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Tracing multiple resedimentation on an isolated karstified plateau: The bauxite-bearing Miocene red clay of the Southern Bakony Mountains, Hungary

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ABSTRACT

The Vöröstó (=Red Lake) Formation, located in the Southern Bakony Mountains and the Balaton Highlands (Hungary), is a red, clayey continental assemblage containing hard, up to fist-sized bauxite pebbles, occurring in a large apparent stratigraphic gap between underlying karstified Triassic carbonates and mid' Miocene to Quaternary cover. The origin and the exact stratigraphic position of the assemblage have been controversial for a long time. In this study, petrographic observations on the bauxite pebbles revealed common features with Cretaceous bauxite deposits known in the region, whereas heavy mineral composition of the red clay matrix is similar to those known from the Eocene bauxite horizon of the region. Single grain zircon U–Pb ages obtained from the bauxite pebbles and their red clayey matrix show similar late Archean to Jurassic age components. Additionally, Cenozoic U–Pb ages are well represented in the mostly euhedral zircon crystals separated from the red clays, whereas this volcanogenic contribution completely missing from the bauxite pebbles. SEM morphology and related EDX chemical analysis of clay minerals indicate polygenetic, detrital origin for the red clays. The main source material of the bauxite bearing Vöröstó Formation is most probably local Cretaceous and Eocene bauxite deposits exposed during the middle-late Miocene. These tropical weathering products were partly decomposed and degraded, but dilution by siliciclastic contribution is negligible. We suggest a transport mechanism dominated by local redeposition of mostly pelitic and allitic material through seasonal muddy debris flows within a karstic landscape.

1. Introduction

The Vöröstó Formation (VF) is a continental red clay assemblage that is exposed in the Southern Bakony Mountains and the Balaton Highlands between Diszel and Vörösberény (Fig. 1). This area belongs to the Transdanubian Range (Fig. 1). The Transdanubian Range (TR) is situated in the western part of the Pannonian Basin and belongs to the 'ALCAPA' composite terrane (Fig. 1). This terrane was amalgamated during Paleogene to early Miocene time and consists of (i) the Eastern Alps (various Paleozoic formations and mainly carbonatic Mesozoic sequences), (ii) Carpathian elements of dominantly low to medium grade metamorphic rocks and (iii) Neogene sedimentary sequences of the Pannonian Basin (Haas, 2013).

The Vöröstó Formation essentially consists of a red clayey matrix, which contains up to 15 cm sized mostly well rounded, hard bauxite-pebbles. It was deposited during Miocene time and mainly comprises the fillings of karstic dolinas and sinkholes within Triassic Carbonates. It thus represents a huge stratigraphic gap giving rise to several contrasting evolutionary models for the VF. The main controversy relates to the question whether the entire sequence is recycled from older Cretaceous and Paleogene bauxite levels or the deposits reflect some bauxitic sediment and/or bauxite pebbles formed in-situ at the time of the Middle Miocene Climatic Optimum (e.g. Bárdossy, 1982; Knauer and Mindszenty, 1987; Bárdossy and Dercourt, 1990; Budai et al., 1999; Tóth and Varga, 2014). Given the high relevance of ferrallitic paleosoils and related bauxitic sediments for terrestrial paleoclimate reconstructions (e.g. Kovács et al., 2013; Mindszenty, 2016), providing a solution to this controversy is important for the paleoclimatic and paleoenvironmental interpretation of bauxitic deposits in general.

To shed light on this controversy we present a multi-proxy provenance approach to the VF bauxitic continental deposits, including thin

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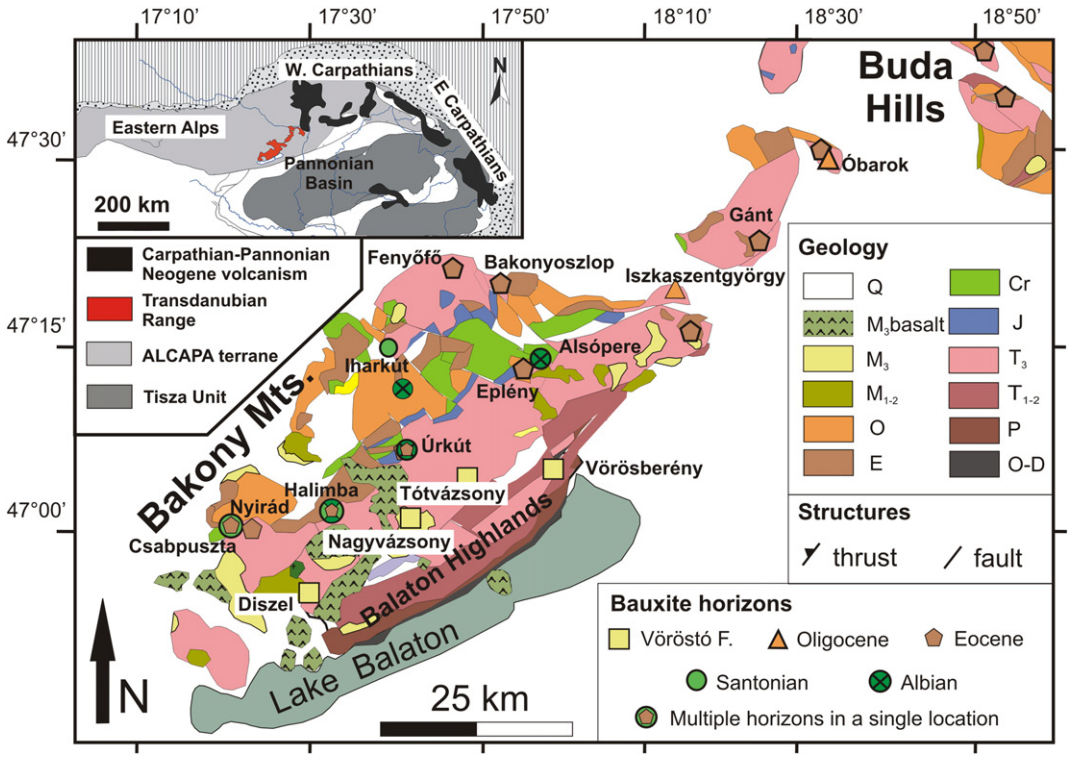

Fig. 1. Simplified geological map of the Transdanubian Range showing the main occurrences of the Vöröstó Formation and bauxites (base map: Gyalog, 2005, 1:100,000). Abbreviations: O-D: Ordovician to Devonian mostly low-grade quartz phyllite and slate. P: Permian continental red sandstone. T_{1-2}: Early to middle Triassic carbonates and the "pietra verde" tuff (Horváth and Tari, 1987; Pálfy et al., 2003). T_3: Late Triassic carbonates, dominantly Dachstein Limestone and Main Dolomite. J: Jurassic carbonates. Cr: Cretaceous in general. E: Eocene in general. O: Oligocene in general. M_{1-2}: Early and middle Miocene in general. M_3: Late Miocene in general. M_3basalt: Late Miocene to Pliocene basalts. Q: Quarternary in general. For detailed lithology see Haas (2013). The Carpathian-Pannonian Neogene volcanism is described in details in Harangi and Lenkey (2007) and Lukács et al. (2015).

section petrography, phase analysis by X-ray powder diffraction (XRD), bulk-rock geochemical analysis by X-ray fluorescence spectrometry (XRF), microscale morphological observations on clay minerals by scanning electron microscopy coupled with energy dispersive X-ray analysis (SEM-EDX), quantitative heavy mineral analysis and U–Pb geochronology of detrital zircon grains. Because VF was most likely never buried deep enough to undergo significant diagenetic alteration, these data are considered to record primary information on the Mesozoic to Paleogene rocks exposed at the surface in the surroundings of the karstic depocenters. Especially if outcrop conditions are poor, such approach is considered most promising for (i) the regional comparison to other, eventually better preserved archives, (ii) deciphering (multiple) recycling of older bauxitic levels, and (iii) constraining the timing of deposition and bauxite formation.

2. Geological setting

The main occurrences of the Vöröstó Formation are located in the Southern Bakony Mountains and the Balaton Highlands within the Transdanubian Range (TR, Fig. 1). The TR sensu stricto is bounded by major strike-slip faults and dominated by sedimentary successions, which are part of a major NE-SW striking synclinal structure formed within the Alpine nappe system during the Aptian to early Albian (Tari, 1994; Kiss and Fodor, 2005). The Transdanubian Range detached from the Alpine zone during Paleogene times and moved eastwards along a major dextral strike-slip fault system to the Pannonian Basin from Paleogene to Neogene times. In the early Miocene the hitherto separated ALCAPA and Tisza terranes (Fig. 1) were already located close to each other and their final amalgamation finished during the middle Miocene and created the modern tectonic framework for landscape evolution (Kázmér, 1984; Tari, 1994; Márton and Fodor, 2003; Csillag and Sebe, 2015). For the purpose of this paper we divided the Palaeozoic to Cenozoic successions into six sedimentary cycles (Fig. 2).

The first cycle is the Ordovician to lower Carboniferous, mostly dominated by slates, which experienced Variscan low-grade to medium grade metamorphism. They are exposed at the southern margins of the syncline only. The second, Permian to Aptian cycle starts with massive, several hundred meters thick continental clastic red sandstone-type Permo-Triassic sediments covered by up to 3 km thick, mostly shallow marine carbonates of Mesozoic age. Mid-Cretaceous compression triggered syncline formation, uplift, subaerial exposure, partial erosion and concomitant karstification of the predominantly carbonate landscape. The Albian greenhouse climate conditions (Ufnar et al., 2004) provided the preferable circumstances for the formation of the oldest, Albian "Alsópere" bauxite horizon of the region (Fig. 1). The bauxites are traditionally dated by the age of their immediate cover. The Albian bauxites fill shallow karstic features of either upper Triassic or sometimes lower Jurassic limestones and are covered by Albian freshwater or brackish marls (Fig. 2). Towards the end of the third, Albian to Turonian sedimentary cycle, subaerial exposure and bauxite formation occurred again, resulting in the erosion of all Turonian sediments and the accumulation of commercial-grade bauxite deposits. These are covered mostly by upper Cretaceous sediments. The major occurrences of this younger Late Cretaceous (Santonian) bauxite horizon can be found at Halimba, Iharkút and at Csabpuszta (Fig. 1). Their bedrock is also mostly upper Triassic dolomite and limestone and they are covered by Coniacian to Maastrichtian sediments of the fourth cycle (Fig. 2). The next erosional event resulted in the formation of the Eocene bauxite horizon. Considerable deposits can be found, for instance, at Nyirád,