

SLOPE FAILURES AROUND THE ROCK CASTLE DRÁBSKÉ SVĚTNIČKY, CZECH REPUBLIC

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ABSTRACT

Stability conditions in a wider surrounding of the rock castle Drábské Světničky (Drábské Rooms) near the town of Mnichovo Hradiště were investigated. The area which has been intensively disturbed by large old as well as present slope movements is located in the north-western part of Příhrazy Platform. Solid, thick bedded sandstones, well resistant to weathering, are lying on claystones apt to plastic deformations. Marginal sandstone blocks separate, move down on the slope and sink into the plastic bedrock. As a result, block fields with many crevasses develop. In rock walls that separate individual blocks, rockfalls originate and central, as well as lower parts of the slopes develop large landslides. A zone comprising up to 400 m wide rim of the high and exposed platform has been subject to a process of loosening. A local group of tower-like sandstone blocks was used in the 15th century to build a small rock castle called Drábské Světničky. An extensive landslide that destroyed a substantial part of the village of Dneboh in June 1926, reached in its separating zone up to the toe of marginal rock towers belonging to the complex of Drábské Světničky with the result of local movement activation. Marginal zones of the flat land behind display fresh linear, as well as oval depressions and sinks. Fissure and pseudocast caves develop. Present activity of the movements has been evidenced by dilatometric measurements on two selected rock objects where movement rates reached 1 to 2 mm per year in average.

KEYWORDS: landslide inventory, landslide susceptibility mapping, slide, spread, fall, dilatometric measurements, pseudocast

1. INTRODUCTION

It was in 2005 when one phase of detailed investigations of stability slope conditions in the area of Příhrazy Platform, which represents a conspicuous elevated dominant of Pojizeří Region east of the town of Mnichovo Hradiště, was finished. Příhrazy Platform is found intensively disturbed by slope movements in its western, north-western and northern part and the area repeatedly suffers from slope failures of different type.

The research was aimed to the analysis of present geodynamic processes effective in the relief development of Příhrazy Platform which belongs to most remarkable regions, regarding geomorphology and engineering geology of the Czech Cretaceous Table.

As to natural environment and its preservation, this region should be given consideration also for its important archaeological and historical objects. Special attention was paid, therefore, to the development of the relief around the rock castle Drábské Světničky because of construction details and forms of fortification techniques applied at the end of the 14th and 15th centuries that can be studied here.

2. PROCEDURES

Archives in the region provide numerous manuscript and published elaborates about geology, engineering geology, geomorphology and historical structures. It is mainly due to the fact that a large landslide destroyed a substantial part of the village of Dneboh in 1926. The village was situated on the slope right under the rock castle Drábské Světničky. The event was duly registered (Dědina, 1926; Záruba, 1927).

In the 1950s an increased attention was paid to the complex of Drábské Světničky on the part of experts in medieval architecture (Vojáček, 1951/2; Menclová, 1951/2). Dobroslava Menclová led and finished reconstruction works, a spatial model at a scale of 1:17 is deposited in Mnichovo Hradiště Museum.

It was in 1962 when inventory of dangerous landslides in a larger part of Příhrazy Platform was provided at a scale of 1 : 25 000 (Fencl and Zeman, 1963) and the landslide of 1926 has been studied in detail since. The area in its full probable extent was investigated geodetically at a scale of 1 : 5 000. Two geological cross-sections were set that included three

core and five dug holes. Mineralogical and chemical composition of the rock was investigated and slope stability calculations made (Záruba et al., 1966).

Geomorphologists B. Balatka and J. Sládek paid an increased attention to Příhrazy Platform in 1980s. The results were summarised by Balatka (1980). The attention to the relief of Příhrazy Platform was again increased by the end of 1990s due to observations of "Český Ráj" Protected Landscape Area administration workers who called public attention to accelerated loosening of slopes and changes in hydrogeological conditions. In 1990 movement monitoring was introduced (Stemberk and Zvelebil, 1999). First, an isolated rock tower (area A) and later a pseudocarst fissure cave were started to be monitored here (area B).

A core hole Př-1 that provides data about groundwater fluctuations was drilled in 2001 as a part of the Czech Republic Grant Agency project No 205/01/0743 (Stemberk et al., 2004). Specimens taken from the bedrock claystones were analysed for clay minerals composition. The hole provided an opportunity to use seismic tomography for verification of microtremors and to make borehole logging for verification of fissures. In 2002 another core borehole Př-2 was drilled east of a fissure crack called "Studený Průchod" (Cold Passage). The hole provides monitoring data about groundwater fluctuations.

The whole area of Příhrazy Platform has been mapped at a scale of 1 : 10 000 while diploma thesis results (Kvasnicová, 1994 and Kyrianová, 2003) were partially implemented. Special engineering geological maps of stability conditions and derived slope failure susceptibility maps were prepared at a scale of 1 : 10 000 (Rybář et al., 2004).

Engineering geological conditions around the rock castle "Drábské Světničky" were analysed between 2003 and 2005 (Rybář, 2005). The work was financed by the Grant Agency of the Czech Republic No 205/03/0335. Conclusions of the field mapping were included into a synoptic map evaluating stability conditions in the NW part of Příhrazy Platform (Fig. 1). This map is a sort of an engineering geological zoning map evaluating the character of failure in the studied area. Fig. 2 displays a cut of a more detailed map of geodynamical phenomena. Relief forms bound to deep gravitational loosening, to rockfalling along sandstone rock walls, and to old as well as recent sliding and creep block-type movements were recorded in it, combined with hydrological data.

For the region of Příhrazy Platform a digital GIS model of the relief was prepared (Fig. 3). The treatment included the use of digitalized contour lines of General Map of the Czech Rep. 1 : 10 000 with 2 m step density. The work involved a detailed

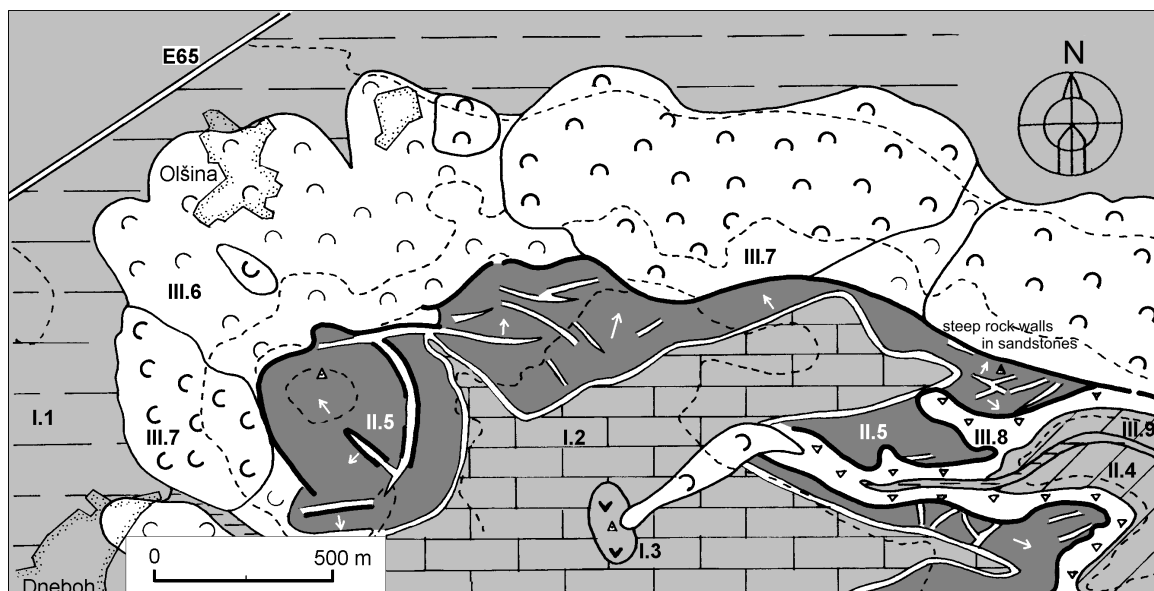


Fig. 1 Synoptic map of stability conditions in NW part of Příhrazy Platform.

- I - stable area: I.1 - permanently stable moderate slopes and flatlands of fluvial plains;
- I.2 - elevated stable areas in thick-bedded sandstones of Turonian or in the claystones of Coniacian (surrounding of the nepheline body of Mužský Hill); I.3 - stable slopes in nepheline rocks.
- II - area where instability cannot be excluded: II.4 - moderate, as well as steep slopes without any signs of deep-seated failure; II.5 - moderate slopes and elevated flatlands in sandstones with deep-seated gravitational loosening (arrows mark assumed directions of block movements).
- III - unstable areas: III.6 - slopes disturbed by landslides in the past, as well as block-type movements;
- III.7 - slopes disturbed by present active and temporarily dormant landslides; III.8 - slopes in sandstones endangered by rock falls from rock walls; III.9 - erosion furrows of water flows and gaps.

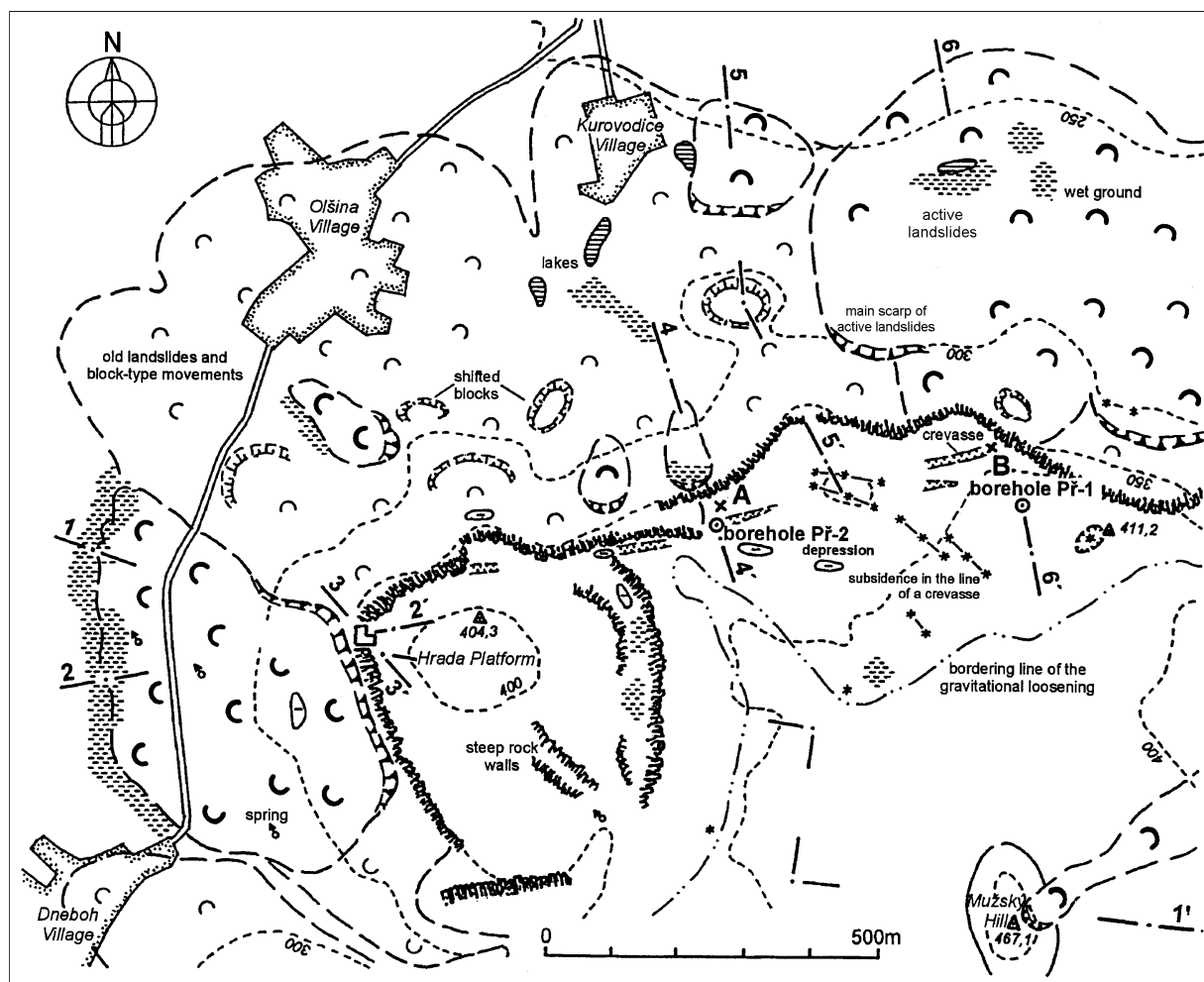


Fig. 2 Map of geodynamical phenomena in NW part of Příhrazy Platform. 1-1' to 6-6' - geological cross-sections; A and B - monitoring positions.

documentation of the relief pertinent to the walls and towers that provided foundations for the rock castle Drábské Světničky in the 15th century. As a special output of 3D data obtained by GIS, several cross-sections through slopes along Příhrazy Platform in the vicinity of Drábské Světničky were made. An exaggerated geological cross-section 1-1' was produced which runs E-W through Mužský Hill, Hrada Platform, and the castle Drábské Světničky, up to the toe of the landslide area of 1926. The field measurements provided relief documentation along five lines, in unexaggerated cross-sections 2-2' to 6-6' characteristic of individual sections of the north-western part of the platform.

An essential part of the stability conditions study in the north-western part of the Příhrazy Platform was photodocumentation. Some photos from archives were accepted. Nevertheless, actual snaps were used principally. The area of Drábské Světničky was photodocumented in March 2006 from a remotely controlled aeroplane model of Aerodata Co.

3. NATURAL CONDITIONS OF THE STUDIED AREA

The area of Příhrazy Platform is found in the "Český Ráj" Protected Landscape Area. It belongs to the Vyškeř Highlands at the northern part of a more general unit which is Turnov Upland. Here, several areas were selected as natural parks or protected areas. Generally, the territory has a typical relief of thick-bedded sandstones of the Czech Cretaceous Basin with an unusual variation of weathering forms and removal of sandstones (Balatka and Sládek, 1984). Příhrazy Platform, as an outstanding tabular eminence, comes out in W and N dominating the substantially lower basin of Mnichovo Hradiště. Its surface is tilted from NW to SE. The highest point is Mužský Hill (467.1 a.s.l.).

3.1. GEOLOGICAL CONDITIONS

From the geological point of view, the area in question belongs to Jizera facial-lithogenetical complex of Czech Cretaceous Table. Stratigraphically,

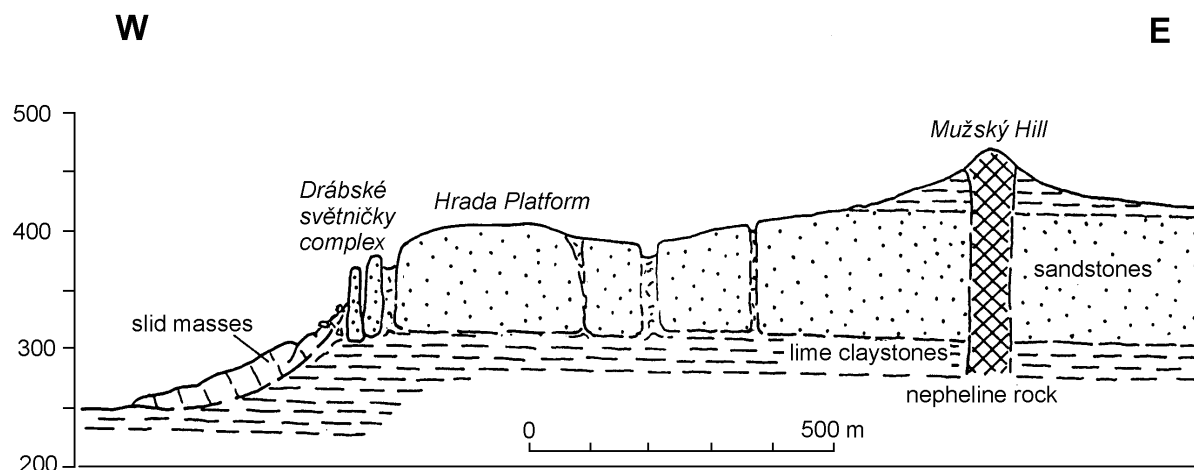


Fig. 3 Schematic vertically exaggerated geological cross-section 1-1'.

the Cretaceous System is represented by Middle Turonian to Coniacian. At the bedrock one finds lime claystones and siltstones of Teplice group of strata (Tima ed., 1996). They are outcropping in the foreground of western and northern slopes rimming Příhrazy Platform. Their superincumbent bed is built by quarzitic thick-bedded sandstone facies which represent a rigid body.

Cretaceous sediments were penetrated by volcanites during Miocene, and veins, as well as volcanic necks were documented here. Dikes can be found mainly in the SE section of Příhrazy Platform where rock cities occur. They follow tectonic fault lines of Krušné Hory Mts. orientation, which is WSW - NEE. These lines can be well observed on the digital model (Fig. 3). Volcanic bodies are resistant to weathering and slow down disintegration of the platform. In the relief one can find also lines of failure planes of Sudetic orientation (NW - SE and WNW - SEE) and even lines of Jizera orientation (N - S) in the western margin of the platform. Krušné Hory and Sudetic lines are also effective in the separation process of marginal blocks in the central part of the platform N of Mužský Hill (Kyrianová, 2004; Forczek, 2005; Rybář and Forczek-Kyrianová, 2005), which can be observed in Figs. 1 and 2.

Sandstone beds are moderately slanted to SE or SSE under the angle of about 1 deg. They are characteristic of thick-bedded block disintegration along a system of subvertical fissures and bedding planes. They are of fine to medium granularity, whitish grey or yellowish in colour. Basal plane of thick-bedded sandstones is between 290 and 315 a.s.l. on the NW and N side of the platform. In its surrounding, Mužský Hill has denudation remnants of the youngest Cretaceous sediments, which are lime claystones and siltstones of Coniacian.

The character of sedimentation conditions in the NW part of Příhrazy Platform is depicted schematically in an exaggerated geological profile 1-1' of Fig. 4.

3.2. ROCK PROPERTIES IN THE ENVIRONMENT

Stability behaviour on the Příhrazy Platform slopes is given by the properties of two rock complexes, thick-bedded sandstones and lime claystones.

Strata complex of sandstones is 80 to 120 m thick and its lithological composition is variable. Sandstone beds with clayey cement have the least resistance to weathering. In exposed walls such beds suffer easily from weathering, which results in overhangs apt to toppling and rockfalling.

Properties of lime claystones were studied by Záruba et al. (1966). Using documentation of core holes and dug holes they find that the claystones are of a slab-like separation and deformed by old slope movements up to 30 m of depth. They show a character of shattered clay, kneaded attitudes are of a slip texture. Minerals of clay were analysed by X-ray and thermal differential analysis showing a mixture of kaolinite and montmorillonite. The authors pointed out that properties of claystones with a considerable volume of montmorillonite display a considerable deterioration due to percolation of water containing nitrogen which has been released from upper layers containing glauconite. Considering content of carbonates they are mostly lime claystones defined by the content of carbonates higher than 10 per cent. Superficial layers contained 8 to 12 per cent of carbonates, undisturbed samples from deeper layers 17 to 25 per cent and accessories of glauconite in small grains.

In 2002, drill hole PŘ-2 provided samples from the depths of 63.0, 63.3, and 63.7 m of kneaded lime

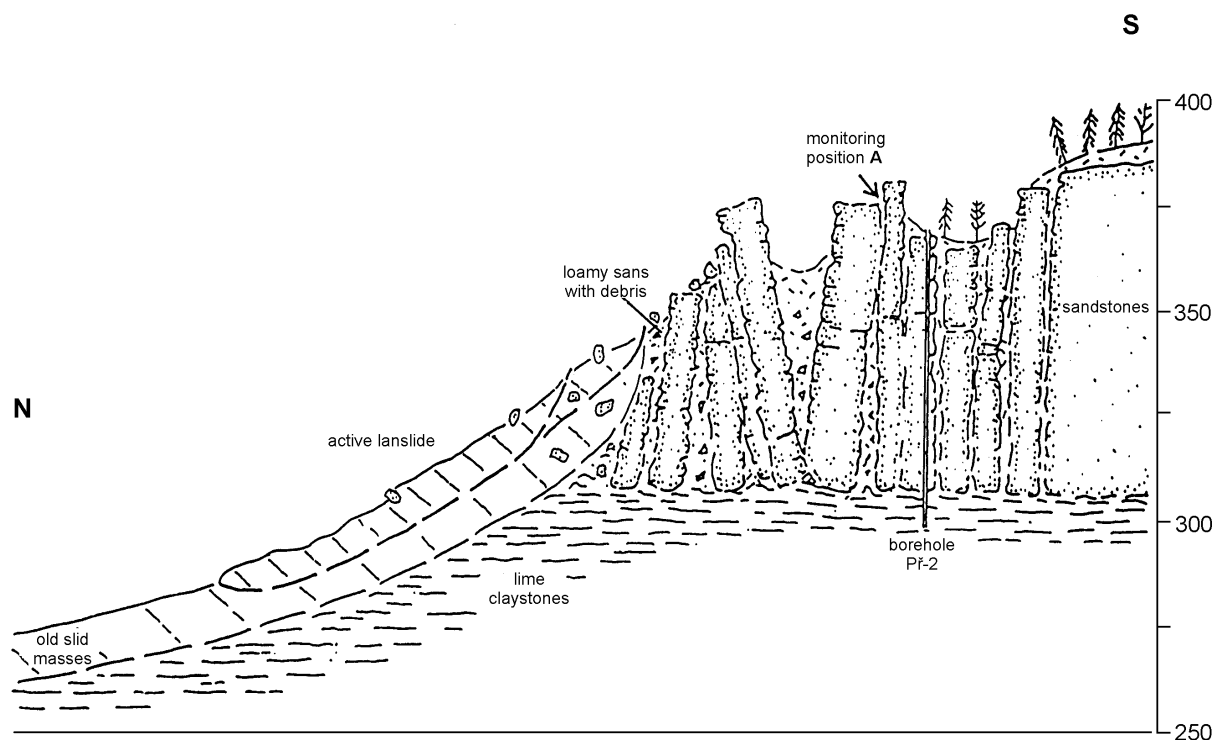


Fig. 6 Geological cross-section 4-4'. (no vertical exaggeration).

claystones analysed in regard to clayey minerals. High content of smectite was indicated (31 per cent in 62.0 m) decreasing with depth in the bedrock (21 per cent in 63.7 m).

3.3. HYDROGEOLOGICAL CONDITIONS

A continuous groundwater level is bound to the base of the thick-bedded sandstones at the contact with the bedrock of lime claystones. Groundwater level is monitored in two boreholes. Hole PŘ-1 situated at a distance of about 500 m NEE from Drábské Světničky is 121.5 m deep. It was finished in October 2001. A boundary between sandstones and claystones was found at the depth of 108.0 m and a stabilised groundwater level at 106.5 m. In the period of monitoring, the level does not show any important variations. Fluctuations appear in limits of 5 cm only.

Hole PŘ-2 situated near the so called "Studený Průchod" about 250 m from Drábské Světničky, found the boundary between sandstones and claystones in the depth of 62 m. Groundwater level was not found. It was only later, with one month delay, when the level started to show lifting. During 2003 which was extremely dry, the level rose by about 1 m, and lifting continued till September 2004 up to 1.9 m from the hole bottom. Later the level started to drop down and at the beginning of 2006 disappeared totally. Both the holes are situated on the top platform of sandstones disrupted by deep gravitational loosening.

Precipitation water percolate into the complex of sandstones through fissures and pores, and at the

boundary between sandstones and claystones disappear in Quaternary slope sediments built mainly from the slid masses of different age and generations. In the central and specially in the lower zone of the slopes built by claystones one can find wet ground and smaller springs. Such watered places can be considered as outcrops of the old slipping planes. This would be so primarily in the area of the historical landslide which destroyed a part of the village of Dneboh in 1926, and which can be found on the slope oriented to W below the complex of Drábské Světničky (Fig. 2).

3.4. GEODYNAMICAL PHENOMENA

Příhrazy Platform suffered mainly from extensive slope deformations, old and young. Besides, weathering processes, pseudocarst phenomena, as well as suffosion are present. Buildings founded on lime claystones and on their weathered forms developed cracks locally. These result from shrinkage of rock that is unstable due to exsiccation.

The process of gravitational decomposition of Příhrazy Platform started in Pleistocene when erosion basis of the Jizera River was reaching the surface of the thick-bedded sandstones. Záruba et al. (1966) assumed that the process of slope block-type deformation was most intensive under the periglacial conditions of Pleistocene. Step by step, deep freeze-thaw cycles deteriorated rock properties, most intensively in claystones and in the bedrock of sandstones. Pašek and Košťák (1977) on the basis of a

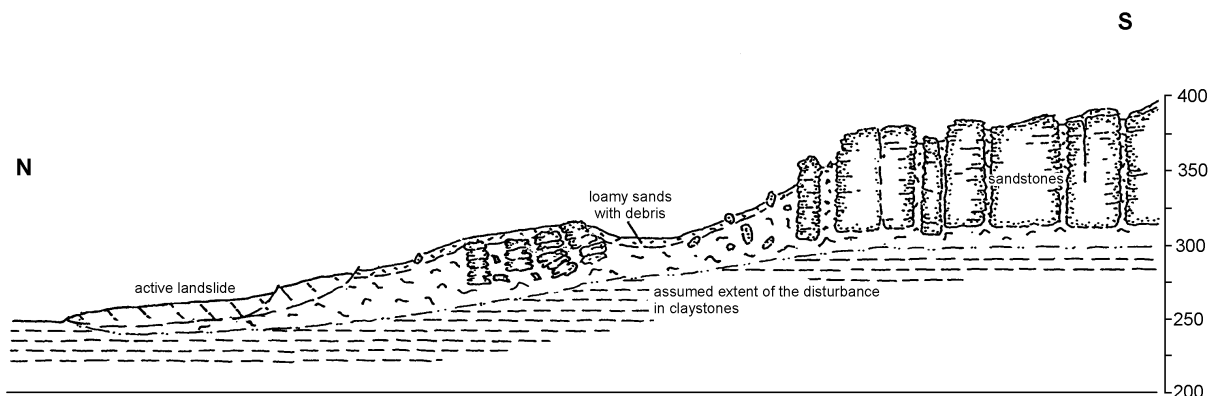


Fig. 7 Geological cross-section 5-5'. (no vertical exaggeration).

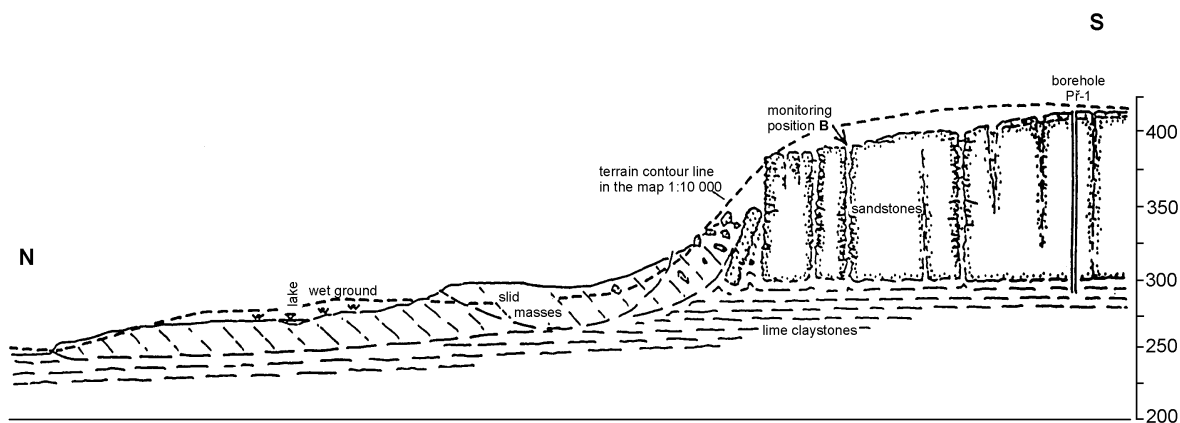


Fig. 8 Geological cross-section 6-6'. (no vertical exaggeration).

series of block-type movement examples found in the former Czechoslovakia defined such movements as very slow but not calmed down under present natural conditions. One can observe that block fissure monitoring almost regularly confirm such an activity even under present climatic conditions (cf. Košťák, 2002).

Fig.1 represents a general, highly simplified evaluation map of stability conditions in the NW part of the platform, where most favourable structural conditions occur giving way to deep seated slides and creep movements. Thick-bedded sandstones, solid and more resistant to weathering, are overlaying here plastic claystones and marlstones outcropping on lower sections of slopes. Clayey bedrock is not a satisfactory support for overlaying beds apt to brittle fracturing. Marginal blocks of the thick-bedded sandstones structured by sub-vertical systems of fissures, separate, move down and sink into the plastic bedrock. Separating rock walls suffer from rockfalls which leads to a large amount of debris in the forefield. Additional loading of deformable bedrock layers results in extensive landsliding.

Forms of gravitational slope deformations in individual sections of the NW part of Příhrazy Platform are schematically exemplified with non-exaggerated cross-sections 2-2' (Fig. 5 - the upper), 4-4' (Fig. 6), 5-5' (Fig. 7) and 6-6' (Fig. 8). The relief in the cross-section 2-2' is well comparable with a panoramic photo (Fig. 5 - the lower). The form of bedrock layering deep in the slopes is mostly hypothetical because there were only data from two deep boreholes (Př-1 and Př-2) available. Then, data from some older but shallow boreholes and dug-holes situated in the landslide area below Drábské Světničky were taken into consideration. Assumed depths of multiple slipping planes of a rotational - planar form, cross-sections 2-2', 4-4', 6-6', should be between 25 and 40 m. Contrary to that, Záruba et al. (1966) assumed a depth of up to 60 m for a slipping plane of a rotational form at the slide below Drábské Světničky. When preparing cross-section 5-5', we gave preference to drawing limits of a zone in which the deep deformation of claystones should occur. Field survey that comes to construct cross-sections used successfully a laser-beam clinometer LaserAce

which is able to provide a swift relief detection in the terrain, as well as a much higher accuracy than data from a general map 1 : 10 000 (this can be compared in Fig. 8).

Four stability failure zones in slopes can be differentiated:

1. Zone of deep gravitational loosening (Fig. 1, sub-area II.5).
2. Zone of crevasse and block fields (Fig. 1, contact of sub-areas II.5 and III.6 and III.7).
3. Zone of debris at the toe of rock-block faces (sub-area III.8).
4. Zone of the old, as well as active landslides and of block-type movements (sub-area III.6 and III.7).

Separation zones of landslide areas are rimmed with steep rock walls in sandstones, which disintegrate gradually due to gravitation, and disintegration goes on to the interior. Such a loosening reaches an area up to 400 m from the edge of the high platform into the interior near Mužský Hill. The process of loosening (sub-area II.5) is manifested by displacements in the field of blocks and rock towers. These often also tilt down or up the slope. Block and crevasse fields originate (Fig. 9). Above widening crevasses linear, oval, and circular depressions and pseudo-sinkholes develop, and even dangerous sudden foundering takes place. Crevasses are filled up partially by Quaternary sediments including debris. As to the borehole PŘ-1, the drill foreman reported a void in 60 m of depth full of schlick. Clearly, it was a crevasse crack filled up with weathering products of Cretaceous sediments. Besides, even mechanical suffusion will be present in such cracks in a process of decantation when loose rock particles are washed out by infiltrated water.

Balatka (1980) reported 61 sinkholes along the northern edge of Přihrazy Platform. Half of them were saucer-shaped, one third were fissure like, and the rest funnel-shaped. A more detailed mapping 1 : 10 000 in 2001 and 2004 registered much more sinks in the area. Besides, depressions and sinkholes migrate relatively quickly in the zone where loosening takes place. Supposedly, it is due to low and variable resistance of sandstone layers to weathering and mechanical suffusion.

Closer to the edge of the elevated plateau one could register block crevasses in a very advanced stage of development like that of the so called "Studený Průchod" (Cold Passage), then also crevasses in the early stage of development. This is the case of the crevasse where movement monitoring in the B area takes place (Fig. 10). Further from the edge, only isolated sinks can be found. Fig. 1 shows the assumed directions of sandstone edge block shifts.

The platform near the elevation 404,3 is interesting because of archaeological findings about a settlement dated to the Young Stone Age. It is registered under the name of "Hrada" or "Na Hra-



Fig. 10 A progressing block crevasse bordering the active block-type landslide. Here, in the superficial fissure zone where movement monitoring takes place, a fresh subsidence is undergoing. The entrance to a cave can be seen in the background. Photo by J. Stemberk 2001.



Fig. 11 A crevasse separating Hrada Platform from the central part of the highlands. Photo by J. Rybář 2005.

dech". Together with Zvelebil et al. (2001) we assume that it is a giant sandstone block shifted to W or NW. It is separated from the central part of the platform by a crevasse up to 60 m wide (Fig. 11). The block can

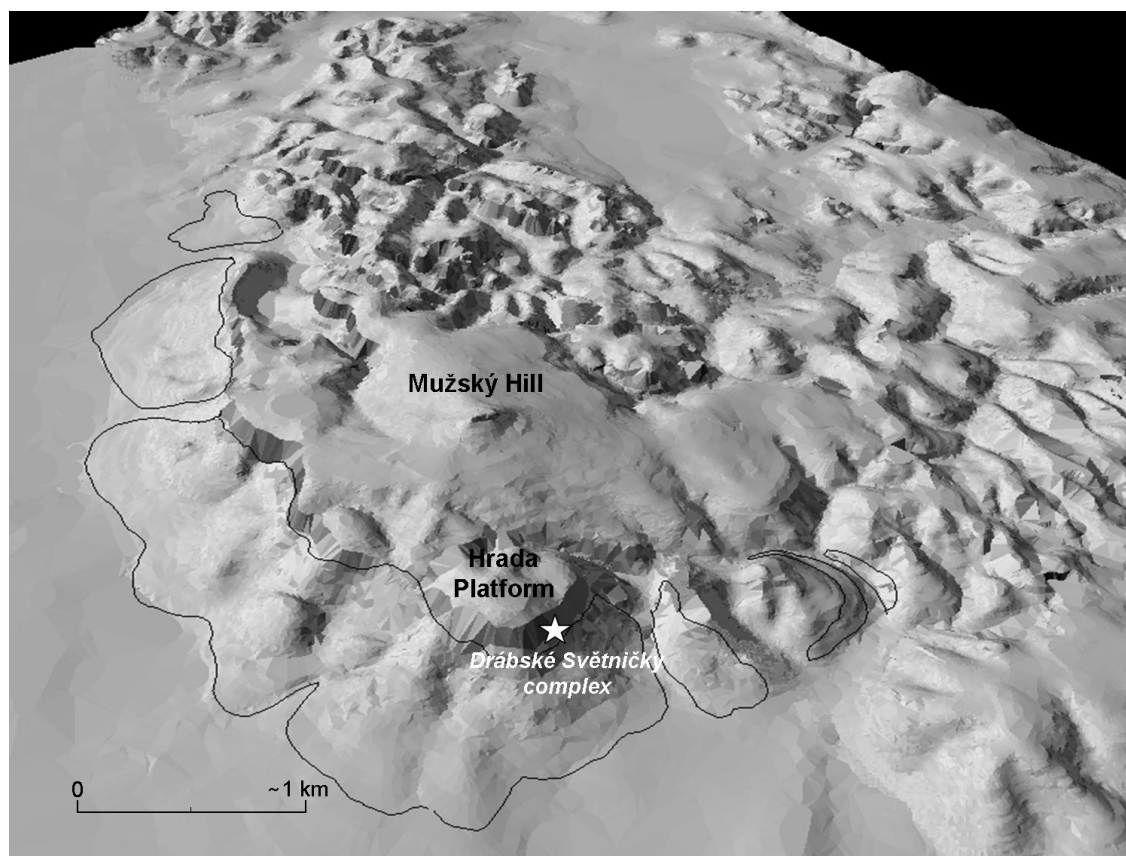


Fig. 12 An oblique view of the digital model of Příhrazy Platform from NW.

be well noticed in the lower part of the skew view to the digital model of Fig. 12.

It was near the NW edge of the platform Hrada where a group of sandstone blocks was utilised to construct a small rock castle Drábské Světničky (Menclová, 1976).

3.5. THE LANDSLIDE OF 1926

An extensive landslide that destroyed a substantial part of the village of Dneboh, including the road to the Olšina Village, reached through the separated zone up to the toe of the edge towers of Drábské Světničky (Fig. 5 the upper). The length of the landslide area was about 400 m, it was up to 500 m wide, and the slope slanted 10 to 12 deg. The first signs of the slide movements appeared on buildings reportedly about 14 days prior to the main catastrophe. It was on June 27 at 11 o'clock a.m. when the slide accelerated suddenly and after 5 hours of duration it calmed down.

Any situation plan of the devastated area from 1926 has not been found. It was only 36 years later when the area, transformed meanwhile by different human activities, was mapped at a scale of 1 : 25 000 (Fencl and Zeman 1963). The assumed area was then geodetically surveyed in 1963 at a scale of 1 : 5000. Fig. 2 shows the landslide area at a scale of 1 : 10 000 after the results of surveying of 2004.

The landslide was triggered by extreme precipitation, when 339 mm dropped down in May and June of that year. It was an absolute two month maximum in a period of 70 years of registration in Turnov and Karlovice rain gauges. We can agree with Dědina's (1926) assumption that such rains chronically appeared even in the past, covering the whole section between the villages of Dneboh and Příhrazy. An interesting observation comes from Záruba et al. (1966). During their mapping work in the central part of the slid masses, i.e. about 110 m above the road, they discovered a huge sandstone block that came out evidently from the rock castle. The block contained apparent signs of mortised pockets of console beams. This edge block must have fallen down after the erection of the castle, therefore after 1430 or even later. This finding shows that the slope below Drábské Světničky suffered from landslide movements even before 1926, and the deformations caused apparently a progressing stability deterioration of the edge towers of the Hrada Plateau. Záruba et al. (1966) deducted at the same time that the sandstone edge blocks of Drábské Světničky are presently stable and have been for a long time. They base such deduction on the fact that found mortised beam pockets of the 15th century are still facing well one another being in a horizontal position. They accept this finding as a proof that the blocks did not move mutually from the 15th century.

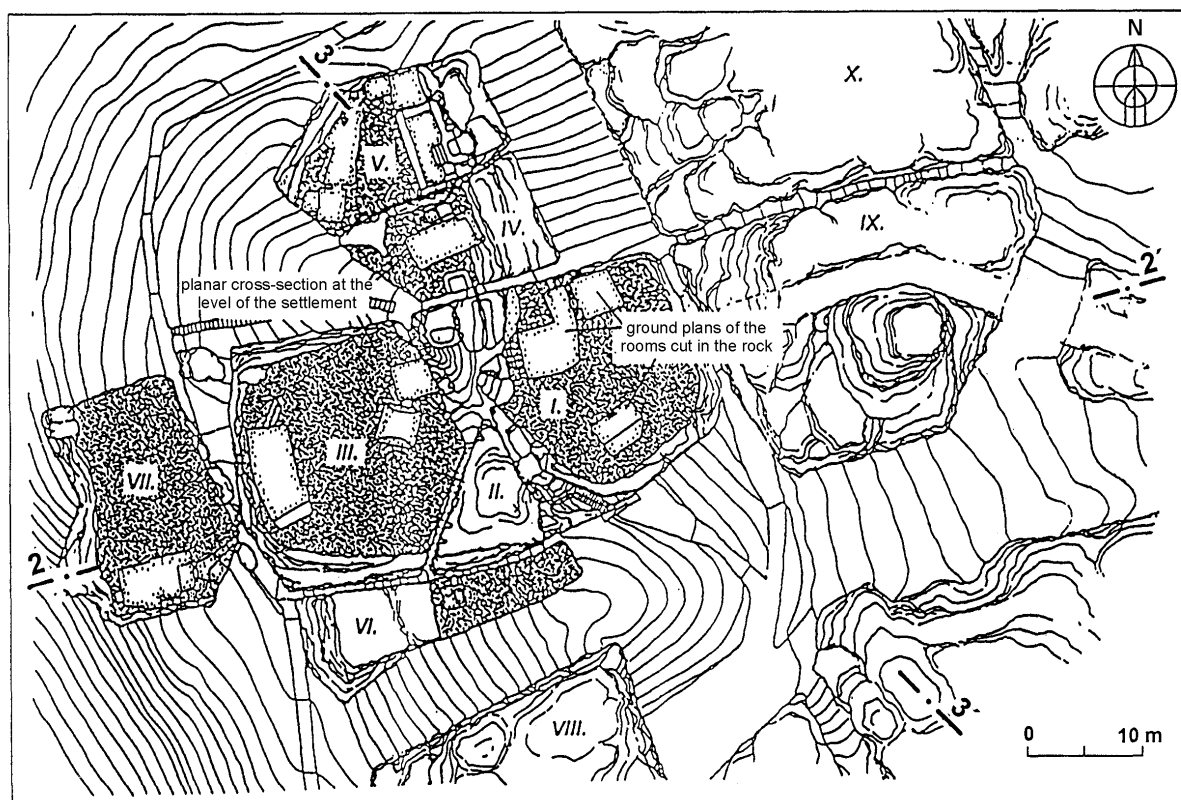


Fig. 13 Situation of rock blocks No I to X in the complex of the rock castle Drábské Světničky. I - main tower block; II - connecting block; III - main dwelling block; IV - block with the room for the priest; V - block "Svatyně" (Sanctuary); VI - block "Sloup" (Column); VII - block "Strážnice" (Watch-house); VIII - block "Dráb"; IX - bridge block; X - block "Babí zub".

However, they did not exclude possible creep movements that would shift the blocks horizontally. Evidently, it is neither possible to indicate the place where the block of Drábské Světničky complex comes from, nor the period when it occurred.

3.6. ANTHROPOGENIC EFFECTS

The wider area of Drábské Světničky was extensively affected in the past by quarrying of high quality beds of thick-bedded sandstones. A series of small quarries can be found in the area of 1926 landslide. Apparent traces of sandstone extraction, that occurred no doubt during the 19th century, have been found right near the entrance to the complex of Drábské Světničky.

Stability conditions of the Příhrazky Plateau are further affected by farming. It was in 1970s when the land at the top of the plateau W of Mužský Hill, was changed from fields to orchards. Grazing land and grass field with turf cover were transformed to orchards where the surface is ploughed regularly. Ploughed planes will considerably increase infiltration of precipitation water, and, at the same time, the volume of evaporated water will be decreased (Stemberk and Zvelebil, 1999).

One cannot omit the influence of increasing tourism in the "Český Ráj" Protected Landscape Area. It comes to be a deteriorating factor in the natural environment, and it is namely in the complex of Drábské Světničky where even the traces of the 15th century settlement are progressively disturbed.

4. PRINCIPAL DATA CONCERNING DRÁBSKÉ SVĚTNIČKY CASTLE

A thorough description of the complex of Drábské Světničky was published in the proceedings of the office that takes care of historical monuments "Památková Péče" (Vojáček, 1951/2; Menclová, 1951/2). The published papers include several seriously prepared plans that come out of geodetic surveying of the complex and its surrounding.

Published data provided a basis for compiling a general map of the complex of Drábské Světničky including its surrounding (Fig. 13). Individual blocks were given numbers I to X. A ground plan showing the intersection of individual rock walls was adopted from the earlier documentation and completed with a precise field documentation of wall relief. In the situation where maps 1 : 10 000 cannot be sufficiently correct in the dissected terrain of sandstone blocks and

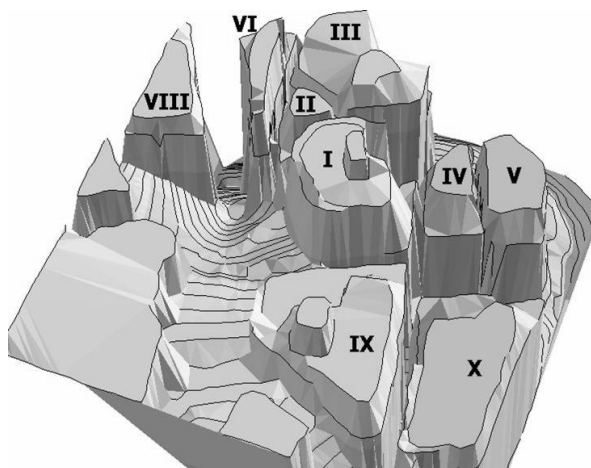


Fig. 14 A 3D model of Drábské Světničky. A view of the block field from NEE.

steep rock slopes, we used situation data of geodetic surveying of the rock castle complex given by Vojáček (1951/2), completed with our own data obtained from laser trigonometry, to prepare a detailed 3D block model of Drábské Světničky relief. Surveying was performed with the use of laser-beam clinometer/rangefinder LaserAce, produced by MDL. Surveying was made both, by polar method, i.e. by sight-lines from a single pole towards individual block edges, and by surveying several detailed cross-sections. As a result we obtained relative elevations and shapes of individual blocks, later transformed to absolute elevations and to positions found with GPS, so that the whole model could be geo-registered to a co-ordinate system S-JTSK, i.e. to the appropriate situation in the map 1 : 10 000. An example of the resulting 3D model is given in Fig. 14. Such a model provides a chance to have a correct view about the

situation, mutual position and mass disposition between individual rock blocks, which is especially useful in a simulated environment of GIS.

As stated by Menclová (1976): "Drábské Světničky represent an independent fortress built on the NW margin of the elevated platform called Hrada, 86 to 141 m above the Jizera River with its numerous marches and swamps. In seven sandstone blocks separated with crevasses and narrow fissures a perfect system of underground rooms was built up, cut into the easily workable sandstone, together with timbered facilities anchored into the rock by mortised pockets and slots. The entrance into the fortress was from E through a narrow gully between rock towers.

Any documentation that would provide clear dating of the fortress is missing. Broken ceramic and other findings bear signs that the platform of Hrada was more systematically inhabited from the Young Stone Age to the beginning of Bronze Age, i.e. in a period between 3000 and 1700 BC, then later on with an interruption of about 1000 years till the beginning of our age, and finally, without interruption, from the time of strongholds until the middle of the 15th century. Fortifications of Drábské Světničky were created after 1430 AD when Hussite captains started to settle here trying to control a long-range road that passed just below Hrad through the valley of the Jizera River in the direction to Prague."

Builders of the rock castle used the relief of the block field with fissures up to several meters wide between individual blocks. About 18 rooms were cut out into the rock, partially or totally. Traces from 7 timbered superficial constructions can be recognised. Six wooden bridges spanned the fissures (Vojáček, 1951/2). Detailed cross-sections of Fig. 15 contain projections of some of the rooms. The fissures bordering individual blocks are oriented 140 to 150 deg and 70 to 75 deg and walls 30 to 50 m high.

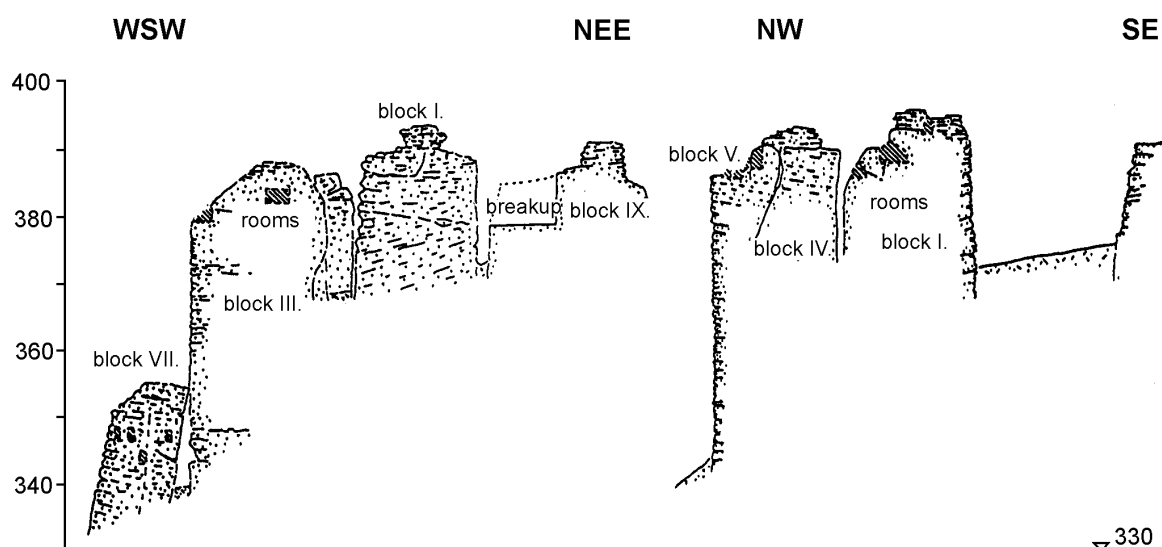


Fig. 15 Detailed cross-sections 2-2' and 3-3' of the complex Drábské Světničky.



Fig. 16 An aerial view of the rock castle Drábské Světničky from NW. The snap taken from a model aeroplane.

Fig. 16 shows an aerial view of Drábské Světničky from NW taken from a model air plane. Frontal block is the block No. V "Svatyně" (Sanctuary) and the adjacent block with the room of the priest labelled No. IV, the two containing relics of 6 rooms. On the left in the background, one finds a block of the main tower (No. I), and on the right is

"the main dwelling house" (No. III), with another block (No. VII) leaning against it below and called "Strážnice" (Watch-house).

Most of the blocks sustained vertical position, approximately. Let us see the towering block No. VII called "Sloup" (Column), as an example. Block No. VII "Strážnice" with about 3 rooms accessible from the passage between blocks Nos III and VII is a little inclined (10 deg up-slope), and leaned against "the main dwelling house" (No. III) with its upper edge, (see Fig. 17 right). The landslide of 1926 disclosed its toe to the height of about 15 m (Fig. 17 left).

5. RESULTS OF ACTIVE MOVEMENTS MONITORING

The landslide area of the year 1926 can be considered as calmed down generally, although locally active movements of low rate can be indicated. These are centred into the wet ground which is in the centre of the area above the road. Here, relatively steep slopes of accumulation mounds can be found. Even the frontal part of the landslide area with its foreground is heavily water bearing (Fig. 2).

Present slow movements are evidenced by bent trunks of pine trees found in the upper part of the slope devastated in 1926. A typical "drunk forest" is on the surface of a sliding block which is being

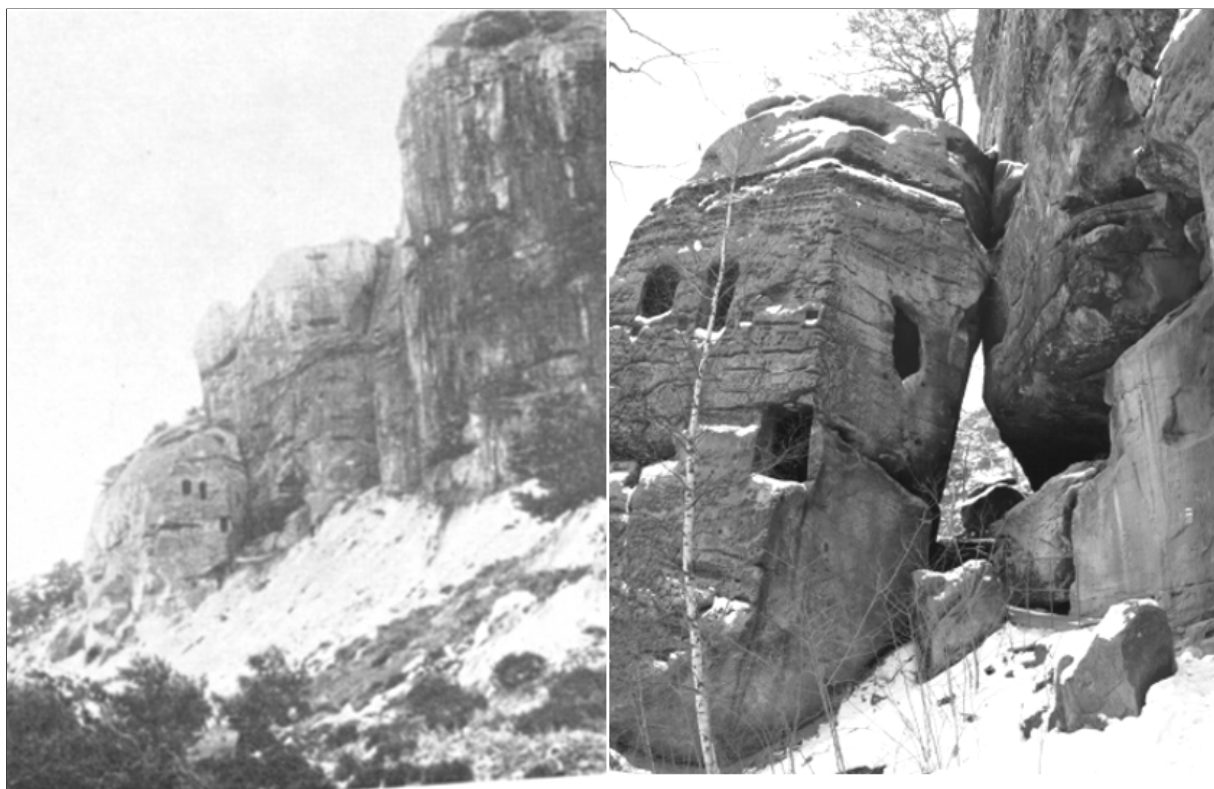


Fig. 17 A (left): A view of the landslide separation wall that originated in 1926. The block No VII (with three rooms inside) of Drábské Světničky complex is leaning against the main dwelling block No III. Photo by Q. Záruba 1926. B (right): Block No VII "Strážnice" (Watch-house) slightly turned and leaning against the main dwelling block No III. Photo by F. Hartvich, 2006.



Fig. 18 "Drunken forest" in the upper part of the landslide which destroyed a part of Dneboh Village in June 1926. Photo by P. Vácha 1963.

continuously slanted upslope due to rotational movements (Fig. 18). Similar creep movements originate even on the steep separation wall of the landslide.

One can assume that the deep landslide of 1926 was reflected even in the behaviour of the marginal parts of Hrada Platform including the block field of Drábské Světničky. In the last years, fresh linear and oval sinks and depressions in superficial sediments (Fig. 10) on the terrain surface were observed in the NW and W parts of Příhrazy Platform. The observations induced regular measurements of relative movements in fissures of selected rock objects and crevasses.

It was in 1990 when monitoring of relative movements of a disturbed sandstone tower (Fig. 19) lying about 250 m NEE of Drábské Světničky (Fig. 2, area A) was introduced with the aim to confirm or disprove present activity of slope movements. Measurements on six line segments performed with the use of an attachable dilatometer confirmed active movements. The approximate movement rate reached 1 to 2 mm per year in average. During the last six years, registration movements showed a stepwise course. Three times, movements produced acceleration, notably by the end of 2001 and 2002, then also during the second half of 2005 (Fig. 20 - the lower), while in 2000 and 2001 the rate showed a quasi-continual course not over 0.7 mm per year. The accelerations can be correlated with the rising sections of the cumulative line of differences between the actual and average totals of monthly precipitation recorded in the rain gauge station ČHMÚ Boseň -

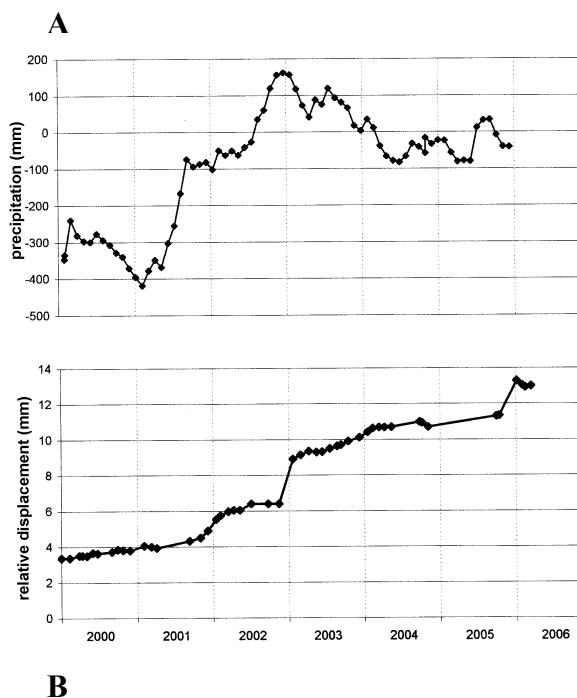


Fig. 20 A: The course of horizontal movement component on the monitored rock tower in area A during the period 2000 - 2006.
B: A section taken from cumulative line of differences between actual and average monthly precipitation totals recorded at the meteorological station ČHMÚ Boseň - Mužský.

Mužský (Fig. 20 - the upper). Total displacement between 2000 and 2005 reached 10 mm. Quasi-linear character of the movements corresponds with the hypothesis that movements reached up to the claystones in the bedrock.

The activity of block-type movements was proved also by monitoring of a crevasse oriented NEE - WSW, located about 500 m NEE from Drábské Světničky. The crevasse and its surrounding display fresh sinking of the surface (Fig. 2, area B), which at the end of the 1980s was seen as indicating possible reactivating of slope deformations and led to launching monitoring (Stemberk and Zvelebil, 1999; Stemberk, 2003). 3D - monitoring with the use of the mechanical-optical dilatometer TM-71 proves that periods of relatively slow movements alternate with short periods of relatively fast movements. Such a movement was indicated at the end of 2003 when a rock block sank suddenly by about 0.4 mm. Registered movements also show a significant change in their course. The crevasse under investigation contracted, and the amplitudes that follow seasonal temperature oscillation decreased thereafter in all the three monitoring movement components.

Monitoring results in the areas A and B proved therefore the activity of slope movements even in the flat part of Příhrazy Platform, i.e. in the zone affected by the deep gravitational loosening.

Present active movements were also indirectly indicated by geophysical measurements. During the measurements in the borehole Př-1 performed for seismic tomography, some seismic phenomena were registered that could be evaluated as micro-tremors of a natural origin. The seismic source was localised in the depth of about 25 to 30 m (oral communication by Dr. V. Beneš, G Impuls, Prague, Ltd.). The following year after the original geophysical measurements, the measurements were repeated and the micro-tremors were found again. The evaluations resulted in a statement that the said micro-tremors are of a natural origin and show a character of a mountain rock bursts. The tremors are evidently accompanying manifestations of a progressing failure of sandstone strata. The borehole Př-1 near monitoring B position, is located about 60 m from the face of the valley rock wall, and belongs to the zone of deep gravitational loosening (Fig. 1, sub-area II.5). It was in September 2001 when borehole logging department of AQUATEST-Stavební Geologie Comp. realised calliper logging measurements in the borehole Př-1. It detected three zones seriously disturbed in the depths of 15.0 – 15.3 m; 32.0 – 32.5 m; and then also at the base of sandstone strata, in a wide interval of 104.0 – 109.3 m.

As an indirect evidence of active movements, one can accept also oscillations of ground water level in the borehole Př-2 that are difficult to explain. An acceptable explanation for the oscillation in the water-bearing could be in alternating opening and contraction of the cracks in the crevasse between moving blocks. Such an explanation is supported even by a sudden movement recorded on a nearby monitoring A position at the end of 2002 followed by a ground water rise in 2003 and 2004. The rise ended with new movements at the end of 2005.

6. FINAL CONCLUSIONS

The rock castle of Drábské Světničky is situated in NW part of Příhrazy Platform, which is intensively disturbed by large old and new slope movements. The research came to findings about the character of failure of slopes, as well as marginal zones of the flat area of the platform. Edge blocks of thick-bedded sandstones separate and displace down the slope, and then sink into the plastic clayey bedrock. The area that is disturbed by the process of loosening reaches up to the distance of 400 m from the edge of the high platform towards the centre around Mužský Hill.

The process of loosening can be evidenced by block displacements, as well as rock tower movements showed by downslope or upslope tilting. Pseudo-sinkholes, linear depressions, crevasses and block fields develop. A platform called Hrada around the elevation 404.3 which contains archaeological documents about young stone-age settlement is of a special interest. It is considered to be giant sandstone block moving slowly to W or NW. The block is separated by a 60 m wide crevasse from the central part of the platform.

A part of the platform containing a group of sandstone blocks near its NW edge was used in the 15th century to build a small rock castle of Drábské Světničky. An extensive landslide that destroyed a part of Dneboh Village in 1926 reached in its separating area up to the toe of marginal towers of Drábské Světničky. It is very likely that the landslide process affected even the movements of Hrada marginal zone. An evidence of present movements can be seen in the bent trunks of trees in the historical landslide area, as well as fresh linear and oval sinks in the superficial forms of marginal flat parts of the platform that have been affected by the process of loosening. Besides, it is also the groundwater level oscillation in the borehole Př-2 that would be difficult to explain, and also micro-tremors recorded by geophysics methods in the borehole Př-1 that can be accepted as a proof of instability. Active slope movements have been also proved by the results of dilatometric monitoring on two positions, where the rate reached 1 to 2 mm per year. It is going to be proved than, that the marginal zones of Příhrazy Platform suffer from an observable gravitational deformation even during the present geological period, i. e. during Holocene. An earlier assumption accepted for quite a long time that local deep slope movements of block-type could appear in Pleistocene only, has been disproved therefore.

It is recommended that present monitoring of the movements, as well as of water bearing oscillations should continue in regard to desirable verification of slope movement activity on slopes and tabular area of Příhrazy Platform. Moreover, we recommend to start monitoring of the deformations directly in the block field of Drábské Světničky. One possibility can be seen in the monitoring of the block No. VII lying in the separation zone of the catastrophic landslide of 1926.

To preserve the object of Drábské Světničky which is a historical monument, we recommend to restrict movements of tourists in the area. It is mainly in the summer holidays period when the traces of the 15th century settlement are increasingly disturbed in the sandstone rock that is weakly consolidated.

ACKNOWLEDGEMENT

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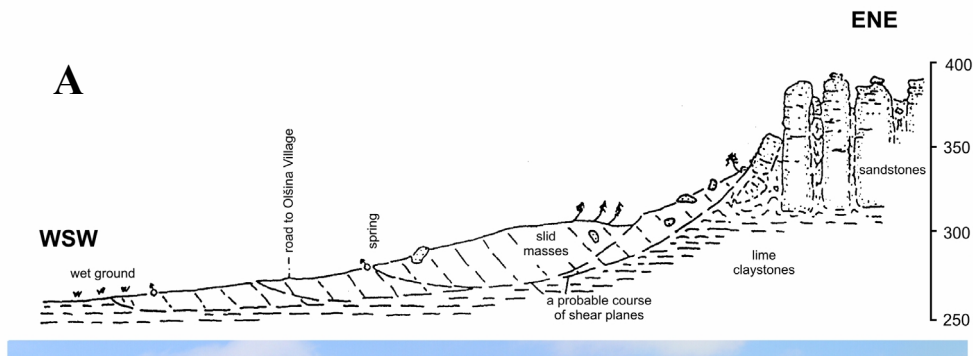


Fig. 5

A: Geological cross-section 2-2'. (no vertical exaggeration)



B: SW view of the landslide area from the year 1926 under the NW rim of Hrada platform. Photo by F. Hartvich 2005.



Fig. 9

View of a block field at the northern rim of Příhazy Platform; multiple block arrangement of sandstones with upslope inclination. Photo by J. Stemberk 2001.

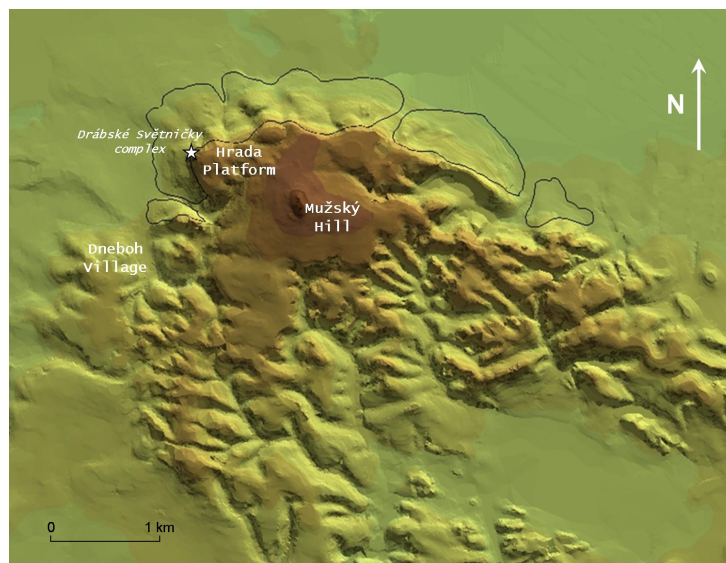


Fig. 3 Digital model of Příhazy Platform. Landslide areas are indicated.

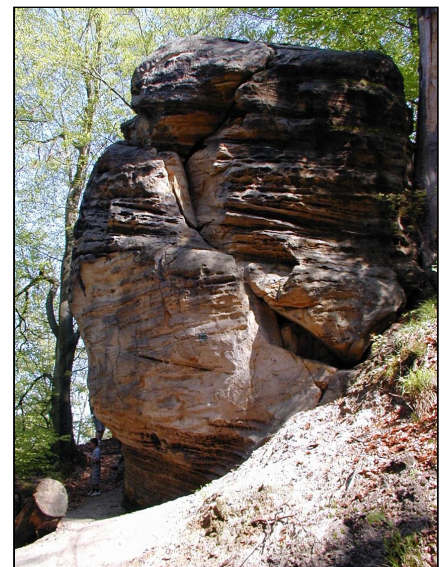


Fig. 19 The rock tower monitored with the use of an attachable dilatometer. Movement rate reaches 1 - 2 mm per year. Photo by J. Stemberk 2001.