

## MINERAL COMPOSITION OF THE GYÓD SERPENTINITE BODY, SOUTHERN TRANSDANUBIA, HUNGARY

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### ABSTRACT

Re-examination of mineral composition of Gyód Serpentinite Body is accounted for by the different results in literature. On the base of qualitative and semiquantitative XRD determinations, the main phases of the examined rocks are mostly serpentine minerals (30-60 %), talc (10-30 %) and chlorite (10-20 %). Chrysotile (2Or<sub>c1</sub> symmetry orthochrysotile) and 1T-lizardite could have been analysed surely in several samples. The amount of dolomite, quartz, olivine and spinel reaches 10-20 % in several samples; however, these are generally minor phases together with calcite and orthopyroxene. Olivine (F<sub>90-91</sub>) and orthopyroxene (En<sub>88-93</sub>) composition and also Cr# of spinels suggest that the examined rocks are the partial melting residua of a mantle source material. On the base of spinel composition, we assumed that the Gyód Serpentinite Body was probably formed in an island-arc environment.

**Key words:** harzburgite, serpentinization, mineral chemistry, Tisia Unit.

### INTRODUCTION

In Southern Transdanubia field magnetic, aerogamma and aeromagnetic investigations indicated strong magnetic anomalies in the crystalline basement and, subsequently, some of these anomalies were penetrated by boreholes (boreholes of G-2 and He-1,-2). These resulted in the discovery of a serpentinized body in the region of Gyód (Fig. 1) and Helesfa. In the 1970s and 1980s more detailed research was carried out on the Gyód Serpentinite to identify its mineralogy and geochemistry. In these studies different mineral compositions of Gyód Serpentinite Body were determined from which different conclusions were drawn in the point of view of ultramafic protolith and its alteration processes. On the basis of X-ray diffraction analysis Erdélyi (1970) determined numerous minerals (Table 1) of the serpentinized peridotite. Szederkényi (1974) and Ghoneim (1978) claimed that the protolith of the serpentinite must have been pyroxenite or lherzolite or dunite. According to Papp (1989) the most frequent serpentine minerals are lizardite, chrysotile and polygonal serpentine. Balla (1980, 1985) established that the chemical composition of Gyód body is harzburgitic, and stated a multi-step metamorphic evolution path of it.

The aim of this paper to re-examine the mineral composition of the Gyód Serpentinite Body in order to determine the type of protholith and know more accurate the evolution of this body.

### METHODS

The X-ray powder measurements were made at the Department of Earth and Environmental Sciences at the

University of Veszprém using a Philips PW 1710 type diffractometer with a PW 1730/10 generator, a PW1050/70 type goniometer, a graphite single crystal monochromator and a proportional counter detector. The instrumental parameters of the measurements were CuK<sub>α</sub> X-ray source, 40 mA tube current, 50 kV tube voltage, 1°-1° slit system, 0.035°/s velocity of goniometer. Bulk samples were measured on disoriented specimens. <2 μm fraction was separated by sedimentation after dissolution of CaCO<sub>3</sub> by 10% acetic acid and ultrasonic deflocculation. X-ray diffraction analysis of clay minerals was performed on oriented specimens made by smear on glass method. Two X-ray diagrams were taken on each samples of <2 μm fraction: one under natural, air-dried conditions, one after saturation with ethylene glycol.

EMP analyses were performed in the Laboratory for Geochemical Research, Hungarian Academy of Sciences using a JEOL JXA-733 electron microprobe equipped with an Oxford INCA 200 EDS. Operating conditions were 15 keV accelerating voltage, 4 nA sample current, and 100 s counting time. The PAP correction procedure was applied for data preparation.

Mineral chemistry data was calculated by MINPROG computer program written by Sz. Harangi (Eötvös University, Budapest). For spinel Fe<sup>2+</sup>-Fe<sup>3+</sup> calculation Droop's equation (1987) was used.

### X-RAY POWDER DIFFRACTION INVESTIGATIONS

From the whole drilling sequence of Gyód-2 borehole twelve samples were chosen for X-ray powder diffraction (Table 2). Qualitative and semiquantitative determinations were carried out on whole samples and fraction of <2 μm.

The main phases of the examined rocks are mostly serpentine minerals (30-60%), talc (10-30% in the samples of No. ÁGK-7004, 7033, 7083/b and 7084) and chlorite (10-20% in the samples of No. 7004, 7033, 7083/b and 7084) (Fig 2A-D). The amount of dolomite can be estimated 10-20% (in the samples of No. ÁGK-7004, 7022, 7024, 7028, 7029 and 7039). Quartz (7022), olivine (7083/b) and spinel (7033, 7035) reaches 10-20% in several samples, however, these are generally minor phases together with dolomite, calcite and orthopyroxene. The sample No. 400389 contains unique components which were not detected elsewhere in this well log. It consists of mostly chlorite (clinocllore), talc and anthophyllite. As a minor phases actinolite and serpentine were analysed.

The determination of multiphase serpentine minerals is rather uncertain, however, in several samples we can analyse surely chrysotile (probably  $2O_{rcl}$  symmetry orthochrysotile) and (probably 1T) lizardite. Most samples consist of more than one serpentine mineral, but antigorite was not detected in anyone.

Regarding some uncertainties in the determination of phyllosilicates, the separated, oriented samples of  $<2 \mu\text{m}$  fractions were examined again, which represent Mg-chlorite, and swelling phase was not detected. On the base of peak maxima between 7.06-7.10 Å and 3.48-3.53 Å, presence of kaolinite can be precluded.

#### MINERAL CHEMISTRY

During microprobe analysis we tend to determine the chemical compositions of the relic minerals in three samples. Mostly olivine and orthopyroxene composed the unaltered ultramafic rock. According to the pervasive serpentinization, only these two primary minerals can be found in certain sheared, strongly foliated, mylonitized lenses, zones (Fig. 2C, D). Other parts of the well log are completely serpentinized where olivine altered to mesh structure unites, pyroxenes and/or amphiboles to bastites.

There are textural and chemical differences between Opx of No. ÁGK-7084 and ÁGK-7083 sample. In the No. ÁGK-7084 sample the Opx are

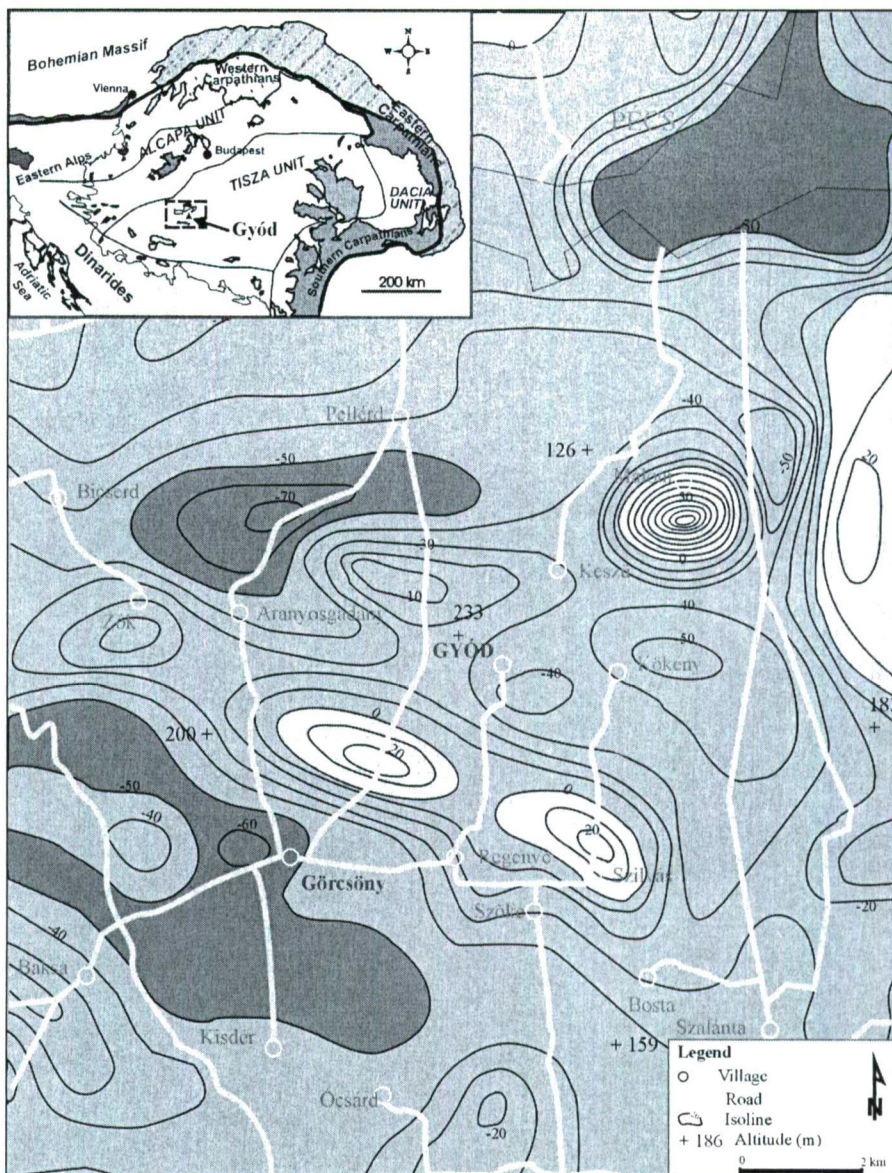


Fig. 1. Schematic geomagnetic map of the location of Gyód Serpentinite Body (after Barabás et al., 1969)

Table 1. Mineral composition of Gyód Serpentinite body in the earlier studies

Authors	minerals
Erdélyi, 1970	lizardite, hydrochrysotile, clinochrysotile, chlorite, talc, montmorillonite, biotite, muscovite, albite, bytownite, clinoenstatite, tourmaline, magnetite, boehmite, diaspore, lepidocrocite, brucite, wilkeite, calcite, dolomite, ankerite
Ghoneim, 1978	enstatite+olivine, lizardite+chrysotile, chlorite+dolomite, chromite, magnetite, pentlandite, pyrrhotine
Balla, 1985	enstatite <sub>1</sub> , olivine, enstatite <sub>2</sub> , anthophyllite, talc <sub>1</sub> , magnetite <sub>1</sub> , antigorite, talc <sub>2</sub> , carbonates, magnetite <sub>2</sub> , chlorite, Cr-magnetite, chrysotile, lizardite

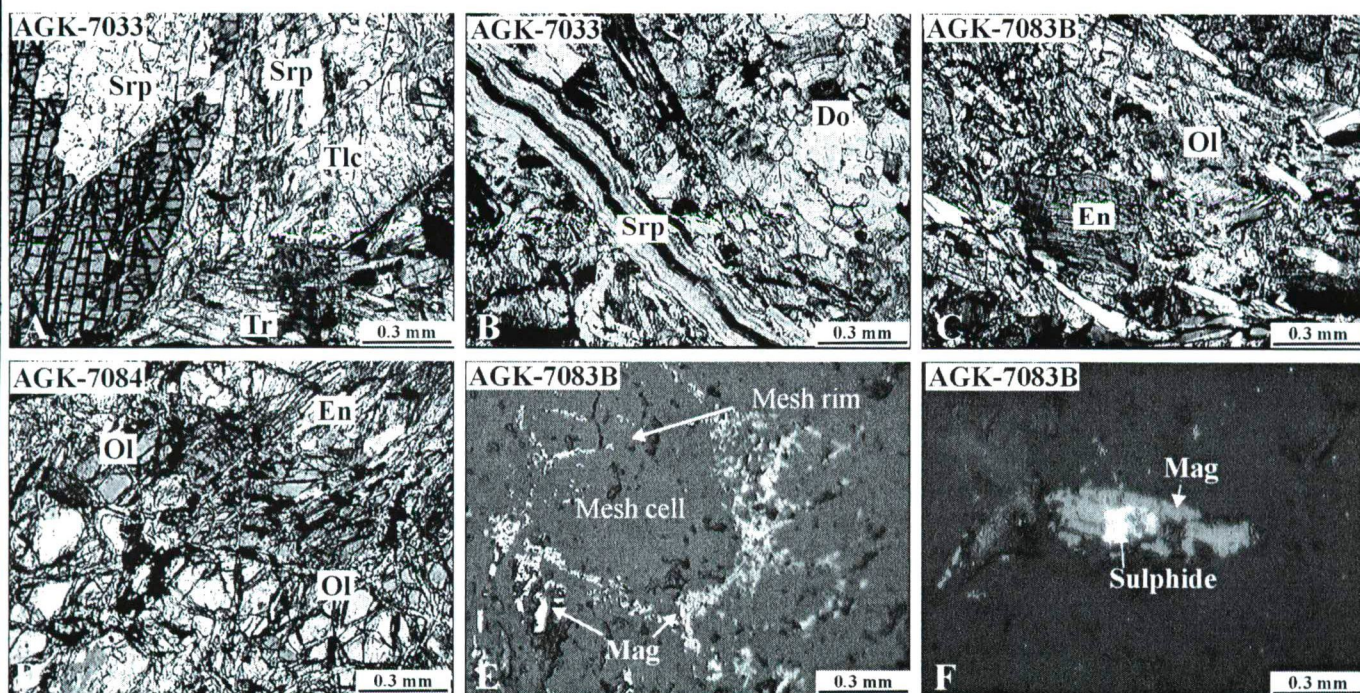
more elongated and larger (up to several cm) than in the No. ÁGK-7083. The NiO content (mean value: 0.15 wt%), CaO content (0.11 wt%) is higher, and MnO content (not determined) is smaller in ÁGK-7084 than in the ÁGK-7083 (Table 3) where NiO and CaO are not determined, MnO

is 0.3-6.3 wt%. The FeO content is the same in the samples, ca. 6-7 wt%. The Mg# is higher in the ÁGK-7083 (0.96-1.0) while 0.91 in the ÁGK-7084. Orthopyroxenes are enstatite 88-92%. Olivine compositions are rather similar; there are not any significant differences between the studied samples ( $FO_{91-92}$ ).

**Table 2.** Results of XRD analysis - abbreviations used after Kretz (1983)

sample	sample description	major components	minor components or uncertain analyses
ÁGK-7004	whole rock: white-greenish matrix	chl, tlc, liz, dol	cal (?), qtz, kln (?)
ÁGK-7022	white lamellar cast	dol, qtz, chry	mgs (?)
ÁGK-7024	greenish-brownish vein	dol, chry	liz (?), qtz
ÁGK-7028	complex vein: green srp and white fibrous cast	chry, dol	qtz
ÁGK-7029	white fibrous vein	chry, dol	-
ÁGK-7031	light green, yellowish vein	chry	liz (?)
ÁGK-7033	whole rock	chry, liz, tlc, chl, spl	cal, dol (?), kln (?)
ÁGK-7035	whole rock	chry, liz, spl	chl, dol, qtz
ÁGK-7037	elongated, columnar bastites	chry, liz	spl, dol
ÁGK-7039	whites grey massive crystalline cast	dol, liz	spl
ÁGK-7083/b	relic ultramafite	chl, tlc, ol	opx, spl (?), chry (?), liz (?), kln (?)
ÁGK-7084	whole rock	liz, chl, tlc	opx, dol (?), mgs (?), spl (?), kln (?)
400389	whole rock	chl, tlc, ath	act, srp

abbreviations: cal: calcite, chl: chlorite, chry: chrysotile, dol: dolomite, spl: spinel, kln: kaolinite, liz: lizardite, mgs: magnesite, ol: olivine, opx: orthopyroxene, qtz: quartz, tlc: talc, srp: serpentine minerals, ath: anthophyllite, act: actinolite.

**Fig. 2.** Photomicrographs of studied samples (abbreviations are the same than in Table 2)**Table 3.** Chemical composition of examined pyroxenes

sample	7083B			7084			7083		
	Opx1	Opx2	Opx3	Opx1	Opx2	Opx3	Opx1	Opx2	Opx3
MgO	36.95	36.67	36.36	37.41	37.03	36.79	36.32	36.98	36.47
Al <sub>2</sub> O <sub>3</sub>	0.00	0.10	0.38	0.24	0.25	0.00	0.00	0.09	1.06
SiO <sub>2</sub>	56.06	55.78	55.56	55.93	55.99	56.46	56.34	55.78	55.52
CaO	0.12	0.05	0.15	0.11	0.17	0.13	0.00	0.00	0.14
TiO <sub>2</sub>	0.00	0.05	0.10	0.00	0.07	0.00	0.19	0.00	0.19
V <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
MnO	0.00	0.00	0.32	0.00	0.00	0.00	0.27	0.25	6.28
FeO	6.87	7.35	7.13	6.31	6.37	6.62	6.88	6.91	0.00
NiO	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.01	100.01



[Mg#= $Mg/(Mg+Fe)$ ] of spinels show a small compositional variety, ranging from 0.91 to 0.94 and from 0.14 to 0.20.

During examination of opaque minerals pentlandite ( $Fe_{18.73}Ni_{33.82}Co_{0.63}S_{46.82}$ ) was analysed in which other iron sulphide (pyrrhotite, or pyrite) component phase was pointed out (Fig. 2E). Magnetite grains compose the boundary (central parting) of mesh cell and rim the sulphide phases (Fig. 2F).

#### DISCUSSION AND CONCLUSION

Pervasive serpentinization caused alteration of primary minerals and formation of chrysotile, lizardite, talc, Mg-chlorite, quartz, magnetite and carbonates. Anthophyllite was formed probably by thermal effect of an aplite dyke because it occurs exclusively close to it. Consequently, serpentinization was a general process which affected the whole serpentinite body, while formation of anthophyllite should have meant local event. We assume that anthophyllite formation followed the serpentinization, because of they have much more fresh texture than primary olivine and enstatite. Probably the intruded aplite dyke metamorphosed the ultramafic rocks which had already been serpentinized.

Mineral compositions of Gyód Serpentinite were determined by X-ray powder diffraction and electron microprobe. On the basis of the composition of relict minerals ( $Fe_{90-91}, En_{90-92}$ ) the unaltered rock should have been harzburgite corresponding with earlier results (Balla, 1983; Kovács, 2000). The high ratio of forsterite component in olivine can suggest that the partial melting of a lherzolitic protolith resulted this depleted residuum. The spinel composition also confirms depleted character of the studied rocks since Cr# is 0.92-0.94. Cr# of spinel in lherzolites and harzburgites depends mainly on the degree of partial melting and the initial composition of the melting rocks. On the base of literature (e.g. Stevens, 1944; Pober and Faupl, 1988) one can distinguish the less depleted lherzolites from harzburgites in the sense of Cr# of spinels (Fig. 4). The upper limit of Cr# in lherzolites are 0.5, and 0.3 is the lower in harzburgites. The high Cr# value of the examined spinels reinforces the harzburgitic composition of unaltered rock of Gyód Serpentinite.

**Table 5.** Chemical composition of studied spinels

sample	ÁGK-7083B		ÁGK-7084			
	spl1	spl2	spl1	spl2	spl3	spl4
MgO	2.66	3.08	3.82	3.06	3.04	2.72
Al <sub>2</sub> O <sub>3</sub>	2.00	2.25	2.67	1.80	1.71	2.04
SiO <sub>2</sub>	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.00	0.00	0.00	0.00	0.00	0.00
TiO <sub>2</sub>	0.90	0.95	1.07	1.16	1.13	1.32
V <sub>2</sub> O <sub>3</sub>	1.07	0.58	0.56	0.28	0.72	0.54
Cr <sub>2</sub> O <sub>3</sub>	40.20	40.17	41.17	40.47	39.70	40.14
MnO	0.08	0.70	0.29	0.70	0.58	1.06
Fe <sub>2</sub> O <sub>3</sub>	24.07	24.73	23.42	24.85	25.33	24.14
FeO	28.59	27.53	26.99	27.68	27.79	28.03
Sum.:	99.57	99.99	99.99	100.00	100.00	99.99
Cation numbers based on 32 (spinel phases) or 3 (rhombohedral phases) oxygens						
Mg	1.1640	1.3368	1.6440	1.3312	1.3232	1.1848
Al	0.6912	0.7720	0.9088	0.6192	0.5888	0.7024
Si	-	-	-	-	-	-
Ca	-	-	-	-	-	-
Ti	0.1984	0.2080	0.2320	0.2544	0.2480	0.2896
V	0.2512	0.1344	0.1296	0.0648	0.1680	0.1264
Cr	9.3336	9.2496	9.4024	9.3408	9.1704	9.2752
Mn	0.0192	0.1720	0.0704	0.1728	0.1432	0.2624
Fe <sub>3</sub>	5.3192	5.4200	5.0904	5.4592	5.5688	5.3088
Fe <sub>2</sub>	7.0216	6.7056	6.5200	6.7576	6.7896	6.8512
CAT#:	23.9992	24.0000	23.9976	24.0000	24.0000	24.0008
mg#:	0.14	0.17	0.20	0.16	0.16	0.15
cr#:	0.93	0.92	0.91	0.94	0.94	0.93
End-members for spinels						
Spi	4.33	4.83	5.68	3.87	3.68	4.39
Her	-	-	-	-	-	-
Gah	-	-	-	-	-	-
Gal	-	-	-	-	-	-
Qua	2.48	2.60	2.90	3.18	3.10	3.62
Mfe	5.27	6.69	9.07	6.41	6.66	3.18
Cou	1.57	0.85	0.81	0.41	1.05	0.79
Tre	-	-	-	-	-	-
Fra	-	-	-	-	-	-
Jac	0.24	2.15	0.88	2.16	1.79	3.28
Usp	-	-	-	-	-	-
Nic	-	-	-	-	-	-
Mnc	-	-	-	-	-	-
Pic	-	-	-	-	-	-
Chr	58.36	57.84	58.78	58.41	57.34	58.00
Mag	27.75	25.05	21.87	25.56	26.37	26.73
SUM:	99.95	99.96	99.97	99.96	99.95	99.95

The plots of examined samples fall into the metamorphic spinel field.

On the base of spinel composition the different alpine type peridotites can be divided into three groups (Dick and Bullen, 1984). The Cr# of the examined spinels is greater than 0.6, consequently these belong to Type III which are refractory and pyroxene-poor, consisting largely harzburgite and enstatite-rich dunite. Previous petrographic and geochemical studies

resulted similar mineral composition (Balla, 1983, 1985; Kovács and M. Tóth 2000; Kovács, 2000). Type III peridotites are related to the earliest stages of arc-formation on oceanic crust environments which may be preserved in the tectonized material found in the forearc regions of many modern island-arcs. Most of the Alpine-type peridotites are the residues of partial melting and the generation of magmas in island-arc.

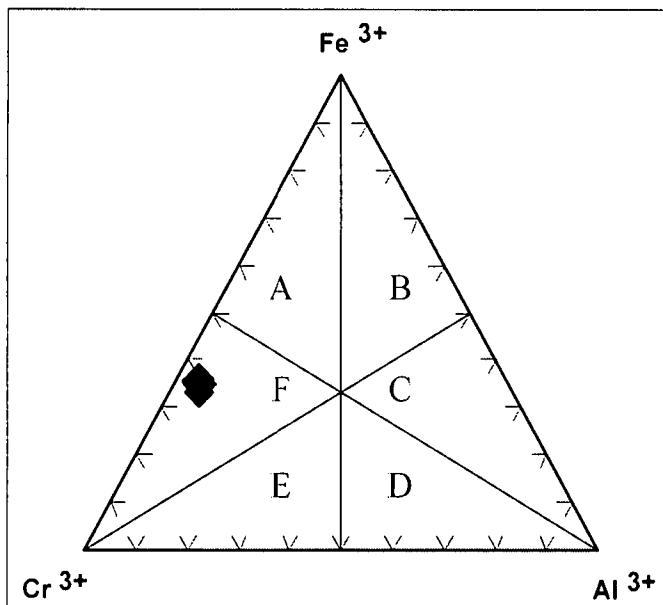


Fig. 3. Trivalent ion diagram for spinel nomenclature (after Stevens, 1944): A, chromian magnetite; B, aluminian magnetite; C, ferrian spinel; D, chromian spinel; E, aluminian chromite; F, ferrian chromite

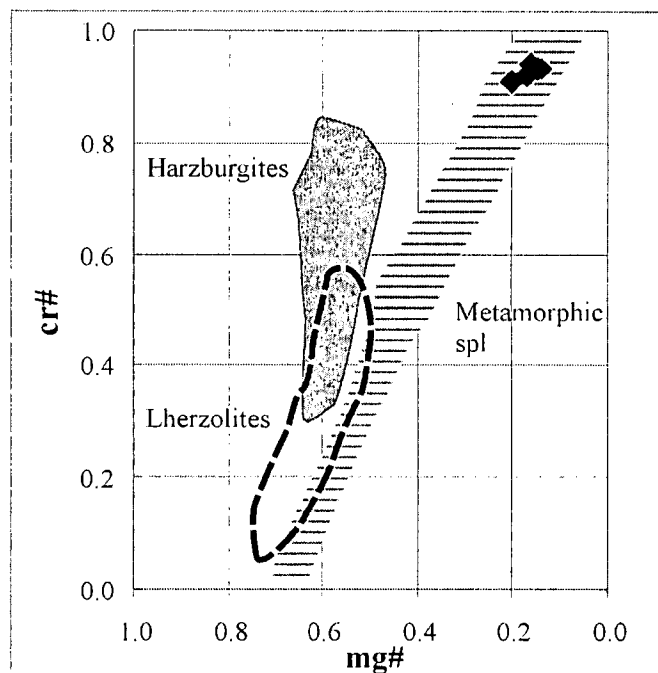


Fig. 4. Chemical composition of studied spinel plotted on Cr# vs. Mg# diagram using compositional field after Stevens (1944)

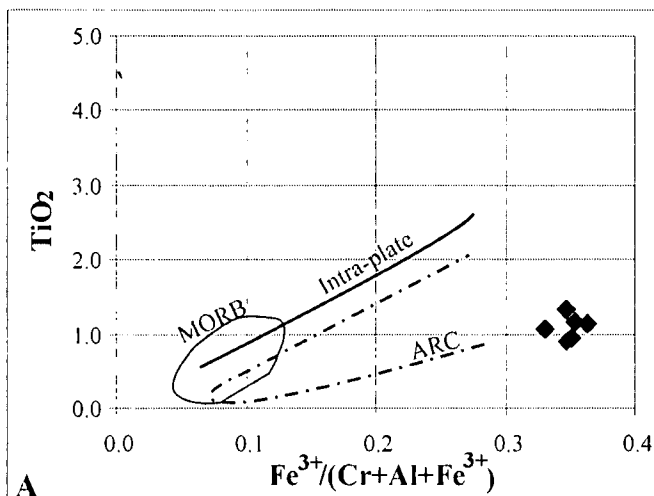
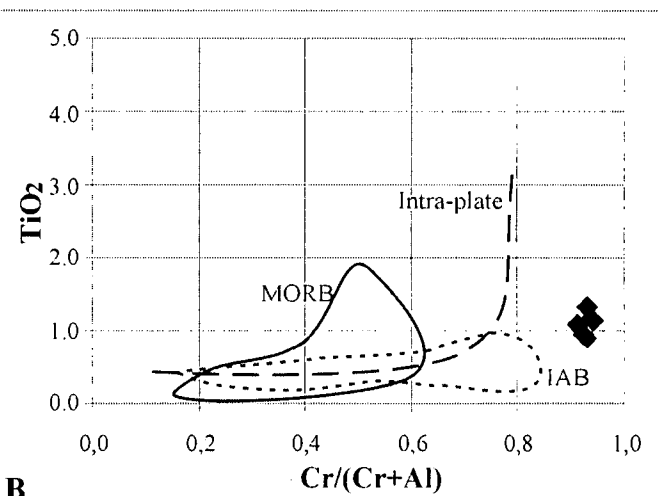


Fig. 5. Chemical analyses of studied spinel in the TiO<sub>2</sub> wt% vs. Fe<sup>3+</sup># diagram (A), and TiO<sub>2</sub> wt% vs. Cr# diagram (B). Discrimination lines after Arai (1992)



The TiO<sub>2</sub> content of chromian spinels is useful for separating mid-ocean ridge, island-arc and intra-plate basalts (Arai, 1992). TiO<sub>2</sub> content increases from island-arc magmas through MORB to intra-plate tholeiitic basalts. Spinel derived from upper mantle peridotites usually have TiO<sub>2</sub> content lower than 1.0-1.2 wt%. On the diagrams of TiO<sub>2</sub> vs. Fe<sup>3+</sup># and TiO<sub>2</sub> vs. Cr#, (Arai, 1992) (Fig. 5A, B), we suggest that the samples related more to island-arc region than to intra-plate or ocean ridge environment. This is supported by the Type III peridotites character of the examined rocks, but further geochemical investigations are necessary to verify this statement.

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