

Nonna BAKUN-CZUBAROW¹, Anna BIAŁOWOLSKA²

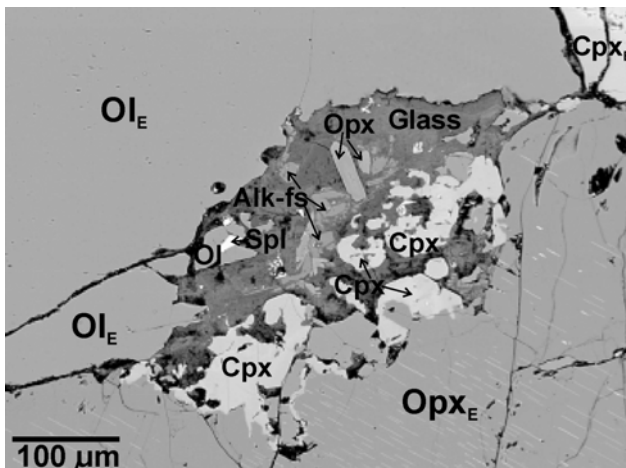
INTERNAL BLEBS WITHIN MANTLE PERIDOTITE ENCLAVES FROM LOWER SILESIA BASALTOIDS – PRELIMINARY RESULTS

Abstract: Mantle peridotite enclaves occurring within basanites of the Złotoryja region contain internal blebs consisting of newly formed clinopyroxene, olivine, spinel, often anorthoclase, set within residual silicic, alkaline glass. The blebs originated due to the thermal melting of the wall-rock lithospheric peridotite adjacent to the basaltic magma chamber, followed by a rapid disequilibrium crystallization of secondary mineral phases during ascent of enclaves to the Earth's surface.

Keywords: spinel lherzolite, spinel harzburgite, peridotite enclaves, lithosphere, partial melting, mantle metasomatism, internal blebs, glass

INTRODUCTION

Small microcrystalline glass bearing blebs formed from a partial melt in spinel lherzolite enclaves from Dreiser Weiher, Germany, were for the first time described by Maaløe, Printzlau (1979). Similar glass bearing blebs (pockets, pools, patches) can be also found in intergranular spaces of the mantle peridotite enclaves in the Lower Silesian basalts (Białowska 1993). Blebs are usually rounded and ellipsoidal in shape, their size varies from 0.1 to several mm in diameter. They always display sharp boundaries with the surrounding peridotite and are randomly distributed within enclaves. Their volume



percentage in peridotite ranges from traces to 11 per cent. The blebs consist of microcrysts of olivines, clinopyroxenes,

Fig. 1. BSE image of a bleb within lherzolite enclave from basanite of Łysanka hill in the Złotoryja region. Primary minerals of lherzolite: Ol_E – olivine, Opx_E – orthopyroxene, Cpx_E – clinopyroxene; secondary minerals of the glass bearing bleb: Ol – olivine, Opx – orthopyroxene, Cpx – clinopyroxene, Spl – spinel, Alk-fs – anorthoclase.

¹Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland; e-mail: nbakun@twarda.pan.pl

²Institute of Geochemistry, Mineralogy and Petrology, Faculty of Geology, Warsaw University, al. Żwirki i Wigury 93, 02-089 Warszawa, Poland

spinel, often also alkali feldspars, set into partly altered glass (Fig. 1). They can also contain not fully resorbed mineral phases of the host peridotite. The aim of our present study was an attempt to decipher the origin and evolution of the blebs occurring in lherzolite and harzburgite enclaves found in basanites of the Złotoryja region in Lower Silesia, being the eastern part of Tertiary Central European Volcanic Province – CEVP. Presented paper is the first one in the planned series of papers based on the results of our study on the lithospheric mantle processes taking place in the area of Lower Silesia and in other select areas of CEVP.

METHODS OF INVESTIGATION

Petrography and mineral chemistry of 40 blebs found within 6 lherzolite and harzburgite enclaves from basanites outcropping in the Złotoryja region were studied in details. Quantitative electron microprobe analyses of minerals and glasses were partly performed on a CAMECA SX100 microprobe equipped with three WDS spectrometers, in the Inter-Institution Laboratory of Microanalysis of Minerals and Synthetic Substances housed at the Faculty of Geology of Warsaw University, while the remaining analyses were carried out with the JEOL scanning electron microscope JSM 840A equipped with the Thermo-NORAN EDS, at the Laboratory of Scanning Electron Microscopy and Microanalysis of the Institute of Geological Sciences of the Polish Academy of Sciences. In both the laboratories a combination of natural minerals, metals, synthetic silicates and oxides was used for reference, as well as the ZAF program for corrections of the raw data. Representative microprobe analyses chosen from among 320 point analyses of minerals and glasses are presented in Tables 1–3.

CHEMICAL CHARACTERISTICS OF MINERALS AND GLASSES

Spinel, pyroxenes and olivine from blebs display close compositional similarity to appropriate minerals of the host mantle peridotites.

Primary **Cr-spinels** from the studied peridotite enclaves, with the following average composition $(\text{Mg}_{0.64}\text{Fe}^{2+}_{0.36})(\text{Al}_{0.56}\text{Cr}_{1.36}\text{Fe}^{3+}_{0.08})\text{O}_4$ (cf. Table 1) plot in central area of the field of chromites, on the Cr-Al-Fe³⁺ diagram (Fig. 2a). They also plot within relatively small area in the center of the field of chromites from podiform and mantle chromitites, on the diagram *mg* vs *cr* numbers (Fig. 2b). Secondary Cr-spinels, which occur in internal blebs as euhedral microcrysts or as skeletal forms within glass or secondary silicates, are compositionally much more variable $(\text{Mg}_{0.50-0.70}\text{Fe}^{\text{Fe}^{2+}}_{0.30-0.51})(\text{Al}_{0.30-0.93}\text{Cr}_{0.90-1.55}\text{Fe}^{3+}_{0.06-0.07}\text{Ti}_{0.03-0.11})\text{O}_4$ (cf. Table 1) than primary spinels from peridotite enclaves. They comprise from 3 to 10.7 mol. % of ulvite. Spinel from blebs differ essentially from the host basanite titanomagnetites comprising over 60 mol. % of ulvite (Table 1).

Secondary **clinopyroxene** microlites from blebs do not differ essentially from primary Cr-diopsides of host lherzolitic enclaves (Tab. 2), but, on the average, they are richer in Ca (up to 0.91 atoms *pfu*), as well as in Ti (up to 0.03 atoms *pfu*) and show higher *mg* numbers. Very rare euhedral microcrysts of secondary **orthopyroxene** are, as to their chemical composition, undistinguishable from primary orthopyroxene of peridotite enclaves. The latter usually contains abundant fine exsolutions of clinopyroxene lamellae in central parts of the grains (Fig. 1). Microcrysts of secondary **olivine** are randomly distributed within inner blebs. They are only slightly less magnesian ($\text{Fo}_{87.5-90}$) and poorer in Ni (≤ 0.002 atoms *pfu*) than primary olivine from enclaves ($\text{Fo}_{90.5}$). In the vast majority of the inner blebs studied subhedral microcrysts of **anorthoclase** were found. They are strongly

Table 1. Representative microprobe analyses of spinels from peridotite enclaves, their inner blebs and host basalt.

	Enclaves			Internal blebs				Basalt	
	spl 1	spl 2	spl 3	spl 4	spl 5	spl 6	spl 7	mgt 8	mgt 9
SiO ₂	0.13	0.03	0.07	0.35	0.24	0.14	0.27	0.25	0.13
TiO ₂	0.06	0.01	0.03	1.23	1.77	2.05	4.38	22.47	23.82
Al ₂ O ₃	14.88	14.94	14.87	7.52	22.49	26.50	10.28	1.51	1.85
Cr ₂ O ₃	53.72	54.33	54.60	58.23	43.38	38.55	50.52	0.18	0.24
Fe ₂ O ₃	3.62	3.02	2.92	2.86	2.45	3.29	2.82	24.15	23.23
FeO	13.24	12.92	14.16	18.29	14.00	13.82	18.05	45.72	46.08
MnO	0.10	0.10	0.23	0.51	0.10	0.15	0.32	0.73	0.81
ZnO	0.00	0.22	0.20	0.26	0.19	0.10	0.21	0.56	0.77
NiO	0.10	0.10	0.14	0.48	0.05	0.08	0.02	0.00	0.00
MgO	13.85	13.66	12.97	9.91	15.09	15.85	12.53	3.37	4.00
Total	99.60	99.33	100.19	99.64	99.76	100.53	99.40	98.94	100.93
<i>cr</i>	0.71	0.71	0.71	0.84	0.56	0.49	0.77	0.07	0.08
<i>mg</i>	0.65	0.65	0.62	0.49	0.66	0.67	0.55	0.12	0.13
Ulv	0.1	0.0	0.1	3.1	4.0	4.6	10.7	62.1	64.1

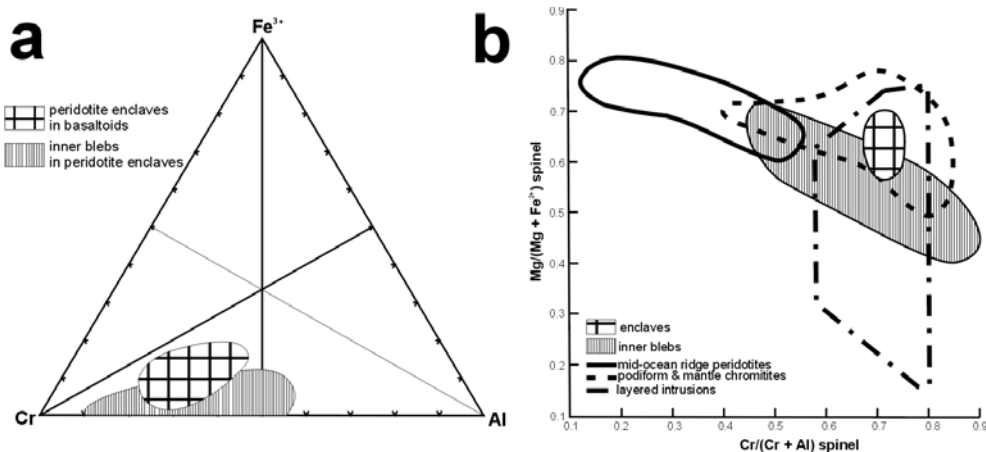


Fig. 2. Composition of spinels from peridotite enclaves and blebs from basaltoids of the Złotyryja region; a – Cr–Al–Fe³⁺ diagram, b – *mg* vs *cr* numbers diagram.

compositionally variable An_{0.2-14.7}Ab_{56.4-71.3}Or_{15.5-43.3} (Table 3). At the contact of blebs with host peridotite tiny laths of **plagioclase** can be seldom found. Compositionally they belong to low-Ca andesine (An₃₂), whereas plagioclase crystals, abundant in host basanite, are distinctly richer in Ca – An₅₃₋₆₂ (Table 3) and represent the labradorite group.

Partly altered **glass**, composing over 20 vol. % of internal blebs, is silica-, alumina- and alkalis-rich variety (Table 3). The glass is relatively poor in Ca and Fe as well as slightly enriched in Ti. It shows high values of *mg* numbers (up to 0.904) and either balance between K and Na atoms or distinct predominance of K over Na. Some analyses of glass (No. 7 in Table 3) point to the high content of volatiles.

Table 2. Representative microprobe analyses of pyroxenes and olivines from peridotite enclaves and their internal blebs.

	Enclaves						Internal blebs					
	pyroxenes				olivines		pyroxenes			olivines		
	cpx 1	cpx 2	opx 3	opx 4	ol 5	ol 6	cpx 7	cpx 8	opx 9	ol 10	ol 11	
SiO ₂	53.03	54.78	56.72	57.45	40.47	40.21	52.38	51.92	57.08	40.80	40.49	
TiO ₂	0.07	0.24	0.05	0.00	0.00	0.02	0.87	1.01	0.10	0.00	0.10	
Al ₂ O ₃	2.39	0.86	0.78	1.11	0.00	0.00	1.44	1.53	1.60	0.00	0.00	
Cr ₂ O ₃	1.23	0.85	0.49	0.25	0.00	0.00	0.77	1.30	0.48	0.06	0.06	
Fe ₂ O ₃	0.80	0.00	1.48	0.00			2.75	2.67	0.00			
FeO	2.16	2.44	4.94	5.66	9.14	9.39	1.11	0.33	5.90	9.92	11.82	
MnO	0.08	0.14	0.00	0.16	0.04	0.09	0.02	0.19	0.09	0.10	0.10	
NiO	nd	nd	nd	nd	0.34	0.25	nd	nd	nd	0.01	0.08	
MgO	17.91	18.78	34.53	34.60	49.05	49.24	16.73	16.85	34.34	48.25	46.72	
CaO	21.72	21.26	0.45	0.32	0.10	0.12	23.27	22.78	0.34	0.10	0.22	
Na ₂ O	0.32	0.45	0.12	0.01			0.52	0.70	0.03			
K ₂ O	0.00	0.00	0.08	0.00			0.08	0.00	0.00			
Total	99.71	99.80	99.64	99.56	99.14	99.32	99.94	99.28	99.96	99.24	99.59	
mg #	0.935	0.928	0.926	0.914	0.905	0.903	0.964	0.983	0.911	0.896	0.875	

Table 3. Representative microprobe analyses of alkali feldspars, plagioclases and glass from inner blebs in peridotite enclaves and of plagioclase from host basalt in the Złotoryja region.

	Internal blebs							Basalt	
	alk-fs 1	alk-fs 2	alk-fs 3	alk-fs 4	pl 5	glass 6	glass 7	pl 8	pl 9
SiO ₂	62.70	65.63	65.45	67.99	59.25	59.38	58.26	53.50	52.85
TiO ₂						0.10	0.68		
Al ₂ O ₃	21.80	19.84	19.77	18.35	25.24	15.75	15.80	28.56	29.30
Cr ₂ O ₃						0.05	0.02		
FeO	0.05	0.59	0.54	0.14	0.06	1.37	1.20	0.34	0.76
MnO						0.03	0.05		
MgO						7.86	2.28		
CaO	3.06	0.67	0.60	0.05	6.80	0.15	1.14	10.99	12.69
BaO	0.05	0.08	0.05	0.07		0.04	0.02		
Na ₂ O	8.02	8.20	7.05	6.50	7.35	4.27	3.50	5.05	4.12
K ₂ O	2.70	4.45	6.15	7.58	0.90	5.85	7.25	0.60	0.30
Total	98.38	99.46	99.61	100.68	99.60	94.85	90.20	98.84	100.02
mg #						0.904	0.773		
an	0.147	0.032	0.029	0.002	0.321			0.527	0.619
ab	0.698	0.713	0.617	0.564	0.628			0.438	0.364
or	0.155	0.255	0.354	0.433	0.051			0.034	0.017

DISCUSSION AND CONCLUSIONS

Internal blebs (pockets, pools, patches) consisting of glasses and microcrysts of secondary minerals can be found in mantle peridotite enclaves within basaltoids worldwide. Their origin and evolution has become recently the subject of hot debates. The role of mantle metasomatism, timing, place and degree of partial melting of mantle

peridotites as well as possible influence of host basaltic magmas are being discussed (Ban *et al.* 2005; Frey, Green 1974; Franz, Wirth 1997; Yaxley *et al.* 1997).

The internal blebs present in spinel lherzolite and harzburgite enclaves occurring within basanites in the Złotoryja region of Lower Silesia were studied in details.

The investigated blebs did not originate in the course of interaction of host basanite magma with the mantle peridotite enclaves. The blebs studied were located well inside not fractured peridotite enclaves and there were no signs of mixing of the bleb and basanite melts observed. In addition, the intensive ingress of host basanite magma into enclaves has been prevented by internal fluid overpressure formed due to rapid decompression of enclaves during their ascent to the surface (Yaxley *et al.* 1997). On one hand, mineral phases that crystallized from the bleb and basanite melts show distinctly different crystal chemistry (for example Cr-spinels and low-Ca andesines in blebs vs ulvites and labradorites in basanites). On the other hand, secondary minerals of blebs, excluding feldspars, show close similarity to the host peridotite minerals. The blebs contain also almost extreme-composition silicic, alkaline glasses, that comprise, on the average, about one fourth of the bleb volume. Most likely, the glasses were on liquidus, at moderate pressures, in the state of equilibrium with spinel lherzolite minerals (Draper, Green 1999).

The results of detailed study on crystal chemistry of Cr-spinels from internal blebs and their host peridotites point to the great variation of *cr* numbers of secondary spinels. The highest values of *cr* numbers can support the notion that the blebs originated during initial melting of wet peridotites of mantle wedge in forarc or island arc settings (Matsukage, Kubo 2003).

At the present state of our knowledge the two-stage scenario, presented below for origin and evolution of the studied internal blebs in spinel peridotite seems to be the most probable one. In the first stage, at the very beginning, silica-rich initial melts of variable composition, corresponding, to some extent, to the average composition of the blebs in separate enclave, originated at the grain boundaries of spinel peridotites. Then initial melts migrated and accumulated at triple junctions forming blebs. The partial melting of the first stage took place in lithosphere, in wall-rock peridotites surrounding a chamber with basaltoid magma. The melting may have occurred there as thermal, contact anatexis. On the basis of composition of secondary Cr-spinels and silicic, alkaline glasses it could be concluded, that, before melting, lower lithospheric peridotites underwent mantle metasomatism by hydrous agent rich in potassium, in spite of the absence of metasomatically introduced phases (amphibole, phlogopite and/or secondary clinopyroxene) in peridotitic enclaves. During second stage of evolution, after entrainment of the enclaves in host basanite magma, prior to ascent to the surface, the additional metasomatic enrichment in K can be suggested to take place in the blebs, by analogy to the alteration of cumulate type gabbroic enclaves, by K agent, in the Złotoryja region basanites (Bakun-Czubarow, Białowolska 2003). During ascent to the surface, decompressional cooling and rapid, disequilibrium crystallization of secondary clinopyroxene, olivine, Cr-spinel and anorthoclase, as well as solidification of residual silicic, alkaline melts took place in the blebs.

Acknowledgements: The authors are indebted to Dr. Piotr Dzierzanowski and Mrs. Lidia Jezak for their assistance during performing the microprobe analyses in IILMMSS at Warsaw University and to Dr. Ryszard Orłowski for carrying out electron microprobe analyses at the Institute of Geological Sciences, Polish Academy of Sciences. The authors extend thanks to Mrs. Danuta Kusy and Mrs. Dorota Grabska for preparing in digital form the data and diagrams for the present study. The support of Warsaw University under the

project BW 1686/13 (A.B.) and of the Institute of Geological Sciences PAS, under the statutory project no 4.2 (N.B-C.) is gratefully acknowledged.

REFERENCES

- BAKUN-CZUBAROW N., BIAŁOWOLSKA A. 2003: Gabbroic enclaves from basalts of the Lubań and Złotoryja regions, Lower Silesia. *Pol. Tow. Mineral. Prace Spec.*, 23, 32–34.
- BIAŁOWOLSKA A. 1993: Enklawy w bazaltoidach wzgórz Łysanka i Trupień (Dolny Śląsk). *Arch. Mineral.*, 49, 2, 145–197.
- BAN M., WITT-EICKSCHEN G., KLEIN M., SECK H. A. 2005: The origin of glasses in hydrous mantle xenoliths from the West Eifel, Germany: incongruent breakdown of amphibole. *Contrib. Mineral. Petrol.*, 148, 511–523.
- DRAPER D.S., GREEN T.H. 1999: P–T phase relations of silicic, alkaline, aluminous liquids: new results and applications to mantle melting and metasomatism. *Earth Planet. Sci. Lett.*, 170, 255–268.
- FRANZ L., WIRTH R. 1997: Thin intergranular melt films and melt pockets in spinel peridotite xenoliths from the Rhön area (Germany): early stage of melt generation by grain boundary melting. *Contrib. Mineral. Petrol.*, 129, 268–283.
- FREY F. A., GREEN D.H. 1974: The mineralogy, geochemistry and origin of lherzolite inclusions in Victorian basanites. *Geochim. Cosmochim. Acta*, 38, 1023–1059.