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ON THE ANATECTIC ORIGIN OF RHYODACITE VEINS FROM THE NORTHERN SEBEŞ-CIBIN MASSIF

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Abstract. Along the Rășinari shear zone (RSZ) on the northern edge of the Sebeș-Cibin Massif, several granodiorite bodies of uncertain age (Permian or post-Laramic) outcrop, accompanied by a swarm of rhyodacite veins of Cretaceous age (Albian), with a chemical composition poor in potassium. The spatial relationship of the vein swarm with the RSZ alignment is also the expression of a genetic relationship. Tectonic heating on the shear zone, associated with the presence of excess fluids and their high pressure, led to the partial melting of a granodioritic batholith whose apophyses outcrop at the current erosion level, along the RSZ.

Keywords: Sebeș-Cibin Massif, rhyodacites, anatectic origin.

Rezumat. Despre originea anatectică a filoanelor de riodacite din nordul masivului Sebeș-Cibin. De-a lungul zonei de forfecare Rășinari (ZFR), la marginea nordică a Masivului Sebeș-Cibin, aflorează mai multe corpuri granodioritice de vârstă incertă (Permian sau post-Laramic), însoțite de un roi de filoane de riodacite de vârstă cretacică (albian), cu o compoziție chimică săracă în potasiu. Relația spațială a roiului de filoane cu aliniamentul ZFR este, de asemenea, expresia unei relații genetice. Încălzirea tectonică pe zona de forfecare, asociată cu prezența excesului de fluide și presiunea ridicată a acestora, a condus la topirea parțială a unui batolit granodioritic ale cărui apofize aflorează la nivelul actual de eroziune, de-a lungul ZFR.

Cuvinte cheie: Masivul Sebeș-Cibin, riodacite, origine anatectică.

INTRODUCTION

During the fieldwork for the geological map of Romania at the scale of 1:50,000, 30 granodiorite bodies and over 400 rhyodacite veins (dykes and sills) were highlighted in the Getic Crystalline in the northern part of the Sebeş-Cibin Massif (Pl. I, Figs. 2a-b), described as porphyritic granodiorites (e.g. STELEA, 2000a). Certainly, a detailed mapping would highlight many more occurrences of igneous rocks. Their outcrop area, 60 km long and 8 km wide, is concentrated along the Răşinari shear zone (RSZ), on both sides of it, in the sector between the Luncani valleys, to the west, and Tilişca, to the east (Fig. 1). Most of the veins crop out in the central sector of the shear zone (20 km long), located between the Sibişel valleys, to the west, and the Râul Mare of Cugir, to the east. The largest granodiorite bodies also occur in this sector.

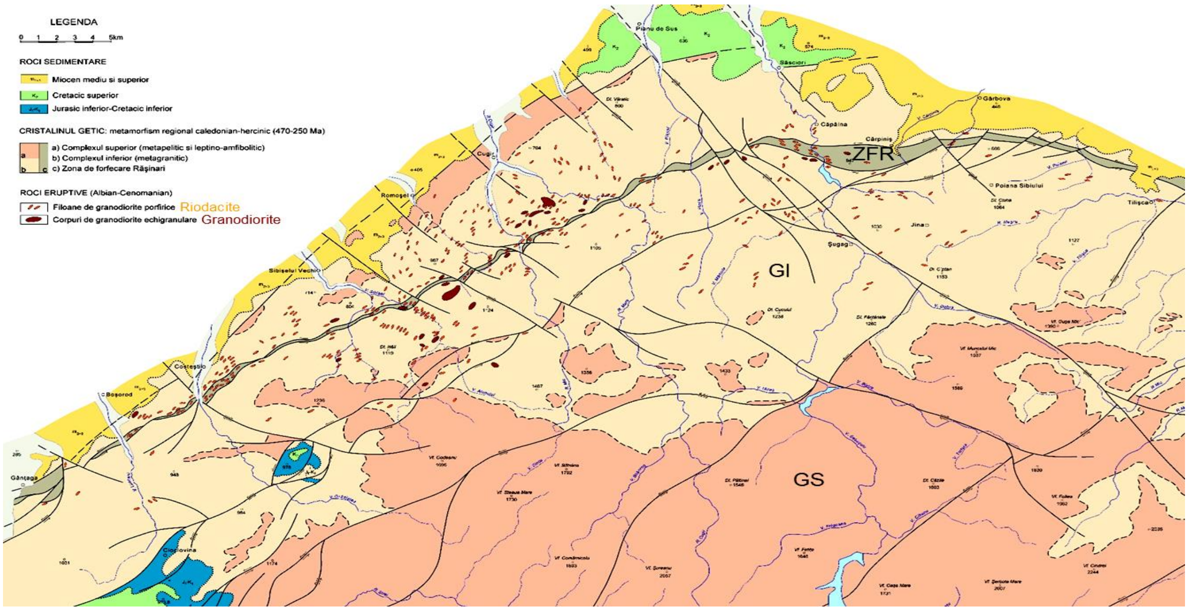

Figure 1. Simplified geological map of the Sebeș-Cibin Massif: GS-Upper Getic Complex (micaceous); GI-Lower Getic Complex (gneissic); ZFR-Rășinari Shear Zone.

The rhyodacite veins are 0.1-12 m thick, frequently in the range of 1-3 m, and 2-40 m long, frequently in the range of 5-20 m. The fact that undeformed veins also appear within the shear zone shows that their emplacement occurred towards the end of the tectonic activity associated with the RSZ. The granodiorite bodies have approximately ellipsoidal shapes, with a long axis of 30 m to 1200 m, frequently in the range of 50-200 m. The exception is the one on the left slope of the Sasului Valley, which has an irregular shape (Fig. 1). Although it is located 2 km away from the RSZ, it contains numerous enclaves of mylonites brought from deep crustal levels. Very likely, these bodies represent apophyses of a granodioritic batholith crossed by the shear zone.

The age of the granodiorites from the northern Sebeş-Cibin Massif has been considered Permian (SAVU et al., 1968) or post-Laramic (CIOFLICA et al., 1981). 39Ar/40Ar dating on biotite from two rhyodacite veins from the Sebeş Valley (DOBRESCU & SMITH, 2000) indicates Cretaceous (Albian) cooling ages of 108.4 ± 0.5 Ma and 109.3 ± 0.5 Ma. The dates correspond to the last tectonic movements on the main alignment of the ZFR, sealed post-tectonically by the Cenomanian conglomerates from Cisnădioara (STELEA, 2000a), on the northwestern edge of the massif. There are no geochronological data for the granodiorites.

RESEARCH HISTORY

In older geological works (SAVU et al., 1968; CHIVU, 1970), the rhyodacites were described as quartz porphyries and the granodiorites as plagioclase granites. CHIVU (1970) considers that the veins in the north of the Sebeş-Cibin Massif are the surface differentiations of the plagioclase granites with which they are associated.

Based on the eutectic composition of the matrix and the restitic character of the phenocrysts, CIOFLICA et al., 1981 first formulated the hypothesis of the anatectic origin of quartz porphyry veins. Among the causes of crustal anatexia, the authors also invoke the frictional heat accumulated at the contact between two tectonic blocks. The respective tectonic contact could not be specified because at that time the Răşinari shear zone was not defined as such, the associated mylonites being considered epimetamorphic schists (e.g. SAVU et al., 1968; CHIVU, 1970).

In a theoretical work, ŞECLĂMAN and LUPULESCU (1986) also refer to the veins in the Sebeş Mountains, noting the presence of lithic restites and the granitoid nature of the pre-anatectic rock.

Based on the regional geological mapping, STELEA (2000a) highlights the close spatial relationship of the vein swarm with the RSZ alignment and considers this to be the clear expression of a genetic relationship. Tectonic heating on the shear zone, associated with the presence of excess fluids and their high pressure, led to the partial melting of a granodioritic batholith whose apophyses outcrop at the current erosion level, along the RSZ.

GEOLOGICAL FRAMEWORK

The Getic crystalline. The metamorphic history of the Getic crystalline records two medium-grade metamorphic events, the first of Cadomian age (M1), syn-collisional, and the second Hercynian (M2), associated with the post-collisional uplift, when the tabular structure of the metamorphic pile was also formed as a result of flattening during the uplift (STELEA, 2000a). The Alpine metamorphism (M3) in the Getic crystalline in the Sebeş-Cibin Massif area is practically absent, significant Alpine deformations being strictly localized on the Răşinari shear zone.

On the exposed thickness, of almost 2 km, in the Getic crystalline two metamorphic complexes with clearly different lithologies are distinguished (STELEA, 2000a). The lower complex, metagranitic, is made up of two relatively monotonous metamorphic formations, namely augen gneisses at the lower part and micaceous gneisses at the upper part. The augen gneisses formation outcrops in domal structures with relics of peraluminous, syn-collisional continental granites (STELEA, 1994, 2000b). The upper metamorphic complex is leptino-amphibolitic and metapelitic. Its lower formation is composed of quartz-feldspathic gneisses intimately associated with amphibolites and the upper one of micaschists, frequently with distene and garnet.

The Răşinari shear zone. At the current level of erosion, the RSZ is an alignment of mylonites and cataclasites, 100 km long and variable in width, from a few tens of meters to 3 km, which crosses the northern edge of the Sebeş-Cibin Massif from the Strei Valley to the Olt Valley.

The mylonites formed in the middle crust during the Hercynian phase of RSZ activity, related to the post-collisional uplift of the Cadomian metamorphic pile. The shear zone acted as normal fault accommodating the faster uplift of the axial zone of the orogen relative to its northern margin. At the current level of erosion, the main protolith rocks are micaceous gneisses. The 40Ar/39Ar dating (DALLMEYER et al., 1994) on muscovite from mylonites indicate an Upper Carboniferous age (285.7 ± 0.5 Ma).

The cataclasites formed in the upper crust during the Alpine reactivation of the RSZ as a sinistral strike-slip fault in the context of a transcurrent tectonic regime in the northern central South Carpathians. Cataclastic deformation heterogeneously affects both the pre-Alpine mylonites and the Getic crystalline adjacent to the shear zone. The 40Ar/39Ar dating (DALLMEYER et al., 1994) on muscovite from cataclasite mylonites indicates a Lower Jurassic age (185.3 ± 0.5 Ma). Alpine mylonites formed at deeper crustal levels are not exposed.

During the Alpine phase, the RSZ geometry was modified by the appearance of curvatures on its route, as well as of secondary faults, the most important being the Cioclovina fault. The sinester movements on this fault and on its western horse-tail ramifications (related left-lateral normal oblique-slip faults) led to the opening of the Pui Basin starting in the Lower Jurassic. The main branch of the ZFR was active until the Albian. At the beginning of the Upper Cretaceous, the tectonic activity on this branch had ceased. The Cioclovina fault remained active until the Lower Maastrichtian, its post-tectonic cover being represented by the upper Maastrichtian molasse from the Haţeg Basin on the southwestern margin of the Sebeş Mountains (STILLĂ, 1985).

PETROGRAPHIC STUDY

The rhyodacite veins have a very homogeneous mineralogical composition and a chemical composition poor in potassium (Tab. 1), which is why they have also been described as trondhjemites (DOBRESCU & STOIAN, 1994). They are made up of a microcrystalline matrix of albite, quartz and potassium feldspar (as an interstitial phase) in which oligoclase restites appear, (frequently with borders of albite), quartz, biotite and epidote, isolated or grouped in polygranular aggregates representing lithic restites of granodioritic nature (Pl I., Figs. 2c, d). In two veins, one at Poiana Sibiului, on the Negrii Valley, and one at Căpâlna, on the Sebeş Valley, green hornblende restites also appear. In the studied samples, there are no potassium feldspar restites.

Table 1. Chemistry of igneous rocks in the northern Sebeș-Cibin Massif.

Oxides (% wt)	Granodiorites						Rhyodacites					
	8052 Sasu V.	8066 Romoșel V.	786 Cugirul Mare V.	1531 Romoșel V.	1560 Sasu V.	1561 Sasu V.	8044 Cugirul Mic V.	8059 Romoșel V.	8118 Costești	8127 Costești	8140 Costești	9568A Sebeș V.
SiO_2	73.48	72.13	73.07	73.84	69.45	74.23	72.77	73.93	73.07	73.17	72.63	75.2
TiO_2	0.09	0.07	0.24	0.16	0.11	0.14	0.07	0.08	0.08	0.07	0.09	0.36
Al_2O_3	14.57	15.82	16.27	14.72	17.93	14.94	15.72	14.94	15.58	16.06	15.46	13.2
Fe_2O_3	1.01	0.69	0.49	1.25	0.82	1.12	0.19	0.76	0.76	0.08	1.69	0.21
FeO	1.14	0.43	0.66	0.60	0.52	0.47	0.85	0.43	0.29	0.14	0.14	1.44
MnO	0.05	0.02	0.03	0.03	0.01	0.02	0.04	0.05	0.03	0.03	0.04	0.03
MgO	1.81	0.49	0.49	0.48	0.37	0.39	0.43	0.54	0.43	0.37	0.71	0.87
CaO	1.20	2.00	1.65	1.42	2.35	1.36	2.13	1.89	2.18	2.29	1.91	1.84
K_2O	1.16	1.60	1.88	2.53	2.01	1.77	1.50	1.17	0.78	1.22	0.95	1.07
Na_2O	4.62	5.95	5.10	4.76	5.90	5.11	5.37	5.31	5.86	5.60	5.52	4.83
P_2O_5	0.10	0.09	0.14	0.16	0.16	0.18	0.09	0.09	0.10	0.09	0.09	0.02
H_2O^+	1.40	0.41	0.39	0.45	0.35	0.46	0.47	0.60	0.52	0.46	0.89	0.40
CO_2	0	0.17	0	0	0	0	0.17	0	0.08	0	-	0.29
S	0.07	0.07	0.12	0.02	0.03	0.03	0.11	0.07	0	0.07	0.07	0
Total	100.7	99.94	99.53	100.42	100.01	100.22	99.91	99.89	99.79	100.37	100.19	99.76
LOI	-	-	0.50	0.45	0.69	0.47	0.64	0.60	-	-	-	-

The restites preserve a pre-anatectic semiplastic deformation, evidenced by mechanical twins in plagioclase (Pl. I, Fig. 2e), undulatory extinctions in quartz and kink bands in biotite. Genetically significant is the presence of undeformed quartz phenocrysts with hexagonal outlines typical of high-temperature quartz. The matrix is undeformed, the strain being eliminated by melting and recrystallization. Fluid textures, generated during magma ascent, are relatively rare.

The deformation contrast between restite and matrix is evident in most veins which outcrop outside the shear zone. Veins within the ZFR frequently show post-cooling cataclastic deformation, associated with alteration processes (sericitization and chloritization). Cataclastic deformation affects both restite phenocrysts and matrix.

Anatectic textures in various stages of partial melting also appear in the granodiorite bodies that outcrop in the central sector of the RSZ (Pl. I, Figs. 2c-f). These are affected by a pre-anatectic deformation in a cataslastic regime, present throughout the rock mass, except for the intergranular spaces in which the melt crystallized. The clasts are of plagioclase, quartz, cordierite, biotite, muscovite, apatite, rarely hornblende and epidote. Very rarely, restitic filiform biotite also appears, resulting from the disaggregation of biotite nodules that appear in the granodiorites along the RSZ.

DISCUSSIONS

Several observations are relevant for outlining a model regarding the genesis of the anatectic magmas that generated the rhyodacite veins in the northern Sebeş-Cibin Massif: a) the genetic relationship between the veins and the RSZ, revealed by their spatial relationship and the presence of pre-anatectic deformations at the level of the restites; b) the presence of lithic granodiorite restites in the rhyodacites; c) the deformation and the incipient anatexis affecting the granodiorites in the central sector of the RSZ; d) the compositional homogeneity of the rhyodacite veins, suggesting the compositional homogeneity of the parent rock.

Synchronous with the Alpine cataclastic deformation in the upper crust, observable at the current level of erosion, the rocks located at greater depths on the RSZ vertical were deformed in a semiplastic regime. At the base of the middle crust (20-22 km) the metamorphic pile was found at temperatures of 600-650ºC and lithostatic pressures of

5-6 Kb, calculated for a geothermal gradient of 30ºC/km, specific to the orogenic belts of continental collision, and a geobaric gradient of 1 Kb/3.8 km, specific to the granitic crust (STELEA, 2000a).

Anatectic processes in various stages, from incipient to relatively advanced, also affect some granodiorite bodies. It is reasonable to assume that these represent the apophyses of a deeper batholith. Under the thermodynamic conditions estimated above, extensive anatectic processes at the level of this batholith could have produced sufficient melt to generate the rhyodacite veins. The lithic granodiorite restites present in the rhyodacite veins (Pl. I, Figs. 2c, d) force us to consider the granodioritic nature of the parent rock. The anatexia was favored by the water content of granodiorites (0.42%), close to that of granites (0.58%), but especially by fluids in the shear zone. In shear zones, fluids circulate over kilometers (e.g. MCCAIg, 1988) due to temporary permeabilization of rocks by tectonic mechanisms, such as seismic pumping (Pf<P) and hydraulic fracturing (Pf>P).

CONCLUSIONS

The genesis of the rhyodacite veins from the northern Sebeş-Cibin Massif through crustal anatexis is credited by most researchers who have studied these rocks. The arguments supporting their anatectic origin are the presence of partially melted restites of oligoclase, quartz and biotite, the eutectic composition of the matrix, the presence of alpha-quartz paramorphoses after beta-quartz and the deformation contrast between the restites and the matrix. The presence of lithic granodiorite restites is a clear argument in favor of the granodioritic nature of the parent rock.

The anatexis is linked to tectonic activity on the Răşinari shear zone during the Alpine deformation phase (Lower Jurassic-Albian). Partial melting conditions were achieved at the base of the middle crust, at depths of 20-22 km and even lower if we also take into account a tectonic heat input generated on the shear zone. The frictional heating and the fluid circulation through tectonic mechanisms favored the anatexis. The obvious spatial relationship of the rhyodacite veins with the ZFR is the expression of a genetic relationship.

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Plate I

Figure 2. a) Rhyodacite vein (RD) in crystalline limestone (CL)-Sebeș Valley; b) outcrop of granodiorite-Romoșel Valley; c) pre-anatectic deformations in granodiorites; d) early stage of melting in granodiorites; e) plagioclase restit with pre-anatectic deformation in rhyodacites; f) anatectic texture in rhyodacites.