ULTRABASIC XENOLITHS FROM ALKALINE BASALTS FROM RACOS AND BOGATA OLTEANA. PHYSICAL CHARACTERISTICS AND THEIR SIGNIFICANCE FOR THE STUDY OF THE STRUCTURE AND COMPOSITION OF THE UPPER MANTLE

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Abstract. The ultrabasic xenoliths from the alkaline basalts from Racoş and Bogata Olteana are of special importance for knowing the structure and composition of the upper mantle because they have a great petrographic and mineralogical variety. In some places they show preferential orientations of minerals, which suggests the existence of some important dynamic processes in their area of origin and show a wide variety in terms of density and magnetic susceptibility. Another interesting fact is the relatively high content of captive water in the crystal lattice of olivine and pyroxene, as well as the presence of metasomatic reactions in olivine and pyroxene. The presence of water can also be seen in the physical properties of xenoliths, especially in the propagation velocities of acoustic waves and in increasing the anisotropy of the propagation velocity distribution. The presence of water can be associated with either a subduction or a gravitational sinking of some metamorphosed components of the crust.

Keywords: Xenolithes, upper mantle, captive water, density, acustic wave velocity, anisotropy.

Rezumat. Xenolitele ultrabazice din bazaltele alcaline de la Racoş şi Bogata Olteană. Caracteristici fizice și semnificația lor pentru studiul structurii și compoziției mantalei superioare. Xenolitele ultrabazice din bazaltele alcaline de la Racoş și Bogata Olteană prezintă o importanță deosebită pentru cunoașterea structurii și compoziției mantalei superioare deoarece au o mare varietate petrografică și mineralogică, prezintă pe alocuri orientări preferenţiale ale mineralelor, ceea ce sugerează existența unor importante procese dinamice la nivelul mantalei în zona lor de proveniență și prezintă o mare varietate din punct de vedere al densității și susceptibilității magnetice. De asemenea, un fapt interesant este conținutul relativ mare de apă captivă în rețeaua cristalină a olivinei și piroxenilor, precum și prezența unor reacții metasomatice la nivelul olivinei și piroxenilor. Prezența apei se remarcă și în proprietățile fizice ale xenolitelor, mai ales în vitezele de propagare ale undelor acustice și în creșterea anizotropiei distribuției vitezelor de propagare. Prezența apei poate fi asociată fie unei subducții, fie unei afundări gravitaționale ale unor componente metamorfozate ale crustei.

Cuvinte cheie: xenolite, manta superioara, apa captiva, densitate, viteza undelor acustice, anizotropie.

INTRODUCTION

Basalts in the southern Perşani Mountains are the product of a short eruptive episode in a period beginning 1.2 million years ago and ending 600000 years ago (HARANGI et al., 2013). The magmas that formed the basis of their formation come from depths between 60 and 85-90 km. These magmas quickly penetrated the crust, generally preserving the original composition and providing important information about the mantle in the source area and how the magma was generated (JANKOVICS et al., 2013).

Also, the ultrabasic xenoliths contained in these rocks are of particular importance. Due to the high velocity of magma ascension, they have retained their mineralogical content and original structure. Thus, they can provide information about the composition of the lithospheric mantle in the area at the time of the eruption, as well as about the processes that affected these rocks until the eruption.

The volcanic area of the Perşani Mountains is located at the border between the Perşani Mountains and the Transylvanian Basin, at the northwestern limit of the intramountain depression of Brasov (SEGHEDI et al., 2011) (Fig. 1).

This area is tectonically characterized by a series of normal faults oriented in the NE-SW direction, generated by an extensional regime with NV-SE orientation (GÎRBACEA et al., 1998).

The location of the volcanoes is structurally controlled, they being aligned in the NE-SW direction. Volcanism is contemporaneous with the post-collision uplift in the Carpathian arc and the subsidence in the foredeep area (GÎRBACEA & FRISCH, 1998); (MAŢENCO et al., 2007). The oldest eruptive rocks in the area are located in the Racoş-Heghes area and the newest in La Gruiu area, near Hoghiz, which is considered the newest volcano in this area (SEGHEDI & SZAKÁCS, 1994) (Fig. 2).

In addition to the petrological, structural and geochemical information presented by the authors cited above and those obtained through studies conducted during the development of the project, we will present several physical properties of basalt xenoliths (magnetic susceptibilities, densities, wave propagation velocities, anisotropies of acoustic waves) that can be used for lithological and structural modeling of the upper part of the lithospheric mantle.

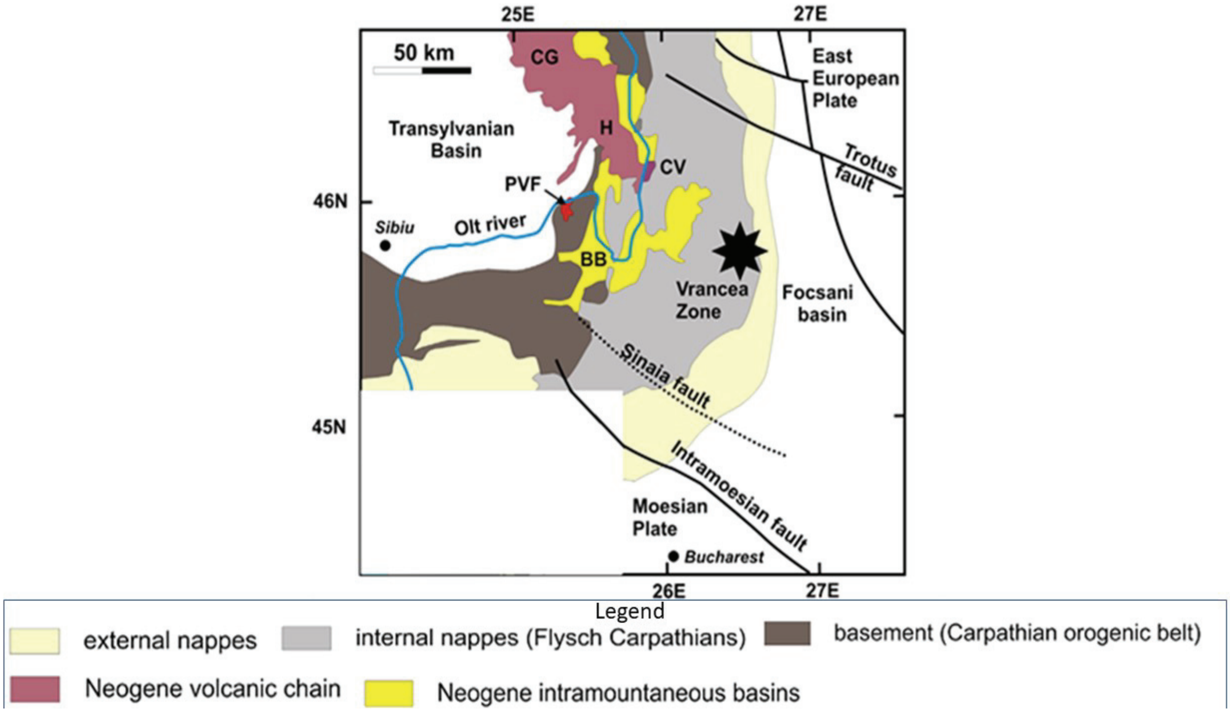

Figure 1. Location of the Perşani Volcanic Field (PVF) in the southeastern Carpathian area of the Carpathian-Pannonian Region. CG = Călimani–Gurghiu volcanic complex, H = Harghita volcanic complex, CV = Ciomadul volcano; BB = Braşov basin (based on SEGHEDI & SAKACS, 1994).

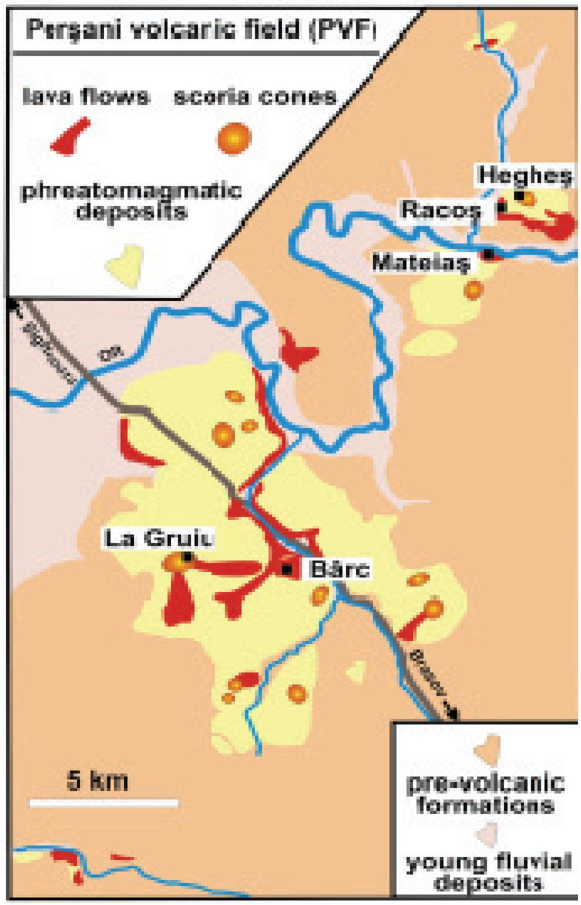

Figure 2. Simplified volcanological map of the Perşani Volcanic Field (SEGHEDI & SAKACS, 1994). Geological map after (CLOETINGH et al., 2004).

LITHOLOGY OF XENOLITHS

38 samples were investigated. Some of them with peridotite lithology (30 samples) and others are garnet and spinel pyroxenites (8 samples). The latter are similar in composition and structure to eclogites.

These samples were investigated with an optical microscope, electron microscope and then geochemically locally investigated on an electron microprobe and globally using XRF. At XRF, several samples of alkaline basalts bearing xenoliths were also investigated.

Table 1. Chemical composition of the samples investigated at XRF.

Sample	Mg	Al	Si	P	Ca	Ti	V	Cr	Mn	Fe	Ni	
XB3	4.3636	3.5982	18.2342	0.1313	2.02985	0.0683	0.00915	0.16625	0.0999	7.27505	0.21915	
BCB5	1.0629	6.54625	20.56005	0.2535	6.02955	0.96345	0.04065	0.0166	0.12655	7.46355	0.0183	
BCB1	1.2053	6.94645	20.28785	0.3119	6.81645	0.9333	0.04115	0.01845	0.1294	7.3006	0.01865	
XB1	3.8204	4.00075	18.6245	0.11475	1.89515	0.0728	0.009	0.18265	0.10365	7.75445	0.2392	
XB2	4.5768	4.01575	13.5761	0.14025	2.35955	0.1087	0.0083	0.20405	0.11175	8.1599	0.22635	
BCB2	1.0087	6.96895	21.83035	0.26625	5.99045	0.8501	0.0364	0.0379	0.12505	7.6259	0.0458	
BSB1	1.0052	7.89215	21.5224	0.2954	5.17205	0.96805	0.0369	0.01155	0.1141	6.8499	0.0146	
BCB3	1.2253	6.6165	24.9693	0.2496	5.41155	0.71645	0.0286	0.0362	0.11295	6.86635	0.0494	
BCB4	0.9319	7.61495	20.7485	0.34455	6.1348	0.92155	0.03955	0.0175	0.12655	7.32515	0.0179	
BCB6	0.8982	8.025	21.53495	0.28585	5.28365	0.94775	0.0398	0.01225	0.1117	6.79275	0.0144	
Err med	0.4638	0.06255	0.056947	0.0588	0.01707	0.00629	0.00074	0.00105	0.00279	0.03088	0.001027	
	Cu	**Zn**	**Sr**	**Zr**	**Nb**	**Mo**	**Sn**	**Pb**	**Sb**	**Rb**	**S**	**K**
XB3	0.002	0.00685	0.0013	0.0011	0.0004	0.0007	<LOD	0.0006	<LOD	<LOD	0.0534	0.1663
BCB5	0.0038	0.00795	0.0764	0.0202	0.0093	0.0008	0.001	0.001	<LOD	0.0072	0.0228	0.6241
BCB1	0.0048	0.0069	0.0746	0.01955	0.0088	0.0009	0.0014	0.0009	0.0059	0.0059	0.0745	1.5861
XB1	0.0014	0.0069	0.00185	0.0012	0.0005	0.0006	<LOD	0.001	<LOD	<LOD	0.0772	0.222
XB2	0.0029	0.00765	0.00315	0.0016	0.0006	0.0009	<LOD	0.0007	0.0065	<LOD	0.0376	0.2295
BCB2	0.0046	0.00765	0.06515	0.0168	0.0079	0.001	0.001	0.0011	<LOD	0.0046	0.0682	1.4816
BSB1	0.0031	0.0077	0.0967	0.01925	0.0073	0.0007	0.0013	0.0018	<LOD	0.0066	0.0588	1.6548
BCB3	0.0038	0.0072	0.0581	0.01455	0.0067	0.0007	0.0013	0.0008	<LOD	0.0047	0.0586	1.333
BCB4	0.004	0.00705	0.0746	0.01955	0.0092	0.0009	<LOD	0.0008	<LOD	0.0058	0.065	1.6
BCB6	0.0039	0.00825	0.09905	0.01955	0.0074	0.0007	0.0009	0.0019	<LOD	0.0058	0.1003	1.7897
Err med		0.00103	0.000967	0.00073				0.00155	0.00499	0.00072	0.01218	0.0115

LOD-Limit of detection

The optical microscope investigation showed that most of the samples are of the lherzolitic type (Fig. 3a), with or without spinels, with olivine contents of over 80% and pyroxene contents around 10-15%, the rest being represented by other minerals resulting from metasomatic transformation of the main components and spinels, in some cases (Figs. 3c, d).

Garnet pyroxenites are composed mainly of clinopyroxene and garnets, have an isotropic structure and sometimes have amphiboles formed by metasomatic processes on clinopyroxenes.

The content of clinopyroxenes varies in these rocks between 50 and 60% depending on the presence or absence of transformations in amphibole, and garnets represent between 45% and 25% depending on the existing spinel content. In some places, in very particular situations, the plagioclase feldspar is present in these rocks, suggesting a crustal origin of these formations (Fig. 3b).

Samples investigated by XRF and electron microprobe are peridotites in which the forsterite component of olivine is predominant (Table 2).

The observed spinel content varies between 2 and 8% and is evidenced by the presence of a higher amount of Cr in xenoliths compared to basalt samples, and that of orthopyroxenes between 5 and 20%. Clinopyroxenes are present in only 3 of the studied samples and do not exceed 3%.

The iron content indicated by XRF is erroneous due to iron contamination of the sample during preparation.

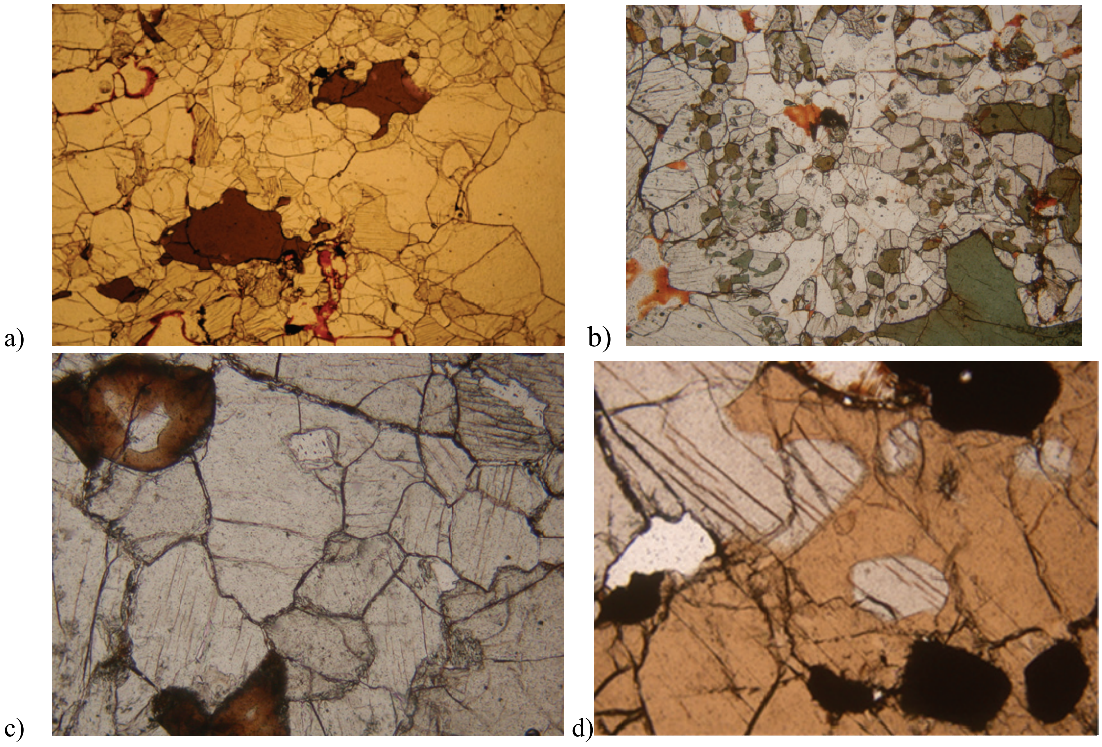

Figure 3. Ultrabasic xenoliths observed under an optical microscope: a) peridotite with cromiferous spinel and orthopyroxene; b) pyroxenite with garnets and spinel in which there are also nests of spinels and plagioclase feldspar; c) pyroxenite with garnets, spinel and amphibole; d) amphibole secondary on clinopyroxene (original).

Table 2. Fe / Mg ratio in olivine crystals tested by electronic microprobe.

Sample	Fe/Mg ratio
1.3.	0.308
1.4.	0.299
1.5.	0.167
2.3.	0.142
3.2.	0.338
3.3.	0.288
3.4.	0.289
4.1.	0.426
4.3.	0.298
4.5.	0.403
5.1.	0.313

PHYSICAL PROPERTIES OF THE INVESTIGATED SAMPLES

The density of peridotite samples varies between 3.1 and 3.32 g/cm^3 depending on the higher or lower fayalite olivine content and the proportion in which pyroxenes are present (density decreases with increasing pyroxene content). The densities of eclogites (pyroxenite with garnet) are in the range of 3.45-3.6 g/cm^3, which suggests a magnesium composition (pirop) of the garnets contained in these rocks.

Magnetic susceptibility has values between 30 and 280 * 10 $^{-6}$ USI and the anisotropy of susceptibility varies proportionally with its value and is between 0% (perfectly isotropic) and 8.451% in samples with magnetic susceptibilities over 200 * 10^{-6} USI. This depends on the amount of spinels present in the peridotite.

The ultrasound propagation speeds corrected for a depth of 30 km and the temperature and pressure conditions related to this depth and a normal geothermal gradient of 30 ^{o}C/km vary for peridotites between 7.97 and 8.2 km/s in the direction of maximum speed and between 7.68–8.05 km/s in the direction of minimum speed. For the investigated eclogite samples, similar to garnets pyroxenites, minimum speeds between 8.30–8.52 km/s were determined and maximum speeds between 8.50–8.64 km/s. A higher aniosotropy of velocities in peridotite can be observed compared to pyroxenites. The occurrence of lower acoustic wave velocities (7.68 km/s) can be considered to be caused by the structural alignment of olivine crystals in the direction of minimum propagation velocity or the presence of water in the olivine and pyroxene lattice (FALUS et al., 2008), (KOVÁCS et al., 2018), which leads to changes of the normal velocity through these minerals, in the sense of decreasing it.

The relatively wide range of velocity variation and also that of velocity anisotropies suggest a wide variety of peridotite rocks both mineralogically and structurally. The narrower range of variation and the smaller speed difference between the maximum and minimum speed directions, in the case of eclogites, are in accordance with the usual structural characteristics for these rocks.

DISCUTIONS AND CONCLUSIONS

The ultrabasic xenoliths present in the alkaline basalts of the southern Perşani Mountains present a great lithological and structural variety. This is evidenced both by petrological investigation methods (optical microscope, electron microscope) and by geochemical (electron microprobe, XRF) and physical methods (determination of density, magnetic susceptibility and ultrasonic propagation velocities).

This suggests that at the origin of important variations in the propagation velocities of seismic waves through the upper mantle, determined by tomography studies of Pn and Sn waves are both lithological causes and structural causes (preferential orientations of minerals resulting from processes of plastic flow at the level of the lithospheric mantle (NICULICI, 2011).

The presence of water in the pyroxene and olivine latrice (FALUS et al., 2008), the metasomatic transformations produced in the presence of water as well as the presence of plagioclase feldspar suggest an important amount of crust formations at the level of the upper mantle in this area.

This is possible by subduction or gravitational sinking of crust rock bodies subjected to transformations in the event of a continental collision (NICULICI, 2011).

Another indication related to the presence of crust formations is the presence of garnet pyroxenites (eclogites), rather characteristic of crust metamorphic facies in areas with high pressures and relatively low temperatures (areas of continental collision).

The study of ultrabasic xenoliths provides a wide range of information about the geochemical and structural characteristics of the lithospheric mantle in the area of the volcanic apparatus that transported them to the surface. Also, together with the rocks formed by the lava solidification, it provides important information about the tectonic processes produced in the adjacent area in the period before the volcanic eruption.

ACKNOWLEDGEMENT

We thank the Geological Institute of Romania which supported this research. Also, we thank for the support of the Ministry of Research for financing the project "The realization of 3D geological / geophysical models for the characterization of some areas of economic and scientific interest in Romania", with Contract no. 28N / 2019.

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Received: March 22, 2022
Accepted: August 13, 2022