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Tracking Sediment Mixing Along the Lower Danube River From the Carpathians to the Black Sea

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ABSTRACT

We use detrital zircon U–Pb geochronology as a sediment provenance tracer in modern river sands to better understand how tectonic, climatic, and anthropogenic processes modulate sediment transport dynamics of the Carpathians to the Black Sea source to sink system. Our findings show that anthropogenic factors can either amplify or diminish environmental signals along the Danube River system. Tributary river catchments that have experienced significant land use change from forest to more erodible farmlands are interpreted to amplify the sediment provenance signatures of bedrock erosion, whereas tributary river systems with a high density of dams exhibit diminished sediment contributions to the Danube River. This summary dataset provides the groundwork for future inquiry within the Carpathians to Black Sea sediment transfer system in both space and time.

1 | Introduction

The Danube Delta is a vital natural economical resource and a locus of immense biodiversity (ICPDR 2015; Gogaladze et al. 2021) that has been impacted by anthropogenic changes in land use for the past ~2000 years (Giosan et al. 2006; Oaie et al. 2015). Here, we track the sediment mixing that occurs along the Danube River en route to the Danube Delta at the Black Sea to understand how erosion and sediment transport are impacted by anthropogenic forcings. Detrital geochronology is an effective tool to track external and internal impacts on sediment transfer dynamics in fluvial-coastal systems (Malkowski et al. 2019). Because the distribution of sediment sources and drainage networks is known in active orogenic systems, studies of modern environments with detrital geochronology provide opportunities to isolate sediment provenance responses to several variables such as tectonic (Amidon et al. 2005; Castillo et al. 2022), climatic (Zhang et al. 2018; Garzanti et al. 2022), and anthropogenic (Sickmann et al. 2019; Thomson et al. 2022) forcings. In this study, we incorporate new and previously published (Ducea et al. 2018; Balica et al. 2020) detrital zircon (DZ) U–Pb geochronology data from tributaries, the Danube River and the Black Sea (Figure 1) into mixture models to understand how these tributary signatures are modified from Carpathian sources to the Black Sea sink.

2 | Geologic Framework

The 1075 km long Lower Danube and associated tributary rivers transect the tectonic provinces of the Carpathian Mountains (Figure 1) that include from upstream to downstream: the Apuseni Mountains and Transylvanian back-arc basin; the Southern Carpathians comprised of Dacia and Danubian

engineered waterways along the Danube River and major tributaries that may interfere with sedimentary flux to the Black Sea (Bondar 2008; Nedea et al. 2012; Constantinescu et al. 2015; Habersack et al. 2016). The Olt tributary has a higher density of dams along the river relative to our other sampled tributaries (Figure 5C). Sediment transport and propagation of provenance signatures from the Olt River catchment may be significantly dampened by the dams through the temporary storage of sediment within dam reservoirs. Thus, the relatively lower model-predicted contribution of Olt River zircon ages may in part be explained by dam construction diminishing the sediment to the Danube River.

Jiu, Olt and the other sediment provenance signatures in the tributary contributions to the Danube River appear to be diluted by the contribution of the Siret River prior to the Danube Delta and Black Sea (Figure 4B). The Siret River has a large catchment area characterised by high to moderate relief and focused seismicity at the front of the thin-skinned nappes of the East and Southeast Carpathians fold-thrust belt (Figure 5A). This part of the Southeast Carpathians is at the locus of the recent tectonic exhumation since the Pliocene–Pleistocene (Merten et al. 2010; Danisik et al. 2012; Matenco et al. 2016). Moreover, the accumulation of sediments in the Eastern Carpathians flysch units was based on the erosion of Baltica (East European Platform) and Variscan/Post-Variscan, Caledonian and Cadomian orogens (Roban et al. 2020, 2023). The more proximal Siret River system with older detrital zircon age components (Baltica) recycled from the Eastern Carpathians overwhelms the upstream tributary signals of the South Carpathians.

6 | Conclusions

New detrital zircon geochronology and mixture modelling results indicate changes in sediment contribution and mixing of tributary rivers along the lower Danube. We propose that the Olt River has been impacted by current anthropogenic factors that diminish the sediment contribution to the Danube River, whereas the Jiu tributary provenance signature may be amplified by intrinsic tectonic and climatic forcings. The Jiu provenance signature is prominent until the confluence with the Siret tributary. At the Danube Delta and Black Sea terminus, the upstream Danube River sediment is diluted by the Siret River. Future work on rain patterns and bedform migration is required to accurately test these hypotheses, which would also involve examining the Holocene Danube Delta deposits to determine if sediment provenance signals are modified during anthropogenic land use change.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that supports the findings of this study are available in the Supporting Information material of this article.

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