New data on chromitites from Dobromirtsi, Eastern Rhodopes

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Introduction

Podiform chromitites are widespread in most ophiolite complexes worldwide. They occur at variable depths in the mantle sequence, which is made up of variably depleted harzburgites, minor dunites and rare pyroxenite layers or dykes. Chromitites can be concordant, sub-concordant or discordant to the primary foliation, caused by mantle flow of the host peridotite, and are surrounded by a variable-thick dunite envelope. In most ophiolitic complexes, mineral chemistry of chromite varies according to the location of chromitite bodies in the mantle sequence: Cr# = Cr/(Cr+Al) tends to increase with deepness. Thus, chromitite bodies located in the mantle-crust transition zone [e.g. in the Oman (Ahmed and Arai, 2002) and Mayarí-Baracoa, Cuba (Proenza et al., 1999) ophiolites], contain chromite rich in Al_2O_3 (Cr# between 0.40 and 0.55), but chromitite bodies located in deeper regions of the mantle contain chromites progressively rich in Cr_2O_3, exhibiting Cr# up to 0.90. The bulk platinum-group element (PGE) content of chromitites also varies with their location in the mantle sequence and consequently, is closely related to the Cr_2O_3 content of chromite: PGE concentration increases with increasing Cr# of chromite (e.g. Crocket, 1979; Economou-Eliopoulos, 1986; Leblanc, 1991, 1995; Ahmed and Arai, 2002; Gervilla et al., 2005). With the exception of few deposits, ophiolitic chromitites generally concentrate Os, Ir and Ru, and are highly depleted in Pt and Pd (e.g. Leblanc, 1991, 1995; Prichard et al., 1996; Zhou et al., 1998, 2001; Ahmed and Arai, 2002; Gervilla et al., 2005).

Geological setting

The ultramafic rocks, considered in the present study, belong to the Borovitza lithotectonic unit — the upper most unit of the Variegated Complex. The unit is separated from the underlying Startzevo unit by the Borovitza fault zone. According to Ovcharova et al. (2001) this unit comprises marbles, biotite gneisses and gneisoshists, porphyric and equigranular granites, massive metabasic and the studied serpentinized ultramafic rocks (fig. 1). During the Upper Oligocene small granite bodies are also emplaced in the Borovitza fault zone. The grade of metamorphism is amphibolitic, without any signs of migmatization. The unit is limited above by the Kurdjali shear zone.

The age of the ultramafic body here remains undetermined. Traditional views on the geological history of the Rhodopes regards them as Paleozoic or older (Бончев, 1986), but more recent studies tend to accept Mesozoic age (Ivanov, 1989; Ricou et al., 1989). According to Zhelyazkova-Panayotova et al. (2000), the Dobromirtsi ultrabasite is the biggest one in the country. Its outcrop area is over 11 km^2. It is platy shaped and NW dipping.

Structural features of the Dobromirtsi massif

The Dobromirtsi massif is a small ultramafic body slightly elongated along the NE-SW direction. It is mainly composed of highly serpentinized harzburgites containing variable amounts of orthopyroxene and abundant dunites. Both types of rocks are cut by few centimeter-thick, strongly folded (nearly isoclinal) layers of pyroxenites. Two different foliations have been recognized: 1) a possible mantle foliation defined by the elongation of pyroxene and spinel crystals in porphyroclastic rocks, and 2) a later, almost mylonitic foliation. Mantle foliation tend to be transposed by the later one and as a consequence is difficult to be observed in the field. It has been clearly measured in the NW part of the massif where it is oriented N-S, dipping 45° to the West. It is partly preserved in the orientation of the pyroxenite layers. In the northern part of the massif some of these layers are oriented E-W, dipping 75° to the north. This

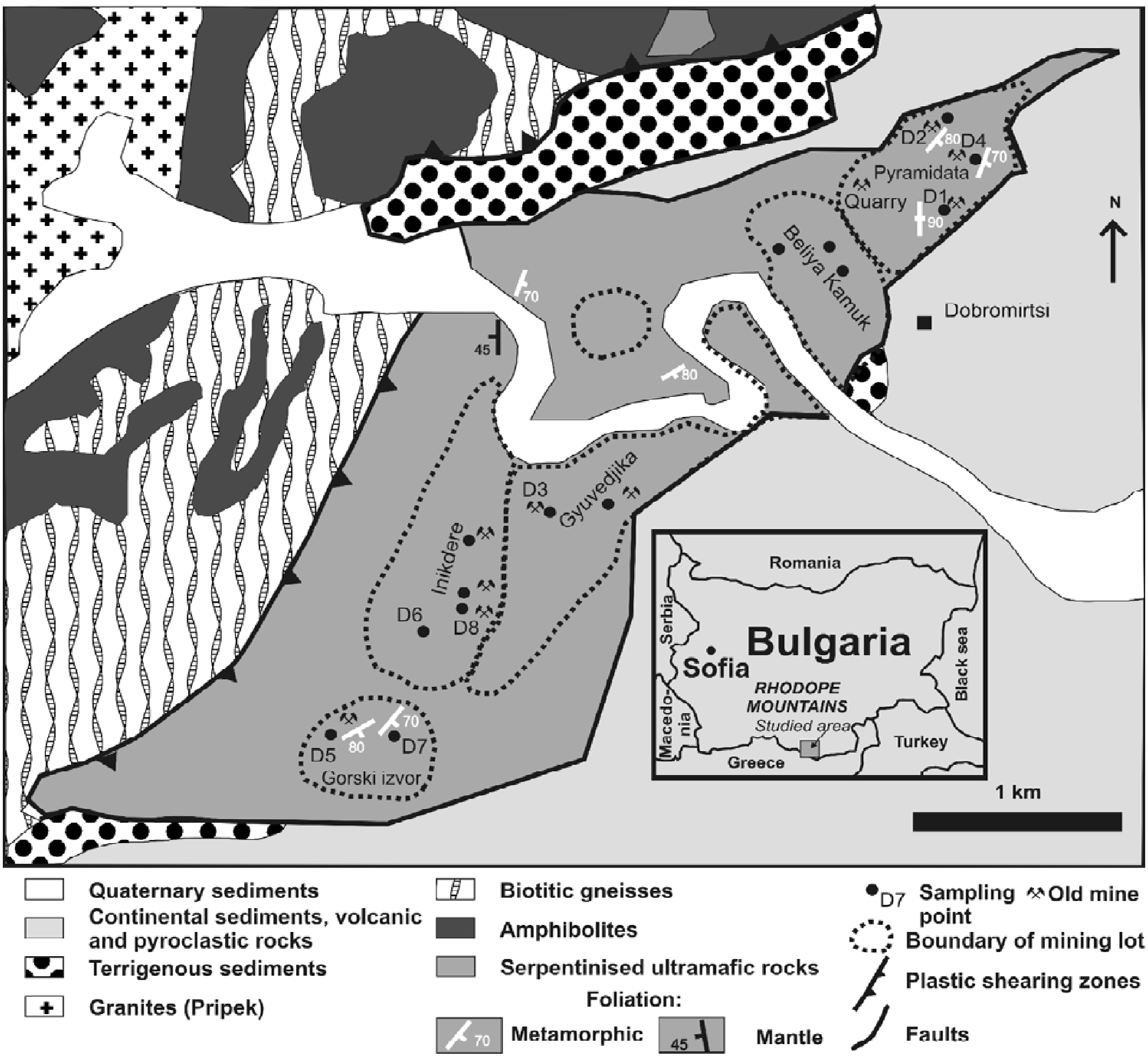

Fig. 1. Symplified geological map of the Dobromirtsi ultramafic body area

foliation is given in black on fig. 1. The late mylonitic foliation (white) tends to be vertical and is probably related either to the crustal emplacement of the peridotites or to the amphibolite-facies regional metamorphism that affected the Rhodopes. This foliation strikes 20-60°, dipping 70-80°. Its general strike is 40°, but slightly deviates at SW and NE ends of the body.

Chromite deposits

Chromitite bodies, recognized in the Dobromirtsi massif, are all concordant to the mylonitic foliation of the host peridotites and located along a single, dunite-rich horizon. This means that they probably formed at similar deepness in the ophiolitic mantle. Accordingly, mineral chemistry of unaltered chromite in the different bodies studied is relatively homogeneous, having Cr# between 0.57 and 0.77 (fig. 2b). On fig. 2a altered chromites with higher Fe^{3+} are also shown. The PGE contents also vary within a restricted range (from 60 to 234 ppb total PGE). Like in most ophiolitic complexes, the studied chromitites are rich in Os, Ir and especially Ru (from 37 to 135 ppb) and strongly depleted in Pt and Pd (mostly below 2 ppb). These PGE contents agree with the mineralogy of the identified PGE. Platinum-group minerals (PGM) occur as single or composite, minute (<50 μm) inclusions in chromite. The most abundant PGM recognized is laurite (RuS_2) which constitutes more than 70% of the total PGM, and has a similar chemical composition in the different chromitites (Os between 0.1 and 8 at.% and less than 2.5 at.% Ir). Other mineral phases identified are Os-Ir alloys and Ir sulfarsenides.

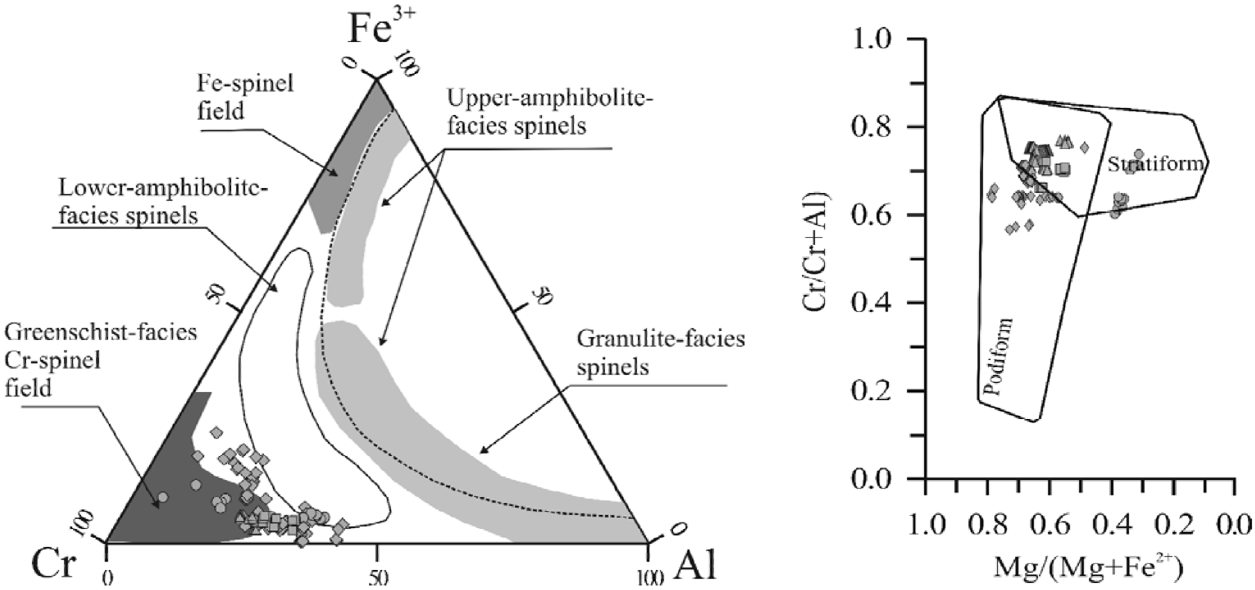

Fig. 2. Composition of the Dobromirtsi chromites, according to: a) Occupation of the trivalent cation position, and b) Cr# vs. Mg#. Sample locations: diamonds — D1, circles — D2, triangles — D3, squares — D4

Chromitites are predominantly massive, grading to disseminated towards the borders of the body. Most of them are variably fractured, and altered along grain boundaries and cracks. During alteration, chromites lost Al_2O_3 and MgO, and become rich in FeO and Fe_2O_3, giving rise to a phase known as ferritchromite. Similarly, we have observed an increase in the amount of arsenide phases disseminated in the silicate matrix of the chromitites and a partial replacement of those PGM which were liberated from the chromite grains during fracturing. All these PGM are replaced by arsenide-bearing phases.

Concluding remarks

As a consequence of our study we can state that the Dobromirtsi massif constitute a dismembered portion of an ophiolitic sequence affected by an amphibolite-facies metamorphic event after its emplacement in the crust. Mantle processes still recorded in the massif include intensive partial melting that promoted the formation of abundant dunites, containing several chromitite bodies along a single mantle horizon. The primary mantle foliation is almost completely transposed to a nearly vertical, mylonitic foliation produced either during the crustal emplacement of the peridotites or, more probably, during the metamorphic event. This deformation gave also rise to the fracturation of the chromitites and metamorphism driven fluid circulation in the peridotite body causing the alteration of chromites to ferritchromite and introduced significant amounts of arsenic from the surrounding metapelitic, locally mineralized rocks.

The presence of Os-rich alloys is an interesting feature of the Dobromirtsi massif. These alloys are typically attributed to extreme ***P-T*** conditions in the lowermost mantle. However, recently Brenker et al. (2003) showed that they could form in much shallower mantle areas, in arc-environment, where H_2O-rich fluids and siliceous melts (e.g., boninites) are produced in the mantle wedge above the descending and dehydrating plate. Arc environment is proposed for the formation of Dobromirtsi massif also by Zhelyaskova-Panayotova and Economou-Eliopoulos (1994). However, according to the recent studies, such environment occurs in the Rhodopes not earlier than the late Mesozoic and can be used as a hint to the age of formation of the ultramafic massif. Thus, the Os-rich alloys here can provide a mineralogical evidence for the regional geological concepts.

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Нови данни за хромититите от Добромирци, Източни Родопи

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Резюме. Малко ултрабазитово тяло, изградено предимно от силно серпентинизирани харцбургити, перидотити и дунити и на места процепено от пироксенити, се разкрива в района на с. Добромирци. Шистозността на скалите е близка до вертикалната 70—90° и с посока СИ—ЮЗ, сравнително добре издържана с известно отклонение в СИ и ЮЗ краища на тялото. Следи от първична мантийна фолиация се наблюдават на изолирани места. Хромитовите орудявания са конкордантни на шистозността на вместващите перидотити и са разположени в един богат на дунити хоризонт, което е указание за вероятното им образуване на една и съща дълбочина в мантията. Такова предположение се потвърждава от незначителните вариации в хромовия номер на хромитите — от 0,57 до 0,77. Съдържанието на елементите от платиновата група също варира в тесни рамки — от 60 до 234 ppb общо ЕГП. Както при повечето офиолити, и тук орудяването е набогатено на Os, Ir и особено на Ru (37—135 ppb) и силно обеднено на Pt и Pd. Присъствието на Os-Ir сплави е интересен факт. Тяхното образуване до скоро се свързваше с екстремални температури и налягания, възможни само в най-дълбоките мантийни нива. Нови изследвания обаче доказаха, че в островнодъгови условия, в относително по-плитката мантийна част над субдуциращата и дехидратиращата се плоча е възможно образуването на такива сплави в резултат на интензивното хидратиране на мантийното вещество. Този факт може да служи като минераложки аргумент при позиционирането на Добромирските ултрабазити в регионален контекст.