Pedologic Study of the Serpentinite Hills in the Eastern Alps

BARLA, Ferenc[a, f] - HALBRITTER, András Albert[b, f] - SZABÓ, Krisztina[c,f *] - FARKAS, Péter[d, f] - MOLNÁR, Zsolt[e, f] - SZABÓ, Péter[b, f*]

[a]Petz Aladár County Educational Hospital, Győr, Hungary
[b]University of West Hungary, Apáczai Csere János Faculty, Győr, Hungary
[c]University of West Hungary, Faculty of Agricultural and Food Sciences, Mosonmagyaróvár, Hungary
[d]Tájház és Környezetkultúra Ld., Győr, Hungary
[e]Czuczor Gergely Benedictine Secondary School, Győr, Hungary
[f]University of West Hungary, Apáczai Csere János Faculty, Győr, Hungary
Botanical Research Group

Abstract- The paper reports on our study on the Bernstein, the most characteristic serpentine site of the Carpatian basin. Serpentinite is a rare rock on the Earth's surface, and due to its unfavourable chemical composition, plant communities exhibit the *serpentine syndrome*, by their restricted growth and cover, morphological alterations, floristic composition, drought stress markers, element (e.g. Nickel) accumulation or hyperaccumulation. In this study we demonstrated the following geological and edaphic stress factors in the Bernstein soils (*Ranker,* USDA: *Magnesic nonacid mesic lithic udorthents,* WRB: *Hyperskeletic leptosol (magnesic)*): high Mg/Ca ratio, N+P deficiency, high Ni concentrations, hypersceletic (rocky) structure. Ni-accumulating plants were also found. In the region three other, less characteristic serpentine sites (Kleine Plischa, Schwarzgraben, Elsenau) and a non-serpentine site (Kőszeg, Hungary) were chosen as control sites.
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Keywords: Bernstein, Eastern Alps, serpentinite, serpentine syndrome

1. INTRODUCTION

Eastern Sub-Alps is a geographic transition from the Alps and the Small Hungarian Plain (Kisalföld). Its surface formed of marine sediments was made smooth by the rivers running to the Kisalföld at the end of the Pliocene, by polishing and river-gravel cover. In reality it is a terraced wide hill landscape with a slope down to the East.

* Corresponding author: statebuoni@freemail.hu; H-9028 Győr, Konini u. 1.

From its plain the Wechsel-mountain (600-800 m above sea level), as the edge of the Eastern Alps emerges with its Variscan cristalline chines as islands. It is divided into the Sopron-, Lánzsér-, Kőszeg- and Bernstein mountains (SZÉKELY, 1968, MAROSI – SÁRFALVI, 1968, PAHR, 1984). Bernstein is predominantly composed of the magmatic ultramafic serpentine, a high iron-containing Magnesia-silicate (FARKAS, 2011, FARKAS et al., 2011a,b) Concerning their vegetation, these soils can be characterized by the relatively high level of substrate effect; low Ca/Mg ratio; relatively low amounts of N, P, K, Mo; the high, metabolism suppressing levels of heavy metals (e.g. Ni: 440-1180 $mgkg^{-1}$ at Bernstein). In the struggle for life those species are favorized on serpentine sites, that can adaptate to these extreme conditions.

This rock determines the plants to mobilize the full range of adaptability, and thus to form several new species. So, serpentine zones are often viewed as hot spots of speciation (BORHIDI, 1974, PUNZ, 1992).

Six members of the Botanical Research Group of the University of West Hungary, in collaboration with the Faculty of Natural Sciences, funded by TAMOP 4.2.1.b. studied the serpentine sites of the Eastern Alps in 2010-2012 *(Figure 1)*.

Figure 1: View of the Bernstein – Kienberg

2. THE SERPENTINE SYNDROME IN THE EASTERN ALPS

Serpentine flora has been studied for a half millennium. ANDREA CESALPINO (1583) in his work, *De Plantis Libris,* wrote the famous sentence: '*Alyssum grows ont he black rock'*. PANČIČ (1859) was the first to intensively study the serpentine flora. He researched the serpentine hills of Central Serbia and described their special vegetation. In the last decades three sites of the Earth (Tuscany, California, Cuba) gave the most important contribution to the serpentine floristic and ecological research. (CHIARUCCI, 1994, CHIARUCCI et al., 1994, VERCESI, 2004, ALEXANDER, 2004, BRADY et al., 2005, BAKER et al., 1991, BAKER, 2001, BOYD et al.,2004, HARRISON et al., 2004, SÁNCHEZ-MATA et al., 2004, BORHIDI, 1996, 2001, BERAZAIN et al., 2004, FLORA et al., 2004). Also important the serpentine floristic results of Bulgaria (ASENOV, 2009), Iran (GHADERIAN et al., 2004) Albania (SHUKA, 2008).

The evolutionary ecology research of the serpentine adapted plants lead to the description of the serpentine syndrome (JENNY, 1980). Its most important characters are the following:

- Low Ca/Mg ratio in the soil
- N and P deficiency int he soil
- High concentration of phytotoxic metals (Ni, Cr, Co) *(*REEVES *et al., 1996)*
- Low nutrient content *(*WHITTAKER, 1954, RICOTTA et al., 2005)
- Low productivity (RUNE, 1953)
- Low species diversity compared to neighbouring areas
- Several unique, endemic species (KRUCKEBERG, 2002)

Anatomic characters of the serpentine syndrome (JENNY, 1980):

- Small, xeromorphic leaves, sclerophyllous markers (SZABÓ P., 2011)
- Reduced size
- Well developed roots
- Serpentinomorphosis (SZABÓ K. et al., 2011a)
- Therophyta paradoxon (SELVI, 2006), drought tolerance (BRADY et al., 2005).

From an ecological point of view, members of serpentine flora can be grouped into five clusters. Obligate serpentinophytes, preferencial serpentinophytes fakultative basophyles, facultative limestone sensitives and the indifferent (bodenvag) species groups (SELVI, 2006). Serpentine syndrome was described in tropical and mediterranean areas. Our research has aimed at studying wheather the existence of the syndrome can be floristically proven ont he suboceanic-continental area of the Eastern Alps, especially the Bernstein (SZABÓ K., 2011, HALBRITTER et al., 2011a.).

In Austria there are several evolutionary hot spot zones (ESSL et al., 2009). The serpetine rock of the Bernstein – Kienberg 49 Tracheophyte was found by EGGLER (1944). 77.5% of them belongs to T5 (deciduous forest) by temperature types. By water demand 62.5 % is drought tolerant. In case of soil reaction, 42.5% belongs to R4 (slightly alkalic)

2.1. Microclimatic conditions at Bernstein

For the studies we needed a deeper knowlende of the microclimatic conditions at Bernstein (KLIMADATEN VON ÖSTERREICH, 1971 – 2000). From the temperature data it can be concluded that the mean annual temperature is (8,3 C^o) is less than the mean of the neighbouring Hungary. From the distribution of the characteristic meteorological days it is clear that the number of the frozen winter days is relatively high, but the number of days with ice is relatively low.In the summer there are a lot of summer days, but there are only hot days.

The annual precipitation (718.3 mm) is just sligtly higher than in Szombathely (700 mm), but remarkably lower than in Graz (840 mm). Humidity values are not high. In summer afternoons it decreases to 60 % from the typical 70% in the morning. In all year it is characterstic, that there is 10% difference int he morning and afternoon values. There is no marked difference compared to e.g. Szombathely, where the average annual humidity is 77%. High number of winter days with snow cover is also not characteristic, although every winter month has some snow cover. Days with ice pellets are few, buti n the summer there are a lot of stormy days, so as the windy days. In spring and autumn there are high number of days with more than 8B wind, but very rarely 8B. There are often forests ont he slopes opened by the wind. Wind direction shows seasonality. In winter West winds, in summer Northwest winds are typical.

The area of Kienberg in the Gaussen bioclimatic system belongs to the psychroaxeric slightly cold zone subtype, with less than four frosty months. Typical vegetation is the deciduous forest and the mixed coniferous-deciduous forest (GAUSSEN, 1954, MEHER – HOMJI, 1963, BORHIDI, 1996).
Pittioni bioclimatic index (continentaliting index, I = Σ precipitation (annual mean temperature + 20) / 100 (φ +100) – (altitude above sea level + 1000) was calculated to be I = 1.55. Compared to other indices, e.g. of Szombathely (1.52), Debrecen (1,25, Turgai Valley (0.3), it is visible that the continentality of Bernstein is weak. Xerothermic index of the area was calculated (I = annual monthly precipitation / 2-month-mean temperature; arid, if precipitation$\geq$ 2month mean temperature). For July it is 2.64. Hydrothermic quotient (Qh = Σ monthly precipitation/ 3 month mean temperature) is 1.76 for July. If Qh $\geq$ 1,5, the are is very humid, while if Qh $\leq$ 0,4, is arid. Thus, Kienberg is very humid.

3. MATERIALS AND METHODS

Among the serpentine emergences of Austria *(Figure 2)* we chosen the most Eastern Bernstein – Kienberg as the key site.

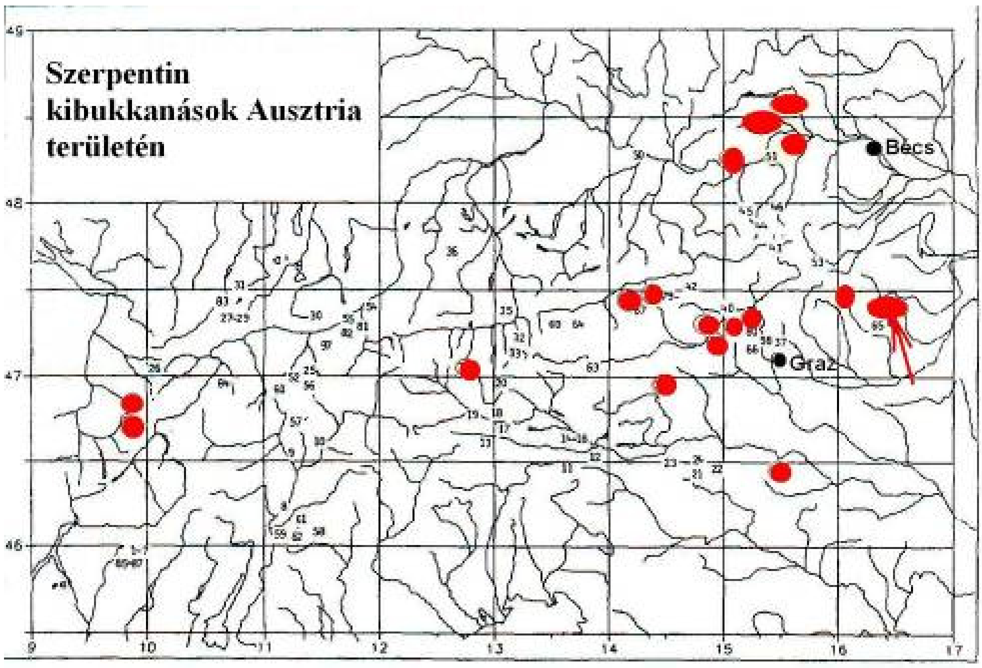

Figure 2: Serpentine emergences in Austria (Bernstein is marked by arrow, Essl et al., 2009)

The studied site lays North of the town Bernstein at an area of appr. 6 km^2 in all seasonal aspects. The surveys were performed on 10x10 m quadrats and Braun-Blanquet method *(Reisinger, 2000, Berzsenyi, 2000)* with cover-abundance (%). In the *Pino-Festucetum ovinae* there were 108 registered species. From the plots soil sections were sampled and analysed. We recorded data of slope direction, slope degree, tree, shrub and herb cover. It was obvious that soil analyses were needed, knowing the strict relationship of soil and vegetation development (BORHIDI-BOTTA, 2001, BORHIDI, 1995). These soils hold edaphic (with pedologic, rather than climatic determination) phytocoenosis types, often with severe endemic species.

These soils can be characterized by the relatively high level of substrate effect; low Ca/Mg ratio; relatively low amounts of N, P, K; the high heavy metal concentrations (e.g. Ni: 440-1180 $mgkg^{-1}$ at Bernstein).

The soils of Mount Kienberg, Bernstein can be classified int he historic ranker group. In the WRB (IUSS WORKING GROUP WRB, 2006). these soils are *Hyperskeletic leptosol magnesic,* in the US. Soil Taxonomy (USDA, 1999): *Magnesic nonacid mesic lithic udorthents*. The rockiness was 65-85%(m/m). Based on the soil chemistry analyses, the premised soil chemical stress factors on the study sites are proved to exist (HALBRITTER ET AL., 2011, a, b, c, d).

Apart from Kienberg-Bernstein three other serpentine sites were chosen (Kleine Plischa, Schwarzgraben, Elsenau) in Austria for floristic studies, as control sites *(Figure 3)*.

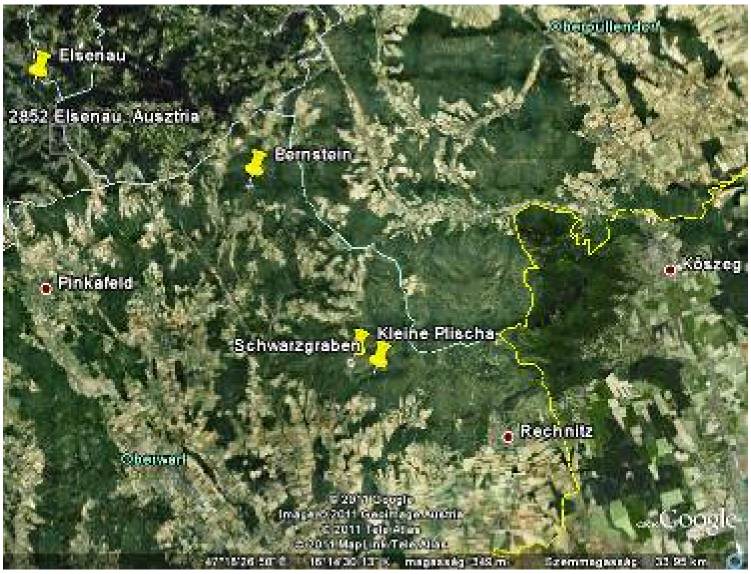

Figure 3: Control sites compared to Bernstein

4. RESULTS AND CONCLUSIONS

The basic rock of serpentine soils is the metamorphic, ultramafic, Mg-rich serpentinite, originates from the Earth's mantle. The special elemental composition of serpentine soils originates in the chemical composition of serpentinite rock.

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Table 1. Soil chemistry data of typical Kienberg-Bernstein sites.

Sample No.	pH_{KCl}	Organic matter	$CaCO_3$	P_2O_5	K_2O	Na_{total}	Mg_{total}	Ca_{total}	Ca/Mg
		m/m%		mg/kg					
1/A	4.47	38.5	0.22	207	252	34.3	4650	8600	**1.8**
1/B	5.45	11.7	0.3	**40.7**	**76.4**	25.1	3160	3300	**1.0**
1/C	5.15	8.95	0.21	**29.2**	**71.1**	20.3	3690	2500	**1.5**
5/A	5.1	35.3	0.33	451	582	35.9	3390	7200	**0.5**
5/B	5.25	19.3	0.27	106	163	35.9	3080	4300	**0.7**

Sample No.	As_{total}	Cd_{total}	Cr_{total}	Cu_{total}	Hg_{total}	Ni_{total}	Pb_{total}	Zn_{total}	Al_{total}
	mg/kg								
1/A	4.75	0.72	**748**	15.3	0.38	**441**	80.5	65.8	7300
1/B	<1.00	<0.50	**1480**	13.3	<0.25	**937**	41.3	42.9	10100
1/C	<1.00	<0.50	**1540**	14.4	<0.25	**1180**	33	38.7	10300
5/A	3.11	1.1	**1020**	21.6	<0.25	**636**	72.4	82.6	7700
5/B	3	0.9	**1560**	16.6	<0.25	**797**	74.7	54.3	9700

Values supposed to be stress factors are in bold.
Legend: 1 and 5 – Bernstein ranker soils; A, B, C – soil layers

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