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On the position of some Ediacaran–Cambrian Balkanide units along the Cadomian active margin of Gondwana

Относно позицията на някои едиакарско-камбрийски Балканидни единици по протежение на активната Кадомска окрайнина на Гондвана

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Introduction

The Alpine-Himalayan collision zone involves a number of crustal fragments that originated in the Neoproterozoic to Cambrian Avalonian–Cadomian belt of northern Gondwana. This belt developed as an extensive active margin of northern Gondwana during Neoproterozoic to early Cambrian times. The whole belt stretched for about 8000–10000 km, rimming the continental landmass of Archean and Paleoproterozoic cratons, amalgamated during the Pan-African collisional orogeny (e.g., Nance et al., 1991, 2010; Nance and Murphy, 1994; Murphy et al., 2004; Linnemann et al., 2014; Garfunkel, 2015). In contrast, the Cadomian orogeny was accretionary, forming a number of subduction complexes, oceanic arcs, and back-arc basins, and was controlled by Pacific-type subduction of oceanic lithosphere without a hard collision, being one of the most important orogenic events at the time (e.g., Murphy et al., 2002; Stern, 2008). The importance of the Cadomian orogeny for global crustal growth can be readily appreciated from the present-day extent of the Avalonian–Cadomian crustal fragments (often referred to as terranes), which underlie large portions of the Eurasian plate and can be traced from Spain to Iran, though scattered and variably reworked within the younger Caledonian, Variscan, and Alpine orogenic belts. However a significant gap in knowledge still exists, especially on the vestiges of Cadomian orogeny in the Balkan chain of the Alpine orogen in Bulgaria and paleogeographic position of these terranes along the former northern Gondwana margin.

The main goal of this study is to compare the westerly and easterly terranes of the Avalonian–Cadomian orogenic belt and to bridge this gap in understanding their early history. This goal is pursued in three steps. First, we present new U–Pb detrital zircon ages from four Neoproterozoic to early Paleozoic basement units in the Balkans in Bulgaria and Serbia. Second, to place the new data in a broader context, we have compiled an extensive database of igneous and metamorphic zircon ages in Northern Africa and detrital zircon ages from other, possibly correlative terranes from the Eastern Alps through the Carpathians and Balkans to Turkey and Iran. Using a statistical analysis of the data, we quantitatively characterize the degree of similarity of the obtained zircon age spectra. Finally, the statistical analysis of both new and published age spectra is used to interpret the most likely source areas and terrane provenances and to construct a new paleogeographic model involving both westerly and easterly Cadomian terranes.

Results and discussion

We use the detrital zircon U-Pb geochronology to examine four lithotectonic units from different parts of the Balkanide orogen and of probable Cadomian origin, now exposed in Bulgaria and Serbia. Although the Cadomian tectonic evolution of the Balkan terranes has been discussed since the late 1980s (e.g., Haydoutov, 1989), the lack of geochronologic and paleomagnetic data leaves their provenance and original paleogeography still poorly constrained. Our new detrital zircon ages thus not only add to the scarce literature, but also help to track the earliest evolution of Cadomian crustal fragments dispersed today within the Alpine-Himalayan collision zone. We interpret the detrital zircon ages from the four sampled units as pointing to several, originally separate terranes that were likely located in different segments of the Cadomian active margin. These units are characterized by different U-Pb detrital zircon age spectra ranging from a unimodal distribution with a single late Ediacaran peak (Diabase-Phyllitoid Complex in Iskar gorge) through a bimodal distribution with Neoproterozoic and Paleoproterozoic ages (Stara Planina Complex in the central part of the Balkan fold-and-thrust belt) to multimodal distributions that also include rare and common Mesoproterozoic ages (Sredna Gora and Vlasina complexes) – Fig. 1.

A comparison of the detrital zircon ages with igneous and metamorphic ages from the potential source areas in northern Africa suggests different provenances and, hence, original paleogeographic

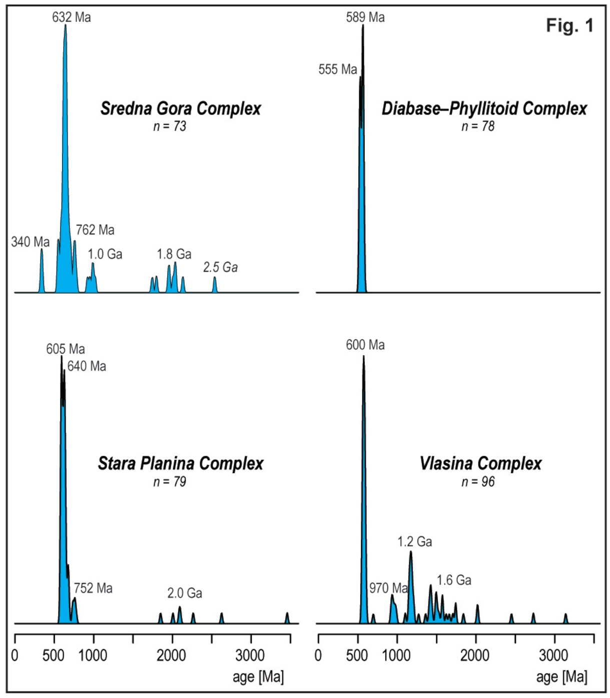

Fig. 1. Kernel density estimate (KDE) curves for the four dated samples showing detrital zircon age distributions with U-Pb data less than 5% discordant; *n* denotes the number of analyses

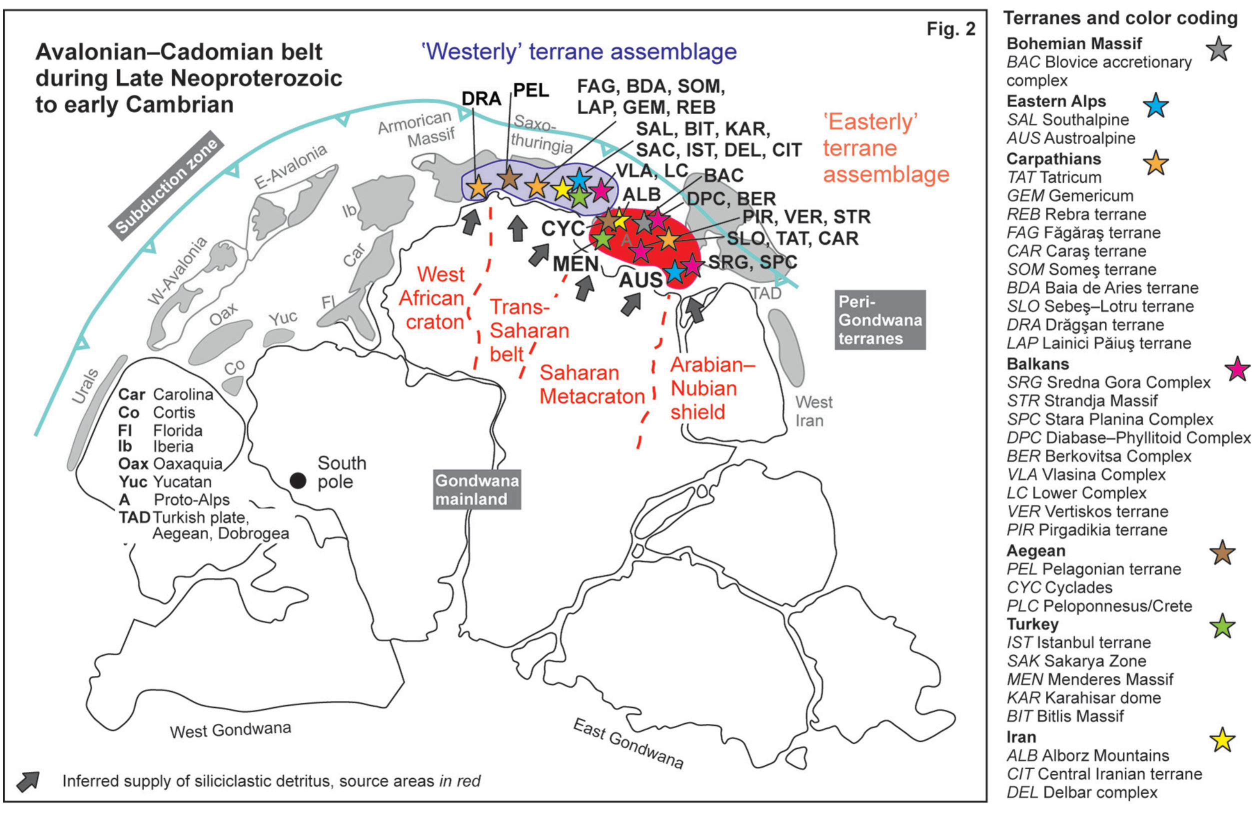

Fig. 2. A tentative paleogeographic map showing the presumed position of terranes discussed in this study along the northern Gondwana margin during late Neoproterozoic to early Cambrian times. The position of each terrane is inferred from a statistical comparison of detrital zircon ages with igneous and metamorphic ages in northern Africa. See text for discussion. The position of Avalonian–Cadomian terranes (in gray) from Linnemann et al. (2004, 2014) and and Stern (1994) is provided for comparison.

positions within the former Avalonian–Cadomian belt (Fig. 2). The sample from the Diabase-Phyllitoid Complex lacks the Paleoproterozoic and Neoarchean zircon ages indicative of a cratonic source and is dominated by Ediacaran (Cadomian) ages with a weighted mean of 571±4 Ma. Hence, it was probably sourced exclusively from a magmatic arc and thus likely formed in an outboard forearc part of the active margin. The available data, however, do not allow a particular paleo-position along the northern Gondwana margin to be identified.

The zircon age spectra and the statistical analysis indicate that the Vlasina Complex was the most „westerly“ positioned terrane, likely sourced from the Trans-Saharan belt, whereas the Sredna Gora and Stara Planina complexes were close to each other, maybe even as parts of a single unit. Our analysis suggests that the latter two complexes, differing in their Variscan evolution (e.g., Balkanska, 2011), initially occupied a common, more „easterly“ position and likely were sourced from both the Saharan Metacraton and Arabian-Nubian shield. On the other hand, similar Ediacaran–Cambrian volcano-sedimentary units aligned today within the Balkan fold-and-thrust belt (from west to east: Berkovitsa, Diabase-Phyllitoid Complex, and Stara Planina Low-Grade Complex), often considered as part of a single terrane (e.g., Haydoutov, 1989; Haydoutov and Yanev, 1997), turn out to be probably distinct units that occupied different positions along the northern margin of Gondwana (Fig. 2). Likewise, our analysis suggests that the lithologically similar Vlasina and Berkovitsa complexes (Fig. 1), tectonically juxtaposed during the Alpine and probably already during the Variscan orogeny (e.g., Kounov et al., 2012; Antić et al., 2016), originated in different parts of the Avalonian–Cadomian belt.

An intriguing pattern emerges from a statistical comparison of detrital zircon ages from the four analyzed units with those from other correlative terranes within the Alpine-Himalayan belt and with the igneous and metamorphic ages from North African source areas. The multidimensional scaling (MDS) method reveals two distinct age groupings, interpreted here as representing two principal paleogeographic positions along the former active margin of Gondwana. The „westerly“ Cadomian terrane assemblage includes the Drăgşan and Pelagonian terranes, characterized by the presence of Mesoproterozoic ages, previously thought to be indicative of exclusively Amazonian source but shown here to be present also in the West African craton. Most of the other terranes were likely supplied from the Trans-Saharan belt (e.g., the Vlasina Complex) or the Saharan Metacraton, or both (Cyclades, Menderes Massif, Alborz). Finally, the "easterly" terranes (Austroalpine, the Sredna Gora and Stara Planina complexes) received detritus from the Arabian-Nubian shield.

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