GEOLOGICA CARPATHICA, 46, 2, BRATISLAVA, APRIL 1995
95 - 99

GEOCHEMISTRY AND Rb/Sr ISOCHRON AGE OF PEGMATITES FROM THE WESTERN TATRA MTS. (S-POLAND)

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(Manuscript received March 11, 1994; accepted in revised form September 22, 1994)

Abstract: According to geochemical data the pegmatites from the Western Tatra Mts. (S-Poland) crystallized from a water-saturated melt, peraluminous in composition, rather poor in trace elements, at temperatures below 700 °C. Their origin is connected with partial melting of metamorphic rocks. A Rb/Sr whole-rock isochron study indicates that the pegmatites under consideration were emplaced during the early Hercynian period. They yield an age of 345 ± 9.5 Ma and initial $^{87}Sr/^{86}Sr$ ratio of 0.70625 ± 0.0002.
The low value of the initial Sr isotope ratio suggests a significant admixture of mantle-derived material in the parent rocks melted during metamorphic processes in the Western Tatra crystalline complex.

Key words: Western Tatra Mts., West-Carpathian pegmatites, Rb/Sr isochron age, partial melting.

Introduction

The Tatra Mts. are one of the numerous crystalline massifs in the Central Western Carpathians. Their western part consists of mainly metamorphic rocks, embedding small granitic and pegmatitic intrusions, wrapped up in Mesozoic sedimentary formations (Fig. 1). The crystalline complex is cut by numerous faults and cracks with predominant sets: NNE-SSW to ENE-WSW and NW-SE to N-S (Jaroszewski 1965). The whole metamorphic complex is thought to be metasedimentary in origin and was metamorphosed under amphibolite facies conditions (Janák et al. 1988).

Pegmatites from the Polish part of the Western Tatra Mts., ranging in size from a few centimeters to a few meters, form veins and lenses within biotite and plagioclase-biotite gneisses and migmatites. They seem to be independent of the granitoids. Only a few of them were found inside the granitic bodies. Small pegmatitic bodies do not display a zoned structure, but thicker ones have four different types of internal zoning (Fig. 2). Their mineralogy is rather simple; the main mineral constituents are: apatite, zircon, allanite, tourmaline. As the secondary minerals one can find: chlorite, sericite, kaolinite, celadonite, illite/smectite (Gaweda 1993). Pegmatites in the area under consideration are peraluminous in composition and are considered to be products of the partial melting of a metamorphic complex (Skupinski 1975; Gaweda 1992a, b).

Previous isotopic studies suggested a Hercynian age for the granites and pegmatites from both the High and Western Tatra Mts. (Burchart 1968). The age of pegmatites from the Western Tatra Mts. (Stara Robota Valley) was estimated, using Rb/Sr whole isochrone method, at 280 ± 80 Ma with IR 0.731 ± 0.018. Ar/Ar muscovite and biotite cooling ages from granitoids and metamorphic rocks (Janák & Onstott 1993) suggest an older (Early Carboniferous) age for granitoid magmatism in the Western Tatra Mts.

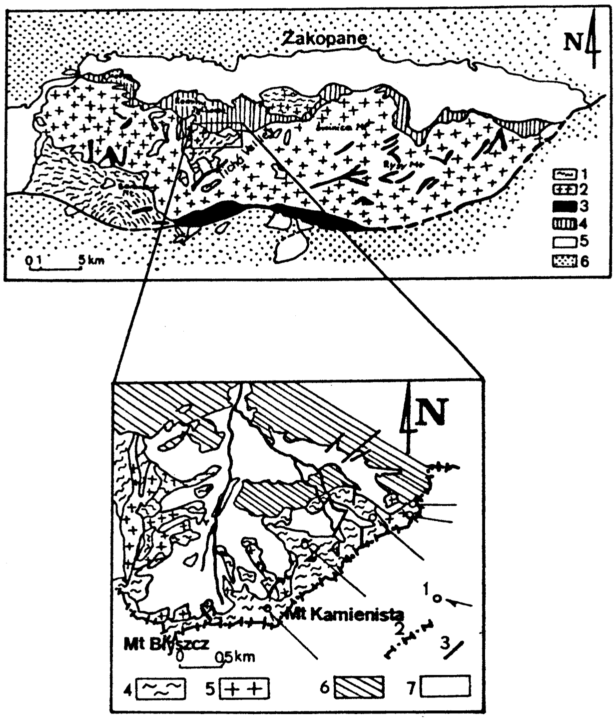

Fig. 1. A. Simplified geological map of the Tatra Mts. (after Ksiazkiewicz 1972). 1 - metamorphic rocks, 2 - granitoids, 3 - mylonitic zones in the crystalline core, 4 - autochthonous sedimentary series, 5 - allochthonous sedimentary series (Tatric nappes), 6 - Eocene sediments. **B.** Geological sketch of the Upper Koscieliska Valley with the points of sampling. 1 - points of sampling (with appropriate numbers), 2 - Poland-Slovakia border, 3 - dislocations, 4 - metamorphic rocks, 5 - granitoids rocks, 6 - Triassic quartzites, 7 - Quaternary sediments.

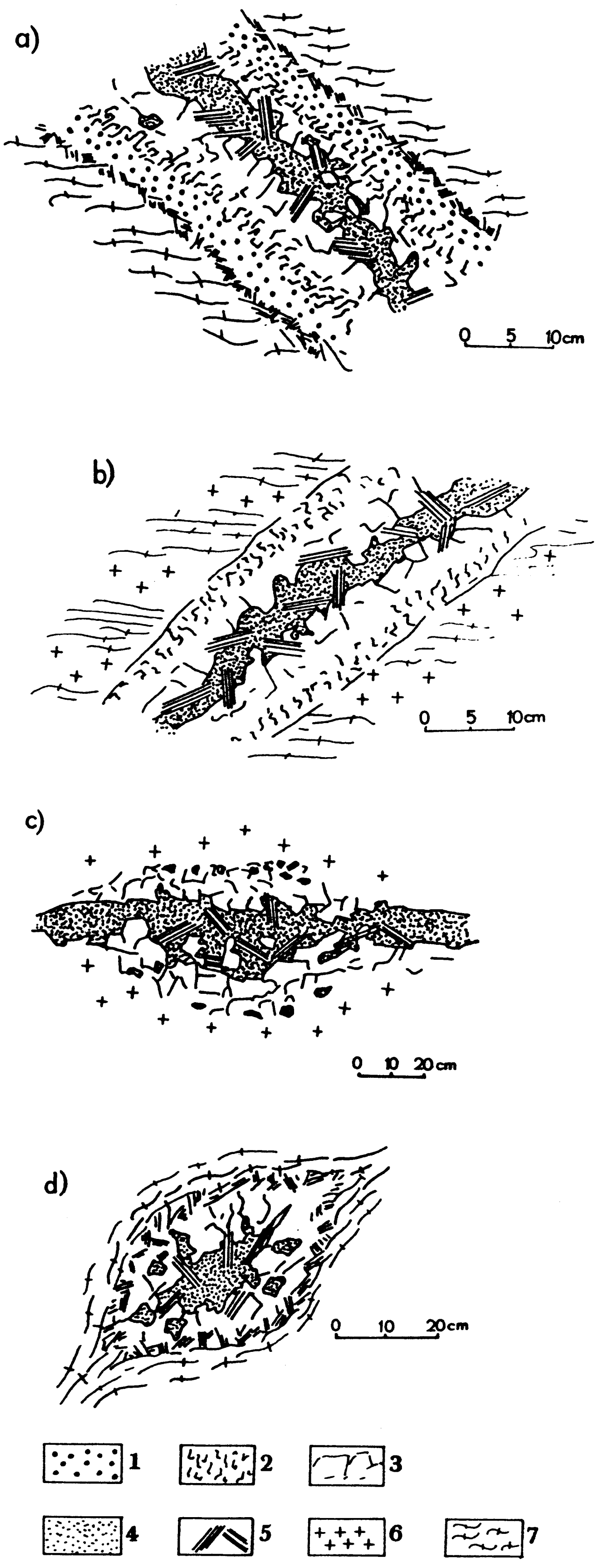

Fig. 2. Four types of the pegmatites zonal structures. 1 - aplitic zone, 2 - graphic intergrowths, 3 - blocky feldspar zone, 4 - quartz axis, 5 - muscovite, 6 - granitoid, 7 - metamorphic rocks.

This paper is an attempt to define the age of the pegmatite intrusion as well as the origin of the pegmatitic melt, taking into account the geological setting, geochemistry and a value of initial $^{87}Sr/^{86}Sr$ ratio (IR). The influence of source rocks on the IR value is also discussed here.

Analytical methods and results

Representative whole-rock samples, each weighting 1-4 kg, were collected from several locations (Fig. 1). The weight of the sample depended on the size of the pegmatite (for example, a whole-rock sample from a 6 m in size pegmatite on the NW slopes of Tomanowa Polska was 4 kg in weight, whereas the sample from a smaller, up to 0.3 m in width pegmatitic vein was about 1 kg in weight). Because of the pervasive hydrothermal alteration of the rocks here, sampling was carried out very carefully to avoid the strongly hydrothermally altered or weathered rocks.

The whole-rock samples were analysed for main-elements ("wet"-method) in the Department of Earth Sciences, University of Silesia (Sosnowiec, Poland) and for trace elements using XRF-technique in the Mining Institute (Katowice, Poland). They have a high SiO_2, Al_2O_3 and alkaline elements content and a small CaO content. Samples with the An-content below 3 % are plotted on the diagram Ab-Or-Q (Luth & Tuttle 1969). Almost all plots of normative compositions of pegmatites assemble in the central part of the Ab-Or-Q triangle, near the cotective curves for pressures: 2, 5, 7 kbar (Fig. 3a) and near the so called "thermic valley" (Luth & Tuttle 1969) (Fig. 3b).

The trace elements content is rather low both in the pegmatites and in their main minerals (feldspars and micas - Tab. 1) when compared with the rare-element granitic pegmatites from literature (Černy & Meintzer 1988). Correlation coefficients for Li, Ba, Sr, Rb and the Na/(Na + K) ratio have negative values and figure out respectively: $r_{Li} = -0.504$, $r_{Ba} = -0.603$, $r_{Sr} = -0.651$, $r_{Rb} = -0.482$.

Five samples were chosen for isotopic investigations (Fig. 1b, Tab. 2). After powdering they were prepared for isotopic analysis by dissolution in HF - HNO_3 acids, followed by separation of Rb and Sr using standard isotope dilution techniques. Isotopic measurements were carried out on VG Micromass 30 mass spectrometer under partial computer control with automatic data acquisition in University College Dublin, Ireland. Errors were quoted at 2 σ. The decay constant used is $\lambda = 1.42 \times 10^{-11} \times yr^{-1}$. Analytical uncertainties were estimated at 1.5 % for $^{87}Sr/^{86}Sr$ and 0.015 % for $^{87}Sr/^{86}Sr$. The value from the isotopic standard WBS SRM 987 for $^{87}Sr/^{86}Sr$ is 0.710289. The regression line was calculated using the least squares method of York (1969) and the MSWD reviewed by Brooks et al. (1972).

The range of Rb/Sr, as well as $^{87}Sr/^{86}Sr$ ratios is wide (Tab. 3) but the scatter of the points along the regression line is small (correlation coefficient r = 0.9993, MSWD = 5.255). The calculated age for the pegmatite suite is 345.2 ± 9.5 Ma with an initial $^{87}Sr/^{86}Sr$ ratio (IR) of 0.70625 ± 0.0002. Sample No. 5 strongly influences the value of the IR (Fig. 4).

Discussion

The plots of the analysed samples on the Ab-Or-Q diagram near the "thermic valley" suggest that at a temperature near 700 °C the pegmatitic magma was completely or partly liquid (Puziewicz 1984). Such a medium - water-saturated melt -

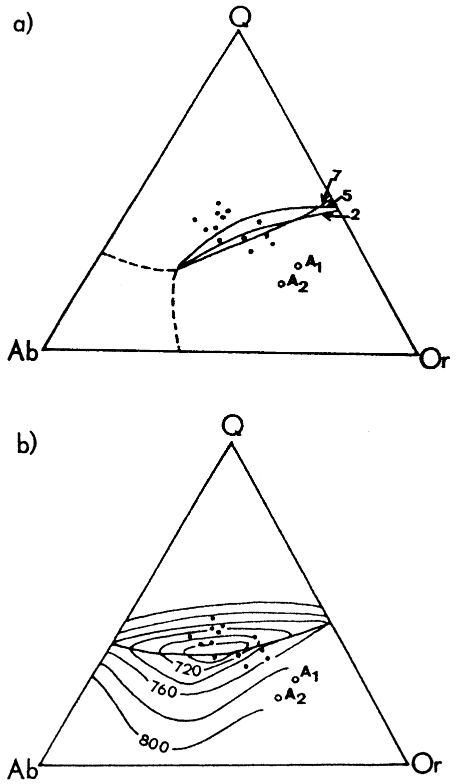

Fig. 3. Location of the samples in the Ab-Or-Q triangle in relation to cotectic curves for 2, 5, 7 kbars (**a**) and the thermic valley with P_{tot} = 2 kbar (**b**).

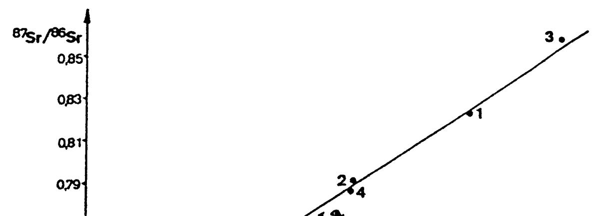

Fig. 4. A whole-rock Rb/Sr isochron for the Western Tatra pegmatites. Errors are 2 sigma and incorporated both experimental error and geological scatter. Data in Tab. 3.

favoured diffusion - driven processes (Burnham 1967). This statement is not true for aplites. Their plots lie outside the "thermic valley" (samples A_1, A_2 - Fig. 3b). Probably they contained a large amount of the solid phase which caused "hermetization" of the aplites for diffusion processes, especially for albitization. The influence of albitization of K-feldspars on the trace elements content was cosidered. The correlations for Li, Ba, Sr, Rb and degree of albitization given here as Na/(Na + K), are not very strong. Probably the scarcity of trace elements in the pegmatites under consideration and their minerals is not only a result of albitization. It is probably a feature inherited from the parent magma. Such a geochemical depletion is typical for anatectic, poorly fractionated magmas (Wickham 1987).

According to the calculation of the author the initial $^{87}Sr/^{86}Sr$ ratio is 0.70625 + 0.0002. It is similar to data known from other igneous massifs occuring in the Central Western Carpathians (f.e. Cambel et al. 1985), but not typical for crustal partial melts (Pankhurst 1979). Investigated Western Carpathians granitoids show initial $^{87}Sr/^{86}Sr$ ratios: 0.7076 for Malé Karpaty granite and 0.70627 for Malá and Velká Fatra Mts. (Cambel et al. 1985; 1989; Bagdasaryan et al. 1992). They all have isotopic characteristics resembling the I-type granites (Pitcher 1983). The only exception was the Tatra Mts. complex with the IR ratio of 0.715 (Burchart 1968). There are two possible explanations of such a low value for pegmatites from the Western Tatra Mts.: First - the pegmatitic melt is mantle type; second - that the initial $^{87}Sr/^{86}Sr$ ratio of melted rocks was very low and the IR value of pegmatites is inherited from the source rocks.

In the area under consideration there is no trace of a Hercynian suture zone or any other features of the existing ocean floor, so the first possibility seems to be unrealistic.

Considering the geochemical characteristics of the whole rock samples of the pegmatites, especially A/CNK values, they are all peraluminous in composition, as well as granites, gneisses and migmatites from the same area (Tab. 4). Probably the melted source material (metasedimentary series) must have contained a considerable portion of basic, probably mantle-derived material, e.g. layers of amphibolites.

According to preliminary geochemical data, the amphibolites of the studied area are thought to be, at least partly, the products of submarine pyroclastic volcanism in the Hercynian (or late Caledonian ?) cycle (Narebski & Wichrowski 1973; Cambel 1989). As a result of melting of the metagreywackes and metaargillaceous material alternating with the mantle-derived metavolcanic rocks (Cambel & Kamenický 1982), the hybridic magma might have been produced. A similar - mixed - origin for Malá and Velká Fatra Mts. was suggested by Bagdasaryan et al. (1992).

The initial $^{87}Sr/^{86}Sr$ ratio of pegmatites under consideration is a reflection of the geochemistry of melted material of different origin. The relatively old age of pegmatites is probably a record of the early Hercynian metamorphic events in the Western Tatra Mts. crystalline complex.

Judging from the description of the samples given in the cited paper (Burchart 1968) all the samples analysed for Rb/Sr isotopes were strongly hydrotermally altered. The previously accepted age seems to be in fact, rather the age of hydrotermal activity, than the real age of pegmatite emplacement.

Conclusions

1 - The pegmatites from the Western Tatra Mts. were at least partly liquid at a temperature of about 700 °C. Their crystallization took place in rather low temperatures, typical for pegmatitic systems.

2 - The geological position, peraluminous character, scarcity of trace elements as well as simple mineralogy (see previous studies) suggest that they were a result of partial melting of the metamorphic complex.

3 - New isotopic data do not support the previously accepted age of 280 ± 80 Ma years for pegmatites. The newly calculated Rb/Sr isochron age is 345.2 + 9.5 Ma.

4 - The low initial $^{87}Sr/^{86}Sr$ ratio (0.70625 + 0.0002) seems to be a reflection of the geochemistry of the source rocks. The pres-

Table 1: Trace-element contents in feldspars (a), micas (b) and whole-rock samples (c) of pegmatites [in ppm].

S. No.	Elem.	Li	Rb	Ba	Sr	Mn	Pb	Zn	Cr	Cu	Ni	Ti	V
2	a	114	150	320	45	50	60	67	-	-	-	-	-
	b	126	940	270	-	117	-	54	-	-	214	490	10
	c	200	155	300	25	155	55	55	-	170	225	400	-
8	a	260	85	670	95	97	-	170	-	-	-	-	-
	b	117	850	1000	-	110	10	30	120	45	127	2400	10
	c	300	100	840	160	80	65	60	-	150	310	-	-
10	a	580	330	330	30	120	70	40	-	50	-	-	-
	b	550	590	340	-	200	50	104	-	-	-	520	10
	c	370	265	390	155	150	60	50	-	140	220	100	-
17	a	600	710	1220	190	30	-	20	-	-	-	100	-
	b	120	900	230	-	240	10	10	120	35	-	450	170
	c	200	600	300	50	100	-	10	50	-	-	200	10

Table 2: Samples description and location.

Sample	Description	Locality
1	pegmatite with well developed pink blocky-feldspar zone in alaskitic granite	eastern slope of Tomanowa Polska Mt.
2	unzoned pegmatite with oligoclase orthoclase and biotite in amphibole gneiss	Smreczynski Terrace
3	graphic granite consists of microcline max. + quartz in biotite gneiss	northern slopes of Tomanowa Polska Mt.
4	weakly zoned pegmatite with a predomination of the pink K-feldspar plagioclase gneiss	ES-slope of Tomanowa Polska Mt.
5	segregation of graphic granite in biotite gneiss	S -slope of Kamienista Mt.

Table 3: Whole-rock analytical data for pegmatites from the Western Tatra Mts.

Sample No.	Sr [ppm]	Rb [ppm]	$^{87}Sr/^{86}Sr$	$^{87}Rb/^{86}Sr$
1	163.1	20.0	0.823303±2	24.066±1
2	154.7	26.8	0.791687±2	16.804±1
3	334.4	31.5	0.856716±2	31.189±1
4	438.9	77.0	0.786948±2	16.612±1
5	108.3	158.6	0.715827±2	1.9760±1

Table 4: A/CNK coefficients of the crystalline rocks from the Western Tatra Mts.

Sample	G1	G2	G3	GR1	GR2	M1	M2
A/CNK	1.77	2.06	2.99	2.13	1.767	1.501	1.856

Sample	P1	P2	P3	P4	P5	P6	P7
A/CNK	1.53	1.83	1.765	1.92	1.23	1.646	1.316

Symbols used in the Tab. 4: Gx - gneiss, GRx - granite, Mx - migmatite, Px - pegmatite.

ence of the intercalations of metavolcanic rocks (amphibolites) or their tuffs could be a key to the geochemistry of pegmatites.

5 - The pegmatites described here were a record of early Hercynian metamorphic processes, which formed the crystalline core of the Western Tatra Mts.

Acknowledgements: The isotopic analyses were done during the author's stay in University College Dublin (Ireland) sposored by the Tempus Programm (JEP-3656-1-92). Thanks are due to dr. P. S. Kennan for all his valuable help during the author's work in University College Dublin, to M. Murphy for his help during laboratory works, to dr. J. Puziewicz and prof. W. Narebski for improving the manuscript and valuable discussions, and to two anonymous referee for valuable comments and advice.

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