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On the Age of Metamorphism in the Fertörákos Metamorphic Complex, NW Hungary

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With 3 figures

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Summary

In the Fertörákos metamorphic complex supposedly belonging to the Wechsel Series of the Lower Austroalpine nappe, a Rb-Sr mineral isochron age of 351 ± 9 m. y. has been determined on pegmatitic muscovites of metamorphic origin. This datum places the amphibolite-grade progressive metamorphism of the metamorphic series into the Early Hercynian (Devonian-Carboniferous boundary). Biotite Rb-Sr ages (121 ± 18 resp. 90 ± 10 m. y.) give an upper limit for the age of retrogressive Early Alpine metamorphism in the study area. Considerations based on blocking temperatures of isotopic systems led ot the conclusion that ambient temperatures during the Hercynian metamorphism did not exceed 550° C and remained below about 320° C during the Alpine retrogressive phase. These temperature values are in good agreement with conclusions about metamorphic facies based on mineralogical data.

Zusammenfassung

Im Fertörákos-Metamorphitkomplex (wahrscheinlich Wechselserie, Unterostalpin) wurde an Pegmatitmuskowiten metamorpher Entstehung ein Rb-Sr-Alter von 351 ± 9 Mio. J. gemessen. Dieses Datum stellt die amphibolitfazielle progressive Metamorphose der metamorphen Serien in das frühe Variszikum (Devon-Karbon-Grenze). Rb-Sr-Alter an Biotiten (121 ± 18 bzw. 90 ± 10 Mio. J.) geben eine Obergrenze für das Alter der retrograden frühalpinen Metamorphose im Untersuchungsgebiet. Überlegungen, basierend auf den Blocking-Temperaturen von Isotopensystemen, führten zur Schlußfolgerung, daß die Temperaturen während der variszischen Metamorphose 550° C nicht überschritten und unterhalb 320° C während der alpinen Phase blieben. Diese Temperaturwerte stimmen gut mit petrographischen Beobachtungen überein.

1. Introduction

The easternmost occurrences of Austroalpine rocks on the surface are known in western and northwestern Hungary. While the crystalline schists of the Sopron Mountains (see M. VENDEL, 1973; P. KISHÁZI, 1977) are considered to belong to the Grobgneis-Series (cf. H. WIESENEDER, 1971) of the Lower Austroalpine nappe, the

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Fertörákos schists nearby reveal a sedimentary origin and are supposed to represent equivalents of the Wechsel Series.

Although the polymetamorphic character of the Wechsel Series is well known since long and the effect of Alpine retrogressive metamorphism has been well demonstrated both in the type area (P. Faupl, 1970) and outside it, the age of the dominant progressive metamorphism has remained uncertain except that it must have been clearly pre-Alpine (P. Faupl, 1970).

The principal aim of the present study was to obtain independent information on the age of the amphibolite-grade progressive phase of metamorphism by Rb-Sr geochronometry and by choosing appropriate samples devoid of retrograde effects induced by the subsequent alpine metamorphism.

2. Geological setting

The metamorphic complex of Fertörákos near Sopron has been described recently by L. Kósa (1976). According to A. Tollmann (1976) it belongs to the tectonic window of Rust which, being a Wechsel-type window now in an elevated position with respect to its immediate surroundings, is considered to expose the deepest level of the Lower Austroalpine nappe. On the surface it covers about one km^2 of Hungary and continues on Austrian territory near Mörbisch. Further northwards two small occurrences near St. Margarethen and Oslip mark the northern extension of the metamorphic complex.

W. Fuchs (1965) was the first to recognize the Wechsel-type character of the metamorphics near Oslip. Later studies of L. Kósa (1976) on Hungarian territory support this assumption. The studies of L. Kósa being the most extensive in the Fertörákos area up till now, we follow in a very concise form his description of the metamorphic complex. For details see L. Kósa (1976).

In the frames of an extensive mapping project drilling activity helped to expose the metamorphic complex in a total extrapolated thickness of about 2000 m. The idealized column section is shown in Fig. 1 in a simplified way after L. Kósa (1976) who divides the metamorphic complex into three main formations.

The formation lying deepest consists of alternating amphibolite and amphibolitic schist horizons, with biotite schists appearing in the upper part of the formation. The total thickness of this formation is unknown as no drilling has reached underlying rocks. Since the whole complex dips 20°—30° to the SE, even deeper horizons are expected to be present near the surface on the Austrian side of the border.

The next formation upwards — called by L. Kosa (1976) the "Feldspar-bearing micaschist formation" — consists of feldspar-bearing rocks of varying composition, with signs of intense disharmonic folding at various levels. The formation develops gradually out of the base formation, intermittent beds of amphibolitic and biotite schists still appear, but become gradually rarer in the upper levels. An apatite-rich horizon is characteristic for this formation, quartzitic horizons and layers containing graphite are common both in this and in the upper formation. The total thickness of the feldspar-bearing micaschists is about 500 m.

The uppermost formation consists mainly of phyllitic micaschists in a total thickness of 400—600 m. A gneiss horizon appears at an extrapolated depth of about 350 m, with leucophyllite at its border.

The whole metamorphic complex thus may be considered as a single, metamorphosed eugeosyncline sequence starting with basaltic lavas and tuffs, which gave place later on to geosyncline sediments corresponding to a gradually decreasing depth in the sedimentation area with increasing contribution of terrigenous material. The protolith of the amphibolitic formation might have consisted mainly of basic lavas and tuffs, the lava beds now being transformed into amphibolite, the tuffs into amphibolitic schists. The precursory material of the biotite schists might have been argillaceous sediments devoid of carbonates and carbonaceous material. Later on, the intensity of submarine volcanism has decreased as shown by the continuous

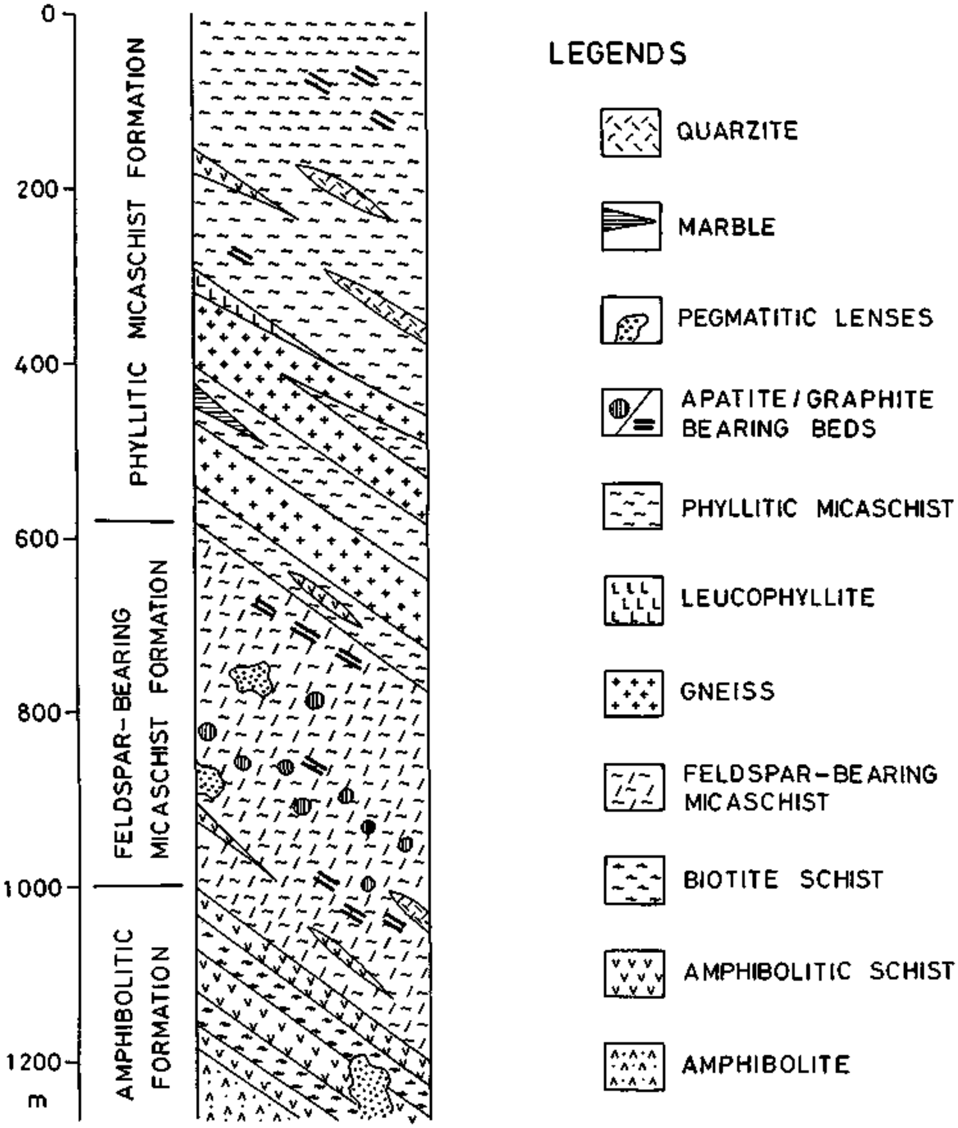

Fig. 1: Idealized vertical section of the Fertörákos metamorphic complex (simplified, after L. Kósa, 1976)

decrease in number and size of the amphibolitic beds in the feldspar-bearing micaschist formation. Here clastic type terrigenous sediments become dominant, the argillaceous beds containing also carbonates as primary constituents. The upper phyllitic micaschist formation has been formed from entirely terrigenous sediments, the arkoses — according to L. Kósa (1976) — having been metamorphosed into gneiss beds, locally with marble between the two gneissic horizons. Evidences for the age of sedimentation are very scarce, a few remains of Graptolites and Chitinozoa point to the Lower Palaeozoic (Silurian ?) age of the sediments.

Although the secondary, retrogressive metamorphism has obliterated many of the characteristics induced by the primary, progressive metamorphism, it is concluded by L. Kósa (1976) that this progressive process acting in an uniform way in the whole vertical section of the complex must have been of the Barrovian type, reaching the p-T conditions of the hornblende-epidote and even the almandine-amphibolite facies, but the conditions of regional anatexis were not reached. As shown by relict characteristic minerals, the grade of metamorphism throughout this phase was uniform in the whole sedimentary column.

The effects of the superimposed retrogressive metamorphism, however, show a marked increase in strength with depth. Chloritization, the breakdown of garnets, sericitization, relative enrichment of secondary ore minerals are present in the whole vertical section, but their intensity gradually increases with depth. Strong albitization is observed in the deeper two formations. The polyphase character of the retrogressive metamorphism is reflected by the presence of several new albite generations. The grade of the retrogressive metamorphism, however, nowhere exceeds the conditions of the upper greenschist facies.

The only rock type which does not exhibit any obvious sign of retrograde metamorphism consists of pegmatitic lenses and veins not uncommon in both the amphibolitic and feldspar-bearing formations. They consist of quartz, feldspar (albite-oligoclase, in some rare cases microcline) and some muscovite. The metamorphic origin of the pegmatitic rocks is beyond any doubt, and they do not contain any alteration product characteristic for the retrogressive processes in other rock types. Due to their simple and stable mineralogy, the pegmatitic rocks have preserved their original composition even during the Alpine movements. The pegmatitic muscovites used in this study were all large platy crystals with no admixture or intergrowth of phengite or serizite often being present in all the other rock types.

3. Analytical methods and results

In order to obtain information on both the progressive and retrograde phases of metamorphism, Rb-Sr isotopic analyses have been carried out on total rock, muscovite and biotite samples from the deeper two formations of the complex, including first of all analyses of muscovites of metamorphic derivation. The samples have been ground, and 0,2 g of the homogenized sample was dissolved in a mixture of cc. HF and $HClO_4$. After evaporation, the sample was taken up in 3N HCl and an aliquot part of the solution was run twice on a Dowex-5OW ion exchange column to prepare the sample for Sr mass spectrometry. Prior to dissolution, known amounts of ^{84}Sr and ^{87}Rb spikes were added to the samples. Measured $^{87}Sr/^{86}Sr$ isotopic ratios were normalized to $^{86}Sr/^{88}Sr = 0.1194$. The concentration of strontium was determined in the same run through the spiked ^{84}Sr peak by stable isotope dilution. The determination of rubidium followed in a separate run using some drops of the original spiked sample solution without any chemical separation.

All mass spectrometric measurements have been carried out with a MI-1309 type mass spectrometer by using a triple filament ion source with a rhenium central band and tantalum side filaments. The ion currents have been measured by a Cary 401 vibrating reed electrometer. The spectra have been evaluated from records made with a W+W 1100 type potentiometric recorder. This way of evaluation of course imposed considerable statistical errors on the isotopic ratio measurements. However, since the measurements were made on mineral samples with fairly high Rb/Sr ratios, the individual model ages calculated with the respective total rock data as a reference exhibit reasonably small resultant errors even at the 95% confidence level.

Table I. Analytical results

Sample	^{87}Rb µg/g	Rb µg/g	^{86}Sr µg/g	Sr µg/g	^{87}Sr/^{86}Sr	^{87}Rb/^{86}Sr	T m. y.
FR-1393							
total rock	12.59	42.3	17.10	179.6	0.7170±0.0043	0.728	
muscovite	77.40	278	2.354	24.67	0.8453±0.0051	32.502	284±15
FR-1784							
total rock	18.35	65.9	13.71	65.93	0.7216±0.0030	1.324	
muscovite	73.15	263	2.559	26.84	0.8563±0.0067	28.257	351±20
FR-1785							
total rock	25.10	90.2	20.88	216.3	0.7218±0.0039	1.188	
muscovite	69.60	250	3.195	33.41	0.8203±0.0050	21.534	340±22
plagioclase	19.13	68.7	19.43	201.1	0.7188±0.0042	0.973	
SOP-13							
total rock	14.96	53.7	8.404	87.06	0.7221±0.0064	1.759	
muscovite	76.34	274	2.730	28.64	0.8538±0.0048	27.642	357±23
FR-4461							
total rock	40.21	145	14.96	154.9	0.7238±0.0054	2.657	
white mica	53.54	192	5.518	57.38	0.7648±0.0016	9.591	415±57
biotite	115.0	413	2.564	26.74	0.7956±0.0090	44.336	121±18
FR-1013/533							
total rock	27.52	98.9	29.84	308.8	0.7161±0.0037	0.912	
white mica	40.85	147	16.86	174.7	0.7315±0.0016	2.395	
biotite	111.8	402	3.087	32.09	0.7619±0.0033	35.800	92±10
FR-1013/534							
total rock	29.68	107	27.72	287.0	0.7220±0.0026	1.058	
white mica	48.93	179	6.491	67.41	0.7517±0.0038	7.588	320±50
biotite	116.8	420	3.140	32.66	0.7676±0.0076	36.770	90±16

All analytical data are summarized in Table I, including also the individual model ages calculated by using the $\lambda = 1.42.10^{-11}y^{-1}$ ^{87}Rb decay constant. As the respective total rock data were taken as reference values, the model ages are actually two-point isochron ages. The errors given in Table I correspond to a 95% confidence interval.

Samples FR-1393, FR-1784 and FR-1785 are from pegmatitic lenses with simple mineralogy as described above, just like the sample SOP-13 which actually originates from outside the Fertőrákos area. This sample was collected in the nearby Sopron Mountains (at the top of Szarvas Hill) but it seems to be totally unrelated to the Sopron gneisses and bears conspicuous similarities both in mineralogy and chemistry with the Fertörákos pegmatoids. Further, the model age of this sample coincides with the model ages obtained on pegmatitic muscovites from the Fertörákos area and differs from the age values characteristic for the Sopron gneisses and schists (A. Kovách and E. Svingor, unpublished data). Thus we feel justified to include this sample into the present study, although the actual tectonic relationships between the two areas and thus the exact relation of this sample to the Fertörákos ones are still unclear.

Sample FR-4461 is a feldspar-rich micaschist, while the two samples FR-1013/533 and FR-1013/534 are biotitic schists from the base formation. All samples except SOP-13 are drill core samples obtained by us through the courtesy of Dr. L. Kósa.

4. Evaluation and discussion

Three out of the four pegmatitic samples FR-1784, FR-1785 and SOP-13 yielded concordant muscovite ages (351 ± 20; 340 ± 22 resp. 357 ± 38 m. y.) while the model age determined for FR-1393 differs from the others well beyond error limits. Whether this datum (284 ± 15 m. y.) corresponds to a distinct, second metamorphic event or not, cannot be judged on the basis of the present work, so we restrict our discussion to the results obtained on the three other samples.

To facilitate easy comparison, the results obtained on the pegmatitic samples are shown in the ^{87}Rb-^{87}Sr isotope evolution diagram in Fig. 2. The mineralogical and petrochemical similarity of the samples reflected also in the isotopic data and in

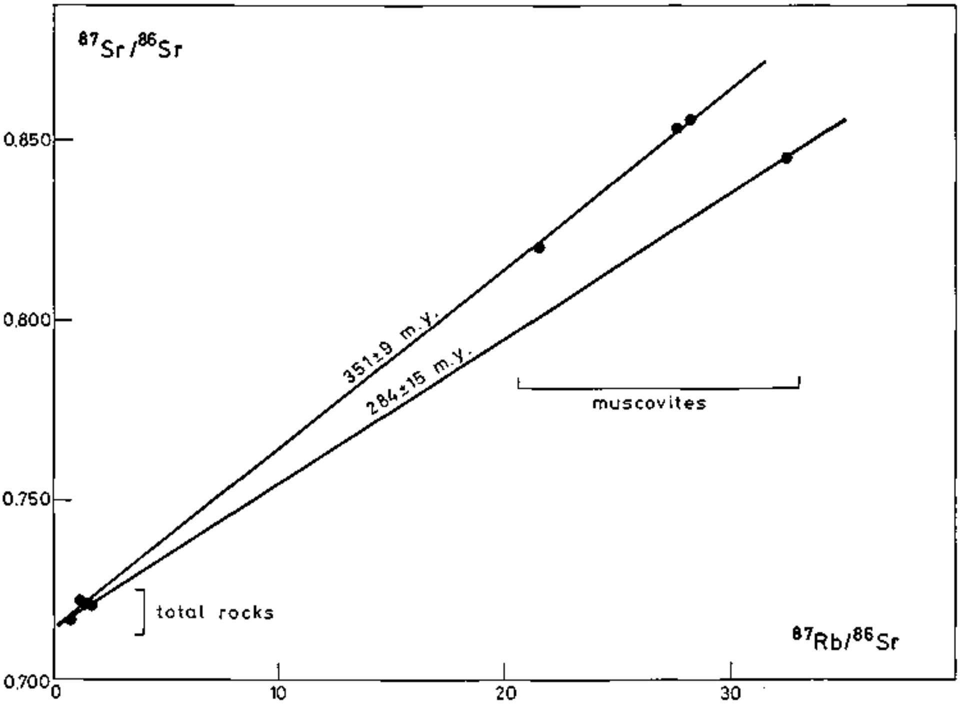

Fig. 2: Rb/Sr mineral isochron diagram for pegmatitic samples of metamorphic derivation from the Fertörákos metamorphic complex

the arrangement of the experimental points in the diagram allows the interpolation of the measured data by a single isochron which fits the three total rock resp. muscovite results well within experimental errors. The common isochron age deduced this way is 351 ± 9 m. y., with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7146 ± 0.0024. The initial Sr isotopic ratio is in good accordance with the assumed metamorphic origin of the pegmatitic samples.

Additional and independent support is given to the 351 m. y. isochron age by the analyses on white micas which were separated from samples FR-4461, FR-1013/533 and FR-1013/534. These results plotted as open diamonds in Fig. 3 show a uniform scatter along the isochron of pegmatitic muscovites included as a reference isochron (broken line). However, the deviations from the reference isochron are considerable, probably due to the presence of sericite, and to secondary disturbances in the Rb-Sr isotopic system of these samples during the Alpine era. The presence of such disturbances is clear from the biotite data also plotted in Fig. 3.

As regards the Early Hercynian age of 351 ± 9 m. y. determined for the progressive metamorphism in the Fertörákos area, age values pointing to such an early commencing of Hercynian metamorphic development are not quite uncommon in the Alpine realm. B. GRAUERT (1966) determined a total rock isochron age of 351 ± 14 m. y. for Silvretta nappe pegmatitic orthogneisses (if recalculated with $\lambda = 1.42 \, . \, 10^{-11} \, . \, y^{-1}$ the age is 363 ± 14 m. y.). M. SATIR and J. MORTEANI (1979) published ages well over 300 m. y. for the Schwaz augengneiss. C. HAWKESWORTH (1976) reports an age of 381 ± 30 m. y. (if recalculated, 372 ± 29 m. y.) for the Innerkrems orthogneisses based on an "errorchron". Further, S. SCHARBERT in H. BÖGEL et al. (1979) gives an age of 340 ± 10 m. y. for the Lower Austroalpine Grobgneiss, for which an immediate relationship with the Wechsel Series is assumed (cf. P. FAUPL, 1970). Our results offer in addition independent support to the assumption, that the

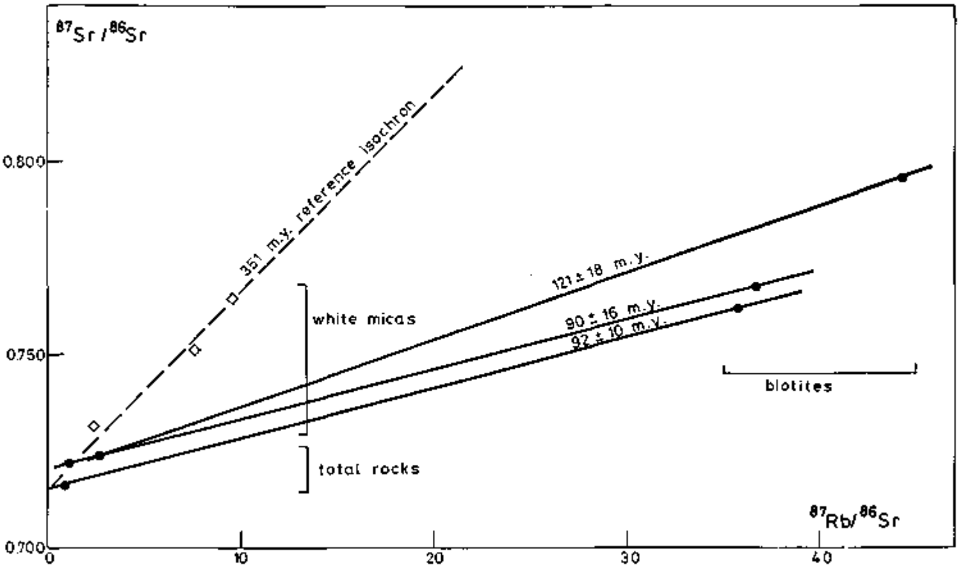

Fig. 3: Rb/Sr mineral isochron diagram for micaschists from the Fertörákos metamorphic complex

Grobgneiss and the Wechsel Series underwent Early Hercynian metamorphism contemporaneously. Accepting 500 ± 50° C for the blocking temperature of the muscovite Rb-Sr system (E. JÄGER, 1973) and bearing in mind that the metamorphism has not reached the conditions of regional anatexis, an upper temperature limit of about 550° C for this metamorphism should be postulated.

The biotite data plotted in Fig. 3. clearly show the effect of Alpine metamorphism and yield ages of 121 ± 18 m. y. for a biotite from the feldspar-bearing formation and 92 ± 10 resp. 90 ± 16 m. y. for the essentially parallel samples from the biotite schists of the base formation. The difference between the two age values (121 resp. 90 m. y.) seems to be real, and allows an interpretation of the biotite model ages as rejuvenated ones, relating the difference in the model ages to the difference in structural level and depth. Thus, the minimum of the biotite model ages (90 m. y.) should be taken as a maximum possible age for the Alpine metamorphism in the study area.

The dependence of Rb-Sr mineral ages on depth resp. structural level in Austroalpine units has been noted already by C. J. HAWKESWORTH (1976) and is brought into connection with thermal disturbances along the planes of nappe overthrust. As the Fertörákos metamorphic complex must have been subject to large-scale horizontal movements (see L. KÓSA, 1976) too, this explanation seems to be valid in this case as well. The age values themselves fit into the general distribution of mineral ages in Austroalpine units (cf. C. J. HAWKESWORTH, 1976) and show no signs of Late Alpine effects characteristic for the Penninic domain.

Up to the present only three K-Ar age determinations made on the Fertörákos schists were known quoted in L. KÓSA (1976). A sample of pegmatitite character gave 250 ± 7 m. y., a feldspar-rich micaschist and a phyllitic schist both total rock samples yielded ages of 303 ± 5 resp. 130 ± 4 m. y. The age values are very likely "mixed" ages, reflecting incomplete degassing during the retrogressive Alpine metamorphism. Taking 350 ± 50° C for the blocking temperature of argon in muscovite and 300 ± 50° C for the biotite Rb-Sr system (E. JÄGER, 1973) one has to conclude that temperatures during the Alpine metamorphism have not exceeded a value of about 320° C, leading to a slight resetting of the K-Ar age of muscovite, and near-complete resetting of the biotite Rb-Sr ages. Conclusions about temperatures during both metamorphic phases drawn here from the distribution of K-Ar and Rb-Sr mineral ages are in a very good agreement with the conclusions of L. KÓSA (1976) based on mineralogical considerations about facies conditions during the individual metamorphis phases.

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