Orogenic evolution of Polish and Slovak Outer Carpathians revealed by a 2D kinematic modeling

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Middle Eocene – Late Miocene (36 to 11 Ma) orogenic evolution of north-eastern Outer Carpathians and their foreland basin has been simulated by a kinematic modeling. The model is based upon a new balanced and restored cross section integrating structural (surface and subsurface), seismic and stratigraphic data. It illustrates the internal kinematics of the Outer Carpathian accretionary wedge and the evolution of the wedge-foreland system as a whole.

Restoration of the balanced cross section indicates at least 496 km of post-Middle Eocene convergence between the Inner Carpathians and European Plate, which is more than most of previous estimates. The higher shortening results from application of more accurate thicknesses of lithostratigraphic units in most cases smaller than in previous works. However, we believe this number to be still the minimum value.

The restored section illustrating the Middle Eocene configuration of sedimentary basins is used as a starting point of the 2D kinematic model. Successive stages of the model are constrained by syn-orogenic sedimentary record and reproduced by kinematic algorithms relevant for thin-skinned deformation. Its quality is evaluated by comparison of successive intermediate geometries with available geological data (stratigraphy, provenance and transport directions of syn-orogenic deposits, palaeobathymetric estimates etc.). Ultimate verification is performed by a comparison of the model's final geometry with the present structure in the balanced section.

The model shows a migration of the Outer Carpathian accretionary wedge towards the foreland and its growth by a successive accretion of new thrust sheets. Position of deformation front in particular time-steps is constrained by stratigraphic data, in particular onset of syn-orogenic deposition, getting progressively younger towards the foreland. However, the kinematic simulation suggests that evolution of the Outer Carpathians cannot be consistently explained by a uniform in-sequence nucleation of successive thrusts. Significant repetitive out-of-sequence thrusting is needed in order to maintain geometry of the modeled accretionary wedge in agreement with existing stratigraphic and sedimentological data as well as with the critical wedge theory. This conclusion is consistent with the present structure of Outer Carpathians, composed of groups of thrust sheets emplaced one on top of the other. The most important of the inferred out-of-sequence events was an emplacement of the Magura Unit on top of previously deformed and partly eroded Dukla imbricates between 20.0 and 17.5 Ma.

Integration of geometries, kinematics and sedimentation into a single model offered us a possibility for tracing evolution of a convergence rate. Relatively low shortening rate of 10 mm/y between 36 and 25 Ma was followed by its increase first to 19.8 and ultimately to 34.1 mm/y since 19.2 Ma until locking of deformation front at around 11 Ma. However, the variations in convergence rate are not directly reflected in a migration of the deformation front of the Outer Carpathians. Propagation of the leading edge towards the foreland was controlled simultaneously by large-scale processes and a mode of shortening accommodation within the accretionary wedge itself. A shift from frontal accretion to out-of-sequence thrusting was resulting in stagnation of the deformation front, regardless the rate of shortening.

The deduced acceleration of convergence coincides well with an onset of back-arc extension in the Pannonian Basin, commonly related to the roll-back of the subducted lithosphere.

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