ROCKS OF THE KRKONOŠE TUNDRA

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Rocks of the Krkonoše Tundra

Rocks and rocky outcrops are an unmistakable part of a mountain range, even though, according to their type, the character of their geological development, representation and diversity of minerals, climatic conditions, as well as various local conditions, there are mountain ranges which are rich in rocks, while others are poor. Rocky areas without a cover of weathering products are not only a significant helper for geologists and geomorphologists who study these mountains, but also play a fundamental role for lay tourists and undemanding visitors, because it is the quantity and shape of the rocks which are probably the most important factors in determining the landscape attractiveness of each region, i. e. its wildness and romantic character. Of course there are mountain ranges with almost no exposed rocks, but they will never be as attractive for visitors as those ranges which are decorated by interesting rock formations. Even more so, that they are very often connected with other popular destinations, such as extensive canyons, gorges, castellated rocks, cliffs and castle koppies, as well as individual points of interest, such as waterfalls, caves, overhangs, rock towers and pinnacles, balanced rocks and many others. The rocks are also of importance for their connections with human activities, as people have long sought them out for building castles and due to their landscape dominance, for the construction of various chapels, tourist chalets and last but not least, lookout towers and vantage points, often accessed by stairs, ladders, footbridges etc.

Krkonoše is a very old mountain range and of course this also determines its relief. Although there are certain exceptions, we can generally say that our developmentally younger mountain ranges, where erosion is more rapid and contributes to the shaping of the rocks, have a higher number of rock formations than older mountain ranges. Whatismore, neither the sedimentary rocks, such as sandstones,

Dívčí kameny Tor

Rock basins are the most interesting microform on granite rocks (Pielgrzymy)

conglomerates, dolomites and limestones (the local ones belong to the crystalline limestones, which we now include amongst the metamorphic rocks), nor the young volcanic rocks, which create the greatest number of rock formations, are represented here in Krkonoše. Therefore, with a few exceptions, the rocks in Krkonoše are not the dominant relief or landscape features, but on the other hand, there are plenty of rock formations here. The high percentage of forest cover is also a certain "handicap" for the rocks, because with the exception of the mountain ridge rock formations, the great majority of the rocks here are partially covered, and the lower-lying rocks are completely covered, by forests. Of the rocks which are located in the forests, we can observe a kind of "three-phase system" from the perspective of human life. If they are in a mature forest, they are relatively easy to see from close up. After the forest is felled they are perfectly visible, even from a distance, and in the case of extensive collections of outcrops, we can see them as a whole. However, the critical period comes as the new growth flourishes, as it often covers the rocks so completely that we can forget about trying to photograph them for the next few years.

Isolated granite rocks, tors and castle koppies

These types of rocks are the most typical for the summit, or tundra areas of Krkonoše, but even here they are not so numerous. The majority of them are found at lower, montane positions in the mountain range, so are hidden in the forests. On the other hand, it is clearly

visible that in the colder periods of the Quaternary, most of these rocks also found themselves in places with a tundra climate.

At first we should explain the terminological distinction between tors and castle koppies. Genetically, the way in which they were formed is the same, but they differ in the ratio between their height and width (dimensions). With narrow, tower-like tors their appearance is clearly dominated by their height, but on the contrary, with castle koppies, often with a quite irregular footprint, their area is the dominant feature. However, there are no binding criteria, so the distinction is often a subjective one, and in fact, in many localities tors and castle koppies stand next to each other (Dívčí kameny and a number of Polish localities). Some of the castle koppies in summit areas could be transformed into tors (Svinské kameny, Pielgrzymy).

The modelling of these types of rocks is strongly influenced by the primary fracture system of the Krkonoše granite, which formed during the solidification and contraction of magma in the granite massif already. Granite belongs to the abyssal igneous rocks. Magma rising up from the Earth's core was stopped deep underneath the strata of older overlying rocks (in Krkonoše these are schists: mainly gneisses, mica schists, phyllites), where it gradually solidified at depth and only emerged on the surface after the erosional-denudational removal of the overlying rocks. The German

The rocky outcrops in the Labské jámy cirques are the largest in the Czech Republic

The largest tor of the Svinské kameny complex

geologist H. Cloos described the fracture system of granite according to the three basic directions of fracturing and their German names as the LQS system. L are bedding-parallel fractures, mostly horizontal or slightly inclined, Q are transverse, vertical (or steep) fractures, roughly perpendicular to the main, Silesian Krkonoše Ridge, and S are longitudinal, vertical fractures, roughly perpendicular to the Q fractures. This results in ashlar- to cubic-shaped blocks of rock, which we can observe in various modifications on most of the cliffs; in places where the L fractures predominate, the blocks usually transform into a more slab-like shape. However, this is the "ideal form", which, under the influence of local conditions and secondary fracture systems can change into a multi-directional fracture system. Of the secondary fracture systems, the most important is exfoliation. Exfoliation fractures most commonly have an arched character and in places, where their sloping section emerges on the surface, they may conform with the slope of the valley or cirque, where they create extensive and smooth rock plates, which are sometimes mistaken for glacial polishing by the visitors (Velká Kotelní jáma Cirque, Navorské plotny in the Labský důl Valley, the upper part of the Důl Bílého Labe valley). The formation of exfoliation fracturing is explained by the unloading of the massif after the removal of the overlying crystalline rocks by erosional processes, as well as by climatic influences during the previous warm geological periods. Much more probable is a new theory, that they were already formed by primary (compressive) factors inside the granite pluton.

Opinions on the conception of these cliffs are not entirely unanimous. Some geologists and geomorphologists look at them only from the perspective of their shape and apply these terms to all isolated rock formations, emerging above their surroundings from all directions. However, the predominant opinion that only rocks which meet the criteria concerning shape, but mainly those which formed in a specific two-phase genesis, should be referred to in this way, is undoubtedly more correct. Even in this case, however, the opinions of the geomorphologists are not completely uniform: for example, the age of the individual phases but also the effect of the glacial periods (ice ages) on their formation are still being discussed.

Their development already began in the warm and damp climatic conditions of the interglacials in the Early Quaternary (Pleistocene), but according to some experts this began in the Late Tertiary.

The groups of rocks (castle koppies or tors) represent the remnants of the original mass of the parent material, a more resistant core (usually in places where it was harder and less fractured), which formed underground during the first phase of sub-surface weathering. In the climate described, this took the form of intensive *chemical* weathering of the rock (granites, which form the majority of Krkonoše, are especially susceptible to this), the result of which are fine-grained weathering products, most commonly called coarse sand by laymen. In the second phase, after the climatic changes and the onset of a temperate to cold climate, these hard sections were exhumed, because the surrounding fine-grained weathering products (often coarse-sandy) were rapidly transported away as a result of *mechanical* removal, and the rock formations began to emerge on the surface, rising above the surrounding relief and landscape. However, in the conditions of the ice ages (especially the last one – called Würm) the rocks were – already completely exposed on the surface – further shaped, although this was often in the opposite sense, i.e. leading to their destruction. Frost fracturing advanced along the cracks induced rock disintegration of a variable intensity, leading to the destruction of the whole rocky outcrop. In this case the fracture system played a very important role: in general the outcrops with dominant bedding-parallel horizontal or sub-horizontal fractures were the most resistant, because the least water penetrated into them. For this reason they have retained their pillar-like shape with sharp sides, and almost without weathering products at their foot (Svinské kameny, Dívčí kameny, Słonecznik). These rocks were later transformed by weathering, including frost weathering, mainly in the form of rounding of the edges of individual blocks, which could take on the shape of an oven, or even a ball, or rarely, a false balanced rock or a true balanced rock.

On the contrary, where the predominant fractures were vertical and sub-vertical, respectively where irregular fractures were abundant, water penetrated the rocks more easily and deeper into the massif, and after it froze the rocks broke up most intensively and the destruction caused by ice in the fractures was most rapid. The most affected rocks almost completely disintegrated and became boulder fields, or only small outcrops of the original rock remained (Śmielec on the Polish side of the Silesian Ridge, and we cannot rule out that this was the case on Mt. Malý Šišák too), while in other cases only small cliffs

Various types of granite jointing can be seen in the Harrachova jáma Cirque

Pančavská skála is the most perfect example of blocky jointing of granite

remained (Szrenica) and in further cases a central "core" formation of varying size remains and is surrounded by boulder fields and talus piles at the foot (Violík, Mužské kameny).

The youngest phase of weathering also includes the formation of distinctive microforms on the surface of the rocks, such as rock basins, "rock seats" (also known as the Devil's seats) and their drainage runnels and also rinnenkarren (also known as pseudo-lapiés), most often running vertically. Particularly eye-catching features are the rock basins (weathering pits): rounded (circular, ellipsoidal, rarely even lobe-shaped, and in the most advanced stages of development they may even join together), bowl-shaped depressions, sometimes partly filled with detritus (disintegrated rock), or even biogenic material (wind-blown humus, leaves, etc, as well as dead parts of lichens, algae etc), and sometimes filled with water to different depths, although nearly always only seasonally. On the Czech side of Krkonoše they are quite rare, but the Polish part of Karkonosze is built predominantly of granite and in the neighbouring Jizerské hory Mountains there are many more. Their regular shapes, sometimes connecting to the drainage runnels, caught people's eyes long ago, and because people were unable to explain their origin by natural processes, they were considered to be the work of pagan ancestors and that they served for sacrificial purposes. This is why they were also called sacrificial bowls in the past; in German this has remained as a scientific or technical term until today (Opferkessel). Today we know for sure that they are the work of nature. There are many theories concerning how they were formed, but we still do not know the exact mechanism

of their formation. It is most probable that they were created polygenetically, under the joint impacts of mechanical, chemical, or most likely, by biochemical processes. According to some opinions, the selective weathering of the spherical formations of different compositions in the granite, the so-called schlieren, plays an important role. We can eliminate climate change as the clear cause of their formation, because they occur on cliffs both on the Krkonoše mountain ridges, but also deep in the valleys. It is also difficult to explain the irregularity of their occurrence; on some cliffs there are large numbers of them, but for example, on the next cliff there are none.

We must give a separate mention to the so-called sliced cliffs, popularly known as pancake rocks, because they remind us of a stack of pancakes. These are very densely dissected by horizontal cracks; therefore the surface of the rock has a thin plate-like shape. Atmospheric weathering occurs more rapidly along the fissures and the rock surface is in effect a structured network of parallel grooves and intermediate protruding plates. Their formation was previously explained by the unloading of the rock mass during the erosional-denudational removal of the overlying strata, but this does not explain why they only occur rarely and in a scattered distribution. However, according to new research, we can assume that the cause is different and relates to the primary fracturing of the rocks as a result of internal pressure.

On these rocks we can occasionally see aplite rock tiles, or facets. Aplite is a distinctively light-coloured dyke rock, which occurs in the granite quite often and is similar in composition. In some cases aplite is recognisable by its distinctive character of cracking into small blocks, most commonly square in shape, looking like a cobblestone pavement. In places where the dyke emerges longitudinally on the surface, different sized areas of this appearance are formed (Svinské kameny).

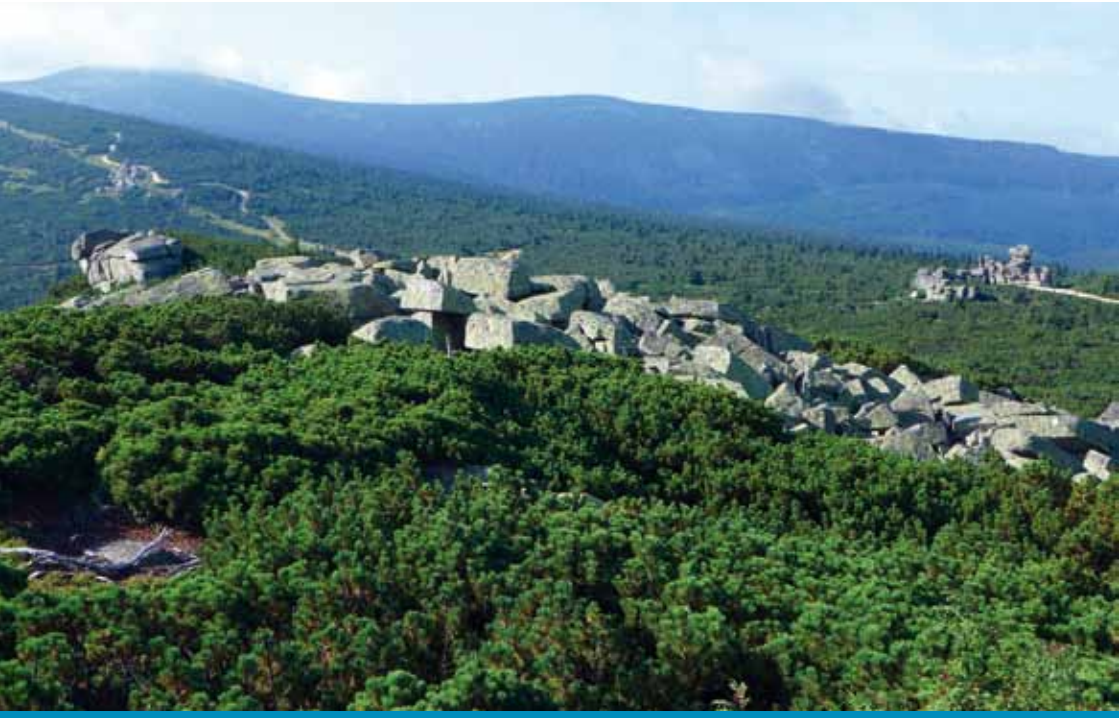
We can distinguish between three basic types of tors and castle koppies according to their relief position. The most dominant in the landscape are the summit tors and castle koppies (Svinské kameny, Violík, Dívčí kameny). Rocks of the second type are also visible from afar as they stand on the edge of the slopes (changes in gradient); most often where the summit levelled surface (etchplain) passes into the slope (Slonecznik, Harrachovy kameny). However, by far the most numerous tors and castle koppies in Krkonoše are those on the slopes, which also includes those on the crowns of the inclined slopes of side ridges and ribs (in Czechia all of those in the Mumlava valley and, with the exception of Pevnost, even in the Sedmidolí valley, and also the great majority of the numerous outcrops on the Polish side of the mountain range).

It is also necessary to mention that granite tors and castle koppies are far more numerous in the neighbouring Jizerské hory Mountains, which is logical as that mountain range is mostly built of granite. Today they are mostly in the montane zone, but from the perspective of geological development and the creation of rock formations, it is necessary to know that in the ice ages the whole of the Jizerské hory Mountains experienced tundra climatic conditions, just like those in Krkonoše. In terms of numbers of rock formations, the Polish side of Karkonosze, which is also mostly built of granite, is much richer than the Czech side.

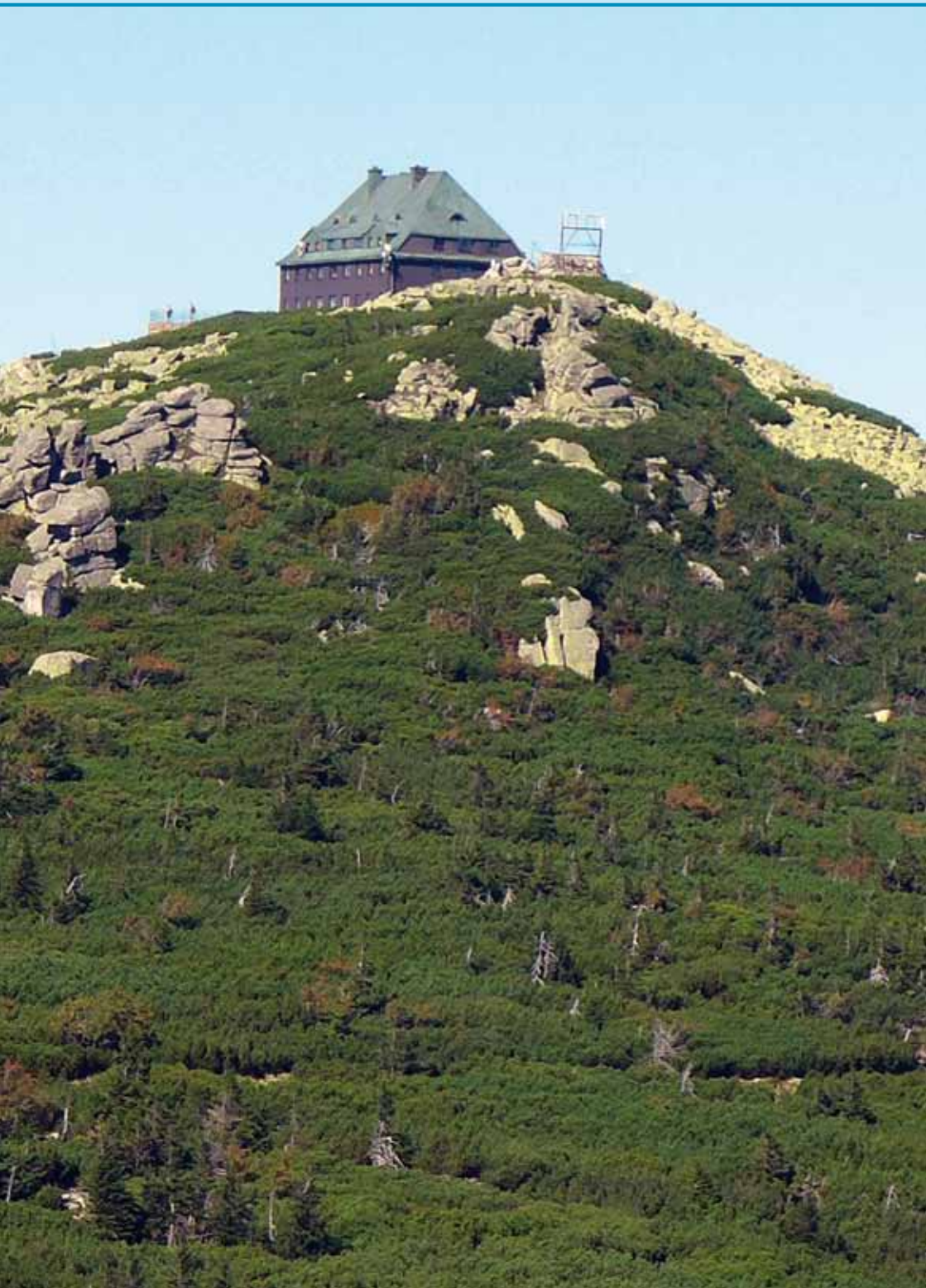
Svinské kameny (Trzy Świnki in Polish, 1,314 m)

This group of three summit, compact, blocky tors along the line of the state border to the south of the summit of Mt. Szrenica (Jínonoše) are the westernmost summit outcrops of this type in the Czech Republic. The border passes between them; the most distinctive tor with a double tower structure stands on the Czech side, while two smaller tors stand on the Polish side. The highest block, 8 metres high, lies on the Czech side. The modelling of the Czech tor is mostly due to the LQS fracture system, i.e. fractures in all three directions. This contributed to the fact that its base is a castle koppie, but its two towers have the appearance of tors. One of them is a perforated rock (rock window). In the lower block, next to the lower section which separates them, there is a clearly visible aplite dyke. Just below it there are three boulders, which were once connected to it, but have since completely broken off due to weathering. On these boulders we can see small areas of square aplite rock pavement. The Polish tor closer to the trail is 4–5 m high. Part of it contains thin horizontal fractures, which form an imperfect "sliced" surface. It demonstrates a rather high level of frost destruction and the boulders trapped in one of its crevasses form an irregular, false perforated rock. The third outcrop, farther from the trail, is the lowest, most hidden in the pine scrub and also the most destroyed, because it has the largest talus mounds below it, something which the other tors cannot match.

Szrenica *(the older – rather obsolete – Czech name is Jínonoš, 1,362 m)*



According to the extensive distribution of the rocky outcrops (on the western edge of the summit, on the crown of the summit next to the chalets, called the Szrenicka Skała and the most numerous are on the eastern to south-eastern slopes), the summit of Szrenica was probably originally a very large castle koppie. However, it is at an advanced state of destruction now and has transformed into an extensive boulder field. According to the distribution and position of the slab-shaped boulders on the southern edge of the crown, it cannot be ruled out that the summit was once a high exfoliation dome (inselberg). The rocky outcrops which have survived are low, not exceeding 5 m in height, and are not very interesting. The largest of them on the southern slopes are surrounded by contiguous dwarf pine scrub and no trail leads to them. Some of the blocks of the Szrenicka Skała on the summit have distinctly sharp edges. In this case, however, this was caused by quarrying the rocks in connection with the construction of the chalet. The largest and most complete boulder field lies on the longest, north-eastern slope of the mountain.



Końskie Łby *(around 1,270 m)*

A group of two castle koppies and two tors, which stands nearby, on the northern slope of Szrenica, close to the alpine upper tree line. The majority of them feature blocky jointing, although in some sections the predominant feature is slab-disintegration. Weak frost destruction has taken place here, so there are only small talus piles at their feet. On the contrary, the western rock outcrop with its arched surface and fractures at its northern slope suggest that this could be the torso of a low exfoliation dome (ruwar), the southern half of which already succumbed to ancient, pre-glacial destruction.

Tvarožník (Twarożnik, 1,322 m)

This small summit tor stands directly on the state border, very close to the Czech-Polish Friendship Trail and around 400 m NE of the Vosecká bouda Chalet. The border line actually passes through the head of the highest block. It is not one of the largest tors, but has one of the most interesting shapes in all of Krkonoše. The untypical appearance of this formation, unlike any other tor, is partially due to the unusual dominance of bedding-parallel fractures, relatively steeply inclined to the NW, which creates “tilted”, but relatively thick slab-like blocks (more than 1 m thick). The destruction of the whole rocky outcrop progresses along these bedding-parallel fractures. The

blocks which were broken off are further transported down the slopes, forming small boulder fields. Their most massive boulders are 5–6 m in length, undoubtedly the largest in the surroundings of any of the tors on the Krkonoše summit areas. The summit block, trapezoidal in plan view, 7×5 m in size and 1.3 m in thickness, rests in a seemingly precarious position on a small area, therefore it is often wrongly referred to as a balanced rock. However, it does not have the ability to waggle and is only a false balanced rock (only looks like a true balanced rock). A portion of densely fractured granite (total thickness only 20–50 cm) in the lower part of the cliff face near the tourist trail weathers more rapidly. This contributed to the formation of a low rock perforation (rock window), 2 m wide and up to 0.8 m high. On the side of the block forming its roof we can see rather imperfectly developed rock facets.

At the bend in the trail below Tvarožník there is another flattened (only 2–3 m high) rocky outcrop, mostly hidden amongst the dwarf pine scrub. It is interesting for its very flat summit boulders, under which there is also a low rock window. The small boulder field in its surroundings provides evidence that most of the original formation has already disintegrated.

Sokolník (Sokolnik, 1,384 m)

A small and less attractive tor, situated directly on the state border at the point where it changes direction. It is one of the smallest tors, and even though by its genesis it belongs to tors, from a morphological perspective it should really be called a rocky outcrop. Its dimensions are only 3 × 5 m with a height of 2.5–3.5 metres. This formation is dominated by horizontal bedding-parallel fractures, which is why each of the levels contain slab-shaped rocks and from the south side they even form small overhangs below the slabs. Unlike other tors with their surfaces of smooth fracture planes, the surface of the rocks here is rather uneven. The slab-shaped blocks which were broken off form a narrow fringe at the foot and are mostly in an oblique position, as they broke off and fell into the pile of weathering products. This provides evidence that the destruction of the outcrop is of later, sub-recent date. Despite its imperfect shape, it is probably the summit tor which is most "connected" to the typical, hummocky, although currently overgrown tundra soils, which are found right next to it.

Sokolník is not accessible to the public as it stands away from marked hiking trails (although the trails – green-marked trail to the south and red-marked to the north are less than 300 metres away). Its low height and the surrounding dwarf pine scrub make it almost invisible, which is why it is unknown to most visitors.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Violík (Łabski Szcyt, 1,472 m)

The most dominant over the landscape and the second highest elevation of a summit castle koppie in Krkonoše. It stands directly on the state border, less than 1 km NE of the spring of the Labe. Its current knob-like appearance represents the castle koppies in an advanced stage of destruction, mainly due to frost-weathering processes. Today we could say that it is mostly "buried" in its own weathering products, as the massive talus heaps, or boulder fields, at its foot hide the greater part of the knob and reduce the height of its visible part. For this reason the walls of Violík are only 5–6 m high.

In the central part the preserved part of the rocky outcrop was formed according to the distinctive granite fracture system, with predominantly vertical and very steep fractures. This explains why the disintegration of the tor was so intense – because of the angle of these fractures the water flowed extremely deep into the rocks and accelerated their breakdown. The boulder fields of differing widths which surround the actual rocky outcrop show that in the ice ages the frost-weathering here was exceptionally intensive. Other factors which contributed significantly were its exposed and extraglacial location, in combination with the optimal orientation towards the predominant wind directions. The head of the outcrop is very rugged in a close-up view; this provides evidence that the frost disintegration is still in progress here, although of much less intensity than in the past. The most extensive talus pile lies on the NE side of the knob, and even shows signs of frost-sorting into the form of cryoplanation terraces. The Czech name Violík is probably derived from the widespread, but untrue, story that "violet rocks" (the algae *Trentepohlia iolithus*), which were previously a popular Krkonoše souvenir, grow here. The completely different Polish name is simply derived from the fact that the rocks stands close to the spring of the Labe.

Czarcia Ambona *(Krakonošova kazatelna – Krakonoš's Pulpit, 1,490 m); in Polish the name means Magic Pulpit)*

These small, but compact and relatively low summit castle koppie (4–4.5 m) stands next to the telecommunications station (commonly called Wawel) on the upper rim of the Śnieżne Kotły Cirques. It stands near the state border, but on the Polish territory. These rocks are dominated by horizontal bedding-parallel fractures, which caused the flattened loaf-shaped appearance of the individual slabs. Some of the few vertical fractures have the form of fissures or crevasses; therefore, they are filled with free boulders, which fell from above and remained wedged into them. As with the majority of castle koppies with predominantly horizontal fractures, there are no talus heaps at the foot, and the base is well-defined, only with individual fallen boulders. However, the northern side of the rocks was artificially modified, walled in and serves as a rest area for tourists. The castle koppie itself is not particularly interesting, but it can boast of holding a record. As it is part of the wider massif of Mt. Vysoké Kolo, this makes it the highest-positioned castle koppie not only in Krkonoše, but in our entire republic.

Harrachovy kameny (1,421 m)

Thanks to the easy access (less than 1 km on the flat trail from Vrbatova bouda Chalet), the Harrachovy kameny rocks are well-known and attract many visitors, as the red-marked trail passes between them. Typologically they represent one of the least interesting outcrops of granite castle koppies, and are also of small dimensions (both in area and in height). They consist of two parallel belts of rocky outcrops of 2–4 m in width and only 1–2.5 m in height; the highest rocky spur is by the trail in the eastern belt and only reaches 3 m in height. However, these cliffs have never been much taller than they are now, as we can see from the small or absent talus piles below them, which rule out more extensive destruction of the rocks. They are typical representatives of tors on relief breaks (slope breaks), in this case the Kotelní jámy Cirques. Despite their small size, the Harrachovy kameny hold one exception: they are the only granite tors on the Český hřbet Ridge in Krkonoše, which is predominantly built of schists.

All of the fractures of the LQS system contributed to the modelling of these rocks, which is why blocky jointing and disintegration predominates, but towards the slope on the eastern belt of rocks, inclined exfoliation joints begin to predominate; these are fully apparent further down the slopes of the cirque, where they form extensive rock plates. The atypical, “obliquely tilted” appearance of the perfectly angular highest cliff developed as a result of S fractures, which are not vertical here but sub-vertically inclined. The block released along the fracture was then transported gravitationally down the slope. This also caused the fractures between the blocks to open up, so that in several places the cliffs contain miniature rock windows. Transitional forms and microforms are completely absent here. The cliffs are a popular vantage point over the Kotelní jámy Cirques and lower-lying parts of western Krkonoše and the Podkrkonoší Foothills.

Mužské kameny (Czeskie Kamienie, 1,417 m)

Although the Mužské kameny cliffs are near neighbours with the Dívčí kameny cliffs on the main, Slezský hřbet Ridge, these two rocky outcrops were modelled in entirely different ways. The more westerly Mužské kameny are the most perfect example of a monolithic castle koppie on the Czech side of Krkonoše. While its upper end stands almost on the head of the ridge, its larger part with a length of almost 60 m and a width of 12 m runs down the slope on the Czech side. The eastern wall reaches up to 14 m in height, making it one of the tallest castle koppies. Unlike the Dívčí kameny with their predominance of horizontal fractures, here the fractures in all three directions are represented equally, which caused the predominance of imperfectly blocky-jointed rocks. This is also reflected in the effects of recent frost weathering, the result of which is the rugged head of the rocky ridge. The eastern wall of the castle koppie is relatively compact and only has a narrow talus apron at its foot, but moving southwards the disintegration is stronger, making the talus piles wider here. The western side of the castle koppie was subject to much more intensive destruction, which is why the talus piles of chaotically piled boulders at the foot are much bigger, and reach the same height as the summit of the cliff at the southern end.

Directly next to the tourist trail on the Polish side, to the west of the main outcrop, there is a solitary, slender, 3-metre-high tor with a beak-shaped overhang at its head portion. Although it stands nearby, its shape was controlled by platy jointing, which is reflected in its differing appearance.

Dívčí kameny (Śląskie Kamienie, 1,413 m)

This is the most perfect combination of a castle koppie and a tor on the Slezský hřbet Ridge. The main rocky outcrops now represent smaller castle koppies, while the two separate pinnacles are textbook examples of perfect tors. Their position directly on the Czech-Polish Friendship Trail on the mountain ridge makes them a very popular tourist attraction. Dívčí kameny consists of two groups of rocky outcrops, of which the western group includes 4 individual cliffs (the tallest reaches a height of 7 m); while the eastern group has 2 cliffs (the taller of them is 5.5 m high). Thanks to its more rugged relief, however, the western group is more interesting and is probably the most attractive cliff of this type in the Czech Krkonoše. The appearance of Dívčí kameny is strongly influenced by the dominant horizontal fractures, meaning that platy jointing of the rock predominates. This is probably also the reason why destruction due to frost weathering has not played an important role and why there are no accumulations of weathering products at the foot of the cliffs. Therefore, the cliffs have well-defined bases. More extensive boulder fields can be found further down the slopes, especially on the northern, Polish side. Dívčí kameny is also one of the few summit

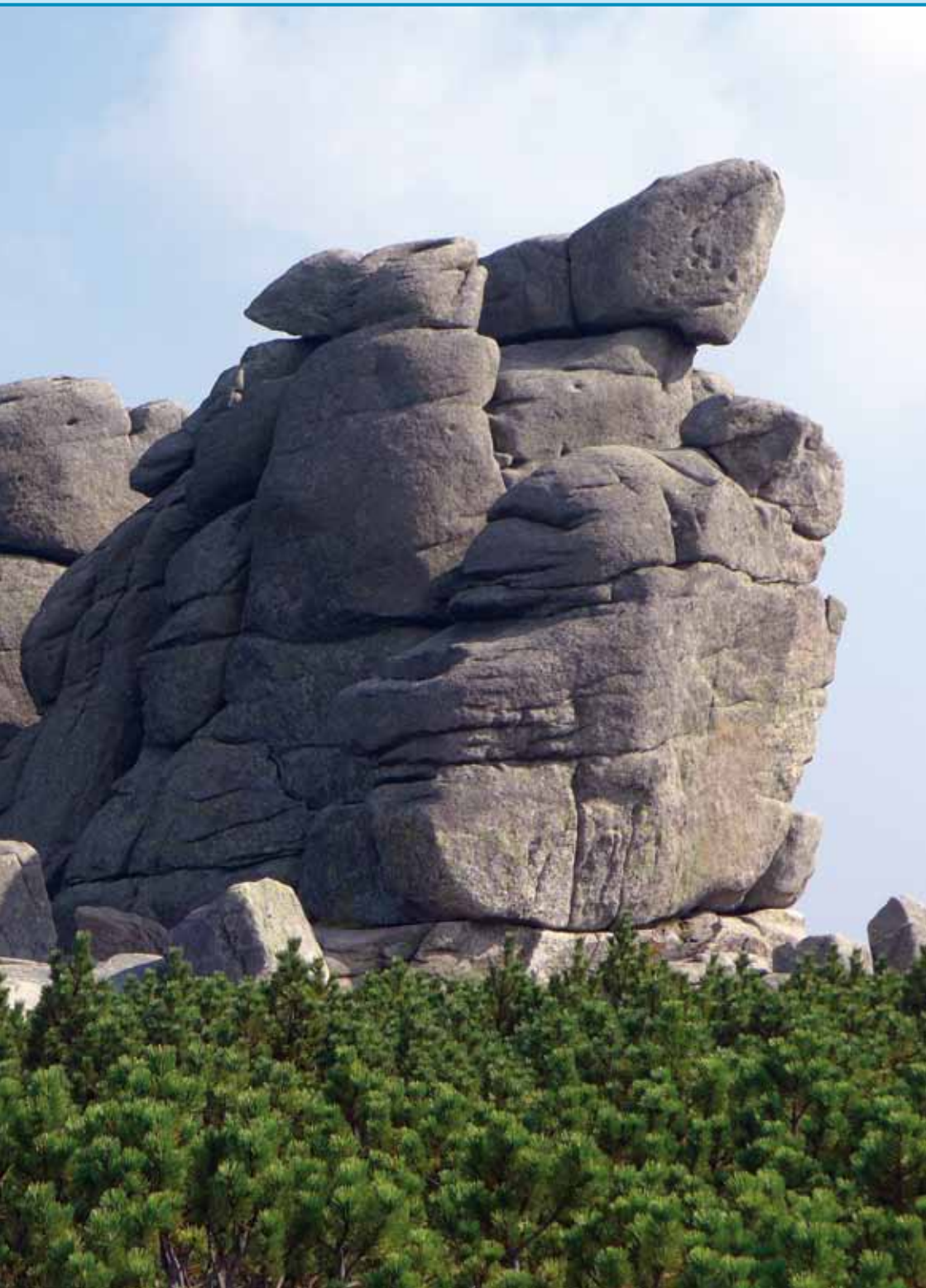
castle koppies which contain several rock basins; the most visible is the vertically asymmetrical basin on the top of the eastern outcrop.

The Dívčí kameny complex also includes the so-called "Krakonošova hrobka -Krakonoš's Tomb", located several metres from the trail around halfway between the two main cliff groups. This is a very flat rock outcrop, consisting of several slab-like blocks and boulders that were loosened by frost-weathering processes, with the help of fissure ice in the first phase of development, into the form of a crevasse with straight walls defined by vertical fractures. This crevasse is mostly covered from above by a "lid" of another slab, also transported here by frost-weathering processes. This is how the cavity with smooth walls, reminding us of a grave, was created, or maybe because it is only connected to the ground by a small, rectangular opening. Human fantasy and its position on the summits of Krkonoše only required the addition of the Giant Krakonoš.

Lower down the northern slope, in the middle of the boulder field, we can find a smaller castle koppie called Małe Śląskie Kamienie.

Stonecznik (Polední kámen, 1,420 m)

This is the only significant tor on the summit areas of eastern Krkonoše, situated on the northern slopes of Mt. Smogornia a little to the west of the Wielki Staw glacial lake. It is the most distinctive tor in a slope-break position in all of Krkonoše, which makes it visible from a great distance and when viewed from the north it stands high on the horizon in the line of the midday sun. This is why it is named "Noon Rock". It rises abruptly from the surrounding land and does not have an apron of talus piles. The rugged nature of its head indicates the recent and intensive frost weathering. Even though it is clearly a tor, it has a rather untypical elongated footprint, reminding us of the low torso of a wall. Its northern edge is formed of a rock pillar, which is isolated from the main body by a vertical cleft, and reminds us of a human figure looking out over the landscape. This is probably why the old legend connected this tor to the giant Krakonoš; the rock should represent his palace, which he did not manage to complete before noon.



Větrný kámen *(Wietrzny kamień)*

This name cannot be found on any map, as it is a new and fresh name, derived from the Větrný hřeben Ridge (Windy Ridge), on the lower end of which it is located. It rises at the foot of Mt. Sněžka, on the rim of the Kocioł Łomniczki Cirque. It stands 200 m from the Dom Śląski building (by the former Obří bouda Chalet) and is clearly visible from the start of the trail to the summit. However, it does not attract the attention of many tourists, as it is only an inconspicuous, flat castle koppie, the walls of which are only 2–3 m high. It is fractured in a rather chaotic manner, with a slight dominance of bedding-parallel fractures, which explains the predominance of irregular slab-like blocks and boulders. On the contrary, along with Dívčí kameny, it is the only summit rocky outcrop in Krkonoše, in which a rock basin has developed. It can be found on the upper surface of the lowest part of the outcrop and has a circular shape with a diameter of 30 cm and a depth of 12 cm. The bottom of the rock basin contains granite sand and airblown humus. Only 2 m from it there is also a smaller and shallower embryonic rock basin of the same origin.

The majority of tors and castle koppies now stand at the montane level, so they are hidden in the forests, even though they also developed under tundra conditions during the cold periods of the Quaternary. Most of them stand on the Polish side of the mountain range, although several can be found on the Czech side too, especially in the Sedmidolí area. There are fewer tors, but reaching down to lower elevations, in the Mumlavský důl Valley.

Rocks of the Pudlavský hřbet Ridge

Pudlavský kámen

Martinův kámen

Martinův kámen

The Pudlavský hřbet Ridge runs as a short slope spur from the southern slope of Mt. Vysoké Kolo and on the head of the spur there are 5 rocky outcrops of the tor or castle koppie types. They make up the largest such group of cliffs on the Czech side of Krkonoše.

The topmost-positioned and nearest to the Martinova bouda Chalet is the Martinův kámen, also known as Martinova skála. This is the most massive, tallest (up to 10 m) and most ruggedly dissected castle koppie. It is distinctively divided by horizontal, as well as vertical fractures, the combination of which created numerous steps and terraces overgrown with herb vegetation and trees, which reduces its attractiveness.

Pudlavská skála

Pudlavská skála and Pudlavský kámen

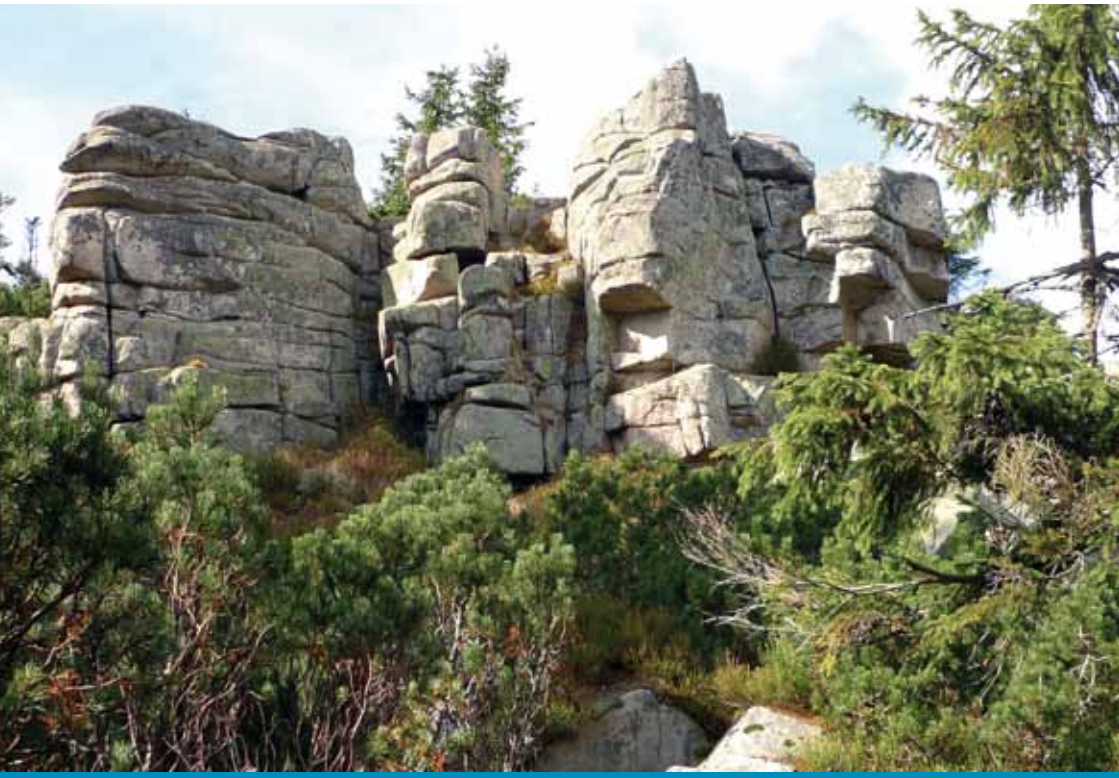
These cliffs stand near the upper logging road starting near the Medvědí bouda Chalet. Pudlavská skála is a two-part, but not very high (3–5 m) and flat cliff, with predominantly gently inclined bedding-parallel fractures. However, it is quite overgrown, which makes it less attractive. It is only more interesting when viewed from the west, because it looks a little like a sphinx.

On the other hand, the near Pudlavský kámen, right by the logging road, is the most dramatic and most striking tor on the entire Pudlavský hřbet Ridge. It is a fully isolated pillar-like formation, covering an area of 6 × 5 m, and 6 m high. It was mainly modelled by the sub-horizontal fractures, which also separate two of the rounded summit blocks.

Děravý kámen and Hlava (Rock with Holes and Head Rock)

These last two rock formations are close to the lower logging road from the Medvědí bouda Chalet. Both of their names are derived from their main characteristic. Děravý kámen is the flat torso of a castle koppie, disintegrating in places into free boulders. The most interesting of them is the lowermost part of the sphinx-shaped formation, which has a small rock window at the point where the fractures intersect. As a result of the irregular weathering of the last pillar along the sub-horizontal fractures, an isolated block developed and stands above a narrower “neck” like a head. The whole of the castle koppie is named after this most striking and attractive formation.

Ptačí kámen *(1,310 m; incorrectly also stated as 1,258 m)*



The most typical slope castle koppie on the Czech side of Krkonoše is located on the south slope below Dívčí kameny, along the blue-marked trail from Petrova bouda Chalet to Martinova bouda Chalet. As a whole it is shaped like a knob, comprising of two rocky outcrops. The main, taller and more extensive castle koppie is broken up as a result of rather advanced frost destruction. The walls only reach a height of 5 m. Here the granite displays distinctive blocky jointing, although the sub-horizontal bedding-parallel fractures are predominant. With the exception of one tiny "devil's seat" in a free boulder on the summit, there are no microforms on these rocks. The north side of the outcrop facing the trail has suffered the most destruction, with a small talus pile of boulders at its foot. The second, more southerly outcrop is flat, only 1–2 m high, and most of it is hidden below dwarf pine scrub. From the main summit of Ptačí kámen there are attractive views of the Sedmidolí valley and Mt. Vysoké Kolo.

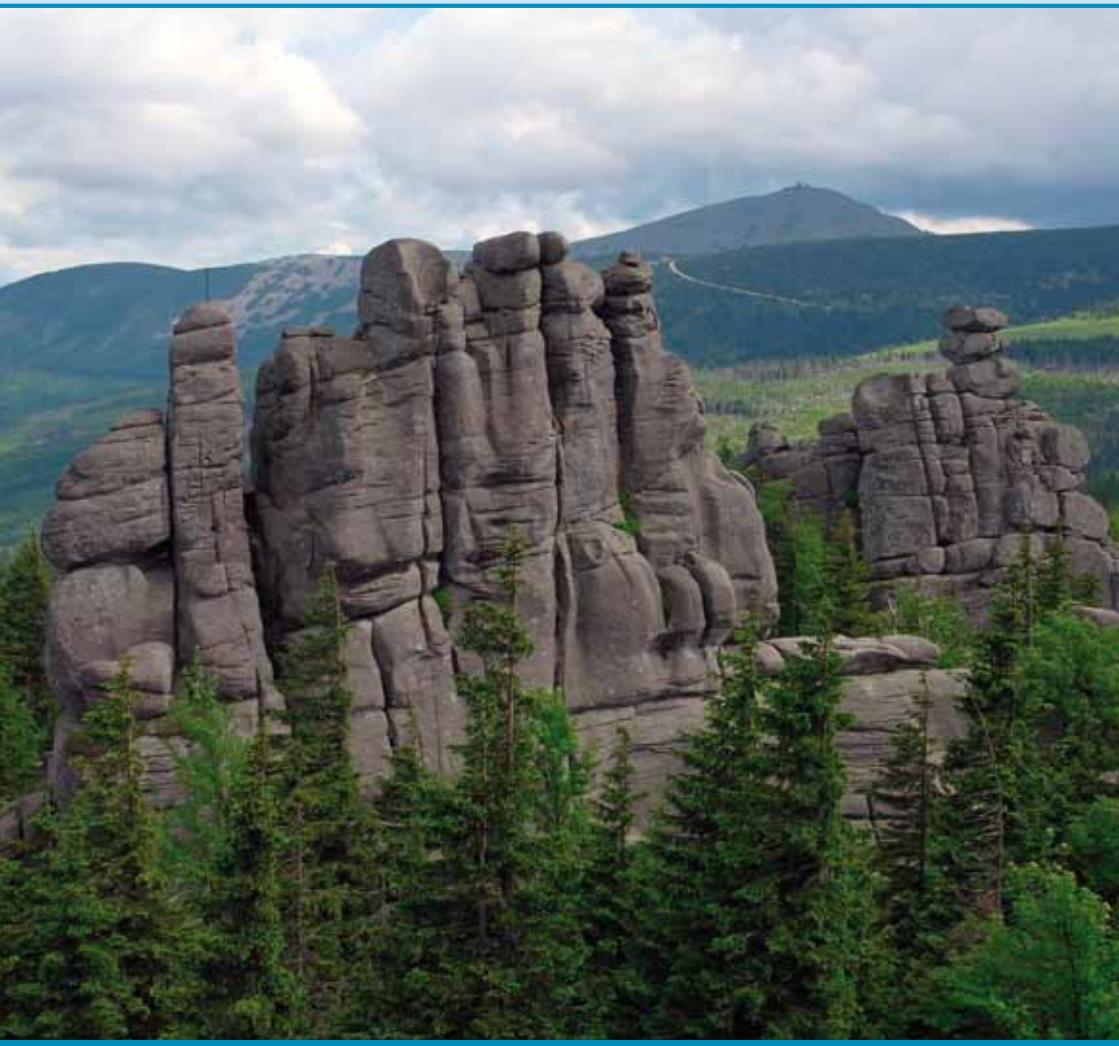
Pevnost *(1,012 m)*

This group of four granite castle koppies stands on the hilltop of the same name at the end of the slope spur on the Slezský hřeben Ridge. It stands directly above the Dívčí lávky Bridges at the confluence of the Labe and Bílé Labe streams. These cliffs are not particularly tall (the tallest is 5.5 m, the others only 3–4 m), but as they rise abruptly from the terrain around, without talus heaps of weathering products, they are a relatively prominent landform. However, the surrounding forests reduce their landscape significance. This is a shame, because they are the best example of "sliced" cliffs, also known as "pancake rocks", on the Czech side of Krkonoše. They are dissected by a dense network of horizontal fractures, only spaced 5–20 cm from each other. Weathering advances more rapidly along these fractures, meaning that the walls of individual outcrops display whole systems of weathered notches, separated by protruding ledges.

Pielgrzymy *(Poutníci, 1,204 m)*

On the Polish side of the mountain range there are such large numbers of rocky outcrops of the castle koppie or tor types that describing them all would fill a separate book. Many of them are also difficult to access for tourists, because no trail (marked or unmarked) leads to them. Thus we will only mention one of them, which is not only the tallest but is the most famous and is visible lower down the slope below Słonecznik (Polední kamen), from the red-marked Czech-Polish Friendship Trail, which is used by many of our tourists.

The Pielgrzymy group represents a combination of a castle koppie and a tor and reaches heights of up to 25 m. It consists of three obliquely parallel-positioned rocky outcrops, the slim heads of which resemble three human figures walking one behind the other. This is probably how they got their name of “The Pilgrims”, or more probably it



is because – thanks to the height of their pillars – they have always stood prominently over the forest, unlike many other cliffs. Their original German name Dreisteine (Three Rocks) was more apt.

The elongated base of all three cliffs is primarily due to the effects of orthogonal granite tectonics. Unlike many other rocky outcrops of this type, these cliffs also feature small microforms like rock basins and their drainage runnels, as well as their one-sided forms (rock seats or "devil's seats") and rinnenkarren. Some parts of their walls take the form of sliced (pancake) rocks, because they are strongly permeated with thick horizontal fracturing. The rocks are characterised by weak frost-induced disintegration, which is why they have sharply defined bases. Boulder piles or boulder fields, which accompany some of the other rocky outcrops, are absent here.

Velká Sněžná jáma Cirque has the most isolated rock outcrops of all the cirques in Krkonoše

Rocks in the glacial cirques

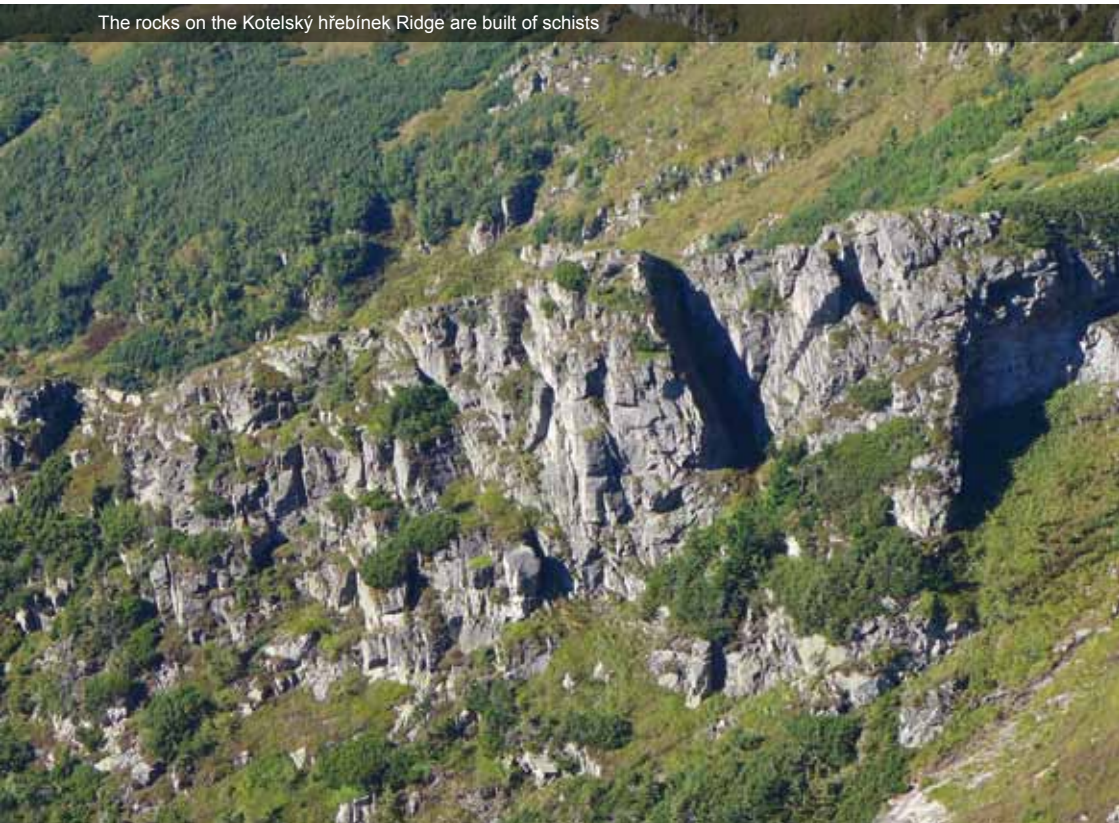
The glacial cirques, or at least their upper sections, rising above the alpine upper tree limit are a part of the mountain tundra. The numerous rocky outcrops, or even separate landforms, which emerge from the slopes of the cirques, are mostly the results of glacial erosion (in the case of Krkonoše, mostly glaciers from the last, Würm glaciation), but processes during the post-glacial period (Holocene) also contribute to their current appearance. This mostly involves frost weathering, which can be surprisingly intensive in the heavily waterlogged rocky cirques and can cause the disintegration and tearing off of rocks, followed by their gravitational transport or falls of blocks. Gravitational transport can affect individual cliffs, or more often it involves whole groups of cliffs with a greater volume. Such processes are described as rockfall. To a lesser extent the rocky outcrops in the cirques are also shaped by earth and snow avalanches, which can also use their energy to tear off blocks of rock. And of course biological weathering, in which the root systems of dwarf pines and other woody plants disturb the rocks along fracture lines, also makes its contribution. However, due to the steep slopes of the cirques, most of the cliffs here only show one-sided faces and terraced steps. This implies that they lack the isolation we know from other types of cliffs. As a result, these cliffs are rarely given individual names, or their names

are only known to a small group of climbers. These cliffs, especially the orientations of the individual sections of their straight walls and the grikes that dissect them or separate them, are controlled by the orientations of tectonic structures. Specifically, the dominance of transverse vertical Q fractures takes control. This is perfectly evident especially in granite, but unfortunately only from aerial photographs. When moving through the terrain it is not usually possible to see the cliffs as a whole; moreover, they are partly covered by vegetation.

The most perfect examples on the Czech side can be found at the head of the Labský důl Valley, on the cliffs in the Velká Labská rokle Ravine and Malá Labská rokle Ravine below the Labský vodopád Waterfall, and especially on the more southerly cliffs, which emerge from the cliffline from two, or even three, sides. From the north these are the Ambrožova vyhlídka Viewpoint, Pančavská skála Cliff next to the Pančavský vodopád Waterfall (this is also the most perfect example of blocky jointing in all of Czech Krkonoše) and the highest of them is Krakonošova hlava (Krakonoš's Head) near to the Harrachova jáma Cirque.

The major part of the nearby Kotelní jámy Cirque is developed on the bedrock of schists (especially mica schists), the properties of which are less favourable for the formation of more distinctive rock formations in the cirques. Here we can only find one, the Kotelský hřebínek Ridge, running down the slope and dividing the Velká Kotelní jáma and Malá

The rocks on the Kotelský hřebínek Ridge are built of schists



Granite tectonics greatly influenced the shape of the cirque cliffs (Velká Sněžná jáma)

Kotelní jáma Cirques. The landforms are controlled by geological structures here, i.e. on the contrasting hardness and resistance of various rock types of rocks. This is different from granite, where the most common deciding factor for the formation and appearance of cliffs is the granite tectonics. In this case the controlling structures are bodies of quartzite, which resist erosion much more than the surrounding schists, therefore they form convex relief elements and, in places with intensive erosion, they also give rise to cliffs. The highest cliff faces of the Kotelský hřebínek Ridge dip towards the Velká Kotelní jáma Cirque.

In eastern Krkonoše a similar situation exists in the Úpská jáma Cirque only. However, in its granite part the more intensive and multi-directional fracturing of granite has a negative effect, which is why there are no such perfect rock formations here as in the Labské jámy Cirques, where the perfect blocky jointing leads to the formation of more distinctive cliffs. Therefore, the Studniční stěna and Úpská stěna rock formations are typified only by rocky slopes, rather than actual cliffs. More distinctive, but still one-sided cliff faces are found in the Úpská rokle Gully below the Horní Úpský vodopád Waterfall and in the trough called Žlab Úpičky below the former Obří bouda Chalet, but none of them are significant enough to have their own local names. But even here we can see from aerial photographs the same features we see in the Labský důl Valley, i.e., that the orientations of cliff faces are controlled by the granite tectonics.

The southern edge of the Úpská jáma Cirque is formed by the Čertův hřebínek Ridge (1,418 m), which is a structural form similar to the Kotelský hřebínek Ridge, and is built of hard quartzite intercalations. In contrast to the localised occurrence of quartzites in the Kotelní jamy Cirques, here they form the larger relief forms, the development of which follows the contact zone at the border of the granite pluton and the Krkonoše Crystalline Complex. They were already formed in the Palaeogene period and represent one of the most important building elements of Krkonoše, which has influenced the further development

Rocky outcrops in the Mały Staw Cirque

and appearance of the entire mountain range. The Čertův hřebínek Ridge is one of these elements.

Cliffs within glacial cirques can, however, also be found on the Polish side of the mountain range. The most distinctive of these are in the Śnieżne Kotły Cirques, which are the rockiest cirques in all of Krkonoše, with the highest cliffs, which are vertical in places. The reason why these exceptionally rocky slopes were formed here is due to the properties of the local granite. In contrast to the dominant horizontal fracturing of the Czarcia Ambona (Devil's Pulpit) tor, which only stands a little higher, the granite here has a dense network of vertical fractures of Q and S strikes. This combination allowed the exceptionally rapid progress of frost weathering, as well as erosion by water flowing down from the plateau above the cirque. These processes split the cirque walls into a series of comb-shaped to slab-shaped rocks, reminding us of short rock walls. Their cliff faces also display "smooth" sections of various sizes, which were created by the advance of erosion along the fracture planes and their exposure. The most extensive cliff is called Grzęda (its Czech name means "roost") which separates the two cirques and follows a harder portion of the granite. Several imperfect, but very distinctive rocky ridges, which are sufficiently isolated that they have been given individual names (Turnia Popiela, Ząb Rekina, Suche Baszty, Maly Ganek etc.), divide up the slopes of the Wielki Śnieżny Kocioł Cirque. They are separated from each other by rock cuts and grikes, which also have individual names and contain clearly visible evidence of sub-recent to recent stream erosion in the form of torrential rain runoff channels.

Distinctive forms of this type on the Polish side also include the rocky ridge which divides the Kocioł Wielkiego Stawu and Kocioł Małego Stawu Cirques. This is basically a structural landform too, as it developed on the hard dyke of porphyritic, fine-grained granodiorite (previously known as granite porphyry) and follows its strike for its entire length.

Basalt Gully (on right) and basalt outcrops in the middle foreground

Volcanic cliffs of the Krkonoše tundra

For this case we could write in the singular, because this type of cliffs only occurs in one place in Krkonoše, which makes it an exceptional case. Tiny intrusions of neovolcanics (basalts of Tertiary age) can be found in many places in Krkonoše, mostly on the territory of the granite pluton, and especially on the Polish side, as well as in several places around Harrachov. But they are so small that, with the one exception, they do not form any separate landforms and the great majority of them are hidden under the cover of weathering products, as well as vegetation. This exception is found on the western slope of the Mały Śnieżny Kocioł, where basalt is found at an elevation of 1,425 m, which is clearly at a "tundra" altitude. It represents the highest emergence of neovolcanics not only in Krkonoše, but in all of central Europe. This position on the slope of the cirque could be included in the previous groups, but genetically it is so different, that it represents a separate "unit".

Due to the considerably more intense fracturing, basalt (which is otherwise a hard rock) is subject to significantly faster erosion than the surrounding blocky-jointed granite. The dyke runs down the cirque slope perpendicular to contour lines, and therefore precipitation waters carved out a distinctive erosional gully, named after the rock type as the Żleb Bazaltowy or Basalt Ravine. Due to the small area and extremely steep slopes (the south slope is completely vertical in places) there are no separate, isolated rock formations here. Basaltic columns exposed in the sides of the ravine were formed by the cooling and shrinkage of the magma. The trends of their long axes are perpendicular to the cooling surface.

The Basalt Ravine is best known as one of the most important botanical localities, with the highest species diversity in all of Krkonoše. This is because the basalt and its weathering products are basic and rich in mineral elements in comparison with the surrounding extremely nutrient-poor granite or crystalline bedrock. Therefore, they provide habitats for a range of rare plants, including endemics, or those which can be found only here in all of central Europe.

Janova skála

Cliffs of structural origin and frost-riven cliffs

Structural landforms are defined as those relief shapes which formed as a consequence of the contrasting hardness and resistance of the various types of rock. Of course, this also concerns the cliffs in which the portions of harder rock are more resistant to erosion and denudation, therefore during the geological development they have remained in raised positions above the surrounding less resistant and more rapidly eroded rocks. We know of many such examples from Krkonoše, but most of them are at lower elevations, or directly on the valley slopes. In summit positions, where tundra conditions prevailed during the history of this area, the occurrence of such rocks is restricted. Most often they are bound to the muscovitic quartzites (especially in the contact aureole, i.e. in the line of the Český hřbet Ridge in the highest parts of Krkonoše), sericitic quartzites (most commonly in the Jizera River valley around Rokytnice and in the surroundings of Janské Lázně), but also orthogneiss (scattered over multiple localities).

Cliffs of this type also have close relationship to frost-riven cliffs, as they were shaped by frost processes in the ice ages too. There are also many cases where the rocks belong to both categories, i.e., they are of a primary structural genesis, but underwent secondary and very intensive shaping into the form of frost-riven cliffs. These are most common at lower elevations, for example, on the slopes of the main Krkonoše valleys (most of all in the Jizera River and Jizerka Stream valleys, but we can also find them in the valleys of the Labe, Úpa and Malá Úpa rivers). However, their landscape-forming role is limited, because they are strongly influenced by the schistosity of the rock. This means that these cliffs and their faces are usually extremely rugged, divided

by numerous terraces and steps, often with humus and vegetation cover, so very few of them develop into high cliff faces and even fewer into isolated or pillar-shaped landforms. With a few exceptions (such as the Bártlova skála and Emin kámen cliffs in the Labe River valley) they do not include formations which attract tourists and for this reason there are usually no tourist trails leading to them and visitors do not search them out. Another negative factor is that the great majority of them are hidden in the forest, which very often grows on the outcrops themselves, so that few of them offer attractive views, or only very limited views.

In a similar way, some cliffs fulfil the conditions for cliffs in glacial cirques, but are also conditioned structurally. For this reason, they have already been described above as cliffs in glacial cirques (e.g. Kotelský hřebínek and Čertův hřebínek Ridges).

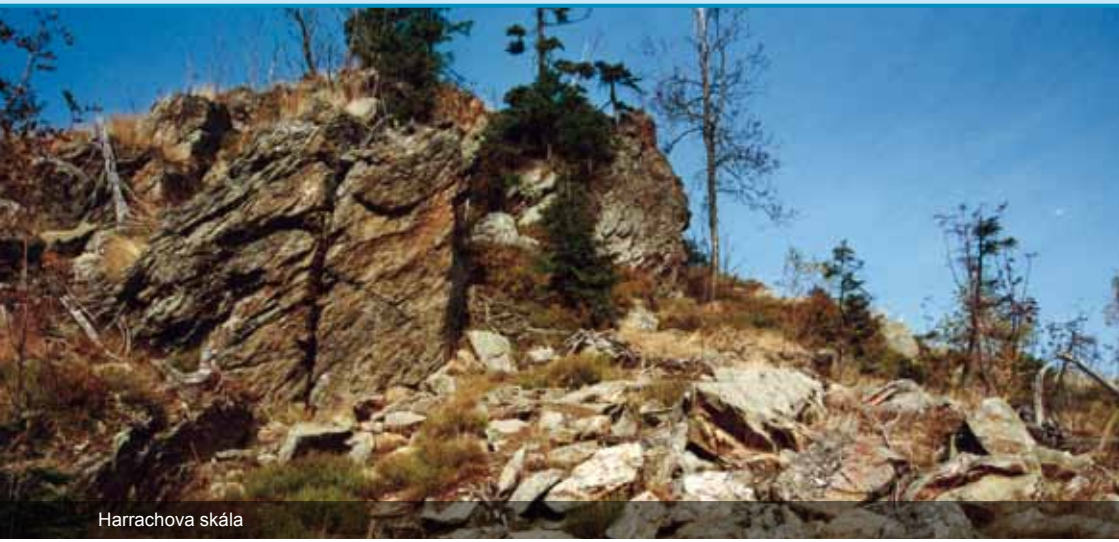
From the perspective of the highest altitude, which fully reflects the current tundra conditions, significant are the cliffs of structural origin on the slopes of Mt. Železná hora, the western spur of the massif of Mt. Luční hora, towards the Hrazený důl Valley. The most distinctive of them is the down-slope rocky ridge between the upper part of the Hrazený důl Valley and the Železný žlab Gully. They formed on hard quartzite intercalations of the contact aureole. Although from the climatic perspective, they fully meet the criteria for rocks in a tundra position, most visitors to the mountains do not even notice them because they are low and inconspicuous, and also hidden in the dwarf pine scrub.

From the genetic perspective the eastern half of the summit cliffs on the Kozí hřbety Ridge are similar. They are also built of hard quartzites of the contact aureole. Even though they are also low, mostly less than 5 m, unlike the previous rocks, they are more distinctive in the relief. It is these rocks which form the most rugged part of the summit area of the Kozí hřbety Ridge, which, thanks to such rocks, has a roof-like appearance. They are also the fundamental reason for the Kozí hřbety Ridges being one of the most alpine-type (i.e. similar to the high mountains) landforms in the whole of Krkonoše.

The situation is more complicated in the area of Krakonošova rukavice (the giant Krakonoš's Glove), the fan-shaped closure of the Rudná rokle Gully on the SW slope of Mt. Sněžka. These areas are also part of the contact aureole, but here narrow belts of phyllites, mica schists and quartzites alternate in rapid succession, meaning that the slope is divided by low, down-slope elongated cliff series, emerging in stripes of harder rocks interspersed by narrow belts of rocky talus from the frost-destructed softer rocks. It is the only rocky terrain of this type in all of Krkonoše, but the cliffs are so low, that they do not attract much attention from visitors.

Of the other cliffs of this type, i.e., located on a mountain ridge, but at lower altitudes, we can also mention Janova skála (1,002 m) above Rokytnice nad Jizerou on a bedrock of sericitic quartzites, emerging sharply from the flat head of the Čertova hora side ridge. It forms a massive and compact, unilaterally sloping block, distinctively shaped by the inclined schistosity planes.

Close to Horní Mísečky we can find a similar rocky outcrop called Harrachova skála (1,035 m), which takes the form of an asymmetric, knob-like, frost-riven cliff



Harrachova skála

on the edge of the flat head of the ridge (on the slope break). It is an attractive example of the frost destruction, which has mainly affected the highest northern and eastern faces. Thanks to the southerly dips of the schistosity planes, these faces represent its "forehead", which is bordered by fracture systems. Small talus piles of angular blocks lay under the faces. Here we can clearly see the difference between the weathering of granite (forming larger and more angular boulders) and crystalline rocks (forming smaller, often plate-shaped, fragments). The summit with metal railings is a popular vantage point with views of Špindlerův Mlýn and eastern Krkonoše.

Similar unilateral shaping can be seen on the two low summit rocky outcrops called Tabule (Skalny Stół, 1,282 m), a part of the Střecha massif on the opposite side of Krkonoše, above the Pomezní Boudy Chalet. However, only a resistant portion of mica schists is involved here, and the term "cliffs" is only symbolic – their steep edge faces north towards Poland, but only reaches a height of around 2 m. The cliffs are very distinctively shaped by the schistosity of the rock, which is why their upper edge is noticeably protruding. At the base and in the near surroundings we can find a small talus cone, which was created by the frost destruction to this outcrop and has a distinctly shingle-shaped arrangement of its tabular fragments.

At an even lower altitude of around 900 m we can find the Modré kameny Cliffs above Janské Lázně. They consist of a group of six quartzite cliffs lined in down-slope direction on the side rib of Mt. Světlá hora. In accordance with the dips of schistosity planes in the rock, most of the cliffs have one gentle slope and a steep or vertical face on the other side. The disintegration caused by frost weathering, mainly progressing along the steep to vertical fractures, in a very similar way to rocks at higher elevations, is clearly visible, especially on higher outcrops. The talus piles to small talus fields at their bases are also identical with those at higher elevations; they formed in periods of cold climate.

Rocks of the Krkonoše Tundra

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