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GRANITIC PEBBLES IN UPPER CRETACEOUS RED CONGLOMERATES OF THE HAŢEG BASIN (SOUTHERN CARPATHIANS, ROMANIA): GEOCHEMISTRY AND PROVENANCE AS CLUES IN A TECTONIC CONTROVERSY

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Abstract: The Southern Carpathians (Romania) represent a segment of the Alpine belt of Europe where Cretaceous collision generating nappe stacking was followed by normal faulting leading to core complex formation and exhumation of the lower (Danubian) nappe system, in a process of orogen-parallel extension. There is a controversy on the timing of the normal faulting: latest Cretaceous versus Eocene. One of the reasons for the Cretaceous option rests on the consideration of the basement of the Danubian nappes from the Retezat Mountains as the source area for granite and gneiss pebbles in Upper Maastrichtian-Paleogene(?) red conglomerates of the Haţeg Basin. Zircon fission-track ages around 80 Ma of granitic pebbles from these red conglomerates have been previously used to date the start of the exhumation and erosion of Danubian nappes since the Late Cretaceous, assuming their provenance from the southerly located Retezat pluton. But the major and trace element composition of a granite pebble, from the same outcrop at Clopotiva, shows K, Na, Rb and Th excess and Ca, Fe and Sr deficit, precluding its origin from this major Danubian granitoid pluton. This leaves room for an Eocene to Early Oligocene start for the exhumation of the Danubian nappes.

Key words: Southern Carpathians, Haţeg Basin, Maastrichtian conglomerates, Danubian granitoids, basement exhumation, pebbles.

Introduction

Recent progress in knowledge of the geology of the Southern Carpathians mostly results from the application of modern techniques, approaches, models and paradigms developed in the last decades for the study of the Caledonian, Variscan and Alpine belts. One of the most spectacular results was the change from an old tectonic model, several times refined but essentially the same for almost 100 years (summarized in Berza 1997) and based exclusively on nappe structure, to a much more complex model, in which strike-slip and normal faulting play important roles.

Murgoci (1905a,b,c) introduced the concept of the Getic Nappe and his map of the Southern Carpathians, particularly the nappe limits (Murgoci 1912), is still valid. A post-nappe, high-angle normal faulting has been later suggested for some segments of the Getic Nappe border and dextral strike-slip faulting with a 35 km offset of Getic Nappe outliers was identified for the Cerna-Jiu fault system by Berza & Drăgănescu (1988). Pavelescu & Nitu (1977, 1984) have proposed post-nappe Tertiary dextral orogen-parallel flow of the South Carpathians' nappe-pile, between the Moesian Platform to the South and the Pannonian-Transylvanian block to the North. They introduced to Romania the concept of tectonic flow and used it for the lower part of the nappe-pile (Danubian units), recognizing for the upper part (Getic-Supragetic units) the role of strike-slip faults. Documenting a 90° clock-wise Tertiary rotation of the western part of the Southern Carpathians around a pole situated in the western end of the Moesian Platform, these two papers predate later paleomagnetic or tectonic reconstructions.

Looking for the consequences of the eastward escape by lateral extrusion of the Austrian Eastern Alps, Ratschbacher et al. (1993) first applied the techniques and models of modern structural analysis to the Southern Carpathians. Later papers by Dallmeyer et al. (1996, 1998), Linzer (1996), Neubauer et al. (1997), Schmid et al. (1997, 1998), Bojar et al. (1998), Linzer et al. (1998), Sanders (1998), Maţenco & Schmid (1999), Füegenschuh et al. (1999), Willingshofer et al. (1999a,b, 2001), Willingshofer (2000), Füegenschuh & Schmid (2001), Moser (2001) have developed this structural data basis, adding results of $^{40}Ar/^{39}Ar$ and fission-track (FT) dating and of basin analysis of intra-montane troughs in the Southern Carpathians. Paleomagnetic studies (review in Panaiotu 1998) documented the above mentioned 90° clock-wise rotation and showed an attenuation of this rotation south of the Danube (Panaiotu et al. 2002). Simultaneously, petrological studies have offered a better knowledge of the geochemistry of magmatic and metamorphic rocks from the pre-Alpine basements (e.g. Duchesne et al. 1998; Berza & Tatu 2002) and of the Upper Cretaceous intrusions and volcanics (e.g. Dupont et al. 2002). In this paper we intend to use such geochemical advances to solve a tectonic controversy.

In the reconstruction of the geological evolution of the Southern Carpathians, the study of the Cretaceous and Tertiary deposits, now incorporated in various sedimentary successions, was repeatedly used for dating the two major Alpine tectonic events recorded in this mountain belt: the middle Cretaceous or "Austrian" tectogenesis around 110–100 Ma and the Late Cretaceous or "Laramian" tectogenesis around 75–65 Ma (Iancu 1985; Balintoni et al. 1989; Iancu et al. 1990; Berza et al. 1994b). In 1996 an Austrian group of geologists (Willingshofer et al. 2001) sampled granite pebbles from the red conglomerates at Clopotiva, on the southern border of Haţeg Basin. Samples HA 26 and HA 28 revealed zircon FT ages of 82 ± 10 and 52 ± 4 Ma, typical of Getic samples and bracketing the exhumation of the Getic basement. However, these granites were ascribed by Willingshofer et al. (2001) to the Danubian basement, as well as detritic minerals and pebbles from the Maastrichtian Sînpetru Formation from the centre of the Haţeg Basin, presumed to underlie the red conglomerates. This assumption has led Willingshofer et al. (2001) to propose a geological model relating basin formation to basement tectonics, presented in their Fig. 7 as two cartoons. The first depicts the supposed situation for the Aptian–Santonian/Campanian Stage (112–83 Ma), with the Supragetic/Getic, Getic/Danubian and Danubian/Moesian Platform overthrustings ongoing in a WNW–ESE convergence régime and sedimentation excusively with Getic material occurring in the Haţeg piggy-back basin on the Getic Nappe (their Fig. 7a). This model contradicts the known pre-Albian age (> 110 Ma) of the Supragetic/Getic thrusts and the proved post-Campanian (< 70 Ma) age of the Getic/Danubian and Danubian/Moesian Platform overthrusts (Iancu 1985; Iancu et al. 1990; Berza et al. 1994b; Berza & Iancu 1994; Berza 1997). The second cartoon (their Fig. 7b), imagined for the Campanian?–Late Maastrichtian/Paleogene Stage (83–55 Ma), presents the Danubian basement exposed in the Ţarcu-Retezat Dome through tectonic denudation caused by the Getic detachement (sensu Schmid et al. 1998), nourishing with sediments the Haţeg Basin resting on the Getic Unit (nappe). This cartoon is the last expression of previous attempts to demonstrate, using fission-track measurements on apatite and/or zircon crystals (Neubauer et al. 1997; Willingshofer et al. 1999a,b; Willingshofer 2000), that the exhumation by a combination of detachment faulting and erosion of the Danubian nappes started in the western Southern Carpathians as early as the Late Cretaceous.

On the other hand, similar structural and fission-track studies by Bojar et al. (1998), Sanders (1998), Schmid et al. (1998), Maţenco & Schmid (1999), Füegenschuh et al. (1999), Füegenschuh & Schmid (2001) have advocated an Eocene-Early Oligocene exhumation of the Danubian nappes. Moreover, in a study of FT ages of detrital apatite grains from the Petroşani Basin, Moser (2001) found in Upper Paleogene to Lower Miocene sediments (30–16 Ma) only crystals coming from the Getic Nappe, the first Danubian crystals occurring in the Middle Miocene sediments (15–11 Ma) from the eastern part of the basin. Previous Romanian studies have documented exhumation by erosion of the Danubian formations only as late as the Oligocene to Miocene, with the exception of papers by Grigorescu (1983), Anastasiu & Csobuka (1989) and Grigorescu et al. (1990), who advocated the presence of Danubian granitoid and metamorphic pebbles in the latest Cretaceous deposits of the Haţeg Basin. Granites, gneisses, amphibolites and chlorite schists (or mylonites) are, however, common in the basements of both Getic and Danubian Units, and discriminating them needs petrological studies, far from the paleontological or sedimentological approach of the quoted authors. Marin Seclăman, author of a PhD thesis on the petrology of the Getic basement in the Strei Valley, considers the pebbles from the Cretaceous conglomerates in the Haţeg Basin to represent only Getic basement-derived rocks (personal communication, 2001).

I present here a comparison of the mineralogy and chemistry of a granitic pebble, similar and from the same outcrop at Clopotiva as samples HA 26 and HA 28, supposed by Willingshofer et al. (2001) to come from the southerly located Retezat pluton of the Danubian basement, with the mineralogy and chemistry of Retezat granitoids. This petrological approach is necessary before the use of pebble provenance for or against the timing of the start of Danubian exhumation as early as 70–60 Ma ago, or the period of sedimentation of the Upper Maastrichtian–Paleogene(?) red conglomerates of the Haţeg Basin.

Red conglomerates on the southern border of the Haţeg Basin

Haţeg Basin is a complex term, in the geographical sense involving the present low (500 m) area around the town of Haţeg, 40 × 20 km in size, surrounded by mountains reaching more than 2000 m, where thick Quaternary deposits cover Neogene, Paleogene and Cretaceous detrital formations, lying on Jurassic limestones of the Getic Nappe cover, or directly on various crystalline schists of the Getic Nappe basement. In the Romanian geological literature, the Cretaceous detrital formations (review in Willingshofer et al. 2001) are also ascribed to the Getic Nappe cover, only the Paleogene and Neogene formations being labelled as post-nappe covers. While general agreement exists on the Getic origin of the material for the Albian to Campanian detrital formations, some papers by Grigorescu and Anastasiu claim a Danubian origin for sediments in the Maastrichtian formations. The latter are paleontologically dated (review in Grigorescu 1983) and contain, beside conglomerates and sandstones, also rhyolitic volcaniclastic material — an important source of apatite and zircon crystals with Late Cretaceous FT age. Zircon FT data of Willingshofer et al. (2001) of a volcaniclastic rock is 80 ± 9 Ma according to their Table 1 and Figs. 4, 5 and 6, but in the text (p. 388) they interpret the youngest and best defined age component (61 ± 4 Ma) as dating the volcanic event. This is a much too young age in relation to the U-Pb (Nicolescu et al. 1999; von Quadt et al. 2003) and Re-Os (Ciobanu et al. 2002) dating of the Late Cretaceous magmatism in the Romanian and Serbian Southern Carpathians at 75–85 Ma and the 80 Ma age from their Table1 corresponds better to the isotopic dating, but is too old in relation to the Maastrichtian time shown by the paleontological data.

Red conglomerates crop out on the south border of the Haţeg morphological basin West of the Sebişel Valley, bordered southwards by a normal fault against the Danubian (West of Râu de Mori) or Getic (East of Râu de Mori) crystalline basement and covered northwards by Quaternary deposits (Fig. 1). Lacking paleontological records and stratigraphic

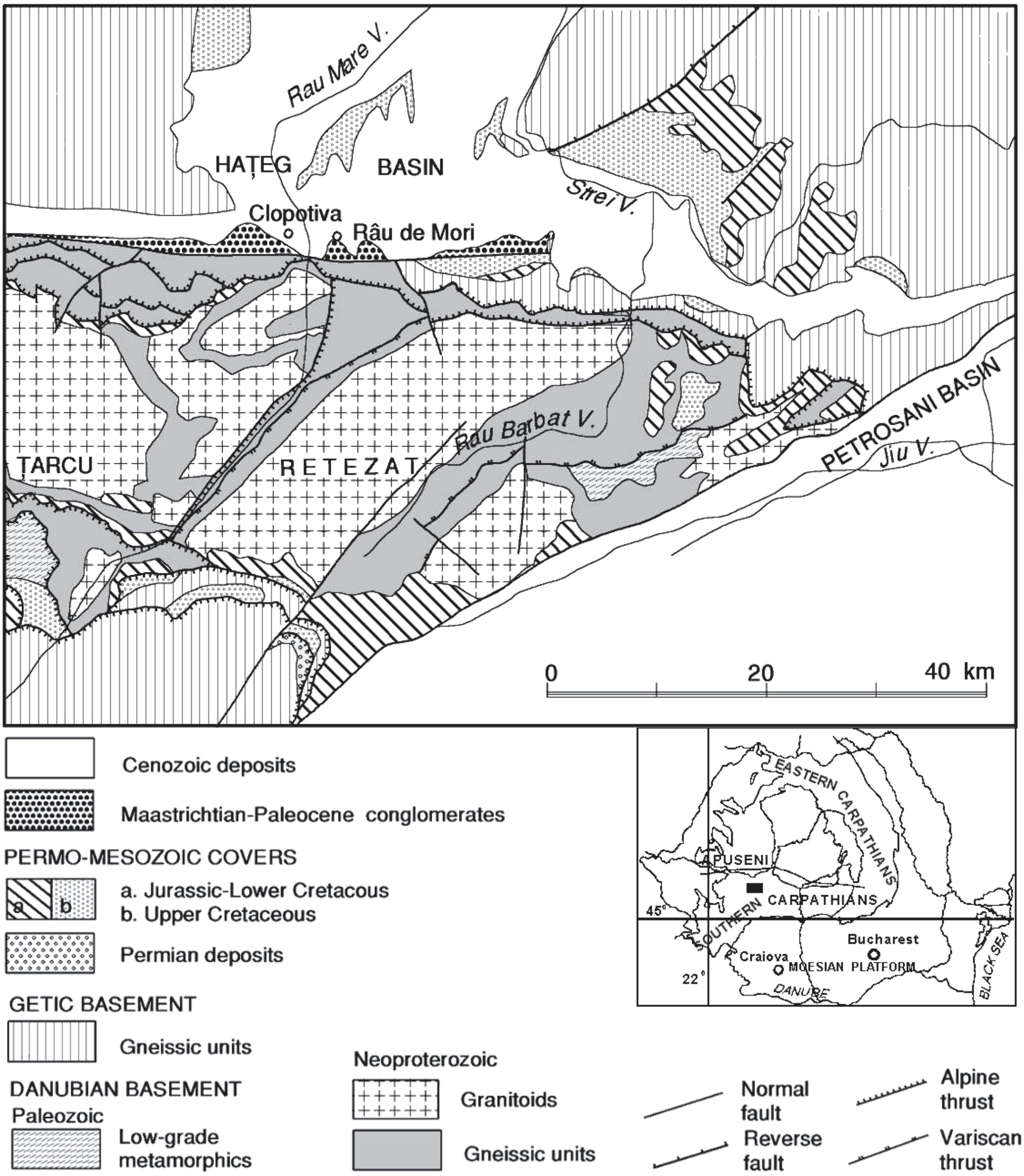

Fig. 1. A geologic sketch of the Haţeg Basin and surrounding mountains (Southern Carpathians), redrawn after Berza, Iancu, Seghedi & Drăgănescu, in Berza & Iancu (1994).

borders with older sedimentary deposits, these red deposits have been considered to top the Maastrichtian deposits, and were ascribed by various authors to the Danian (65–61 Ma), to the Paleogene (65–34 Ma), or to a Maastrichtian–Paleocene(?) (71–55 Ma) composite age. They represent a mainly coarse-grained (boulders up to 0.5 m) sequence, but sandstone and clay strata are locally found, all with the typical red colour. The conglomerates offer red outcrops, due to a red to violet varnish of the boulders, indicating oxidative conditions. The pebbles represent granites (50–60 %) and various metamorphic rocks (amphibolites, biotite gneisses, migmatites, mylonites). The high proportion of granites do not match well with the Getic basement, even if these are frequent in the Strei Basin, but suggests a Danubian origin, since south of the Haţeg Basin several granitoid plutons outcrop at present time in the basement of the Danubian nappes. The most important one is the Retezat pluton (Berza et al. 1994a), now visible on ~200 km^2 in the Retezat Mountains, but also as countless boulders and pebbles in the Quaternary deposits of the Haţeg Basin lowlands.

Geochemical and petrographical characterization

A comparison of the petrography and geochemistry of a granite pebble (R-437) from the Clopotiva red conglomerates with Retezat granitoids gives the following results. The granite pebble, medium grained (2–5 mm), is composed of microcline, quartz and plagioclase, with some biotite and muscovite. The accessory minerals are apatite, zircon and ores. No primary epidote is present, a marked difference with the Retezat granitoids (Berza et al. 1994a). The structure is mylonitic with a weak foliation expressed by the orientation of fine-grained layers of recrystallized material. K-feldspar phenoclasts with patchy extinction and fracturing are embedded in a matrix, made up of fine-grained quartz, coarser saussuritized plagioclase clasts, and micas. Quartz may locally develop larger elongated crystals. Biotite, completely oxidized (by Cretaceous weathering?), and muscovite (fresh) occur as large, deformed, bent or sheared grains, as well as in the matrix, where muscovite obviously recrystallized in the foliation. All these characters point to a deformation at a higher temperature (chlorite is unstable) than for the Retezat granitoids (chlorite is stable).

The chemical composition of the sample R-437 is presented in Table 1, major elements and trace elements being measured by a combination of XRF and ICP-MS methods (Bologne & Duchesne 1991; Vander Auwera et al. 1998) at the Geological, Petrological and Geochemical Associated Laboratories of the University of Liège (Belgium).

Berza et al. (1994a) have presented major element data for 157 Retezat granitoids ranging from diorites to granites, sampled along a 1 km grid and analysed by the wet chemical method; their minimum, maximum and average values for the 12 analysed granites are presented in Table 2. At similar SiO_2 and Al_2O_3 contents, sample R-437 is strikingly poorer in CaO and Na_2O and richer in K_2O and $FeO+Fe_2O_3$.

Berza & Tatu (2002) have presented geochemical data for Retezat granitoids obtained in the same laboratory and with the same methods as for sample R-437. The lower content of CaO (Fig. 2a) is confirmed, just as the higher K_2O content (Fig. 2b); accordingly, the Sr content is lower (Fig. 2c) and the Rb content higher (Fig. 2d).

In the Pearce et al. (1984) discrimination diagram (Fig. 3), sample R-437 plots in the field of syncollisional granites, while the Retezat granitoids plot in the field of arc granites.

Chondrite-normalized REE pattern for R-437 plots in the area of the Retezat granitoids (Fig. 4, upper diagram), but the MORB-normalized (Pearce 1983) spidergram pattern shows for R-437 positive differences for K and Th and negative ones for Sr compared with the Retezat granitoids (Fig. 4, lower diagram).

The geochemical comparison made on a granite pebble from the red conglomerate at Clopotiva does not confirm its origin from the Retezat Massif. Evidently, there are also many other granites in the Danubian basement, but the Retezat pluton, mentioned by the geologists claiming a Danubian origin for the granite pebbles in the Upper Maastrichtian–Paleogene(?) red conglomerates of Haţeg Basin, is not sustained as source area.

Conclusions

The Late Cretaceous was undoubtedly a crucial time in the evolution of the realms now incorporated in the nappe pile exposed in the Southern Carpathians. Following mid-Cretaceous nappe stacking (Balintoni et al. 1989), detrital covers which accumulated on the Getic-Supragetic upper plate are now preserved in several basins: Brezoi, Iscroni, Haţeg, Rusca Montană, Deva, Şopot. Some of these basins contain calc-alkaline volcanics and intrusions described in the local geological literature as Banatites, recently reviewed in a general Carpathian-Balkan context by Berza et al. (1998). In the other realm, now the lower plate, Cenomanian-Turonian pre-flysch and Late Turonian–Early Maastrichtian flysch sequences (Stănoiu 1997) were deposited and some are preserved in various Danubian nappes (Berza et al. 1994b), testifying to an ac-

Table 1: Chemical composition of sample R-437.

R-437												
	SiO_2	**TiO_2**	**Al_2O_3**	**Fe_2O_3t**	**MnO**	**MgO**	**CaO**	**K_2O**	**Na_2O**	**P_2O_5**	**LOI**	**Total**
%	71.23	0.24	15.79	1.51	0.01	0.49	0.44	4.79	3.66	0.14	1.37	99.66
	U	**Th**	**Th/U**	**Zr**	**Hf**	**Nb**	**Ta**	**Rb**	**Cs**	**Sr**	**Ba**	
ppm	1.3	11.8	9.07	110.4	2.91	10.4	1.92	249.4	11.51	135.2	575.3	
	V	**Cr**	**Zn**	**Co**	**Cu**	**Ga**	**Pb**	**Ni**				
ppm	21.0	13.9	23.8	1.6	15.1	24.4	29.9	17.3				
	La	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	
ppm	16.25	30.66	3.39	12.96	2.68	0.58	1.97	0.29	1.63	0.32	0.86	
	Tm	**Yb**	**Lu**									
ppm	0.13	0.86	0.13									

Table 2: Chemical data (average and limits) for 12 Retezat granites (from Berza et al. 1994a).

	SiO_2	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**K_2O**	**Na_2O**	**P_2O_5**
minimum	70.20	0.01	12.04	0.24	0.16	0.02	0.09	0.71	2.98	3.12	0.03
Average (n=12)	**72.99**	**0.27**	**15.18**	**0.69**	**0.39**	**0.05**	**0.53**	**1.77**	**3.59**	**4.24**	**0.05**
maximum	76.70	0.61	17.70	1.36	0.71	0.16	0.32	2.63	5.22	4.84	0.09

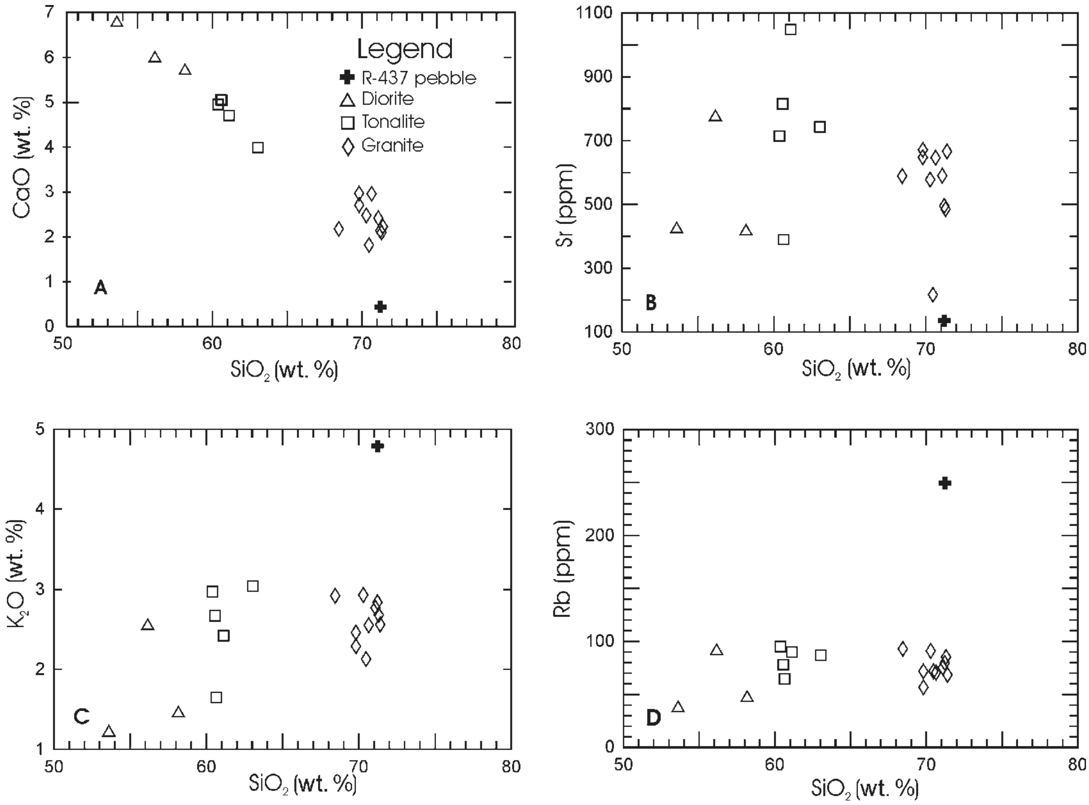

Fig. 2. Comparison of sample R-437 (cross) and Retezat granites (triangles, squares and rhombs). **a** — CaO versus SiO_2 diagram; **b** — Sr versus SiO_2 diagram; **c** — K_2O versus SiO_2 diagram; **d** — Rb versus SiO_2 diagram.

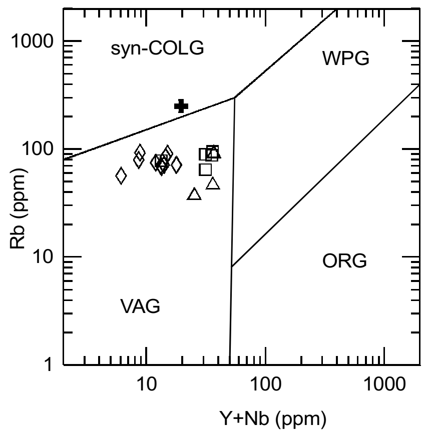

Fig. 3. Rb versus Y+Nb diagram for R-437 (cross) and Retezat granitoids (triangles, squares and rhombs).

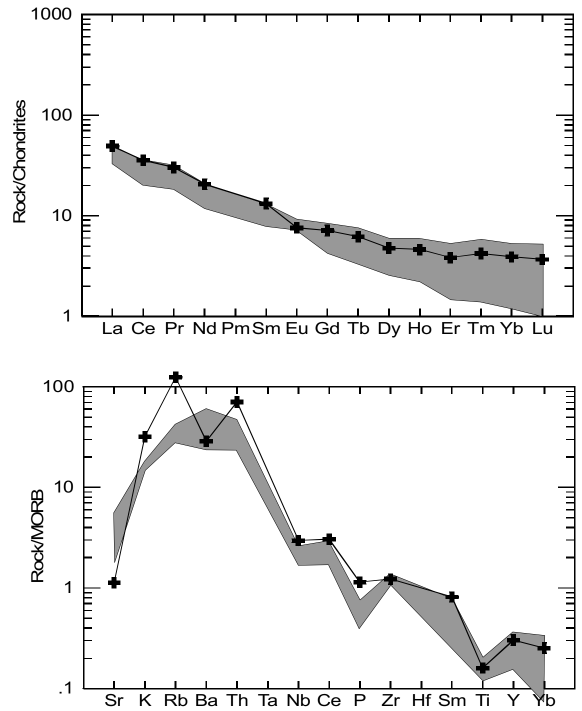

Fig. 4. Upper diagram: Chondrite-normalized REE patterns for R-437 (cross) and Retezat granitoids (grey area). Lower diagram: MORB-normalized (Pearce 1983) trace-element patterns for R-437 (cross) and Retezat granitoids (grey area).

tive margin régime outwards. The model of Willingshofer et al. (2001) involves Danubian accretion to the Getic plate from the Aptian–Santonian/Campanian Stage (their Fig. 7a) and coeval sedimentation only innerwards on the Getic Unit and outwards on the Moesian Platform. It ignores the Danubian Late Cretaceous flysch present at the top of various Upper and Lower Danubian nappes, being in conflict with basic facts relevant for the geology of the Southern Carpathians. As for the second stage, Campanian?–Late Maastrichtian/Paleogene (their Fig. 7b), when Danubian units are supposed to nourish the Haţeg Basin on the Getic Unit, there is no direct evidence for this situation, since the supposed Retezat granite pebbles in the red conglomerates at Clopotiva are not related with the Danubian Retezat Massif from the Ţarcu-Retezat Dome and seemingly represent Getic granitoids. This leaves room for the model of Schmid et al. (1998) of an Eocene to Early Oligocene age of the normal faulting leading to core complex formation and exhumation of the Danubian, in a process of orogen-parallel extension.

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