

Geomorphological Inventory as a Tool for Proclaiming Geomorphosite (a Case Study of Mt. Myslivna in the Novohradské hory Mts.—Czech Republic)

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Abstract The study locality of Mt. Myslivna within the Novohradské hory Mts. (Czech Republic) represents an area which had restricted access prior to 1989. Detailed geomorphological inventory carried out in years 2002–2010 revealed prominent rock landforms developed within late Variscan, Weinsberg-type granite. Destructive as well as accumulative rock landforms were mapped with the use of GPS and include two cryoplanation platform, three frost-riven cliffs, three tors, two low exfoliation domes, two castle koppies, two blockfields, one relic of tor and smaller forms, such as rock ledges and laths. A distinct fissure system that shapes the rock relief consists of two sets of fissures: The primary set is formed by dominant fissures with NE-SW orientation accompanied by fissures with NW-SE orientation; the secondary set comprises of fissures oriented in ENE-WSW and NNW-SSE directions. The north-western slopes of Mt. Myslivna were declared a natural monument in 1992 due to natural beech woodland vegetation. However, the extent of the protected area does not include qualitatively as well as quantitatively the unique rock landforms on the southern slopes of Mt.

Myslivna. Therefore, this research led to declaration of this site as a ‘Geomorphologically Significant Locality’ (Geomorphosite) in 2010. In addition, a proposal for extension of the natural monument boundary has been submitted.

Keywords Geomorphological inventory · GPS mapping · Rock landforms · Novohradské hory Mts. · Mt. Myslivna · Geomorphosite

Introduction

Landscapes developed on granitic bedrock display a multitude of variegated relief forms. The Czech Republic features many granitic areas (e.g. Jizerské hory Mts., Krkonoše—the ‘Giant Mountains’, the Podyjí area; Fig. 1) with some spectacular landforms of which the Novohradské hory Mts. represent well-preserved granite-based rock landforms. The excellent state of preservation is a result of restricted access prior to 1989 due to its position along the Czech–Austrian border. The minimal exposure to human intervention led to the preservation of complex ecosystems along with their geological and geomorphological background. In the post-1989 era, this unique region was opened to the interests of developers, industrial use as well as recreational activities. At the same time, research interest commenced with detailed geomorphological mapping in order to support declaration of the site as a protected landscape area. So far, this effort has not been successful, however, but has led to several other levels of protection. In 1992, selected localities with rare fauna-flora associations were proclaimed as local protected areas under the Act No. 114/1992 Coll. The north-western slopes of Mt. Myslivna were declared a natural monument due to its natural beechwood vegetation in 1992. However, the extent of the protected area does not include qualitatively as well as

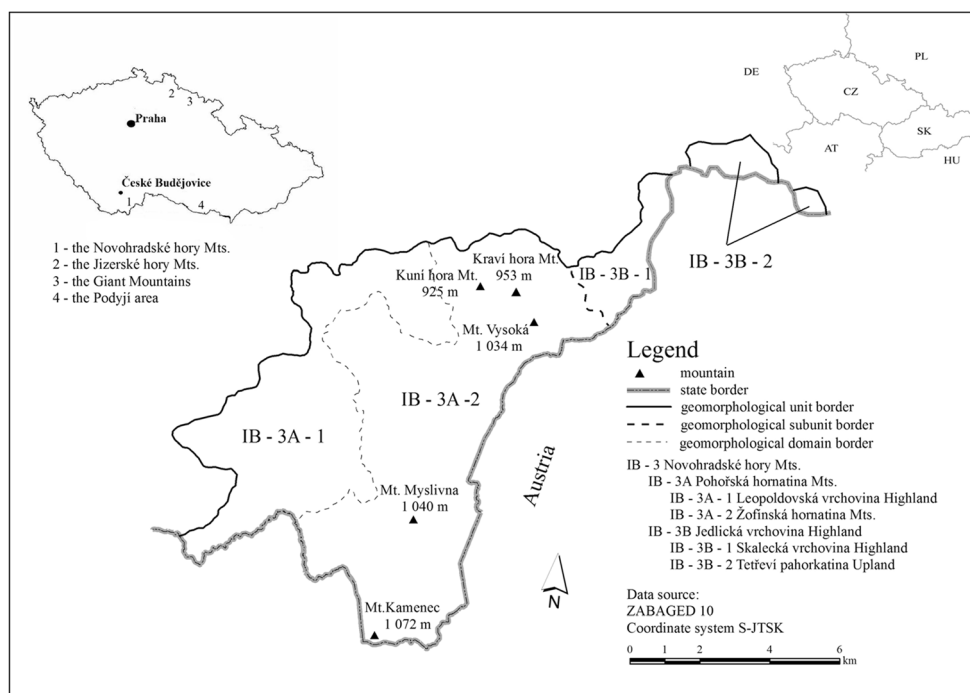
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Fig. 1 Location of the Novohradské hory Mts, the Jizerské hory Mts, Krkonoše (the Giant Mountains) and the Podyjí area within the scope of the Czech Republic and the basic geomorphological structure of the Novohradské hory Mts. (Balatka and Kalvoda 2006; with modifications)



quantitatively the rock landforms on the southern slopes of Mt. Myslivna. In 2000, the Novohradské hory Mts. were declared as a special protection area for Birds under the scope of the programme NATURA 2000, and in 2003, the Novohradské hory Mts. were declared a natural park, which enables the local council to be an important decision-maker in planning processes. However, no protection was based on its abiotic features—it was the main goal of this research to submit protection proposals in order to declare this locality a *geomorphologically significant locality* and to extend the boundary of the natural monument to include the rock landforms on southern slopes of Mt. Myslivna.

Our investigation also helps to complete geomorphological knowledge about the border area mountains in the southwestern and southern part of Bohemia which have possibilities for economic capitalisation (Erhartič and Zorn 2012; Kirchner and Kubalíková 2013) and the development of tourism (Navrátil et al. 2013; Kubalíková and Kirchner 2015).

Study Area

The studied area encompasses the Myslivna locality which is part of the geomorphological unit of the Novohradské hory Mountains. According to the geomorphological classification of the Czech Republic, the Novohradské hory Mts. unit belongs to the Šumava System (Balatka and Kalvoda 2006; Demek and Mackovčín 2006), the greater part of which is in Austria, where it reaches Danube under the name ‘Waldviertel’ (Weber and Duyster 1990). The location of Novohradské hory Mts. within the scope of the

Czech Republic and its basic geomorphological regionalisation is represented in Fig. 1.

The crystalline basement of the Moldanubicum is the oldest geological unit of the territory, dominated by heavily metamorphosed gneisses and migmatites, sometimes with numerous inserts of quartzite, marble, amphibolite, orthogneiss and other materials (Cháb et al. 2008).

From the geological perspective, the area of the Novohradské hory Mts. stretches within the southern part of the central massif—Moldanubian Pluton (Pavlíček 2004). Of the largest extent are late Variscan magmatites of the Central Moldanubian Pluton, represented by several types (e.g. Weinsberg-type granite, Mrákotí-type granite) and partly covered by cordierite gneisses to nebulitic migmatites, which are the remains of the original pluton’s mantle (Heřmánek and Matějka 1998).

The largest distribution of the medium-grained biotitic granite, referred to as the Weinsberg-type granite, within the southern part of the Central Moldanubian Pluton is located in the Novohradské hory Mts. (Staník 1991; Vrána 1987; Cháb et al. 2008). It is widespread (e.g. forming the greater area of the municipality of Pohoří in Šumava) and also forms the massif of Mt. Myslivna and Mt. Kamenec and the massif of Mt. Vysoká located further to the north.

The basic soil types in the Novohradské hory Mountain are cambisols, cryptopodzols and podzols, gleyish cambisols and pseudogleys, gleys and organosols (according to the nomenclature system of Němeček et al. (2001)), with the most important being cambisols and cryptopodzols. Cambisols are among the most common soil types in the mountain range. They are formed from slope sediments of all solid rocks,

mainly in the areas with rather large slopes. Cryptopodzols dominate the peak areas of the mountain range which display different subtypes of poorly developed soils (Šefrna 2004). Due to the frequency of rocky outcrops, rock fields and other accumulations of bedrock material, cryptopodzols are poorly developed and often transformed into various types of ranker soils.

The basic relief of the Novohradské hory Mts. has characteristic elements of fault-block mountain range with delimitations marked strongly by erosion, whereas it is also clearly polygenetic. It is possible to find recent forms (rounded blocks of different size, alcoves, grooves), as well as fossil forms preserved in granite (exfoliation joints, tors, frost-riven cliffs, etc.) (e.g. Rypl 2013).

Aim of Study

The aim of this study was to undertake a geomorphological inventory of granitic landscape rock landforms at the selected locality and, where there was a confirmed presence of qualitatively as well as quantitatively significant rock landforms, to propose a form of protection under the nature protection system of the Czech Republic. Similar inventory studies have been previously carried out in geologically and geomorphologically corresponding areas of the Javořická vrchovina Mts. and Novobystřická vrchovina Mts. (e.g. Votýpka 1964; Tauber 1987). Unfortunately, however, geomorphological data on rock landforms are missing for the Austrian part of the Novohradské hory Mts.

Methodology

Methods of detailed geomorphological mapping were used (Demek et al. 1972; Smith et al. 2011), including GPS mapping (Condorachi 2011; Smith et al. 2011; Voženílek et al. 2001) and the establishment of a geomorphological inventory (e.g. as in the works of Kirchner and Roštínský (2007), Kirchner and Kubalíková (2011) and Kirchner and Kubalíková (2013)).

The geomorphological inventory survey of selected localities consisted of descriptions of bedrock and landscape mesoforms as well as microforms in respect to their character and their landscape significance and protection status. Human influence with its negative impact on the abiotic sector of nature has also been considered. The results of the geomorphological inventory are applicable in the area of basic knowledge regarding rare or significant landforms and also in the application area where landscape management arrangements are being proposed in order to protect these landforms or to remove or diminish any negative impact of human activity in the area of interest (Kirchner and Roštínský 2007).

The survey consisted of three phases:

- 1st phase—preparatory works
- 2nd phase—fieldwork
- 3rd phase—final works and evaluation of results

In the first phase, the source materials related to the geological and geomorphological conditions of the area have been evaluated. Recent publications on geological characteristics of the Novohradské hory Mts. have been used (Heřmánek and Matějka 1998; Pavlíček 2004) accompanied by geological maps of 1:50,000 scale which are freely accessible at www.geology.cz. Information about rock form geomorphology was based on older specialised publications as well as more recent ones (Rypl 2010; Rypl et al. 2014; Vítek 1995).

The second phase of the inventory survey was based on field research at Mt. Myslivna. For mapping of wider surroundings, a topographical map of scale 1:25,000 was used, specifically no. 33–311 Pohoří na Šumavě. The fieldwork was based on a detailed geomorphological mapping method which emphasised mapping of structure-denudational and accumulation rock landforms, as discussed by Bezdovová et al. (1985), Demek et al. (1972) and Smith et al. (2011). Simple measuring devices (telemeter HD 150, measuring tape) were used to describe the rock landforms and their properties. For measurements of bedrock structures, a geological compass was used. An important part of the field research comprised photo-documentation. In addition, a detailed GPS mapping using Garmin GPS V Deluxe was undertaken based on Condorachi (2011), Smith et al. (2011) and Voženílek et al. (2001).

The third and final phase of the inventory consisted of field data evaluation with emphasis on rock landforms. All field data contained information about localisation, basic geological description, description of the main landforms, structures, impact of anthropogenic activity and a proposal for protection. Rock landforms of destructional as well as accumulative character were classified terminologically and genetically according to the common geomorphological practice (Demek 1972, 1987; French 2007; Goudie 2004a, b; Summerfield 1991; Thomas and Goudie 2000). The geomorphological map was accompanied by a legend after Létal (1998) which was complemented by key signs missing in the original. Both the geomorphological map and the legend were processed electronically for ArcGIS 9.1 under the ArcView licence.

There are specific and unique reliefs in the Novohradské hory Mts. with many significant localities (e.g. Kraví hora Mt. and Mt. Kamenec, Rypl et al. (2014) and Mt. Vysoká, Rypl (2010)). Mt. Myslivna was selected as a typical illustration locality that contains the key granite landforms.

Geomorphological Inventory at Mt. Myslivna (1040 m a.s.l.)

Location

Mt. Myslivna is the second highest peak of the Czech part of the Novohradské hory Mts. It is located 3.5 km to the north-west of Pohoří na Šumavě, within the settlement of the same name. In a geomorphological hierarchy, it is a part of the geomorphological district of the Žofínská hornatina Mts., which belongs to the geomorphological Pohořská hornatina Mts. subunit and that in turn to the Novohradské hory Mts. geomorphological unit (Demek and Mackovčín 2006; Balatka and Kalvoda 2006) (Fig. 1). It represents the highest peak of a large mountain range extending in a NNW-SSE to NW-SE direction, forming the watershed between Pohořský potok stream and the river Černá and river Lužnice. The south-western slope of Myslivna and its entire massif are drained by tributaries of the Pohořský potok stream and south-eastern to north-eastern slopes by tributaries of the river Lužnice, and the northern slope is the site of Huťský potok stream, a tributary of the river Černá. Among the most important soil types at the Mysivna locality are cambisols, podzols and cryptopodzols. Mt. Myslivna is afforested predominantly by spruce monoculture. On the north-western slope at an altitude of 950 to 1030 m is the Myslivna nature reserve (with an area of 14 ha), representing the remnant of a native vegetation of florid beechwood and acidophilous scree beechwood with sycamore maple.

Geology

The geology of the study area of the Novohradské hory Mts. is not very varied. Late Variscan migmatites of the Central Moldanubian Pluton reach the widest extent. They are formed by several granitoid types (the Weinsberg- and Mrákotín-type granites), granodiorite (Freistadt type), which are partially covered by cordieritic gneisses to nebulitic migmatites representing a remnant of the original plutonic mantle. The area of Mt. Myslivna and its vicinity is formed by the Weinsberg-type granite (Heřmánek and Matějka 1998; Pavlíček 2004).

Characteristics of Main Landforms

The summit of Mt. Myslivna forms an approximately 1-km-long watershed ridge which is elongated in the NNW-SSE to NW-SE direction. There are erosion-denudational slopes inclined at 10–20° at their apex. The eastern part of the ridge is adjoined by an erosion-denudational slope with 2–5° inclination, which at the altitude of 990 m changes its inclination to 0–2°. In the northern, upper part of the watershed ridge (1040 m) with an upland cryoplanation platform, there is a

frost-riven cliff 5 m in height and 10 m length developed on the western edge. The front of the cliff is oriented to the west and beneath it a rock blockfield is developed (with dimensions of 460 × 160 m). In the uppermost part, there are two low exfoliation domes developed in N-S and NE-SW direction. The N-S dome is 15 m long and 5 m high; the second dome bears more pronounced signs of cryogenic erosion, mainly in the NW side, which is more distinctive and higher compared to the opposite side. This dome is 30 m long and up to 6 m high.

The southern part of the watershed ridge, where the second summit of Mt. Myslivna with altitude of 1025 m is developed, is richer in rock landforms. The uppermost part is formed by an upland cryoplanation platform with a relic of tor (Fig. 2). Dimensions of the platform are 450 × 100 m and of the tor 8 × 5 m with up to 2 m height. Approximately, 30 m westerly from the relic of the tor, in the erosion-denudational slope with 10–20° inclination, a frost-riven cliff (12 × 5 m) is developed. A blockfield, 470 m long and 180 m wide, spreads below this cliff. In the rock pile, around 60 m below the frost-riven cliff resides a tor on a slope 10 m high, accompanied by 15 m long and 8 m high frost-riven cliff.

The most interesting rock landforms at this site are located at the southernmost tip of the upland cryoplanation platform. These include two castle koppies, which are in places eroded to tor shape. The longer of the castle koppies has an orientation almost corresponding with the orientation of the peak ridge (NNW-SSE), and the second castle koppie is then oriented in a NNE-SSW direction. The southern tips of both castle koppies are joined—therefore, it is presumed that in the past, they formed one massive complex. The uppermost sections of the castle koppies probably represent an original topographic surface, which is also supported by the fact that the peak of the northern tip of the longer castle koppie is approximately at the same altitude as the relic of tor on the



Fig. 2 The relic of the tor on the southern top plate of Mt. Myslivna (photo Jiří Rypl)

cryoplanation platform mentioned above. The castle koppie oriented in the NNE-SSW direction is 60 m long, approximately 30 m wide and up to 15 m high. The south-eastern wall of this koppie transverses into steeper part of the erosion-denudational slope with 10–20° inclination. The castle koppie elongated in the direction of the peak ridge is around 150 m long, 20 m wide and 15 m high. Erosion is more pronounced in its upper northern section, where several tors are formed (map illustrates only the koppie, exact positions of all forms would be difficult to take and would make the map cluttered due to its scale). One of the tors lays within the line of the koppie, forms its northern edge and its shape is close to a rock tower, with its height significantly exceeding the length and width. Another two tors, formed in close proximity to the western side of the castle koppie, exhibit similar characters.

Based on a development scheme in the Czech territory, the Paleogene planation surface was developed owing to tropical weathering; a weathered mantle (mostly kaolinitic often than 100 m thick) was created (Czudek and Demek 1970). Owing to neotectonic movements, the territory was uplifted and weathering mantles were removed; the basal surface was

exposed and a younger planation surface of etchplain type developed. The geomorphic evolution of the studied area was accomplished in two stages. On the exposed basal surface of weathering, some resistant rocks stood out as isolated rock formations and tor groups—castle koppies. These landforms were then gradually remodelled by cryogenic processes in the Pleistocene (Czudek 2005).

Existence of these shapes is an evidence of intensive cryogenic erosion in the Pleistocene, when one massive unit led to preservation of resistant sections. Rock landforms are accompanied by numerous rock ledges and laths in the entire locality.

The distribution of the landforms at Mt. Myslivna is illustrated in Fig. 3.

Character of Rock Structures

There were 171 measurements of fissure systems taken at Mt. Myslivna (Tables 1 and 2) which were plotted into a rose diagram (Fig. 4). These measurements represent an almost ideally developed regular fissure system. Fissures with NE-SW (40°) orientation dominate and are accompanied by

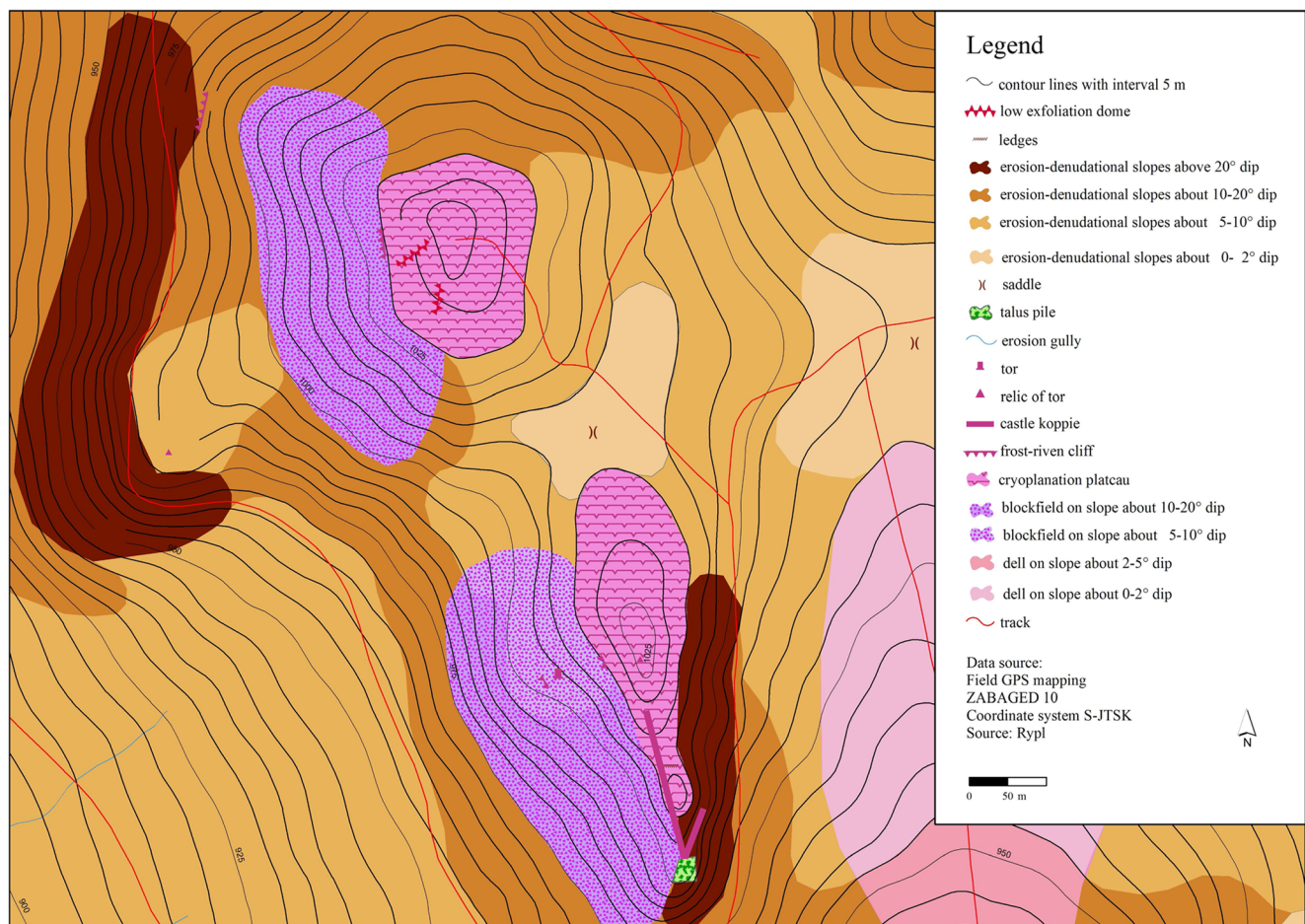


Fig. 3 Geomorphological map of Mt. Myslivna source: Rypl (2013)

Table 1 Measurements of fissure system in the range of 0–90° orientation at Mt. Myslivna

Orientation	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
No. of measurements	6	4	6	10	19	13	9	15	8	7

Source: Rypl (2013)

almost perpendicular set of fissures (NW-SE, with prevailing 130° orientation). Orientation of these massive and morphologically distinct fissures, some of which participate in partitioning of cryogenic relief mezofoms into distinctive units, was postulated to represent the primary fissure system. Secondary systems are then formed by a set of fissures oriented in 70°, respectively in 160° direction. The major fissure systems were established during the Variscan orogeny and subsequently reactivated by Saxonian tectonics in the Cenozoic (Holubec 1990; Kopecký 1983).

Impact of Anthropogenic Activity

Mt. Myslivna lies outside of the reach of the main tourist hiking trails. There is no significant overall trampling nor any considerable destruction of soil cover. An exception is the main peak of Mt. Myslivna, where a non-compacted forestry track exists but is accessible only to vehicles with an access permit. In addition, there is a lodge situated on the peak owned by the state enterprise Woods ČR, used predominantly by forest workers and rented for recreational purposes. The locality of Mt. Myslivna is also among the possible sites considered for the construction of an observatory in South Bohemia, mainly due to its minimal light pollution.

During the ‘Iron curtain’ era, the Novohradské hory Mts. were located within a several-kilometre wide border zone, that also served as a military region and training ground for border patrols. Abandoned military dormitories, trenches and firing range, as well as remnants of watchtowers and barbed wires date from this era (Rypl 2013), although none of these military features have been discovered at Myslivna.

Despite its remoteness, the locality is accessible by car on reinforced forestry tracks. In spite of extensive spruce monoculture, which is full-grown in places, the individual relief mesofoms and microfoms are relatively well visible.

Protection Proposal of Rock Landforms

The regional administration of the South Bohemian region declared the Novohradské hory Mts. as a nature park in 2003. In 1992, the north-western slopes of Myslivna were

declared a national monument with the subject of conservation being natural vegetation of beechwoods and transitions to acidophilous spruce beechwoods (Matoušková 2004). The extent of the nature monument as it is declared, however, does not provide sufficient protection for the prominent rock landforms (mainly castle koppies, tors, frost-riven cliffs) located in the southern section of the Myslivna ridge. Therefore, based on this study, Myslivna was declared in 2010 as a geomorphologically significant locality (i.e. geomorphosite) by the Czech Geological Survey. The Czech Geological Survey has submitted a proposal to the Ministry of Environment for expansion of the nature monument boundary to incorporate these distinctive geomorphological phenomena.

Conclusions

The use of a geomorphological inventory has led to new discoveries of landscape micro- and meso-landforms at localities that had been, prior to 1989, inaccessible to any form of scientific research. As a consequence, the geomorphological unit of the Novohradské hory Mts. had been insufficiently geomorphologically explored as the state border between the Czech Republic and Austria passes through the studied area which was part of the ‘Iron Curtain’ during the ‘Cold War’, meaning that it was virtually inaccessible. As a result, no intensive anthropogenic activity took place in the area during this period and the rich diversity of nature was preserved.

This area also deserves increased attention for other reasons other than a particular diversity of relief. The first reason is a progressive inclusion of Czech protected areas in the system of nature protection of the European Union. The landscape area of the Novohradské hory Mts. with its variety of aesthetic and natural values is protected by law no. 114/1992 in the category of the ‘Natural Park’. Secondly, it is anticipated that there will be interference with the natural environment due to the development of many investment projects, which are expected with post-1989 regional development, particularly in the area of tourism. From these reasons, this area has become the target of multilateral and necessary scientific

Table 2 Measurements of fissure systems in the range of 100–180° orientation at Mt. Myslivna

Orientation	100°	110°	120°	130°	140°	150°	160°	170°	180°
No. of measurements	7	6	8	17	6	10	12	8	6

Source: Rypl (2013)

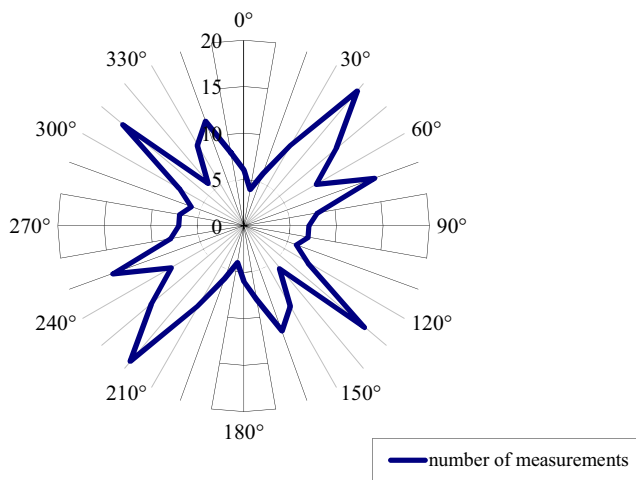


Fig. 4 Rose diagram of fissure system at Mt. Myslivna. Source: Rypl (2013)

research (e.g. Malíček and Palice 2013; Rypl 2010; Rypl et al. 2014; Štykar 2005).

During the mapping and fieldwork, an important number of cryogenic rock landforms were identified (Traczyk and Migoń 2000). Specific landforms generated by frost weathering and cryoplanation include tors, frost-riven cliffs, castle koppies, blockfields, cryoplanation surfaces and terraces.

The completion of this survey is important for any declaration of the area as a protected landscape Area which needed more detailed geomorphological research. In 2005, the Czech Government refused to approve the *protected landscape area* declaration, and as a result, additional research was carried out, including a detailed GPS mapping and geomorphological inventory. The aim was to provide more protection for the most interesting localities of the Novohradské hory Mts. Mt. Myslivna is one of these localities (when viewed from the aspects of basement and meso- and micro-landforms). An attempt was also made to characterise structural elements and the influence of human activities. Novel methods were finally proposed for the conservation of the rock landforms.

The north-western slopes of *Mt. Myslivna* were declared the *Natural Monument* due to its natural beechwood vegetation in 1992. However, the extent of the protected area does not include qualitatively, as well as quantitatively, rock landforms on the southern slopes of Mt. Myslivna. This research, therefore, has led to declaration of this site as a geomorphologically significant locality (i.e. ‘Geomorphosite’) in 2010. Mt. Myslivna is also recorded in the system of the Czech Geological Survey as a *geologically significant locality*. Furthermore, a proposal for extension of the natural monument boundary has also been submitted (Gürtlerová 2010).

Other localities such as Kraví hora Mt., Mt. Vysoká (Rypl 2010) and Mt. Kamenec (Rypl et al. 2014) are also precious examples of relief developed on granite, and therefore, more extensive protection of the entire area is important, in addition to the national parks of Podyjí and Krkonoše which have

already been declared and the protected landscape area of the Jizerské hory Mts.

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