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A new model for the tectonic evolution of the Eastern Alps: Inferences for south-eastern European mountain belts

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The Eastern Alps as well as Carpathians resulted from two stages of closure of two ocean basins (Meliata-Vardar, Penninic) and two, Cretaceous and Eocene-Neogene, stages of plate collision between the European/Moesian plates in the foreland and the Adriatic microplate in the hinterland. We introduce here three new concepts for the tectonic evolution of East-Alpine-Carpathian-Dinaric orogen including: (1) asymmetric Permian to early Mid Triassic rifting resulting in opening of the Meliata ocean; (2) explanation of the Middle Jurassic to Oligocene B- and A-subduction of **one** lithospheric slab (ncl. Meliata, Austroalpine and Penninic units) and, consequently, continuous growth of the orogenic wedge by footwall accretion of cover- and basement cover nappes; and (3) bivergent structure of both Cretaceous and Tertiary orogenic belts.

Facts and models on the tectonic evolution of the Eastern Alps made rapid progress during the last two decades, mainly due to deep seismic profiling, paleogeographic, structural, petrologic and geochronologic investigations. These together with results of the TRANSALP seismic line allow new insights into the present-day structure and triggers new models which fundamentally changed ideas on the geological evolution of the Eastern Alps. However, recent proposals on architecture of Eastern Alps remained quite controversial (Schmid et al., 2004. Eclogae Geol. Helv. 97: 93-117.). The geological evolution of the Eastern Alps can be only understood when data from the north-eastern extension of the Eastern Alpine units in the Carpathians and Dinarides are considered in models, too. Our new model is based on synthesis of new and previous structural and age data from the entire region, and their integration in existing geological data. The principal stages of tectonic evolution are (all orientations are given in present-day coordinates):

(1) The Alpine tectonic evolution started with northwestward prograding Permian rifting immediately subsequent to Variscan orogeny and after deposition of Late Carboniferous molasse in all future continental domains. Rifting may have resulted from continuous dextral transtensional shear between Gondwana and Laurussia. Evidence for strong early to late Permian tectonic subsidence and extension is restricted to the eastern Southalpine domain where a carbonate platform was established during the Permian and the Tethyan Sea transgressed towards west. The diversity, distribution and thickness (including late nonexistence) of Permian and Lower Triassic successions and magmatic rocks argue for a wide rift basin and rift shoulders in an overall asymmetric rift. Further evidence of divergence and extension of the lithosphere was the emplacement of gabbros, low-pressure metamorphism due to unroofing of metamorphic core complexes, and magmatic underplating.

(2) The drift stage is characterized by the main phase of tectonic subsidence in Austroalpine and Adriatic tectonic units was during Middle Triassic times, formation of a new shelf carbonate platform (Southalpine and Austroalpine domains) facing towards the Meliata oceanic basin (filled with Ladinian and Upper Triassic radiolarites in the eastern Northern Calcareous Alps).

(3) A further, independent rift stage during Late Triassic and Early Jurassic led to the opening of the Penninic (Piemontais-Ligurian) ocean due to rifting the Austroalpine domain off from stable Europe.

(4) On the other hand, the Meliata oceanic basin started to close during the Middle Jurassic. The final closure of the Meliata basin occurred during the Early Cretaceous with the formation of a deep sea trench. The overall process is A-subduction and high-pressure metamorphism of the distal Austroalpine continental margin, and subsequent exhumation of high-pressure rocks and in overall transpressional setting. Geochronologic data monitor continuous footwall accretion of cover and basement/cover nappes between 120 and 50 Ma. Late Cretaceous Gosau basins seal the Meliata suture and nappe stacking structures. Formation of these basins in the Eastern Alps was associated with sinistral wrenching, northward tiliting of the orogenic wedge, normal faulting at shallow crustal levels and exhumation of eclogite-bearing crust within Austroalpine units. A model explaining exhumation of high-pressure rocks, accretion of subducting material and subsidence in the upper plate due to trench retreat.

(5) The Penninic ocean was closed not earlier than early Eocene. Obviously, subduc-

tion not only included oceanic crust but also distal (Penninic) continental crust in the Eastern and Western Alps.

(6) Post-collisional shortening was associated with break-off of the subducted lithosphere and associated magmatism, final thrusting, tectonic unroofing and surface denudation within the uprising mountain chain, and onset of back-thrusting towards the Adriatic microplate.

Final post-collision processes were, and are, driven by oblique Oligocene to Recent indentation of the Adriatic microplate into the Alpine nappe edifice. This resulted in Oligocene/Early Miocene sinistral wrenching, and subsequent eastward extrusion of blocks in the Eastern Alps, and westward motion and W-directed indentation of the Adriatic microplate forming the West-Alpine arc, and ca. S-(Adria-)directed back-thrusting along the Periadriatic fault and within the Southalpine and Dinaric units. Upper crustal levels of the down-going Penninic and European continental lithosphere were delaminated and accumulated within a double-vergent orogenic wedge. Exhumation of metamorphic crust, as exposed e.g. within the Tauern window, is achieved, therefore, by the combined effects of shortening and gravity-driven tectonic unroofing in upper levels of the crust.