



Environmental, Structural and Stratigraphical **Evolution of the Western Carpathians** **Abstract book**



Thoughts on the structural phases of the Hungarian part of the ALCAPA

LÁSZLÓ FODOR^{1,2}, JÁNOS HAAS¹, SZILVIA KÖVÉR^{1,3}, MELINDA FIALOWSKI¹,
ANNETTE GÖTZ⁴, GÁBOR HÉJA^{1,3}, ZOLTÁN KOVÁCS^{5,1}, ÉVA ORAVECZ^{1,3},
MARTIN REISER⁶ and BENJÁMIN SCHERMAN^{1,3}

1 – MTA-ELTE Geological, Geophysical and Space Science Research Group, 1117 Budapest, Pázmány P. sétány 1/C, Hungary

2 – MTA-ELTE Volcanology Research Group, Eötvös University, Budapest, Hungary

3 – Department of Physical and Applied Geology, Eötvös University, Budapest, Hungary

4 – School Earth and Environmental Sciences Univ. Portsmouth, United Kingdom

5 – Lithosphere Fluid Research Lab, Department of Petrology and Geochemistry, Eötvös University

6 – Geologische Bundesanstalt, Wien, Austria

This presentation will involve new data, old and new speculations, list of problems and reflections to highly appreciated review work of our friend Dušan Plašienka (2018), all to be proved or disproved in the next future.

1. Two phases of pre-orogenic extension: Middle Triassic (Neotethys) and Late Triassic to early Middle Jurassic (Penninic)

Platform – intraplate basin evolution connected to the Middle Triassic extension of the Neotethyan margin was demonstrated by several authors (Budai & Vörös, 2006). New observations clearly demonstrate the existence of Late Triassic, pre-orogenic ~E–W extension in the Transdanubian Range (TR) (Héja et al., 2018). Similar platform disintegration is demonstrated in the Bükk sequence on the basis of stratigraphic data (Csontos, 2000; Velledits, 2006) although the fault geometry is rarely determined. Extension continued up to Bajocian in the whole range (Galács, 1988; Fodor et al., 2018) but having been connected to Penninic opening.

2. Initiation of Neotethys intra-oceanic subduction (~170–165 Ma)

Several observations may indicate the then far-field effect of the initiating subduction. (1) Drowning of the Bükk platform and radiolarite formation in the Bajocian(?), (2) sedimentological data (clast provenance, Haas et al., 2006) and petrology of igneous clasts (REE, trace element geochemistry and unique age) of the Mónosbél and newly defined Recsk units, (3) small-scale faults, slides and slump folds in the Mónosbél unit (Oravecz et al., 2017).

All these observations may indicate a relatively close position of these units to the Dinaridic Carbonate Platform and the Slovenian Trough (Haas et al., 2006; Kövér et al., 2018). Deformations might have reflected the downbending toward the just then initiating subduction and/or to far-field echo of Penninic extension via the Slovenian Trough.

New and revised data demonstrate Callovian age (164.7 ± 1.6 Ma) and N-MORB character of Szarvaskő magmatic suite (B Kiss et al., 2018; Kovács et al., 2018). However, its geodynamic position is unclear.

3. Neotethys subduction, obduction, imbrication of the passive margins; lower plate position

The late Middle Jurassic Szarvaskő magmatic suite and host sediments could originally be in nappe position above the Mónosbél unit (Balla et al., 1980; Csontos, 1999; Scherman et al., 2018). The Darnó nappe, representing the sub-ophiolitic mélange, may occupy the highest structural position (Dosztály et al., 1998; Kovács et al., 2010). New and revised data suggest a southern or southeastern displacement vergency (top W, SW paleo-directions) of the Mónosbél and Szarvaskő units, with repeated episodes of thrusting, having resulted in a complex, accretionary wedge-like structure. Fission track data may indicate latest Jurassic/earliest Cretaceous exhumation of units, possibly during or just after deformation, constraining nappe stacking to ~160–135 Ma (Árkai et al., 1995; Scherman et al., 2018). During the same time, the TR only registered very moderate extension, related to downbending of the lower plate (Fodor et al., 2013).

The assembled Bükk, Mónosbél, Recsk and Szarvaskő units can be considered as Dinaric elements within the Alcapa (Csontos & Vörös, 2004; Fodor et al., 2017) and were tectonically juxtaposed to the TR and Central Carpathian units in the early Cretaceous, after their internal deformations.

Thrusting of obducted ophiolite, related mélange and some passive margin units onto the eastern Adriatic margin induced the formation of the foreland basin system from ~142–140 Ma. Ophiolite detritus reached only the NE TR (Császár & Árgyelán, 1994) when it was on the subducting plate, but very far from the deformation front.

4. Reorganization of the Neotethyan-derived nappe stack, Eoalpine phase; shifting from lower plate to upper plate position

The tectonic motion which permitted the change from Jurassic to Cretaceous subduction system was often invoked as a sinistral strike-slip faulting. Such displacement of the northern Neotethyan margin with respect to the southwestern one was postulated by several authors (e.g. Frank & Schlager, 2006; Stüwe & Schuster, 2010).

After this strike-slip event of possibly earliest Cretaceous age, important thrusting/ shortening occurred within the entire Alpine-Carpathian region. Following Schmid et al. (2008) the Eoalpine high-pressure belt (Koralpe-Wölz unit) separates the East Alpine–West-Carpathian nappe stack into a lower and upper plate considering Cretaceous subduction and nappe stacking (from ca. ~130 or ~100 to ~75 Ma). The Bundschuch, Gurktal-Drauzug and possibly Gemer belong to this Cretaceous upper plate. We can add to this units the former lower plate TR, Silica, Bódva, Torna/Turňa, and also the passively transported other Late Jurassic lower plate pieces: Meliata, Bôrka units.

This could be the time of folding and detachment of TR from its base, juxtaposition of Recsk and TR units, activity of the paleo-Darnó Fault (still remaining between Dinaridic elements!). The early Nekézseny fault, the contact of the Bükk and Uppony, could form at that time as well as the internal crystalplastic deformation of the Szendrő and Uppony (Árkai et al.,

1995; Koroknai, 2004). Finally, the Diósjenő Fault might have been active as a thrust while placing Tr and Dinaridic elements (Recsk, Darnó, Bükk) onto Inner Carpathian units; in the same time, Bôrka+Meliata units could be transported with Silica on their top far to north. All these thrusting should have a north or northwestern vergency, expect for the southern TR Litér and Bakonybél thrusts (Tari, 1994).

Starting of the deformation can be dated as 113 Ma in the TR. Similar FT ages in the Bükk seems to indicate involvement of the Bükk in this Eoalpine(!) deformation, while this is the definite case for the Uppony and Szendrő (Árkai et al., 1995). Deformation could terminate around ~90 Ma, taking into account the youngest FT data from Szendrő and Uppony.

5. Late Cretaceous extension, renewed shortening

The TR experienced late Cretaceous extension, which resulted in partial exhumation of the underlying Austroalpine units, both at the SW TR and possibly also along the Hurbanovo-Diósjenő zone (Koroknai et al., 2001). This phase is parallel to what has been documented in the Vepor (Plašienka et al., 1999; Vojtko et al., 2015).

Latest Cretaceous (80–65? Ma) reactivation of the Nekézseny fault, folding of Senonian strata (Oravecz et al., 2018), dextral faulting at the eastern Bükk (Koroknai et al., 2001), exhumation of Darnó-Bükk units (AFT data, Scherman et al., 2018) is the next, somewhat enigmatic deformation phase.

Acknowledgement: The research was supported by NKFIH OTKA grant 113013, ÚNKP-16-1 and ÚNKP-17-2.

References:

- Árkai, P., Balogh, K. & Dunkl, I. 1995. Timing of low-temperature metamorphism and cooling of the Paleozoic and Mesozoic formations of the Bükkium, innermost Western Carpathians, Hungary. *Geologische Rundschau* 84, 334–344.
- Balla, Z., Baksa, Cs., Földessy, J., Havas, L. & Szabó, I. 1980. The tectonic setting of ophiolites in the Bükk Mountains (North Hungary). *Geologický Zborník – Geologica Carpathica* 31, 4, 46–493.
- B. Kiss, G., Zagyva, T., Pásztor, D. & Zaccarini, F. 2018. Submarine hydrothermal processes, mirroring the geotectonic evolution of the NE Hungarian Jurassic Szarvaskő Unit. *International Journal of Earth Sciences*, <https://doi.org/10.1007/s00531-018-1619-5>
- Budai, T. & Vörös, A. 2006. Middle Triassic platform and Basin evolution of the southern Bakony Mts. *Rivista Italiana di Paleontologia e Stratigrafia* 112, 3, 359–371.
- Császár, G. & B. Árgyelán, G. 1994. Stratigraphic and micromineralogic investigations on Cretaceous Formations of the Gerecse Mountains, Hungary and their palaeogeographic implications. *Cretaceous Research* 15, 417–434.
- Csontos, L. 1999. Structural outline of the Bükk Mts. (N Hungary). *Földtani Közlöny* 129, 4, 611–653.
- Csontos, L. 2000. Stratigraphic reevaluation of the Bükk Mts. (N. Hungary). *Földtani Közlöny* 130, 1, 95–131.
- Csontos, L. & Vörös, A. 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. *Palaeogeography, Paleoclimatology, Palaeoecology* 210, 1–56.
- Dosztály, L., Gulácsi, Z. & Kovács, S. 1998. Lithostratigraphy of the Jurassic formations of North Hungary. In: Bérczi, I. & Jámor, Á. (Eds.): *Stratigraphy of the geological formations in Hungary*. MOL & Geological Institute of Hungary, Budapest, pp. 309–318.
- Fodor, L., Sztanó, O. & Kövér, Sz. 2013. Pre-conference field trip: Mesozoic deformation of the northern Transdanubian Range (Gerecse and Vértes Hills). *Acta Mineralogica-Petrographica, Field Guide Series* 31, 1–34.

- Fodor, L., Héja, G., Kövér, Sz., Csillag, G. & Csicssek, Á.L. 2017. Cretaceous deformation of the south-eastern Transdanubian Range Unit, and the effect of inherited Triassic–Jurassic normal faults. *Acta Mineralogica-Petrographica, Field Guide Series* 32, 47–76. ISSN 0324-6523, 2061-9766.
- Frank, W., & Schlager, W. 2006. Jurassic strike slip versus subduction in the Eastern Alps. *International Journal of Earth Sciences* 95, 431–450.
- Galács, A. 1988. Tectonically controlled sedimentation in the Jurassic of the Bakony Mountains (Transdanubian Central Range, Hungary). *Acta Geologica Hungarica* 31, 313–328.
- Haas, J., Görög, Á., Kovács, S., Ozsvárt, P., Matyók, I. & Pelikán, P. 2006. Displaced Jurassic foreslope and basin deposits of Dinaridic origin in Northeast Hungary. *Acta Geologica Hungarica* 49, 125–163.
- Héja, G., Kövér, Sz., Csillag, G., Németh, A. & Fodor, L. (*in press*). Evidences for pre-orogenic passive-margin extension in a Cretaceous fold-and-thrust belt on the basis of combined seismic and field data (western Transdanubian Range, Hungary). *International Journal of Earth Sciences*.
- Koroknai, B. 2004. Tektonometamorf fejlődés az Upponyi- és Szendrői-paleozoikumban. *PhD thesis, Eötvös University, Budapest*, 239 pp.
- Koroknai, B., Horváth, P., Balogh, K. & István Dunkl, I. 2001. Alpine metamorphic evolution and cooling history of the Veporic crystalline basement in Northern Hungary: new petrological and geochronological constraints. *International Journal of Earth Sciences* 90, 740–752. (DOI 10.1007/s005310000185).
- Koroknai, B., Árkai, P., Horváth, P. & Balogh K. 2008. Anatomy of a transitional brittle-ductile shear zone developed in a low-T meta-andesite tuff: A microstructural, petrological and geochronological case study from the Bükk Mts. (NE Hungary). *Journal of Structural Geology* 30, 159–176.
- Kovács, S., Ozsvárt, P., L., P., Kiss, G., Molnár, F., Józsa, S., & Kövér, S., 2010. Re-evaluation of the Mesozoic of the Darnó Hill (NE Hungary) and comparison with Neotethyan accretionary complexes of the Dinarides and Hellenides - preliminary data. *Central European Geology* 53, 2–3, 205–231.
- Kovács, Z., Kövér, Sz., Fodor, L. & Schuster, R. 2018. New age and re-evaluated whole rock geochemical data of the Szarvaskő magmatic unit (NE-Hungary): Back-arc basin or N-MORB-type magmatism? *Geologica Balcanica*, Abstract Book of the XXI International Congress of the Carpathian Balkan Geological Association (CBGA), 136.
- Kövé, Sz. Fodor, L., Haas, J., Klötzli, U., Szabó, Cs. & Zajzon, N. (*in press*). Evidence for Late Triassic acidic volcanism in the Neotethyan region: U/Pb zircon ages from Jurassic redeposited clasts and their geodynamic implication. *International Journal of Earth Sciences*. <https://doi.org/10.1007/s00531-018-1638-2>
- Oravecz, É., Fodor, L. & Kövér, Sz., 2017. Significance of Jurassic early deformation structures in the SW-Bükk Mts. *13th Workshop on Alpine Geological Studies, Abstract Volume*, 77.
- Oravecz, É., Fodor, L., Kövér, Sz., 2018. Structural mapping, well data and stress field analysis in the surroundings of the Nekézseny Thrust Fault, NE Hungary. *17th Symposium of Tectonics, Structural Geology and Crystalline Geology, Abstract Volume*, 94.
- Plašienka, D. 2018. Continuity and Episodicity in the Early Alpine Tectonic Evolution of the Western Carpathians: How Large-Scale Processes Are Expressed by the Orogenic Architecture and Rock Record Data. *Tectonics* 37, <https://doi.org/10.1029/2017TC004779>.
- Plašienka, D., Janák, M., Lupták, B., Milovský, R. & Frey, M. 1999. Kinematics and metamorphism of a Cretaceous core complex: the Veporic Unit of the Western Carpathians. *Phys. Chem. Earth A* 24, 651–658.
- Scherman, B., Fialowski, M., Fodor, L., Kövér, Sz. & Reiser, M. 2018. Preliminary observations on low temperature shearing and folding of Middle Jurassic siliciclastic formations, SW Bükk, Hungary. *17th Symposium of Tectonics, Structural Geology and Crystalline Geology, Abstract Volume*, 109.
- Schmid, S.M., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M. & Ustaszewski, K. 2008. The Alpine-Carpathian-Dinaric orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences* 101, 139–183.
- Stüwe, K., & Schuster, R. 2010. Initiation of subduction in the Alps: Continent or ocean? *Geology* 38, 175–178.
- Tari, G. 1994: *Alpine Tectonics of the Pannonian basin*. PhD. Thesis, Rice University, Texas, USA. 501.
- Velledits, F. 2006. Evolution of the Bükk Mountains (NE Hungary) during the Middle–Late Triassic asymmetric rifting of the Vardar-Meliata branch of the Neotethys Ocean. *International Journal of Earth Sciences* 95, 395–412.
- Vojtko, R., Králiková, S., Jeřábek, P., Schuster, R., Danišík, M., Fügenschuh, B., Minár, J. & Madarás, J. 2015. Geochronological evidence for the Alpine tectono-thermal evolution of the Veporic Unit (Western Carpathians, Slovakia). *Tectonophysics*.