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Rb-Sr DATING OF BASEMENT ROCKS FROM THE SOUTHERN FORELAND OF THE MECSEK MOUNTAINS, SOUTHEASTERN TRANSDANUBIA, HUNGARY

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ABSTRACT

Rb-Sr total rock and biotite age determinations have been carried out on samples from the borehole Baksa—2 disclosing sillimanite-grade metamorphic rocks of the Görcsöny Ridge (so called "Baksa Formation") at the northern margine of the Drava Basin in southeast Transdanubia.

The 331±13 Ma total rock isochron age is tentatively interpreted as the time of D_1 deformation immediately coupled to the dominant staurolite — kyanite — sillimanite grades (Barrowian) first phase of metamorphism. The overprinting second progressive metamorphic episod is characterized by high T medium P effects (D_2 deformation) producing among others enstatite minerals in the ultramafics of Gyód as well as microgranitic-aplitic veins and segregations in the pelitic schists. Its age brackets of 331 and 315 Ma, followed by regional emergence and low-temperature retrograde effects probably due to prolongated uplift under low velocity conditions.

INTRODUCTION

The borehole Baksa-2 was drilled within the frames of the Reference Section Project initiated by the Hungarian Geological Bureau. The drilling was aimed at to explore the crystalline basement of the Görcsöny Ridge, located between the Western Mecsek resp. Villány Mountains. It exposed the crystalline basement formation in a total thickness of over 1100 m, with near 100% core recovery.

According to previous investigations (SZEDERKÉNYI, 1974, 1976) the crystalline of the Görcsöny Ridge overlain by a thin cover of Pannonian and Pleistocene age forms a steep, locally near-vertical turned mass, in common structural position with the basement of the Drava Basin as well as with the Papuk-Psunj-Krndija Mountains in Yugoslavia. The NW-SE striking metamorphites at the northern border of the Drava Basin together with those of the Görcsöny Ridge represent a continuous Barrowian facies series from the chlorite to the sillimanite zone with signs of anatexis and granitization.

METAMORPHIC ROCKS OF THE DRILLING BAKSA-2 AND THEIR EVOLUTION

According to the studies of SZEDERKÉNYI (1979, 1981) the drilling Baksa-2, drilled in the sillimanite zone of the Görcsöny Ridge metamorphic mass, exposed a rather heterogeneous metamorphic formation, which could be divided into the following lithostratigraphic units:

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— "upper marble" member
— chloritic two-mica gneiss member
— "lower marble" member
— garnetiferous two-mica gneiss member
— garnetiferous two-mica schist member

According to this lithostratigraphic sequence, the protolith suite consisted of rhytmically intermitting layers of mainly greywacke and pelitic type sediments, with interbedded thin layers of limestone, calcareous marl, dolomite and dolomitic marl in the upper and middle part of the exposed rock-column. The section is quite frequently interrupted by thin basic tuff layers, infrequently by small lava-beds.

The protolith rock mass of predominantly psammitic-pelitic character and of indeterminate age was subject to polyphase deformation under regional metamorphic conditions, resulting in a characteristically polymetamorphic assemblages. Besides the effect of regional metamorphism, contact phenomena have been evoked at some levels by the intrusion of small aplitic-micrograniitic veins. Regional metamorphism itself has occurred in two progressive and two regressive phases.

The dominant metamorphic phase coupled to the D_1 deformation resulted in the development of crystalline schists at a temperature of 630—650 °C and 5—7 kbar pressure corresponding to the amphibolite facies and characterized by sillimanite as an index mineral. This compressional phase was followed by decompression and textural loosening, with strong lateral secretion of quartz.

The second phase of regional metamorphism having occurred at 400—410 °C and 3—4 kbar appears as an overprint, producing mineral associations corresponding to the greenschist facies (quartz-albite-epidote-biotite subfacies). The weak retrogressive phase following D_2 deformation was interrupted by the late-orogenic aplitic-microgranitic magmatism of Herzynian age, which in small zones — especially in the carbonate-rich members — led to the development of contact phenomena corresponding to the pyroxene-hornfels resp. hornblende-hornfels facies.

At some levels of the rock-column cataclastic zones younger than the aplitic-microgranitic magmatism could be observed, with a conspicuous polymetallic sulphide mineralization with a mineral association representing the highest tempered pneumatolitic resp. catathermal phase. Its development is undoubtedly connected to the rhyolitic volcanism of Early Permian age known both in the Western Mecsek resp. Villány Mountains (FAZEKAS *et al.*, 1981).

The relative succession of the individual metamorphic resp. deformational phases could be determined unambiguously, but their accurate dating — except that of the subordinate mineralization phase — raised several questions which could not be solved by geological means only. This was the main impetus for the present investigations, primarily aimed at to obtain chronological information on the deformation history of the rock mass in question.

EXPERIMENTAL METHODS AND RESULTS

The samples used in this study have been chosen so as to represent possibly all the main rock types of the metamorphic base formation, as well as to cover the whole depth range exposed by the drilling Baksa-2. The sample from the depth of 64.0 m belongs to the "upper marble" member; those from 268.0, 366.0 and 752.9 m to the chloritic two-mica member; from 856.7 m to the "lower marble" member; those from the depth of 941.0 m and from below all belong to the garnetiferous two-mica schist member of the formation. The sample from 64.0 m is of aplitic character.

Age determinations have been carried out on total rock samples and biotites in order to obtain information both on the timing of the main phase of regional metamorphism and the uplift and cooling history of the rock mass. Biotites have been separated by conventional methods using an isodynamic magnetic separator and heavy liquids.

In the course of chemical preparation the samples were dissolved in a mixture of hydrofluoric and perchloric acids, dried and dissolved again in a small amount of 3N hydrochloric acid. Enriched ^{84}Sr and ^{87}Rb spikes used in the mass spectrometric determination of Sr resp., Rb concentration values have been added to the samples prior to dissolution.

Strontium samples for mass spectrometry have been prepared on a Dowex 50W×12, 200—400 mesh cation exchange column, and were placed into the ion source of the mass spectrometer in a nitrate form, later converted to oxide. All mass spectrometric measurements have been carried out on a modified MI 1309 type mass spectrometer equipped with a triple filament ion source. Mass discrimination effects have been corrected by normalizing to the $^{86}Sr/^{88}Sr=0.1194$ reference ratio.

To check the accuracy of the measurements, repeated measurements have been carried out on the Eimer and Amend standard strontium carbonate sample ($^{87}Sr/^{86}Sr=$ $=0.7080$). During the time of measurements reported here the average of standard measurements was $^{87}Sr/^{86}Sr=0.7079\pm0.0002$, thus no other correction was found to be necessary.

Experimental results obtained on both total rock and biotite samples are summarized in Table 1, together with the calculated model age values. All age data have been calculated using the ^{87}Rb decay constant $\lambda=1.42\cdot10^{-11}a^{-1}$. Measurement errors are in general RMS errors, whereas error estimates of individual and isochron ages correspond to a 95% probability confidence interval.

Data obtained on total rock samples are shown in *Fig. 1* in a conventional sochron diagram. Irrespective of their petrographical character, the data points can

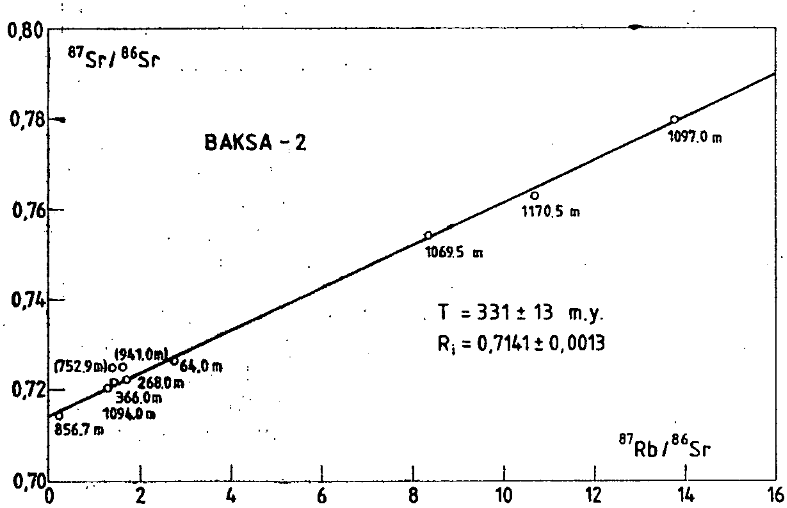

Fig. 1. Analytical data obtained on total rock samples from the borehole Baksa-2, shown in an isochron diagram

be interpolated with a single straight line, corresponding to an isochron age of 331±13 Ma and an initial Sr isotopic ratio $R_i = 0.7141 \pm 0.0013$ (the errors include the analytical errors of the data points and correspond to a 95% confidence interval). The data for the samples taken from the depths of 752.9 and 941.0 meters have been omitted in calculating the isochron age, because theerespective points plot off the isochron well outside analytical errors as ascertained by several repeated measurements.

TABLE 1

Compilation of analytical data obtained on samples from drilling Baksa-2

Depth (m)	^{87}Rb µg/g	Rb µg/g	^{86}Sr µg/g	Sr µg/g	$^{87}Rb/^{86}Sr$ (atomic ratio)	$^{87}Sr/^{86}Sr$ (atomic ratio)	Age (Ma)
Total rock samples							
64.0 m	39.95	143.6	14.17	146.8	2.787	0.7264±0.0012	
268.0 m	37.57	133.5	21.82	225.9	1.702	0.7223±0.0007	
366.0 m	32.64	117.3	22.28	230.8	1.448	0.7218±0.0008	331±13
752.9 m	34.26	123.1	24.13	249.9	1.403	0.7250±0.0011	(iso-
856.7 m	9.09	32.7	40.11	415.1	0.224	0.7144±0.0007	chron
941.0 m	39.24	141.0	23.82	246.7	1.628	0.7252±0.0011	age)
1069.5 m	59.32	213.1	7.01	72.9	8.360	0.7543±0.0015	
1094.0 m	29.74	106.8	22.60	234.0	1.301	0.7210±0.0009	
1097.0 m	83.74	300.9	6.01	62.6	13.766	0.7797±0.0021	
1170.5 m	62.69	225.2	5.81	60.3	10.675	0.7629±0.0012	
Biotites							
268.0 m	101.50	364.7	6.665	69.33	15.054	0.7676±0.0012	239±9
366.0 m	96.22	345.7	3.276	34.34	29.034	0.8467±0.0009	318±4
752.9 m	86.64	311.3	3.167	33.17	27.043	0.8386±0.0016	311±5
941.0 m	82.85	297.8	4.623	48.24	17.715	0.8001±0.0020	327±10
1069.5 m	80.11	287.8	4.461	46.53	17.751	0.7961±0.0025	313±22
1094.0 m	89.42	321.3	2.154	22.70	41.036	0.9004±0.0012	317±9
1097.0 m	92.93	333.9	4.239	44.30	21.671	0.8148±0.0015	312±23
1170.5 m	108.53	390.0	2.326	24.55	46.123	0.9198±0.0015	311±4
						Weighted average of biotite model ages:	315±4

Biotite individual model ages calculated with reference to the corresponding total rock samples are concordant with a weighted average of 315±3 Ma except the biotite sample from depth of 268.0 m, yielding a model age of 239±9 Ma, evidently attributable to the local effect of a Permian disturbance. No systematic dependence of the biotite ages on sampling depth could be ascertained.

A controll of Rb/Sr age determinations was carried out by the laboratory of Padova University on a sample of Baksa-2 metamorphics (from 1095,50 m). The age calculated from the next chemical data is 328±5 m.y. (whole rock — biotite isochron) which is the age of the biotite. Biotite: Rb=364 ppm, Sr=6,8 ppm. $^{87}Rb/^{86}Sr = 168.15$, $^{87}Sr/^{86}Sr = 1.005$. Whole rcok: Rb=139 ppm, Sr=221 ppm, $^{87}Rb/^{86}Sr = 1.82$, $^{87}Sr/^{86}Sr = 0.7248$. It looks like a fairly similar radioactive age to that of Table 1.

DISCUSSION

The 331±13 Ma total rock isochron age, as well as the 315±3 Ma average biotite age are directly comparable with the results of K/Ar measurements carried out by BALOGH *et al.* (1983) on white micas and biotites from the rock column of the Baksa-2 borehole. The average K/Ar muscovite age of 306±6 Ma and the 288±10 Ma average K/Ar biotite age when compared with the data presented here point equivocally to a prolonged Herzynian thermal history of the crystalline in question, the different ages obtained by different methods being in the proper order according to their different blocking temperatures. A detailed analysis of the thermal and uplift history of the Görcsöny Ridge will follow elsewhere, but without going into details one can safely conclude that the time span indicated by the radiochronological data gives an appropriate time frame for a polyphase metamorphic-deformational development during the Herzynian. Previous assumptions (*cf.* LELKES—FELVÁRI *et al.*, 1981) declared the metamorphic development to be partly pre-Herzynian, a possibility still maintained by ÁRKAI (1984) based on petrological investigations on basement rocks from the Drava Basin with results pointing to an analoguous sequence of metamorphic events in the chlorite zone of a facies series belonging to another tectonic unit.

The 331±13 Ma total rock isochron age, however, makes it highly probable that even the oldest metamorphic-deformational phase detectable by petrographical petrological means occurred during the Herzynian. The blocking temperature of the total rock Rb-Sr system on a regional scale is sufficiently high even in the presence of a considerable amount of fluids circulating over the rock column, as implied by the Barrowian character of metamorphism, and is in the order of the temperature conditions attributed to the dominant first phase of metamorphism. Even if we assume, that this datum corresponds already to the (incipient) thermal decline of the first metamorphic event, there is no reason to assume that temperatures of about 600 °C under Barrowian conditions could have been maintained over a prolonged period of time all the more because the strong deformation points to the dynamic behaviour of the system during metamorphism. Even if we assume, that the amphibolite grade metamorphism has occurred (somewhat) prior to the 331±13 Ma datum, we feel convinced that this value gives a reliable age for the deformation D_1, during which conditions inappropriate for isotopic equilibration over a km-scale became manifest. This interpretation might be supported by additional evidences obtained on the anatectic granodiorites of the Mecsek Mountains, adjoining the Görcsöny Ridge metamorphic basement. Rb-Sr studies (SVINGOR and KOVÁCH, 1981) bracket the development of the anatectic mass between the age limits of 400 to 270 Ma with concordant Rb-Sr *(loc. cit.)* and K-Ar (BALOGH *et al.*, 1983) evidence for a prominent event at around 334 Ma. As this concordant datum has been obtained on biotites, it points to the rapid uplift of the anatectic mass, taking into account the 337+18 average K-Ar obtained on amphiboles from the immediate cover. Although a direct link between the Görcsöny Ridge metamorphites and the Mecsek granodiorites could not have been ascertained up till now, the increase of metamorphic grade towards the granitized mass of the Western Mecsek Mountains supports the interpretation that the D_1 deformation might have been synchronous with the emergence of the anatectic mass nearby. If this parallelization is correct, the zircon concordia age of 365±8 Ma quoted by BALOGH *et al.* (1983) for the Mecsek anatectites might serve as additional evidence for the peak of metamorphism in the area under study, in support of placing the main phase of metamorphism into the Late Devonian-Early Carboniferous, i.e. into Herzynian times.

The timing of the second metamorphic-deformational overprint is bracketed by the total rock isochron age and the 315±3 Ma average biotite Rb-Sr age, the blocking temperature of the biotite Rb/Sr system (PURDY and JÄGER, 1976) being definitely lower than possible temperatures assigned to this metamorphic episode. A more accurate positioning in time of this metamorphic event might be possible in the course of a detailed analysis of the thermal history of the rock unit.

The present data allow no conclusion with respect to the age of the subordinate dyke intrusions interrupting the decline of the second metamorphic event. The aplitic sample from the depth of 64.0 m fits into the isochron picture and does not seem to represent a definitely different source for the late dyke intrusions. It rather points to the possibility, that most of the late aplitic dykes represent paraautochtonous mobilizates of the basement. It should be mentioned, however, that Rb-Sr data obtained on highly differentiated micrognanitic dyke rocks from the Mecsek Mountain area supply evidence for dyke intrusions appearing locally in the final stage of uplift of the anatectic region, too (SVINGOR and KOVÁCH, 1981).

The only discordant biotite age of 238±9 Ma obtained on a sample from the depth of 268.0 m is in agreement with the 243+15 Ma total rock isochron age obtained on Permian rhyolites from the Villány Mountains nearby, supporting the interpretation of FAZEKAS *et al.*, (1981) on the locally appearing late stage disturbances.

As shown by the data in Table 1 as well as by the K-Ar data of BALOGH *et al.* (1983) already quoted, no distinct Alpine effects could be ascertained by radiochronological means. This fact might be in favour of the interpretation, that the low-temperature retrograde effects shown by ÁRKAI (1984) in metamorphites of the Drava Basin might be evoked mainly during the continuous, low-velocity uplift of the metamorphic mass.

CONCLUSIONS

Based on the discussion above, the following tentative timing sequence for the individual metamorphic-deformational events might be given for the metamorphic rocks of the Görcsöny Ridge, considered as the southern foreland of the Mecsek Mountains in the Southeastern part of the Transdanubian region in Hungary:

— 1st phase of metamorphism: (365) ... 331±13 Ma
— D_1 deformation: 331±13 Ma (Devonian/Carboniferous boundary)
— 2nd phase of metamorphism and D_2 deformation: about 315 Ma (Early/Late Carboniferous boundary)
— Continuing emergence and low-temperature retrograde alteration: 315 to about 280 Ma
— Local disturbances: about 240 Ma (Permian).

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