Available online at www.sciencedirect.com
SCIENCE DIRECT®

Tectonophysics 410 (2005) 81–95

TECTONOPHYSICS

www.elsevier.com/locate/tecto

Soft-sediment deformation structures in Late Miocene–Pleistocene sediments on the pediment of the Mátra Hills (Visonta, Atkár, Verseg): Cryoturbation, load structures or seismites?

Zoltán Horváth [a,*], Erika Michéli [b,1], Andrea Mindszenty [a,2], Judit Berényi-Üveges [c,3]

[a] Department of Applied and Environmental Geology, Eötvös Loránd University, H-1117 Budapest, Pázmány Péter s. 1/C, room: 710, Hungary
[b] Department of Soil Science and Agricultural Chemistry, Szent István University, H-2103 Gödöllő, Páter Károly u. 1, Hungary
[c] Central Service for Plant Protection and Soil Conservation, H-1118 Budapest, Budaörsi út 141–145, Hungary

Received 18 June 2003; accepted 18 August 2005
Available online 20 October 2005

Abstract

The studied area, built up by silty clayey and partly sandy sediments and paleosols, lies on the tectonically active Northern margins of the Pannonian Basin. Wavy, sagging load casts can be observed in the upper part of the Late Miocene alluvial complex and larger scale sagging load casts, flame structures, drops and pillows detected in its Quaternary cover were studied in detail, in order to understand the origins of soft sediment deformation which characterized this young sedimentary suite. Sedimentological, paleopedological and mineralogical observations suggest that:

1. One of the reasons for the soft-sediment deformation might have been the relatively low cohesive strength of the predominantly smectitic sediment covering a gentle slope similar to the actual landscape.
2. On such a surface, the down-slope gravitational component of the mud-blanket might easily have been sufficient to overcome its cohesive strength.
3. Frost action traceable in the studied formations might also have contributed to the observed deformation, particularly along the eroded top of the Late Miocene sediments.

Combined evidence from field observations and laboratory analyses support the idea that liquefaction–fluidization was of prime importance in bringing about the observed structures. In conclusion two alternative Quaternary/Holocene scenarios are proposed, which might have resulted in the unusual behaviour of the sediments/paleosols. One is a seismic event, the other is the combined effect of freeze–thaw cycles and of the sloping foothill position, which might have resulted in episodic downslope transport and the associated deformation of the eroded soil material when its water content surpassed a certain threshold. We accept that the anomalous abundance of soft-sediment deformation in this marginal position may be causally related to paleo-earthquakes, but the obvious complexity of the phenomenon requires caution. In case the proposed scenarios would not have

* Corresponding author. Tel.: +36 1 381 2129 or +36 1 209 0555/1782; fax: +36 1 381 2130.
E-mail addresses: hzoli@iris.elte.hu (Z. Horváth), micheli@fau.gau.hu (E. Michéli), andrea@iris.elte.hu (A. Mindszenty), BerenyiUveges.Judit@ntksz.ontsz.hu (J. Berényi-Üveges).
[1] Tel.: +36 28 410 200/1812 or 1809.
[2] Tel.: +36 1 381 2129 or +36 1 209 0555/1789; fax: +36 1 381 2130.
[3] Tel.: +36 1 309 1047; fax: +36 1 246 2962.

0040-1951/$ - see front matter
doi:10.1016/j.tecto.2005.08.012

been alternatives but acted simultaneously, the analysed phenomena were to be interpreted as the joint results of tectonics and climate change.

Keywords: Soft-sediment deformation; Pannonian basin; Late Miocene; Quaternary; Environmental change; Frost; Seismites; Calcrete

1. Introduction

There is a general consensus about the study and interpretation of soft-sediment deformation structures being helpful in paleoenvironmental reconstructions.

The target of the present paper is the description and tentative interpretation of a set of unusual structures observed in Late Miocene (Upper Pannonian)—partly lignitiferous—alluvial sediments and their Quaternary cover which is a pedo-sedimentary complex. The structures suggest that the soil-complex may have been subject to soft-sediment deformation triggered either by seismic shock-related sudden pore-pressure increase or by frost-and-thaw induced instability on a gentle slope. In order to decide which one of the possible mechanisms was predominant, field and laboratory data were collected, evaluated and combined with the available general geological and paleoclimatological evidence.

1.1. Soft-sediment deformation structures

Soft-sediment deformation is a general term for altering the fabric and layering of a bed of unconsolidated sediments (Ricci-Lucci and Amorosi, 2003). It affects most commonly multilayer deposits, especially sand-clay alternations, and can be diffused through the whole packet or concentrated along bedding planes or individual beds. Terms for soft-sediment deformations in modern and ancient sediments were reviewed by Ricci-Lucci and Amorosi (2003).

Generally it is accepted that soft-sediment deformation structures may form when the sediment has low or zero shear resistance. This natural condition may result in liquefaction–fluidization either in cohesionless sediments (Lowe, 1975, Allen, 1982, Owen, 1987, Alfaro et al., 1997), or in cohesive fine sediments as a consequence of smectitic clays reacting in water systems (thixotropy, viscosity, plasticity, shrinkage). They are determined by the individual structural features and the type of the interlayer cation of smectites (Grim and Güven, 1978). The driving mechanism for formation of soft-sediment deformations is primarily pore–water pressure in combination with liquefaction of sand-rich sediment (Obermeier, 1996).

Pore–water pressure may increase as a result of melting ice in the soil (Van Vliet-Lanoë, 1985, 1998). Involutions are surficial manifestations of frost-related stirring (cryoturbations) and are generally characterized by distortion and mixing of the uppermost meters of the ground (Obermeier, 1996). Load casting during melting, pressure-development in water trapped between freezing fronts and pressures and heaving during freezing could be correlated to the genesis of involutions (Vandenberghe, 1988).

Seismic shock is another important liquefaction process (e.g. Munson et al., 1995; Van Vliet-Lanoë et al., 1997).

Obermeier (1996) called attention to features of nonseismic or unknown origin (artesian flow, streambanks landslides, ground disturbance by trees, load structures in muds, water escape structures in granular sediments, etc.).

Swelling and shrinking in Vertisol type paleosols (rich in smectitic clays) may generate wavy formations which are usually called "mukkara" or "gilgai" (Paton, 1974). Soft-sediment deformation (converging forms) may be significantly enlarged due to differential swelling and shrinking of clayey soils (Knight, 1980).

1.2. Tectonic framework

Subsidence and sedimentation in the greater part of the Pannonian Basin were interrupted in the early Quaternary; extensional basin formation had come to an end and compressional inversion had started (Horváth and Cloetingh, 1996). From that time on the Pannonian lithosphere has been bent. As a result of increasing intraplate stress, the peripheral areas of the basin experienced uplift, while subsidence of some of the internal sectors accelerated (Fig. 1) (Bada et al., 1999).

According to earlier geomorphological analyses (Franyó, 1982; Pécsi, 1992) and our latest observations (Horváth et al., 2001) the Mátra Hills could have been uplifted at least 100–200 m from the beginnings of the Quaternary. However taking into consideration the recent vertical movement (average 1–2 mm/year uplift in the hills and a subsidence of similar magnitude in the basins after Joó, 1992) and the proven 1–1.5 km Middle–Late Miocene and Pliocene paleoburial of the