Acknowledgements

The financial background of this work was ensured by the Hungarian National Science Found (OTKA), Grant No. T 046736.

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Structural and Paleomagnetic Analysis of Miocene Rocks in Northern Transdanubia

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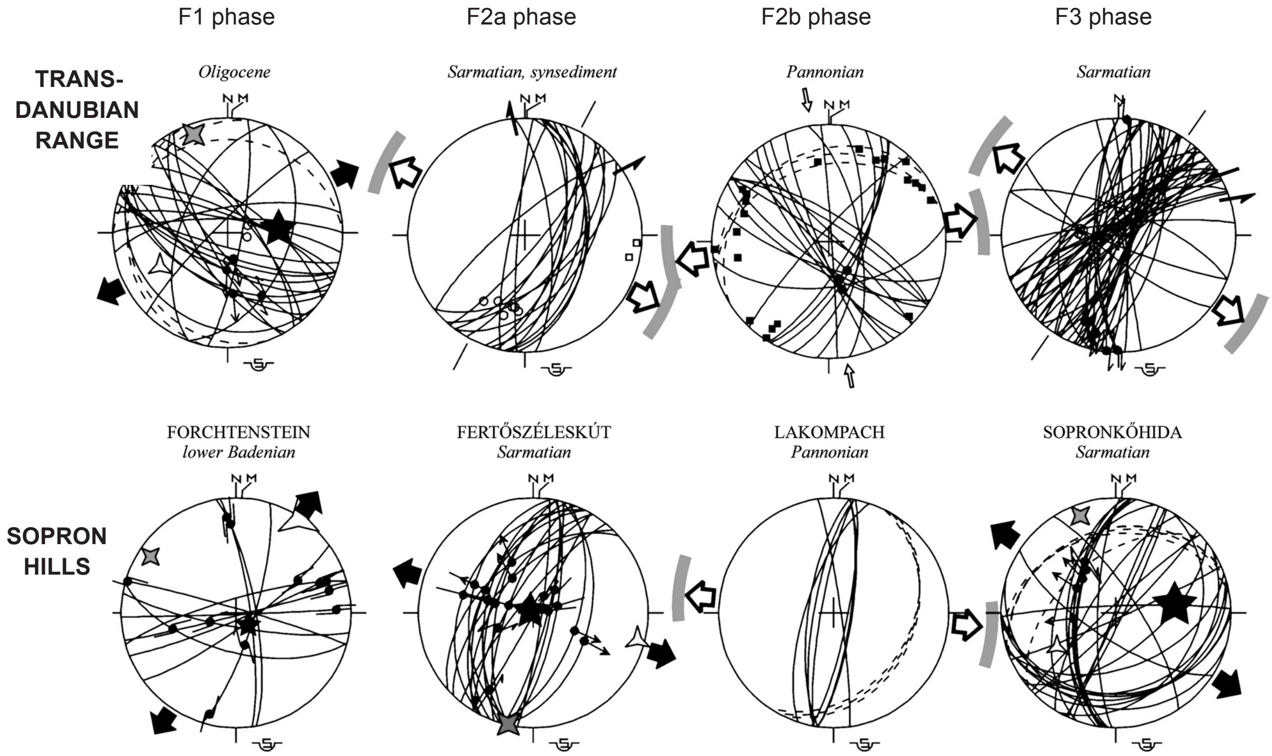
We carried out coordinated paleomagnetic investigation and structural analysis in the northwestern part of the Pannonian basin (northern Transdanubia: Transdanubian Range and Sopron Hills). Our aim was to reconstruct the structural evolution and to establish the temporal and casual connection of rotation(s) and brittle faulting. In addition we used previously published results (Csillag et. al., 2004, Fodor, 1991, 1995, Márton and Fodor, 2003) and reinterpreted some structural ones (Bada el. al., 1996).

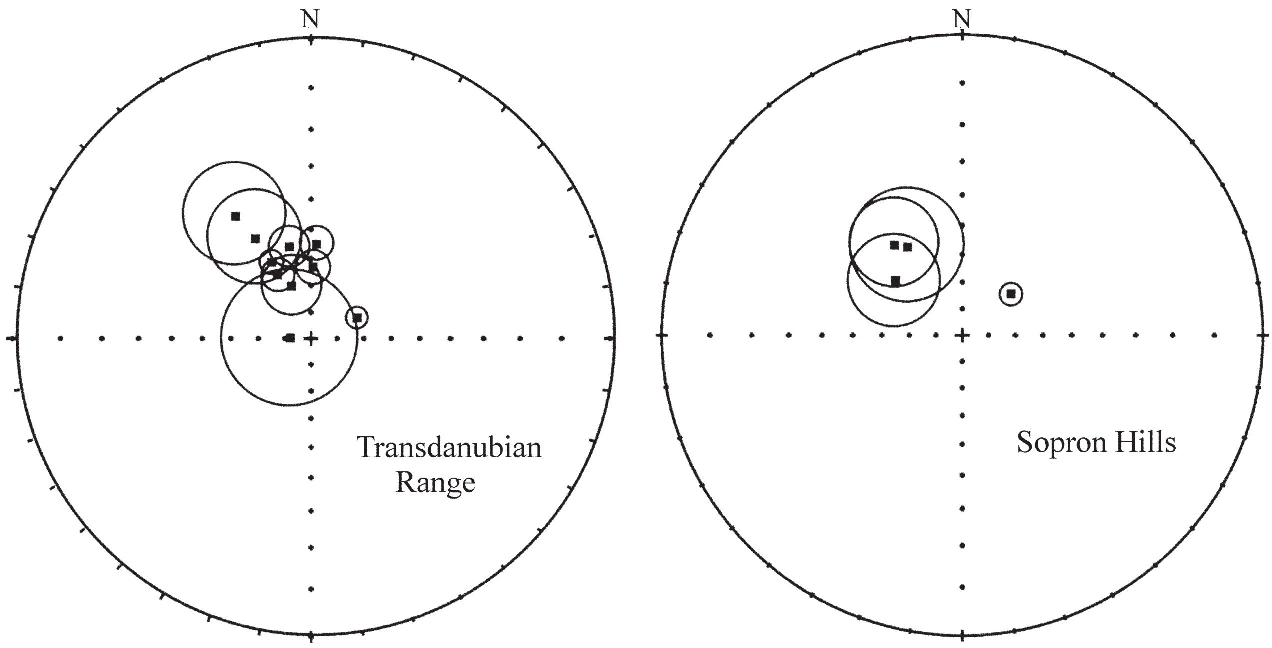
We could distinguish three main events of deformation, all of them tensional in character. The first (F1) could have lasted from late early Miocene to late Badenian with NE-SW tension. During the second phase the tension was WNW-ESE (to E-W?) directed (Sarmatian, F2a), and changed to E-W (F2b) in early Pannonian. The third phase, characterized by NW-SE tension started in late Pannonian and was probably active till the Quarternary (Fig. 1.).

The first phase (F1) was observed in the Transdanubian Range only on the pre-Badenian rocks, in the Sopron Hill area on Badenian limestone. The earlier event of the second phase (F2a) was measured on the Sarmatian rocks both the Transdanubian Range and the Sopron Hills. This stress field affected the rocks both in syn-sedimantary and post-sedimentary manners. The third phase was visible on all studied rocks from pre-Badenian to Pannonian age.

Fifteen localities were collected for paleomagnetic analysis from the Transdanubian Range (10 localities) and from the surroundings of the Sopron Hills (5 localities). Most of the localities were freshly excavated, but the grain-size of the sediments was not always ideal. In the Transdanubian Range, Pannonian marls and siltstones were drilled. In the Sopron Hills, we sampled Badenian marl, Karpatian siltstone and underlying Paleozoic gneiss,



■ **Fig. 1.** The fault pattern and stress field in the Transdanubian Range and Sopron Hills. Stars with three, four and five branches correspond to principal stress axes (σ3, σ2, σ1). The grey arrows correspond to estimated stress axes.



■ **Fig. 2.** Mean paleomagnetic declinations, inclinations for Transdanubian Range and for Sopron Hills with α95 on stereographic projection. The symbols mean the normal polarity.

and Pannonian clay. The samples were drilled and oriented magnetically in the field. Standard-size specimens cut from the samples were subjected to detailed thermal or AF demagnetization. Magnetic susceptibility anisotropy was measured for most of the sites. We found that the magnetic fabric was of sedimentary character. Although, lineation was observed at several point the relation between lineation and stress field was ambiguous.

In the Transdanubian Range about 30° counterclockwise rotation was measured at most localities. Two localities showed present-day north paleomagnetic direction, and one locality clockwise rotation. In the Sopron Hills one locality failed, three localities were rotated counterclockwise and one clockwise (Fig. 2).

The paleomagnetic observations indicated dominant counterclockwise rotation taking place during or after Pannonian in the Transdanubian Range and after the Badenian in the Sopron Hills (the latter suggestion is also supported by results from the Vienna Basin, Scholger and Sting, 2004). It is quite possible that the rotation occurred in the two areas simultaneously. However, there are outliers which maybe due to secondary remagnetization or undetected slumping. This rotation may have caused the apparent change in stress field orientation between the second (F2) and the third (F3) phases of extension.

Acknowledgements

This work was supported by the Hungarian Scientific Research Foundation (OTKA) Project Nos. T034364, T042799.

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Fluids and Earthquake Swarms in Western Bohemia Region

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The western part of the Bohemian Massif is a well-known resort landscape of Bohemia, Saxonia, and Bavaria. The Karlovy Vary spa with 12 mineral springs ranging in temperatures between 42 °C and 72 °C is the best-known spa town in the region. Besides the spas, the recent geodynamics, complex structure, and singular geological evolution range this region among unique natural laboratories in Europe. In addition to the carbonated mineral springs, one of its most spectacular geodynamic feature is periodically reoccurring intraplate earthquake swarms, mostly of magnitude $M_L<3.5$ at focal depths below 6 km, and exceptional occurrence of earthquakes with magnitudes $M_L>4.5$.

This type of seismicity is, generally, associated with active volcanism, geothermal fields, and sea-floor spreading. Its origin is usually explained as an interaction of the tectonic stress and high-pressurised crustal fluids in a subcritically loaded rock environment. Evidence of the fluid-triggered swarm earthquakes also stems from stable tectonic areas, e.g. the Vosges Massif in France (Audin et al., 2002).

The region is intersected by an ENE-WSW trending neotectonic structure, the Ohře rift, and by the NNW-SSW striking Mariánské Lázně fault (Fig. 1). According to Bankwitz et al. (2003), the Ohře rift and the active faults trending N-S and E-W serve for fluid transport in the region. More than one hundred mineral springs and a few hundred gas vents in eight moffete fields are located at the intersection of these fault zones. Current hypotheses claim that all mineral springs and moffetes in the WBM are supplied with CO_2 and other gases from a magmatic reservoir located in the uppermost mantle (Weinlich et al., 1999). Two Quaternary volcanoes, Komorní Hůrka and Železná Hůrka, are located in the seismoactive region; the age of the later is about 0.3 Ma.

A total CO2 discharge in the whole region was valuated to be about 330 m^3/hour. The highest CO_2 discharge in the Cheb basin (20 m^3/hour) and the anomaly of the occurrence of a He of a deep origin, were found at the Bublák mofette (Weinlich et al., 1999), that is situated in the southern tip of the main epicentral