

other sandstone areas in Central Europe to find out general patterns of bryophyte distribution and phytosociology.

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General characteristics of the vascular flora and geobotanical division of the Góry Stołowe Mountains, Sudety Mts. (Poland)

Krzysztof Świerkosz¹

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Nomenclature: species: Mirek et al. (2002), plant communities: Matuszkiewicz (2001)

Introduction

The relatively small area of the Góry Stołowe Mts. (about 180 sq. km) is highly differentiated, both geologically and climatically. This abiotic differentiation creates many kinds of habitats, available for various ecological groups of plants, which occur in the same type of area. Detailed analysis of the distribution of plants reveals an interesting pattern and provides grounds for a division of the whole range into smaller geobotanical units.

Objectives and methods

The area of the Góry Stołowe Mts. was divided into a 1 km square grid, according to the topographic maps in the scale 1: 25 000. In each square the full list of vascular plant taxa was recorded. Altogether, more than 49 000 records were made, in which each taxon is characterised by the square number, description of the site, altitude, form of the terrain, inclination, geographical exposure and the level of the habitat hemeroby. More than 450 phytosociological relevés were made in order to document the differentiation of plant communities. The distribution of

vascular plants and the plant communities was analysed, and, on this basis, different geobotanical units recognised.

Physiography of the study area

The area under study includes the Góry Stołowe Mts. massif and the adjacent intermountain basins. The Góry Stołowe Mts. are situated in the core of the Central Sudety, and can be divided into four regions: Tableland, Wzgórza Lewińskie Hills (north part), Duszniki and Kudowa Depressions (Staffa 1992). This diversification is caused by the complex geological structure of the area, which includes formations of effusive rocks (granodiorites and monzonite granites of Kudowa, with calcareous and amphibolite insertions) and sedimentary rocks of the Permian, Cretaceous and Carboniferous periods (Rotnicka 1996).

In the pluviothermal division of Lower Silesia, Schmuck (1960) ranked the Góry Stołowe Mts. with the cool, moderately moist region. The growing season here lasts from 173 to 213 days. The most important factor responsible for the diversification of climatic conditions is altitude. Precipitation increases with altitude (from 650 mm at the foot to 944 mm at 750 m a.s.l.), and the "rain" period is delayed (Schmuck 1960, Kicińska et al. 1999). The spatial distribution of precipitation is also important – the south slopes are favoured, where the precipitation may be 200 mm higher. February is the coldest month (–3°C at 400 m a.s.l.), July is the warmest (16.7 °C). The lack of climatic data from higher altitudes renders it difficult to estimate the direct influence of climate on the diversification of flora. A typical

¹ Museum of Natural History, Wrocław University, ul. Sienkiewicza 21, PL-50-335 Wrocław, Poland, e-mail: krissw@biol.uni.wroc.pl

feature of the microclimate is the occurrence of wide differences in temperature and relative humidity within a small area, which stems from the local diversification of geological forms and their vegetation cover (Kicińska et al. 1999).

The predominant soil types are brown, mostly acid, leached and podzolic. At many sites soil erosion is manifested, which takes place through dissolution and rinsing away of organic-mineral matter, leaf litter drying and mineral degradation of a part of the sorption complex (Kabała et al. 2002).

Results

General characteristics of the flora

Since the beginning of the 19th century 1006 taxa have been recorded from the Góry Stołowe Mts.; this includes 938 taxa currently treated as species, 12 at the rank of subspecies or variety, 3 forms and 53 hybrid taxa. The research carried out in 1990–2003 confirmed the occurrence of 868 taxa, which include 820 species, 9 subspecies, 1 variety and 38 hybrids (15 fixed and 23 spontaneous). Some of the 138 recently unconfirmed taxa should be considered as extinct, whereas the remaining ones as misidentifications since there is no evidence material (Świerkosz

2004). Unconfirmed are also 11 spontaneous hybrids and 9 ephemerophytes. At least six species were mistakenly reported.

The taxa presently occurring in the Góry Stołowe Mts. belong to 96 families and 389 genera. At present the most abundant are the families *Asteraceae* (92 taxa), *Rosaceae* (73 taxa) and *Poaceae* (71 taxa). From 30 to 45 taxa in each of the families *Fabaceae*, *Salicaceae* (many hybrids), *Brassicaceae*, *Cyperaceae*, *Scrophulariaceae* and *Lamiaceae* are present. The most abundantly represented genera are *Carex* (33 species and 1 hybrid), *Salix* (12 species and 10 hybrids) and *Galium* (12 species).

The occurrence of 77 montane taxa (Figure 1), 42 xerothermic taxa (Figure 2) and 157 anthropophytes (Figure 3) has been confirmed.

The vertical vegetation limits

Based on the collected data on the distribution of particular species and groups of vascular plants, the borders of the vegetation layers in the Góry Stołowe Mts. range have been established. Indications are provided by the vertical distribution of species which are locally submontane (not exceeding the altitude of 650 m a.s.l.) and ones locally montane (not descending lower than 600 m a.s.l.) in character.

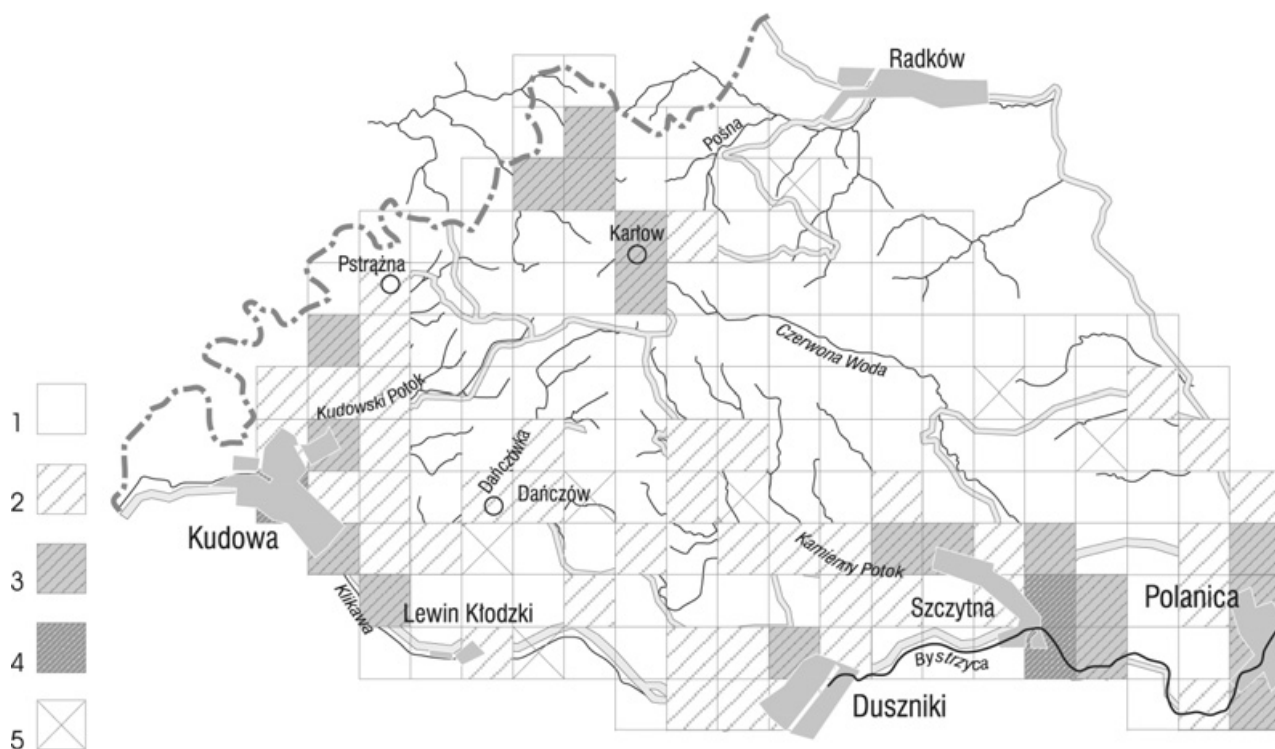


Figure 1. (top) Number of mountain species recorded in investigated squares. Explanation: 1: 1–9 species; 2: 10–20 species; 3: 21–30 species; 4: 31–40 species; 5: squares insufficiently known

Figure 2. (below) Number of xerothermic species recorded in investigated squares. Explanation: 1: 0–1 species; 2: 2–3 species; 3: 4–9 species; 4: 10 and more species; 5: squares insufficiently known



Figure 3. Number of anthropophytes recorded in investigated squares. Explanation: 1: 1–10 species; 2: 11–20 species; 3: 21–30 species; 4: 31 and more species; 5: squares insufficiently known



Submountain zone (350–600 m)

In the light of a floristic analysis, the border between the *submountain* and the lower *mountain* zone in the Góry Stołowe Mts. runs between 580 and 620 m a.s.l. An exception is the Grodzca Massif, where, owing to specific microclimatic conditions and the character of parent rocks, the border of the distribution of *lowland-submountain* flora is locally higher. This border is characterised by species locally connected with the foothill, which form two most important groups:

- xerothermic: *Chamaecytisus supinus*, *Genista germanica*, *Vicia sylvatica*, *Viscaria vulgaris*, *Brachypodium pinnatum*, *Bromus erectus* and 20 further species (compare e.g. Zemanek 1991).
- forest species from the alliance *Carpinion* (*Stellaria holostea*, *Tilia cordata*, *Dactylis polygama*, *Corydalis intermedia*), the class *Quercio-Fagetea* and the order *Fagetalia* of *lowland-submontane* character (*Hedera helix*, *Hepatica nobilis*, *Tilia platyphyllos*, *Polygonatum multiflorum*, *Melampyrum nemorosum*, *Euonymus europaea*, *Lonicera xylosteum*, *Campanula rapunculoides*, *Cornus sanguinea*, *Crataegus laevigata*).

Also hydro- and helophytes (*Alopecurus aequalis*, *Batrachium aquatile*, *Bidens tripartita*, *Iris pseudacorus*, *Lycopus europaeus*, *Rorippa amphibia*, *Sparganium erectum*) as well as certain species of fertile and moist meadows (e.g., *Selinum carvifolia*, *Euphorbia esula*, *Saxifraga granulata*, *Betonica vulgaris*, *Scutellaria galericulata*, *Juncus inflexus* and *Salix rosmarinifolia*) are linked with the *submontane* zone. These groups are too poorly documented to regard the information collected as representative, although these same species determine the range of the foothills in the group of Pilsko (Białecka 1982) and in Gorce Mts. (Kornaś 1955).

The number of *montane species* in the foothill layer slowly increases to reach 9.2 % of the flora of this belt at an altitude of 600 m a.s.l. This value agrees with the proportion of *montane species* in the *submontane flora* obtained by Białecka (1982). With an increase in altitude the share of anthropophytes and xerothermic species drops (from 12 % to 9 % and from 4.5 % to 3.4 % respectively).

Among the plant communities characteristic of this storey and not entering the lower mountain zone, 12 phytocoenoses of different rank can be mentioned (Świerkosz 1999, 2004).

The view presented herein does not agree with the so far accepted division of the Sudety into altitudinal storeys. That division goes back as far as the pre-war times (e.g., Pax 1927), and its criteria were not clearly stated. The methods employed today, based on an analysis of vertical distribution of particular species, enable the verification of the former opinions. In the massif of Śnieżnik Kłodzki Mount, Szelağ (2000) observes a similar relationship, interpreting the belt between 530 and 600 m a.s.l. as a transitional zone, “in which the border between the *submountain* and the *lower mountain zone* becomes at many places hardly discernible”. Similar conclusions have been

drawn by Barć et al. (1995) with regard to the massif of Babia Góra Mount.

Lower mountain zone (600–850)

The majority of the Góry Stołowe Mts. is situated within the lower *mountain zone*, which ranges from ca 600 m a.s.l. to the foot of the highest peaks. Plants which are clearly connected with the Góry Stołowe Mts. lower *mountain zone* belong to two altitude groups: strict locally *montane* (not descending below 600 m a.s.l.) and locally *montane* (only sporadically found below this border). They include species of:

- *Nardus* grasslands and *montane meadows*: *Arnica montana*, *Euphrasia coerulea*, *Galium saxatile*, *Gentianella ciliata*, *Gymnadenia conopsea*, *Cirsium helenioides*;
- coniferous forest: *Blechnum spicant*, *Homogyne alpina*, *Lycopodium annotinum*;
- *montane tall herb communities*: *Cicerbita alpina*, *Dactylorhiza fuchsii*, *Ranunculus platanifolius*, *Salix silesiaca*, *Senecio rivularis*, *Streptopus amplexifolius*, *Veratrum lobelianum*;
- sandstone hilltops and peat bogs of the Miocene plateau, such as *Drosera rotundifolia*, *Empetrum nigrum*, *Carex echinata*, *Andromeda polifolia*, *Carex lasiocarpa*, *Ledum palustre*, *Pinus x rhaetica*, *Juncus filiformis*, *Vaccinium uliginosum* and others.

Among the groups distinguished, a particularly high diagnostic value is that of herbaceous taxa, species of rock habitats connected with marl, and ones of *Nardus* grasslands and *montane meadows*. Many species of peat bogs have a very clear lower limit of distributional range, which in the study area is of edaphic character. Similar borders of peat-bog vegetation have been found also in other mountain ranges of Poland. In the West Sudetes, Boratyński (1991) has defined *Vaccinium uliginosum*, *Oxycoccus quadripetalus* and *Empetrum nigrum* as “locally montane”. Białecka (1982) mentions an identical situation in the group of Pilsko Mount, as does Szelağ (2000) with respect to the Śnieżnik Kłodzki Mount.

Plant communities particularly typical of this belt are tall herbs communities from the class *Betulo-Adenostyletea* (only *Petasitetum albi* occurs in the foothills), *Nardus* grasslands (mountain association of *Violion caninae*), “the Sudety orchid meadow” representing the alliance *Polygono-Trisetion* (Świerkosz 1999), *Caricetum fuscae*, *Cystopteridetum fragilis* and *Lunario-Aceretum* (along streams sporadically descending below 600 m a.s.l.).

Upper mountain zone (850–919 m)

The border, clearly distinguishable in floristic analysis between 800 and 850 m a.s.l., is characterised by numerous specific features. A rapid decline of plant species diversity and percentage of archeophytes, the absence of xerothermic species and a stepwise increase in the proportion of *montane species* (from 12 to 20 %) are noted here.

Another typical character of the upper mountain zone are the plant communities occurring here. *Empetrum nigrum* sandstone

communities on the exposed rocks of Mount Skalniak, Szczeliniec and Narożnik can be interpreted as strongly impoverished communities representing the alliance *Loiseleurio-Vaccinion*. In the highest sections of the Góry Stołowe Mts. there are also fragments of pine-spruce forest (Świerkosz 1999), with an admixture of relic populations of *Pinus mugo*, *Betula pubescens* ssp. *carpatica*, *Pinus x rhaetica* and *Pinus sylvestris*. This community is defined as *Betulo carpaticae-Pinetum* (Mikyška 1970, Passarge 1981, Świerkosz 1994, 1999) and considered as endemic in the Sudetes and Rudawy Mts., although its syntaxonomic position has not been clarified.

Also, the occurrence in the Góry Stołowe Mts. of the association *Calamagrostio villosae-Piceetum* (R. Tx. 1937) Hartm. ex Schluter 1966 has been indicated many times (Szmajda 1979, Pender 1996, Matuszkiewicz 2001, Świerkosz 1999, 2004). Its characteristic species is the moss *Plagiothecium undulatum*, a locally distinguishing one is *Betula pubescens* ssp. *carpatica* and its hybrids with *B. pubescens* ssp. *pubescens*, whereas *Trientalis europaea*, common in spruce forest below 850 m a.s.l., is lacking here.

Floristic distinctness of the highest sections of the Góry Stołowe Mts. was also observed during research on sporozoans. A large group of liverworts, lichens and bryophytes occurring here is composed of high-montane and alpine species (Tobolewski 1955, Szwejkowski 1953, Szmajda 1979), many of them descending considerably lower than the altitudinal border reached by these plants in other mountain ranges.

Geobotanical division

The geobotanical division described here is based on differences found in the distribution of vascular plant taxa having a clearly definable type of distribution range. Based on an analysis of horizontal distribution of vascular plants in the Góry Stołowe Mts., six smaller geobotanical units have been distinguished, which are characterised by specific floristic features (Figure 4). The diversity of the units distinguished can be accounted for by their location, geological structure and management level.

Units connected with the submountain belt

The foothills area of the Góry Stołowe Mts. can be divided into three distinct units: central – connected with the Grodziec Massif, eastern – where species penetrating from the Kotlina Kłodzka Basin are recorded, and western – connected with the Czech Republic territory.

(1) Grodziec Massif

Flora – a characteristic feature is the occurrence of limestone outcrops and steep scarps, on which numerous xerothermic and thermophilous species grow. Only here were found *Orobancha elatior*, *Alyssum calycinum*, *Acinos arvensis*, *Scabiosa ochroleuca*, *Allium vineale*, *Melampyrum nemorosum*, *Veronica teucrium*, *Rosa sherardii*, *Gentianella germanica*, *Primula veris*, *Helianthemum*

nummularium ssp. *obscurum* and *Sanguisorba minor*. This thermophilous flora is accompanied by montane species such as *Phyteuma orbiculare*, *Gymnadenia conopsea* and, sporadically, *Streptopus amplexifolius*.

Topographic features and geological structure – peaks exceeding 800 m a.s.l. (Grodzcyń Mount) of very steep slopes, neighbour with sloping parts (in the Obniżenie Dusznickie Depression) and mild domed hills. This creates a mosaic of habitats with highly variable microclimates. The geological structure of the region is highly diverse (mica-slates with an admixture of limestone rocks and amphibolites, marls, granitoides and red sandstone deposits). Due to specific environmental conditions and long lasting anthropopressure, the borders of the vegetation layers within this unit have risen considerably.

(2) South-eastern foreland and Mount Piekielna Massif

Flora – typical species include *Genista germanica* and *Chamaecytisus supinus* – occurring exclusively here (penetrating from the Kotlina Kłodzka Basin), and *Vicia sylvatica*, which reaches slightly more eastward. A characteristic feature is the occurrence of rich populations of *Astrantia major* and *Galanthus nivalis* and a large colony of montane species which have found favourable habitat conditions in Piekielna dolina Valley (e.g., *Leucojum vernalis*, *Veratrum lobelianum*, *Geranium phaeum*, *Campanula latifolia*).

Topographic features and geological structure – the majority of the substratum is built by Turon sandstone and Permian deposits, and thus the soil is poor or of medium fertility (podzolic and brown leached soils). The predominating forms of the land sculpture are domed and flat, and only sporadically (in Piekielna dolina Valley) are steep rocky slopes encountered. The highest point is 680 m a.s.l.

(3) Obniżenie Kudowy Depression

Flora – this unit is distinguishable by the occurrence of *Bromus erectus* (an absolute concentration of records), *Cerinthe minor*, *Onobrychis vicifolia*, *Falcaria vulgaris*, *Inula salicina*, *Rosa rubiginosa*, *Rosa micrantha*, *Thlaspi perfoliatum* and *Trifolium ochroleucon*. Also, the largest populations of *Arabis hirsuta*, *Orchis mascula*, *Hepatica nobilis*, *Potentilla neumanniana* and *Dactylorhiza sambucina* occur in this region.

Topographic features and geological structure – typical landmarks are hills with steep slopes, rising over the valleys of the Bystra River, Czermnica River and Kudowski Potok Stream. Marls make the substratum. The soils are fertile, with a high content of calcium carbonate.

Units of the lower mountain zone

Within the Góry Stołowe Mts. lower mountain zone two smaller units can be distinguished. They cover central portions of the study area at an altitude of 600–850 m a.s.l.

(1) Tableland Proper

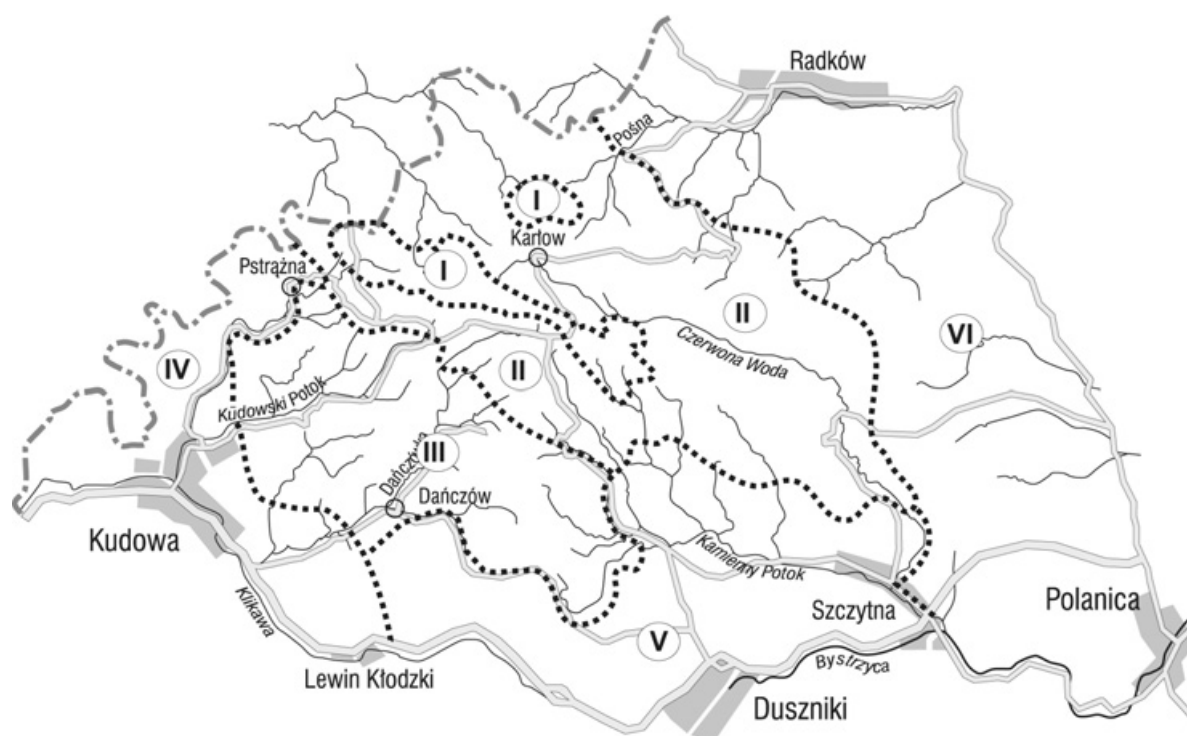


Figure 4. Geobotanical division of the Góry Stołowe Mountains. Explanation: I – Upper Tableland; II – Tableland Proper; III – Northwestern part of the Wzgórza Lewińskie Hills; IV – Obniżenie Kudowskie Depression; V – Grodziec Massif; VI – Southeastern foreland and Mt. Piekielna Massif

Flora – the following species were recorded exclusively within the Tableland: *Arnica montana*, *Euphrasia coerulea*, *Galium saxatile*, *Asplenium viride*, *Cardaminopsis arenosa* ssp. *borbasii*, *Saxifraga decipiens*, *Rumex alpinus*, *Drosera rotundifolia*, *Carex echinata*, *Carex lasiocarpa*, *Eriophorum vaginatum*, *Ledum palustre*, *Oxycoccus palustris*, *Juncus filiformis*, *Andromeda polifolia*, *Homogyne alpina*, *Lycopodium annotinum*, *Pyrola minor*, *Cicerbita alpina*, *Dactylorhiza fuchsii*, *Ranunculus platanifolius*, *Salix silesiaca*, *Senecio rivularis*, *Streptopus amplexifolius* and *Digitalis purpurea*. Many plant communities are limited to the tableland area: *Lunario-Aceretum*, *Sorbo-Aceretum*, *Hieracio-Nardetum*, *Caricetum fuscae*, communities of the class *Betulo-Adenostyletea* and peat associations among others.

Topographic features and geological structure – the terrain is built of marls and the lower layer of sandstone, within the Lower Miocene plateau (between 600 and 800 m a.s.l.). Landmarks include extensive ridge flats sharply delimited from the surrounding terrain by rocky escarpments. The soils are diverse, predominantly brown and podzolic; regosols and peaty soils.

(2) North-western part of the Wzgórza Lewińskie Hills

Flora – strongly deformed, without its own characteristic

species. In particular, many herbaceous and montane species, as well as plant communities typical of the Tableland, are lacking.

Topographic features and geological structure – Kudowa granitoides, hence the majority are acid brown soils. Typical features are isolated, comparatively high peaks (Krucza Kopa, Czarna Kopa and Lełkowa) separated by long valleys of the Kudowski Potok Stream, Czermnica River and their tributaries.

Upper tableland (Upper mountain zone)

The portions of the Tableland situated above the isohypse of 850 m a.s.l. (Skalniak Mt., Szczeliniec Wielki Mt. and Szczeliniec Mały Mt.), which are dominated by natural ecosystems and characterised by a number of distinctive features of topography, geology, pedosphere and climate. In this region the sites of *Empetrum nigrum*, *Betula pubescens* ssp. *carpatica* and *Vaccinium uliginosum* are concentrated, and only here *Solidago alpestris* and *Pinus mugo* are recorded. These differences justify the creation of a distinct unit, particularly when the occurrence of three high-montane plant communities is considered: the Scots pine sandstone forest, the *Empetrum nigrum* sandstone formation and the spruce forest of *Calmagrostio villosae-Piceetum*.

Conclusions

Since the beginning of the 19th century 1006 taxa have been recorded from the Góry Stołowe Mts., including 938 taxa currently treated as species. Currently, the flora of the Góry Stołowe Mts. comprises 868 taxa representing 96 families and 389 genera. Of the taxa noted in pre-war sources, 138 have not been found now. Nearly 12 % of this flora are species having their northern and eastern distribution range limit in Poland, which indicates the southwestern character of the Góry Stołowe Mts. vegetation. The occurrence of 77 montane taxa, 42 xerothermic taxa and 157 anthropophytes has been confirmed. Fifty six plant communities have been recorded, at least in the area of the Góry Stołowe National Park.

Based on the collected data on the distribution of particular species and groups of vascular plants (more than 49 000 data), the borders of the vegetation layers in the Góry Stołowe Mts. range have been established. The border between the submountain

and the lower mountain zone in the Góry Stołowe Mts. was found to be at an altitude of 580–600 m a.s.l.; the highest sections (from 850 m) displaying features typical of the upper mountain zone.

Based on an analysis of horizontal distribution of vascular plants in the Góry Stołowe Mts., six smaller geobotanical units, which are characterised by specific floristic features, have been described (Figure 4).

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The lichen flora of the Bohemian Switzerland National Park (Czech Republic)

Zdeněk Palice^{1, 2}, Štěpánka Slavíková-Bayerová¹, Ondřej Peksa²,
David Svoboda² and Lenka Kučerová³

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Introduction

Lichen species composition of sandstone regions in the Bohemian Cretaceous Basin is unique. Despite relatively low species diversity this area may qualify as a “hot-spot”, boasting the best known and most luxuriantly developed individuals of taxa that are very rare elsewhere in the Czech Republic. Moreover, some lichen species reach their distributional/altitudinal limit here. No lichens are endemic to the region. However, the crustose,

saxicolous lichen *Pertusaria ocellata* is almost confined to the sandstone areas of Central Europe, spreading into the territory of Lower Saxony, northeastern Bohemia and southwestern Poland. Besides this, only a few, single, recent records of this species exist from other distant areas (e.g., Aslan et al. 2002).

Unfortunately, the lichen flora, especially the epiphytes, has distinctly declined in the last century due to atmospheric pollution and acidification. Apparently, also Norway spruce-monoculture forestry management has considerably contributed to impoverishment of the local lichen flora. Some of the microlichen taxa (e.g., most of corticolous *Arthonia* species) possibly vanished a long time ago, well before the lethal influence

¹ Institute of Botany, Academy of Sciences of the Czech Republic, CZ-252 43 Průhonice, Czech Republic, e-mail: palice@ibot.cas.cz; slavikova@ibot.cas.cz

² Department of Botany, Faculty of Science, Charles University, Benátská 2, CZ-128 01 Prague 2, Czech Republic, e-mail: opeksa@seznam.cz; cednik@email.cz

³ CZ-373 33 Hranice 10, Czech Republic