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The Alpar canyon system in the Pannonian Basin, Hungary – its morphology, infill and development

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ABSTRACT

Giant incised canyons were recently recognized in Late-Miocene post-rift sediments in the central part of the Pannonian Basin. Though not connected to the world seas, Lake Pannon shows significant signs of relative lake level variations controlled by tectonics and climate changes. The incision surface of the Alpar canyon system is connected to SB Pa-4 (6.8 Ma sensu Vakarcs, 1997), earlier reported to represent a significant relative base-level fall in the basin, however, debated recently.

Incised several hundred meters in the preexisting substrate, the individual canyon valleys of the Alpar canyon system are enormous in size and display a multi-story nature. They loose topographic expression headwards and basinward. Widths of individual valleys range from 5 to 10 km, with smaller tributaries. In the study area several adjacent canyon valleys can be seen on seismic profiles. The valley depth is greatest near their confluence, where a major trunk valley (600–700 m deep) was formed by eroding most of the Upper Miocene succession. The canyons are filled with clay marls. They are incised into an extremely thick aggrading deltaic complex and are overlain by fluvial sediments, suggesting a major transgression in between.

The Late Miocene Alpár canyon system developed on the southern margin of the Mid-Hungarian Mobile Belt, the latter is characterized by NE-SW oriented fold axis and NE-SW oriented left lateral strike-slip faults. The canyon system coincides with a large releasing bend and/or extensional duplex of the Paks–Szolnok strike-slip system being active as sinistral during the Late Miocene.

Presumably, the formation of the deep canyons was generated by the close interaction of several factors and events in space and time, among them tectonic uplift forced relative base-level fall, the reactivation and bending/duplexing of a strike-slip fault system located near the coeval zone of the lake shoreline and shelf edge, and the possible change of sediment supply carried by overfed rivers.

1. Introduction

Giant erosional features have been recently recognized in the Upper Miocene (Pannonian s.l.) post-rift lacustrine sediments of the Pannonian Basin. Surrounded by the orogenic belts of the Eastern Alps, Carpathians and Dinarides at the convergence zone between the European and African plates, the Pannonian Basin is a Neogene extensional basin system located inside the Central European Carpathian loop (Fig. 1). It was isolated from the remainder of the Paratethys around the Middle/Late Miocene boundary, thus forming Lake Pannon, a huge brackish lake in the basin. Lake Pannon was several hundred kilometers in diameter, and several hundred meters in depth. In spite of the fact that it was a lake, it exhibits characteristics in its development and sedimentology of a deep marine basin rather than a lake with high rates of sediment accumulation, in the deepest parts exceeding 6000 m. The sedimentary evolution of the lake in the past was thought to be continuous through time. The newly recognized erosional features in the central part of the basin, however, allow us to infer a more complicated history with significant events that interrupted its evolution.

We interpret the erosional features as elements of a huge canyon system, orders of magnitude larger than other incised valleys reported from the Pannonian basin to date and larger than many modern marine canyons. It is most spectacularly displayed on seismic records near the village of Alpar (hence its name) in the vicinity of the towns of Kecskemét and Nagykörös (Fig. 2).

The objective of this study was to document and describe this erosional geomorphological feature and to interpret the depositional processes and tectonic events that may have triggered its formation. We relied on both conventional and modern models and examples of deep-water canyons (Clark and Pickering, 1996; Posamentier, 2001; Posamentier and Kolla, 2003; Baztan et al., 2005; Cronin et al., 2005; Mitchell, 2006). These models, however, were all developed for deep-marine settings, therefore their application to the Pannonian Basin requires caution.

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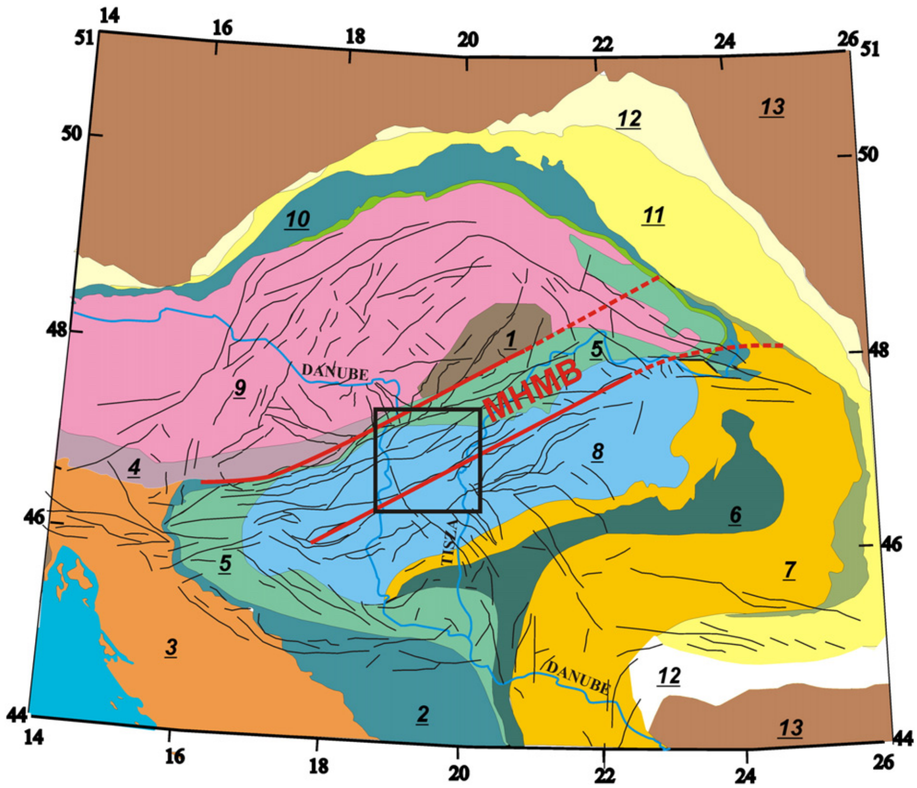

Fig. 1. Tectonic sketch map of the Pannonian Basin and the surrounding Alps, Carpathians and Dinarides and location of the study area (modified after Schmid et al., 2008 and Ustaszewski et al., 2008). The boundary zone of the two main terrains, the ALCAPA and the TISZA terrain, represents an oceanic suture zone, and it forms the Mid-Hungarian Mobile Belt (MHMB). It is the most significant neotectonic zone of the Pannonian Basin. Legend: 1. Bükk, 2. Obducted western Vardar (Neotethys) ophiolites and Meliata, 3. Karst Unit and Bosnian Flysch Unit, 4. Southern Alps (3. and 4. consist of thrust sheets derived from Adriatic plate), 5. Alpine Tethys and Neotethys junction (Piemont-Liguria, Kriscevo, Sava, and Szolnok units) suture zones, oceanic accretionary prizm and ophiolites, 6. Obducted eastern Vardar (Neotethys) ophiolites, 7. Dacia Unit, 8. Tisza Unit, 9. ALCAPA Unit, 10. Rhenodanubia, Magura (Alpine Tethys) suture zone and oceanic accretionary prizm, 11. Carpathian Miocene external thrust belt, 12. undeformed external foredeeps, and 13. East European and Moesian platform of the European plate. The map includes a fault pattern (modified after Mahel, 1974; Kocak et al., 1981; Royden, 1985, 1988; Krus and Sutora, 1986; Ratschbacher et al., 1993; Csontos et al., 1992; Kovac and Hok, 1993; Vass et al., 1993; Linzer, 1996; Nemcok et al., 1998, 2006; Haas et al., 2010).

2. Regional geology

2.1. Tectonic setting

The Pannonian Basin is underlain by an orogenic collage built up by several crustal blocks (Fig. 1). The whole Pannonian–Carpathian region is characterized by highly arcuate plate boundaries resulting from the roll-back and steepening of subducted lithosphere into landlocked remnant oceanic basins (Wortel and Spakman, 2000; Leever et al., 2011). Crustal blocks are separated by mobile belts formed during Late Jurassic, Cretaceous and Tertiary times and characterized by extreme changes along strike, including changes in subduction polarity, and Alpine–Carpathian polarity versus Dinaric polarity (e.g. Laubscher, 1971; Schmid et al., 2004, 2008). The general driving mechanism of the Carpathian–Pannonian development was the long-term Africa–Europe convergence with a separate northwestward and northward movement of the Adriatic block (e.g., Laubscher, 1971; Bada, 1999) resulting in a NE push (Loriczi and Houseman, 2010). The formation of the Pannonian Basin system by rifting and extension (Tari and Horváth, 2006) was generated and/or controlled by different tectonic processes: a NE pull from the retreating subduction zone and subduction roll-back in the remnant Carpathian Flysch Basin area (e.g., Royden, 1988, 1993), a gentle collision and an oceanic slab break-off at the end of the subduction (e.g. Spakman, 1990; Lillie et al., 1994; von Blanckenburg and Davies, 1995; Nemcok et al., 1998, 2006; Sperner et al., 2002), gravitational collapse, astenospheric updoming (Cloetingh et al., 2006), and the internal buoyancy forces arising from crustal thickness variations (Loriczi and Houseman, 2010). These processes, especially the astenospheric updoming, led to weakening of the lithosphere in the Pannonian basin.

The basement of the Neogene Pannonian basin is built up by Mesozoic nappe systems of the major crustal blocks consisting of the northwestern ALCAPA (Alpine–Carpathian–Pannonian) and the southeastern Tisza (Bardócz et al., 1991; Kókai and Pogácsás, 1991a; Pogácsás et al., 1991; Csontos et al., 1992; Tari, 1992; Fodor et al., 1999; Hámor et al., 2001; Tari and Horváth, 2006). Schmid et al. (2008) believe that the branch (or boundary) between Tisza and ALCAPA Mega-Units forms part of the Mid-Hungarian Fault Zone. Lőrincz et al. (2002) identified the Mid-Hungarian Mobile Belt as a weakness zone situated on the boundary of the ALCAPA and Tisza terranes of different Mesozoic origin (see Fig.1).

Rotation and deformation vary across both blocks, with anticlockwise rotation occurring in the ALCAPA crustal block, and clockwise rotation in the Tisza block that happened in several phases (Márton et al., 2000; Márton and Fodor, 2003). Different models for the Tertiary development of the Tisza block were also described (Csontos et al., 2002). The opposite rotations of the ALCAPA and Tisza block led to NW-SE convergence in the space between the two main Intra-Carpathian terranes in a wide inherited weakness zone, being identified by different names in the tectonic literature all having a slightly different meaning: Ustaszewski et al. (2008) Mid-Hungarian Fault Zone, Jarosinski et al. (2011) Mid-Hungarian Shear Zone (MHSZ), and Loriczi and Houseman (2010) Mid-Hungarian Zone.

In this contribution we prefer to use the name Mid-Hungarian Mobile Belt (referred to as MHMB in the figures and text, see Fig. 1) in a broader sense referring to a wider weakness zone including the Mid-Hungarian Fault Zone of Ustaszewski et al., 2008 (see Fig. 2) and