margin of the studied area is characteristic of prevailing extensional stress component with NW–SE direction. This phase of the evolution of the Subtatric–Ružbachy Fault System is associated with normal faults of NE-SW direction. This indicates the Late Miocene and/or Pliocene age of the faults.

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Geodynamics of the foreland plate during the Neogene Carpathian collision - integration of outcrop and seismic data (Polish Carpathian Foredeep basin)

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The Outer Carpathians and Carpathian Foredeep Basin (CFB) have developed due to convergence of the Alcapa microplate and the European plate. This convergence has resulted in plate flexure, forebulge migration and related erosion, development of compressional and extensional structures and reactivation of inherited faults. In order to study geodynamics of the foreland plate response to collision events, outcrop data have been combined with seismic data for the area located in the front of present-day Carpathian orogen. CFB deposits can be presently found both below the Carpathians (so-called inner CFB) as well as in front of the orogenic wedge (so-called outer CFB).

The Miocene foredeep basement is formed by European plate that was shaped by Late Cretaceous/Paleocene inversion of the Permo–Mesozoic Polish Trough. Subsequent Paleogene erosion resulted in partial peneplenation.

During the Lower Miocene the peneplain was cut down by deep paleovalleys located over pre-existing, NW striking basement faults. They were formed due to large morphological gradients related to development of inner CFB and forebulge uplift. The foredeep–forebulge geodynamic system developed in response to flexure of the lithosphere caused by subduction of the relict oceanic crust (Magura basin) beneath the Alcapa microplate. The advance of the Alcapa towards N (probably with eastward motion component) was associated with subduction-related volcanism in the Pannonian region, and with left-lateral rotation, forced by oblique collision with European plate.

The main phase of collision in the Polish segment of the Outer Carpathians took place during the Badenian. Contraction of the orogenic wedge induced shift of the CFB from its "inner" to "outer" position. Outer CFB sedimentary complex in Poland is divided into (simplified): the Lower Badenian pre-evaporitic series, the Middle Badenian evaporites, the Upper Badenian post-evaporitic series and, the youngest Sarmatian and Pannonian series.

In the Lower Badenian, marine transgression of the outer CFB associated with extensional stresses related to flexural stretching led to minor normal offsets on pre-existing basement faults. In the beginning of Upper Badenian, northward allocation of lithospheric flexure led to successive migration of subsidence centre to the north, associated with the main phase of foreland plate extension. For proximal zone of the foredeep, structural extension of the foreland plate, calculated along two seismic sections was of an order of 1.7 % and 2.5 %. Assuming that the whole extension was due to the bending of the plate, a depth of neutral surface (of constant length) was computed at 5–7 km. Shallow neutral surface implies thin brittle upper crust (ca. 10–14 km) being mechanically detached from the lower lithospheric levels. Obtained thickness of the upper crust is similar to the effective elastic thickness of the lithosphere (8–15 km) inferred from flexural modelling. The Miocene subduction was driven by slab-pull and roll back mechanisms. Simultaneously with extension of the foreland plate, thin-skinned compression was exerted at the orogen wedge causing folding and northward thrusting of the Outer Carpathians.

End of the Upper Badenian, compressional stresses was transmitted into the top of the foreland plate. It was evidenced by structural analysis of synsedimentary deformations of the uppermost Badenian series from open-cast sulphur mine located in a distal zone of the CFB. In this area, system of contractional features of wrench tectonic origin developed over dextral transpressive basement faults trending NW–SE.

NNW-directed maximum contraction was estimated from fold axes, reverse faults and striation on reactivated faults. At the prolongation of these basement faults towards SE, transpressive structures like basement pop-ups and positive flower structures were identified on seismic profiles. Episode of basement-involved compression was probably coeval with last stage of thin-skinned orogenic movements. These movements are related to formation of syndepositional compressional structures within the frontal part of the Carpathians that also involve CFB deposits. Both outcrop and seismic data point to northward-oriented compression. During compressive deformations, E component of Alcapa motion probably ceased due to resistance of the Ukrainian part of European plate.

During the Sarmatian, the Alcapa advance to the N was locked. Therefore, it continued its escape towards the NE. This resulted in thrusting of the Skole and Stebnice Units over the Badenian foredeep complex. It was accompanied by normal faults offset in the foreland plate. End of the Sarmatian or during Pannonian collision, sinistral strike-slip reactivation of NE-striking basement faults took place. These faults are clustered in the linear zone at the extension of the Mur–Muertz–Žilina lineament towards the foreland plate. In the Outer Carpathians, the shift of compression direction from N to NE was reported, but timing of this change was not possible prior to this study.

The uppermost part of the foreland basin fill was eroded, due to post orogenic uplift driven by isostatic rebound and elastic deflection of the plate enhanced by slab detachment.

Present-day tectonic stress directions from breakouts in the basement of the Carpathians and their foredeep shows compressive stress in NW direction in the basement of the Bruno–Vistulicum massif and dramatically different NNE direction in the eastern segment of the Małopolska massif. NNE direction of basement compression is similar to contemporary advance of the Carpatho–Pannonian microplate against the N European plate as determined by means of GPS. This suggests a possibility of stress transmission between the Carpatho–Pannonian plate and the Małopolska massif basement across the suture, but mechanical décollement between the Carpatho–Pannonian plate and the Bruno–Vistulicum massif.

Development of strain parameters in front of an obliquely colliding indenter

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We discuss the deformation in a ductile viscous zone in front of an obliquely moving indenter. We approximate solutions for the velocities in the interior of a viscous sheet deformed by a converging indenter (England et al. 1985), and show that the deformation across the zone decreases exponentially with the distance from the indenter and that the transcurrent deformation has a higher attenuation factor than the compressional deformation. In this model, the across-strike width of the indenter, a frontal or lateral type of collision, together with the viscosity of the foreland, play key roles in the indentation process.

Similar to other models of oblique transpression (Tikoff and Teyssier 1984) we consider the velocity of the indenter to be split into components parallel and perpendicular to the indenter - depending on the angle of collision. Thus, we develop a model of deformation in front of an obliquely moving rigid indenter producing such strain partitioning

To describe the deformation history in front of the indenter we consider a rock sample in the deformed zone and compute its relative velocity with respect to the approaching indenter. As the velocity of the ductile material is always less than the velocity of the indenter, the distance of the sample to the indenter is progressively shortened. For the considered rock sample we compute temporal development of finite strain parameters - strain intensity, strain symmetry, lineation and foliation.

The model typically produces a narrow domain near the indenter with prevailing tangential strain followed by a wide zone dominated by compressional strain. We develop a formula expressing the distance at which the strain rate for the tangential strain and the compressional rate equal each other. Below this distance the instantaneous shearing parallel to the indenter boundary prevails over the compression. However, from the viewpoint of finite deformation,