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Late Cretaceous intra-oceanic magmatism in the internal Dinarides (northern Bosnia and Herzegovina): Implications for the collision of the Adriatic and European plates

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ABSTRACT

The Kozara Mountains of northern Bosnia and Hercegovina form part of the internal Dinarides and host two tectonically juxtaposed ophiolitic successions of different age. The southern part of the Kozara Mountains exposes the Western Vardar Ophiolitic Unit, which was obducted onto the Adriatic margin in the Late Jurassic. The northern part exposes a bimodal igneous succession that was thrust onto the Western Vardar Ophiolitic Unit during the latest Cretaceous to Early Paleogene. This bimodal igneous succession comprises isotropic gabbros, doleritic dikes, basaltic pillow lavas and rhyolites. Pelagic limestones, intercalated with pillow lavas, yielded a Campanian globotruncanid association, consistent with concordant U–Pb ages on zircons from dolerites and rhyolites of 81.39±0.11 and 81.6±0.12 Ma, respectively.

Chondrite-normalised rare earth element patterns of the bimodal igneous rocks show enrichment of LREE over HREE. Primitive mantle-normalised multi-element diagrams do not reveal significant depletion of HFSE. The εNd(T) and initial $^{87}Sr/^{86}Sr$ isotopic values range from +4.4 to +6.3 and from 0.70346 to 0.70507 respectively, suggesting an intraoceanic origin.

The bimodal igneous succession is unconformably overlain by Maastrichtian to Paleocene siliciclastics that contain abundant ophiolitic detritus, suggesting reworking of the Campanian magmatics. An Eocene turbiditic sandstone succession unconformably covers both the Western Vardar Ophiolitic Unit and the Late Cretaceous bimodal igneous successions. These observations suggest that the Adriatic Plate and the Europe-derived Tisza and Dacia Mega-Units were still separated by a deep basin floored by oceanic lithosphere until the Campanian and that its closure did not occur before the Maastrichtian to earliest Paleogene. This Late Cretaceous oceanic domain probably represented a remnant of the Vardar Ocean, or alternatively, the Alpine Tethys; possibly the traces of both oceanic domains were connected in the area.

1. Introduction

1.1. Large-scale tectonic setting

The widespread occurrence of ophiolites is one of the most distinctive features of the Dinarides and Hellenides of the Balkan Peninsula. They can be traced for about 1000 km along strike, from the area of Zagreb (Croatia) in the northwest to the Peloponnesus (Greece) in the southeast and beyond (Fig. 1). In map view, the ophiolites exposed west of a line Zagreb–Beograd–Skopje form two parallel, spatially separate belts (Smith and Spray, 1984). Petrographic and geochemical differences between the ophiolites of the two belts were used as evidence for the existence of two distinct oceanic basins, originally separated by one or several Adria-derived micro-continents that included the Drina-Ivanjica, Jadar and Pelagonian blocks (Robertson and Karamata, 1994; Dimitrijević, 1997, 2001; Karamata, 2006; Dilek et al., 2008). This 'two ocean' model contrasts with that of Bernoulli and Laubscher (1972), Smith and Spray (1984) and Pamić et al. (2002), who suggested an origin of both ophiolitic belts in one ocean. Schmid et al. (2008) support the 'single ocean' model and consider the two belts of ophiolites as relics of the same, formerly coherent ophiolitic sheet (their Western Vardar Ophiolitic Unit) that was obducted onto the Adriatic passive margin in the Late Jurassic and was disrupted by Cretaceous to Tertiary thrusting. Thrusting has exposed units derived from the Adriatic margin below the ophiolitic units in the form of windows, which were interpreted as micro-continents by earlier authors (Fig. 1).

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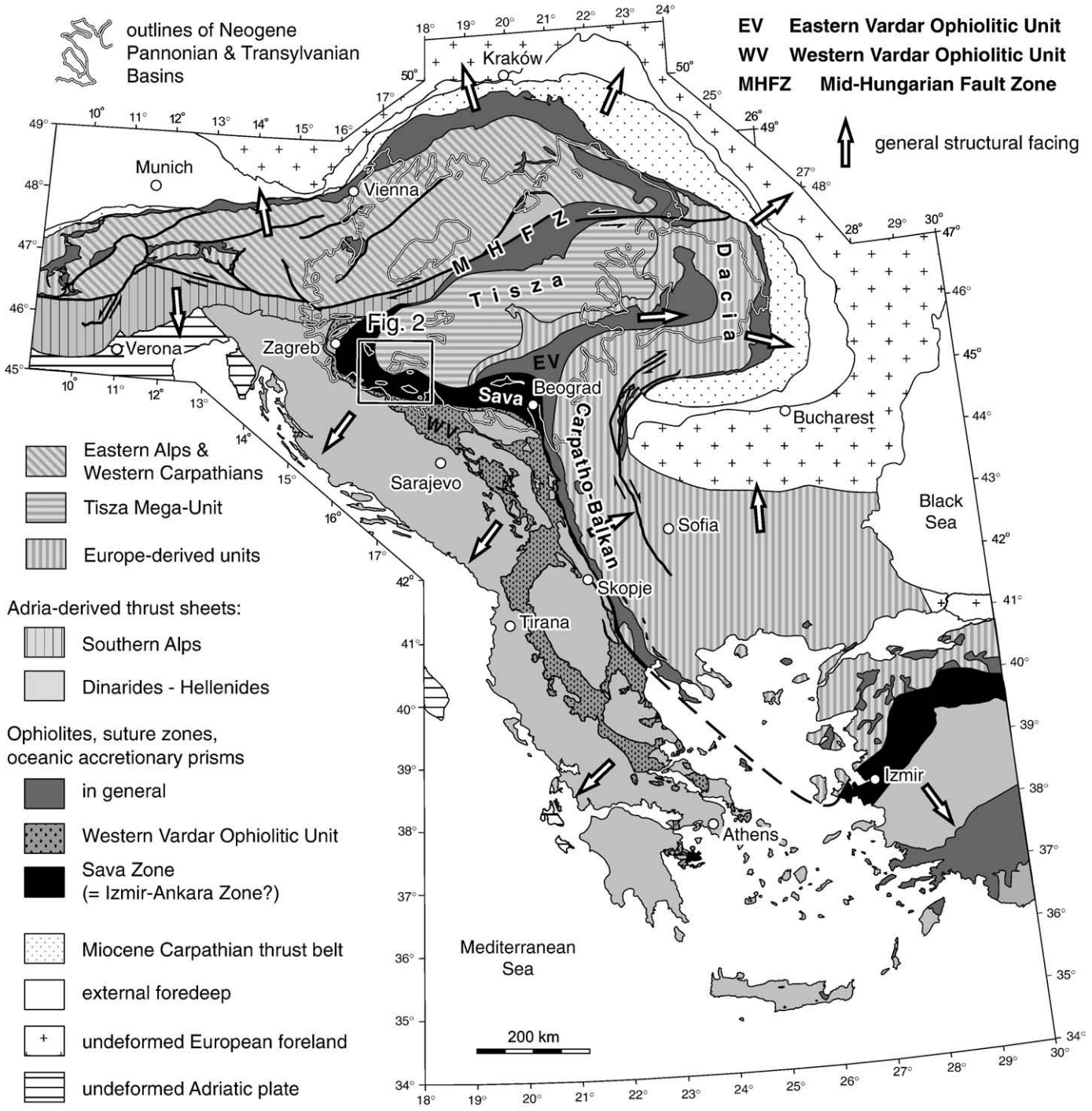

Fig. 1. Major tectonic units of the Alps, Carpathians, Dinarides and Hellenides (north of 42°N, simplified after Schmid et al., 2008).

The spatial separation of these ophiolitic belts gave rise to a number of different names. The western (external) belt is referred to as Dinaride (or Dinaridic) ophiolite belt (Robertson and Karamata, 1994; Pamić et al., 2002), or as the Central Dinaridic ophiolite belt (Lugović et al., 1991). The eastern (internal) belt has a variety of names: Western Vardar ophiolites (Karamata, 2006), Inner Dinaridic ophiolite belt (Lugović et al., 1991), External Vardar Subzone (Dimitrijević, 1997, 2001) or simply Vardar Zone (Robertson and Karamata, 1994; Pamić et al., 2002). The terminology adopted here follows that of Schmid et al. (2008), who refer to the two belts located west and east of the Drina-Ivanjica unit as Dinaridic and Western Vardar ophiolites, respectively, in a structural sense. Since Schmid et al. (2008) regard the two ophiolitic belts as having formed in the same ocean, they use "Western Vardar Ophiolitic Unit" (WV; Fig. 1) when collectively referring to both the ophiolite belts and the ocean from which the ophiolites were derived. There is yet another ophiolitic branch of the Vardar Ocean, located further to the east, referred to as the Eastern Vardar Ophiolitic Unit (Fig. 1).

1.2. When did the Vardar Ocean close?

A controversial topic is the time of the closure of the Vardar Ocean that led to collision of Adria with smaller Europe-derived plates like the