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Late Quaternary paleodrainage reconstruction of the Maros River alluvial fan

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ABSTRACT

The surface of the extensive Maros alluvial fan is densely (0.78 km/km^2) covered by paleochannels. The aim of the present study is to reconstruct the final (late Quaternary) stage of the alluvial fan development by identifying paleodrainage directions and determining morphology and pattern of the paleochannels and the age of their activity.
On the surface of the alluvial fan, 18 meandering, braided, anastomosing, or misfit paleochannel zones were identified. The existence of these channels indicates that the main process of the fan development was avulsion rather than lateral channel shift, and the overbank floodplain accumulation played a minor role as the paleochannels were not buried. The oldest paleodrainages (A–C) shifted towards north from the east–west-axis of the alluvial fan, draining water to the Körös basin. The similar age (18.7 ± 2.3 ka–14.2 ± 1.4 ka) of the paleochannel zones indicates rapid avulsions or the coexistence of paleodrainages. In the northern half of the alluvial fan, the last large (D) paleodrainage change occurred 12.4 ± 2.1 ka, when the channel turned westward. A large meandering channel functioned for a period (12.4 ± 2.1 ka–9.6 ± 1.3 ka); and with the coexisting misfit channels, these channels drained a considerable amount of water (Q_b = 2500 m^3/s). In the next development phase (E paleodrainages), the Maros flowed north; but after a sharp bend, it turned toward the south, and it started to form the southern lobe of the alluvial fan. These channels existed between 8.5 ± 0.9 ka and 3.5 ± 0.4 ka and had a bankfull discharge of 1000–2000 m^3/s. The last (F) paleodrainage of the Maros River existed for a short time (1.9 ± 0.3 ka–1.6 ± 0.3 ka) and indicated decreasing discharge (Q_b = 1400 m^3/s). In the final phase of the alluvial fan evolution, the present-day course of the river was developed, and its discharge decreased further (680 m^3/s).

1. Introduction

The development and forms of alluvial fans are related to sedimentary basin environments, thus they are sensitive indicators of climate and vegetation change, tectonic activity, and base-level variations (Porat et al., 1997; Harvey et al., 2005). The long-term evolutionary history of alluvial fans is reflected by their sedimentary structure, while the last phase of their development is reflected by superficial forms and processes. Based on the characteristic processes, alluvial fans could be classified as fluvial sediment transport dominated or debris flow dominated (Yuste et al., 2004). This type of characterization reflects their size and slope conditions, as mass movements mostly appear on smaller and steeper alluvial fans, while fluvial processes are dominant on larger and low gradient alluvial fans (Kochel, 1990).

The studies on the superficial forms and processes of alluvial fans apply to different scales. In large-scale studies, sets of alluvial fans and their broad environment are studied for their tectonic setting, relief conditions and accommodation space (Borsy, 1989, 1990; Al-Farraj and Harvey, 2005; Harvey, 2005; Weissmann et al., 2005; Gábris and Nádor, 2007). At this large scale, morphometric and volumetric analysis is also possible (Viseras et al., 2003; Volker et al., 2007; Giles, 2010). In smaller scale studies, the geomorphologic forms and active processes are studied in detail. On steep, smaller fans, rock falls, debris flows, and sheet-flood processes are dominant (e.g., Gomez-Villar and Garcia-Ruiz, 2000; Nichols, 2005). On alluvial fans dominated by fluvial sediment transport processes, most attention is paid on the paleodrainage changes in connection with tectonic activity (Borsy, 1989; Arche and López-Gómez, 1999; Yuste et al., 2004). Some research investigated fluvial forms in detail (Gohain and Parkash, 1990; Maizels, 1990; Gábris and Nagy, 2005), the avulsion process (Field, 2001; Tooth et al., 2009), or the interaction between fluvial and aeolian processes (Kiss and Bódis, 2000). However, detailed geomorphic mapping of large alluvial fans is missing, though the development history of an alluvial fan could be reconstructed more precisely with absolute age measurements.

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In the development of fluvial process-dominated alluvial fans, the most important form is the river channel as it is the most significant factor in sediment transport. During the evolution of the alluvial fan, the channel changes its drainage direction owing to tectonic and climatic changes, avulsions, or sometimes because of human impact (Lecce, 1990; Sümegi et al., 1999; Nagy, 2002; Blair and McPherson, 2009). These drainage changes are reflected by abandoned channels on the surface of the alluvial fan or by the development of terraces on the apex (Rachocki, 1981; Blair and McPherson, 2009). The surface of the alluvial fans could be densely covered by paleochannels; some of them could be active during extreme floods; and very often they have a braided pattern (Murkerji, 1990). According to Rachocki (1981), braided channels develop on surfaces with higher slopes, as on the terrace edges of the apex and on the margin of the alluvial fan. On the distal areas and on the margin headward, erosional gullies also appear and by reworking the material of the alluvial fan, they could form secondary alluvial fans (Rachocki, 1981; Blair and McPherson, 2009).

The main geomorphological characteristics of an alluvial fan are determined by primary (constructional) and secondary (destructional) processes (Blair and McPherson, 2009), which often exist simultaneously (Nagy and Félegyházi, 2001). The constructional processes are responsible for water and sediment transport from the catchment area to the alluvial fan; and they determine the slope conditions, channel pattern, and the occurrence of avulsions. The destructional processes redistribute the accumulated sediment. Such processes include surface runoff, aeolian activity, weathering, bioturbation and soil development, tectonism, and human activity. These destructional processes could deform, or in extreme cases destroy, the alluvial fan (Nichols, 2005); and they usually develop in periods of reduced sediment supply or increased runoff (Harvey et al., 1999). The controls on long-term fan evolution were classified in a different way by Maizels (1990) as follows: the long-term fan aggradation, changes of catchment area, or sediment availability are the autocyclic factors; while the allocyclic factors are climate change, tectonic effects, and eustatic changes.

The development of the alluvial fans of the Carpathian basin started in the Pliocene, when the huge alluvial fans were built by the rivers of the Carpathians toward the center of the basin (Borsy, 1990; Mike, 1991; Gábris and Nádor, 2007). However, the evolution of these alluvial fans was not uniform temporally or spatially, as it was driven by very active tectonic movements and climatic changes (Schafarzik, 1918; Borsy, 1989; Sümegi et al., 1999). Thus the fluvial development ceased from time-to-time as the rivers shifted on the surface of the alluvial fans. Therefore, the fans have quite complex vertical and horizontal structure. The spatial extension and the sedimentary structure of the Hungarian alluvial fans were studied in detail (Schafarzik, 1918; Pécsi, 1959; Borsy, 1989, 1990; Nagy, 2002); however, the age of their sedimentary strata was deducted with the lack of suitable dating techniques. Though in the last decades some dates were derived from the sinking floodplain areas in front of the alluvial fans, where channels were dated by pollen analysis, radiocarbon, or OSL dating (Borsy et al., 1989; Félegyházi, 1998; Gábris, 1998; Nádor et al., 2005). According to Borsy (1990), on the Great Hungarian Plain alluvial fan development terminated by the end of the Pleistocene, as the climate and the tectonic setting were no longer favorable. However, nineteenth century river regulation works on the Maros River increased the slope of the channel, resulting in a greater sediment discharge and a secondary alluvial fan developing (Kiss et al., 2011). This recent example suggests that alluvial fans could develop further in certain locations during the Holocene.

The main goal of the present study was to reconstruct the final development stage of the Maros alluvial fan by analyzing its surficial forms. To reach this aim, the directions of paleodrainage and channel pattern were determined. Based on the vertical parameters of the paleochannels, paleodischarge was calculated. We also aimed to determine the OSL age of paleochannels, which could be the final step in the reconstruction of the drainage changes of the river.

2. Study area

The Maros River drains the water of the eastern and southern Carpathians. As it reached the Great Hungarian Plain it built an extensive alluvial fan (ca. 9000 km^2) with a radial length of 80–100 km (Fig. 1). The present-day Maros River is located within the E–W axis of the alluvial fan; north of the axis, the alluvial fan is more elongated than on the southern part. The alluvial fan is shared by Hungary (35%), Romania (50%), and Serbia (15%); but in the present study, only the geomorphology of the Hungarian part is analyzed in depth because of the lack of detailed topographic maps in the other countries. However, OSL samples were collected on the Romanian side as well to make the reconstruction of the paleodrainage more precise.

Tectonic activity has always played an important role in the evolution of the alluvial fan as the surrounding floodplain areas are sinking areas (Szeged and Körös grabens), and the territory of the alluvial fan itself is also dissected by fault lines (Andó, 2002). It is reflected by the dissected base-rock, which consists of uplifting blocks (Battonya and Battonya–Pusztaföldvár High) and sinking basins (Békés basin and Makó–Hódmezővásárhely graben) characterized by continuous sedimentation during the Quaternary (Joó et al., 2000; Nádor et al., 2005, 2007).

Similarly to the other vast alluvial fans of the Carpathian basin, the Maros alluvial fan developed throughout the Quaternary (Borsy, 1989, 1990; Mike, 1991; Gábris and Nádor, 2007). In front of the Zaránd Mountains, thick pebble layers were deposited; but most of the alluvial fan is built of sand, silt, and clay. From the apex to the western margin of the alluvial fan, the thickness of the sedimentary body increases from 100 to 500–700 m (Borsy, 1989). The course of the paleo-Maros was driven by the neighboring sinking floodplain areas of the Körös and Tisza Rivers, which acted as the local erosional base of the Maros River (Nádor et al., 2005; Gábris and Nádor, 2007).

Several ambiguous statements exist about the evolution of the Maros alluvial fan. For example, according to Andó (2002), it developed in the Ice Age (he did not define which one), when the cold and wet climate increased the fluvial activity of the Maros River, thus it eroded the upstream sediment bodies and transported and deposited them on the alluvial fan. Mike (1991) drew a more detailed evolutionary history, though the evidence of development was not revealed. Seemingly his statements on the paleodrainage are based on the paleochannels on the surface, and he projected these courses throughout the Pleistocene. According to Borsy (1989), at the beginning of the Würm, the Maros incised itself into the apex of the alluvial fan, and it started to build a secondary alluvial fan. However, its construction also terminated because, since the Late Glacial Maximum, the Tisza River slowly incised into its floodplain; and the base-level drop initiated the incision of the Maros River, halting construction of the alluvial fan. However, since the late nineteenth century as the result of levee construction confining the floodplain, intensive floodplain aggradation started at the front of the alluvial fan (Kiss et al., 2011), which could also be defined as development of a new secondary alluvial fan.

The surface of the Maros alluvial fan is covered by loess, sandy loess, and clayey–silty overbank deposits, which do not form a continuous layer (Sümegi et al., 1999). The area is characterized by paleochannels, secondary channels, ox-bows, and fluvio–aeolian dunes (Andó, 2002). However, according to Sümegi et al. (1999), aeolian activity was not present on the alluvial fan (in contrast with the other alluvial fans of the Hungary), thus its original fluvial structure is still preserved.

3. Methods

To reconstruct the final development stage of the Maros alluvial fan, the fluvial forms on the surface were analyzed and their age was determined.