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Middle Miocene paleoenvironmental crises in Central Eurasia caused by changes in marine gateway configuration

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ABSTRACT

Marine gateways prove to be important factors for changes in the ecology and biochemistry of marginal seas. Changes in gateway configuration played a dominant role in the Middle Miocene paleogeographic evolution of the Paratethys Sea that covered Central Eurasia. Here, we focus on the connection between the Central (CP) and Eastern Paratethys (EP) to understand the paleoenvironmental changes caused by the evolution of this marine gateway. We first construct an integrated magneto-biostratigraphic framework for the late Langhian-Serravallian (Chokrakian-Karaganian-Konkian-Volhynian) sedimentary record of the eastern domain, which allows a correlation to the well-dated successions west of the gateway. The magneto-biostratigraphic results from the Zelensky-Panagia section on the Black Sea coast of Russia show that the Chokrakian/Karaganian boundary has an age of 13.8 Ma, the Karaganian/Konkian boundary is dated at 13.4 Ma, and the Konkian/Volhynian boundary at 12.65 Ma. We identify three major phases on gateway functioning that are reflected in specific environmental changes. During the Karaganian, the EP turned into a lake-sea that supplied a unidirectional flow of low-salinity waters to the west, where the CP sea experienced its Badenian Salinity Crisis. This configuration is remarkably similar to the Mediterranean during its Messinian Salinity Crisis. The second phase is marked by a marine transgression from the west, reinstalling open-marine conditions in the CP and causing marine incursions in the EP during the Konkian. The Volhynian is characterized by a new gateway configuration that allows exchange between CP and EP, creating unified conditions all over the Paratethys. We hypothesize that a density driven pumping mechanism is triggered by the increase in connectivity at the Konkian/Volhynian boundary, which simultaneously caused major paleoenvironmental changes at both sides of the gateway and led to the Badenian-Sarmatian extinction event in the CP.

1. Introduction

Marine gateways play a critical role in the exchange of water, heat, salt and nutrients between oceans and seas and hence impact regional and global climate. Where marine gateways link to marginal basins, the impact of hydrological exchange on the depositional environment can be profound. Even subtle changes to the hydrologic budget can alter the temperature, salinity and circulation of the marginal basin and hence transform its entire depositional environment (e.g. Bethoux and Pierre, 1999; Cramp and O'Sullivan, 1999; Flecker et al., 2015).

The Paratethys is an excellent example of a marginal basin that experienced extreme environmental crises in response to gateway evolution. During the Middle Miocene the Eastern Paratethys (Black Sea-Caspian Sea region) was connected to the open ocean via two shallow restricted gateways; the Barlad Strait to the Central Paratethys and the Trans-Tethyan gateway to the Mediterranean Sea (Popov et al., 2006, Bartol et al., 2014) (Fig. 1a). In addition, findings of polyhaline fauna in Transcaucasia and Northern Iran hint at a possible marine corridor from the South Caspian region to the Eastern Mediterranean (Popov et al., 2015). Variations in gateway configuration caused dramatic paleoceanographic events in the Central Paratethys such as marine invasions (e.g. Sant et al., 2017), huge fluctuations in salinity during the Badenian Salinity Crisis (BSC; e.g. Peryt, 2006), a major biodiversity decrease related to the Badenian Sarmatian Extinction Event (BSEE; Harzhauser and Piller, 2007) and a basin-wide change to brackish and very low salinity water conditions at the base of the regional Sarmatian and Pannonian stages, respectively (e.g. Harzhauser and Piller, 2004; Magyar et al., 1999.

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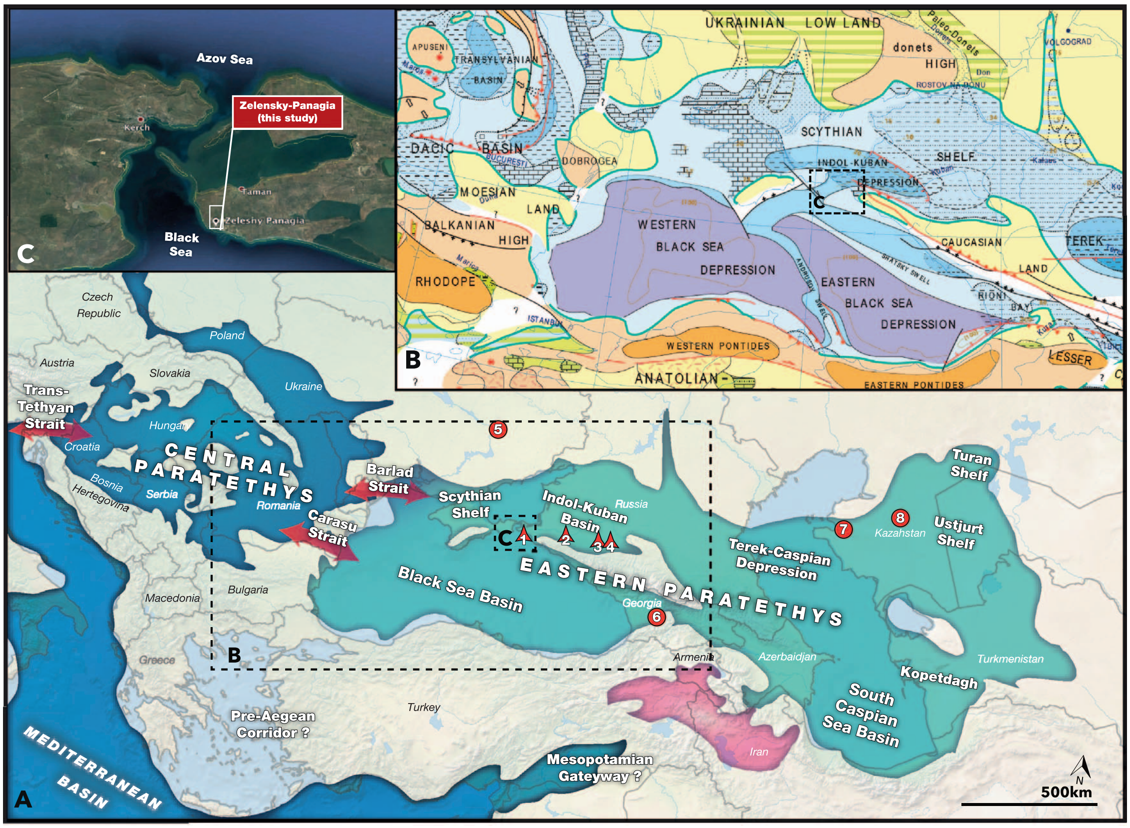

Fig. 1. (A) The Paratethys realm and its major sub-basins as suggested by the distribution of middle Miocene sediments. Marine gateways are figured as red arrows. Geographic position of sections where bio-magneto-stratigraphic studies were conducted (1.Zelensky, 2.CK12000, 3.Pshekha, 4.Belaya) and sections where biostratigraphy was performed (5.Konka River, 6.Naspere, 7.Ujratam, 8.Aschiktaypak); (B) Paleogeographic map for the mid-Konkian – upper Badenian (Kosovian) time (after Popov et al., 2004 map 6) and position of studied section. (C) Zoom on the study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A reliable time frame for the basinal Paratethyan successions is essential to unravel the geodynamic and climatic forcing factors of gateway restriction and to understand the mechanism of paleoenvironmental change. During the last decade, significant progress has been made to date the Central Paratethys successions by radiometric dating and magnetostratigraphy (e.g. Handler et al., 2006; Hohenegger et al., 2009; Vasiliev et al., 2010; De Leeuw et al., 2010, De Leeuw et al., 2013; Bukowski et al., 2010; Paulissen et al., 2011; Selmeczi et al., 2012; Śliwiński et al., 2012; Mandic et al., 2011; ter Borgh et al., 2013; Palcu et al., 2015), allowing correlations to the open ocean climate and sea level records. Radiometric dating indicated that the onset of the BSC in the Paratethys took place at 13.8 Ma and was primarily controlled by climatic changes and in particular by the Mi3 global cooling event which terminates the Middle Miocene Climatic Optimum (De Leeuw et al., 2010). Magnetostratigraphic dating of the BSEE indicated an age of 12.65 Ma which, in contrast, suggested a tectonic forcing affecting in particular the Barlad gateway to the Eastern Paratethys and increasing interbasinal connectivity (Palcu et al., 2015). Magneto-biostratigraphy in combination with radiometric dating showed that the transition to low salinity water conditions of the Pannonian stage was triggered by tectonic uplift of the Carpathians (ter Borgh et al., 2013). Although these Central Paratethyan events have been the subject of intense study, many key questions concerning the mechanisms of their onset, progression and termination remain unanswered especially because the temporal evolution of the Eastern Paratethys region is poorly constrained (e.g. Popov et al., 2006).

The Middle Miocene stratigraphic framework of the Eastern Paratethys is largely based on transgressive-regressive cycles and characteristic faunal assemblages reflecting changes in the hydrological regime of this semi-enclosed basin (Nevesskaya et al., 2005a; Popov et al., 2006). Radiometric and magnetostratigraphic age constraints for this region are notoriously lacking. The fragmentation and subsequent isolation of the Eastern Paratethys led to the development of biota that are characterized by recurrent endemism. These endemic faunal assemblages hamper straightforward correlations to the Geological Time Scale and led to the establishment of numerous regional stages (Tarkhanian, Chokrakian, Karaganian, Konkian and Volhynian), all with very limited age constraints (Fig. 2).

In this paper we establish a new chronological framework for the sedimentary successions of the Eastern Paratethys by applying integrated magneto-biostratigraphic dating techniques to the uppermost Chokrakian-Volhynian successions of the Zelensky-Panagia section (Fig. 1c). Zelensky-Panagia is located in the Taman Peninsula in Southern Russia and it represents a continuous outer shelf depositional facies in the northern part of the Euxinic Basin and can therefore be considered an archetype for Eastern Paratethys environmental change. Our new time frame allows a direct correlation of the Eastern Paratethys stratigraphy to the Central Paratethys successions and a better understanding of the mechanisms of paleoenvironmental change in both restricted basins. The results will be discussed in the context of gateway evolution and hydrological changes affecting the connectivity between the two Paratethys domains.

2. Geological and stratigraphic background

The epicontinental Paratethys Sea became progressively separated from the Mediterranean basin by tectonic uplift of the Alpine-Balkan-Pontides-Alborz-Kopetdagh orogenic belt since the early Oligocene (e.g. Rogl, 1999). During the Middle Miocene, Paratethys covered the area from the Vienna Basin in Austria to the Kopetdagh region in Turkmenistan (Popov et al., 2006). Paratethys was fragmented in smaller sub-basins that were grouped in two systems: the Central European (Central