GEOLOGICA CARPATHICA, 49, 3, BRATISLAVA, JUNE 1998
161–167

THE BREAKDOWN OF MONAZITE IN THE WEST-CARPATHIAN VEPORIC ORTHOGNEISSES AND TATRIC GRANITES

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(Manuscript received June 26, 1997; accepted in revised form March 24, 1998)

Abstract: The complete breakdown of monazite was observed in metagranites of the Veporic Superunit while only slight alteration of monazite occurs in unmetamorphosed Tatric granitoids (Tribeč Mts., Malá Fatra and Strážovské vrchy Mts.). Monazite breakdown is probably a result of the reaction monazite+annite+anorthite+quartz+fluids giving apatite+allanite+muscovite. During monazite breakdown its margins are replaced outward by apatite corona, allanite rim and REE-rich epidote. In extreme cases monazite cores are fully consumed by apatite which occupies the place of the former monazite. The result of such breakdown is grains with apatite cores and the allanite–REE epidote rims. The monazite breakdown in the Veporic Superunit occurred under conditions of amphibolite facies during an Alpine metamorphic event, although the proccess of breakdown had probably already started during the Variscan metamorphosis. In the case of monazite from Tatric granites initial breakdown of monazite was found in the context of Variscan subsolidus granite alteration. Only restricted mobility of the REE is supposed during the breakdown of monazite.

Key words: Alpine metamorphism, REE mobility, monazite, allanite, granite, metagranite.

Introduction

Monazite and allanite are two of the most frequent primary magmatic LREE acccessory mineral phases of granitoids, however, they show an antipathetic relationship — either monazite or allanite is present in granitoids, or one of them strongly prevails in paragenesis (Lee & Dodge 1964; Lyakhovich 1968; Gromet & Silver 1983; Broska & Uher 1991; Montel 1993). Generally monazite is typical of S-type, Ca-poor or peraluminious granitoid accessory mineral paragenesis, while allanite is reported mainly from I-type granitoids (Snetsinger 1967; Parrish 1990).

Both monazite and allanite can also form during metamorphism, where they show the dichotomy known from the felsic magmas. Accessory monazite is rare in the greenschist facies, rare to scarce in amphibolite facies, and quite abundant in the granulite facies of metamorphic rocks. On the contrary, allanite or REE-rich zoisite is common at lower metamorphic grades (Overstreet 1967). However, in the Ori Dome low-grade slates (Central Pyrenees) poikiloblastic monazite was described, which nucleated on small detrital grains during anchimetamorphic conditions. In greenschist facies this monazite is replaced by allanite (Bons 1988). Metamorphic monazite, as grey Eu-rich monazite, is also known from greenschist facies (Donnot et al. 1973; Read et al. 1987), but monazite was also reported in staurolite-kyanite metamorphic grade (Mohr 1984) or staurolite-in isograde in conditions of 525 °C and 3 kb (Smith & Barreiro 1990). Franz et al. (1996) described monazite in Bavaria newly formed at ca. 450–700 °C in low pressure metapelites. The possible origin of monazite from breakdown of allanite or allanite hornblende and apatite in the augen gneisses from the Swedish-Norwegian province in Cpx-in and Opx-on isograde showed Bingen et al. (1996).

The aim of the paper is to describe the monazite being replaced by allanite which we have found in the Western Carpathian granites and metagranites. The first replacement of monazite by allanite was reported from pegmatite in North Carolina (Murata et al. 1957) and some remarks on this alteration phenomenon in the alkalic complex of the Vishnevyje gory can be found in Yeskova & Ganzyeva (1964). The origin of deuteric allanite and sphene during chloritization of biotite in the Dartmoor Granite was described by Ward et al. (1992). Secondary allanite as a product of chloritization was also reported from the Bohus Granite in SW Sweden (Eliasson & Petersson 1996). The recent work of Finger et al. (1998) brings a modern and comprehensive description of monazite breakdown in localities from the Austrian part of the Alps and from the Southern Bohemian Massif.

Total monazite breakdown in West-Carpathian metagranites from the Veporic Superunit is described in this contribution. We also report a low-degree monazite alteration during postmagmatic subsolidus activity of the fluids in non or (anchi)-metamorphic Tatric granites.

Geological setting

Migmatites with signs of a high degree of monazite breakdown belong to the Veporic basement which consists of three basic lithotectonic units (Bezák 1994). The lower unit occurs mainly in the southern part of the Veporic basement, the middle unit is thrust over the lower unit, the upper unit is present in separate tectonic remnants beyond the studied area. The lower unit consists of Lower Paleozoic metamorphites of the greenschist facies (mica schists, albitic gneisses, chlorite-muscovite schists). The middle unit comprises a broader scale of metamorphites starting from the upper part of the greenschist facies up to the upper part of the amphibolite facies. The age of the above mentioned metamorphites is uncertain, but probably Proterozoic to Early Paleozoic. The studied migmatites come from the locality Lipové village in the middle unit (loc. 4 in Fig. 1). According to Siman et al. (1996a) the P-T conditions for the earliest metamorphism of the host rocks with migmatite structure and with the tonalite composition (Fig. 2) were 680–730 °C at 400–600 MPa and around 550–600 °C for a retrograde branch. The degree of Alpine overprint is a matter of discussion, but the minimum temperature estimate is T 480–510 °C and around 7 kbars (Siman et al. l.c.).

By contrast, only low degrees of monazite breakdown were observed in the granites of the Tatric Superunit (Fig. 1). The Tatric granites which form the cores of the crystalline basement in the central Western Carpathians belong to the two main Carboniferous granite groups: S-type granites are the most widespread granite type, while I-type granites (Petrík et al. 1994), which include mainly granitoids known as the Sihla type sensu lato are less frequent (Broska & Petrík 1993). No metamorphism, or only anchimetamorphism is known in these granites, but strong subsolidus overprint of the primary mineral assemblage is their typical phenomenon. Monazite alteration was found in the Tribeč Granite (I-type), Malá Fatra Mts. and Malá Magura Granite (both S-type). Biotite granite in the Tribeč Mts. occurs in the form of veins 1–0.1 m in size which cut the undifferentiated biotite tonalite host rocks near the Kozlišov elevation point. The occurrences in the Malá Fatra Mts. come from the Bystrička quarry (leucocratic granodiorite), in the Malá Magura two mica granite showing monazite breakdown was found in the Chvojnica Valley (Fig. 1).

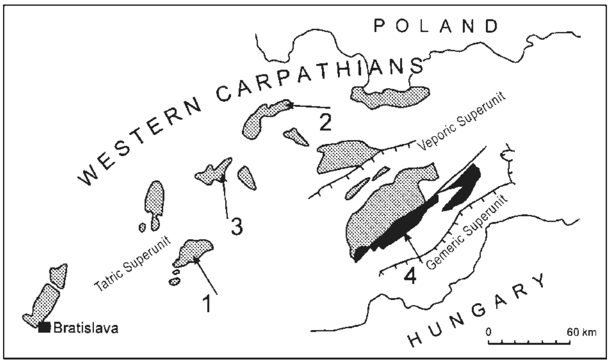

Fig. 1. Geological outlines of the crystalline basement of the Western Carpathians with the localities of the monazite breakdown observation. The light shaded area represents the granite bodies of the Tatric units. The darker shade filling represents the areal distribution of the hybrid complex in the Veporic Superunit, which is a structure of host migmatites and orthogneisses with a high degree of monazite breakdown (locality Lipové for example), arrows approx. indicate the position of the studied localities: 1 — Tribeč Mts., Velčice village, 750 m W from the elevation point Kozlišov. Outcrop on the slope. 2 — Malá Fatra Mts. Kraľovany, Bystrička quarry. 3 — Strážovské vrchy Mts., Suchý, Chvojnica Valley. 4 — Slovak Ore Mts. Kokava/Rimavica, 2 km from Kokava direction to Šoltýska, outcrop on the road near the village of Lipové.

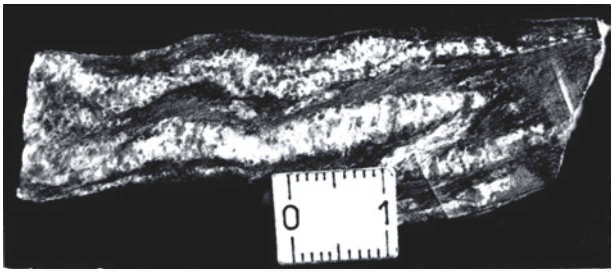

Fig. 2. Example of migmatite structure from the Lipové locality (hybrid complex, Veporic Superunit). Scale bar is 1 cm.

Petrography and mineral composition

Migmatite from the Veporic Superunit

The host migmatites with a high degree of monazite breakdown consist of well developed paleosom and neosom up to 5 mm thick (Fig. 2). They are peraluminious “metagreywacks” (lacking Al_2O_5 phases and containing quartz, plagioclase, biotite, phengite, ±K-feldspar, chlorite). Syngenetic ductile deformation associated with partial melting in the whole hybrid complex was observed. Plagioclase forms partly retrogressed to granoblastic aggregates of more or less sodic grains filled with sericite±zoisite. In the most deformed places plagioclase is replaced by albite and/or sericite felt. The maximum anorthite content is in the range of An_{20} to An_{25}. Quartz represents mylonitic crushed grains or it is recrystallized into granoblastic aggregates. K-feldspar is found as cataclastic and from place to place shows perthitic texture. White mica has a phengitic composition, biotite has Mg/(Mg+Fe) from 0.33 to 0.57, Al^{VI} varies from 0.6 to 1, TiO_2 is up to 3 wt. % (Siman et al. 1996a). Two types of garnet occur in the migmatites. The older garnet has almandine-pyrope compositions, the younger garnet forming rims around older garnets (sometimes isolated grains) with 33–40 % grossularite molecule (Siman et al. 1996a).

Granites from the Tatric Superunit

The strong sericitization of plagioclases, chloritization and epidotization of the biotites are characteristic alterations of the main mineral assemblages in these Tatric granites. The basicity of the plagioclase is mainly $An_{30\text{-}20}$, the biotite in the Tribeč locality is relatively Mg-rich, with Fe/(Fe+Mg) ranging from 0.4–0.5, on the other hand in the S-type granites from the Malá Magura and Malá Fatra Mts. there are Fe-rich biotites with Fe/(Fe+Mg) above 0.6 and more Ti-rich in comparison with the I-type in the Tribeč Mts. (Petrík & Broska 1994; Broska et al. 1997). The Malá Fatra granite almost lost its biotite due to its strong alteration to chlorite and white mica and only part of the monazite grains inside of biotite or former biotite are attacked by fluids and

Table 1: Chemical analyses of the host rocks of altered monazites. Sample BGM-1 and BMF-1 represent granodiorites, sample T-37 is biotite monzogranite. VM-4/90 represents a typical migmatite to orthogneiss of the hybrid complex of the Veporic basement.

	Magura	Tribeč	Malá Fatra	Veporic Superunit*
	BGM-1	T-37	BMF-1	VM-4/90
SiO_2	66.58	72.60	68.26	64.34
TiO_2	0.67	0.15	0.34	0.91
Al_2O_3	16.32	13.61	16.71	15.91
Fe_2O_3	0.83	1.33	2.49	2.84
FeO	2.83	0.64	n.d.	4.86
MnO	0.01	0.03	0.04	0.12
MgO	1.54	0.59	0.71	2.36
CaO	3.51	1.59	2.81	2.38
Na_2O	3.85	3.32	5.09	2.97
K_2O	2.04	4.68	1.89	3.37
P_2O_5	0.42	0.21	0.06	0.08
H_2O^+	0.9	0.14	1.30	n.d.
H_2O^-	0.44	1.16	n.d.	n.d.
Total	99.94	100.05	99.70	100.14
Rb	n.d.	n.d.	54	116
Ba	820	1020	n.d.	953
V	14	8	25	n.d.
Cu	55	<3	n.d.	n.d.
Ni	13.5	5.4	0	n.d.
Zr	207	120	154	314
Co	6.8	7.1	2	n.d.
Y	12.6	17.8	10	43
Cr	14	2.3	16	n.d.
Sr	496	229	n.d.	251

*mezosom

changed to allanite. The chemical compositions of the granites with altered monazites as well as migmatite from the Veporic Superunit are presented in Table 1.

Monazite breakdown

Monazite, a common accessory phase in the migmatite and metagranites from the Veporic Superunit is transformed into apatite and allanite-epidote in the way which was first observed and described in the Granatspitze Granite Tauern Window, Penninic Unit, Eastern Alps (Finger et al. 1998) (Fig. 3A). The size of grains is around 10 μm but in some cases monazite reaches up to 200 μm. The monazite grains are surrounded by tiny grains of apatite which always continues outwards as allanite–epidote, with irregular shapes which often penetrate into the biotite grains (Fig. 3A). Cases where only unhomogeneous apatite is surrounded by allanite-epidote rim are also present, and in this case no monazite remnants in the cores of the apatite–allanite–epidote mineral complex have been observed. Such phenomena represent the last stage of the monazite transformation when the monazite is completely replaced by newly-formed apatite and allanite minerals (Fig. 3B). The rim forming allanite consists of two principal phases — the inner part which is richer in REE elements, the outer part which has epidote composition (Fig. 3A, Table 2). The inner part of allanite-epidote phase respects the monazite morphology, the outermost epidote phase has low integrity, and often fills cracks and spaces within sheets in the biotite.

During replacement the phosphorus anion from monazite is fixed in apatite, REE's enter the allanite and epidote. The elements nourishing the growing allanite, such as silica, iron and aluminium as well as OH groups come from annite, and calcium mainly from anorthite components. It is possible to express the breakdown of monazite in the form of a hypothetical reaction where hydrogen comes from dissociated water:

monazite + annite + anorthite + quartz + fluids = apatite + allanite + muscovite (or K-feldspar)

or in chemical form:

$$3LaPO_4 + KFe_3(Si_3AlO_{10})(OH,F)_2 + 4CaAl_2Si_2O_8 + 3SiO_2 + 4Ca^{2+} + 2H^+ \rightarrow Ca_5(PO_4)_3(OH,F) + 3CaLaFe\,Al_2Si_3O_{12}(OH,F) + KAl(Si_3AlO_{10})(OH)_2$$

We suggest that the reaction was activated by the origin of phosphoric acid on the monazite rim. The apatite, which originated firstly on the monazite rim could later be the transport medium for exsolvus of the REE from the monazite outward into the allanite–epidote, is inhomogeneous and free of the REE. Probably it was in gel form and perhaps the recent mosaic or grained polycrystalic structure of apatite (Fig. 3a,b) indicate this stage. In this sense the apatite is the memory of the role of the phosphoric acid in the monazite breakdown processes.

The monazite breakdown recorded in the Alps and the Southern Bohemian Batholith is known only from the granite lithologies which were overprinted by Alpine metamorphism under amphibolite facies. On the other hand metapelite lithology brings an opposite effect, when during these metamorphic conditions new monazite is formed Finger et al. (l.c.).

The breakdown of the monazite in the Tatric granites is not so widespread, and the processes produce only small fringes of allanite without an intercalated apatite zone. However, the apatite zone is most probably also present in the monazite-allanite grains, and is not detectable in the studied samples only as a result of its small size. The process of monazite breakdown is found in the S-type, granite but also in the I-type, especially in the more evolved or differentiated varieties of the Tatric Superunit.

Discussion

Because the subsolidus fluids were able to transform monazite to allanite only in the restricted form (Ward et al. 1992; Eliasson & Petersson 1996), the high degree of monazite breakdown from Lipové (Veporic Superunit) could be a result of metamorphic processes. In the case of the primary monazite from the non-metamorphic Tatric granites, where only initial breakdown of monazite was observed, the monazite breakdown should coincide with chloritization during subsolidus pervasive alteration of these granites. On the other hand, the high degree of monazite breakdown in the Lipové migmatite suggests the overprint of monazite during

Table 2: Representative microprobe analyses of the grain 1 and 2 in the migmatite from Veporic Superunit. The points of analyses are in the BSE images (see Fig. 3). The measure conditions: 20kV, 20 nA, 3 M beam diameter, using ZAF corection and natural and synthetic standards. Jeol Superprobe 733.

Grain	1	1	1	1	1	1	1	2	2	2	2
Sample	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2	VM-2
Mineral	mnz	mnz	mnz	ap	aln	aln	REE-ep	ap	aln	aln	REE-ep
Position	1	2	3	4	5	6	7	1	2	3	4
SiO_2	0.39	0.45	0.33	1.83	32.00	31.06	40.26	0.21	32.54	36.15	36.04
P_2O_5	30.47	30.43	30.84	39.33	0.00	0.00	0.00	41.68	0.00	0.00	0.00
CaO	1.00	0.72	0.88	52.15	11.79	11.69	19.71	54.23	12.54	20.88	21.75
La_2O_3	11.38	11.15	13.32	0.00	3.99	3.53	0.00	0.00	7.21	5.41	3.93
Ce_2O_3	26.23	27.18	28.17	0.00	8.98	8.57	0.00	0.00	6.45	0.22	0.00
Pr_2O_3	3.68	3.92	3.74	0.00	1.49	1.47	0.08	0.00	0.00	0.00	0.00
Nd_2O_3	10.63	11.82	10.83	0.00	4.79	4.53	0.34	0.00	3.19	0.61	0.42
Sm_2O_3	2.92	3.57	2.87	0.00	0.88	0.98	0.11	0.00	0.35	0.15	0.14
Gd_2O_3	2.76	3.17	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yb_2O_3	0.27	0.27	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y_2O_3	4.65	3.68	3.02	0.00	0.65	0.30	0.31	0.00	0.14	0.00	0.00
ThO_2	3.97	3.56	3.57	0.00	0.22	0.83	0.00	0.00	1.92	0.00	0.00
UO_2	1.30	0.19	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al_2O_3	0.00	0.00	0.00	1.04	16.33	18.01	21.78	0.02	22.42	27.24	26.95
FeO	0.00	0.00	0.00	0.66	12.57	11.64	6.51	0.00	10.00	6.49	7.13
MnO	0.00	0.00	0.00	0.00	0.16	0.18	0.09	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00	0.23	0.30	0.51	0.00	0.37	0.07	0.06
TiO_2	0.00	0.00	0.00	0.00	0.24	0.26	0.06	0.00	0.20	0.15	0.15
PbO	0.77	0.13	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.42	100.24	100.56	95.01	94.32	93.35	89.76	96.14	97.33	97.37	96.57
Si	0.015	0.017	0.013	0.321	3.114	3.028	3.423	0.036	2.952	2.971	2.968
P	0.992	0.992	0.999	5.843	0.000	0.000	0.000	6.125	0.000	0.000	0.000
Ca	0.041	0.030	0.036	9.804	1.229	1.221	1.795	10.086	1.219	1.838	1.919
La	0.161	0.158	0.188	0.000	0.143	0.127	0.000	0.000	0.241	0.164	0.119
Ce	0.369	0.383	0.395	0.000	0.320	0.306	0.000	0.000	0.214	0.007	0.000
Pr	0.052	0.055	0.052	0.000	0.053	0.052	0.002	0.000	0.000	0.000	0.000
Nd	0.146	0.163	0.148	0.000	0.166	0.158	0.010	0.000	0.103	0.018	0.012
Sm	0.039	0.047	0.038	0.000	0.030	0.033	0.003	0.000	0.011	0.004	0.004
Gd	0.035	0.040	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yb	0.003	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y	0.095	0.075	0.062	0.000	0.034	0.016	0.014	0.000	0.007	0.000	0.000
Th	0.035	0.031	0.031	0.000	0.005	0.018	0.000	0.000	0.040	0.000	0.000
U	0.011	0.002	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.000	0.000	0.000	0.215	1.873	2.069	2.182	0.004	2.397	2.638	2.616
Fe	0.000	0.000	0.000	0.097	1.023	0.949	0.463	0.000	0.759	0.446	0.491
Mn	0.000	0.000	0.000	0.000	0.013	0.015	0.006	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.033	0.044	0.065	0.000	0.050	0.009	0.007
Ti	0.000	0.000	0.000	0.000	0.018	0.019	0.004	0.000	0.014	0.009	0.009
Pb	0.008	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

metamorphosis, and it should be similar to the process known from the Alpine terrain in the Tauern Window (Granatspitz granite gneiss), Austro-Alpine Unit (Raabalpen Massif, Winnebach migmatite gneiss, Sulztal granite gneiss, Zinken granite gneiss) and the Moravian Unit in the Eastern Bohemian Massif (Witersfeld gneiss, Bitesch gneiss) (Finger et al. 1998). The observed breakdown of monazite in all the mentioned cases occurred in the amphibolite facies (500–600 °C and 4–7 kbar) (Finger et al. 1998 and references therein).

The monazite zoning (Fig. 3A, Table 2), indicating its magmatic origin (Lipové locality) in the formerly felsic magmatite of Devonian age, is also preserved during monazite breakdown in the monazite cores. Felsic magmatites from the early Variscan stage (Devonian age) are known, apart from the Veporic hybrid complex, also in the Western and Low Tatras, Veľká Fatra (Petrík & Kohút in press). After the emplacement of the Devonian felsic magma, intrusions of the layered magmas into shear zones are known from this area, as a process accompaning the main Variscan metamorphic event, which reaches amphibolite facies in this area and with the formation of orthogneisses and migmatites. The breakdown of monazite in the Lipové metagranites, in this sense, started as a result of this prograde metamorphism of the amphibolite stage and deformation during thrusting together with the Hercynian thickening and the following relaxation (Siman et al. 1996a,b), which is dated by the main Variscan granite intrusions of the S-type granites (Cambel et al. 1990) ca. 350–330 Ma.

The P-T conditions during the Alpine metamorphism which contributed to the breakdown of the monazite in the Veporic Superunit, especially in its southern part, are being widely discussed at present. In this region the Alpine metamorphic assemblages as well as the mineral zoning indicate

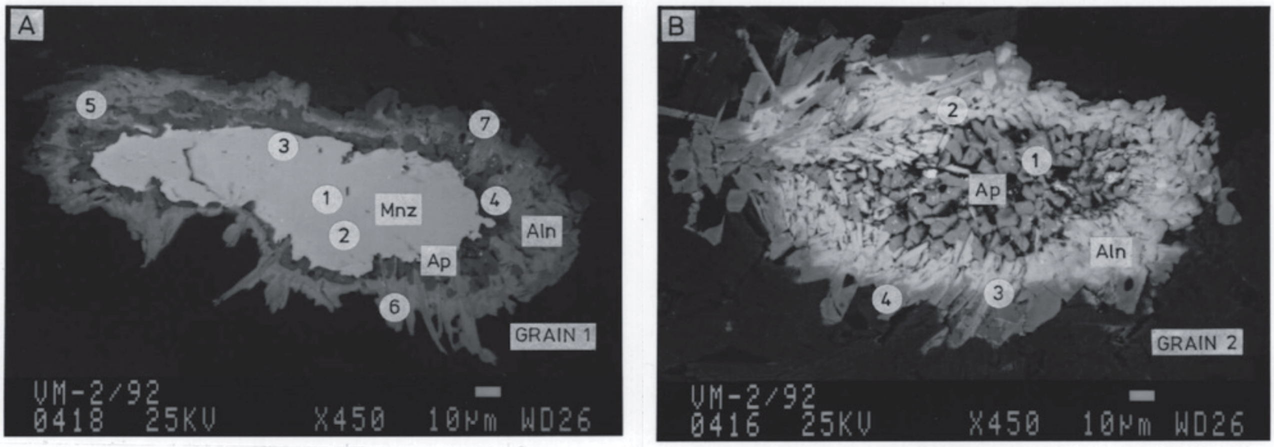

Fig. 3. The BSE images of the analyzed grains from the magmatite (Hybrid complex, locality Liešnica). The number of analyses are the curent position of the analyses from Table 2. **A**—Grain 1 consists of a monazite core (Mnz), apatite transition zone (Ap) and rim of allanite-REE epidote (Aln). **B**—Grain 2 has an apatite core and allanite-REE epidote rim. The analyses of grains A and B are given in Table 1.

a progressive trend of metamorphism (Méres & Hovorka 1991; Kováčik et al. 1996). According to Kováčik et al. (1996), the Alpine regional metamorphism occurred at temperatures estimated between 350 and 500 °C and under low to medium pressure conditions (300 MPa) i.e. in greenschist metamorphic conditions. According to these authors, the Alpine regional metamorphism is characterized by infiltration metamorphism and relatively high fluid pressure, which could have contributed to the reduction of lithostatic pressure. The model implying convective fluid flows, operating due to higher heat flow as well as differences in permeability of the rocks, seems to fit the geodynamic interpretation of the Alpine metamorphism of the southern Veporic Superunit (Kováčik et al. 1996). On the other hand the latest geothermobarometric calculations give higher P-T conditions during peaks of metamorphism: 550–600 °C and 800–1000 MPa (Janák et al. 1997; Plašienka et al. 1997), which represents the amphibolite facies (epidote–amphibolite subfacies). According to Plašienka et al. (1997), the Alpine metamorphism in the southern Veporic Superunit was caused by burial of the Veporic basement as well as its Permomesozoic cover during the Cretaceous collisional events. The possibility of the temperature exceeding 500 °C in some parts of the southern Veporic Superunit is also indicated by Kráľ et al. (1996). The Alpine metamorphism in this sense triggered the intensive breakdown of the monazite (Fig. 3) as in the case of the Alpine terraine because the amphibolite facies was reached, which seems to be a neccessary condition for extensive development of this process (Finger et al. 1998). Although the high degree of monazite breakdown reflects both the Late-Variscan and Alpine metamorphic events in a hybrid complex (the Lipové locality), the contribution of Alpine metamorphism was more significant which is the reason for monazite instability with areal distribution in the southern Veporic Superunit. The monazite breakdown is observable not only in the hybrid complex (Fig. 1) but this phenomenon is also known in the adjacent area. Recently Hraško et al. (1997) described apatite with allanite rim in Klenovec granites and also in the Rimavica Granite (oral communication).

The age of the Alpine metamorphism which caused the monazite breakdown was determined as around 110 Ma by the ^{40}Ar/^{39}Ar method on amphiboles. Then, after the metamorphic peak conditions, the Veporic Superunit was uplifted and younger Ar/Ar ages of around 88 Ma are connected with the emplacement of higher superficial nappes (Kováčik et al. 1996).

REE mobility: The monazite breakdown indicates a mobility of the rare earth elements, but it seems that it was in restricted form and the mobilization of REE's was on a local scale only. It could be stated that the monazite grains preserved features of their primary magmatic zonality with increasing LREE (La, Ce) towards the rim of the grains and decreasing yttrium (Table 2), while the REE whole rock patterns of the studied samples in the Tatric granites show no significant anomalies (Broska et al. 1997). The diffusion of the REE was continual which is evident from the REE pattern of the monazite and its breakdown products, newly formed allanite (Fig. 4). The rapid decrease of REE in allanite to REE-epidote in the small distance to the outermost rim of brokendown monazite also suggests that only limited mobility of REE occurred.

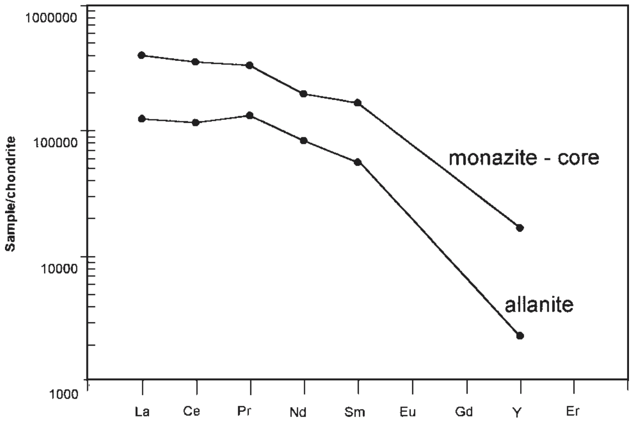

Fig. 4. REE pattern of the monazite core and the newly-formed allanite in the metagranite of the Veporic Superunit.

Conclusion

The replacement of primary magmatic monazite by metamorphic allanite and apatite was observed in the Lipové migmatite and other metagranites from the Veporic Superunit (Western Carpathians). The Alpine metamorphic event caused the widespread breakdown of primary monazite in the Veporic Superunit, although we presume that the monazite transformation started already during the late-Variscan orogenesis. The replacement is accompanied by formation of a transition zone between these mineral phases which consist of apatite. Apatite was formed from phosphoric acid and it acted as a transport medium for the rare earth elements outward from monazite. Sometimes total breakdown of monazite occurred. In this case monazite completely disappeared and only apatite remains in the core of grains overgrown by allanite and REE epidote. The monazite reaction with biotite and anorthite which produced the allanite may have been triggered by fluids with higher activity of phosphorus. The P-T conditions of this replacement were estimated for amphibolite facies.

A much lower degree of monazite breakdown was observed in the Tatric granites. In this case we concluded that the monazite alteration coincided with pervasive alteration of granites in the subsolidus stage.

Acknowledgement: This research was supported by Project No. 150 of Lise-Meitner stipendium (Austria) and (Ga 4078 VEGA Slovak Acad. Sci.). The authors are thankful for critical comments and discussion with Prof. Dr. F. Finger from Salzburg University, and also wish to thank Dr. Igor Petrík from the Geological Institute of the Slovak Academy of Sciances who helped improve the final version of the paper.

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