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The evolution of the Danube gateway between Central and Eastern Paratethys (SE Europe): Insight from numerical modelling of the causes and effects of connectivity between basins and its expression in the sedimentary record

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ABSTRACT

The Pannonian and Dacic Basins in SE Europe are presently connected by the Danube River across the South Carpathians, to which they are in a back-arc and foreland position respectively. Part of the Paratethys realm during the Neogene, open water communication between the basins was interrupted by the Late Miocene uplift of the Carpathians. Different mechanisms have been proposed for the formation of the Danube gateway: capture of the upstream lake or an upstream river or incision of an antecedent river. Estimates on its age range from Late Miocene to Quaternary. A related issue is the effect of the large Mediterranean sea level fall related to the Messinian Salinity Crisis on the Paratethys subbasins, specifically the "isolated" Pannonian Basin.

In a synthetic numerical modelling study, using a pseudo-3D code integrating tectonics, surface processes and isostasy, we addressed the causes and effects of changes in connectivity between two large sedimentary basins separated by an elevated barrier. Specifically, we aimed to find the expression of connectivity events in the sedimentary record in general and the consequences for the evolution of the Pannonian–Dacic area in particular. We studied a range of parameters including the geometry and uplift rate of the barrier, downstream sea level change and lithosphere rigidity.

We found that changes in connectivity are expressed in the sedimentary record through their effect on base level in the upstream basin and supply in the downstream basin. The most important factors controlling the response are the elevation difference between the basins and the upstream accommodation space at the time of reconnection. The most pronounced effect of reconnection through lake capture is predicted for a large elevation difference and limited upstream accommodation space. Downstream increase in sediment supply is dependent on the latter rather than the reconnection event itself.

Of the parameters we tested, the rigidity of the lithosphere was found to be of major importance by its control on sediment loaded subsidence and generation of accommodation space. A downstream sea level change is unlikely to induce capture, but may affect the upstream lake level by enhancing incision in a pre-existing gateway. In the Pannonian–Dacic region, the mechanically weak, continuously subsiding Pannonian lithosphere allowed accommodation of significant volumes of continental sedimentation and as a consequence, transfer of excess sediment to the downstream Dacic Basin was only gradual. The Messinian sea level fall in the Dacic Basin could have been recorded in the Pannonian Basin only if a connection between the basins already existed. More detailed modelling of river incision taking into account lateral differences in erodibility in the South Carpathians will be required to give better time constraints on the formation of the Danube Gateway.

1. Introduction

Paratethys, extending from the foreland of the Alps to the Aral Sea (Fig. 1a), was a large brackish epicontinental sea that was separated from the world oceans during the progressive closure of the Tethys Ocean and associated rising of the Alpine chain. In Southeast Europe, formation and Late Miocene uplift of the Carpathians disrupted open water communication between the Central/Western and Eastern Paratethys, corresponding to the Pannonian Basin and the Dacic Basin respectively (Fig. 1). The separation of the basins led to the evolution of separate faunas and different biostratigraphies (e.g. Rögl, 1996) making stratigraphic correlations problematic.

The Pannonian Basin to the west and the Dacic Basin to the east (Fig. 1) are in a back-arc and foreland position relative to the Carpathians, respectively. The Pannonian Basin system formed as a result of back-arc extension during the Miocene (Horváth et al., 2006) and features the

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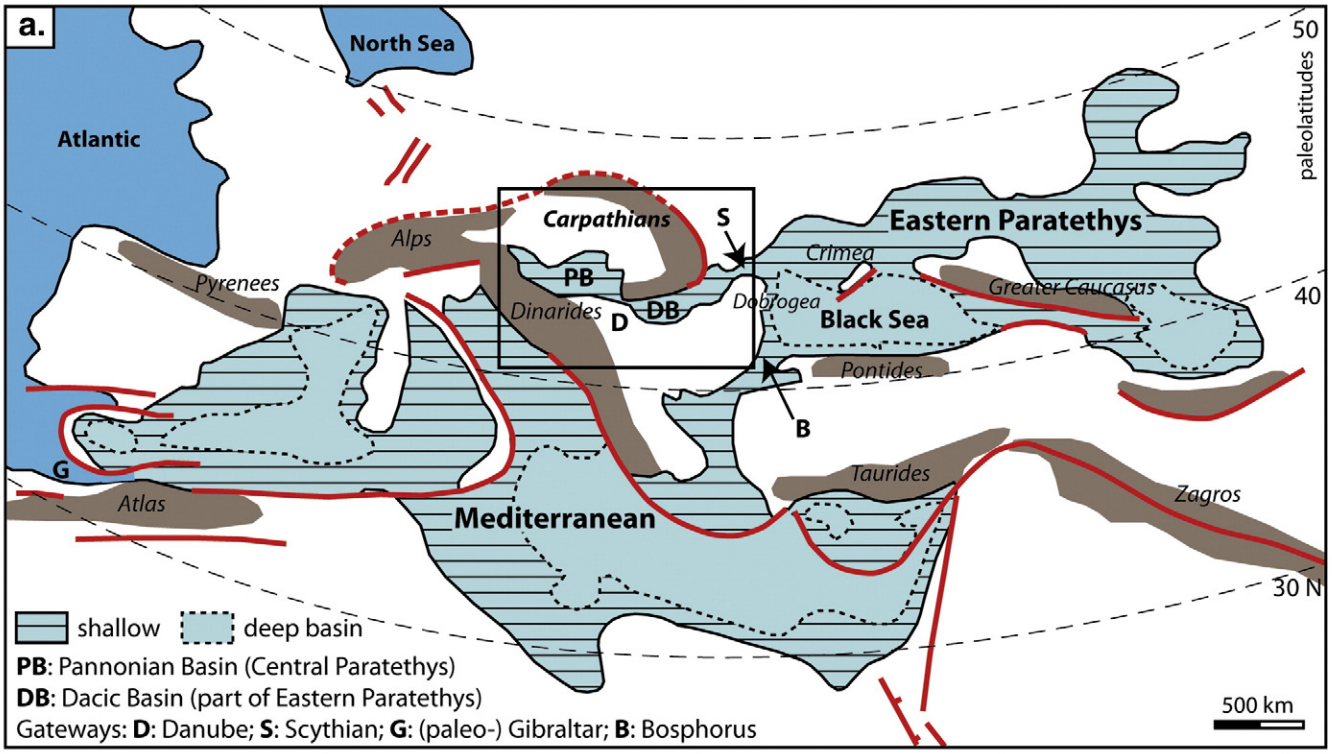
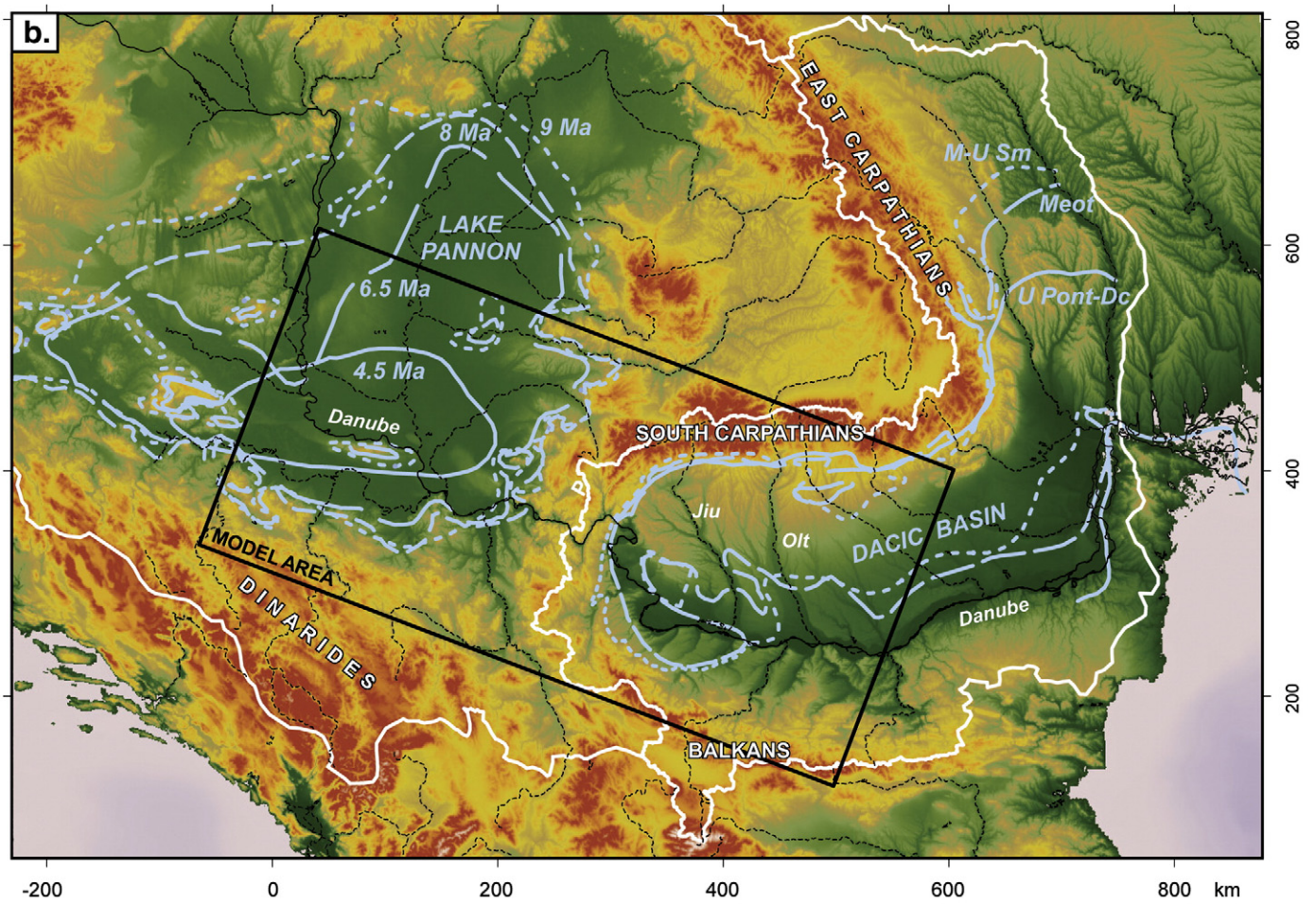

a.
North Sea
Atlantic
Carpathians
S
Alps
Eastern Paratethys
Crimea
Pyrenees
PB
Dinarides
D
DB
Dobrogea
Greater Caucasus
Black Sea
Pontides
B
G
Taurides
Atlas
Zagros
Mediterranean
50
40
30 N
paleolatitudes
shallow
deep basin
PB: Pannonian Basin (Central Paratethys)
DB: Dacic Basin (part of Eastern Paratethys)
Gateways: D: Danube; S: Scythian; G: (paleo-) Gibraltar; B: Bosphorus
500 km


b.
8 Ma
9 Ma
LAKE PANNON
6.5 Ma
4.5 Ma
Danube
EAST CARPATHIANS
M-U Sm
Meot
U Pont-Dc
SOUTH CARPATHIANS
Jiu
Olt
DACIC BASIN
Danube
MODEL AREA
DINARIDES
BALKANS
800
600
400
200
-200
0
200
400
600
800
km