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The Early Alpine overprint in the northern «Silvrettakristallin» and the western «Phyllitgneiszone» (Vorarlberg-Tirol, Austria): radiometric evidence

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ABSTRACT. — Within the ambit of an investigation concerning the metamorphic history of the western «Phyllitgneiszone» (Austrides), rock samples from the northern «Silvrettakristallin», the western «Phyllitgneiszone» and the sedimentary cover (Northern Calcareous Alps) were taken into consideration for radiometric geochronological analyses. The investigated area is located in the most westerly part of the Austrian Austrides. K-Ar and Rb-Sr age data demonstrated the occurence of a thermal overprint in the northern «Silvrettakristallin» and the «Phyllitgneiszone», the intensity of which increases from west to east.

The Early Alpine age of this metamorphism could be determined by K-Ar age data of fine fractions from the post-Hercynian sedimentary rocks and from sericitized feldspar of a retrograde paragneiss from the «Phyllitgneiszone». The K-Ar age data of the fine fractions also show that, at least in the most westerly part of the «Phyllitgneiszone», Alpine temperature conditions were not high enough to affect illites from sedimentary rocks younger than the Anisian layers. The distribution of all available age data also shows that the Alpine isotherms have a NE-SW trend and crosscut the tectonic boundary between the «Phyllitgneiszone» and the «Silvrettakristallin».

Key words: K-Ar micas, Rb-Sr micas, Early Alpine metamorphism, Austrides, Eastern Alps.

RIASSUNTO. — Nell'ambito di ricerche riguardanti la storia metamorfica della parte occidentale della «Phyllitgneiszone» (Austridi), sono stati presi in considerazione per determinazioni geocronologiche radiometriche alcuni campioni provenienti dalla parte settentrionale del cristallino della Silvretta, della adiaciante «Phyllitgneiszone» e della copertura sedimentaria (Falda di Lechtal, Alpi Calcaree Settentrionali). L'area presa in considerazione è situata nella parte più occidentale delle Austridi affioranti in Austria.

I dati radiometrici ottenuti dalle miche con i metodi K-Ar e Rb-Sr hanno permesso di riconoscere una sovrimpronta termica sia nel cristallino della Silvretta che nella «Phyllitgneiszone», con intensità crescente da ovest verso est.

L'età Eo-Alpina di questo metamorfismo è stata determinata col metodo K-Ar sulla frazione fillosilicatica fine separata da rocce sedimentarie post-Erciniche, e su feldspati sericitizzati separati da un paragneiss retrocesso della «Phyllitgneiszone». Le età radiometriche (K-Ar) della frazione fine hanno inoltre messo in evidenza che almeno per la parte occidentale della «Phyllitgneiszone», le condizioni termiche Eo-Alpine non furono sufficientemente alte da influenzare significativamente le illiti di rocce sedimentarie appartenenti a livelli stratigrafici superiori all'Anisico. La distribuzione di tutte le età radiometriche disponibili mostra che le isoterme Alpine seguono un andamento NE-SW, e tagliano trasversalmente la linea tettonica fra il basamento cristallino della Silvretta e la «Phyllitgneiszone».

Parole chiave: miche K-Ar, miche Rb-Sr, metamorfismo Eo-Alpino, Austridi, Alpi Orientali.

Introduction

This paper presents the radiometric results and relative geochronological interpretations obtained within the ambit of multidisciplinary research carried out by the author on the metamorphic and tectonic evolution of the most westerly part of the Austrides in the Eastern Alps (SPIESS, 1985). The investigated area is located in western Austria (Vorarlberg-Tirol), within the Rätikon and Verwall Alps. The rocks of this area belong to three tectonic units (Fig. 1): the «Lechtal Nappe», the «Phyllitgneiszone» and the «Silvrettakristallin».

The «Lechtal Nappe» is a tectonic unit of the Northern Calcareous Alps. It lies with a primary stratigraphic boundary partly over the phyllites of the so-called «Quarzphyllitzone» (HAMMER, 1918) and partly over the phyllitic gneisses of the so-called «Phyllitgneiszone» (Montafon valley: MOSTLER, 1972). The «Lechtal Nappe» was therefore deposited over a crystalline basement which had been previously eroded in such a way that a deeper metamorphic level outcropped in its western part when sedimentation began.

The «Phyllitgneiszone» is considered to be primarily strictly related to the «Quarzphyllitzone», of which it probably represents the deeper higher-grade part. The «Quarzphyllitzone» indeed makes up the northern limb of a large-scale anticline of the «Phyllitgneiszone» in the Venet area near Landeck (ROCKENSCHAUB et al., 1983).

The «Silvrettakristallin» is the old high-grade metamorphic basement in this part of the Austrides. Its main features can be found in BECKER et al. (1987, and references therein).

As regards the original position of the «Phyllitgneiszone» with respect to the «Silvrettakristallin» in pre-Alpine times, contrasting ideas have been proposed. TOLLMANN (1963) maintains that this zone and its sedimentary cover (Northern Calcareous Alps) were originally located south of the «Silvrettakristallin», whereas FRANK (1983) maintains that the «Phyllitgneiszone» was already north of the «Silvrettakristallin» when Cretaceous regional heating began.

The present radiometric research aimed on one hand, at clarifying this problem and, on the other, at making available for this area the type of data concerning the existence of

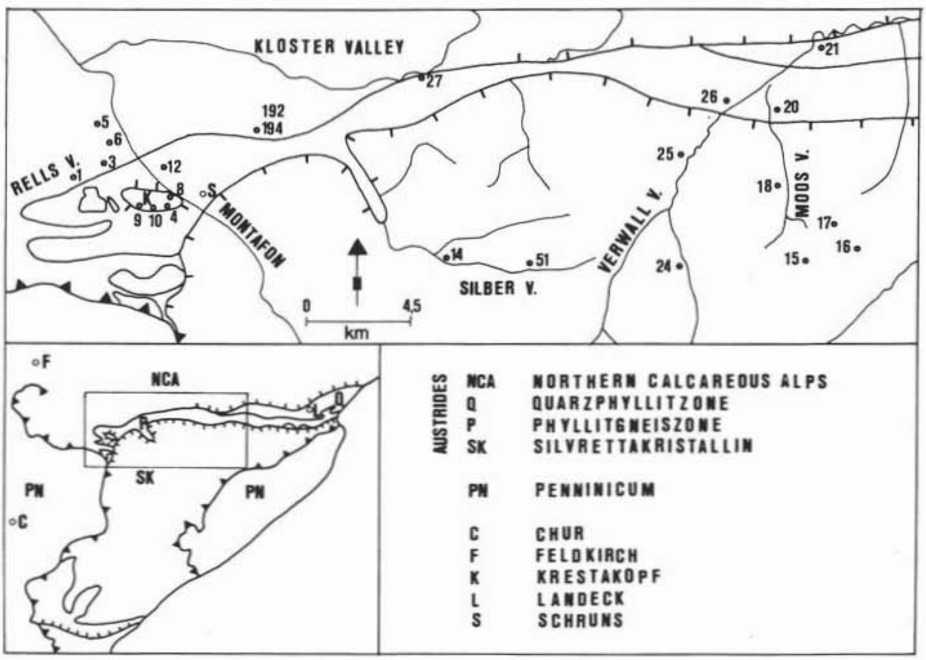

Fig. 1. — Simplified geological-tectonic map of investigated area and location of rock samples from northern «Silvrettakristallin», western «Phyllitgneiszone» and sedimentary cover (Northern Calcareous Alps) examined for radiometric geochronological analyses.

an Early Alpine metamorphic overprint, which Kreczy (1981) and Thöni (1981) produced in neighbouring areas. If the radiometric geochronological data had ascertained that the isotherms of the Early Alpine metamorphism crosscut the boundary between the «Phyllitgneiszone» and the «Silvrettakristallin», further support to Frank's model would be available.

Sample preparation and analytical procedures

Sericite and illite fine fractions from post-Hercynian sedimentary rocks were separated by sedimentation or by centrifugation in distilled water. After crushing, the Permian metasediments were ground for 15 sec. Carbonaceous samples were treated with strongly diluted hydrochloric acid before centrifugation. The mineral concentrates obtained from the crystalline rocks were very pure. However, some biotite concentrates used for K-Ar analyses contained a small amount of chlorite. The sericitized feldspars were separated by means of standard procedures; they were then crushed in a hand agate mortar, and concentrates of 2 μm sericites were obtained by means of sedimentation and centrifugation.

Ar measurements were carried out with a Balzers CMS 80 cycloid mass spectrometer. Using the GLO glauconite international standard (24.69 ccm $\times 10^{-6}$ $^{40}Ar_{rad}$) reproducibility is higher than 5‰. K contents were measured by atomic absorbtion (Perkin-Elmer 300). The error of the analyses is $\pm 2\%$.

The isotopic dilution method was used in all Rb-Sr analyses. All Rb-Sr measurements were made using a Micromass M 30 machine. The long time reproducibility for the $^{87}Sr/^{86}Sr$ ratio using the NBS 987 Sr-standard is higher than 0.15‰. The measured mean $^{87}Sr/^{86}Sr$ ratio for this standard is 0.71010. The blank for the whole chemical treatment is < 2 ng Sr.

All Rb-Sr model ages are «uncorrected» and were calculated using an initial $^{87}Sr/^{86}Sr$ ratio of 0.71014. In calculating age values, the decay constants given by Steiger and Jäger (1977) were used.

Analytical data

A total of 23 rock samples was taken from the «Phyllitgneiszone», the northern «Silvrettakristallin» and the sedimentary rocks of the

Table 1

Rb-Sr data of biotite (B) from «Phyllitgneiszone» (PHZ) and northern «Silvrettakristallin» (SK)

Sample n.	Lithology Sample locality	Tec. unit	Analysed sample	^{87}Rb ppm	$^{87}Sr_{rad}$ ppm	Sr_{total} ppm	%rad	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Model age Ma I_o =0,71014
12	Paragneiss Schruns	PHZ	B 150-300µ	89,14	0,383	19,31	22,60	48,16	0,91753 ± 7	302 ± 12
20	Paragneiss Moos valley	PHZ	B 150-450µ	124,60	0,537	5,95	58,91	234,9	1,72830 ± 68	304 ± 12
26	Paragneiss Verwall valley	PHZ	B 150-450µ	138,40	0,545	3,71	71,37	446,6	2,48042 ± 34	278 ± 11
27	Paragneiss Klösterle	PHZ	B 150-450µ	86,12	0,338	4,91	51,67	192,5	1,46949 ± 61	277 ± 11
14	Paragneiss Silber valley	SK	B 150-450µ	119,90	0,587	5,88	61,56	231,4	1,83753 ± 23	345 ± 14
16	Paragneiss Niederelb hut	SK	B 150-450µ	106,70	0,323	8,92	35,20	127,0	1,09580 ± 202	213 ± 8
17	Paragneiss Sessladjöchly	SK	B 150-450µ	119,70	0,520	10,83	42,19	118,7	1,22489 ± 18	306 ± 12
18	Micaschist Moos valley	SK	B 150-450µ	130,10	0,513	5,11	61,76	289,7	1,85689 ± 158	278 ± 11
24	Biotitegranitegneiss Verwall valley	SK	B 150-450µ	178,60	0,883	4,02	80,29	581,2	3,60293 ± 303	349 ± 14
25	Pragneiss Verwall valley	SK	B 150-450µ	126,70	0,569	5,84	60,94	245,7	1,81814 ± 34	316 ± 12
51	Paragneiss Silber valley	SK	B 150-450µ	129,50	0,531	5,03	63,04	293,9	1,92154 ± 59	289 ± 11

TABLE 2

K-Ar data of muscovite (M), biotite (B) and sericitized feldspars (S) from «Quarzphyllitzone» (QZ), «Phyllitgneiszone» (PHZ) and northern «Silvrettakristallin» (SK)

Sample n.	Lithology Sample locality	Tec. unit	Analysed sample	% K	$^{40}Ar_{rad}$ ccm 10^{-6} NTP/g	% rad	Model age Ma
21	Quartzphyllite St.Anton	QZ	M 150-450μ	7,86	91,29	98,0	276 ± 11
20	Paragneiss Moos valley	PHZ	B 150-450μ	7,66	85,04	95,0	265 ± 11
20	Paragneiss Moos valley	PHZ	S < 2μ	2,43	11,87	81,1	121 ± 6
15	Granitegneiss Schneidjöchl	SK	M 150-450μ	8,00	110,60	98,8	324 ± 13
16	Paragneiss Niederelb hut	SK	B 150-450μ	7,02	59,09	96,9	204 ± 8
17	Paragneiss Sessladjöchly	SK	B 150-450μ	6,48	84,32	97,5	292 ± 12
18	Micaschist Moos valley	SK	B 150-450μ	6,94	80,91	98,9	277 ± 11

TABLE 3

K-Ar data of muscovite (M), sericite (S) and illite (I) from post-Hercynian sediments of «Lechtal Nappe» - Davenna-Schesaplana Unit (DS) and Frescalot-Krestakopf Unit (FK) - in Montafon valley

Sample n.	Lithology Sample locality	Tec. unit	Analysed sample	% K	$^{40}Ar_{rad}$ ccm 10^{-6} NTP/g	% rad	Model age Ma
5	Partnach beds Vandans-Außervens	DS	I 2μ	5,09	31,49	81,5	152 ± 7
6	Muschelkalk Vandans-Außervens	DS	I 2μ	4,53	21,24	72,4	116 ± 6
1	Permian seric.schist Rells valley	DS	S < 2μ	4,99	14,37	77,0	73 ± 4
3	Permian sandstone Rells valley	DS	M 150-250μ	8,21	93,04	94,6	270 ± 11
192	Granite gneiss Bartholomäberg	DS	M 150-450μ	8,43	113,99	95,6	318 ± 13
194	Granite gneiss Bartholomäberg	DS	M 150-450μ	7,93	115,41	97,0	340 ± 14
8	Partnach beds Tschagguns-Krestakopf	FK	I 2μ	5,98	25,49	83,2	106 ± 5
4	Muschelkalk Tschagguns-Krestakopf	FK	I 2μ	6,57	23,25	88,6	89 ± 4
10	Permian seric.schist Latschau-Krestakopf	FK	S < 2μ	5,79	21,93	90,0	94 ± 4
9	Permian seric.schists Latschau-Krestakopf	FK	S < 2μ	6,82	23,74	85,9	87 ± 4

NOTES TO TABLE 3

The sedimentary rocks of the «Krestakopf» are overlain by the «Phyllitgneiszone» and form a tectonic window in the Montafon valley. Probably because of the special tectonic position below the «Phyllitgneiszone», the decreasing Early Alpine overprint going upwards in the stratigraphic sequence cannot be recognized.

«Lechtal Nappe» in the Montafon valley. Sample location is shown in Fig. 1.

Biotite-bearing paragneisses were collected from the crystalline «Phyllitgneiszone». They mainly consists of plagioclase nodules and quartz bands alternating with thin layers of micas (biotite and muscovite). Garnet may also occur, as well as staurolite and kyanite.

Biotite-bearing micaschists, granite gneisses and paragneisses were collected from the northern part of the «Silvrettakristallin». It should be pointed out that, from the mineralogic and petrographic points of view, the rock typs belonging to the western «Phyllitgneiszone» generally cannot clearly be separated from those of the «Silvrettakristallin»: both rock-types in many cases have identical metamorphic characters.

As regards the sedimentary cover («Lechtal Nappe»), the rock samples for geochronological investigation were taken from the Carboniferous basal conglomerates, the Permian sandstones and sericite schists, as well as from the Middle Triassic sequences of the «Muschelkalk» and «Partnach beds» occurring in the Montafon valley.

The 28 sets of analytical data obtained are shown in Tables 1, 2 and 3. Table 1 shows the Rb-Sr data of biotites from the «Phyllitgneiszone» and «Silvrettakristallin»: the corresponding age values mostly fall in the interval 270-320 Ma, but two are a little higher and one is significantly lower. Table 2 shows the K-Ar data of biotites, muscovites and sericitized feldspars from the «Quarzphyllitzone», «Phyllitgneiszone» and northern «Silvrettakristallin»: here too, the corresponding age values mostly fall in the interval 270-320 Ma, and only two are significantly lower. Table 3 shows the K-Ar data of muscovites, sericites and illites from the post-Hercynian sediments occurring in the Montafon valley. The range of the corresponding age values is larger in this case: besides typically Hercynian age values (muscovites from the crystalline pebbles of the Carboniferous basal conglomerate), typical Early Alpine ones were also obtained, as well as intermediate age values.

Geochronological interpretations

Fig. 2 shows all the obtained age values and their frequency distribution, as well as the corresponding geochronological method, analysed minerals and geological classification. The following main considerations can be drawn from this histogram and from Tables 1, 2 and 3:

(a) typical Hercynian age values (270-320 Ma) have been obtained from the analysed biotites and/or muscovites coming from all tectonic units («Silvrettakristallin», «Phyllitgneiszone», «Lechtal Nappe»: coarse-grained muscovites from the crystalline pebbles of the Carboniferous basal conglomerate);

(b) age values in the range 70-100 Ma have been obtained only from the sericites and the illites of the post-Hercynian sediments, clearly indicating an Early Alpine metamorphic overprint;

(c) the occurrence of age values in the range 190-270 Ma in all three pre-Alpine rock sequences («Silvrettakristallin»,

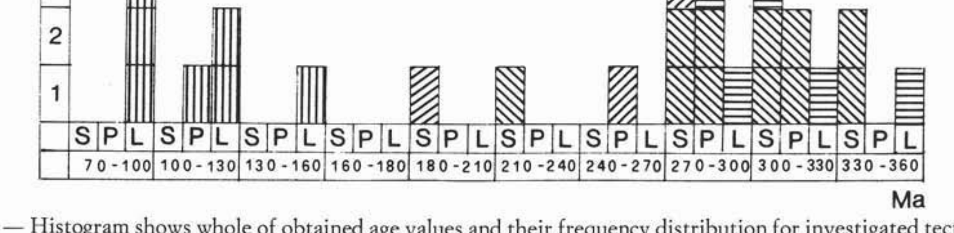

Fig. 2. — Histogram shows whole of obtained age values and their frequency distribution for investigated tectonic units: N = number of data; S = «Silvrettakristallin»; P = «Phyllitgneiszone»; L = «Lechtal Nappe»; 1 = illite and sericite fine fraction K-Ar; 2 = biotite K-Ar; 3 = biotite Rb-Sr; 4 = white mica K-Ar.

«Phyllitgneiszone», «Quarzphyllitzone») indicates that the Alpine overprint affected the whole region and that the rejuvenation of the Hercynian age values was only partial.

After having ascertained the occurrence of an Alpine metamorphic overprint within the area shown in Fig. 1 consistently with the results obtained by KRECZY (1981), THÖNI (1981) and AMANN (1985) in the neighbouring areas, problems arise in (1) dating this overprint, (2) locating the boundary between the undisturbed Hercynian area and that partly rejuvenated by the Alpine metamorphic overprint, (3) estimating the temperature of the Alpine event. For a more complete discussion of these problems, the age values shown in Tables 1, 2 and 3 have been integrated with those occurring in the literature (Fig. 3).

1) *The age of the Alpine overprint.* Interesting results were obtained from the sericitized feldspars of a retrograde paragneiss and the illites and sericites from the post-Hercynian sediments.

As regards the sericitized feldspars, crystals deeply altered into sericite were separated from specimen 20 («Phyllitgneiszone» in the Moos valley), the biotite of which (fraction 150-450 μm) supplied undisturbed Hercynian Rb-Sr cooling ages (304 $\pm$ 12 Ma), and a slightly rejuvenated K-Ar age (265 $\pm$ 11 Ma). Considering that the crystallization of this sericite took place at the expense of the plagioclase crystals in which the sericite occurs, the assumption that it is related to the Early Alpine overprint is reasonable (see MILOTA, 1985, 1986 as regards similar alterations in the Stubai basement). However, the rocks in which this retrograde alteration occurs did not undergo temperatures higher than 300°C during their post-Hercynian history (as the persistence of Hercynian Rb-Sr biotite cooling ages demonstrates). Therefore, the K-Ar age of this sericite is expected to indicate its crystallization age. The corresponding model age value is 121 $\pm$ 6 Ma. This may agree with the first appearance of the flat thermal plateau in the Lower Cretaceous discussed by KRALIK (1983), and seems to be significant from the geologic point of view. On the other hand, significantly lower K-Ar model age values (73 $\pm$ 4 Ma, 87 $\pm$ 4 Ma, 94 $\pm$ 4 Ma) were obtained from $<$ 2 μm sericite concentrates from Permian sericite schists in the Montafon valley (Table 3). The age values of the sericitized faldspars is therefore probably too high.

2) *Boundary between Early Alpine rejuvenated area and undisturbed Hercynian area.* The following considerations may be made on this boundary, also utilizing the age values published by other authors (KRECZY, 1981; THÖNI, 1981; AMANN, 1985).

The area affected by the Early Alpine thermal overprint is located east of the Malfon valley (Fig. 3). The gradual transition from the area of undisturbed Hercynian biotite cooling ages prevailing west of this valley to the area of mixed mica ages (biotite as well as white micas) prevailing eastwards, is well documented by «Sessladjöchly» (sample 17), «Kappler Kopf» (sample 16) and «Kappl» (sample of AMANN, 1985) data points.

The «Sessladjöchly» paragneiss supplied a K-Ar biotite model age of 292 $\pm$ 12 Ma and a Rb-Sr biotite model age of 306 $\pm$ 12 Ma (Tables 1, 2), which are clearly undisturbed Hercynian cooling ages. The «Kappler Kopf» paragneiss (somewhat to the east of the Niederelb refuge hut) supplied a K-Ar biotite age of 204 $\pm$ 8 Ma and a Rb-Sr biotite age of 213 $\pm$ 8 Ma, which both display a clear Alpine overprint. The «Kappl» paragneiss, which is located more to the east (Paznau valley) records a rejuvenation of the K-Ar system in the white micas (AMANN, 1985): the K-Ar model age of muscovite is 236 $\pm$ 10 Ma. Biotites in the same rock sample show a K-Ar model age of 345 $\pm$ 14 Ma, probably due to the incorporation of excess radiogenic Ar.

The above-discussed rock samples clearly indicate the occurrence and location of a boundary, to the west of which only undisturbed Hercynian cooling ages occur, ranging between 316 and 280 Ma (Tables 1 and 2).

The biotite age values obtained from sample 24 (a biotite granite gneiss from the Patteriol-Verwall valley) and sample 14 (a paragneiss from near the Gafluna Alp-Silber valley), require further considerations. They are both Hercynian age values (349 $\pm$ 14 Ma and 345 $\pm$ 14 Ma respectively) but slightly higher than the usual Hercynian cooling age

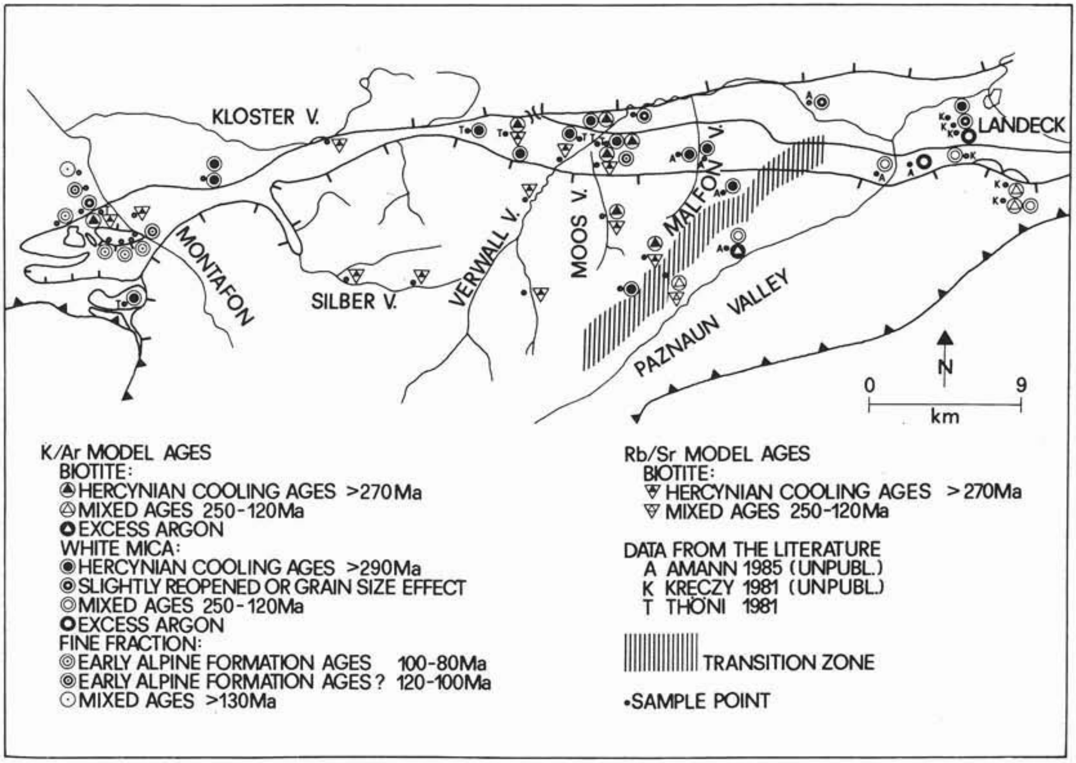

Fig. 3. — Regional distribution of age values shown in Tables 1, 2, 3 and those occurring in literature for «Phyllitgneiszone», northern «Silvrettakristallin» and sedimentary rocks in Montafon valley.

values of biotites. They are both uncorrected age values, calculated by using a value of 0.71014 for the initial $^{87}Sr/^{86}Sr$ ratio: however, their whole-rock correction does not significantly change the age value, because of the high values of the $^{87}Rb/^{86}Sr$ ratio in biotites. Therefore, an inequivocal explanation for these high age values is difficult to find, and this problem remains in the fiel of speculation.

The biotites from the «Phyllitgneiszone» (Schruns, Klösterle, Verwall valley and Moss valley) supplied Rb-Sr model ages in the interval 270-304 ma. They can be interpreted as Hercynian biotite cooling ages, in agreement with THÖNI (1981). The biotite concentrate from the paragneiss of the Moos valley gave a K-Ar model age value of 265 ± 11 Ma, which is slightly lower than its Rb-Sr model age value (304 ± 12 Ma). The vanishing influence of the Early Alpine reheating westwards probably slightly reopened the K-Ar system only. In any case, somewhat to the east, in the Malfon valley, Alpine temperatures were not high enough to reopen the K-Ar system in the white micas (AMANN, 1985). Based on the presently available data, the first reopening of the K-Ar system in white micas has only been detected in the Paznaun valley (AMANN, 1985). To the east of this valley, in the area of the «Thial Spitze», the Early Alpine thermal influence is stronger, as proved by KRECZY (1981).

In conclusion, the Alpine thermal influence increases from west to east, both in the «Phyllitgneiszone» and in the neighbouring «Silvrettakristallin». Although the presently available data do not allow the transition zone to be precisely located within the «Phyllitgneiszone» (because the biotites in this zone frequently show retrograde alteration and are not suitable for analyses), it is clear that the Alpine 300°C isotherm crosscut the tectonic boundary between the

«Phyllitgneiszone» and the «Silvrettakristallin», striking NE-SW.

3) *Temperature values of the Early Alpine event*. The metamorphic grade of this event was very low, considering the overprinted mineral assemblages. However, further information on this problem can be obtained by interpreting the K-Ar age values prevailing at different stratigraphic levels in the post-Hercynian sedimentary cover. Rock samples from the stratigraphic cross-section of the Davenna-Schesaplana Unit («Lechtal Nappe») between Rells valley and Vandans were considered for this purpose. The analysed mineral concentrates, corresponding stratigraphic levels and obtained age values are summarized below:

(a) Carboniferous basal conglomerate: 150-450 μm white mica concentrates, obtained from two pebbles of a diaphtoritic granite gneiss, supplied K-Ar model ages of 318 ± 13 Ma and 340 ± 14 Ma; these age values are interpreted as Hercynian cooling ages and support the idea that diaphtoresis and the related crenulation occurring in these gneisses is not Alpine; the above-mentioned age value of 340 ± 14 Ma could be close to the crystallization age and possibly related to a local earlier Hercynian uplifting;

(b) Lower Permian «transgressive» series below the volcanic sequence («Verrucano» sandstones): a 150-250 μm, detrital white mica concentrate supplied a K-Ar model age of 270 ± 11 Ma, which is slightly lower than the typical Hercynian cooling ages of white micas (THÖNI, 1982); it is difficult to evaluate whether this lower age is due to the smaller grain size or to a small $^{40}Ar_{rad}$ loss as an effect of natural weathering; the former hypothesis seems to be more probable

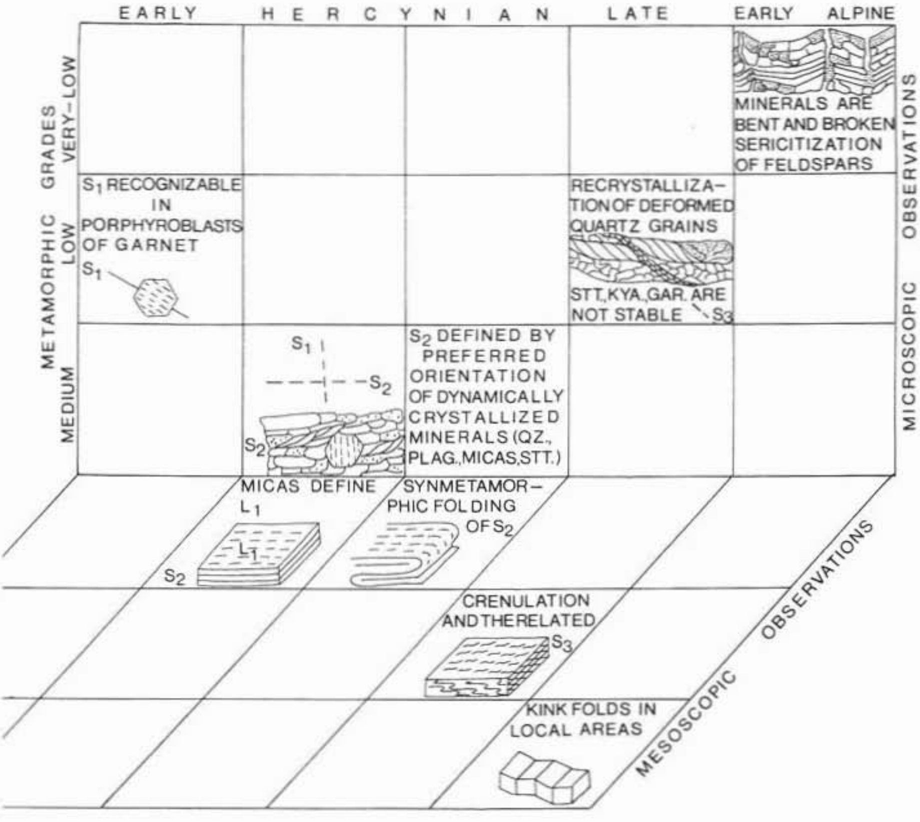

Fig. 4. — Graphic representation of crystallization and deformation history of westernmost «Phyllitgneiszone», based on microtextural analyses, mesoscopic observations and radiometric age data.

(CLAUER, 1981);

(c) Permian sericite schists intercalated within the volcanic sequence («Verrucano»): a < 2 μm sericite concentrate supplied the above discussed age value of 73 ± 4 Ma;

(d) Middle Triassic «Muschelkalk» and «Partnach beds»: 2 μm illite concentrates supplied age values 116 ± 6 Ma and 152 ± 7 Ma.

The latter age values indicate that the Early Alpine overprint decreases going upwards in the stratigraphic sequence. It is only well recorded, by means of pure Early Alpine crystallization ages, in the < 2 μm concentrates of sericite from «Verrucano» and illite from the Anisian «Muschelkalk». The Early Alpine temperature was therefore not high enough to affect the detrital white micas in the «Verrucano» and rejuvenate the illites in the higher stratigraphic levels.

Conclusions

All the age data presented in this paper and those available in the literature concerning the surrounding areas (KRECZY, 1981; THÖNI, 1981; AMANN, 1985) allow the following conclusions to be made;

1) the Early Alpine overprint is well documented both in the northern «Silvrettakristallin» and in the «Phyllitgneiszone»;

2) this thermal effect increases from west to east;

3) the boundary between the area affected by Early Alpine metamorphism (mixed ages) and that in which undisturbed Hercynian cooling ages of biotites persist has a SW-NE trend;

4) this boundary, which may represent the 300°C isotherm of Early Alpine age, crosscuts the tectonic boundary between the «Silvrettakristallin» and the «Phyllitgneiszone»;

5) diaphtoresis and the related crenulation in the most westerly «Phyllitgneiszone» is demonstratedly Hercynian; consequently, the main aspects of the crystallization - deformation history of this zone can be chronologically classified, as shown in Fig. 4.

The above conclusions under points 4 and 5 are consistent with FRANK's interpretation (1983) that the «Phyllitgneiszone» was already to the north of the «Silvrettakristallin» at the beginning of the Cretaceous metamorphism.

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