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Granitoids associated with East Vardar ophiolites (Serbia, F.Y.R. of Macedonia and northern Greece): Origin, evolution and geodynamic significance inferred from major and trace element data and Sr–Nd–Pb isotopes

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ABSTRACT

The paper presents and discusses a new set of major, trace and Sr–Nd–Pb data concerning Upper Jurassic granitoid rocks associated with the East Vardar ophiolites. These rocks form a discontinuous belt from Serbia in the north to northern Greece in the south. Two major styles of granitoid magmatism are recognized: (1) the southern granitoids form large intrusions cutting both the East Vardar ophiolites and the metamorphic rocks of the Serbo-Macedonian massif; (2) the northern granitoids are small petrogenetically variable bodies that are always spatially associated with ophiolites; these are probably multiphase, resulting in numerous low-volume granitoid intrusions within ophiolites. The southern granitoids (except at Fanos, N Greece) form an almost complete suite of decreasing radiogenic neodymium ($\varepsilon_{Nd}(T)$=3.3 to −8.9) and increasing radiogenic strontium (Sr_i=0.70740–0.71588) with increasing silica contents, and assimilation fractional crystallization (AFC) processes seem to have played an important role in their petrogenesis. Their primary magmas most probably originated by melting of a slightly enriched MORB-like mantle. The Fanos granite is a special case as it is characterized by a uniform isotopic composition for differently evolved rocks (Sr_i=0.70516–0.70559, $\varepsilon_{Nd}(T)$=−1.6 to −0.7). This granite is interpreted to have derived from lower crustal melts that differentiated mainly through fractionation processes. The northern granitoid group consists of intermediate rocks (Sr_i=0.70557–0.70746, $\varepsilon_{Nd}(T)$=−4.5 to −0.8), high-Sr_i granites (Sr_i=0.70956–0.71602, $\varepsilon_{Nd}(T)$=−6 to −5.1, HREE- and Y-enriched) and low-Sr_i granites (Sr_i=0.70330–0.70767, $\varepsilon_{Nd}(T)$=−5.1 to 1.5). High-Sr_i granites are interpreted to have crystallized from peraluminous magmas generated by fusion of (meta)sedimentary rocks caused by obduction-induced melting. The northern intermediate rocks and the related low-Sr_i granites have a wider range of composition and may be explained as genetically different rock groups. Some of them could have originated during obduction-induced melting of a source that was different from the source of high-Sr_i granitoids, whereas others could be products of subduction-related volcanic arc magmatism.

1. Introduction

The central Balkan Peninsula is characterized by a complex geotectonic framework which mainly developed during Mesozoic convergence and collision processes. There is general agreement that the Tethys finally closed during the late Mesozoic and that the Dinaride (west) and the Vardar Zone (east) ophiolites represent relicts of formerly wide oceans. Some of the main issues for understanding the Mesozoic geodynamics of this region are related to the nature and origin of these ophiolite belts, as well as to the age and mode of their emplacement. This problem has been commonly addressed by studying basalts and peridotites, whereas granitoid rocks that are closely associated with the ophiolites both in space and time have received little attention.

Granitoids associated with ophiolites, although volumetrically small, provide important constrains on geodynamic setting. Generally, the ophiolite-related granitoids can be divided into: (1) oceanic plagiogranites and trondhjemites (e.g. Coleman and Peterman, 1975; Pedersen and Malpas, 1984; Floyd et al., 1998), (2) pre-collision calc-alkaline to adakitic subduction-related rocks (e.g., Li and Li, 2003; Kamei, 2004), (3) calc-alkaline and alkaline collision-related granitoids, connected with the final emplacement of ophiolites (e.g., Brown and D'Lemos, 1991; Karsli et al., 2007), and, in some rare cases (4) exotic blocks of granitoid rocks, which tectonically incorporated into a trench assemblage during subduction (e.g., Cvetković et al., 2004a).

This study focuses on a regional suite of predominantly peraluminous calc-alkaline granitoid rocks, which crop out along the border

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between the easternmost Vardar Zone and Serbo-Macedonian Massif (Fig. 1). These occurrences include granitoids in Serbia (localities Ždraljica near Kragujevac, and Kuršumlija), F.Y.R. of Macedonia (localities Štip, Gradeška Mt and Furka) and northern Greece (Fanos). Most granitoid occurrences of this region have not been investigated geochemically. For example, granitoids associated with mafic ophiolitic rocks in Serbia were previously studied, mostly petrographically and commonly regarded as acid differentiation products of basic rocks (Dolić et al., 1981; Hadži-Vuković et al., 1981). Thus, in the absence of geochemical evidence, all of the ophiolite-related granitoids occurring in Ždraljica and Kuršumlija were classified as oceanic plagiogranites. Recently, Resimić (2000) demonstrated that the granites intruding the Ždraljica ophiolites do not all have trondhjemitic compositions. Instead, these granitic rocks compositionally resemble collision-related granites and this places new constraints on the possible geotectonic setting of these ophiolites. The southern granitoids have been studied in slightly more detail previously. The petrography and age of the calc-alkaline granitoids from F.Y.R. of Macedonia were studied by Šoptrajanova (1967) and Mercier (1965). The age of the Fanos intrusion was determined by Anders et al. (2005), while Pearce (1989), Christofides et al. (1990) and Soldatos et al. (1993) discussed some aspects of its petrogenesis.

In this paper we present and discuss a full set of geochemical data, including major and trace element concentrations and Sr–Nd–Pb isotope ratios for granite and associated intermediate magmatic rocks. The study includes samples from all of the known occurrences of Jurassic granitoids in Serbia and most of the occurrences in F.Y.R. of Macedonia, whereas sampling in Greece was restricted to the Fanos granite. The focus of this study was: (i) to characterize the granitoids geochemically, (ii) to try to recognize petrogenetically different rock groups, and (iii) to constrain the origin and evolution of the granitoids. The petrogenesis of the granitoid magmatism places constraints on the evolution of the East Vardar Zone and, thus, indirectly on the Mesozoic geodynamic setting of this region.

2. Geotectonic setting

The central Balkan Peninsula (Fig. 1) is characterized by a complex suture dominated by two ophiolitic belts: (i) The Dinaride ophiolite belt, which stretches NW–SE from north Bosnia–Herzegovina and west Serbia (e.g. Karamata, 2006) towards Albania and Greece as Mirdita–Pindos ophiolite belt (e.g. Pe-Piper and Piper, 2002; Robertson, 2002; Karamata, 2006), and (ii) the Vardar Zone ophiolites which can be traced along a NNW–SSE line from Belgrade to Thessaloniki. Interpretations of the origin and evolution of these ophiolites range from those involving an 'one ocean model' (e.g. Bernoulli and Laubscher, 1972; Smith and Spray, 1984) to those involving up to three different ocean domains (e.g. Karamata, 2006). Most authors,

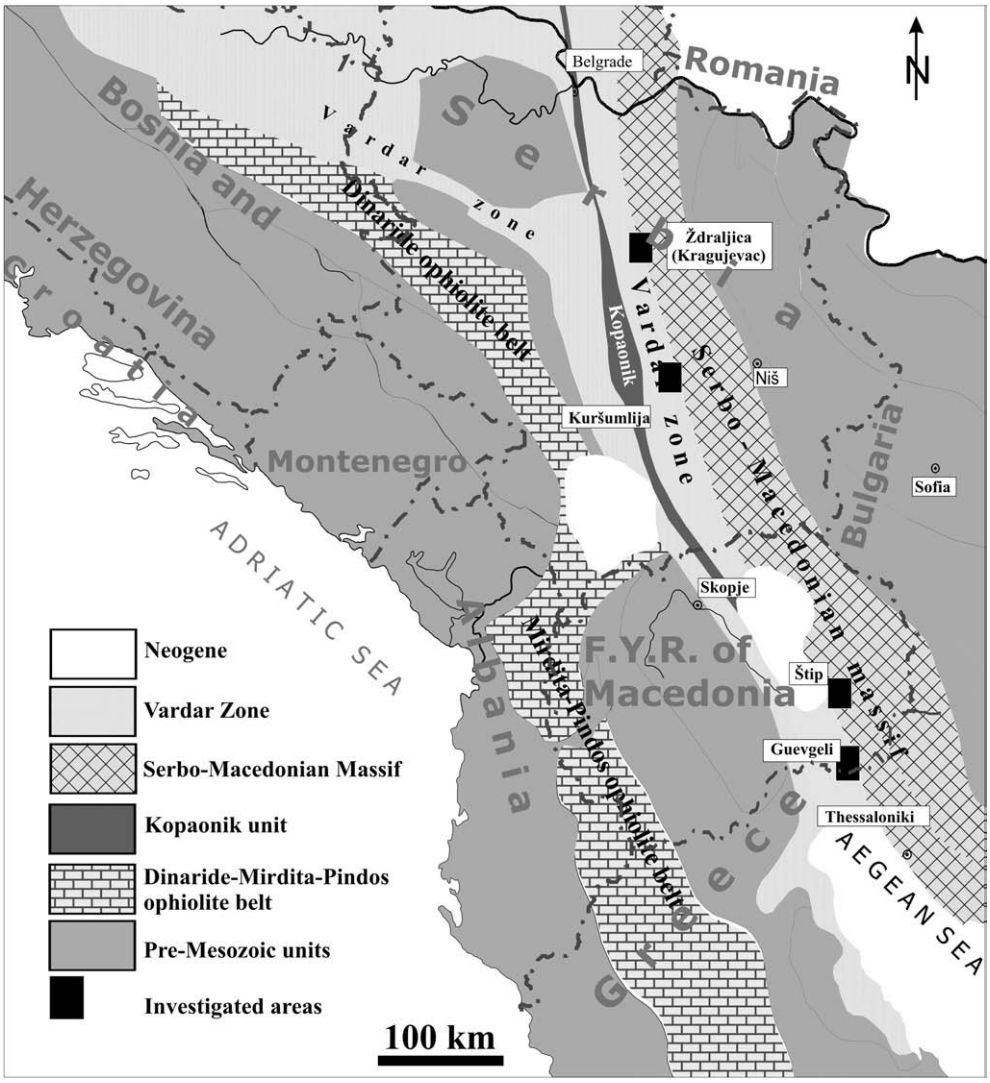

Fig. 1. Simplified geological map of the central axis of the Balkan Peninsula showing the position of the Upper Jurassic granitoids (Karamata, 2006).