Periglacial Landforms of the Hrubý Jeseník Mountains

22

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Abstract

This chapter deals with the occurrence, morphology and activity of periglacial landforms in the Hrubý Jeseník Mts. Redistribution of snow during the Last Glacial period, cold climate and the presence of extensive planation surfaces at high elevations have created favourable conditions for the formation and evolution of periglacial landforms, some of which are preserved to this day. Most of these landforms are relict (tors, frost-riven cliffs, cryoplanation terraces, blockfields, sorted polygons and nets, and large solifluction steps), and only a small part of climatically less demanding periglacial landforms are active (ploughing blocks, earth hummocks, small sorted circles, nivation hollows and small solifluction lobes). Special attention is paid to patterned ground, which provides information about current and past freeze-thaw effectiveness. Earth hummocks, found at wind-swept sites, on frost-susceptible, fine-grained regoliths, are the most interesting type of patterned ground. Evidence of present-day activity of earth hummocks are distorted soil horizons, vertical and horizontal displacement of clasts, cryoexpulsion features and cracks on crests of earth hummocks, frequent freeze-thaw cycles and long-term freezing. The origin of earth hummocks has been identified as being at the break of the Subboreal/Subatlantic. The occurrence and activity of earth hummocks, sorted circles and ploughing blocks at several sites above the alpine timberline of the Hrubý Jeseník Mts. allows us to regard these areas as parts of the mountain periglacial zone.

Keywords

The Hrubý Jeseník Mountains • The High Sudetes • Planation surfaces • Cirque • Periglacial landforms • Patterned ground • Nivation hollow

22.1 Introduction

22.1.1 Geographical Setting

The Hrubý Jeseník Mts. in the north-eastern part of the Bohemian Massif (Fig. 22.1) constitute the second highest mountain range in the Czech Republic after the Krkonoše Mts. (see Chap. 15). Mt. Praděd (1,492 m a.s.l., 50°4′59″N; 17°13′51″E) is the highest peak in the mountain range. The total area of this range is 520 km^2. This Variscan fault-block mountain range is composed of metamorphic rocks (gneisses, phyllites, mica schists and quartzites).

The mountains are situated in a cold climate region (Quitt 1971), which is characterized by short, cool and wet summers, cold springs and long cold winters with very long duration of snow cover. The mean annual air temperature on Mt. Praděd is +1.7 °C (1960–1990; Coufal et al. 1992). The mean air temperature of the warmest month (July) is 9.7 °C, whilst the lowest mean air temperature goes down to −7.5 °C in January. Mean annual precipitation is 1,231 mm (1947–

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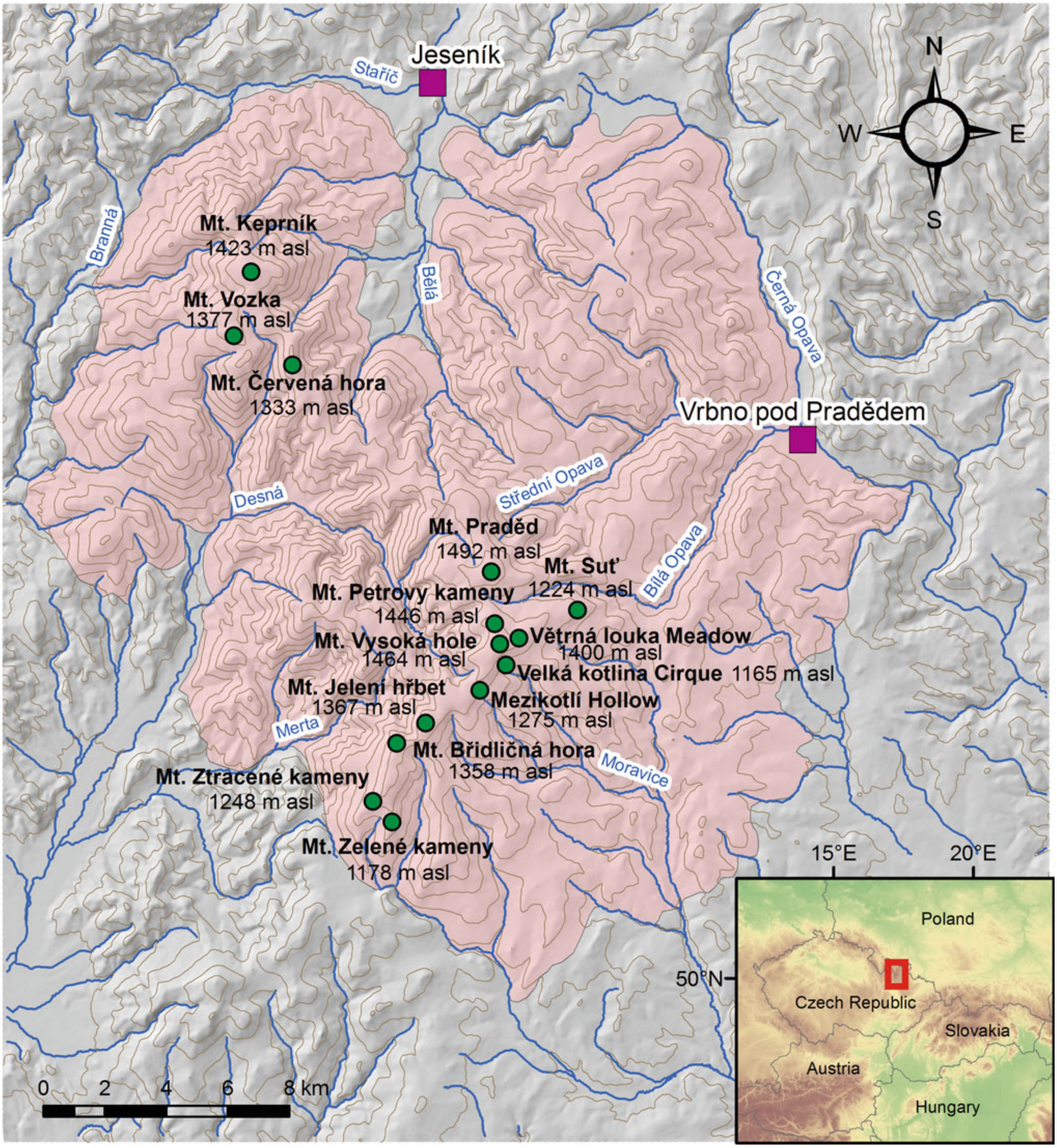

Fig. 22.1 Geographic position of the Hrubý Jeseník Mts. and location of described periglacial and glacial phenomena

1985; data of the CHKO Jeseníky). July and August are months with the highest precipitation, while the lowest precipitation is in February. Although snowfall may occur in the highest parts of the mountain range at any time during the year, the mean number of days with snow cover is 171 per year (data of the CHKO Jeseníky). The mean annual maximum snow depth is 195 cm on Mt. Praděd and the greatest snow depth occurs in early March. Podzol and cryptopodzol soils are dominant (Tomášek 2003), and cambisols are developed in the lower parts of the valley slopes.

The Hrubý Jeseník Mts. includes montane, subalpine and alpine vegetation areas (Neuhaüselová et al. 1998). The flora is predominantly montane, and thermophilic species are very rare. Most of the range (approx. 80 %) is covered by secondary forests. Spruce trees predominate from the lowest areas to the alpine timberline, which occurs at an average altitude of 1,310 m a.s.l. (Treml and Banaš 2000). The alpine belt of the Hrubý Jeseník Mts. is of natural origin (Jeník 1961) and its area is 1,048 ha (Treml and Banaš 2000). Nevertheless, medieval colonization caused a change in the alpine timberline and influenced the species composition of vegetation by mowing and grazing (Novák et al. 2010). This alpine timberline ecotone naturally lacked dwarf pine (*Pinus mugo*), which is a non-native species in the Hrubý Jeseník Mts. (Rybníček and Rybníčková 2004). However, dwarf pine was planted near the alpine timberline in the second half of the nineteenth century, covering today large areas above it. In the second half of the twentieth century, there was a sharp increase in the area covered by dwarf pine. In the period 1973–2003, it increased by 63 % (Treml et al. 2010a).

In this mountain range there are 1,200 species of plants, which account for more than one third of the total number of plant species growing in the Czech Republic. The Velká kotlina Cirque is the richest locality in the whole mountain range as regards the number of plant species, with over 500 species of vascular plants and mosses (Jeník et al. 1980). In addition, there are five species that grow only in the Hrubý Jeseník Mts. and nowhere else in the world. These are *Poa riphaea*, *Campanula gelida*, *Plantago atrata sudetica*, *Dianthus carthusianorum sudeticus* and *Carlina biebersteinii sudetica* (Bureš 2013). Several glacial relicts have survived, e.g. *Salix herbacea lapponum*, *Bartsia alpina* and *Carex rupestris* (Bureš 2013), animals include *Sicista betulina*, *Charadrius morinellus*, *Xestia speciosa*, *Aphodius limbolarius*, *Aeshna subarctica elisabethae*, *Somatochlora arctica* and *Somatochlora alpestris* (Kočí 2007). In summit areas and mountain saddles there are peat bogs of different sizes. They began to form in the middle Holocene (during the Subboreal period, ca 4,700 BP, uncal. age ^{14}C, Rybníček and Rybníčková 2004; 4,180 BC, Dudová et al. 2013). Rare animals, which can be found there, include the lynx (*Lynx lynx*), lesser horseshoe bat (*Rhinolopus hipposideros*), peregrine falcon (*Falco peregrinus*), capercaillie (*Tetrao urogallus*) and water pipit (*Anthus spinoletta*). Sometimes wolves (*Canis lupus*) or bears (*Ursus arctos*) come to the range from the nearby Carpathians.

The great wealth of animate and inanimate nature was the reason for the founding of the Jeseníky Protected Landscape Area (the CHKO Jeseníky) in 1969 (covering an area of 740 km^2). The area is part of the Natura 2000 EU-wide network of protected areas with 13 different Sites of Community Importance and Special Protection Areas.

22.1.2 Main Landforms and Their Evolution

The main landforms of the Hrubý Jeseník Mts—steep slopes, deep valleys and summit plateaus—were formed during the Cenozoic (Czudek 1997). Tectonic movements, which were a response to the pressure of the Alpine-Carpathian system, started to intensify from the Oligocene/Miocene boundary (Demek 1985). However, the main phase of tectonic uplift took place at the end of the Pliocene and Quaternary (Kopecký 1986). The total Cenozoic uplift of the upper parts of the Hrubý Jeseník Mts. is estimated at up to 1,200 m. Tectonic uplift reached 60–70 m in the northern foreland of the mountain range during the Early Pleistocene (Badura et al. 2007). Krzyszkowski and Pijet (1993) estimated tectonic uplift along the Sudetic Marginal Fault at up to 60–80 m from the Middle to the Late Pleistocene. During the Late Pleistocene, the maximum uplift is estimated at 20–35 m. The post-Saalian uplift reached a maximum of 25 m in the nearby valley of Nysa Kłodzka river (Krzyszkowski et al. 2000). The mountain range has well-developed summit planation surfaces (Fig. 22.2), concentrated at four basic altitudinal levels. The highest one is situated at 1,300–1,463 m a.s.l. (Křížek and Jablonská, unpublished). The planation surfaces were very important for the formation of glacial and periglacial landforms during the last Ice Age and the Holocene. Snow that was blown from the summit plateaus of planation surfaces by prevailing westerly winds (Jeník 1961) helped to create the only one cirque of the Hrubý Jeseník Mts. in the headwater part of the Moravice valley, known as Velká kotlina, and many nivation hollows on leeward slopes and valleys. On the other hand, blown snow and thinner snow cover on wind-exposed plateaus brought specific environmental conditions allowing for more intensive frost weathering and sorting (sensu Křížek and Uxa 2013), which are necessary for the development of sorted polygons and nets.

During cold periods of the Pleistocene, the Hrubý Jeseník Mts. were located in the periglacial zone in a foreland area of continental glaciation (Czudek 1997). Mountain glaciation was nevertheless very limited. There was only one short cirque glacier in the range (Fig. 22.3), 600 m long (Prosová 1973), with the terminal moraine situated at 1,060 m a.s.l. The cirque is ca 300 metres long and 400 metres wide, its headwall is 195 metres high, and its cirque overdeepening is 0.82 (Křížek et al. 2012). The average altitude of the cirque floor is 1,170 m a.s.l., thus the snowline (TPW-ELA) altitude during the last glaciation was 1,170 m a.s.l. A high degree of continentality with low precipitation was the reason for weak mountain glaciation in the Hrubý Jeseník Mts. in the Last Glacial period.

Fluvial erosion was the main geomorphological process which formed and remodelled valleys in the Hrubý Jeseník Mts. after the end of the Last Glaciation. Longitudinal profiles of streams are steep and stepped. Material from the slopes and transported by streams or debris flows has accumulated at the bottom of the valleys and on weakly developed floodplains. Less resistant metamorphic rocks,

Fig. 22.2 Summit planation surface on the main ridge of the Hrubý Jeseník Mts (*Photo* M. Křížek)

mainly phyllites and mica schists, support a weathered mantle up to several metres thick. Debris flows occurred where the products of weathering were saturated with water from melting snow or rainfall, e.g. in 1893, 1903, 1907, 1938, 1940, 1951, 1965, 1991, 1994, 1997 and 2004 (Gába 1992; Polách and Gába 1998; Hrádek and Malik 2007; Malik and Owczarek 2009; Krause and Křížek unpublished). The largest debris flows occurred after intense rainfall in 1880 and 1921. For example, debris flows involving a total of 50,000 cubic metres destroyed an area of 16 ha on the slopes of Mt. Červená hora in 1921 (Polách and Gába 1998). Landslides into Hučivá Desná River caused large-scale devastation over a stretch of almost 25 km. Relicts of landslides at the valley bottoms are evidence of former debris flow activity. Some mounds of debris flow deposits are so large that they were previously interpreted incorrectly as relicts of glacial moraines (see Prosová 1973).

Some debris flow paths are also avalanche paths. Kříž (1995) described a total of 22 avalanche paths in eight areas of the mountain range, but the actual number is now lower (about 16 avalanche paths in six areas). This is because slopes prone to avalanches were afforested and overgrown with dwarf pine or trees, which prevent avalanches. Current avalanche activity in the Hrubý Jeseník Mts. is minimal—events occur once every few years.

22.2 Periglacial Landforms

The redistribution of snow during the Last Glacial period, the cold climate (periglacial) and extensive planation surfaces at high elevations of the Hrubý Jeseník Mts. have created favourable conditions for the formation and evolution of periglacial landforms, some of which are preserved to this day. Most of these landforms—tors, frost-riven cliffs, cryoplanation terraces, blockfields, sorted polygons and nets, and large solifluction steps—are inactive and relict, and only a small part of climatically less demanding periglacial landforms are active. These include ploughing blocks, earth hummocks, small sorted circles, nivation hollows and small

Fig. 22.3 Velká kotlina Cirque (*Photo* M. Křížek)

solifluction lobes. Likewise, some geomorphological processes, such as frost heaving, frost sorting, needle-ice activity (Fig. 22.4) and solifluction, which are necessary for the formation and evolution of periglacial landforms, can be observed on wind-exposed sites (Křížek et al. 2010). Although there is no evidence of recent permafrost occurrence in the Hrubý Jeseník Mts., selected summit parts of this range can be regarded as mountain periglacial zones according to certain criteria, e.g. mean annual temperature below +3 °C (sensu French 2007), position above the alpine timberline (sensu Ballantyne and Harris 1994), solifluction activity (sensu Williams 1961, Leser in Embleton 1984) or activity of ploughing blocks (Furrer in Washburn 1979).

22.2.1 Cryoplanation Terraces and Blockfields

Cryoplanation terraces in the Hrubý Jeseník Mts. are related to old planation surfaces (Demek 1969) and often occur as multiple steps on slopes. Their size varies from several tens to several hundreds of square metres. The cryoplanation flats are several metres wide and separated by distinct edges (accompanied by a significant change of slopes) from cryoplanation steps, whose slope mostly varies between 10 and 35°. Inclinations of the flats themselves vary from 3 to 12° (Křížek 2007). In some locations patterned ground has developed on cryoplanation terraces, above all sorted polygons, nets and stripes in steeper slopes, and there are tors. These have the character of isolated rock outcrops, such as Petrovy kameny (Fig. 22.5, 1,446 m a.s.l.), Ztracené kameny (1,245 m a.s.l.) and Vozka (1,377 m a.s.l.), and are often surrounded by a mass of collapsed blocks. These tors on summit plateaus, unlike the frost-riven cliffs below them, represent a more advanced stage of slope development, i.e. slope retreat (sensu Demek 1969). The heights of tors and frost-riven cliffs are limited to 10 m and their horizontal dimensions reach a maximum of a few tens of metres.

Blockfields and block streams in the Hrubý Jeseník Mts. create contiguous areas covered with angular blocks, produced by cryogenic disintegration of bedrock outcrops (tors

Fig. 22.4 Needle ice pushing up soil particles and clasts up to several tens of centimetres in diameter on Mt. Keprník (1,423 m a.s.l.) on the 20th April 2007 (*Photo* M. Křížek)

and frost-riven cliffs). The dimensions of these blocks are from tens of centimetres up to several metres. These blockfields and blockstreams are mainly developed on slopes with an inclination of between 10 and 50°. The essential difference between blockfields and blockstreams is in their shape, the latter being significantly elongated in the direction of the slope. Large blockfields occur on Mt. Břidličná hora (1,358 m a.s.l.), Mt. Ztracené kameny (1,245 m a.s.l.), Mt. Zelené kameny (1,178 m a.s.l.) and Mt. Suť (1,224 m a.s.l.). The blockfield on Mt. Suť is the largest, covering 4.13 ha. It has been gradually covered by forest growth like most other blockfields situated below the alpine timberline. In today´s conditions, mechanical weathering is of lower intensity, so the blockfields are not being enriched with new material, and movement of the blocks, formerly caused by solifluction, has ceased (Prosová 1954) or is very small (Demek et al. 2011).

22.2.2 Patterned Ground

Patterned ground covering an area of 98 ha above the alpine timberline is the most common periglacial landform in the Hrubý Jeseník Mts. (Křížek et al. 2007). There are two main genetic types of patterned ground on the high elevated planation surfaces, namely sorted and non-sorted variants. On flat planation surfaces (inclination of 0–3°) sorted polygons and sorted nets occur. They elongate gradually with increasing slope inclination (3–7°) and then change to sorted stripes on the slopes with an inclination of 7–12°. The case of non-sorted patterned ground is similar, where earth hummocks have been turned to non-sorted stripes as a result of solifluction on steeper slopes.

The best developed sorted polygons with straight sides occur on Mt. Břidličná hora (1,358 m a.s.l., Figure 22.6). Their average size is 489 × 377 cm (Table 22.1). This type

Fig. 22.5 Tor of Mt. Petrovy kameny (1,446 m a.s.l.) in 1907 and 2005 (*Photo* M. Křížek). At the back the highest point of the Hrubý Jeseník Mts.—Mt. Praděd (1,492 m a.s.l.) with an old watchtower (in construction) and the present transmitter tower, which is 162 m high

of patterned ground has the best developed frost sorting of clasts (Křížek and Uxa 2013). It can therefore be considered as the climactic stage of sorted patterned ground. While the borders of sorted polygons consist of coarse-grained clasts, the finer-grained and domed centres of the polygons are now covered with vegetation. The occurrence of these sorted polygons is associated with quartzite, which facilitated frost sorting by its characteristic disintegration.

Sorted nets surrounding areas of sorted polygons are the most common patterned ground in the Hrubý Jeseník Mts. They have an irregular shape and are smaller (their average size is 308 × 242 cm) than sorted polygons. Today, these landforms are covered with vegetation. In some places (e.g. on Mt. Vysoká Hole, 1,464 m a.s.l.), the relief of this vegetated surface does not always correspond to the real structure of buried sorted nets, i.e. the coarse clast rim of sorted nets is under the domed surface, and the centre is developed under the furrows of the hummocky surface (Křížek 2007). Sorted stripes occur on slopes steeper than 7° and adjoin sorted polygons and sorted nets areas. Sorted stripes are parallel lines of coarse-grained clasts elongated down the slopes. Small clasts and finer sediment situated between these stripes are domed. The length of sorted stripes ranges from a few metres to several tens of metres.

Sorted circles are found at only one site in the Hrubý Jeseník Mts.—on the wind-exposed edge of the summit plateau on Mt. Keprník. Clasts of this type of patterned ground are arranged in regular circles with a diameter of about 20 cm. They arise regularly in spring, but are very soon destroyed by the feet of tourists.

Earth hummocks occur at four sites: at the top of Mt. Keprník (1,423 m a.s.l.), on the northern plateau of Mt.

Fig. 22.6 Sorted polygons on Mt. Břidličná hora (*Photo* M. Křížek)

Table 22.1 Mean morphometric characteristics of patterned ground at selected sites of the Hrubý Jeseník Mts. (Krížek et al. 2007, modified)

Locality	Type of patterned ground	Altitude (m a.s.l.)	Length (cm)	Width (cm)	Height (cm)	Relative height (Height/Width)
Břidličná hora	Sorted polygons	1,355	489	377	18	0.05
Praděd	Earth hummocks	1,446	185	142	32	0.24
Keprník	Earth hummocks	1,420	166	126	40	0.34
Vysoká hole	Sorted nets	1,460	335	280	17	0.06
Velký Máj	Sorted nets	1,385	313	246	24	0.1
Kamzičník	Sorted nets	1,419	349	264	20	0.08
Mravenečník	Sorted nets	1,340	232	179	21	0.12

Červená hora (1,333 m a.s.l.), on the north-west plateau (1,435 m a.s.l.) of Mt. Petrovy kameny and on Větrná louka (=meadow; 1,400 m a.s.l.). The best developed earth hummocks are located on Mt. Keprník, where their average size reaches 166 × 126 cm and the average height is 40 cm (Treml et al. 2010b). Compared with the sorted polygons and nets they are higher and more domed, i.e. earth hummocks have a greater height/width ratio. These earth hummocks are characterized by a high proportion of the fine-grained fraction (particle size median of A_h − B/C horizons is between 0.1 and 0.2 mm) and a high content of organic matter (i.e. content of combustible soil organic matter is about 30 % down to the depth of 60 cm of the soil profile). Thus, the organic matter of the earth hummocks is susceptible to frost action (sensu Ballantyne 1996). The age of the earth hummocks has been identified as going back to the Subboreal/Subatlantic boundary. This is based on a pollen analysis and ^{14}C radiometric dating (2,090 ± 35 uncal. years BP; Křížek 2007). Evidence of present-day activity of earth hummocks is provided by soil horizons distorted by cryoturbation (Fig. 22.7) and vertical and horizontal displacement of clasts, indicating movement within the earth hummocks, cryoexpulsion features and cracks on crests of earth hummocks with disturbed vegetation cover, frequent freeze-thaw cycles and long-term freezing. Cores of segregation ice created inside the earth hummocks (Fig. 22.8) during the winter remain until the end of May or June, depending on the severity of winter. The freeze-thaw season for the earth hummocks starts in the second half of November and terminates at the end of spring (Table 22.2). In 2003 a core of segregation ice inside an earth hummock on Mt. Keprník was detected even on 7 July (Křížek 2007). The occurrence and activity of earth hummocks, sorted circles and ploughing blocks on Mt. Keprník allows us to regard this area as being part of a mountain periglacial zone (sensu Leser in Embleton 1984), located at its lower limit (sensu Furrer in Washburn 1979), which is defined by ploughing blocks activity. However, the top of Mt. Keprník and similar isolated sites in the Hrubý Jeseník Mts. are among the climatically most exposed areas in the Czech Republic (Křížek et al. 2010), which is why they are unique. The closest equivalent locations can be found in the significantly higher Alps, the High Tatras or in the distant Scandinavian mountains.

Non-sorted stripes (or hummocky stripes) in the Hrubý Jeseník Mts. can be described as being an elongated form of earth hummocks. This type of patterned ground occurs mainly on gentle slopes (typical inclination is 3–12°) around

Fig. 22.7 Cross-section profile through the earth hummock on Mt. Keprník. There are cryoturbation pockets. Note: *solid black line* represents an interface between A and B horizon twisted by cryoturbation. (*Photo* Z. Engel)

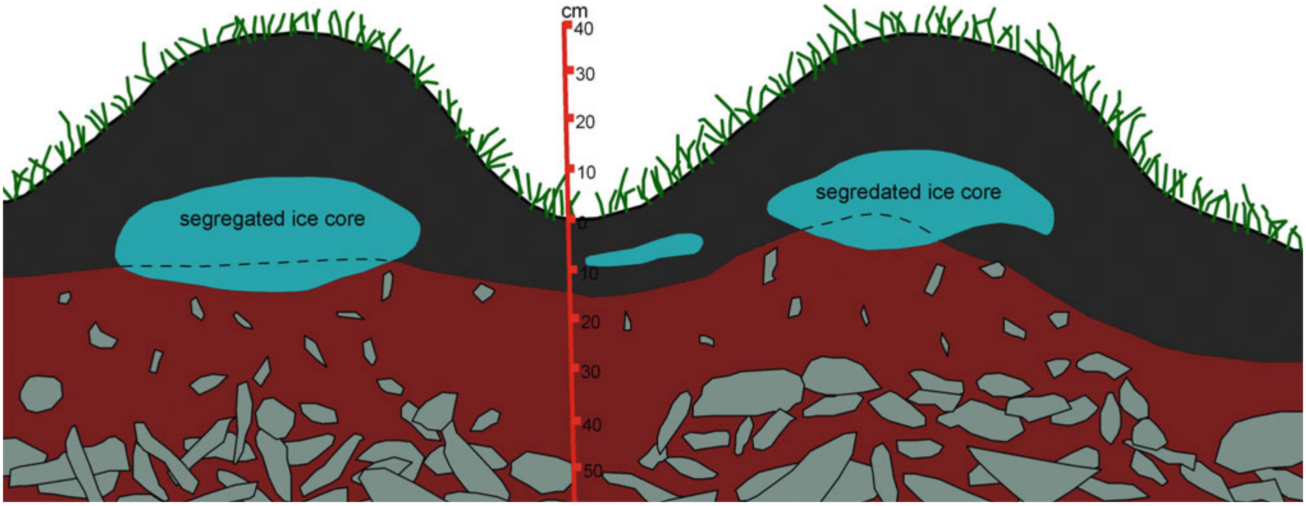

Fig. 22.8 Segregation ice forming lenses within the earth hummock on Mt. Keprník on 7th June 2003

Table 22.2 Selected characteristics of the freeze-thaw action of an earth hummock on Mt. Keprník (temperature measured at the depth of 5 cm)

Freeze-thaw season	Measured object	Start of feeze-thaw season	End of freeze-thaw season	Number of days of freeze-thaw season	Minimum temperature during freeze-thaw season (°C)	Number of drops below 0 °C
2008/2009	Earth hummock	18.9.2008, 14.00	14.5.2009, 9.00	238	−5.5	32
	Control measurement outside of earth hummock	17.9.2008, 9.00	13.4.2009, 11.00	208	−1.6	14
2009/2010	Earth hummock	22.10.2009, 14.00	20.5.2010, 10.00	210	−4.3	18
	Control measurement outside of earth hummock	3.11.2009, 11.00	21.5.2010, 11.00	199	−0.9	14
2010/2011	Earth hummock	30.10.2010, 10.00	5.5.2011, 9.00	187	−8.1	12
	Control measurement outside of earth hummock	30.10.2010, 9.00	9.5.2011, 8.00	191	−3.6	18
2011/2012	Earth hummock	17.11.2011, 5.00	25.4.2012, 8.00	161	−7.9	15
	Control measurement outside of earth hummock	21.11.2011, 8.00	26.4.2012, 11.00	157	−2.7	10
2012/2013	Earth hummock	3.12.2012, 6.00	21.4.2013, 8.00	139	−6.1	9
	Control measurement outside of earth hummock	7.12.2012, 16.00	22.4.2013, 10.00	136	−2.0	8

summit plateaus. Hummocky stripes have a domed centre (between 15 and 40 cm) like earth hummocks and are elongated down the steepest available slope. These stripes are parallel. The width of stripes is between 45 and 150 cm and they are usually several tens of metres long.

22.2.3 Nivation Hollows, Solifluction Phenomena and Ploughing Blocks

Nivation hollows are shallow depressions with a steep scarp (20–35°) and a gently inclined bottom (5–12°). Their dimensions range from tens (these are the most common) to hundreds of metres. The occurrence of nivation hollows is linked to eastern leeward slopes, where snow accumulates (Křížek 2007). Long-lying snow patches cause solifluction phenomena to concentrate near nivation hollows. The largest nivation hollow lies in the Mezikotlí locality (1,275 m a.s.l., situated south-west of the Velká kotlina cirque, in the neighbouring valley) and has two well-developed pronival ramparts. The first one is located on the edge of the nivation hollow and has blocked its outlet. The bottom of this hollow is covered by a 3–4 m thick layer of sediments and weathered rock, and a 1.3 m layer of peat (Křížek et al. 2010). The age of this peat bog is 1,520 ± 39 ^{14}C uncal. BP, and run-off sediments at the bottom of the peat bog are at least 1,000 years older (2,696 ± 40 ^{14}C uncal. BP; Křížek et al. 2010). The second pronival rampart is smaller and younger than the first one and occurs below the 40° steep headwall of the nivation hollow.

Hundreds of ploughing blocks are located on the slopes of Mt. Keprník (1,423 m a.s.l.), Mt. Vysoká hole (1,464 m a.s.l., Fig. 22.9), Mt. Jelení hřbet (1,367 m a.s.l.) and Mt. Břidličná hora (1,358 m a.s.l.). The boulders range in size from tens of centimetres to several metres. The basic feature of the ploughing blocks is the furrow behind them—a linear depression elongated in the direction of the slope gradient. Furrows are several metres long and 10–35 cm deep. Some of the ploughing blocks have 10–50 cm niches in front of their furrows. Almost 75 % of blocks have a mound, usually 20–40 cm high, developed in front of them (Křížek 2007). The lithology of the ploughing blocks usually corresponds to the basement rock in the area, with the exception of the Mt. Vysoká Hole—Mt. Břidličná hora ridge, where quartzite blocks originating from the upper parts of the slopes dominate. This fact, together with the developed furrows, proves that ploughing blocks in the mountain range are moving, and are thus active.

Fig. 22.9 Ploughing block with a developed mound on the north-west slope of Mt. Vysoká hole (*Photo* M. Křížek)

The solifluction steps in the Hrubý Jeseník Mts. are landforms with morphologically distinct short and high (up to 4 m) steps. Well-developed solifluction steps occur on the south-east slope of Mt. Keprník. The bodies of these landforms are consolidated, without disturbance to turf cover. Creep probes did not record any movement during the period of 2005–2010. The solifluction steps have been inactive in recent times, unlike solifluction lobes. Solifluction lobes are elongated in the direction of greater slope inclination and are between 5 and 20 cm high. Some of them have a disturbed turf cover. The rates of their movement ranged between 0 and 17 mm in 3 years (Křížek 2007). Solifluction movements usually reach the maximum depth of 20 cm and the rate of movement decreases with increasing depth. Further evidence of solifluction lobe activity is provided by an increased amount of fine-grained material and humus in the A_h horizon in the faces of the lobes (Treml et al. 2003).

22.3 Periglacial Landforms and Human Activity

When dealing with periglacial phenomena in the Hrubý Jeseník Mts., mention must be made of human encroachment into the highest localities of this range. In the second half of the twelfth century, prospectors began to operate, looking for and then mining iron ore and non-ferrous and precious metals, including gold. Locally, Střední Opava river is called the Golden Opava river, recalling the times when gold was panned. In the thirteenth century, the first settlements began to appear and the first castles were built in the middle of thick forests. The end of the sixteenth century saw the building of iron works and mills making use of the local supply of iron ore and charcoal. In the seventeenth century, people began to make use of mountain meadows above the alpine timberline to graze livestock (cattle grazed there even after the Second World War). Grazing, mowing and wood extraction led to the lowering of the alpine timberline. At this time, local settlers came into direct contact with periglacial phenomena, which they did not understand. Bizarrely shaped tors became the subject of myths and legends. According to one legend, the tor called Vozka (waggoner) is a petrified wagon that was carrying bread. God punished the driver, because he demonstrated his disrespect for bread by putting it under the wheels of his wagon on a broken forest road. Today, the silhouette of this well-known periglacial landform is used to promote beer from the local brewery. The strange and exotic shapes of a number of periglacial landforms were also associated with black magic and witchcraft. The tor at Mt. Petrovy kameny played a sad role in the seventeenth century as the location where witches' Sabbaths were allegedly held. As a consequence, 81 "witches and sorcerers" were tortured and burned to death in the period of 1679–1696. The mysterious nature of this tor was certainly enhanced by the surrounding regular patterns of sorted polygons.

The first scientists came to the Hrubý Jeseník Mts. and started to reveal the real secrets behind the individual periglacial landforms in the late nineteenth and early twentieth centuries. However, these periglacial landforms were not left in peace for very long. Following the foundation of Czechoslovakia, the summit planation surface of Mt. Vysoká hole and its surroundings became a military shooting range for the mountain artillery. Unfortunately, some of the local sorted nets and nivation hollows situated below the eastern edge of the summit plateau were destroyed by artillery shells that created craters of up to several metres in diameter. In addition, in 1944, construction of a mountain airport was commenced on the summit plateau of the planation surface of Mt. Vysoká hole. With the approaching end of the Second World War, the airport was not built, with the exception of concrete foundations for radar installations. The Jeseníky Protected Landscape Area (CHKO Jeseníky) was founded in 1969, and today the periglacial phenomena are protected along with other components of nature in the area. From the viewpoint of periglacial phenomena protection, the biggest current problem is presented by the invasive dwarf pine, which is not native to the Hrubý Jeseník Mts. (see Sect. 22.1.1). Earth hummocks covered by dwarf pine are destroyed mechanically by its roots and thermally by the increased accumulation of snow. This prevents deep freezing, which is necessary for the development of earth hummocks (Treml and Křížek 2006). For this reason, dwarf pines were removed in the location with the best developed earth hummocks, on the top of Mt. Keprník, in 2009–2010.

22.4 Conclusion

The presence of high elevation planation surfaces of the Hrubý Jeseník Mts. was the main preconditioning factor of formation of periglacial landforms that are good evidence of climate variability in Central Europe during the Quaternary. The local periglacial environment has created a wide variety of mountain cold climate landforms. There is very well-developed patterned ground, which reflects microclimatically more exposed sites (in the sense of intensity of freeze-thaw action). The age of patterned ground in the mountain range is estimated for the end of the Last Glacial period (sorted polygons and nets) or for during colder periods of the Holocene (sorted circles, earth hummocks, non-sorted stripes). Earth hummocks are unique landforms that are found at wind-swept sites on frost-susceptible, fine-grained regoliths. These landforms—together with ploughing blocks, nivation hollows and small solifluction lobes—are still active. Other periglacial landforms such as sorted polygons and nets, cryoplanation terraces, tors and frost-riven cliffs were active during the Last Glacial period, but are now inactive.

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