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Tectonic strain changes affecting the development of deep seated gravitational slope deformations in the Bohemian Massif and Outer Western Carpathians

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ABSTRACT

This paper describes a pair of intensively studied deep seated gravitational slope deformations from the Czech Republic. Structural geological mapping and the interrogation of high resolution LiDAR DEMs have been used to reassess the extent of each slope deformation and to obtain new information about their surface morphologies. Electrical resistivity tomography has been used to image the subsurface structures while rod dilatometers and permanently installed mechanical extensometers have been used to define their kinematic behaviour. Dilatometric measurements from across a fissure the edge of the Mužský Hill DSGSD show that the progressive trend has been interspersed by five periods of movement acceleration since monitoring began in 1990 while extensometric measurements from across a second fissure about 50 m from the edge of the plateau show that this discontinuity was affected by an significant period of extension from 2004 to 2006 and a significant period of compression from 2006 to 2008. These data demonstrate that the Mužský Hill DSGSD is characterised by the lateral spreading of rigid sandstone blocks across a plastic marl formation at the edge of Příhrazy Plateau. Extensometric measurements from the Kněhyně Mountain DSGSD show that a fault located at a depth of about 25 m below the surface is characterised by progressive dilation whereas a fault located at a depth of about 57.5 m below the surface is characterised by episodic vertical dip-slip displacements. Both faults are affected by horizontal dextral strike slip displacements. These data demonstrate that the Kněhyně Mountain DSGSD is characterised by translational rocksliding associated with the neotectonic uplift of the Outer Western Carpathians. The presented kinematic data have been compared to records of precipitation, groundwater level, earthquakes, and strain changes measured by the fault displacement monitoring network EU-TecNet. Strain changes induced by the widespread redistribution of stress through the crustal appear to represent an important and hitherto underappreciated geomorphological process affecting the development of the slope deformations at Mužský Hill and Kněhyně Mountain. Future research will focus discovering whether this finding holds true for other deep seated gravitational slope deformations in different geomorphological and geological settings.

1. Introduction

Researchers from the Czech Republic have long been involved with monitoring the kinematic behaviour of deep seated gravitational slope deformations at home (e.g. Košťák, 1977;Stemberk and Zvelebil, 1999; Klimeš et al., 2012), in neighbouring countries (e.g. Cacoń and Košťák, 1975;Mąkolski et al., 2005; Baroň et al., 2016), and elsewhere across the globe (e.g. Košťák and Avramova-Tačeva, 1981; Košťák and Cruden, 1990; Klimeš et al., 2016). This paper describes a pair of intensively studied deep seated gravitational slope deformations from contrasting geomorphological and geological settings in the Czech Republic. Mužský Hill DSGSD has developed in Cretaceous sandstones in a protected area in the Bohemian Massif while Kněhyně Mountain DSGSD has developed in Cretaceous flysch rocks in the Outer Western Carpathians (Fig. 1).Structural geological mapping and the interrogation of high resolution LiDAR DEMs is used to reassess the extent of each slope deformation and to obtain new information about their surface morphologies. Electrical resistivity tomography is used to image the subsurface structures while rod dilatometers and permanently installed mechanical extensometers are used to define their kinematic behaviour. The kinematic data obtained from the dilatometers and extensometers are compared to records of climate, groundwater, seismicity, and tectonic strain changes measured by the fault displacement monitoring network EU-TecNet. These comparisons allow us to propose models to explain the ongoing geomorphological development of the deep seated gravitational slope deformations at Mužský Hill and Kněhyně Mountain.

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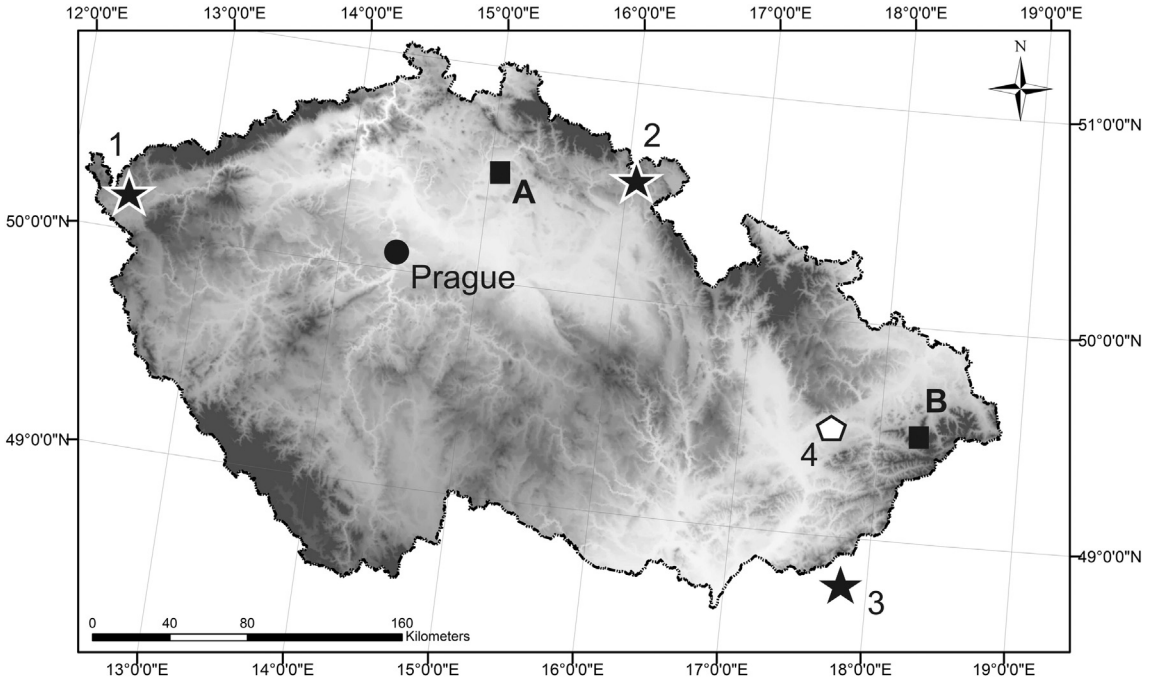

Fig. 1. Overview map showing the position of the study sites and other referenced localities. A - Mužský Hill; B - Kněhyně Mountain; 1 - The epicentral area of the western Bohemia: earthquake swarms occurred in January 1997 ($M_{Lmax} = 2.9$), August–December 2000 ($M_{Lmax} = 3.3$), October–November 2008 ($M_{Lmax} = 3.8$), and August–September 2011 ($M_{Lmax} = 3.5$); 2 - The epicentral area of northeastern Bohemia: earthquakes occurred in August and November 2005 ($M_{Lmax} = 2.4$ and 3.2); 3 - The epicentral area of the Western Carpathians: earthquakes occurred in March 2006 ($M_{Lmax} = 3.2$) and March 2012 ($M_{Lmax} = 3.4$); 4 - Zbrašov Aragonite Caves.

2. The DSGSDs

2.1. Mužský Hill in the Bohemian Massif

Mužský Hill (463 m asl) is formed by the Turonian to Coniacian Jizera Group of the Bohemian Cretaceous Basin. Hereabouts, the upper parts of this group comprise thick-bedded quartzitic sandstone, slightly tilted towards the SE, while its lower parts are dominated by marls of the Teplice Formation (Tíma, 1966). In the study area the contact between the upper part and the lower part of the group lies between 290 and 315 m asl with the marls outcropping at the base of the northern and northwestern slopes of Mužský Hill. Volcanic intrusions were emplaced in the Bohemian Cretaceous Basin during the Miocene and these comparatively resistant intrusions impede erosion around the edge of Příhrazy Plateau. The intrusions were tectonically predisposed and are most commonly orientated WSW-ENE. Kopecký (1989) assumed that the NNW slope of Mužský Hill is controlled by a Quaternary reactivated (uplift of the Mužský Hill) fault striking WSW-ENE (Fig. 2).Mass movements have been monitored here since 1926 when an extensive landslide from the southwestern slope of Mužský Hill destroyed a substantial part of the village of Dneboh (Dědina, 1926; Záruba, 1927; Záruba et al., 1966). In 1962 a landslide inventory covering much of Mužský Hill was compiled at a scale of 1:25,000 (Fencl and Zeman, 1963) while the whole area was mapped during the 1990s in

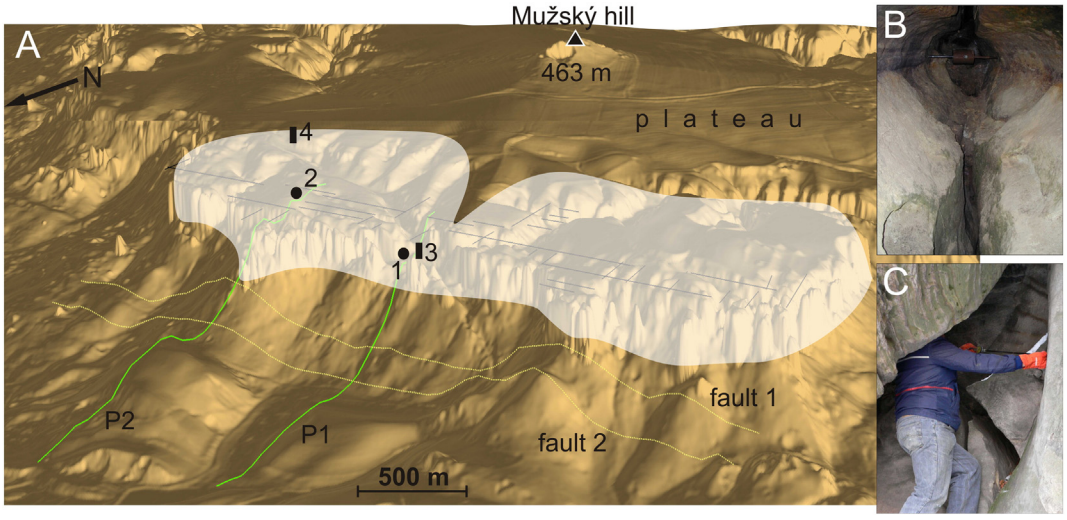

Fig. 2. A - 3D view of the NNW margin of Mužský Hill Plateau with the studied DSGSD. The zone of gravitationally loosened sandstones (according to Rybář et al., 2006) is indicated by white shading. P1 - ERT profile No. 1; P2 - ERT profile No. 2; 1 - Position of the sandstone block monitored using a rod dilatometer; 2 - Position of the TM-71 extensometer monitoring site; 3 - Borehole Pr-2; Dotted lines - Approximate position of faults observed on the ERT profiles. Full lines - Tectonic discontinuities observed on the 1 m LiDAR-based DEM; B - TM-71 extensometer across a WSW-ENE striking fissure (Site 2); C - Horizontal dilatometer across a NNE-SSW striking fissure (Site 1).

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