Numerical modelling of the roughly simultaneous emplacement of two distinct ophiolite belts

Nikola Stanković, Vesna Cvetkov, Vladica Cvetković

NUMERICAL MODELLING OF THE ROUGHLY SIMULTANEOUS EMPLACEMENT OF TWO DISTINCT OPHIOLITE BELTS

[1]Nikola Stanković, [2]Vesna Cvetkov, [3]Vladica Cvetković

[1]*University of Belgrade, Faculty of Mining and Geology, Serbia, nikola.stankovic@rgf.bg.ac.rs*
[2]*University of Belgrade, Faculty of Mining and Geology, Serbia, vesna.cvetkov@rgf.bg.ac.rs*
[3]*University of Belgrade, Faculty of Mining and Geology, Serbia, vladica.cvetkovic@rgf.bg.ac.rs*

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INTRODUCTION

Ophiolites represent segments of oceanic lithosphere found emplaced on top of the continental crust and were long understood to be related to oceanic closure processes [1]. Although different physical mechanisms have been proposed [2,3], the process of ophiolite emplacement has long been difficult to model numerically, since it requires positioning of more dense oceanic crustal and mantle rocks onto less dense continental crust. However, some notable advancements have been made in the last decade, where successful ophiolite emplacement was found to be related to both reversal of plate velocities [4] and extrusion of subducted continental crust [5]. Some suture zones that delineate the oceanic closure, are accompanied by two ophiolite zones of distinct structure and composition, and such an example is the Vardar Zone [6]. In this communication we report new results of numerical modelling of the emplacement of two distinct ophiolite belts. Our model reproduces the ophiolite emplacement on two oposite continental margins via a shallow intra-oceanic subduction and a step-by-step reversal of the plate velocities.

MODELLING APPROACH

To model numerically the above described processes, we utilize a marker-in-cell method with conservative finite differences [7]. Equations are solved on a staggered grid while the rock properties are trasported via material markers. The initial 2D model consists of an oceanic lithosphere situated between two continental domains. All outer boundary conditions for velocity are free-slip. The temperature is constant on the upper boundary (273K) and at the bottom boundary (2200K), whereas an insulating boundary condition is applied on the two vertical boundaries. Top 20km of the model domain consists of „sticky air" [8], which allows the upper surface to deform freely and develop topography. Rock rheology is visco-plastic. Hydration, partial melting, sedimentation, erosion and melt extraction are all accounted for. In order to model the plate velocities, two internal regions situated deep within the two continental plates are assigned values of the horizontal component of velocity vector. To model variable plate velocities, a three step evolution of the internal velocity boundary conditions is imposed, namely: convergence – divergence – convergence. Subduction is initiated at a rheologically weak zone dipping towards the continent on the right. A flat subduction of small subduction angle is achieved by varying oceanic crust thickness within the oceanic domain [9].

RESULTS AND DISCUSSION

Firstly, the model creates a flat intra-oceanic subduction which develops along the initial weak zone (Fig. 1). The upper oceanic plate reaches the left continental margin after 17Myrs. The lower plate undergoes subduction angle steepening underneath the continent on the right side. This is accompanied by mantle hydration, partial melting and melt extraction and emplacement along the continental margin. After 20Myrs of convergence, the plate velocities are revereсed. This is achieved by linear changes in prescribed velocities within 1Myr. An extensional regime is maintained for additional 5Myrs. The results of this reversal are twofold. Firstly, the oceanic lithosphere that already obducted on top of the left continent, is now permanently emplaced by detaching itself from the rest of the ocean. Secondly, the margin of the continent on the right, weakened by percolation of fluids and melts, now serves as a weakened zone for mantle upwelling, rifting and the onset of spreading. This region now consists of magmatic rocks and traces of newly-formed oceanic lithosphere. Second reversal of plate velocities occurs during 25-26Myrs. The new compressional regime lasts until the end of the simulation. The compression now serves to stop the new spreading center and finally to close the remaining oceanic realm.

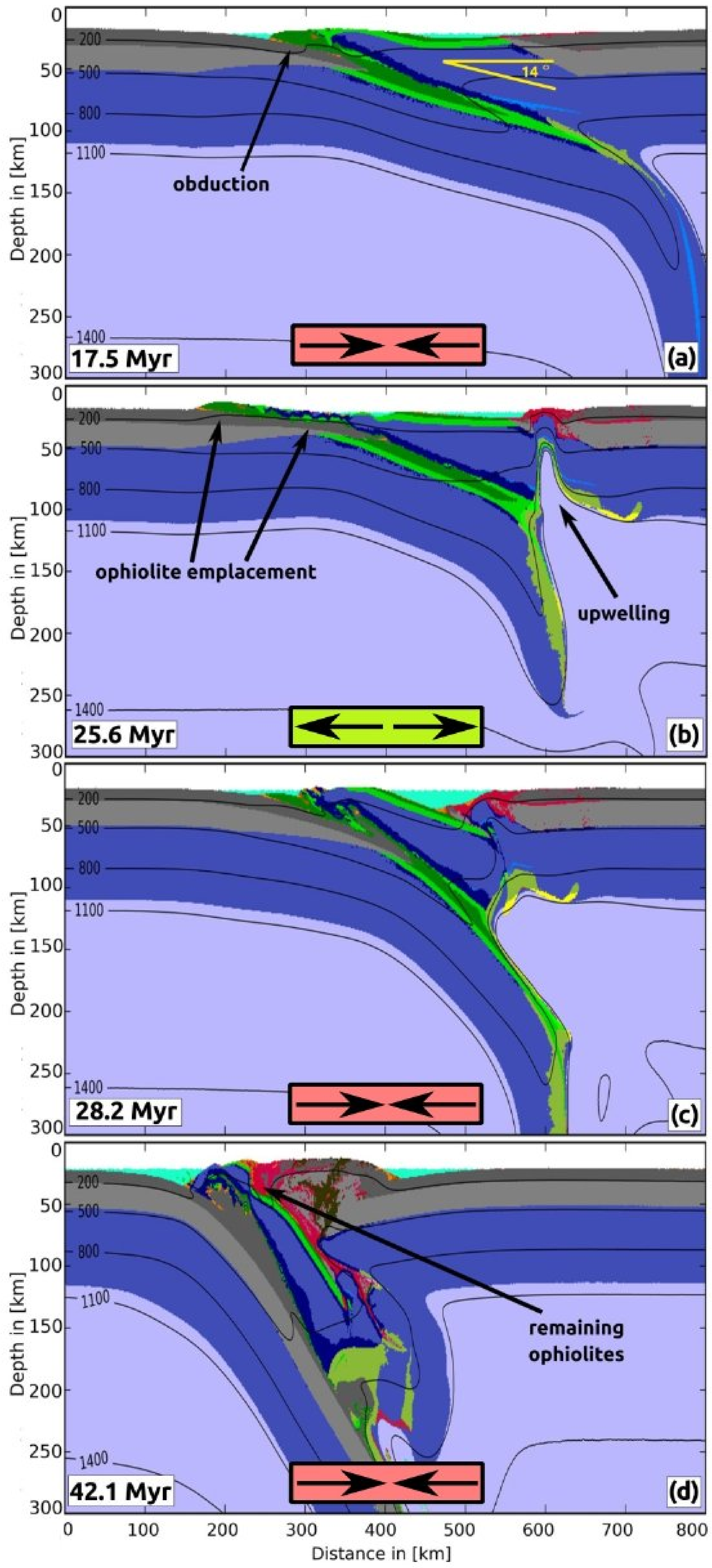

Figure 1. Time evolution of the model. Different rocks are represented by different colours. Black lines denote isotherms. Arrows indicate the imposed plate convergence or divergence.

The final period of the simulation is characterised by subduction of the remaining oceanic parts, with two distinct ophiolite belts permanently emplaced at the contact between the two continents. The modelling presented here confirms that the reversal of plate motions is very important in successful emplacement of ophiolites. On the other hand, the modelling shows that the same plate reversal can have significant consequences on the opposite margin, leading to the development of spreading and creation of new oceanic floor that can be subsequently emplaced during the final oceanic closure.

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