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Ductile Deformation Studies of Anchimetamorphic Sequences in the Bükk Mts., NE Hungary

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The Paleo-Mesozoic anchimetamorphic series of the Bükk Mountains (NE Hungary) are showing similar stratigraphic and tectonometamorphic development to those of the Inner Dinarides (Balla 1987, Csontos 1999, Protić et al. 2000, Filipović et al. 2003). Displacement of the Bükk Unit from the Dinaric margin to the present position along a large-scale fault zone was accompanied by a significant counter-clockwise rotation (Márton and Fodor 1995). In the Bükk Mountains regional dynamothermal metamorphism (160–120 Ma, peak metamorphism around the younger age limit) and a subsequent Late Cretaceous (80–95 Ma, interpreted as cooling age) metamorphic event was reported (Dunkl et al. 1994, Árkai et al. 1995), with the lack of any earlier (Variscan) metamorphism and/or deformation. The ductile deformation is combined or followed by the emplacement of small-scale nappe slices, imbricates and olistoliths, which often have an uncertain timing. The large-scale folding and thinning of anchimetamorphic series was well outlined by previous geological mappers (Balogh 1964, Csontos 1988, Less et al. 2002). However, the intensity and style of the layer-parallel flattening and the axial plane foliation is sometimes hardly observable, and strongly depends on the lithologic conditions and on the position inside the major, folded structure. The ductile deformation is mainly attributed to the early, synmetamorphic phases (Csontos 1999, Németh and Mádai 2004); later events are showing more brittle tectonic style.

Our investigation was aimed to characterize deformation patterns, especially those of ductile behaviour. Working methods were based on detailed field observations and microtectonic investigations on oriented samples taken from scattered, mostly stratigraphically controlled sites of the Bükk Paleo-Mesozoic. Field measurements were followed by deformation analysis of the samples. Different techniques were applied, including microscopic study of thin sections and acetate peels, combined with image-statistic evaluation of the sections and the three scanned, polished surfaces perpendicular to each other.

In the less deformed, massive limestone bodies, where sedimentary structures are partly preserved, bedding-parallel flattening can be traced in zones with a thickness of some cm-s or dm-s. Their deformation ellipsoid (which can be reconstructed for ooidal, oncoidal limestones using texture-statistic method, Fry 1979) is predominantly oblate (lenticular). The maximum elongation (if observable) of such clasts is generally not horizontal, and it is subparallel to the general cleavage and to the E-W trending, but later arched strike of the series. The deformation ellipsoid of the same rock type becomes more elongated (prolate), when it is placed close to the hinge zone of a tight fold. In outcrops and samples containing less competent rock types, simple shear can be traced along the cleavage and the bedding-parallel foliation planes at the limbs of the S-vergent folds, formed in the main folding phase. At right angles to the originally E–W striking, but now arched (and therefore SW–NE, then W–E, then NW–SE tending) anticline–syncline structures, shear criteria indicate different, but mainly top to S movement. Parallel to the subhorizontal lineation, significant elongation can be measured from boudinaged and splitted segments of cherty layers and crinoid fragments. Another, lineation-parallel shearing is also observable in outcrops as well as in thin sections. Probably this dataset is a result of different mechanisms. During the prograde stage of the deformation, planes with different orientations (and different shearing senses on them) become subparallel to the foliation. In cases, when the re-folded sequence gives the same shear criteria, this layer-parallel shearing can also be considered as earlier than syn-cleavage folding. In this case, the first, bedding-parallel deformation has a shear component as a consequence of an early tectonic event.

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Paleogeography of the Outer Carpathian Carbonate Platforms in Poland

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The Northern Carpathians are subdivided into an older range known as the Inner Carpathians and the younger ones, known as the Outer or Flysch Carpathians. At the boundary of these two ranges the Pieniny Klippen Belt is situated. The Outer Carpathians are built up of a stack of nappes and thrust-sheets changing along the Carpathians built mainly of flysch. All the Outer Carpathians nappes are overthrusting onto the European platform covered by Miocene deposits of the Carpathian Foredeep. These nappes have mainly allochtonous character, and originated in basins situated outside their present location. On the other hand, traditionally (e.g. Pescatore and Ślączka 1984) the following sedimentary basins have been distinguished within Northern Outer Carpathians from south to north: the Magura Basin, the Dukla and Fore-Magura set of basins, the Silesian Basin, the Sub-Silesian Ridge and the Skole Basin.

The Mesozoic and Cenozoic paleogeography of the Outer Carpathians reflects the series of continental break-ups, rifts and collisions (Golonka et al. 2000, 2003, Golonka 2004). The Magura Basin originated as part of the Penninic-Pieniny Klippen created during Mesozoic time between Tethyan terranes and Eurasia. The other Outer Carpathian basins had developed in the process of rifting and fragmentation of the European platform. During the Cretaceous tectonic reorganization the new Outer Carpathian realm was formed. Within this realm in the foreland of the folded Inner Carpathians area, several basins divided by ridges and underwater swells became distinctly separated.

The orogenic processes in the Northern Outer Carpathians produced an enormous amount of the clastic material that started to fill the basins. The material was derived from the northern and southern margins as well as from the inner ridges and swells. Each basin had the specific type of clastic deposits, and sedimentation commenced in different time.

In Paleogene the movement of Adria and Alcapa terranes resulted in gradually closing of the flysch basins and development of an accretionary prism. The ridges dividing the flysch basins in Outer Carpathians became more distinguished providing favorable conditions for development of shallow banks with the carbonate platform sedimentation. These platforms have been destroyed during the orogenic process. The platform deposits formed numerous carbonate fragments that have been found in the Outer Carpathians flysch and olistostromes. These fragments were transported with the turbidity currents to the flysch, forming the organodetritic limestones and sandstones. Their distribution provides significant help in an attempt to find the original location of carbonate platforms and finally, to make proper palinspastic reconstruction of the Northern Outer Carpathian realm.

During the final orogenic stage Africa converged with Eurasia. The direct collision of the supercontinents never happened,