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Paleotectonic controls and tentative palinspastic restoration of the Carpathian realm during the Mesozoic

DUŠAN PLAŠIENKA

Geological Institute, Slovak Academy of Sciences, Dúbravská 9, SK-842 26 Bratislava, Slovakia
geolplas@savba.sk

Abstract. The wide area between the East Alpine-Carpathian-Balkan and the South Alpine-Dinaride orogenic fronts inside the Carpathian orocline is composed of several pre–Tertiary continental terranes that show ambiguous relationships either to the northern or southern Tethyan margin at different time levels. At the same time, the intervening suture zones mostly containing Mesozoic oceanic material were reactivated several times and almost obliterated by Tertiary wrenching. Consequently, no simple solution of pre-Tertiary plate configuration and their motions during the Mesozoic is possible. Based on constraints given by the restored Early Tertiary situation, Mesozoic facies links and polarities towards basinal, supposedly oceanic domains, on the movement paths of large plates and on the tectonic progradation trends and shortening directions, a tentative palinspastic restoration of the Carpathian realm is presented for the Sinemurian, Oxfordian, Early Albian and Maastrichtian stages. The presented reconstruction considers the possible driving forces for the displaced terranes as well.

Key words: Alpine-Carpathian-Dinaric realm, Mesozoic, plate motion, driving forces, kinematic reconstruction

Introduction

The Tethyside Alpidic orogenic system of central and southeastern Europe consists of two bivergent branches – the northern East Alpine-Carpathian-Balkan, and the southern South Alpine-Dinaric-Helenic branch. While convergent movements in the outermost, frontal zones of both branches ceased by the Late Tertiary only, the interiors of the system appear to be a collage of more-or-less independent continental terranes separated by suture zones containing Mesozoic oceanic material. Sutures depict a very complex, wriggling pattern that wrap up the continental terranes (Fig. 1). Since the sutures were frequently reactivated as wrench corridors during the Tertiary, their original character has been mostly obliterated. Moreover, a great deal of suture complexes is presently hidden below a thick Tertiary sedimentary cover of the Pannonian basin system. That is the main reason why there is no general agreement about their mutual relationships and links.

There are many uncertainties also about the age of ophiolitic and oceanic sedimentary complexes and, consequently, about the time of opening and final closure of various oceanic domains within the region. Concerning the continental terranes, several possible solutions of how to assemble the Tertiary collage were published, but the main disagreement concerns the Early Mesozoic positions of these segments with respect either to Europe, or to Adria-Africa. This discord may be exemplified by totally diverging views of two groups of Carpathian researchers about the original pre-Tertiary position of a large intra-Carpathian segment called Tisia or the Tisza unit. For one group Tisia is a segment of the northern margin of Tethys showing distinct European affinities, especially during the Triassic and Jurassic (e.g. Haas et al., 1995). The second group argues for an independent, „within-Tethys“, i.e. much more southern original position of this microcontinent (e.g. Mišík, 1987; Kozur and Mock, 1987). Recently, even the position of Tisia far to the west, in the proximity of the northern margin of Adria, has been proposed by Stampfli et al. (1998).

In a tentative palinspastic restoration presented in Fig. 3, data from both the continental domains and from intervening oceanic suture zones have been considered. The principal constraints taken into account were defined by Plašienka & Kováč (1999). The following, well-documented data have been preferred: (1) polarity and age of shortening processes, vergence of contractional structures; (2) facies polarity within continental terranes indicating position of basinal, presumably oceanic zones at various time levels. The reconstruction is supplemented by paleotectonic considerations assuming the global plate movements (e.g. the Adria path) and local plate driving boundary and body forces arising from plate interactions within the realm. The methodical approach adopted was the backward reconstruction starting from the Late Cretaceous situation, which was partly based on the Early Tertiary state as interpreted e.g. by Balla (1984), Csontos et al. (1992) and Willingshofer (2000).

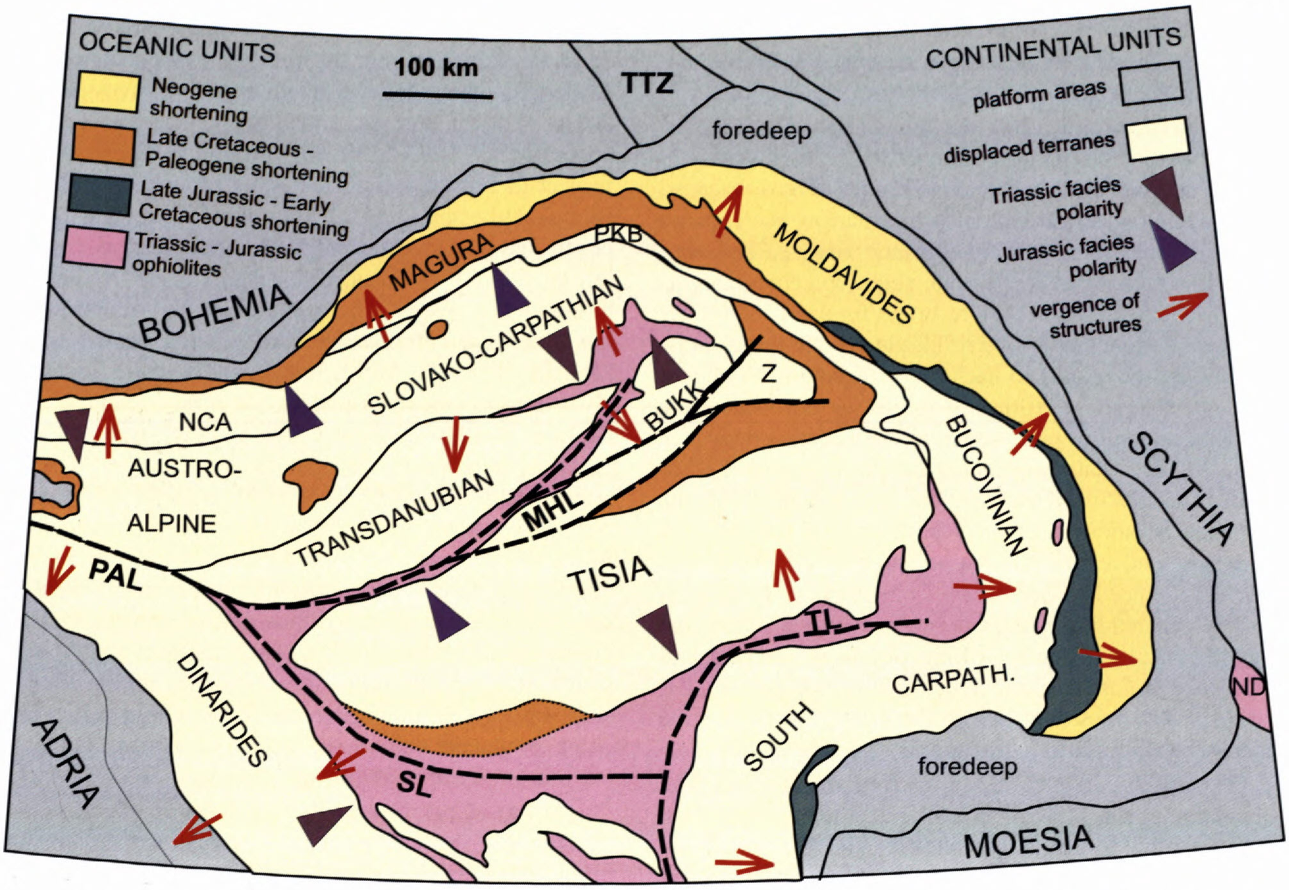

Fig. 1. Sketch of principal pre-Tertiary continental and oceanic terranes of the Carpathian realm. Abbreviations: TTZ – Teysseire-Tornquist Zone; ND – Northern Dobrogea; NCA – Northern Calcareous Alps; PKB – Pieniny Klippen Belt; Z – Zemplín block. Thick dashed lines indicate the main wrench faults that accommodated the Late Tertiary escape and rotation tectonics: PAL – Periadriatic Lineament; MHL – Mid-Hungarian Lineament; SL – Sava Line; TL – Transylvanian Line. Thick arrows indicating facies polarity point to presumably oceanic paleogeographic domains.

Palinspastic restoration

During the Triassic, the northern margin of Paleotethys was subducted northward below the Eurasian plate (e.g. Stampfli, 1996). Oceanic basins of hard determinable shape, collectively referred to as the Meliatic ocean, opened in the southern European areas probably due to back-arc rifting during the Middle Triassic (Fig. 2). Oceanic rifting was preceded by a Permian HT/LP event that substantially weakened the epi-Variscan crust. Based on remnants of Triassic ophiolites and oceanic sediments, this oceanic realm comprised a SW-NE trending, SW-ward wedging out Hallstatt-Meliata-Transylvanian branch, which was linked to the Karakaya basin of western Pontides through the NW-SE trending Siret (Dobrogea) branch that followed the unstable Teisseyre-Tornquist Zone (TTZ). Future displaced continental terranes of the Austroalpine, Slovakocarpathian and Tisia domains were located at the SE margin of the stable North European Platform. The Adriatic microplate with its northern relatives (units of the South Alpine-Transdanubian-Bükkian-Dinaric margin) and the Balkan (Rhodopean-Moesian-Getic) segment were separated from Europe and drifted southward. The oceanic domains

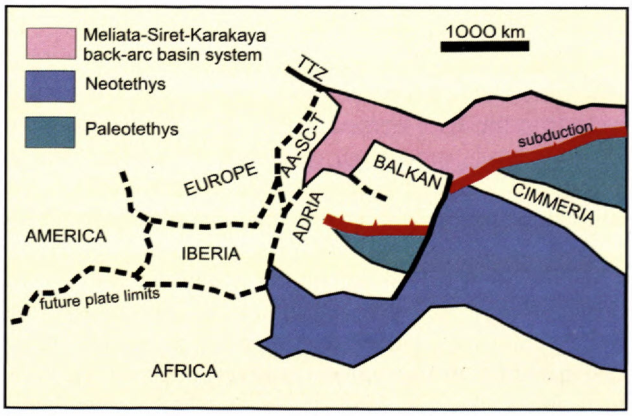

Fig. 2. Western Tethyan plate configuration during the Middle Triassic, partly after Stampfli (1996). AA – Austroalpine; SC – Slovakocarpathian; T – Tisia domains.

were dominated by pelagic limestones or cherts, their passive margins by huge carbonate platforms and reefs, while lagoonal and continental deposition occurred in regions adjacent to the North European Platform. This facies distribution is still well traceable and helps to restore the former passive margins of the Meliatic ocean.

The results of the Jurassic – Cretaceous palinspastic and paleotectonic restoration are presented in four snapshots (Fig. 3):

(1) Early Jurassic (200 Ma, Sinemurian; Fig. 3a). The Meliatic ocean was partly consumed by a southward subduction starting form the latest Triassic. The associated deformed belt was restricted only to a narrow accretionary wedge rimming the northern Adriatic margin, however. Both the northern passive and the southern active margins of the Meliatic ocean, as well as broad foreland and hinterland areas suffered extensive rifting during the Early Jurassic. This can be related to back-arc extension of the upper plate, and the passive rifting of the lower European plate due to the southward pull exerted by the negative buoyancy of the Meliatic slab, augmented by the eastward drift of Adria. The SW-ward subduction and roll-back of the Dobrogea oceanic branch may have account for an eastward shift and counterclockwise rotation of the Balkan plate that initiated its separation from Adria and rifting of the NW-SE trending Vardar ocean in between during the latest Triassic. Continental rifting produced elevated and subsided domains, the former being indicated by shallow-water syn-rift limestones rich in the clastic admixture, the latter by hemiturbiditic, partly anoxic sediments.

(2) Late Jurassic (155 Ma, Oxfordian; Fig. 3b). The subduction of the Meliatic ocean split into two branches. The western, Meliata-Hallstatt branch was gradually closing, but the oceanic Szarvaskő back-arc basin opened on its SE site. Within the European lower plate, the South Penninic (Ligurian-Piemont-Vahic) ocean spread out after the latest Liassic break-up, which separated the Austroalpine-Slovakocarpathian-Tisia terranes from the North European Platform by passive rifting. Tisia and the Zemplín block were separated from the Slovakocarpathian terrane and drifted further SE-ward. The eastern, Transylvanian-Mureş Meliatic branch became to be unified with the Vardar trough and remained opened until the Albian, whilst the Dobrogea branch was sutured and Moesia was welded to the East European Platform. The intraoceanic Transylvanian subduction propagated to the Vardar ocean. This initiated opening of the Severin back-arc basin that separated Moesia from the Getic domain. In the Late Jurassic, an immature orogenic wedge nucleated along the Meliata-Hallstatt suture, associated with HP/LT metamorphism and blueschists exhumation during the initial collision, and with synorogenic sedimentation dominated by olistostromes. However, the northern lower plate was still in tension. This is ascribed to the B-subduction and persisting southward slab-pull of the Meliatic oceanic lithosphere attached to the European lower plate. Finally, the Briançonnais, Hochstegen (Hohe Tauern) and Oravic (Pieniny Klippen Belt) continental ribbons, marked by swell sedimentation, were separated from the southern passive European margin by passive rifting. The North Penninic oceanic branches, as the Valais, Ybbsitz and Magura, opened during the Late Jurassic and Early Cretaceous. All these are characterized by eupelagic sedimentation, often below the CCD.

(3) Mid-Cretaceous (110 Ma, Early Albian; Fig. 3c). From the Early Jurassic onward, the movement vector of Adria has been reconstructed e.g. by Savostin et al. (1986). For the Jurassic and Early Cretaceous a systematic east- to SE-ward drift of Adria and its pendants with respect to Europe is inferred. This brought about diminishing of the meridionally trending Vardar and Severin oceans associated with ophiolite obductions, as well as a left-lateral shift of Adria with respect to the Meliatic suture-collision wedge. This wedge widened due to persisting subcrustal compressive load exerted by the sinking Meliatic slab. The Mureş and Severin sutures expanded NE-ward to consume a part of the Siret oceanic crust of the later Moldavide Outer Carpathians, forming the compressive, intraoceanic Silesian ridge. However, tensional stresses still dominated in the western sector of the European lower plate. Orogenic wedge of the Austroalpine-Slovakocarpathian system widened considerably by mid-Cretaceous times, accompanied by basement stacking, crustal thickening and eo-Alpine metamorphism. Outward progradation of the orogenic growth from the Meliatic suture indicates the pull exerted by the sinking Meliatic slab was still the main driving force. Large-scale shortening produced voluminous flysch sediments along the oceanic and/or intracontinental sutures.

(4) Late Cretaceous (70 Ma, Maastrichtian; Fig. 3d). The general geodynamic situation fundamentally changed during the Late Cretaceous. Adria began to move northwards, bulldozing in its front all the previously shortened or stretched continental, as well as oceanic realms. The detached Meliatic slab drowned in the mantle and did not affect the crustal dynamics any more. The Austroalpine-Slovakocarpathian system was welded to Adria and its northern pendants (Transdanubian, Bükk), but these become to be separated from Adria by the wedging in of Tisia along a large-scale dextral strike-slip, a precursor of the Periadriatic and mid-Hungarian lines. At the same time, Tisia was welded with the Getic and Bucovinian segments to form the Tisza-Dacia microplate. The amalgamated Austroalpine, Slovakocarpathian, Transdanubian and Bükk segments constituted the Alcapa microplate. Movement of both the Alcapa and Tisza-Dacia microplates governed the later Tertiary evolution of the area. During the latest Cretaceous, consumption of the Southern Penninic oceanic crust by the A-type subduction started along the northern margin of Alcapa. Consequently, the compressive stresses exerted by drifting Adria were effectively transmitted to far distances towards the north, where they caused basin inversions, wrenching and locally thrusting in the cover complexes of the North European epi-Variscan Platform (Saxon folding). TTZ was one of the main loci of reactivation. The late Senonian is still characterized by extensive synorogenic sedimentation, though it post-dates the important shortening events during the early Late Cretaceous. Nevertheless, apart from the still oceanic Rhenodanubian-Magura and Moldavian zones, these Gosau sequences show a shallowing-upward.

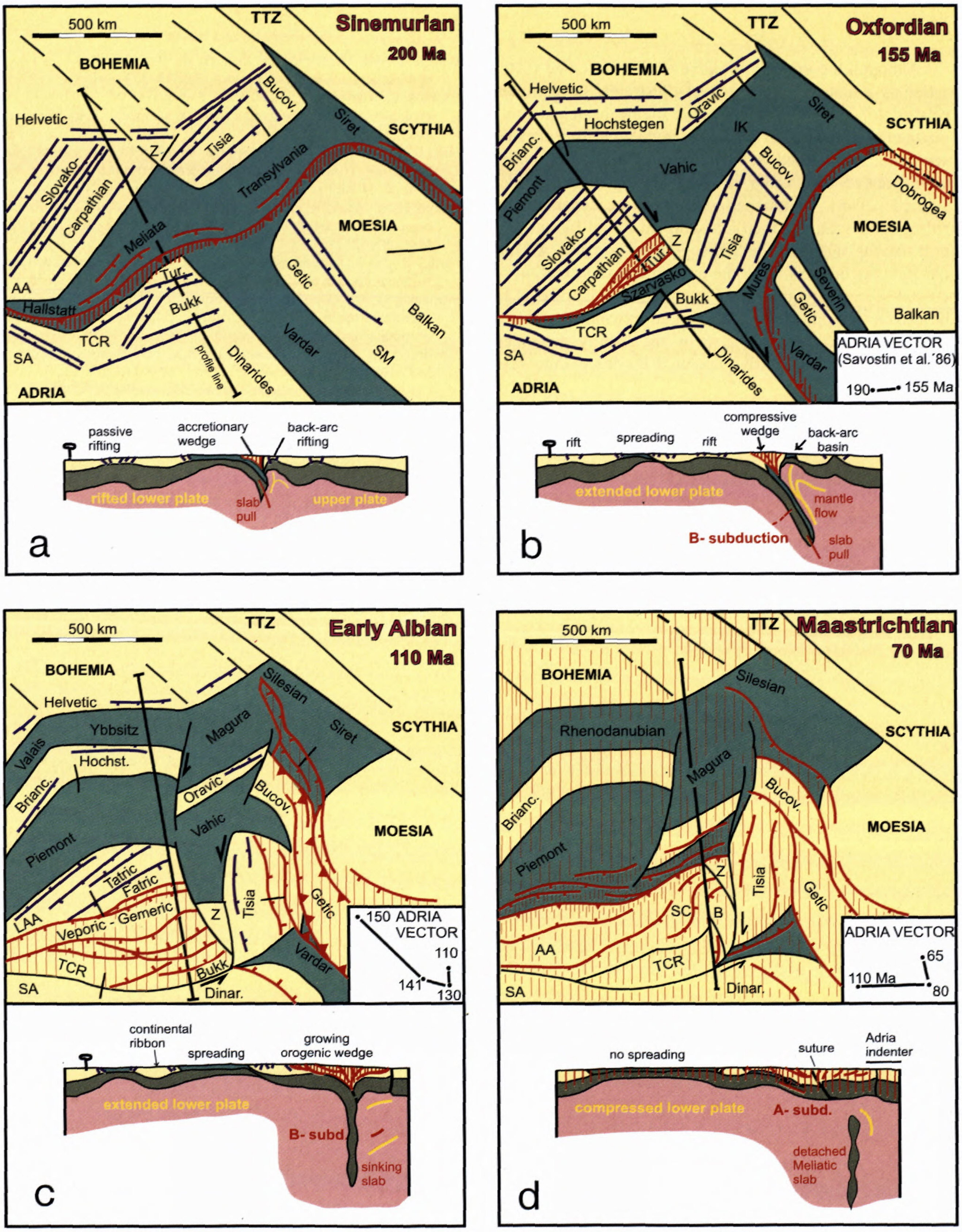

Fig. 3. Tentative palinspastic restoration of the Carpathian realm and possible plate driving forces presented at four Mesozoic time levels. Abbreviations: TTZ – Teysseire-Tornquist Zone; IK – Iňačovce-Krichevo; SM – Serbo-Macedonian Massif; AA – Austroalpine; LAA – Lower Austroalpine; SC – Slovakocarpathian; B – Bükk; Tur. – Turnaic; Z – Zemplín; SA – Southern Alps; TCR – Transdanubian Central Range. Continental crust is shown yellow, oceanic crust green, mantle lithosphere dark green and astenosphere pink. Sticked blue lines indicate normal faults; red ones represent thrust faults. Red pattern covers areas undergoing contraction.

Conclusion

Although the graphic outcome of the presented restoration is a tentative one, it well illustrates the complex relationships and movement paths of the principal units distinguished. Despite the space available for oceanic spreading was limited, several short-living oceanic zones were created, and often re-opened in places of older sutured oceans. Continental terranes were separated by rifting processes, and then reassembled in a different pattern leaving numerous paleogeographic puzzles. A conclusion may be drawn that the motion and deformation of crustal segments within the Carpathian collage seems to be driven, in addition to global plate movements as was the drift of Africa-Adria, also by the locally generated driving forces, dominantly generated by descending oceanic slabs.

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