

Πρακτικά		6ου	Συνεδρίου	Μάιος	1992
Δελτ. Ελλ. Γεωλ. Εταιρ.	Τομ.	XXVIII/2		σελ.	Αθήνα
Bull. Geol. Soc. Greece	Vol.			93-103	1993
				pag.	Athens

GARNET CLINOPYROXENITE FROM BRISTRICA SOUTHERN ZLATIBOR, SERBIA

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ABSTRACT

In a small lherzolite block (olistolite) in the Diabase-Chert Formation (olistostrome melange) thin (up to 30 cm thick) garnet clinopyroxenite veins concordant to the layering of the host rock occur.

The garnet clinopyroxenite consists of clinopyroxene (slightly deformed, comp. ca 66% Di, 9% Hd, 9% Jd, 15% Tsch), garnet (ca 55% Prp, 27% Alm, 17% Grs, 1% Sps), and locally very rare orthopyroxene. The lherzolite is composed of olivine (90% Fo), enstatite (90% En), clinopyroxene (ca 80% Di, 4.5% Hd, 7.5% Jd, 8% Tsch), all slightly deformed, and accessory spinel. The texture of the garnet clinopyroxenite is mosaical with subordinate cataclastic phenomena.

The fabrics of the garnet clinopyroxenite and the host lherzolite are similar (the difference is only in the presence of layering in the lherzolite).

The crystallization temperature of the garnet clinopyroxenite from a picritobasaltic melt low in alkalies and high in calcium was over 1050-1100°C, but the equilibration between the coexisting minerals ended at about 1000°C. The solid state equilibration temperature of the lherzolite was at 900-950°C and at ca 12.5 kb pressure. The mineral pair geobarometers and the elevated sodium content in clinopyroxenes of both rocks indicate that their consolidation was in the higher pressure part of the spinel peridotite stability field.

The origin of the garnet clinopyroxenite is explained by crystallization of a picritobasaltic melt at high pressures, but there is also a possibility that all the metamorphic and ultramafic rocks in this area were metamorphosed under HP/HT - conditions. Retrograde adjustment during decrease of pressure and temperature was prevented by fast uplift.

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INTRODUCTION

A. Popevic described 1976. a vein of "eclogite" from the surrounding of Bistrica (in direction to Priboj, Southern Zlatibor, Western Serbia). Because of the rarity of such rocks, the same area was investigated again and some additional data on the field occurrence and the composition of minerals were obtained. New possibilities to estimate the pressure and temperature of formation of this rock were the main reason for preparing this paper.

In this paper we used the name "garnet clinopyroxenite" (not "eclogite") for these rocks because of, as will be presented later, a relatively low Jd content in the clinopyroxene.

MODE OF OCCURRENCE

The garnet clinopyroxenite occurs as thin veins in the small lherzolite body of Bistrica, representing a block in the olistostrome melange known as Diabase-Chert Formation. The veins are a few cm thick, only in one case up to 30 cm and always concordant to the layering of lherzolite. About 15 veins were found along a 120m long ridge, near to the contact of the (serpentinized) lherzolite with garnet pyroxene amphibolites (Milovanovic, 1989), corundum bearing schistose amphibolites (Popevic and Pamic, 1973), garnet bearing amphibolites, and the rocks of the Diabase-Chert Formation (fig.1).

Popevic (1976) presented the results of the study of a thin vein. Later on, we investigated a few thin veins and the thickest one. Our data confirm the previous results, but there are some important additional data.

PETROLOGY

The garnet clinopyroxenite is mainly composed of dark green pyroxene and red garnet (up to 3mm in size). It consists of:

- clinopyroxene (2V = +62°, Ng:c = 40°), with orthopyroxene exsolution lamellae and deformations (kink bending). Its composition is given in tables 1 and 4. There is no major difference in composition from core to the rim or from grain to grain.

- orthopyroxene is very rarely present only in some veins. 2V = -89°, i.e. 14% Fa (Popevic, 1976).

- garnet is the coarsest mineral. They display a homogenous composition and a weak chemical zoning (table 1), mean composition about 55% Prp, 27% Alm, 17% Grs, 1% Sps.

The texture of the garnet clinopyroxenite is mosaical

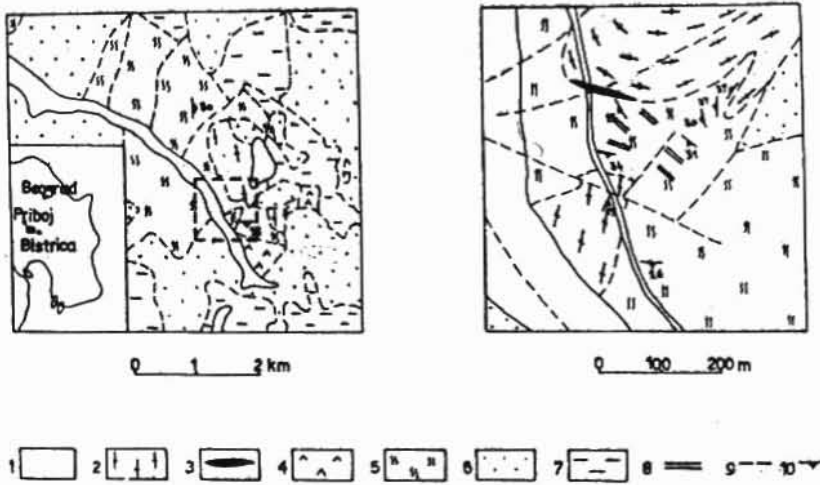


Fig.1 Geological map of the area with the lherzolite body of Bistrice (left) and of the part with garnet clinopyroxenites (right). Mapped by Popevic, 1972.
1 - Alluvium; 2 - Amphibolite; 3 - Corundum bearing schistose amphibolite; 4 - Diabase; 5 - Lherzolite; 6 - Diabase-Chert Formation, sedimentary matrix; 7 - Triassic limestone; 8 - Garnet clinopyroxenite vein; 9 - Fault or boundary of olistolite; 10 - Layering in lherzolite.

Representative electron microprobe analyses of minerals from the garnet clinopyroxenite (N 90/4)

Table 1

	G a r n e t					Clinopyroxene		
	the core 6	7	8	9	10	the edge 11	at contact with Grt 12	in matrix 13
SiO ₂	41.47	41.50	41.26	41.62	41.85	41.32	50.82	50.98
TiO ₂	0.08	0.08	0.10	0.08	0.08	-.	0.47	0.47
Al ₂ O ₃	22.79	23.40	23.28	23.13	23.22	23.45	9.23	9.03
Cr ₂ O ₃	0.10	0.10	0.09	0.10	0.09	0.12	0.11	0.10
FeO	11.79	11.61	11.89	12.15	12.69	13.06	4.06	4.13
MnO	0.40	0.37	0.40	0.40	0.43	0.43	0.06	0.09
MgO	14.94	14.59	14.77	14.81	15.73	15.15	12.59	12.66
CaO	8.64	8.65	8.51	8.02	6.66	6.66	21.14	20.70
Na ₂ O	-.	-.	-.	-.	-.	-.	1.31	1.63
K ₂ O	-.	-.	-.	-.	-.	-.	-.	-.
Tot.	100.21	100.30	100.29	100.32	100.76	100.19	99.79	99.79
X _{Mg}	69.3	69.1	68.9	68.5	68.8	67.4	84.7	84.5

Representative electron microprobe analyses of minerals from the lherzolite (N 90/3)

Table 2

	Primary minerals			Secondary	
	Ol 1	En 2	Cpx 3	Spl 4	Hbl 5
SiO ₂	41.48	55.25	53.39	-.	44.60
TiO ₂	-.	0.08	0.38	0.03	1.98
Al ₂ O ₃	-.	4.37	5.37	58.91	14.19
Cr ₂ O ₃	-.	0.26	0.58	9.34	-.
FeO	9.79	6.10	2.19	10.99	3.51
MnO	0.15	0.17	0.12	0.23	0.08
MgO	48.68	31.87	14.81	19.81	17.23
CaO	-.	0.62	21.12	-.	11.63
Na ₂ O	-.	-.	1.83	-.	3.91
K ₂ O	-.	-.	-.	-.	0.31
Total	100.10	98.71	99.79	99.32	97.44
X _{Mg}	90.0	90.3	92.3	76.3	89.7

with some cataclastic phenomena at the grain boundaries, indicating a weak high temperature dynamic recrystallization (in the sense of Heitzmann, 1985). It is identical with the texture of the lherzolite hosting the veins.

Whole rock analyses of the garnet clinopyroxenite are given in table 3.

The lherzolite is composed of:

- olivine (90% Fo), with wavy extinction and rare mosaic texture because of recrystallization,

- enstatite (90-90.5% En), with clinopyroxene exsolution lamellae and kink bending,

- clinopyroxene ($2V = +54^\circ$, $Ng:c = 40^\circ$) with the same deformation features as the enstatite, composition is given in tables 1 and 4.

- spinel rarely occurs as small grains.

- hornblende is a rare early and serpentine a late secondary mineral.

The layering in the lherzolite is well developed.

The chemical compositions of the lherzolite and its minerals are given in tables 3 and 2 resp. It should be noticed that the Na-contents of the clinopyroxenes from the garnet clinopyroxenites and from the lherzolites are quite similar. The whole rock content of Na_2O of the garnet clinopyroxenite (with the clinopyroxene as the main mineral) is therefore 2 to 3 times higher than the content of the same component in the lherzolite (with about 10% of clinopyroxene).

DISCUSSION

The fabrics of the garnet clinopyroxenite and the surrounding lherzolite indicate that both rocks originated before the final solidification. The solid state deformations at high temperatures are expressed in both rocks. However, these subsolidus deformations were weak: cataclasis associated with dynamic recrystallization occurs only locally and the primary relationship between the lherzolite and the garnet clinopyroxenite was preserved.

High Na_2O contents are characteristic for the garnet clinopyroxenite as well as for the lherzolite from Bistricea (0.43 - 0.65 and 0.21 - 0.22% Na_2O resp.). This is a strong enrichment in Na_2O compared with the lherzolites of the innerdinaric ophiolite belt, containing in average 0.03% Na_2O (Maksimovic, 1971). The high Na_2O -content of the lherzolite can be attributed to the clinopyroxenes, which are also rich in Na_2O compared with the clinopyroxenes from the ophiolites of the Mediterranean area (containing from 0.2 to 0.9%, Lazko and Sharkov, 1988).

The increased Na_2O -contents of the clinopyroxenes from both rocks indicate their growth at relatively high pressure in the range of the spinel peridotite stability.

Popevic (1976) estimated the pressure and temperature of crystallization of the "eclogitic" melt, according the data from Wyllie (1971), in the order of 18-20kb and 1200-1400°C. Nisbet (1982) gives a diagram of liquidus temperatures for magnesian basalts and komatiites (fig 29.2, p.507), i.e. for

Chemical analyses of the ultramafic rocks (wt.%)

Table 3

	Garnet clinopyroxenite			Lherzolite	
	1 90/4	2 90/7	3	4 U-90	5 90/3
SiO ₂	42.32	42.15	43.42	43.95	43.07
TiO ₂	0.45	0.37	0.07	0.16	0.12
Al ₂ O ₃	15.50	14.73	14.30	3.11	3.00
Cr ₂ O ₃	0.11	0.13	-.	0.25	0.34
Fe ₂ O ₃	1.19	0.76	2.79	1.04	1.87
FeO	6.31	7.85	8.38	7.79	6.45
MnO	0.13	0.15	0.20	0.13	0.12
MgO	13.92	12.85	15.03	37.77	37.37
CaO	16.88	17.54	13.67	2.49	2.42
Na ₂ O	0.43	0.65	1.02	0.22	0.21
K ₂ O	0.007	0.008	0.05	0.016	0.007
P ₂ O ₅	0.11	0.03	Tr.	-.	0.12
CoO	0.009	0.009	-.	0.014	0.014
NiO	0.053	0.071	-.	0.25	0.25
H ₂ O ⁻	0.19	0.25	-.	0.33	0.46
H ₂ O ⁺	2.31	2.26	1.46	2.07	4.25
CO ₂	0.18	0.39	-.	0.25	0.20
Total	100.10	100.20	100.39	99.84	100.27
X _{Mg}	77.2	72.9	70.6	88.5	89.1

Analysts: 1,2,4,5 - D.T.Unanova (IGEM Moscow)
3 - D.Dimitrijevic (Geozavod, Beograd),
from Popevic, 1976.

End-members of the clinopyroxene solid solutions from
spinel lherzolite (90/3) and garnet clinopyroxenite
(90/4)

Table 4

Rock	End-members				X _{Mg}
	Di	Hd	Jd	Tsch	
Lherzolite (3)	80.1	4.3	7.5	8.1	92.3
Garnet clinopyroxenite					
(12)	66.1	8.7	9.6	15.6	84.7
(13)	66.6	9.1	8.9	15.4	84.5

the melts similar to the melt which corresponds to the garnet clinopyroxenite from Bistrica, depending on the pressure and MgO content. For the pressure range of 15-20kb, melts with 13-14% MgO, as is the chemistry of the garnet clinopyroxenite, exist at about 1400°C, confirming the assumptions of Popevic. The melting temperature of a garnet clinopyroxenite (composition: 15% Al₂O₃, 15% MgO, 14% CaO and 0.8% Na₂O, i.e. almost analogous to the garnet clinopyroxenite of Bistrica) was determined by Irving (1974) as 1050-1100°C at 13-17kb.

Using the thermobarometry of Mercier (1980) for coexisting Cpx+Spl pairs in the lherzolite yields temperatures of about 900°C at pressures of 12.5kb, representing the end of diffusion of components in solid state. The geobarometry of the same author with the Opx+Spl pairs however indicates much higher pressures (17.2kb). We prefer the results obtained by the Cpx+Spl pair because of the complex chemistry of the clinopyroxene involving more components in the diffusion. The temperatures of solid state equilibration by the methods of other authors (table 5) range between 830 and 950°C. Methods developed in the last years indicate higher values (900 to 950°C).

These melting and solid state equilibration temperatures of lherzolites correspond to those of Western Alps spinel lherzolite massives (Ernst, 1979).

The temperature of equilibration in the system Cpx+Grt, the characteristic association of the garnet clinopyroxenite, i.e. the closing temperature of the system for exchange of components, ranges from 950 to 1030°C for pressure of 12kb. Temperature values about 1000°C are obtained by the newly developed methods (table 6).

The difference between the equilibration temperatures of the lherzolite (ca 900°C) and the garnet clinopyroxenite (ca 1000°C) is probably partly due to the uncertainties of the used systems (compare the data given by Brey and Kohler, 1990) but probably partly also to different possibilities for migration of ions through the spinel and garnet crystal lattices, respectively. These temperatures indicate probably also the end of solid state flowage and recrystallization of cataclased parts, it was for the garnet clinopyroxenite at higher and for the lherzolite at lower temperatures, enabling the development of layering in the lherzolite.

The origin of the melts which gave rise to the clinopyroxenite probably is associated with high degrees of partial melting at high pressures and temperatures in the upper mantle when in partial melts aluminium, calcium, sodium and titanium were enriched whereas the magnesium content decreased (fig.2). The chemistry of this melt corresponds to picritobasalts low in alkalis and with high calcium. The crystallization of these melts as well as the consolidation of the surrounding lherzolites was under HP/HT conditions in the upper mantle which is also indicated by its high contents of Cr, Ni and Co. Later cooling of these ultramafic rocks was probably followed by very fast uplift which prevented retrograde alteration.

Another possibility of the origin of these rocks can be supposed taking into account the presence in the immediate

P-T conditions on the final equilibration by cooling of the
spinel lherzolite (N 90/3)

Table 5

	T, °C (at ca. 12kb) Geothermometers			P _e , kb Geobarometers	
	Cpx+Opx	Ol+Opx+ Spl	Cpx+Spl	Cpx+Spl	Opx+Spl
Wood, Banno (1973)	951				
Wells (1977)	835				
Mori, Green (1978)	856				
Mercier (1980)			893	12.5	17.2
Slavinsky (1983)	906				
Welb, Wood (1986)		947			

T-estimates of the final equilibration by cooling
of the garnet clinopyroxenite (N 90/4) based on
garnet clinopyroxene geothermometers

Table 6

	T, °C (at ca. 12kb)
	Cpx(12)+Grt(11-edge) (see table 1)
Ryburn, Raheim, Green (1976)	943
Wells (1979)	1036
Ellis, Green (1979)	1010
Slavinsky (1980)	992
Powell (1985)	998
Schliestedt (1986)	962
Krogh (1988)	982

Grt: Prp-0.55, Alm-0.27, Grs-0.17, Sps-0.01
Cpx: Di-0.66, Hd-0.09, Jd-0.09, Tsch-0.15

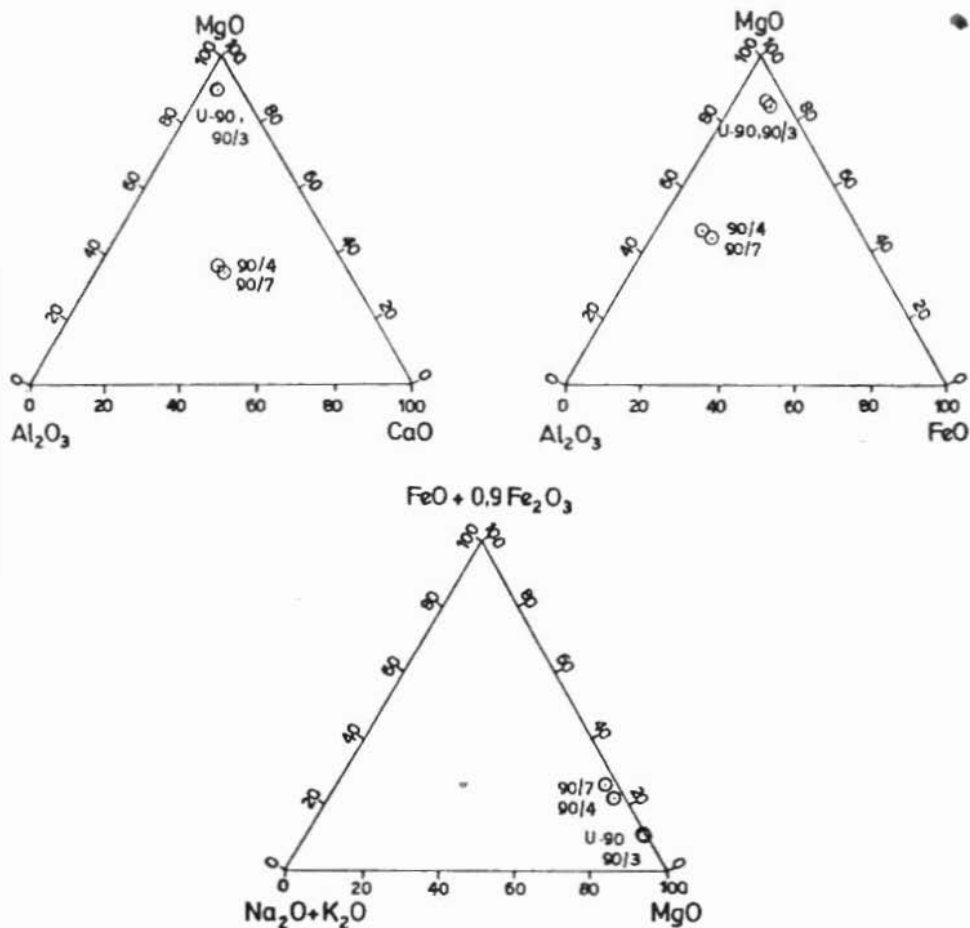


Fig.2 Ratios of the characteristic main components in the Iherzolite (U-90, 90/3) compared with the ratios of the same components in the garnet clinopyroxenite (90/4, 90/7).

neighbourhood (fig 1) of garnet pyroxene amphibolite; metamorphosed according to the garnet+clinopyroxene pair at an assumed pressure of 10kb at 900-1000°C (by the method of Powell, Milovanovic, 1990). Temperatures of 800-880°C were also estimated by Milovanovic (1989) for other mineral pairs. For the corundum bearing amphibolites (a primary pelitic rock, remark S.Karamata), Popevic and Pamic (1973) estimated PT - conditions of the upper mantle. The origin of these rocks at depth of 30-40km together with the associated lherzolites and garnet clinopyroxenites under similar pressure and temperature conditions suggests that all this complex of lherzolites, with garnet clinopyroxenites and amphibolites represent ultramafic to basaltic and associated sedimentary rocks metamorphosed under HP/HT conditions possibly in a subducted slab and later on brought to the surface by rapid uplift and included into the olistostrome melange (Diabase-Chert Formation).

ACKNOWLEDGEMENTS

We thank two anonymous reviewers for helpful criticism of the paper.

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