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Neotectonics of the Pannonian Basin

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New data and reinterpretation of old observations shed light on a very exciting and largely overlooked problem: the tectonic evolution of the Pannonian basin from the beginning of Pliocene to recent time. This period is distinct from the Miocene, which saw the extensional collapse of Alpine orogenic wedges, and the formation of the Pannonian basin system. We think that a new tectonic regime characterised by an increase of intraplate stress (neotectonic phase) was established at about 5 to 4 Ma and has continued up to the Present.

Our tentative model for the neotectonic evolution of the Pannonian basin suggest that desiccation of the Mediterranean sea during the Messinian caused a remarkable water level fall in the Pannonian Lake. It was associated with a tectonic uplift of the basin, and a hot-dry clima, which resulted in desert-like conditions in the former lake areas. Intensive erosion has started mostly in western part of the basin (Transdanubia) and continued up to the Recent. This led to a major erosional gap and tectonic discordance at the top of Pannonian strata, which is locally overlain by late Pleistocene to Holocene loess in a thickness of a few to less than 60 m. In contrast, at the western part of the basin (Great Hungarian Plain) subsidence renewed due to intraplate stress increase, and terrestrial red clays are interfingering with lacustrine and fluviatile deposits up to a thickness of 1000 m. Over here, the base of Quaternary is a paraconformity suggesting practically continuous sedimentary record with a cyclicity most probably controlled by the Milankovitch climatic cycles. High-resolution seismic data offer the first spectacular evidence that folding and/or faulting occurred during this neotectonic period, and locally faults active during the late Pleistocene and possibly even the Holocene can be present.

Contemporary stress partitioning in the Polish Western Carpathians

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In the Polish part of the Western Carpathians and the Carpathian Foredeep, recent horizontal stress direction was determined by mean of breakouts analysis method for four boreholes. Breakouts are compressive failures of the borehole wall which cause its elongation perpendicular to the maximum horizontal stress (S_{Hmax}). Long breakouts profiles give unique opportunity for continuos observation of stress direction changes with depth. Breakouts were detected with Six-Arm Dipmeter (SAD) and borehole televiewer (CAST) and processed with SPIDER program.

In the well PL 19 (located in the westernmost part of the Polish Carpathian Foredeep), S_{Hmax} direction changes from NNW for Devonian to NW for Precambrian basement. There are local deviations of stress direction in the vicinity of the fault zone which cuts Devonian rocks. NWN to NW direction of S_{Hmax} is corroborated by numerous breakouts analysis from neighbouring Czech side of the foredeep basin [Pavel Peska - WSMDB] but any stress partitioning has not been mentioned.

Borehole PL 35 is located in the Magura Nappe in the Carpathians, near Zywiec. Here, S_{Hmax} has different orientation for different structural levels. Mean breakouts direction within the flysch nappes indicates NNE S_{Hmax} orientation (similar stress direction was constrained by poor quality data from PL 32, located in the westernmost part of the same nappe). In the Miocene and Devonian autochthonous basement of PL 35 compression has NNW direction while within the short section of Precambrian metamorphic basement it changes towards NW. Therefore, three detached geodynamic levels could be differentiated in this well profile. Small scale deviations of stress orientation were also observed within Devonian interval. Tectonic examinations of the drill core shows, that the set of steeply dipping strike-slip faults is responsible for small scale stress reorientation.

In the well PL 34 which is located in the central part of the Polish Carpathians, and penetrated both Carpathian nappes and the autochthonous Permo-Mesozoic basement, S_{Hmax} trends N-S while in the deeper Carboniferous and Devonian fundament single breakouts indicate NW compression.

At the moment, three other boreholes from this region are under investigations.

Generally, in the westernmost part of the Polish Carpathians, from the deepest autochthonous basement upwards, S_{Hmax} direction rotates from

NW to NWN, respectively. Overthrusted nappes are compressed N-S or even towards NNE. S_{Hmax} orientation in the nappes is more or less similar with the last stage of folding compression in the Western Outer Carpathians. NW orientation of S_{Hmax} for metamorphic basement is characteristic for regional, „plate" compression characteristic for West European Stress Province.

Pre neogene terranes in the central part of the Balkan Peninsula

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At the end of Oligocene the geological framework of the central part of the Balkan peninsula was established. The preexisting terranes or composite terranes have already been in their recent position, and the last existing oceanic area, the Vardar ocean was closed.

The following units in this frame, from the east to the west, can be distinguished: (1) The composite terrane of the Carpatho-Balkanides (CBCT), composed of five terranes, docked together and to the Moesian plate at the East before the Middle Carboniferous; (2) The Serbian-Macedonian composite terrane (SMCT), which parts docked to the CBCT in Ordovician, but at its West new units were added during the Lower Paleozoic; (3) The Vardar Zone composite terrane (VZCT) representing the suture zone or a relict of the former Vardar Ocean, with a long and complex evolution, including different parts of this large oceanic area and incorporated crustal fragments. The largest and probably the last one among them was the Jadar block terrane, pushed into the Vardar zone oceanic area in Upper Cretaceous. This oceanic area was succesively closed from the East (during Upper Jurassic) to the West (in the Uppermost Cretaceous), but some parts were closed even earlier; (4) The five terranes belonging to the Dinarides: the Drina-Ivanjica terrane (DIT), the Dinaridic Ophiolite Belt terrane (DOBT), the East Bosnian-Durmitor terrane (EBDT), the Central Bosnian Mountains terrane (CBMT), and the Dalmatian-Herzegovinian composite terrane (DHCT). The DIT, the CBMT and the DHCT, or the basement of the Mesozoic carbonate platforms, merged together during Permian. The DOBT originated by Triassic rifting in that, during Permian (?) formed composite terrane, then was developed in an oceanic area and closed before the end of Jurassic, now are exposed only the remnants of this oceanic basin. The position of the EBDT terrane is not clear, it was probably pushed into the DOBT during (Middle/Upper ?) Jurassic.

At the end of Cretaceous this framework was established, during the Paleogene only movements along transcurrent faults, rotation and northwards movement of most units took place.

Neogene tectonics, basin formation and sedimentation at the Alpine-Carpathian-Pannonian junction zone

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During the neo-Alpine period, the basin forming processes led to the evolution of the Neogene basin system in the central and inner zones of the Alpine-Carpathian-Pannonian junction. The Vienna and Danube basins are the most extensive, filled by marine and lacustrine sediments attaining thickness from 5 to 8 km.

In the Early Miocene, during the initial stage of the collision between the Western Carpathians and North-European platform, basins of wrench fault furrow-type originated on the northern margin of the paleo-Alpine consolidated part of the orogene. In the latest Lower Miocene, during the Karpatian (culmination of the collision), the pull-apart basins were formed in the transpressional-transtensional regime in more external zones (Vienna Basin). In the hinterland of the orogene, mainly grabens originated. The basins in the frontal part of the Western Carpathians are characterized by thin-skinned tectonics, while the initial rifting of the back-arc basins were accompanied by whole-lithosphere extension.

An orogenic collapse took place during the Middle to Upper Miocene in a transtensional regime. Extensional basins of the syn-rift and post-rift back-arc types have been formed in the central zone; in the marginal parts the basins were formed by pull-apart mechanism. In the central part, the combination of normal faults and listric décollements took place (Danube basin).

The orogenic collapse attacked also inner zone. Neogene syn-rift and post-rift back-arc basins with graben-like features, superimposed on the Buda Paleogene Basin, were formed in the transtensional regime. Thickness of the Neogene sediments in the examined area reaches some 4-6 km.

During the Pliocene and Quaternary a partial relief inversion took place in the Central Western Carpathian area. The Pliocene compressional event is characterized by the stress-field with compression oriented perpendicular to the orogenic trend.