UNDERGROUND SPACES IN BOSONOŽSKÝ HÁJEK NATURE RESERVE AND THEIR GEOEDUCATION IMPORTANCE

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Abstract
Bosonožský hájek Natural Reserve (Brno, South Moravia) is a very important site from the Earth Science point of view, however, its geodiversity values have been rather overlooked and omitted in the past (the object of legal protection is the occurrence of well-preserved forest ecosystems and endangered species). In the last decades, a series of field work and geophysical measurements has been carried out and the Earth Science phenomena have been identified and described here. These are represented by a dense network of gullies that developed in Pleistocene loess and that are both of natural and anthropogenic origin (some gullies probably developed along the old paths) and specific underground spaces (so called dugouts). Until now, the dugouts in South Moravia have been investigated mainly by archaeologists and those in Bosonožský hájek NR have not been described in detail yet. This brief contribution brings new information about three underground landforms and their possible relationship to the age and development of the gullies. The possibility of different interpretations of the origin of these specific landforms can be considered an opportunity in the field of Earth Science (geosciences) education and as an interesting complement of tourist and recreational activities on site.

Key words: gully network, loess, dugouts, Earth Science education

Introduction
Bosonožský hájek Natural Reserve (NR) is an area situated in the western part of Brno City (South Moravian Region, Czech Republic). From the nature conservation point of view, it is a very valuable area: the subject of the legal protection (NR declared in 1985) are forest ecosystems (ancient forests) including the thermophilic plant species. Thanks to its lithological and morphological diversity, the area is also significant from the Earth Sciences point of view. Specific features are represented by both natural and anthropogenic landforms: especially gullies (both of natural origin and related to or induced by anthropogenic activity) and underground spaces (dugouts) that have been dug in the Quaternary loess. The research on the origin and distribution of these landforms has been carried in the last years and the possible interpretations provide an interesting contribution to the knowledge of the relationships between geodiversity, biodiversity, culture and economic activities in the area.

Material and methods
Geomorphologically, Bosonožský hájek NR belongs to the Bobravská vrchovina Highlands (Figure 1). It is practically a flat ridge of 360 – 370 m.a.s.l. that inclines towards East and South-east. The ridge is built of Proterozoic granodiorites (cca 590 Ma) of the Brno Massive and the slopes are covered with Quaternary loess (up to 9 m of thickness).
In the loess and loess loams, a dense network (or system) of gullies originated being a subject of multidisciplinary research in the last decades (Münster 2005, Buček 2008, Kyclová 2010, Kirchner et al. 2011). These gullies have been researched by using numerous methods: field work, geomorphological mapping, drilling, non-destructive geophysical methods, geoarchaeological surveys, GIS methods, analysis of historical maps and LiDAR (Kirchner et al. 2018). In the south-eastern part of the study area, the system of underground spaces (dugouts) is situated. For the analysis of their distribution, the geomorphological mapping and 3D laser scanning was used (ground laser scanning using the Leica C10/BLK360 device in combination with the Leica GS08 GNSS receiver for linking to the S-JTSK/Bpv coordinate system). Based on this, a picture of the distribution and structure of the dugouts was acquired.

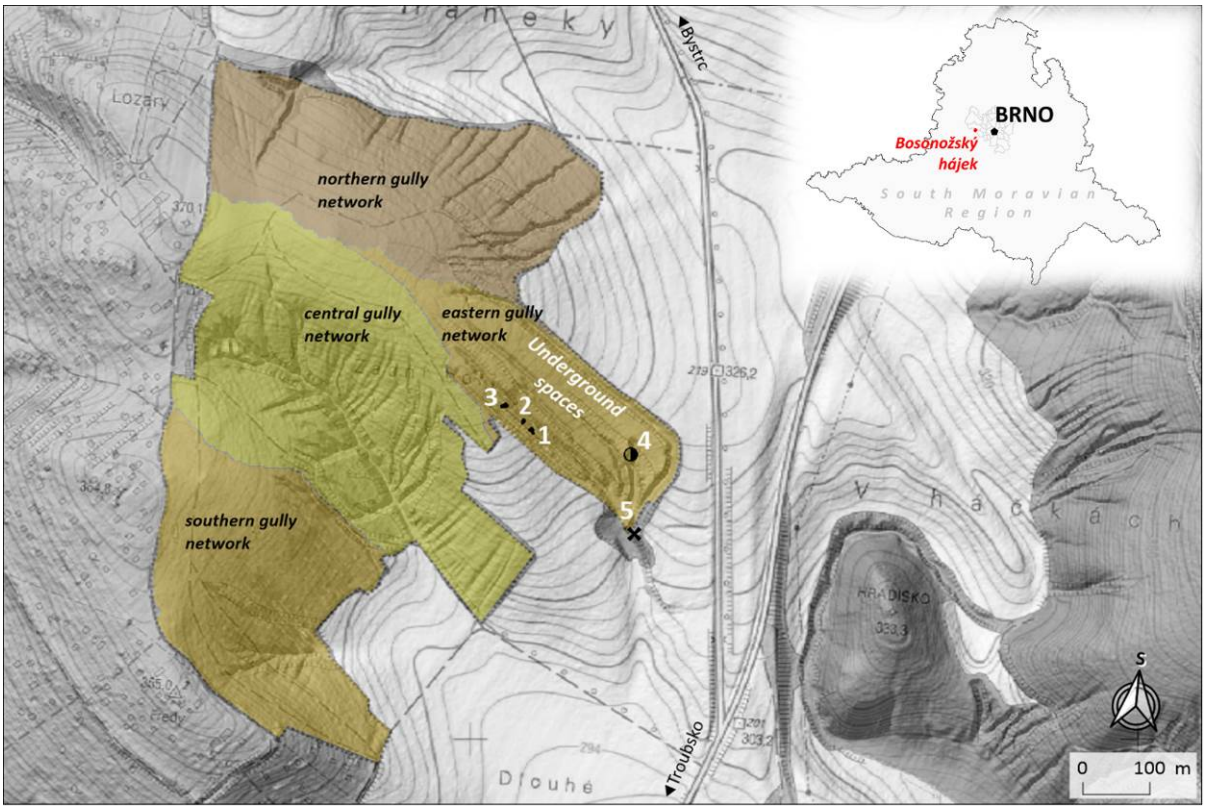

Fig. 1: Situation map of Bosonožský hájek NR showing particular gully networks. The dugouts are marked with a number (1, 2, 3 – accessible dugouts, 4 – mostly buried dugout, 5 – naturally or intentionally collapsed dugout)

Results and Discussion

Confirmed by previous research (Münster 2005, Kirchner et al. 2011), there are four gully systems situated in southern, central, eastern and northern segments of the study area (Figure 1). The sum of the lengths of particular gullies is 18 354 m with a density of 39.25 km.km^{-2} which represents an area with the highest gully density in the South Moravian Region.

Based on existing knowledge, there is a real assumption that the foundations of the gully network in the most of the area (especially central segment) already existed before the loess sedimentation, most probably the new generation of gullies have been inserted into the old valley network (Kirchner et al. 2018). The present forest ecosystems show the typical characteristics of long-term continuous development of the ancient forests (Buček 2009), so this fact can be seen as a supporting argument for a higher age of the gullies.

On the contrary, the gully system in the eastern segment has different morphology and genesis. The longest gully has 613 m with a superelevation of 62 m and deepening max. 5 m. The gullies in this segment run parallel, they have different deepening which is related to the loess thickness and age of the gully. The genesis of these gullies is linked to and influenced by the past anthropogenic activities, especially presence of hollow ways in the Middle Ages (e.g. hollow ways near the extinct village of Kominec) creating the so called “bundles of hollow ways”). Another agent related to the gully formation (or the intensification of their formation) is represented by agricultural activity and forest management.

In the loess ridges that divide particular gullies in the eastern segment, the underground spaces (dugouts) have been discovered. The first appearance in the scientific literature (photos of the entrances to the underground spaces) occur in Münster (2005). Later, Buček (2008) describes the entrances in two parallel gullies. Kynclová (2010) presents four entrances on her topographic map. Our research has been focused on the specification and clarification of the position of the known underground spaces and discovering other dugouts. Also, the elaboration of the schemes and analysis of the relationships of the dugouts to the surrounding landforms has been done. Currently, three accessible underground spaces are identified, the fourth one is mostly buried and the fifth one is naturally or intentionally collapsed (Figure 1). The area of accessible underground spaces is in the order of tens of square meters (Dugout 1: 12.3 m^2; Dugout 2: 8.8 m^2; Dugout 3: 17.1 m^2). The height of entrance corridors reaches of around 0.6 m, main spaces are up to 1.9 m high (Figure 2). The

traces of the tools on the inner walls confirms the sophisticated way of digging and shaping the spatial disposition, but every dugout is quite specific. While Dugout 1 is formed by two rounded cavities, Dugout 2 and 3 are rather square. Dugout 2 has remained unfinished according to the horizontal excavations on the back wall, which would probably serve as ventilation or a second entrance. In Dugout 3, horizontal boreholes are incorporated perpendicular to the direction of the entrance corridors, and with regard to current knowledge, they thus lead into the unknown. For now, it is not excluded that they can connect to other, yet undiscovered spaces.

Fig. 2: Dugout 1 - northeastern entrance (on the left) and its inner spaces (in the middle); Dugout 3 - inner spaces with a stove niche (right)

Generally, the dugouts in Southern Moravia have been already researched by archaeologists and anthropologists (Unger 1987, Kos 2005) who define them as cavities dug in the loess serving usually for storing the foodstuffs or as a shelter in the times of war. Based on the current knowledge, the underground spaces in our study area may be with certainty classified as “dugouts” and according to the typology provided by Kos (2005), they belong to the Type I (underground cavity with direct corridor with small niches and ventilation channels). The majority of the dugouts in South Moravia were built in the Middle Ages, but there are also dugouts dating back to the 19th and 20th centuries – these underground cavities mostly served as a shelter and from a functional point of view, they are completely similar to medieval dugouts. Most often, they were created during the Second World War in relation to threats to the inhabitants of municipalities. Similar shelters were created, for example, in loess around Kníničky village (Hluboček valley, Koňská zmola gully) at the end of World War II (Anonymous 1996). Probably, this is the case of the dugouts in Bosonožský hájek NR as well, Buček (2009) also assumes that the dugouts were created in one of the turbulent periods of the 20th century. Nevertheless, in future, specific (urban) legends about the origin of these underground cavities may occur or can be artificially created (Kirchner and Kubalíková 2015).

Conclusion

The presence of the gullies both of natural origin and anthropogenically induced (or more generally, the presence of one type of landform, but with multiple or different origin) makes the Bosonožský hájek NR unique. In a certain sense, we can consider the anthropogenically induced gullies as a part of so called secondary geodiversity (Kubalíková et al. 2017, 2019). Within the concept of the secondary geodiversity, the artificial underground spaces (dugouts) may be also included. Thus, based on the knowledge of differences of the gully networks in the central and eastern segments and thanks to the existence of specific underground spaces, the Bosonožský hájek NR can be considered an interesting site where the environmentally educative activities (including the excursions for students of high schools and universities) may be developed. In the future, the research will continue with the aim of supplementing knowledge about the age of the gullies and, in particular, gaining knowledge about new underground spaces in loess. The use of different methodological geoscientific approaches will allow to obtain relevant data that will be applied in the formulation of hypotheses about the origin and significance of underground spaces. The possibility of different interpretations of the origin of these specific landforms can be also considered an opportunity in the field of Earth Science (geosciences) education and as an interesting complement of tourist and recreational activities on site. Moreover, thanks to the presence of specific forest ecosystems (ancient forests) and past human activity, the area is a good example of the site where geodiversity, biodiversity and culture (or history) meets. This fact may be also seen as a solid foundation for integral promotion of the natural and cultural heritage of the area.

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Souhrn
Přírodní rezervace Bosonožský hájek na západním okraji Brna představuje modelový příklad vztahů biodiverzity (zastoupené lesními porosty a teplomilnými druhy rostlin), geodiverzity (geologicky podmíněný rozsáhlý systém strží s vícefázovým vývojem) a antropogenních aktivit (výmladkový les, svazky úvozů, podzemní prostory). Minimum informací o stáří nebo účelu zdejších podzemních prostor, tzv. lochů, kterým jsme nově věnovali pozornost, pak umožňuje realizaci výzkumných záměrů (morfografickou a morfometrickou dokumentaci) stejně jako geoedukační aktivity s poukázáním na různé interpretace konkrétních procesů a jevů v krajině. Ty pak mohou být, společně s integrovaným přístupem k propagaci přírodního a kulturního dědictví, jedním ze základů geoturistických a rekreačních aktivit v zájmovém území.

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