QUANTITATIVE MONITORING OF SLOPE MOVEMENTS AT THE BŘIDLIČNÁ HORA MT. (HRUBÝ JESENÍK MTS., CZECH REPUBLIC, EU)

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ABSTRACT

Monitoring of scree cover (blockfield) on a plot located on slopes of the Břidličná hora Mt. (1358.0 m a.s.l.) in the Hrubý Jeseník Mts. in the NE part of the Czech Republic has shown various slow movements of the majority of the blocks in the period of 1972–2008. Irregular and fluctuating movements without a certain trend were observed in 28 percent of cases (rotation and tilting of blocks). By the elevation of 30% blocks moved from minus 10 to minus 50 mm, by 10 percent they moved from minus 50 to 100 mm. Extreme elevation movement values of downslope movements have been observed in 7 percent of blocks (from minus 276 to minus 436 mm). The rest (25 percent) of block was stable.

Key words: blockfield, slow slope processes, monitoring, Hrubý Jeseník Mts.

1. Introduction

Present trends in geomorphology are quantitative measurements and monitoring of current geomorphological processes. Landscape evolution is principally caused by two basic groups of landscape forming processes. The first group covers rapid (up to catastrophic) processes and the second groups are slow processes. By the term "slow slope processes" the authors mean soil creep, debris creep, frost debris creep, frost heave, needle ice, slow solifluction, congelifluction, suffosion (piping) and biological slope processes (Young 1972).

Identification and quantification of rapid processes is relatively simple, in the case of slow processes, however, it is rather difficult, because long-term observation and measurements on monitoring plots are necessary for the evaluation. In this paper the authors deal with results of long-term quantitative measurements of slow slope processes on blockfield on the monitored plot on the Břidličná hora Mt. in the Hrubý Jeseník Mts. in the northeastern part of the Czech Republic (Fig. 1). The blockfield is defined as a continuous spread of broken angular rock fragments up to the dimension of boulder which mantle the surface of mountain slope (Whittow 1984). Fragments in the blockfield must cover more than 50 percent of the slope surface (100 percent on the monitoring plot). The questions include the extent to which blocks of the blockfield move and if they move, the mechanics of their movement. Modelling of climatic influences on slope processes in the studied area is limited by the lack of long term high-elevation climate observations and appropriate instruments.

2. History of the slow slope processes monitoring

Commission on slope development of the International geographical Union (IGU) announced a long–term programme of measuring the slow slope processes in 1964. In 1965 the former Institute of Geography of the Czechoslovak Academy of Sciences in Brno launched quantitative measurements on monitoring plots, inclusive the monitoring plot on the Břidličná hora Mt. (1358.0 m a.s.l.) in the Hrubý Jeseník Mts. (Demek 1973, 1991; Mackovčin et al. 2006).

3. Geomorphological conditions of the Mt. Břidličná hora

The monitoring plot is located on the Břidličná hora Mt. (1358.0 m a.s.l.) in the Hrubý Jeseník Mts. (Fig. 2) The flat topped Mt. Břidličná hora forms a part of the main ridge of the mountains (in Czech Ridge Vysokoholský hřbet). Cols divide the Břidličná hora Mt. from the mount Jelení hřbet (1367 m) on the NE side and the mount Pecný (1337 m) with nice tors on the SW side. The summit structural-denudation flat (etchplain) just reaches above the artificially lowered upper timberline and is capped by subhorizontally bedded whitish resistant Devonian metaquartzites. Lower parts of slopes of the Břidličná hora Mt. consist of less resistant folded graphitic and sericitic phyllites of the Vrbno group (also of Devonian age). The hard bands in metaquartzites produce minor cliffs, while typical slopes of the blockfield are about 30 degrees. The flat top is limited by about 2 m high frost-riven cliff on the SSE side (Fig. 3).

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Fig. 1 Monitoring plots of the Silva Tarouca Research Institute for Landscape and Ornamental Gardening of slow slope processes on the territory of the Czech Republic. The monitoring plot of the Břidličná hora Mt. is located in the NE part of the Czech territory

Fig. 2 Vysokoholský hřbet Ridge (main ridge of the Hrubý Jeseník Mts.) and the Břidličná hora Mt. with scree covers

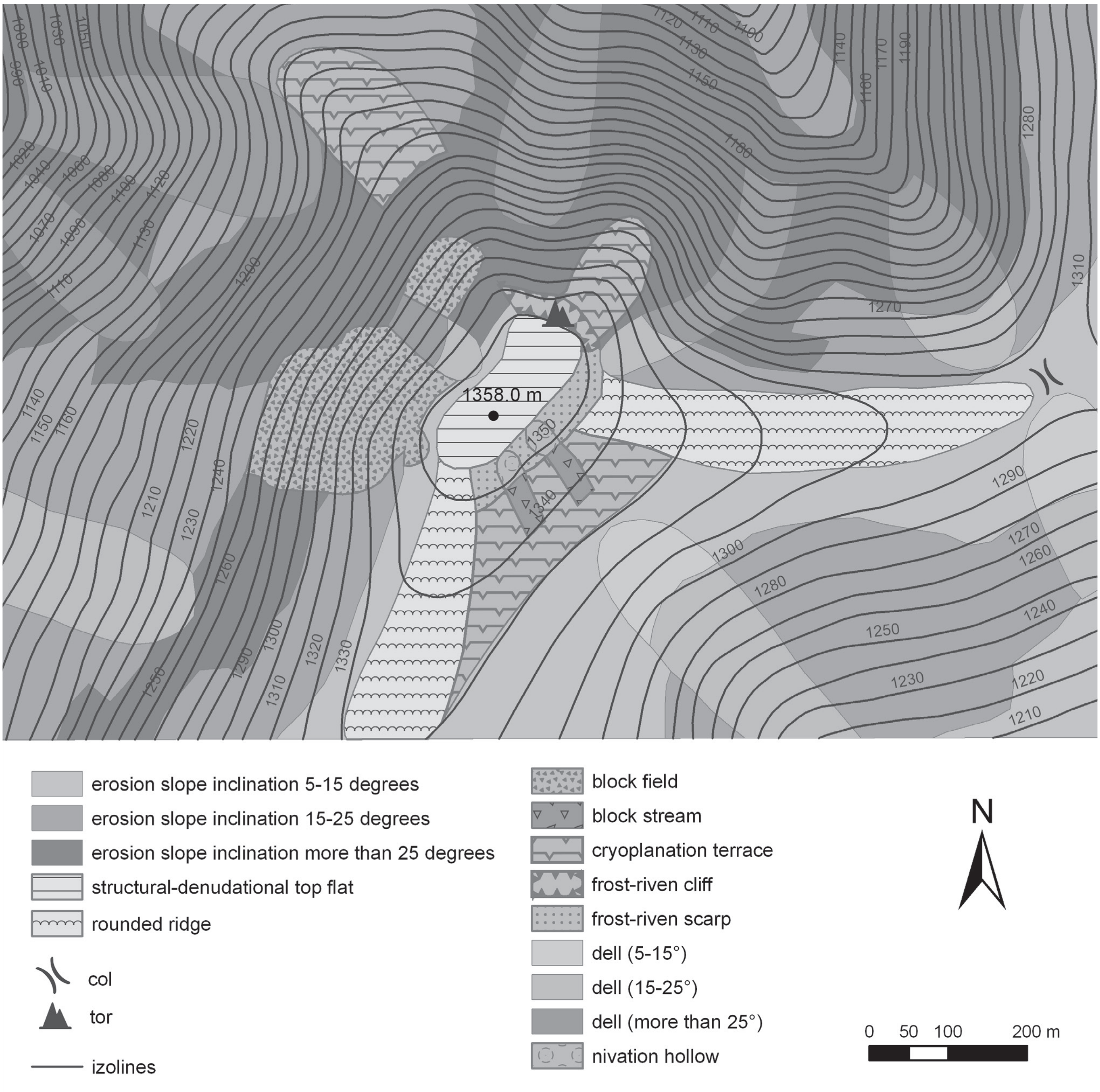


Fig. 3 Geomorphological map of the Mt. Břidličná hora

A cryoplanation terrace developed at its foot levelling folded phyllites and covered partly with congelifractates of metaquartzites.

About 12 m high frost-riven scarp with nivation hollows borders the top flat on the SW, S and SE side (Fig. 4). The extensive cryoplanation terrace developed at the foot of frost riven scarp. Ploughing blocks as evidence of recent solifluction activity occur on the slopes of Mt. Břidličná hora (Křížek 2007). Block streams run from nivation hollows on the cryoplanation terrace. Relict stone polygons can be found on the summit flat (Prosová 1952, 1954).

4. Climatic conditions and vegetation

A typical cold mountain climate above the upper timberline is typical for the Břidličná hora Mt. The summit flat and upper parts of the slopes are covered with alpine meadows with screes patches. The alpine meadows are rimmed by artificially planted dwarf pine (Pinus mugo). The adjacent forest on slopes is dominated by spruce.

Climate records (1947–1985) from the former meteorological station on the nearby Mt. Praděd (1491.3 m a.s.l.) are considered the most reliable proxy for general

Fig. 4 Frost riven scarp at the SE edge of the summit flat of the Břidličná hora Mt. with exposures of metaquartzites and with cryoplanation terrace at the foot

climate of the main ridge of the Hrubý Jeseník Mts. The mean annual air temperature (MAAT) at the summit of the Mt. Praděd is 1.1 °C, the absolute maximum 24.4 °C, the absolute minimum −32.6 °C. The coldest month is January when the mean air temperature is lower than −7 °C. Temperatures below 0 °C can occur any day of the year (Weismannová et al. 2002). Mean annual precipitation reached the values of 1216 mm in the period of 1946–1985. Mean duration of snow cover on the ridge is 6 months (in extremely years 8 months – Kříž, Tolasz 1990). The depth of the snow cover is influenced by strong winter winds on the ridge. West winds blow the snow off the NW block slope in winter. According to Humlum (1997), a coarse debris cover causes ground cooling in case of missing or thin snow cover in winter.

Investigations of polar permafrost occurrences and properties (ground temperatures) in Siberia indicated that different surface cover types and snow cover have an important influence over the ground thermal regime. M. Křížek (2007) measured ground temperatures of bare ground above the upper timberline in depths 0.15 and 0.30 m in the Hrubý Jeseník Mts. on the Mt. Keprník at the altitude 1421 m. The seasonal frozen layer on this locality had duration of 6, respectively 5 months. Needle ice and goletz ice occur on main ridge of the Hrubý Jeseník Mts. up to mid of May.

Scree covers (especially block fields) are regarded as the decisive factors of the local permafrost distribution pattern in the zone with discontinuous permafrost (Romanovskij, Turin 1986). Similarly, a coarse scree cover typical for the Central European Mountains can be treated as an independent layer with certain vertical extent amount of lithospherical (blocks) and atmospherical (free voids between blocks) components (Herz, King, Gubler 2003). Thus microclimatological conditions in blockfields are different from those on adjacent slopes composed of finer grained substrates or solid bedrock.

5. Monitoring plot description

The monitoring plot is located on the edge of the summit flat and on the steep NW slope (gradient up to 54 degree – see Table 1) of the Břidličná hora Mt. (Fig. 5). The slope is covered with allochthonous (block emplaced) angular coarse openwork scree material forming a block field. The blocks were produced by block disintegration of metaquartzites, generally by the impact of frost. A cliff at the head of blockfield is lacking. Nine test pits located in the marginal parts of the blockfield have shown the thickness of screes from 0.4 to 1.8 m. The thickness of screes in the central part of the blockfield is expected more than 2 m. The bedrock is partly represented by metaquartzites (test

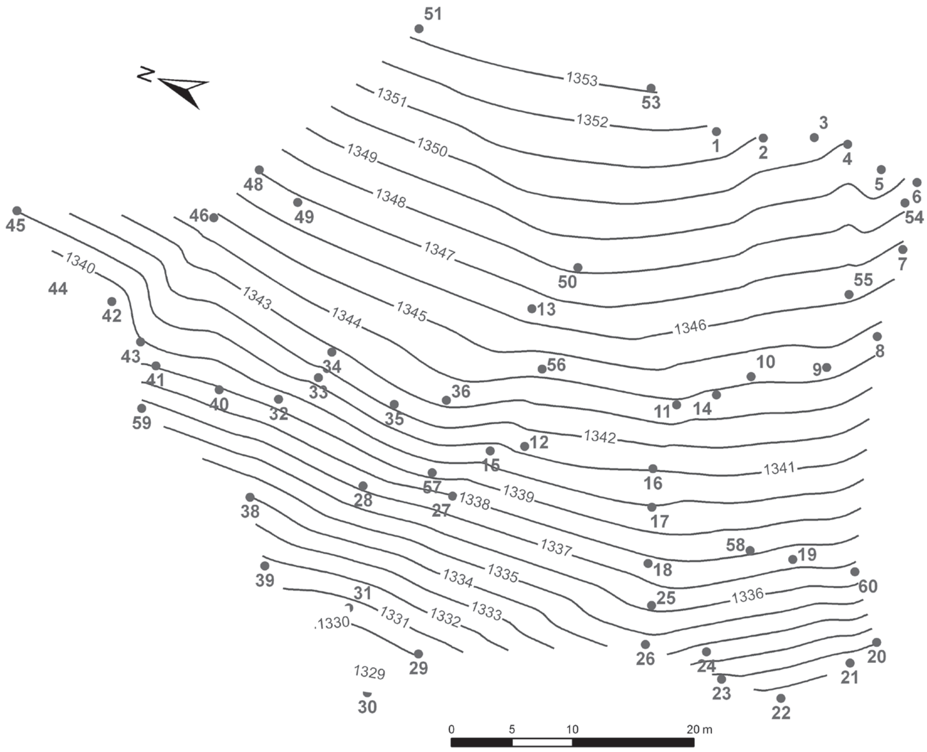


Fig. 5 Map of the monitoring plot with the signalled blocks

pits VI and VIII) and partly by graphitic phyllites (e.g. test pits V and IX). Angular metaquartzite blocks are partly covered with a poor vegetation of lichens, mosses and scattered tufts of grass or herb species. Blocks are loosely piled-up (Fig. 5). Screes are residing at the angle of repose.

Case No. 1:

Geological profile in the marginal part of the block-field (control point No. 6); voids among blocks are partly filled with loam:

0.00–0.40 m turf with black humus loam,
0.40–0.50 m large flat block of metaquartzites,
0.50–0.60 m grey loam with small fragments of graphitic shales up to 0.30 m with the longer axis oriented downslope,
0.60–0.93 m fragments of metaquartzites and graphitic shales up to 0.3 m in the longer axis oriented downslope,
0.93–1.20 m fragments of metaquartzites up to 0.15 m in the longer axis with rust brown loam, fragments cryoturbated,
1.20–1.90 m blocks of metaquartzites up to 0.5 m in the longer axis with rost brown loam,
1.90–2.50 m bedrock, Devonian metaquartzites.

Case No. 2:

Geological profile in the marginal part of the block-field (control point No. 9), open work structure (spaces among blocks are free):

0.00–0.20 m turf,
0.20–1.40 m fragments of metaquartzites up to 0.7 m in longer axis, open work structure,
1.80–2.10 m small fragments of graphitic shales with brown loam,
2.10–2.90 m bedrock, Devonian graphitic shales, thin-cleavage.

Tab. 1 Distribution of signalled block on the monitoring plot in relation to slope gradient

Slope gradient in degrees	*Number of blocks*	*Percent of blocks*
5	2	3.50
7	3	5.26
10–14	1	1.76
15–19	6	10.53
20–24	12	21.05
25–29	20	35.09
30–34	6	10.53
35–39	3	5.26
40–44	2	3.50
45–49	1	1.76
50–54	1	1.76
Total	57	100.00

The majority of measured blocks are situated on slopes with the gradient ranging from 15 to 34 degrees (77.2%).

Fig. 6 Quartzite blocks piled-up in the block field on the NW steep slope of the Břidličná hora Mt. The Mt. Praděd (1491.3 m a.s.l.) is in the background

A shallow depression (dell) runs downslope in the central part of the monitoring plot.

Blockfields composed of large blocks have unique thermal characteristics in comparison to the surrounding mountain slopes lacking substantial interconnecting voids. Mean annual ground temperature in blockfields is lower than in fine materials (Harris and Pedersen 1998) and these thermal characteristics may affect the distribution of permafrost (Sawada, Ishikawa and Ono 2003). Permafrost is sporadically found far below the upper timberline in Central Europe. Measurements of the external air temperature (EAT) and the internal temperature of the talus (IT) in the Lužické hory Mts. and in the České středohoří Mountains have shown that patch permafrost might occur in depth near the base of the scree on surveyed block slopes in the Czech Republic (Zacharda, Gude, Růžička 2007: 307). Air circulation between the atmosphere and free voids in block fields, as well as the ground (goletz) ice formation, have been proposed as the predominant factors controlling patch permafrost occurrence in the Central European climate (e.g. Wakonigg 1996). Much lower ground temperatures in blockfield on the Břidličná hora Mt. could be expected based on the mean annual air temperature (MAAT) measured at the meteorological station Praděd.

6. Methods used

Monitoring of the slow slope processes is based on a geodetic survey of the block movements. Each surveyed block has been signalled by a cross-marked metal cylinder (Fig. 7). The number of signalled blocks is shown in Table 1. Vertical movements of blocks are measured by a precise levelling with precision 0.2–0.3 mm. The geodetic method of cross bearing was applied for the survey of horizontal movements. The precision of this method is about 0.8 to 1.0 mm in location. Conditions for geodetic survey are very hard (steep slope, loose blocks and unstable mountainous weather). The authors tried to choose the time of the year with similar meteorological conditions for the geodetic survey period. As a base for a long-term survey were chosen results from the field survey period of 1972. Repeated surveys were carried out in years 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1981, 1983, 1984, 2005 and 2008.

In total there were movements of 57 blocks of various dimensions on the surface of the block field measured.

Tab. 2 Division of signalled blocks dimension according to their longer axis

Lengths of the longer axis in m	*Number of blocks*	*Percent*
0.4	1	1.76
0.5	4	7.02
0.6	10	17.54
0.7	10	17.54
0.8	4	7.02
0.9	10	17.54
1.0	3	5.26
1.1	5	8.77
1.2	5	8.77
1.3	3	5.26
1.5	1	1.76
2.0	1	1.76
Total	57	100.00

The table shows that signalled blocks have different dimensions from angular fragments 0.6 m in the longer axis up to large block of metaquartzites 2 m in the longer axis.

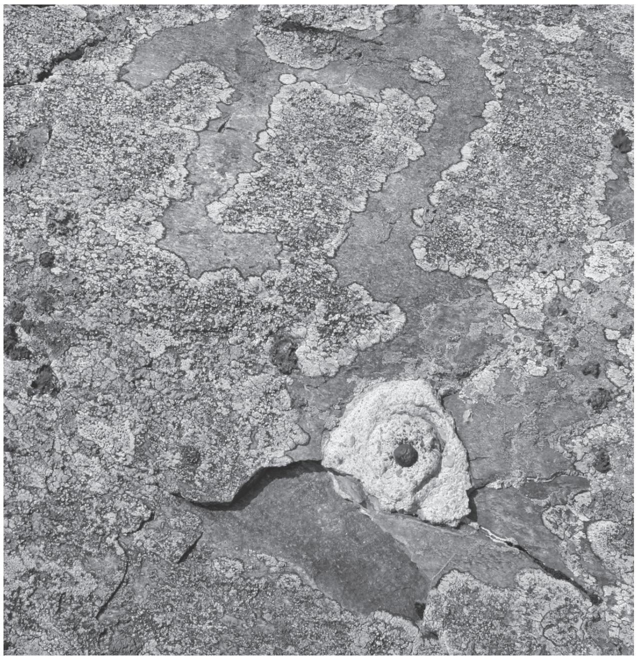


Fig. 7 Cross-marked metal cylinder on the signalled metaquartzite block

7. Results
Movement mechanisms

Geodetic survey confirmed slow movements of debris on the monitoring plot. Movement mechanisms are

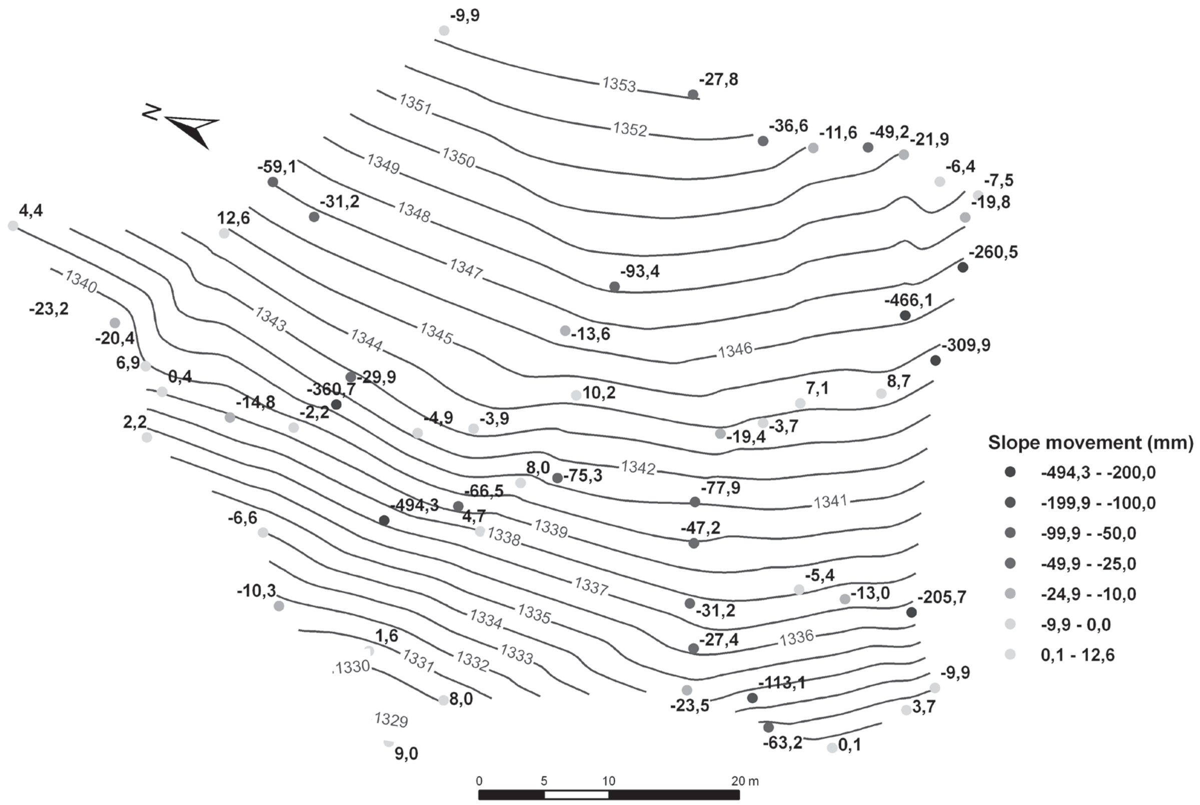


Fig. 8 Movements of blocks on the monitoring plot in the period 1972–2008

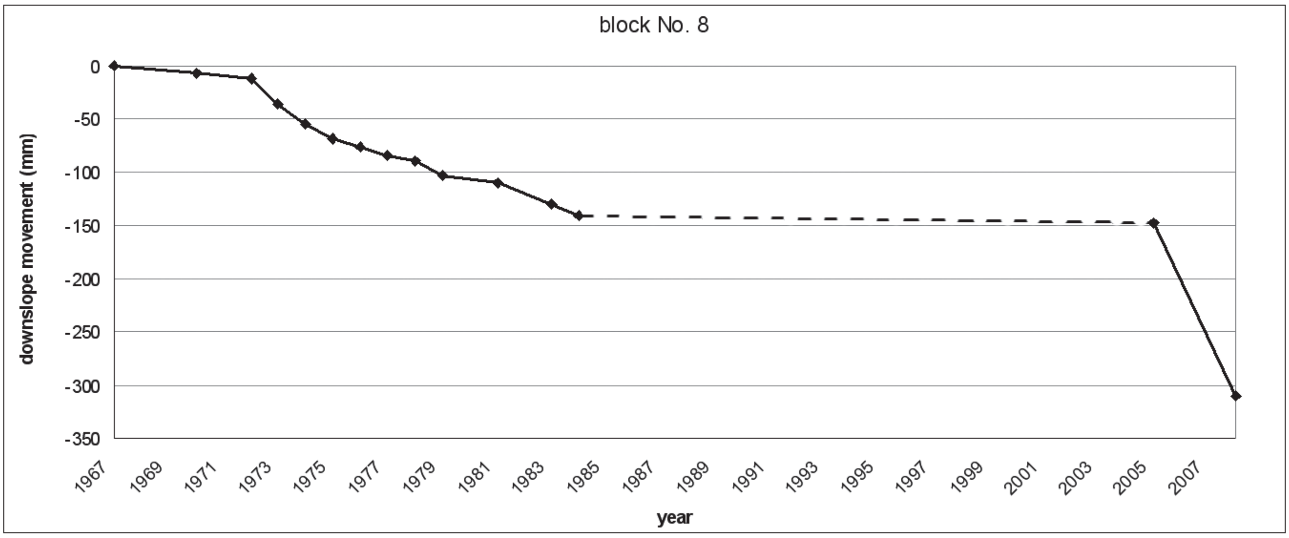
rather complex. Part of the blocks (25 percent) is stable or values are within the frame of a geodetic error. The majority of blocks moved in the period of 1972–2008 downslope. By the elevation of 30% blocks moved from minus 10 to minus 50 mm, by 10 percent they moved from minus 50 to 100 mm. Extreme elevation movement values of downslope movements have been observed in 7 percent of blocks (from minus 276 to minus 436 mm). Survey carried-out in the period of 1972–2008 confirmed the trend of largest downslope movements of blocks No. 7, 8, 28 and 55 indicated in the period of 1967–1984 (Demek 1991: 16, see Table 3). Irregular and fluctuating movements without a certain trend were observed in 28 percent of cases (rotation and tilting of blocks, probably errors during survey). Individual blocks were moving with various speed and direction of the movements. Movements of the blocks are irregular. The speed and type of movements are changing in time and space. Some blocks are rotating and tilting and therefore the authors also observed positive change in the elevation of measured blocks.

Tab. 3 Constant trends in largest values of downslope block movements in period 1967–1984 and 1972–2008

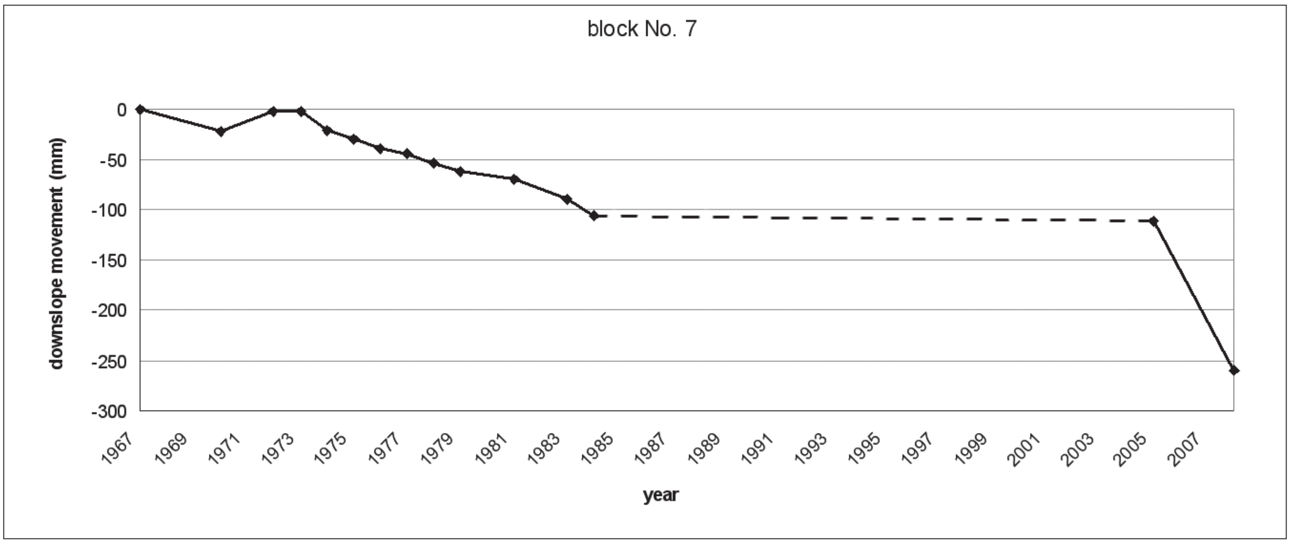
Block No.	*Movement 1967–1984 in mm*	*Movement 1972–2008 in mm*
7	−112.2	−260.5
8	−123.5	−309.9
28	−163.9	−494.3
55	−167.2	−466.1

Examples of trends in block movements

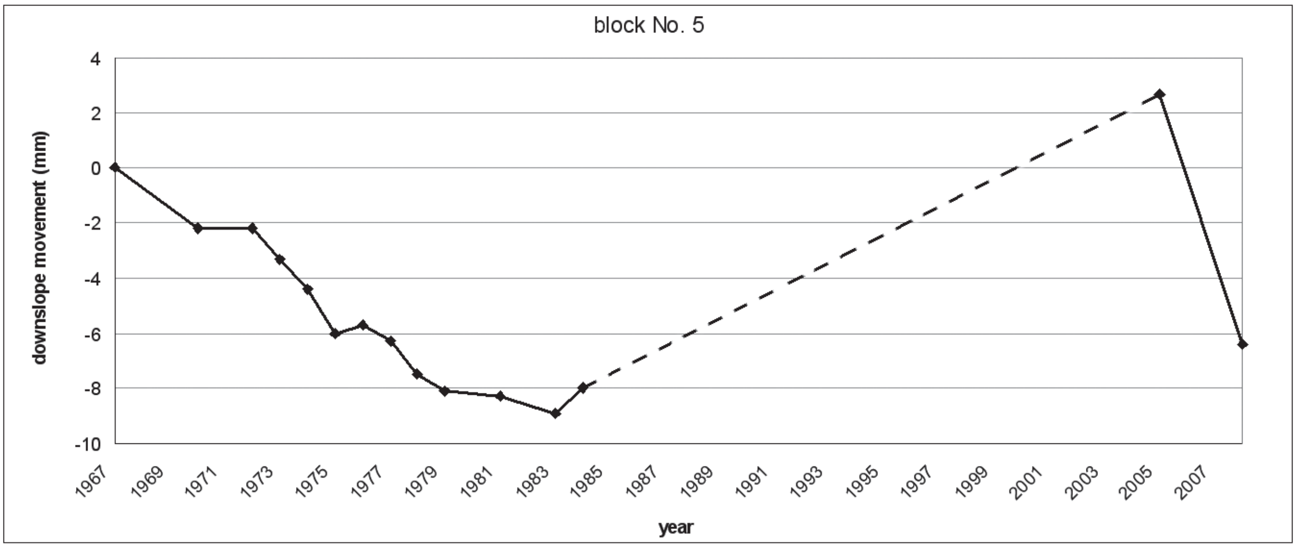
A. Smooth downslope movement with a period of stagnation (block No. 8)



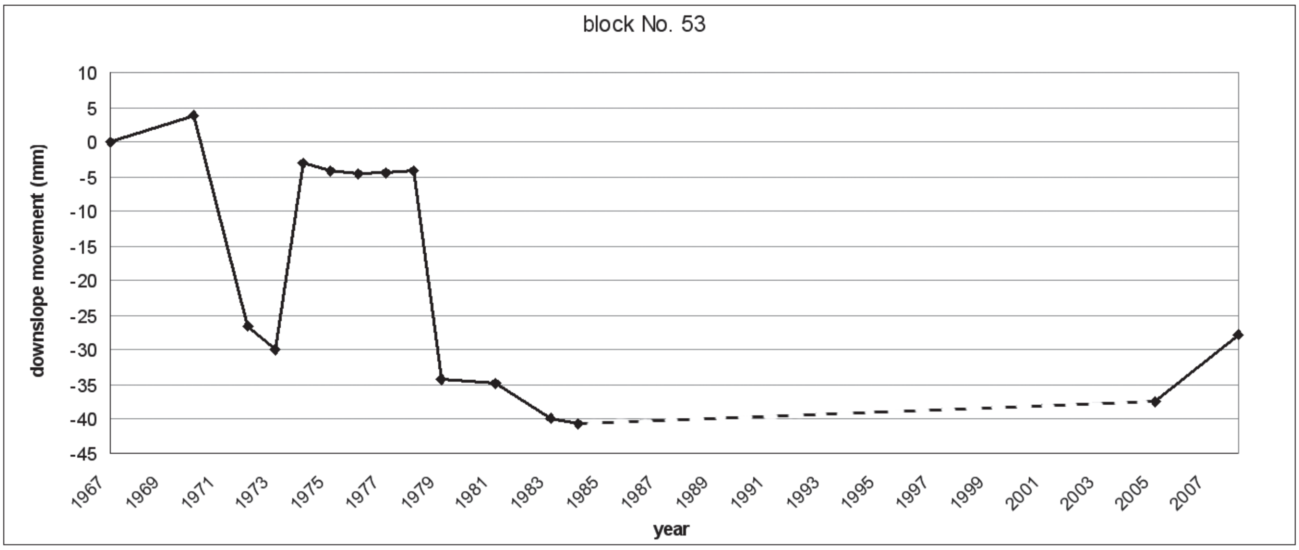
B. Mostly downslope movement with short periods of uplift, stagnation and rapid downslope movement (block No. 7)



C. Slightly irregular downslope movement with uplift and following rapid downslope movement (block No. 5)



D. Very irregular movement with changing repeated downslope and upslope movements and periods of stability (block No. 53)



The reasons of movements are both natural and anthropogenic.

Tab. 4 Signalled blocks, their dimensions (length × width × height), slope inclination and total movement 1972–2008

Block No.	*Block dimensions in m*	*Slope inclination in degrees*	*Total movement 1972–2008 in mm*
1	1.0 × 0.55 × 0.12	18	−36.6
2	0.9 × 0.70 × 0.10	7	−11.6
3	1.2 × 0.40 × 0.25	7	−49.2
4	0.75 × 0.50 × 0.20	7	−21.9
5	0.80 × 0.40 × 0.10	5	−6.4
6	0. 65 × 0.65 × 0.15	27	−7.5
7	0.94 × 0.46 × 0.12	18	−260.5
8	0.65 × 0.50 × 0.10	32	−309.9
9	0.93 × 0.55 × 0.08	25	8.7

Block No.	*Block dimensions in m*	*Slope inclination in degrees*	*Total movement 1972–2008 in mm*
10	0.78 × 0.52 × 0.10	18	7.1
11	0.75 × 0.55 × 0.25	22	−19.4
12	1.20 × 0.55 × 0.35	22	−75.3
13	0.63 × 0.60 × 0.08	22	−13.6
14	1.30 × 1.10 × 0.25	26	−3.7
15	0.80 × 0.80× 0.18	20	8.0
16	1.55 × 0.85 × 0.35	31	−77.9
17	0.95 × 0.58 × 0.30	22	−47.2
18	0.60 × 0.30 × 0.10	31	−31.2
19	0.70 × 0.60 × 0.08	29	−13.0
20	1.15 × 0.75 × 0.10	30	−9.9
21	1.10 × 0.90 × 0.25	37	3.7
22	1.30 × 0.60 × 0.15	20	0.1
23	0.75 × 0.70 × 0.25	28	−63.2
24	0.56 × 0.35 × 0.25	40	−113.1
25	1.15 × 0.90 × 0.20	27	−27.4
26	0.60 × 0.50 × 0.45	30	−23.5
27	1.05 × 0.95 × 0.13	27	4.7
28	0.90 × 0.40 × 0.15	27	−494.3
29	0.65 × 0.58 × 0.35	15	8.0
30	1.00 × 0.75 ×0.30	27	9.0
31	1.10 × 0.85 × 0.15	30	1.6
32	0.40 × 0.25 × 0.25	26	−2.2
33	0.65 × 0.35 × 0.15	45	−360.7
34	0.95 × 0.50 × 0.35	54	−29.9
35	0.60 × 0.40 × 0.12	25	−4.9
36	1.20 × 0.62 × 0.20	20	−3.9
38	0.70 × 0.50 × 0.18	40	−6.6
39	0.75 × 0.75 × 0.17	25	−10.3
40	1.25 × 0.40 × 0.68	27	−14.8
41	0.75 × 0.55 × 0.20	27	0.4
42	1.30 × 1.25 × 0.10	37	−20.4
43	0.95 × 0.50 × 0.25	27	6.9
44	0.60 × 0.35 × 0.35	27	−23.2
45	2.00 × 1.00 × 0.30	25	4.4
46	0.50 × 0.45 × 0.25	15	12.6
48	0.75 × 0.45 × 0.15	15	−59.1
49	0.65 × 0.35 × 0.05	25	−31.2
50	0.90 × 0.80 × 0.15	23	−93.4
51	1.20 × 0.60 × 0.18	12	−9.9
53	0.80 × 0.60 × 0.18	27	−27.8
54	0.55 × 0.35 × 0.22	23	−19.8
55	0.80 × 0.25 × 0.20	22	−466.1
56	0.50 × 0.35 × 0.35	36	10.2
57	0.70 × 0.55 × 0.35	5	−66.5
58	1.15 × 1.0 × 1.50	29	−5.4
59	0.95 × 0.60 × 0.27	23	2.2
60	0.97 × 0.50 × 0.27	27	−205.7

Table 4 presents basic characteristics of all signalled blocks. The table contains numbers of blocks, their dimensions (lengths × widths × height), slope inclination on the place of the block and total movement (minus – downslope movement, plus – upslope movement due to inclination or rotation of blocks).

The authors also investigated relations between slope gradient, dimensions of individual blocks and movements in the period of 1972–2008. The analysis included all monitored values in order to receive mean value of the category of certain dimensions. Analyses without extreme movements were used to exclude random movements (see Table 5).

Tab. 5 Average movement of blocks according to the slope inclination

Slope inclination in degrees	*Number of blocks*	*Average movement total (mm)*	*Average movement out of extreme (mm)*
0–9	5	−31.1	−22.3
10–19	7	−48.3	−13.0
20–24	11	−66.2	−26.2
25–29	21	−42.9	−20.3
30–54	13	−74.4	−50.6

Monitored signalled blocks were divided according to the slope gradient into 5 basic groups: 5–9, 10–19, 20–24, 25–29 and 30–54 degrees. Mean downslope movement in the group of 5–9 degrees was −31.1 mm and all movements were downslope. When omitting the extreme value the mean movement reached −22.3 mm. In the category of 10–19 degrees the mean downslope movement reached −48.3 mm, but three blocks have shown upslope movement (uplift, inclination). When omitting the extreme value the mean movement reached only −13.0 mm. In the following category of 20–24 degree the mean value was −66.2 mm. But in this category, too, were uplifted blocks. When omitting the extreme value of −466.1 mm (block No. 55) the average value of movements reaches only 26.2 mm. In the most common category of 25–29 degrees the authors measured average downslope movement minus 42.9 mm and when omitting one extreme value the average value was only −20.3 mm. Some upslope movements were detected in this category, too. The last category of 30–54 degrees shows clearly the largest downslope movement (−74.4 mm) even when omitting the extreme movement of −50.6 mm. There is not a direct relation between the slope gradient and the values of downslope movements. The survey has only indicated the largest average downslope movement on slopes with the gradient of over 30 degrees. Table 5 also shows larger number of downslope movements of over −200 mm with increased slope gradient in the time period under study.

Tab. 6 Average movement of blocks according to the length of blocks

Length in m	*Number of blocks*	*Average movement total (mm)*	*Average movement out of extreme (mm)*
0.40–0.59	5	−22.5	0.2
0.60–0.69	10	−79.8	−48.6
0.70–0.79	10	−25.3	−20.7
0.80–0.89	4	−123.1	−20.7
0.90–0.99	10	−112.5	−70.1
1.00–1.19	8	−7.5	−3.4
1.19–1.29	5	−30.6	−19.5
1.30–2.00	5	−19.5	−4.9

Table 6 shows relation between the dimensions of signalled blocks and the values of their movements. The analysis used the largest parameter of investigated blocks (lengths). The blocks were divided according to this criterion into 8 categories: 0.40–0.59 m, 0.60–0.69 m, 0.70–0.79 m, 0.80–0.89 m, 0.90–0.99 m, 1.00–1.19 m, 1.19–1.29 m and 1.30–2.00 m. The largest downslope movements were indicated in categories of 0.60–0.69 and 0.90–0.99 m where the average downslope movement made up to over −100 mm. Vertical movements of individual blocks were recorded over −200 mm; these were observed also in the category of 0.60–0.69 m. More common tilting and rotation were measured in the categories of 1.00–1.19 and 0.40–0.59 m. Partial relations between block dimensions and slope movements can be derived only for the categories of over 1.00 m. In this category did not occur any extreme downslope movements of over −200 mm in the studied period and also the average values of downslope movements were lower. Very low downslope movements were observed also in the category of 0.40 to 0.59 m, where tilting of signalled tabular blocks was also indicated.

Tab. 7 Average movement of blocks according to the volume of blocks

Volume (cubic meter)	*Number of blocks*	*Average movement total (mm)*	*Average movement out of extreme (mm)*
0.010–0.049	14	−96.9	−63.6
0.050–0.099	16	−59.1	−30.1
0.100–0.149	15	−33.7	−19.7
0.150–1.725	13	−21.7	−17.1

Table No. 7 presents comparison of mean slope movements according the volume of individual blocks. The signalled blocks were divided according their volume into four groups. The smallest blocks with volume of 0.010–0.049 cubic meters has shown the largest downslope movements (−96.9 mm in the studied period).

With the increasing volume of blocks are their movements slower (in the category 0.150–1.725 cubic meter is the total average movement only 21.7 mm). The volume of blocks and with the volume connected their weight has influence on the intensity of downslope movements.

Tab. 8 Average movement of blocks according to the heights of blocks

Height in m	*Number of blocks*	*Average movement total (mm)*	*Average movement out of extreme (mm)*
0.05–0.10	11	−39.2	−12.2
0.11–0.15	11	−119.1	−81.6
0.16–0.20	10	−56.6	−11.0
0.21–0.25	10	−24.7	−14.9
0.26–0.30	5	−47.5	−7.9
0.31–0.35	7	−36.4	−29.5
0.35–1.50	3	−14.6	−10.1

The relation between the flatness of blocks and their movements in the felsenmeer was also studied during the research. The flatness of blocks is function of their heights. Based on heights of blocks the authors distinguished 7 groups of blocks (Table 8). The largest movements were measured in the group tabular blocks with the heights 0.11–0.15 m. It is surprising that the most flat blocks with the heights 0.05–0.10 m moved downslope slower. Other categories show no relation among speed of downslope movement and the flatness of blocks. More important role is probably played by the weight of blocks.

There are no differences in type and speed of movement in the central and marginal parts of the blockfield.

8. Discussion Natural reasons of movements

Natural movement mechanisms are caused by thermal changes, duration of snow cover and the related snow pressure, formation of ground (goletz) ice, suffosion and animal activity (e.g. chamois). The open-work structure scree acts like a chimney during the cold winter period. The chimney effect brings movement of warm/cold air in open voids between blocks in open-structure blockfield covered with snow. In winter, the warmer air in the blocks tends to be replaced by cold air, entering whenever there are holes in the snow cover (Wakonigg 1996). The process leads to overcooling of the scree in winter and the formation of goletz ice. Air circulation between the atmosphere and the block slope, as well as ground (goletz) ice formation, have been proposed as the predominant factors controlling local permafrost occurrence in warmer climate (Wakonigg 1996). The large dimensions of the scree slope on the Břidličná hora Mt. allow a large amount of goletz ice to be built in winter

Anthropogenic reasons of movements

Anthropogenic influences occur even in this hard mountain conditions and protected area (Nature Reserve Břidličná since 2008) e.g. movements of people in the monitoring plot area (authors, surveyors, berry pickers or tourists).

Problems with techniques of surveying slow slope processes

There are also some problems in the research of slow geomorphological processes on monitoring plots:

i) a long period of survey (38 years) in mountainous cultural landscape (e.g. movement of tourists),
ii) the precision of survey under the condition of evolution of geodetic instruments and methods and very rugged terrain and mountain weather conditions,
iii) the weathering and loss of metal cylinders on blocks during the past decades.

Problems with climatic changes in the second half of the 20th century

Boreholes drilled in creeping ice-rich rock debris in Switzerland show an overall warming trend in the last 2 decades, but with high-amplitude interannual fluctuations that reflect early winter snow cover more strongly than the air temperatures (Harris et al. 2003). It is generally accepted that bedrock temperatures below block fields in mountains are lower than in the neighbouring mineral soils (Sawada, Ishikawa and Ono 2003). The dominant process of heat transfer in the upper layers of the open-structure blockfields is by rapid air movement through the free voids to the depth of at least 0.5 m when compared to slow conduction through the individual grains (Harris and Pedersen 1998). Rain and snow can also penetrate more deeply in the open-work blockfields. This causes the continuous exchange of air between the blockfield and the atmosphere.

9. Conclusions

The aim of the presented paper was to study the slow slope processes on blockfield on the mountain slopes in Central Europe over the period of 1972–2008. Geodetic method was used for these studies. The repeated surveys have shown that the most blocks are slowly moving downslope. The speed of scree movement varies largely (see Tables) and is caused by both natural and anthropogenic influences. The authors were not able to solve the problem of ground temperatures below the scree cover and adjacent rock slopes and to confirm or reject the hypothesis of discontinuous permafrost occurrence under blockfields near or above the upper timberlines in the Hrubý Jeseník Mts. due to lack of appropriate instruments.

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REFERENCES

DEMEK, J. (1973): Současné geomorfologické pochody v Hrubém Jeseníku. Campanula 4, pp. 103–108, Krajské středisko státní památkové péče a ochrany přírody v Ostravě, Ostrava (in Czech).

DEMEK, J. (1991): Kvantitativní výzkum pohybu sutí na svazích Hrubého Jeseníku. Acta Universitatis Palackianae Olomucensis, Facultas rerum naturalium, Geographica – Geologica XXX, vol. 103, pp. 7–23, Olomouc (in Czech).

HARRIS, S., PEDERSEN, D. E. (1998): Thermal Regimes beneath coarse blocky materials. Permafrost and Periglacial processes 9, pp. 107–120.

HARRIS, CH. et al. (2003): Warming permafrost in European mountains. Global and Planetary Change 39, pp. 15–225.

HUMLUM, O. (1997): Active thermal regime at three rock glaciers in Greenland. Permafrost and Periglacial Processes 8, pp. 383–408.

KŘÍŽ, V., TOLASZ, R. (1990): Sněhová pokrývka hornatin a vrchovin Severomoravského kraje. Práce a studie Českého hydrometerologického ústavu, 18, Praha, 46 pp. (in Czech).

KŘÍŽEK, M. (2007): Periglacial landforms above alpine timberline in the High Sudetes. In: *Geomorphological Variations*, Andrew S. Goudie and Jan Kalvoda (eds.), P3K, 1. vydání, Praha, pp. 313–337.

MACKOVČIN, P. et al. (2006): Vyhodnocení svahových deformací v modelových územích České republiky. Geomorfologické výzkumy v roce 2008, pp. 167–172, Olomouc (in Czech).

PROSOVÁ, M. (1952): Předběžná zpráva o polygonálních půdách ve Vysokém Jeseníku. Přírodovědecký sborník Ostravského kraje 13, pp. 1–2, p. 270, Opava (in Czech).

PROSOVÁ, M. (1954): Studie o periglaciálních zjevech v Hrubém Jeseníku. Přírodovědecký sborník Ostravského kraje 15, 1, pp. 1–15, Opava (in Czech).

ROMANOVSKIJ, N. N., TURIN, A. I. (1986): Kurums. Biuletyn Peryglacjalny, 31, 249–259, Lódź.

SAWADA, Y., ISHIKAWA, M., ONO, Y. (2003): Thermal regime on sporadic permafrost in a block slope on Mt. Nishi-Nupukaushinupuri, Hokkaido Island, Northern Japan. Geomorphology 52, pp. 121–130.

WAKONIGG, H. (1996): Unterkühlte Schutthalden. Arbeiten aus dem Institut für Geographie (Graz) 33, pp. 209–223, Graz (in German).

WEISSMANNOVÁ, H. et al. (2004): Ostravsko. In: Mackovčin, P. a Sedláček, M. (eds.): Cráněná území ČR X: 1–456, AOPK a EkoCentrum Brno, Praha (in Czech).

WHITTOW, J. (1984): The Penguin Dictionary of Physical Geography. Penguin Books, London, 591 pp.

YOUNG, A. (1972): Slopes. Oliver and Boyd, Edinburgh, 288 pp.

ZACHARDA, M., GUDE, M., RŮŽIČKA, V. (2007): Thermal Regime of Three Low Elevation Scree Slopes in Central Europe. Permafrost and Periglacial Processes 18, pp 301–308.

RÉSUMÉ

Kvantitativní monitoring svahových pochodů na Břidličné hoře (Hrubý Jeseník, Česká republika, EU)

Autoři v článku hodnotí výsledky dlouhodobého monitoringu pomalých svahových pochodů v balvanovém moři na pokusné ploše ležíci na svahu Břidličné hory (1358 m n. m.) v Hrubém Jeseníku v období 1972–2008. Monitoring je založený na opakovaných podrobných geodetických měřeních pohybů 57 metakvarcitových bloků signalizovaných kovovými terčíky. Opakovaná měření polohy proběhla v létech 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1981, 1983, 1984, 2005 a 2008. Výsledky měření jsou shrnuté v tabulkách, mapě a v grafech. Většina bloků (75 %) se v uvedeném období pomalu posunula po svahu. Balvanové moře se nepohybuje jako celek. Rychlost pohybu jednotlivých bloků se značně různí. Pohyb bloků není jednoduchý, úlomky se při pohybech naklánějí a otáčejí. Příčiny pohybů jsou jak přírodní, tak i antropogenní. V článku se rovněž diskutují problémy spojené s dlouhodobými geomorfologickými měřeními v kulturní krajině Střední Evropy. Pro nedostatek měřících přístrojů se autoři nemohli vyjádřit k hypotéze o výskytu ostrovního permafrostu pod balvanovými moře nad uměle sníženou horní hranicí lesa v Hrubém Jeseníku.

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