaus a band of more than 1.5 km separates the eastern border of AMA from the cataclastic zone. The width of this band steadily falls towards the north (Fig. 2), and the occurrence of partially reset Rb–Sr white mica ages (SATIR, unpubl. data and SATIR, 1975; see above), together with K–Ar mica cooling ages (SATIR, 1975; see above) prove that upper greenschist facies conditions were reached during the eo-Alpine metamorphism. To the east of the tectonic line, all available K–Ar white mica ages were only slightly rejuvenated during the Alpine metamorphism, and the only known Rb–Sr white mica age is still Variscan (THÖNI, 1983). This shows that, east of the cataclastic horizon, the eo-Alpine temperature conditions at the present level of outcrop were very different and probably never exceeded  $350^\circ\text{C}$ . Therefore, these data support the interpretation that the eo-Alpine basement was tectonically juxtaposed against the Variscan Meran–Mauls basement along the cataclastic zone shown in figures 2 and 5.

### Discussion

Although the Passeier–Jaufen Line has already been invoked by various authors to explain the juxtaposition of Variscan and Cretaceous mica ages within the Meran–Mauls basement, this tectonic line has never before been recognized in the field. The new field and radiometric age data combined with those from the literature now provide a sound data base, which allows the Passeier–Jaufen Line to be traced in great detail.

Concerning the development of the Passeier–Jaufen Line, interesting hypotheses were proposed by SELVERSTONE (1988) and SCHMID and HAAS (1989). In the Passeier–Jaufen Line SELVERSTONE (1988) expected a continuation of the Brenner Line, that she interpreted as a Tertiary low angle normal fault along which the Austroalpine basement slipped off westwards during the updoming of the Penninic Tauern Window. SELVERSTONE's interpretation requires a "west side down" movement along the Passeier–Jaufen Line. This sense of movement is opposite to that inferred by the distribution of younger Cretaceous ages north-west of the Passeier–Jaufen Line and older Variscan ages south-east of it.

Instead, the continuation of the Brenner Line may be traced by the distribution of Tertiary mica ages. If this criterion is applied, then the "Brenner Line" defines a detachment surface at the bottom of the Austroalpine basement, coinciding with the small fringe of Tertiary overprinted Austroalpine rocks (SATIR, 1975; THÖNI, 1980; DEL MORO et al., 1982) surrounding the Tauern Window near Sterzing.

SCHMID and HAAS (1989) assume that the Passeier-Jaufen Line formed during the Cretaceous, in response to the backthrusting of the Ötztal basement eastwards. The north-west side up movement along the Passeier-Jaufen Line would fit this Cretaceous backthrusting hypothesis, and the regional distribution of Cretaceous mica ages north-west of the Passeier-Jaufen Line might support the hypothesis that it formed as a consequence of Cretaceous uplifting.

Alternatively, the Passeier-Jaufen Line may represent a fault zone coeval with the Periadriatic Lineament. In this case, the amount of uplift along the Passeier-Jaufen Line would be definitely less than 10 km, further raising a basement which had already risen and cooled to below 300 °C during the Cretaceous. This interpretation is supported by the occurrence of some unusual 60-million-year-old (partially reset?) ages from samples located close to the tectonic boundary (Fig. 3) and the fact that the Passeier-Jaufen Line and the Periadriatic Lineament are parallel. Moreover, an already dated Tertiary mylonitic zone (SPF, Fig. 2) with the same trend as the Passeier-Jaufen Line is known within the Variscan part of the Meran-Mauls basement (SPIESS, 1991, 1992). The Passeier-Jaufen Line is therefore interpreted as a coeval tectonic horizon which evolved because of the Tertiary indentation of the Southern Alps.

#### Acknowledgements

This research was supported by funds of the Italian MURST 40% (FPS) and CNP-Padova (CSGA). W. Frank (Vienna) is acknowledged for the provided facilities at the Labor für Geochronologie und Isotopengeologie. CNR-Padova (Centro Studi per la Geodinamica Alpina) and G. Cavazzini are thanked for Rb-Sr analyses. Reviews by P. Brack (Zürich), N. Mancktelow (Zürich) and F.P. Sassi (Padova) were appreciated and provided helpful criticism on the manuscript.

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Manuscript received April 6, 1995; revision accepted August 15, 1995.