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Pre-Alpine evolution of a segment of the North-Gondwanan margin: Geochronological and geochemical evidence from the central Serbo-Macedonian Massif

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ABSTRACT

The Serbo-Macedonian Massif (SMM) represents a composite crystalline belt within the Eastern European Alpine orogen, outcropping from the Pannonian basin in the north, to the Aegean Sea in the south. The central parts of the massif (i.e. southeastern Serbia, southwestern Bulgaria, eastern Macedonia) consist of the medium- to high-grade Lower Complex, and the low-grade Vlasina Unit. New results of U–Pb LA-ICP-MS analyses, coupled with geochemical analyses of Hf isotopes on magmatic and detrital zircons, and main and trace element concentrations in whole-rock samples suggest that the central SMM and the basement of the adjacent units (i.e. Eastern Veles series and Struma Unit) originated in the central parts of the northern margin of Gondwana. These data provided a basis for a revised tectonic model of the evolution of the SMM from the late Ediacaran to the Early Triassic.

The earliest magmatism in the Lower Complex, Vlasina Unit and the basement of Struma Unit is related to the activity along the late Cadomian magmatic arc (562–522 Ma). Subsequent stage of early Palaeozoic igneous activity is associated with the reactivation of subduction below the Lower Complex and the Eastern Veles series during the Early Ordovician (490–478 Ma), emplacement of mafic dykes in the Lower Complex due to aborted rifting in the Middle Ordovician (472–456 Ma), and felsic within-plate magmatism in the early Silurian (439 ± 2 Ma). The third magmatic stage is represented by Carboniferous late to post-collisional granites (328–304 Ma). These granites intrude the gneisses of the Lower Complex, in which the youngest deformed igneous rocks are of early Silurian age, thus constraining the high-strain deformation and peak metamorphism to the Variscan orogeny. The Permian–Triassic (255–253 Ma) stage of late- to post-collisional and within-plate felsic magmatism is related to the opening of the Mesozoic Tethys.

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1. Introduction

The Alpine orogen is probably the best studied orogenic belt and yet there are several parts where the geological history is still very poorly resolved. These inadequately studied areas hinder the accuracy of global tectonic models, especially those concerning the pre-Alpine evolution. Prime example of such areas are the crystalline basement units of southeastern Europe, which were often omitted from the large-scale tectonic models. However, the last twenty years brought significant amount of knowledge concerning the palaeogeographic position and tectonic evolution of a number of crystalline units previously considered to be ancient microcontinents trapped within the Eastern European Alpine orogenic belt (e.g. Tisza, Rhodope; Kober, 1921). These recent studies revealed that such terranes represent complex collages of reworked continental (and locally oceanic) crust and sediments actively involved in several phases of Alpine deformation and metamorphism (e.g. Ivanov, 1988; Burg et al., 1990, 1996; Liati and Gebauer, 1999; Burg, 2012). Among these terranes, the tectonic position and evolution of the Serbo-Macedonian Massif (SMM) outcropping in Serbia, southwest Bulgaria, Macedonia, and northern Greece, remains enigmatic (Fig. 1). It becomes crucial for valid reconstruction of the long and complex interaction of Gondwana- and Laurussia-derived crustal segments presently outcropping along the Balkan Peninsula (e.g. Munteanu and Tatu, 2003; Himmerkus et al., 2009a; Kalvoda and Bábek, 2010; Meinhold et al., 2010; Kroner and Romer, 2013), to resolve the enigma concerning the provenance and geological history of the Serbo-Macedonian Massif. Recent studies in the Greek part of the SMM reveal a complex

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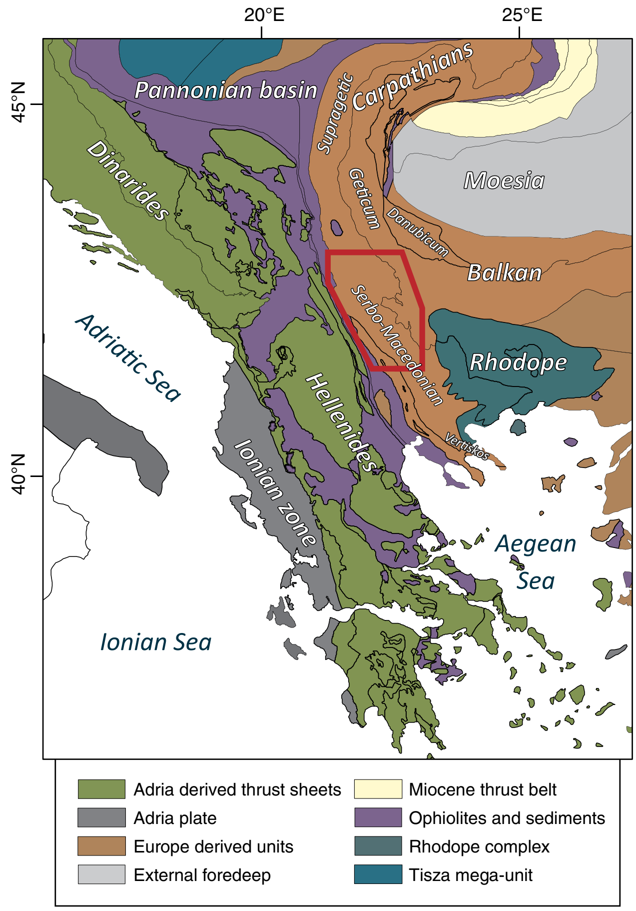

Fig. 1. Tectonic sketch of the Balkan Peninsula (after Schmid et al., 2008; van Hinsbergen and Schmid, 2012) with the position of the study area (dark polygon).

metamorphic and tectonic history since the Cambrian, including intense Alpine overprint suggesting that what we today refer to as the Serbo-Macedonian Massif is not a single tectonic unit (e.g. Kilias et al., 1997; Brun and Sokoutis, 2007; Himmerkus et al., 2007).

In order to provide a basis for reliable reconstruction of the early tectonic history of crystalline units in southeastern Europe, this article presents evidence for the origin and evolution of the SMM obtained through analyses of U–Pb isotopic ages of magmatic and detrital zircons coupled with Hf isotope analysis of the dated zircons and whole-rock geochemical analysis of major and trace elements. The analyses were performed on a wide range of rock types in all units constituting the SMM in southeastern Serbia, southwestern Bulgaria and eastern Macedonia, with additional samples from the adjacent tectonic domains occasionally reported as parts of the SMM (Brković et al., 1980; Dolić et al., 1981; Karamata and Krstić, 1996; Dimitrijević, 1997). The results of the geochronological and geochemical analyses allow correlation with similar units of the Eastern Mediterranean Alpine orogen. These data are used to propose a model of tectonic evolution of the study area and adjacent domains since the late Neoproterozoic until the earliest Mesozoic. This dataset will serve as a sound basis for further research including more detailed sedimentary provenance analyses and geochemical correlations in the wider region, which could correct the deficiencies in the palaeogeographic reconstructions and tectonic models concerning the early evolution of tectonic units presently located in the Eastern Mediterranean Alpine orogen.

2. Geological setting

The Serbo-Macedonian Massif extends from the Aegean Sea to the Southern Carpathians (Fig. 1) where it is correlated with the Supragetic nappe sequence (Dimitrijević, 1997; Iancu et al., 2005). It should be noted that although our study concerns only the pre-Alpine evolution of the SMM, the names of the tectonic units discussed below refer to the Alpine orogen so that results presented here could be correlated with the previously published tectonic frameworks of southeastern Europe. The SMM in Serbia and Macedonia represents an entirely metamorphic belt comprising a structurally lower unit (the Lower Complex) and an upper unit (Vlasina Unit), as originally proposed by Dimitrijević (1957). These units are commonly differentiated on the basis of their metamorphic grade, with the Lower Complex predominantly metamorphosed at medium to lower amphibolite facies, and the Vlasina Unit at greenschist facies. The boundary of these two units is usually reported as tectonic, i.e. the Vrvi Kobila shear zone (Fig. 2). This contact was previously described as a pre-Mesozoic west-vergent brittle thrust of Vlasina Unit over the Lower Complex (Vukanović et al., 1973; Krstić and Karamata, 1992), or a post-Late Cretaceous dextral shear zone (Kräutner and Krstić, 2002). The continuations of the Lower Complex and Vlasina Unit in Bulgaria are referred to as the Ograzhden block (Dimitrijević, 1967; Zagorchev, 1984a; Dabovski et al., 2002) and Morava Unit (Zagorchev, 1985; Zagortchev, 1993), respectively. The Vertiskos Unit in Greece is traditionally considered as the continuation of the Lower Complex of the SMM (Kockel et al., 1971; Burg et al., 1995; Himmerkus et al., 2009a; Meinhold et al., 2010; Burg, 2012). Based on the available geological records from the Greek and Bulgarian extents of the SMM, its provenance was previously assigned to the eastern Avalonian (Meinhold et al., 2010) or Cadomian (Stampfli et al., 2002; von Raumer et al., 2003; Balintoni et al., 2010b; Meinhold et al., 2010; Kounov et al., 2012) assemblages of terranes within the Neoproterozoic north-Gondwanan arc.

During the late Early Cretaceous, the Vlasina Unit was thrust to the east onto the Getic units along a system of east- to northeast-vergent thrusts (Petković, 1930; Mihailescu et al., 1967; Petrović, 1969; Zagorchev and Ruseva, 1982; Zagorchev, 1984b; Lilov and Zagorchev, 1993; Kounov et al., 2010). In southwestern Bulgaria and northern Greece the contact of the Ograzhden block and the Vertiskos Unit with the Rhodope complex is traced along the Strymon Valley and Kerdillion detachments (Dinter and Royden, 1993; Brun and Sokoutis, 2007; Kounov et al., 2015). The distinction between the SMM and the Rhodope complex was often challenged in the past (Popović, 1991; Ricou et al., 1998; Grubić et al., 1999, 2005), although their differences were firmly established in the Greek and Bulgarian parts of the SMM during the past two decades (Burg, 2012 and references therein). A large number of studies in Bulgaria and Greece have shown that the Rhodope complex was formed during the Alpine orogeny (e.g. Burg et al., 1996; Kaiser-Rohrmeier et al., 2004; Liati, 2005; Bosse et al., 2009; Turpaud and Reischmann, 2010), whereas the SMM lacks the high-grade Cenozoic overprint (Georgiev et al., 2010; Kounov et al., 2010, 2012).

The SMM is bounded to the west by Mesozoic sediments and Jurassic ophiolites of the Eastern Vardar suture zone (e.g. Karamata, 2006; Schmid et al., 2008; Meinhold et al., 2009; Robertson et al., 2009). In the study area this contact is reported as a strike-slip fault, an east-vergent thrust (Krstić and Karamata, 1992), or a westward thrust which was partially reactivated as a dextral strike slip fault in the Neogene (Kräutner and Krstić, 2002). South of the Lece andesitic complex, the Lower Complex of the SMM is in tectonic contact with the metamorphic rocks of the Eastern Veles series (Fig. 2). The oldest reported, non-metamorphosed, sedimentary rocks that overlie crystalline rocks of the SMM are Middle Triassic (Karamata and Krstić, 1996; Dimitrijević, 1997).

Earlier studies suggest that being previously variably metamorphosed, the Lower Complex and Vlasina Unit have been amalgamated and subsequently accreted to the Moesian platform during the Variscan orogeny (Karamata and Krstić, 1996; Haydoutov and Yanev, 1997). An alternative scenario proposes that the southern extent of the SMM (i.e. Vertiskos Unit) had joined the European craton in the Late Jurassic to Early Cretaceous (Himmerkus et al., 2009a). Schmid et al. (2008) suggest that the Eastern Vardar ophiolites are at a structurally higher position in respect to the SMM due to the Late Jurassic obduction and final

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