Phytogeographic importance of sandstone landscapes

Handrij HÄRTEL[1,2], Ivana MARKOVÁ[1]
[1]*Institute of Botany, Academy of Sciences of the Czech Republic*
Zámek 1, CZ-25243 Průhonice
hartel@ibot.cas.cz
[2]*Bohemian Switzerland National Park Administration*
Pražská 52, CZ-40746 Krásná Lípa
i.markova@npcs.cz

Keywords: phytogeography; islands; Bohemian Cretaceous Basin; sandstone landscapes

Summary
The sandstone regions – despite many common features (close relationship among relief, microclimate and vegetation, habitat fragmentation, relic character of habitats, high patch dynamics) – vary significantly in their flora. At a large geographical scale, these differences are determined basically by climate (pertinence to various biogeographical regions). At regional level (e.g. Central Europe), the variations can be explained by different combinations of basic factors determining biodiversity: chemistry of the substrata, relief, altitude, microclimate, oceanity/continentality. Generally, sandstone landscapes are characterized by steep environmental gradients, implying a high β-diversity (diversity among habitats) despite the low α-diversity (species richness within a habitat). Therefore, from phytogeograhical point of view, flora of the sandstone regions usually consists of contrasting elements (oceanic vs. continental, montane vs. thermophilous, etc.). Moreover, as the sandstones usually form distinctive islands in the landscape with pronounced refugial environment, the flora is characterized by relic isolation and many exclave elements, recruiting mainly from (sub)-Atlantic (e.g., *Trichomanes speciosum, Hymenophyllum tunbrigense, Kurzia sylvatica, Hypericum pulchrum*) and (boreo)-montane or Arctic-Alpine species (e.g., *Viola biflora, Hygrobiella laxifolia, Anastrophyllum michauxii, Geocalyx graveolens, Lophozia grandiretis, Dicranum majus*).

Introduction

Although a detailed overview of the distribution of sandstone landscapes at European scale, or even over the world, is still missing, there exists at least a basic knowledge of the important European sandstone regions, their geology, geomorphology and biota (Härtel *et al*. in prep. a). These regions vary significantly in their area, age, petrography, morphology and biodiversity. However, differences in the biota of sandstone regions at the European or even global scale are generally determined by the differences in climate, i.e., they can be explained by the pertinence to a particular biogeographical region. Therefore, a phytogeographical comparison of sandstone regions e.g. in Central Europe with those in the Mediterranean is indeed possible, although such comparison would hardly indicate the variation of flora due to different geology and morphology. By contrast, such phytogeographical analyses make more sense in regions with comparable climate, e.g., among sandstone regions within the Central Europe. In such case, phytogeographical differences among individual sandstone regions result from different combinations of basic factors determining biodiversity of sandstone landscapes: chemistry of the substrata, relief, microclimate, altitude, oceanity/continentality. In spite of the pertinence of the sandstone landscapes to various biogeographical regions, their flora and vegetation are determined by some common features resulting from specific geology and geomorphology of the sandstones. These include close relationships among relief, microclimate and vegetation, habitat fragmentation, relic character of habitats, high patch dynamics, and extremely steep environmental gradients. Furthermore, since the sandstone regions as landscape units are usually surrounded by distinctly different landscapes, they form pronounced ecological islands with all the consequences to biogeography (Herben *et al*. in prep.).

The role of sandstone landscapes in phytogeography

Sandstone landscapes, at least in Central Europe, are often considered to be species-poor areas in contrast to other substrata, such as limestones. However, this is true only for quartzose sandstones, not for calcareous sandstones (Buntsandstein), and even in quartzose sandstones just for phanerogams, not for cryptogams. Cryptogams, especially bryophytes and pteridophytes, can occupy the niche of phanerogams on the sandstones (Sádlo et al. in prep.). Species diversity of phanerogams in a sandstone landscape formed by quartzose sandstones can be very low. Only 150–160 phanerogam species are present in some map quadrangles of 2 km^2 in the core zone of the Bohemian Switzerland National Park (Elbe Sandstones). Flora on the quartzose sandstones is thus a good example of how the species diversity does not necessarily respond to the degree of naturalness of an area. However, the low species diversity within a habitat, i.e., α-diversity (Whittaker 1960), is in a sharp contrast with the high diversity among the habitats, i.e., β-diversity. Due to steep environmental gradients, plants of very different ecological groups can be found among very close habitats. Therefore, one of the important phytogeographic features of Central European sandstone regions is an unusual floristic combination of continental and oceanic, thermophilous and boreo-montane, xerophilous and hygrophilous elements. One example might be the Ralsko-bezdězská tabule Plateau in the Czech Republic, where sub-Atlantic species, such as *Hydrocotyle vulgaris, Chrysosplenium oppositifolium, Rhynchospora alba, Teesdalia nudicaulis, Arnoseris minima, Aira praecox, Corynephorus canescens, Trichomanes speciosum* (gametophytes), and continental species, such as *Scabiosa canescens, Astragalus arenarius, Anemone sylvestris, Carex pediformis* subsp. *macroura, Pulsatilla patens, Gypsophila fastigiata*, can be found in one region (Sádlo *et al*. in prep.; Härtel *et al*. in prep. b). Similarly, in the Elbe Sandstones, sub-Arctic-Alpine species, such as *Viola biflora*, and thermophilous species, such as *Centaurea stoebe*, occur at a distance of only few kilometres.

The role of sandstone landscapes as ecological islands is evident in two ways. (i) Due to the pure substrate (in the case of quartzose sandstones), the sandstone region can be characterized primarily in a negative way, i.e., by a high number of vascular plants that are missing on sandstones but present in the surrounding landscape. (ii) Sandstone landscapes as isolated islands with specific relief and microclimate represent a refugial environment, permitting the occurrence of relic species and communities. Many species find their isolated occurrences in sandstone regions, hundreds kilometres away from the nearest localities. Such example

Fig. 1: *Viola biflora*, a sub-Arctic-Alpine element, occurs in the gorges with climatic inversion in the Elbe Sandstones (Saxon-Bohemian Switzerland) at the altitudes of only 130–160 m a.s.l. Photo: Handrij Härtel.

is *Carex pediformis* subsp. *macroura*, a continental element known from the Ralsko-bezdězská tabule Plateau (Czech Republic), which has their closest occurrences in the European part of Russia. These exclave elements can recruit from different species groups (continental, oceanic, (boreo)-montane etc.); however, two species groups are particularly significant for Central European sandstone regions due to the specific microclimate with deep, wet gorges, characterized by strong climatic inversion: (sub)-Atlantic and (boreo)-montane species. (Sub)-Atlantic elements represent a significant proportion of the flora of Central European sandstone regions. They include *Chrysosplenium oppositifolium, Corynephorus canescens, Galium saxatile, Hypericum humifusum, H. pulchrum, Juncus acutiflorus, J. filiformis, J. squarrosus, Lathyrus linifolius, Litorella uniflora, Lotus uliginosus, Luronium natans, Ornithopus perpusillus, Potentilla anglica, Teesdalia nudicaulis,* and *Vulpia myuros,* among bryophytes e.g. *Kurzia sylvatica, Plagiothecium undulatum.* Some Atlantic species find the easternmost limit of their distribution in the Central European sandstone regions: *Hymenophyllum tunbrigense* (extinct in the Elbe Sandstones) or gametophytes of *Trichomanes speciosum*, known from almost all sandstone regions in the Bohemian Cretaceous Basin, with the easternmost occurrence in Poland (Krukowski & Świerkosz 2004). Similarly, sandstone regions are important as exclave occurrences of some (boreo)-montane, or even (sub)-Alpine or (sub)-Arctic-(sub)-Alpine species in landscapes in the colline or submontane belt. Among the Central European sandstone regions, the Elbe Sandstones occupy the lowest altitudes, so the species as *Viola biflora, Streptopus amplexifolius, Huperzia selago, Trienatlis europaea, Picea abies, Lycopodium annotinum*, the liverworts *Hygrobiella laxifolia* (Müller 2003), *Anastrophyllum michauxii, Geocalyx graveolens, Lophozia grandiretis,*

Harpanthus scutatus, and the mosses *Dicranum majus, Tetrodontium repandum* and *T. brownianum* can be found at extremely low altitudes of 150–200 m a.s.l. Some European montane species might probably find their absolute altitudinal minimum of distribution in this region (e.g. *Lonicera nigra*), or at least a minimum in Central Europe in the case of species with Arctic-Alpine or boreal distribution (e.g. *Hygrobiella laxifolia* (Müller 2003), *Viola biflora*).

References

Härtel H., Adamovič J. & Mikuláš R. (in prep. a). - General overview of European Sandstone Landscapes, in Härtel H., Cílek V., Herben T., Jackson A. & Williams R. B. G. (eds), Sandstone Landscapes.

Härtel H., Sádlo J., Świerkosz K. & Marková I. (in prep. b). - Phytogeography of the sandstone areas in the Bohemian Cretaceous Basin, in Härtel H., Cílek V., Herben T., Jackson A. & Williams R. B. G. (eds), Sandstone Landscapes.

Herben T., Härtel H., Trýzna M. & Marková I. (in prep.). - Biota in sandstone habitats: sandstones as ecological islands, in Härtel H., Cílek V., Herben T., Jackson A. & Williams R. B. G. (eds), Sandstone Landscapes.

Krukowski M. & Świerkosz K. 2004. - Discovery of the gametophytes of *Trichomanes speciosum* (*Hymenophyllaceae*: *Pteridophyta*) in Poland and its biogeographical importance. Fern Gaz. 17(2): 79-85.

Müller F. 2003. - *Hygrobiella laxifolia* (Hook.) Spruce – eine neue Lebermoosart für die Tschechische Republik. Bryonora, Praha 31: 10-12.

Sádlo J., Härtel H. & Marková I. (in prep.). - Diversity of flora and vegetation of the sandstone areas in the Bohemian Cretaceous Basin, in Härtel H., Cílek V., Herben T., Jackson A. & Williams R. B. G. (eds), Sandstone Landscapes.

Whittaker R. H. 1960. - Vegetation of the Siskiyou Mountains, Oregon and California, Ecological Monographs 30: 279-338.

Résumé de la présentation

Importance phytogéographique des paysages de grès

<u>**Mots-clés:**</u> phytogéographie; îles; bassin crétacé de Bohème; espèces atlantiques; microclimat

Comparés à d'autres substrats les paysages gréseux constitués de grès quartzeux acides sont la plupart du temps considérés comme des secteurs pauvres en espèces. Ceci est bien souvent valable pour les phanérogames, mais cependant pas pour les cryptogames.

Les paysages de grès, îlots à environnement sensiblement différent, revêtent une grande importance phytogéographique en hébergeant nombre d'espèces isolées, principalement (1) des espèces (sub-) atlantiques (du à un microclimat humide dans les gorges), par exemple *Trichomanes speciosum*, *Hymenophyllum tunbrigense*, *Chrysosplenium oppositifolium*, et (2) des espèces montagnardes (ou même alpestres, du à l'inversion climatique), par exemple *Viola biflora*, *Streptopus amplexifolius*, *Hygrobiella laxifolia*, *Anastrophyllum michauxii*, *Lophozia grandiretis*.

Les régions de grès du bassin crétacé de Bohème (République Tchèque, Allemagne, Pologne), en dépit de beaucoup similitudes, varient de manière significative dans leur flore. Ces différences phytogéographiques résultent d'une combinaison différente des facteurs de base déterminant la biodiversité : chimie, relief et climat (altitude, microclimat, océanité / continentalité). Les paysages de grès sont caractérisés par de forts gradients environnementaux de sorte qu'en dépit d'une diversité α inférieure (richesse d'espèces d'un habitat) on y trouve une diversité β élevée (diversité parmi des habitats).

Par conséquent, du point de vue phytogéograhique, la flore d'une région de grès se compose habituellement d'éléments contrastants (océanique / continental, montagnard / thermophile, etc.).