Heteroaxial shortening, strike-slip faulting and displacement transfer in the Polish Carpathians

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The Oligocene–Miocene tectonic evolution of the Outer Carpathian nappes in the Beskidy Mountains (Poland) is characterized by the superposition of two distinct thrust events, by the reactivation of thrusts during sinistral wrenching, and by repeated events of horizontal extension. Structural analyses of some 70 outcrops revealed the following kinematic evolution: (1) NNW-directed thrusting affected the entire nappe pile of the Outer Carpathians. Consistent data come from the Andrychów Klippen, from the floor thrusts of the Subsilesian, Silesian, Fore-Magura, and Magura nappe, as well as from the Siare, Racza and Bystrica slices within the Magura nappe. Soft-sediment deformation structures in Oligocene flysch sediments and regional comparison indicate that NNW-directed thrusting lasted from the Eocene/Oligocene up to the Early Miocene.

(2) Thrust faults formed by NNW-directed shortening were reactivated as normal faults during subsequent NW-directed extension. Close to the Molasse basin, NW-directed normal faulting towards the foreland dominated. Prominent NW-dipping listric faults and rollovers indicate that extension roots in an unknown detachment horizon.

(3) NNW-directed thrust faults and related folds were overprinted and refolded during NE-directed shortening as already described by Paweł Aleksandrowski. During the same event, the floor thrust of the Fore-Magura nappe, the thrust contact of the Silesian and Magura nappe, and the floor thrust of the Bystrica slice within the Magura nappe were reactivated as sinistral wrench faults. These faults contain convergent strike-slip duplexes forming tectonic windows. Examples are the Fore-Magura windows in the Magura nappe east of Żywiec, and slices of Cretaceous flysch which were squeezed up along the reactivated floor thrust of the Bystrica slice. We propose that sinistral faulting along the Silesian-Magura contact linked up with NE-directed out-of-sequence thrusts farther east. There, a number of Subsilesian windows crop out in front of the NE-directed floor thrust of the Magura nappe. Regional comparison suggests Middle Miocene age for sinistral faulting and NE-directed thrusting.

(4) The youngest event recorded by fibrous slickensides is NE–SW-directed extension. NW–SE-trending grabens cut thrusts and wrench faults. Important normal faults may account for vertical throw in the scale of one kilometer. Regional comparison shows that extension affected both the overthrust units and the autochthonous foreland. The absence of rollovers indicating planar faults which do not root in some detachment horizon corroborates this interpretation. Extension likely occurred in the Late Miocene to Pliocene as the structures are comparable to the graben of Gottwaldov in Moravia which is filled by sediments of corresponding age.