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Monitoring of slow slope processes: the case study Na Hradě (Bohemian Forest, Czech Republic)

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Abstract
This paper presents measured rates of debris movements on the slopes of the Na Hradě monitoring plot in the Bohemian Forest (=Šumava Mts.). The permanent plot was established in 1972 and it is situated on an asymmetric castle-koppie built of paragneiss of the Bohemian Massif. Slope processes are measured by geodetic methods. Present-day slope processes are very slow (mean movement in the monitoring area represents 6.7 mm in height in the period 1972–2005). No direct relation was found between the transport rate and slope inclination.

Key words: Šumava Mts., monitoring plot, slow slope processes

Introduction

Landscape evolution is caused by two basic group of landscape forming processes. The first group is rapid (up to catastrophic) processes and the second group is slow processes. Identification and quantification of rapid processes is relatively simple, in the case of slow processes it is rather difficult, because long-term observation and measurements in monitoring areas are necessary for its study. In this paper, we deal with the slope processes in the Na Hradě monitoring plot in the Bohemian Forest.

By the term ‘slow slope processes’ we mean soil creep, debris creep, frost debris creep, frost heave, needle ice, slow solifluction, congelifluction, and biological slope processes (Young 1972).

In 1964 the Commission on slope development of the International Geographical Union (IGU) announced the long-term programme of measurement of the slow slope processes. In 1965 the former Institute of Geography of the Czechoslovak Academy of Sciences in Brno started quantitative measurements in 5 monitoring areas (Demek 1967, 1986, 1988, 1991). In the period 1985–2005, the research programme was cancelled. In 2005 the Department of Landscape Ecology of the governmental Agency for Nature Conservation and Landscape protection took over the monitoring plots and continued measurements in 4 monitoring areas (Břidličná Hora Mt. in the Hrubý Jeseník Mts., Pasecká Skála Mt. on the Českomoravská Vrchovina highland, Na Hradě Mt. in the Bohemian Forest, and Hradisko Mt. in the Javorníky Mts). In 2006 the Department of Landscape Ecology became a part of the Silva Tarouca Research Institute for Landscape and Ornamental Gardening (STRILOG) of the Czech-

Fig. 1. Slow slope processes monitoring areas operated STRILOG in the Czech Republic.

Ministry of Environment. In 2006 three new experimental plots were established for the monitoring of slow slope processes in Central Bohemia and in Southern Moravia (Fig.1).

Study Area

The Na Hradě monitoring plot is situated in the region of South Bohemia near the settlement of Bošice (part of the village of Vacov) in the Javornická Hornatina highlands (part of the Šumavské Pláně plateau in the Bohemian Forest). The area of the plot is composed of biotitic and sillimanit biotitic paragneisses of the Moldanubicum. Rounded mountain ridges with tors and debris (block fields, block streams) are typical of the Javornická Hornatina highlands. A mosaic of forests, meadows and fields covers the ridges. The monitoring plot was established in 1972.

The monitoring area lies on one of these rounded ridges rising to the SE from Bošice (see Figs. 2 and 3). The forested ridge runs in the direction NW–SE at an elevation 881 m a.s.l. An asymmetric castle-koppie 168 m long rises above the general level of the ridge. To the SW the frost-riven cliff limits side the castle-koppie on the SW. The frost-riven cliff is up to 10 m high. A cryoplanation terrace has developed at the foot of the cliff. The foot of the cliff is covered by debris forming a protalus rampart. The debris cover on the cryoplanation terrace is partly composed of large blocks which were moved, by congelifluction during the Pleistocene.

The monitoring plot proper is situated on the less inclined NE slope of the castle-koppie. The highest part of the castle-koppie forms an outcrop of paragneiss. The slope is steplike (see Fig. 4), there are steeper parts alternating with less inclined parts. On the steeper parts the bedrock lies on the surface or it is covered by debris forming block fields and block streams. Less inclined parts are covered by loam. Polygonal soils (large stone polygons) developed in the same part in cold phases of the Pleistocene (Demek 1967).

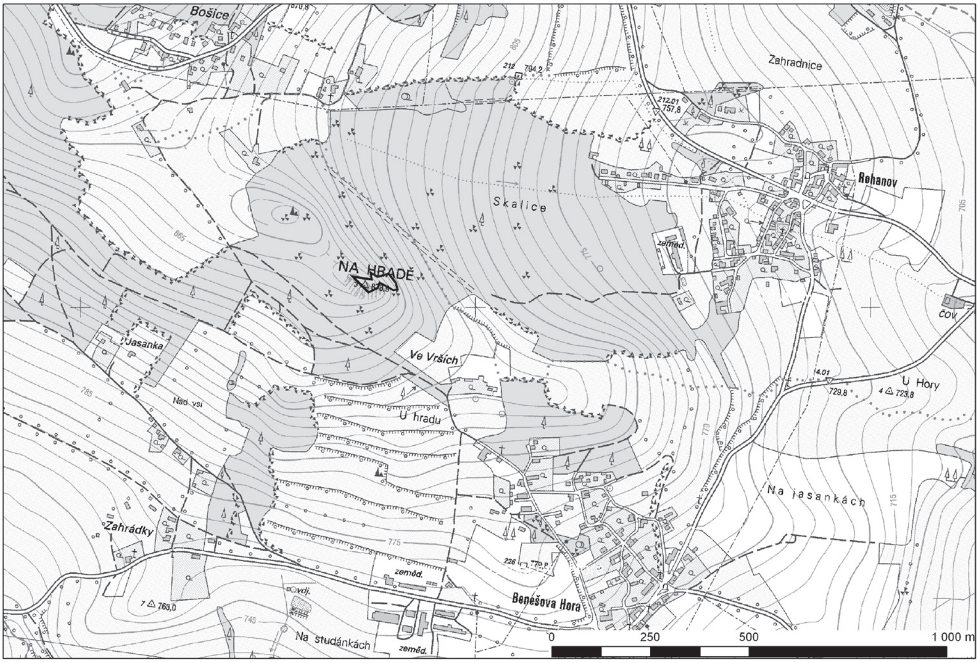

Fig. 2. Topographic map with the location of the Na Hradě monitoring area.

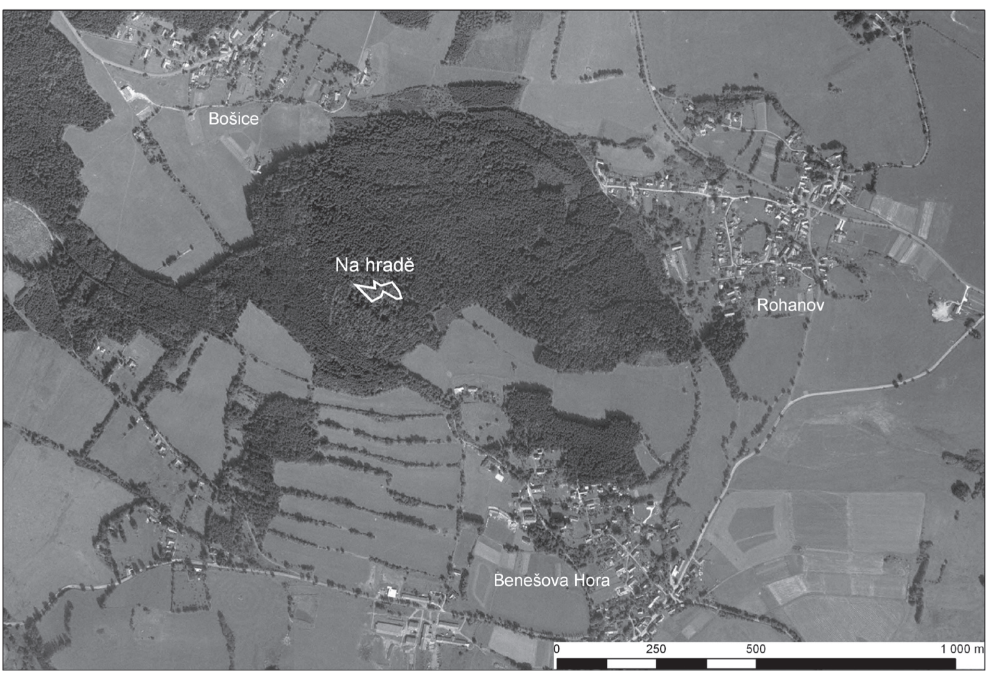

Fig. 3. Aerial photo with the location of the Na Hradě monitoring area.

Methods

Monitoring of the slow slope processes is based on geodetic measurements of the movements of debris lying on the Earth's surface. Each measured block is marked for the geodetic survey by a cross-marked metal cylinder (the numbers of marked blocks in Table 1). Vertical movements of blocks are measured by precise levelling. This method shows the movement with a precision of 0.2–0.3 mm. Point No. 1 is a geodetic point of the state net set in the bedrock in the upper part of the castle-koppie. Point No. 2 is also stabilized in the bedrock. Repeated measurements have shown that these survey points are stable (Fig. 5). The geodetic method of cross bearing was applied for measurement of the horizontal movements. The precision of this method is about 0.8 to 1.0 mm in location. The last measurements in the Na Hradě plot were carried out on August 2, 2005.

Table 1. Relation between the slope inclination and mean block movements in the period 1972–2005.

Slope inclination in degrees	Number of measured points	Mean elevation change in cm
0°–6°	2	0
7°–10°	4	–0.73
11°–15°	6	–0.38
16°–20°	11	–0.51
21°–25°	8	–0.39
26°–30°	7	–0.6
31°–35°	4	–1.74
Total number / mean	42	–0.67

Results and discussion

Geodetic survey confirmed the slow downslope movements of debris in the monitoring area. But the movements in the period 1972–2005 were very slow (see Fig. 6).

The Na Hradě monitoring area showed the lowest movement values from all the 4 test plots (mean value 6.7 mm in 33 years). Examples of the downslope movements of blocks are presented on the profile in Fig. 7.

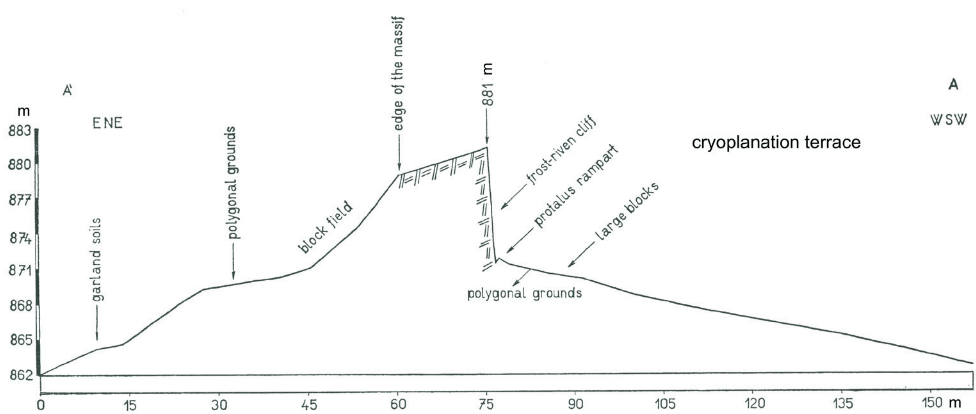

Fig. 4. The Na Hradě castle-koppie, cross profile.

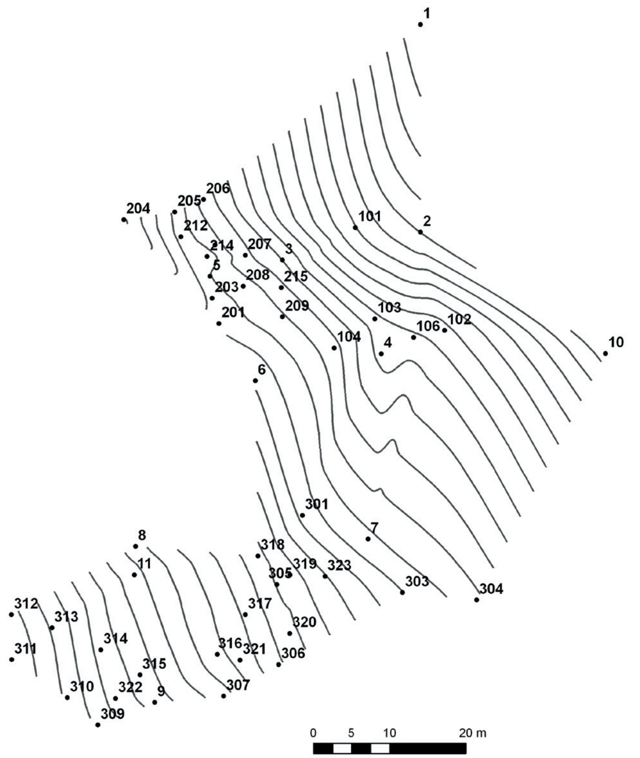

Fig. 5. Plan of the distribution of observed blocks in the monitoring area.

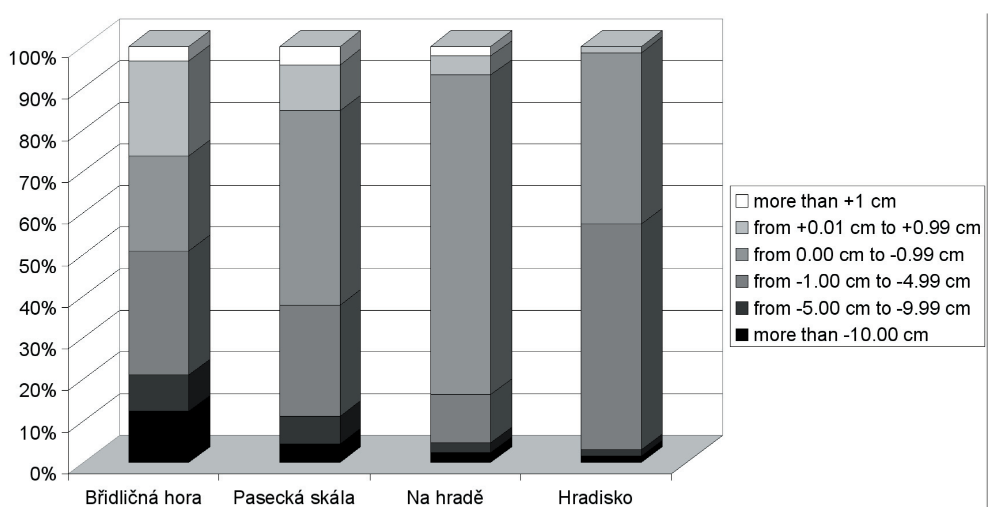

Fig. 6. Elevation changes in the monitoring areas during the period of 1972 (1971) to 2005. For further information about the Břidličná Hora, Pasecká Skála, and Hradisko plots see MACKOVČIN et al. (2006).

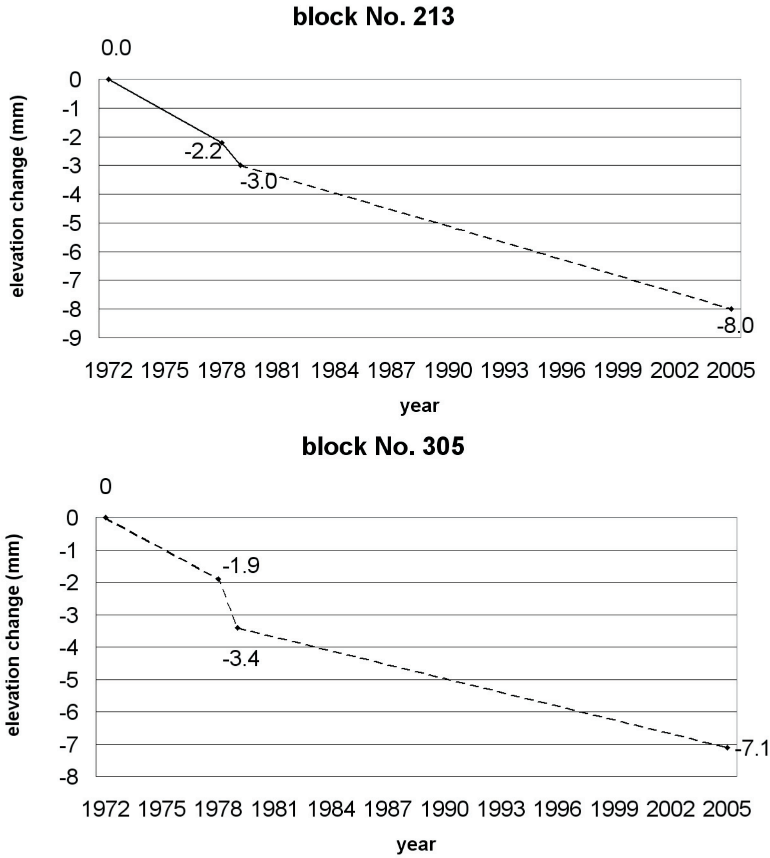

Fig. 7. Examples of downslope movements of blocks No. 213 and No. 305.

Movements of debris blocks are irregular. The speed and type of the movements are changing in time and space. Some blocks are tilting and therefore the authors also observed positive change in the elevation of measured blocks.

There was no direct relation between values of block movements and slope inclination observed in the period 1972–2005 (Table 1). Therefore we can presume that a part from pure gravitational processes such as debris and soil creep there are also other slow slope processes (frost debris creep, frost heave, slow solifluction), and biological slope processes in action on the survey plot.

Table 2 shows relations between the dimensions of measured blocks and changes of their elevations. No clear relation between block dimensions and rates of movements was found on the plot.

An interesting feature is that, in 1972, the debris blocks were free of vegetation. In 2005, the authors found most of the blocks buried under the vegetation cover (thick layers of moss and bilberries,Fig. 8). It was necessary to clear most of the signalled blocks. The impact of this phenomenon on slope processes will be studied in the next few years. This interesting feature cannot be explained by local and common influences because there have been no changes in land-use or human activities in the forest in the last 33 years. Therefore, we prefer to explain it by global climate changes (more humid and wet climate).

Fig. 8. Excavation of a marked block from the thick cover of moss and bilberries.

Table 2. Dimensions of measured blocks (lengths of its longer axis) and mean rates of their movements.

Lengths of the longer axis	**Number of marked blocks**	**Mean elevation change in cm (extreme values not included)**	**Mean elevation change in cm (all values included)**
Bedrock	2	0	0
Less than 0.50 m	2	–1.18	–1.18
0.51–0.75 m	9	–0.46	–3.60
0.76–1.00 m	17	–0.56	–0.56
1.01–2.00 m	10	–0.48	–0.95
2.01–2.65 m	2	–0.30	–0.30
Total	42	–0.67	–1.29

Conclusions

The geodetic survey quantitatively confirmed a complex of slow slope processes acting on the Na Hradě monitoring area in the period 1972–2005. Present-day slope processes are, however, very slow (mean movement of debris is 6.7 mm in the last 33 years), especially in comparison with cryogenic processes, which acted in the area during cold phases of the Pleistocene (e.g. congelifluction). There is no direct relation between the movements and slope inclination and, therefore, besides pure gravitational processes, we presume the action of other slope processes (frost debris creep, frost heave, slow solifluction) and biological slope processes on the survey plot. The density of the measurements, and especially the gap in measurement between 1979 and 2005, do not allow to indicate periods of higher activity of slope processes to be shown in detail. We hope to acquire more information concerning this problem by using more frequent measurements in the next years. The vegetation has changed in recent decades; the originally free debris has been covered by moss and bilberry vegetation.

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