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Editorial
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Understanding geodynamics of the long-lasting Adria – Europe convergence: New constraints from the central Balkans

Ana Mladenović[1], Uroš Stojadinović[1], Vladica Cvetković[1] & Dejan Prelević[1]

Abstract. The Central Balkan region offers particular insights into the very last episodes of the life of oceanic domains that existed between Adria and Europe. This special issue highlights some of the latest developments in the geological research of this important area with a rather small but eclectic selection of papers aimed at better understanding of the geodynamics of the long-lasting Adria – Europe convergence. The road ahead involves more detailed investigations and key studies, including sedimentology, geochronology, provenance and microtectonics, to further enhance our knowledge about the issues that are opened or discussed in this volume.

Scope

Understanding the paleo-history of converging continental plates, including the nature of their boundaries, kinematics, dynamics, and shape, has long been a persistent challenge in the field of geology. The process of such reconstructions is complicated due to multi-phase deformation, which can introduce significant modifications in response to substantial shortening and strike-slip deformation. Consequently, piecing together the puzzle of all these geological events remains a challenging task.

The Balkan sector of the Alpine-Himalayan collisional orogenic belt may serve as a natural laboratory for studying the long-lasting Adria – Europe convergence, which has been active since the Mesozoic period (Schmid et al., 2008). Within the Balkans, numerous tectonomagmatic and sedimentary formations provide valuable insights into the fundamental phases of orogenesis. In this region, extensive and ongoing research has focused on several significant geological issues.

The primary issue revolves around the identification of the number of oceanic domains that existed during the Mesozoic era and the origin of geographically and geochemically diverse ophiolitic belts that dominate the region's geological composition. Geographically, the Balkans exhibit two distinct and parallel ophiolite belts: the Eastern Vardar ophiolite belt and the Western Vardar ophiolite belt (Schmid et al., 2008; Cvetković et al., 2016). The origin and emplacement mechanisms of the Balkan ophiolites have been the subject of intense debate, particularly concerning whether these ophiolites originated from single or multiple oceans (Schmid et al., 2008). However, most recent studies have reached a consensus regarding the geodynamics and origin of these two Vardar belts. The Eastern Vardar belt is interpreted as a Jurassic back-arc basin that underwent rapid closure shortly after its

[1] University of Belgrade, Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia.

formation (Boev et al., 2018) and subsequently obducted towards the east (Schmid et al., 2008). On the other hand, the Western Vardar ophiolite belt is considered to be a substantial fragment of the Neotethys oceanic lithosphere, which experienced relatively uniform westward obduction onto the passive margin of northern Gondwana (Schmid et al., 2008). Although these studies have produced significant knowledge, several questions still remain unanswered. These include the origin and emplacement of the Balkan ophiolites, the development of a viable physical model for obduction, a more precise kinematics of this process, the response of the mantle and crust, and the geochemistry of the volcanic oceanic crust, among others.

Another topic in Balkan geology which needs more answers is related to the late stages of the Tethyan closure and, related to that, the precise timing of the Europe-Adria collision. For a considerable period, the prevailing notion suggested the concurrent closure of all Tethyan oceanic segments with the obduction of ophiolites during the Late Jurassic, thereby implying the absence of any remaining oceanic lithosphere during the Cretaceous (Maksimović & Jovanović, 1988; Robertson & Karamata, 1994; Csontos et al., 2004; Karamata, 2006). During this time, it was widely believed that the convergence between Europe and Adria culminated in the complete consumption of the Tethyan oceans. However, this paradigm has been changed by the discovery of Upper Cretaceous pillow basaltic lavas and sheeted dykes in the Kozara Mts., which were interpreted as part of a dismembered ophiolitic formation (Karamata et al., 2005; Ustaszewski et al., 2009; Cvetković et al., 2014). An important observation is that several Upper Cretaceous magmatic formations are dominantly concentrated along the central axis of the Balkan Peninsula, within a relatively narrow belt known as the Sava Zone. Based on this perspective, it was suggested that the final closure of the last Tethyan ocean occurred at the end of the Cretaceous along the Sava Zone, with complete subduction of its oceanic lithosphere in the Late Cretaceous (Schmid et al., 2008; Ustaszewski et al., 2010; Gallhofer et al., 2015; van Hinsbergen et al., 2020). However, recent studies have raised questions about the geodynamic affinity of the magmatic units in the Sava Zone (Prelević et al., 2017; Sokol et al., 2019), indicating that there are still several unresolved key questions regarding the waning stages of Tethyan ocean closure, particularly concerning the triggers and sources of basaltic magmatism, the origin of sedimentary basins, and a more precise determination of the collision's age.

Contribution

The five papers of this volume are arranged by themes, with mineralogical and petrological studies being considered first, followed by microtectonic, petrologic and tectono-sedimenological studies.

Balen & Petrinec (2023, this issue) present infrared spectra (IR) in the O-H stretching region for tourmaline crystals from the magmatic and magmatic-hydrothermal systems of Late Creataceous Moslavačka Gora (Croatia) granite, situated in the immediate Adria – Europe convergence zone. The origin of spectacular nodular tourmaline is attributed to the interaction of a fluid phase from the residual granitic melt with the fluid originating from the wall rock in the low-pressure crustal setting, which was accompanied by relatively rapid cooling. This interaction resulted in an increased dravite content of the nodular tourmaline and is reflected in the observed IR spectral features.

Löwe et al. (2023, this issue) explore the origin of zircon grains by means of U-Pb zircon geochronology, extracted from three magmatic units distributed within the Jadar block Terrain. This is the first provenance study of this potentially exotic continental crustal block.

Maleš et al. (2023, this issue) present a microtectonic study in the Levač region of central Serbia, where the tectonic contacts between the Europe-derived units and the Eastern Vardar Ophiolitic unit are exposed. Their results indicate two ductile contractional deformation phases associated with the thrusting during the latest Jurassic obduction of the Eastern Vardar ophiolites over the European margin and Cretaceous-Paleogene continental collision between Europe and Adria-derived units, respectively.

Velojić et al. (2023, this issue) conducted research on world-class porphyry deposits Bor and

Čukaru Peki, to determine the age and geochemical affinity of the magmatic rocks that formed these ore deposits. The new geochemical analyses confirm that the lavas show adakitic affinity most probably generated through the amphibole fractionation and sulphide saturation.

Stojadinović & Krstekanić (2023, this issue) report on Cretaceous sedimentary formations along the NE Dinarides margin. The Cretaceous sedimentation on the upper plate of the Sava subduction system took place in a fore-arc basin, developed in frontal parts of the active European continental margin. The Cretaceous sedimentation has been interpreted as being deposited in the basin developed over the passive continental margin of the Internal Dinarides and the sediments deposited in the Sava subduction trench. The authors propose three depositional cycles during the Early Cretaceous-Cenomanian, Turonian-Santonian, and Campanian-early Paleogene, reflecting three stages of deformation, contraction, extension, and ultimately contraction again during the Adria-Europe collision.

Concluding remarks

Despite the inherent simplification and subjectivity of the presented overview, we do hope it provides a valuable starting point for understanding the intricate geological structure of the Balkans and the unresolved questions surrounding its geological history. This special issue emerged from the Symposium titled "Travel in Time - Reconstruction of the Tethys' Waning in the Balkans", held in Svilajnac, Serbia, from November 5th to 6th, 2022. The symposium is being held as part of the project of the same name and acronymed "RECON TETHYS", which received support from the Science Fund of the Republic of Serbia, within the call "Ideje" 2021. The aim of this volume is to offer several snapshots of research on significant geological enigmas pertaining to the Balkans within the context of the Alpine-Himalayan orogenic belt. The five papers included in this volume cover a diverse range of topics, offering readers a comprehensive overview of our current knowledge as well as identifying areas that require further improvement.

Acknowledgments

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